Assessment of the Hydraulic Connection Between Ground Water and the Peace River, West-Central Florida

By B.R. Lewelling, A.B. Tihansky, *and* J.L. Kindinger

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply inch-pound unit	By	To obtain
foot (ft)	0.3048	meter
foot squared per day (ft^2/d)	0.0929	meter squared per day
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
foot per second (ft/s)	0.3048	meter per second
million gallons per day (Mgal/d)	0.4381	cubic meter per second

Degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) by using the following equation:

°C = 5/9 x (°F-32)

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."

ACRONYMS USED IN THIS REPORT:

CF	=	chaotic seismic facies
FZ	=	abrupt discontinuities or breaks in horizontal reflectors
HAR	=	high amplitude concordant parallel reflectors
IAS	=	intermediate aquifer system
ICU	=	intermediate confining unit
PCF	=	low- to high-amplitude continuous or disrupted clinoform reflectors
ROMP	=	Regional Observation Monitor Well Program
RM	=	high amplitude ringing multiples
SA	=	surficial aquifer
UDSC	=	undifferentiated sand, shell, and clay
UFA	=	Upper Floridan aquifer
USGS	=	U.S. Geological Survey

ABBREVIATED WATER-QUALITY UNITS

$\mu S/cm$ = microsiemens per centimeter at 25 degrees Celsius

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Abstract

The hydraulic connection between the Peace River and the underlying aquifers along the length of the Peace River from Bartow to Arcadia was assessed to evaluate flow exchanges between these hydrologic systems. Methods included an evaluation of hydrologic and geologic records and seismic-reflection profiles, seepage investigations, and thermal infrared imagery interpretation. Along the upper Peace River, a progressive long-term decline in streamflow has occurred since 1931 due to a lowering of the potentiometric surface of the Upper Floridan aquifer by as much as 60 feet because of intensive ground-water withdrawals for phosphate mining and agriculture. Another effect from lowering the potentiometric surface has been the cessation of flow at several springs located near and within the Peace River channel, including Kissengen Spring, that once averaged a flow of about 19 million gallons a day. The lowering of ground-water head resulted in flow reversals at locations where streamflow enters sinkholes along the streambed and floodplain.

Hydrogeologic conditions along the Peace River vary from Bartow to Arcadia. Three distinctive hydrogeologic areas along the Peace River were delineated: (1) the upper Peace River near Bartow, where ground-water recharge occurs; (2) the middle Peace River near Bowling Green, where reversals of hydraulic gradients occur; and (3) the lower Peace River near Arcadia, where ground-water discharge occurs.

Seismic-reflection data were used to identify geologic features that could serve as potential conduits for surface-water and ground-water exchange. Depending on the hydrologic regime, this exchange could be recharge of surface water into the aquifer system or discharge of ground water into the stream channel. Geologic features that would provide pathways for water movement were identified in the seismic record; they varied from buried irregular surfaces to large-scale subsidence flexures and vertical fractures or enlarged solution conduits. Generally, the upper Peace River is characterized by a shallow, buried irregular top of rock, numerous observed sinkholes, and subsidence depressions. The downward head gradient provides potential for the Peace River to lose water to the ground-water system. Along the middle Peace River area, head gradients alternate between downward and upward, creating both recharging and discharging ground-water conditions. Seismic records show that buried, laterally continuous reflectors in the lower Peace River pinch out in the middle Peace River streambed. Small springs have been

observed along the streambed where these units pinch out. This area corresponds to the region where highest ground-water seepage volumes were measured during this study. Further south, along the lower Peace River, upward head gradients provide conditions for ground-water discharge into the Peace River. Generally, confinement between the surficial aquifer and the confined ground-water systems in this area is better than to the north. However, localized avenues for surface-water and ground-water interactions may exist along discontinuities observed in seismic reflectors associated with large-scale flexures or subsidence features.

Ground-water seepage gains or losses along the Peace River were quantified by making three seepage runs during periods of: (1) low base flow, (2) high base flow, and (3) high flow. Low and high base-flow seepage runs were performed along a 74-mile length of the Peace River, between Bartow and Nocatee. Maximum losses of 17.3 cubic feet per second (11.2 million gallons per day) were measured along a 3.2-mile reach of the upper Peace River. The high-flow seepage run was conducted to quantify losses in the Peace River channel and floodplain between Bartow and Fort Meade. Seepage losses calculated during high-flow along a 7.2-mile reach of the Peace River, from the Clear Springs Mine bridge to the Mobil Mine bridge, were approximately 10 percent of the river flow, or 118 cubic feet per second. Calculated seepages along the Peace River in Hardee and De Soto Counties were inconclusive, because most seepages were within the range of discharge measurement error.

Two continuous aerial thermal infrared imagery surveys were conducted to locate sites of ground-water discharge along the Peace River. Although temperature and hydrologic conditions were ideal to observe spring flow using thermal infrared imaging techniques, no sources of ground-water discharge were identified using this method. Diffuse ground-water seepage may, however, provide significant ground-water discharge.

INTRODUCTION

The Peace River is 105 mi long, from the confluence of the Peace Creek Drainage Canal and Saddle Creek to Charlotte Harbor, and drains a 2,350-mi^2 area of west-central Florida (fig. 1) that has been intensively developed for agriculture, phosphate mining, and residential uses. Water use demands in the Peace River basin are increasing. Both surface- and ground-water resources are used for public supply, industry, and agriculture. Additional withdrawals from the Peace River are being considered, as are increased withdrawals from ground-water resources. These withdrawals can cause further long-term declines in surface-water discharge and ground-water levels, which will alter rates and areal locations of ground-water recharge and discharge. A progressive long-term decline in discharge of the Peace River has already occurred and is attributed to the decline in the potentiometric surfaces of the underlying intermediate aquifer system and the Upper Floridan aquifer (Hammett, 1990). Decreases in discharge are most significant in the northern and the eastern parts of the Peace River basin where surface mining for phosphate has caused a significant decline in the potentiometric surface. Decline in the potentiometric surfaces directly affects the streamflow by causing decreases in or cessation of spring flows into the stream and flow losses from the stream into sinkholes, and indirectly by increasing the potential for downward leakage from the river into the underlying aquifer system.

Much of the Peace River basin in Polk County has been surface mined for phosphate and reclaimed. Mining and reclamation processes have altered natural drainage patterns and lowered ground-water levels. Some of these alterations include: (1) increased recharge to the underlying aquifer system from rainwater that can infiltrate the disturbed overburden and recharge the intermediate aquifer system more readily because the thickness of the upper confining unit (phosphate-matrix) has been reduced by mining; (2) reduced or eliminated base flow; (3) reduced surface runoff in mined and reclaimed areas where overland flow is impounded in pits and surface depressions; (4) replacement of natural surface drainage by a system of reclaimed ditches, swales, and modified topography; and (5) lowering of water levels in the Upper Floridan aquifer from ground-water withdrawals by the mining industry to transport and process phosphate ore.

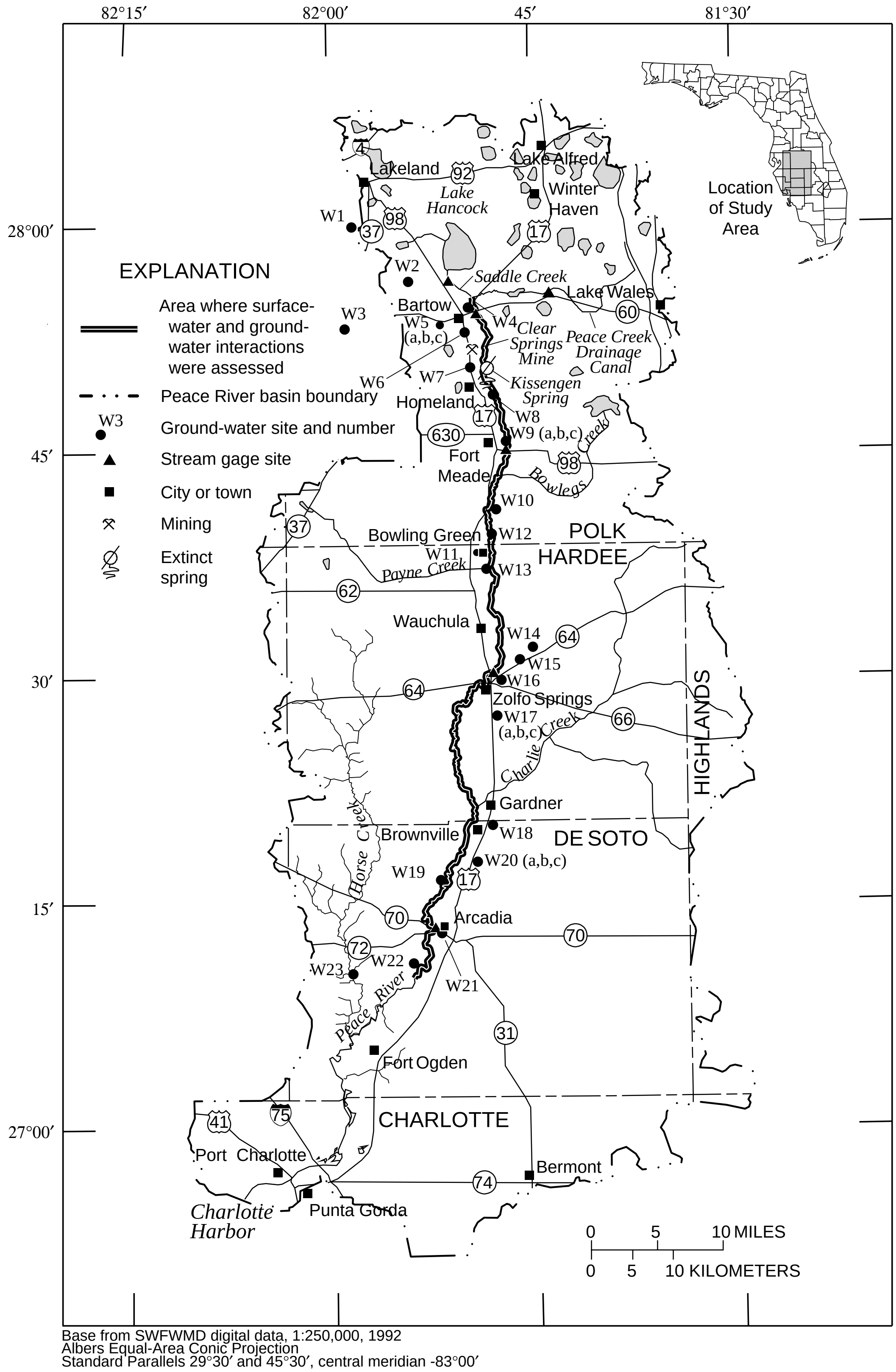


Figure 1. Location of Peace River basin study area and area where surface-water and ground-water interactions were assessed along the Peace River. (Well names and descriptions are shown in table 3.)

To better assess the magnitude of change in the flow regime of the Peace River from the effects of ground-water withdrawals in the intermediate aquifer system and the Upper Floridan aquifer, the U.S. Geological Survey (USGS), in cooperation with the Southwest Florida Water Management District, began a study in 1994 to better define the hydraulic connection between the Peace River and the underlying aquifer systems.

Purpose and Scope

The purpose of this report is to evaluate the hydraulic connection between the Peace River and the underlying aquifer systems. The report examines three distinct hydrologic areas based on the relation between the river and ground-water heads as well as presents potentiometric-surface maps, physical characteristics, streamflow and ground-water-level hydrographs, seismic-reflection profiles, seepage estimates, flow-duration curves, streamflow trend analysis, and the results of thermal infrared imagery along the Peace River.

Methods of Study

Seismic-reflection profiles, seepage runs, and thermal infrared imagery profiles were performed to analyze the hydrologic connection between the Peace River and the underlying aquifers. Continuous and periodic ground-water-level data on 29 wells in the study area from 1948 to 1996 were accessed, based on the USGS data base in Tampa. Comparisons of historical and current ground-water conditions (1934-96) in the upper Peace River basin were based on water-level data from USGS water-supply papers and potentiometric-surface maps, and from reports by Stringfield (1936), Peek (1951), Stewart (1966), and Kaufman (1967). The relations between ground-water levels in wells were determined using regression analysis. Potential recharge areas were identified based on locations of sinkholes and sinkhole complexes located by Patton (1990) and Patton and Klein (1989) in the upper Peace River channel and floodplain. Discharge measurements were made using standard USGS techniques. Trend analysis and 5-yr moving averages of annual mean discharge were performed for the Bartow, Fort Meade, Zolfo Springs, and Arcadia streamflow stations for the 10-yr period (1985-94) following a study by Hammett (1990) that ended in 1984. Water samples for specific conductance analysis were collected at most discharge measurement sites.

Previous Investigations

Studies show that the hydrogeology within west-central Florida is controlled by a complex stratigraphic framework, particularly in the mid-Tertiary strata. Previous investigations describing the hydrogeologic framework have been regional in scope, and include: (1) baseline surficial geology (Scott, 1978; Knapp, 1980), (2) locations, types, and occurrences of sinkholes (Sinclair and others, 1985; Patton, 1981), (3) regional stratigraphy pertaining to the mid-Tertiary geologic units (Scott and MacGill, 1981; Scott, 1988), and (4) the Floridan aquifer system (Miller, 1986). Scott (1988) provided the most recent comprehensive stratigraphic investigation of mid-Tertiary geologic units (Hawthorn Group) in this region, and it is the primary reference for the stratigraphy in this report.

Variability in hydrologic conditions between and during investigations is common and may result from human activity, seasonal effects, and the interaction of ground-water within the complex stratigraphic framework. Stewart (1966) also recognized the importance of the stratigraphy in controlling hydrologic properties and described the geologic units as part of his investigation of ground-water resources of Polk County. Kaufman (1967) described hydrologic effects of ground-water pumpage in the Peace River basin using hydrologic records from 1934 to 1965 (during which ground-water heads declined and spring flows in the upper Peace River basin ceased). Wilson (1977) relied on lithologic characteristics as an indicator of hydrologic properties when describing the ground-water resources of Hardee and De Soto Counties. Because the formational characteristics are so variable and difficult to identify, Duerr and others (1988), in describing the intermediate aquifer system of the region, relied on hydrologic units rather than formational names. Investigations by Ryder (1985), Duerr and Enos (1991), Barr (1992, 1996), Metz (1995b), Yobbi (1996), and Sacks and Tihansky (1996) continued to develop a more detailed description of the complex hydrogeologic framework in Polk, Hardee, and De Soto Counties. These investigations included: areal distribution, delineation, and thickness of hydrogeologic units, hydraulic characteristics of these units, delineation of recharge and discharge areas, ground-water flow paths, chemical evolution of ground water, and projected future ground-water resource development using numerical-model simulations. Results of these recent investigations were used in describing the hydrogeologic framework in the Peace River basin for this report.

Acknowledgments

The authors gratefully acknowledge the cooperation and assistance from the many organizations and individuals that were involved with the study. Special thanks are given to land owners, managers, and companies that permitted access to their property for reconnaissance and data collection. Some of these individuals and companies include: Tim King, Florida Game and Freshwater Fish Commission; Greg Williams and Ross Franklin, IMC-Agrico; Tom Able, Mobil Mining and Minerals; Tom Myers, Cargill Fertilizer; and Ben Hill Griffin. In addition, identification of geologic units from outcrop samples and many useful discussions regarding the complex geology of this region were provided by Jon Arthur and Tom Scott of the Florida Geological Survey. Thanks to Jim Flocks of the U.S. Geological Survey Coastal Center for technical assistance in the field and with processing seismic-reflection data and to Stan Locker of the Department of Marine Science at University of South Florida for reviewing the seismic-reflection interpretations. We are especially grateful to Jean Klein and Thomas Patton for their previous work in locating and documenting sinkholes in the upper reaches of the Peace River.

DESCRIPTION OF STUDY AREA

The 2,350-mi^2 Peace River drainage basin (Foose, 1981) is predominantly located in Polk, Hardee, De Soto, and Charlotte Counties (fig. 1). The Peace River begins northeast of Bartow, at the confluence of Saddle Creek and the Peace Creek Drainage Canal, and flows southward for 105 mi to Charlotte Harbor. Surface-water drainage to the upper Peace River, from Bartow to Bowling Green, generally is limited to phosphate-mine outfalls and reclaimed stream channels. Numerous clay-settling areas, which can cover hundreds of acres, are the dominant reclaimed landform type located along the river. This landform can affect surface-water infiltration and runoff rates. Surface-water drainage to the Peace River, from downstream of Bowling Green to Charlotte Harbor, typically is from well developed, naturally formed tributaries.

Physiographic Setting

The distinct physiographic features identified in this region reflect interactions between geologic units and both the surface- and ground-water systems over geologic time. The physiographic boundaries generally correspond to paleoshorelines that separate several marine plains or terraces recognized by Cooke (1945) and MacNeil (1950). These shorelines have been mapped within the Peace River valley and its major tributaries (Wilson, 1977). The three major physiographic provinces, separated by the paleoshoreline boundaries within the study area, are the Polk Upland, the De Soto Plain, and the Gulf Coastal Lowlands of White (1970). Brooks (1981) further subdivided these general regions into the Bone Valley Uplands, De Soto Slope, and Barrier Island Coastal Strip. A map of the physiography, adapted from both White (1970) and Brooks (1981), is shown in figure 2.

Generally, the physiography changes from an upland, internally drained lake district, dominated by several highland ridges in Polk County, to a poorly drained upland region that extends into the northern half of Hardee County, to a broad, gently sloping plain with well-developed surface drainage in southern Hardee and most of De Soto Counties. A distinct paleoshoreline at the 100-ft elevation separates the upland regions from the plain. Another paleoshoreline at the 30-ft elevation separates the plain from the low coastal region, including the Barrier Island Coastal Strip and the Gulf Coastal Lowlands near the Charlotte Harbor estuary.

Specific physiographic features that likely influence, or are a result of, the regional hydrologic regime are discussed below. The Bartow Embayment is an internally drained, local erosional basin that has been partially infilled with phosphate-rich siliclastic deposits. It extends from above Lake Hancock to directly north of Homeland (Brooks, 1981). In this area, the Peace River basin lies between several ridges to the east and west. The area extending south from Homeland to Zolfo Springs is the Polk Upland of White (1970), which corresponds to the Bone Valley Uplands of Brooks (1981). This upland region, where land surface elevations generally are greater than 130 ft above sea level, is characterized by flatwoods, wetlands, and lakes that occupy a poorly drained plateau, underlain by deeply weathered sand and clayey sand of the Bone Valley Member of the Peace River Formation (fig. 3). Within the upper Peace River

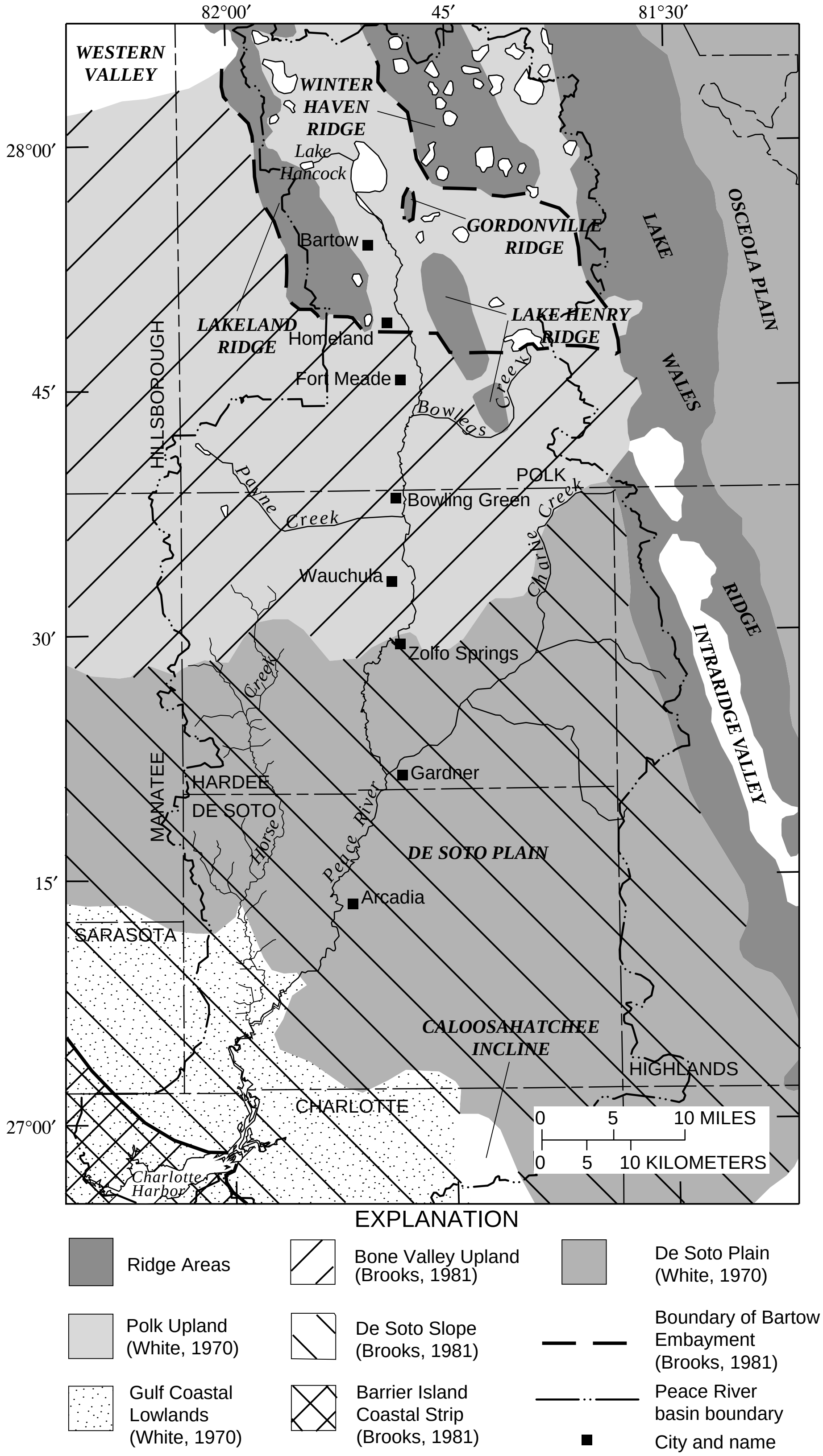


Figure 2. Regional physiographic features of the study area. (Modified from White, 1970, and Brooks, 1981.)

System	Series	Lithostratigraphic Unit		Hydrogeologic Unit		Generalized Lithology
Quaternary	Pleistocene	undifferentiated sand, shell, and clay		surficial aquifer		Highly variable lithology ranging from unconsolidated sands to clay beds with variable amounts of shell fragments, gravel-sized quartz grains and reworked phosphate
Tertiary	Pliocene	Hawthorn Group	Bone Valley Member	intermediate aquifer system and/or intermediate confining unit		Interbedded sands, clays and carbonates with siliciclastic component being dominant and variably mixed; moderate to high phosphate sand/gravel content
	Miocene		Peace River Formation			
			Arcadia Formation			Arcadia Formation is a fine-grained carbonate with low to moderate phosphate and quartz sand, variably dolomitic Tampa Member is a sandy, low phosphate wackestone Nocatee Member is a clayey, carbonate, mud-bearing sand with low amounts of phosphate
	Oligocene		Tampa Member / Nocatee Member			
		Suwannee Limestone		Floridan aquifer system	Upper Floridan aquifer	Fine - to - medium grained packstone to grainstone with trace organics and variable dolomite and clay content
	Eocene	Ocala Limestone				Chalky, very fine - to fine - grained wackestone/packstone varying with depth to a biogenic medium- to coarse - packstone grainstone; trace amounts of organic grained material, clay, and variable amounts of dolomite
		Avon Park Formation				Fine-grained packstone with variable amounts of organic- rich laminations near top; limestone with dolostone interbeds typical in upper part, deeper beds are continuous dolostone with sulfate near base

Figure 3. Hydrogeologic column for units that occur within the study area. (From Covington, 1993; Missimer and others, 1994; Scott and others, 1994; and Wingard and others, 1994.) Shaded area corresponds to units that may be exposed within the Peace River basin. (Modified from Tihansky and others, 1996.)

basin, upstream of Bowling Green, much of the natural drainage system characteristics have been altered by phosphate surface-mining activity. Reclaimed landforms adjacent to the Peace River floodplain, from Bartow to Bowling Green, are predominantly large clay-settling areas that impede natural ground-water recharge and surface-water drainage into the Peace River. The De Soto Slope (Brooks, 1981), or the De Soto Plain of White (1970), is a combination of wet prairie, swamp, and flatwoods that contains the well-developed surface drainage system of the Peace River and its major tributaries. Below Arcadia are the Gulf Coastal Lowlands (White 1970) and the Barrier Island Coastal Strip (Brooks, 1981), physiographic regions where the Peace River ultimately discharges into the Charlotte Harbor estuary.

Hydrogeologic Framework

The regional hydrogeologic framework beneath the study area consists of a thick sequence of carbonate rocks overlain by siliciclastic materials (fig. 3). Locations and schematics of hydrogeologic sections *A*-*A*′, *B*-*B*′, and *C*-*C*′ are shown on figures 4 and 5. Regionally, Tertiary carbonates and siliclastic units dip and thicken to the south and southwest. Three distinct hydrogeologic units occur in the study area. These units are the (1) unconfined surficial aquifer, (2) confined intermediate aquifer system, and (3) confined Upper Floridan aquifer. The intermediate aquifer system is bounded by an upper and a lower confining unit. In the northern part of the study area (central Polk County), the intermediate aquifer system is thinner and less permeable, and is referred to as the intermediate confining unit.

Although the regional hydrogeologic framework within the study area has been described in many prior studies, only a limited number of published reports describe the geology and the effect geology has on the local hydrology, specifically along the Peace River. The hydrogeologic framework presented here was adapted from these prior studies. It focuses on the specific hydrogeology along the Peace River and the possibility of hydrologic interactions between the Peace River, its adjacent floodplain, and the ground-water system.

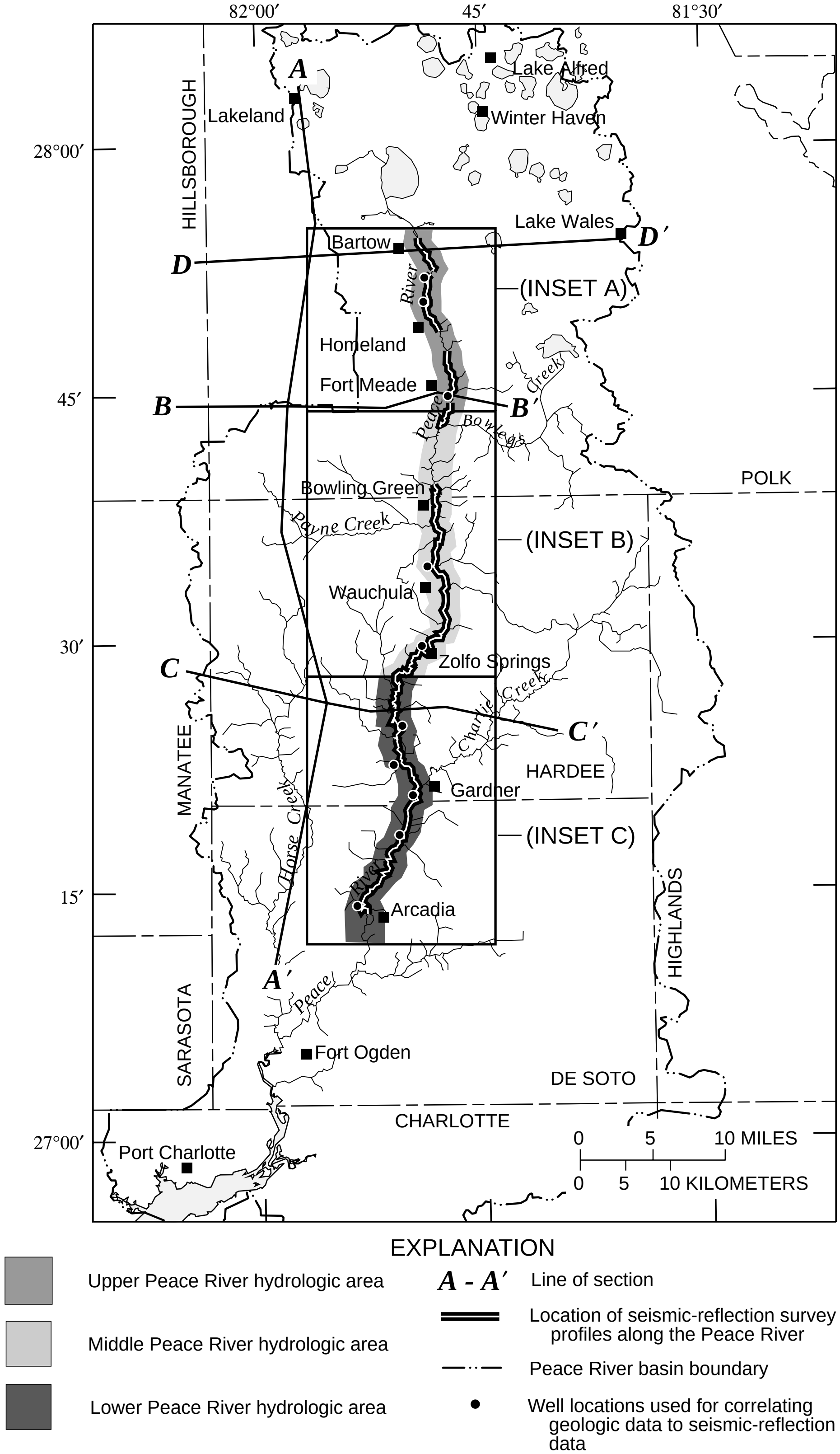


Figure 4. Locations of hydrologic areas, hydrogeologic sections *A-A′, B-B′*, and *C-C′*, seismic-reflection survey profiles, well locations used to correlate to seismic-reflection data, and potentiometric-surface profile section *D-D′*.

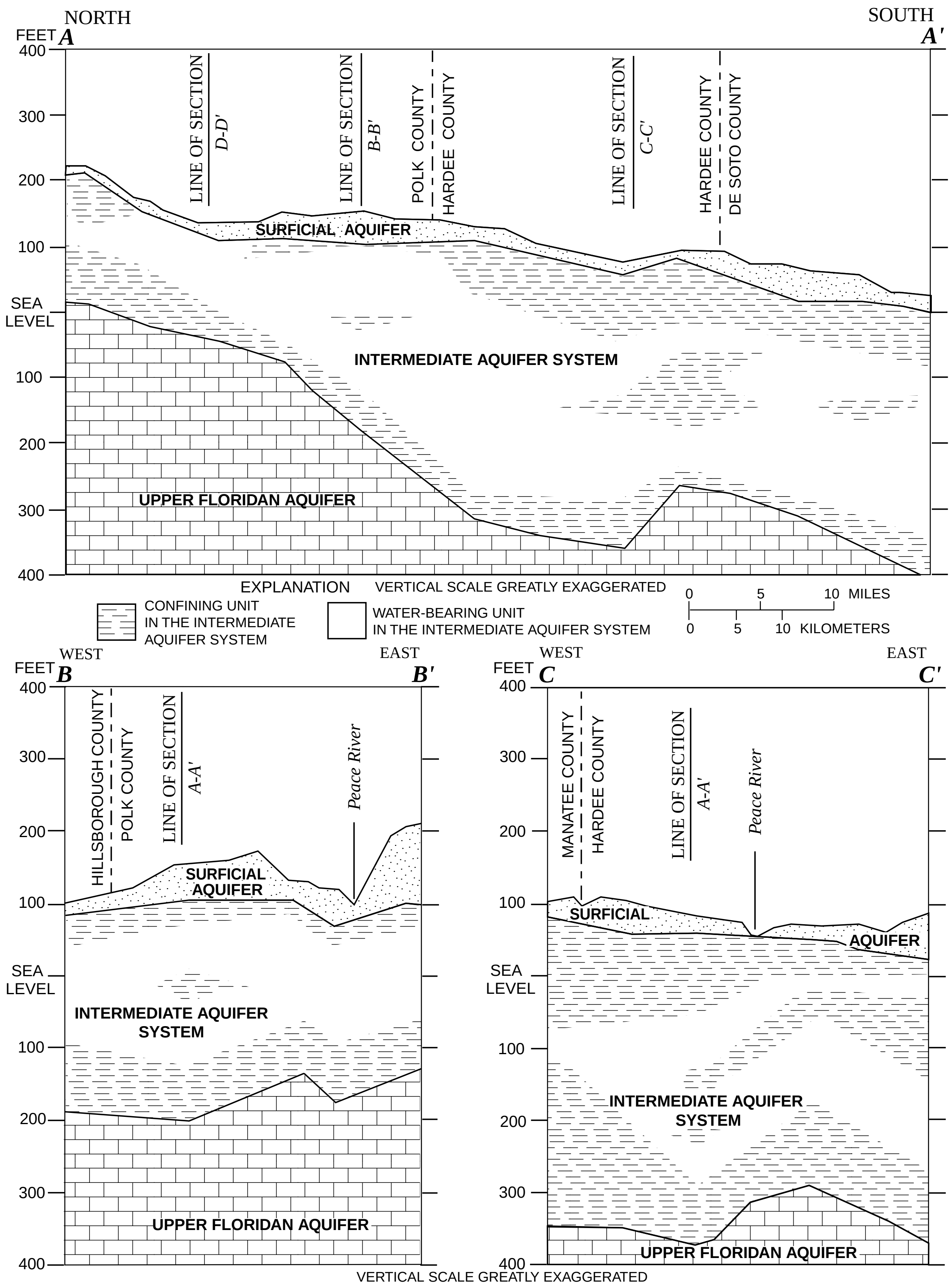


Figure 5. Generalized schematics of hydrogeologic units in sections *A-A′*, *B-B′*, and *C-C′* within the study area. (Location of sections shown in figure 4. Modified from Duerr and others, 1988.)

Surficial Aquifer

The surficial aquifer is the uppermost water-bearing unit throughout the study area. It is composed of undifferentiated sands, clay, and shell of Late Tertiary and Quaternary age (fig. 3), and ranges in thickness from a thin veneer of sand to more than 50 ft within the study area. Along the Peace River, this unit exists as thin sand units within the streambed and exposed cut banks ranging from several feet to more than 20 ft in thickness. The unit is a fairly uniform quartz sand that becomes more clayey with depth to the upper confining unit of the intermediate aquifer system. The surficial aquifer is unconfined and is recharged mainly by rainfall. The depth to the water table averages 5 to 10 ft below land surface. However, along the river, the water table often is exposed in the cut banks or is at land surface within the swampy floodplain and adjacent lowlands. Movement of water within the surficial aquifer results from complex interactions between recharge, discharge, runoff, infiltration, evapotranspiration, and seepage to and from underlying aquifers. Hydraulic properties for this unit, determined from previous studies, are variable due to differences in saturated thickness and lithology. The average transmissivity of the surficial aquifer in Hardee and De Soto Counties is estimated to be 1,100 ft^2/d, based on an average hydraulic conductivity of 20 ft/d (Metz, 1995).

Intermediate Aquifer System

The intermediate aquifer system includes all water-bearing units and confining units between the overlying surficial aquifer and the underlying Upper Florida aquifer (Duerr and others, 1988). It occurs within the Hawthorn Group (fig. 3), which ranges in thickness from less than 50 to more than 250 ft. Lithologic units that comprise the Hawthorn Group have been divided into formations and members, but are often difficult to identify due to their high variability. The carbonate units become thicker and more common to the south and west, interfingering into siliciclastic units to the north and east (Scott, 1988). These units have been weathered, reworked, and modified by fluvial and dissolutional activity. In addition to being highly variable as a geologic unit, this unit varies in thickness and lithologic composition within the study area. This variability greatly affects both local and regional hydrologic properties. Although an intensive study delineating these geologic units and their hydrologic properties would improve our understanding of this complex system, it was beyond the scope of this investigation.

The two dominant geologic formations within the highly variable Hawthorn Group are the Arcadia Formation and the Peace River Formation (fig. 3). Although these two formations are very similar in their characteristic heterogeneity, the Arcadia Formation has a higher carbonate content, whereas the composition of the Peace River Formation is more siliciclastic. The Hawthorn Group underlies all of the Peace River basin. The Arcadia Formation likely is too deep to be exposed within the study area, but the Peace River Formation, where it is sufficiently lithified, forms rock ledges or outcrops within the floodplain and streambed (Scott, 1988). Physical characteristics of the river, such as the width, depth, and streambed composition, change depending on where the Peace River Formation outcrops. Tributaries commonly scour through unconsolidated materials and run along the top of the indurated units. River meanders often are controlled by these outcrops. The Bone Valley Member, the clayey, phosphate-rich object of mining activities, is the upper unit of the Peace River Formation. It is present in places along the upper reaches of the Peace River, from Bartow to Wauchula (Scott, 1988). Based on Scott (1988) and field reconnaissance done during this study, the surficial aquifer and the Peace River Formation of the intermediate aquifer system may be the only units that are exposed along the Peace River channel. However, the complex stratigraphy limits the certainty of identifying these units.

Hydraulic properties of the intermediate aquifer system and intermediate confining unit vary considerably because of the highly variable lithologic composition. Transmissivity values of both confining units and water-bearing units have been reported to range from 0.0001 to 13,300 ft^2/d (Barr, 1992; Metz, 1995). Hydraulic data for the confining units are limited, and most are available only from flow model simulations (Yobbi, 1996). Transmissivity of the permeable units is generally less than 13,000 ft^2/d and is variable over short distances indicating lithologic heterogeneity (Yobbi, 1996). Model-derived transmissivities within the study area are highest in areas adjacent to the Peace River from Fort Meade to south of Zolfo Springs (Metz, 1995). In this region, transmissivity of the intermediate aquifer system has been estimated to be 10,500 ft^2/d. South of Zolfo Springs, transmissivities along the Peace River are lower, ranging from 4,000 to 7,000 ft^2/d.

The confining units present in the intermediate aquifer system have low hydraulic conductivity values and retard the movement of water, although they do transmit water or allow water to leak from one aquifer to another, depending on hydraulic gradients. Leakage between the intermediate aquifer system and adjacent aquifers may be upward or downward and has been mapped along the Peace River by Yobbi (1996) and Metz (1995a) for the southern part of Polk County and for both Hardee and De Soto Counties. Along the Peace River, the leakance across the upper confining unit has been estimated to range from 9.9×10^{-5} to 1.0×10^{-5} (ft/d)/ft between southern Polk County and northern Hardee County (Payne Creek). South of Payne Creek, leakance is an order of magnitude lower, 9.9×10^{-6} to 1.0×10^{-6} (ft/d)/ft. Leakance across the lower confining unit is similar throughout the study area and ranges from 9.9×10^{-5} to 1.0×10^{-5} (ft/d)/ft (Metz, 1995). The general thickness of both the upper and lower confining units decreases in the vicinity of the Peace River (Metz, 1995).

Within the Peace River basin, Metz (1995) mapped areas of upward and downward leakage through the confining units of the intermediate aquifer system, using data from September 1988 (fig. 6). Yobbi (1996) mapped the head difference between the surficial aquifer and underlying aquifers to show where upward and downward leakage between the surficial and the underlying aquifers likely occurs (fig. 7). In areas where the potentiometric surfaces of the underlying aquifers are above the water table of the surficial aquifer, there is the potential for water to move upward to recharge the surficial aquifer. In areas where the potentiometric surface of the water table is higher than the underlying aquifers, downward leakage from the surficial aquifer to the intermediate aquifer system likely occurs. In 1989, the head potential in the surficial aquifer along the Peace River from upstream of Bartow to the Polk-Hardee County line was downward, and from the Polk-Hardee County line to south of Arcadia it was upward (fig. 7). The location and extent of these delineated areas change in response to both annual and seasonal variations in water use, rainfall, and recharge. The movement of potential recharge and discharge areas alters surface- and ground-water interactions within the Peace River floodplain.

Upper Floridan Aquifer

The Oligocene age permeable lower Hawthorn Group and Suwannee Limestone, and the Eocene age Ocala Limestone and Avon Park Formation, are the carbonate units that make up the Upper Floridan aquifer. These units total about 1,200 to 1,400 ft in thickness in the study area.

Hydraulic characteristics of the Upper Floridan aquifer vary widely within the study area due to the heterogeneity of the aquifer. Highly developed secondary porosity and permeability is a result of dissolution of the limestone and dolomite, which enlarges preferential flow zones and structural features such as joints and fractures. Transmissivities for the Upper Floridan aquifer have been derived from field tests and ground-water flow models. Computed field values of transmissivity range from 10,300 to 270,000 ft^2/d; the model-derived transmissivity ranges from 12,000 to 400,000 ft^2/d and averages 130,000 ft^2/d. The lower transmissivity values likely reflect areas where overlying siliciclastic materials have filled fractures and cavities in the carbonate rocks (Yobbi, 1996). The model-derived transmissivities are generally higher than those obtained from aquifer tests because test wells usually do not tap the full thickness of the Upper Floridan aquifer. The partial penetration and the heterogenous and anisotropic nature of the cavernous limestone aquifer give standard aquifer test methods a significant level of uncertainty (Yobbi, 1996).

Model-derived transmissivities determined by Ryder (1985) vary in areas along the Peace River. The reach of the Peace River from Bartow to near Fort Meade has a transmissivity of 130,000 ft^2/d. The transmissivity along the reach from Fort Meade to Zolfo Springs and from several miles north of Arcadia to south of the study area is 400,000 ft^2/d. The transmissivity along the Peace River from Zolfo Springs to several miles north of Arcadia is 130,000 ft^2/d.

Ground-Water Flow Patterns

Ground-water flow patterns along the Peace River are determined by the gradients and differences in head potential both within and between the hydrologic units. The potentiometric surfaces of both the intermediate aquifer system and the Upper Floridan aquifer for May and September of 1995 are shown in figure 8. The extent to which interactions between the surface-water drainage system of the Peace River

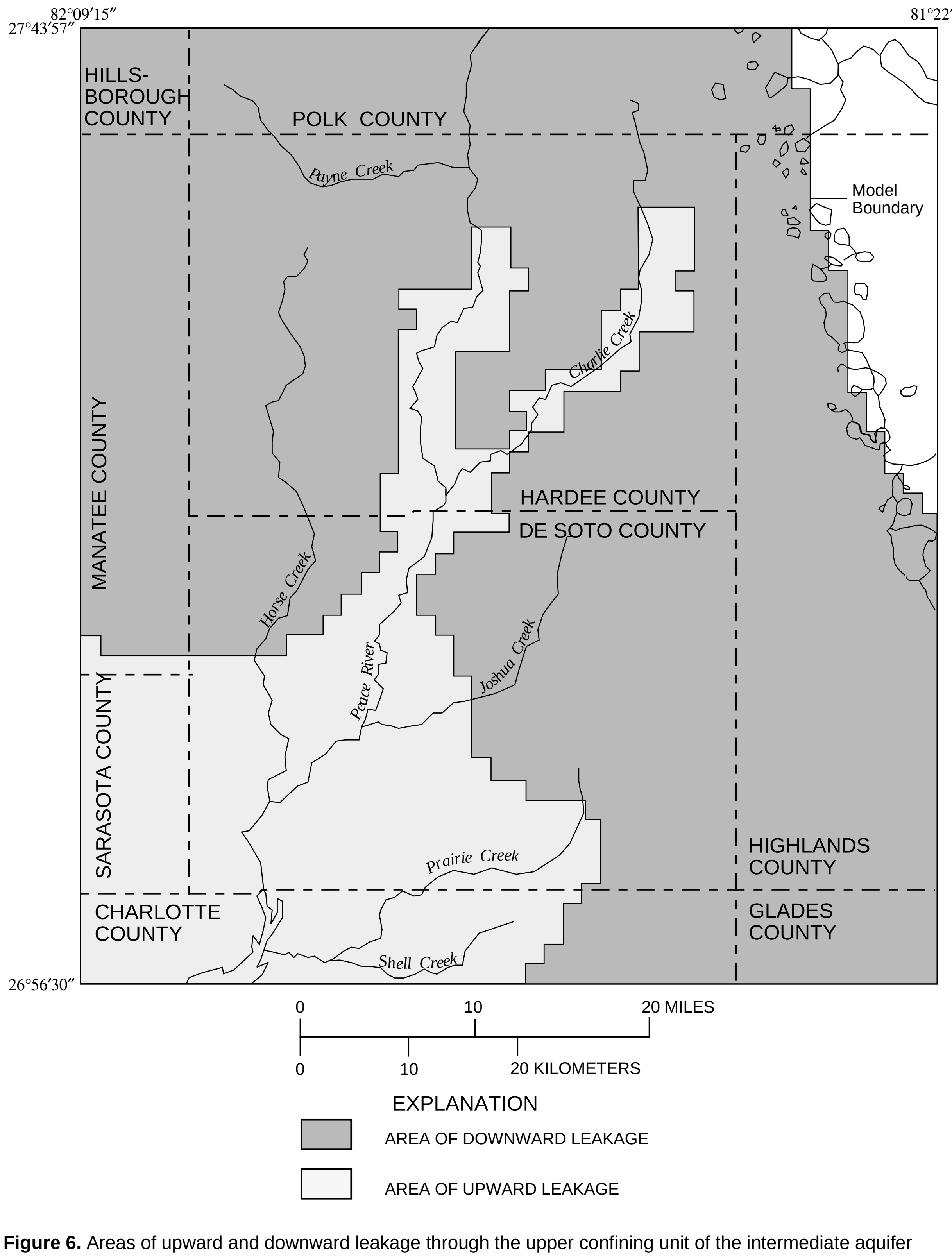


Figure 6. Areas of upward and downward leakage through the upper confining unit of the intermediate aquifer system, September 1988. (Modified from Metz, 1995.)

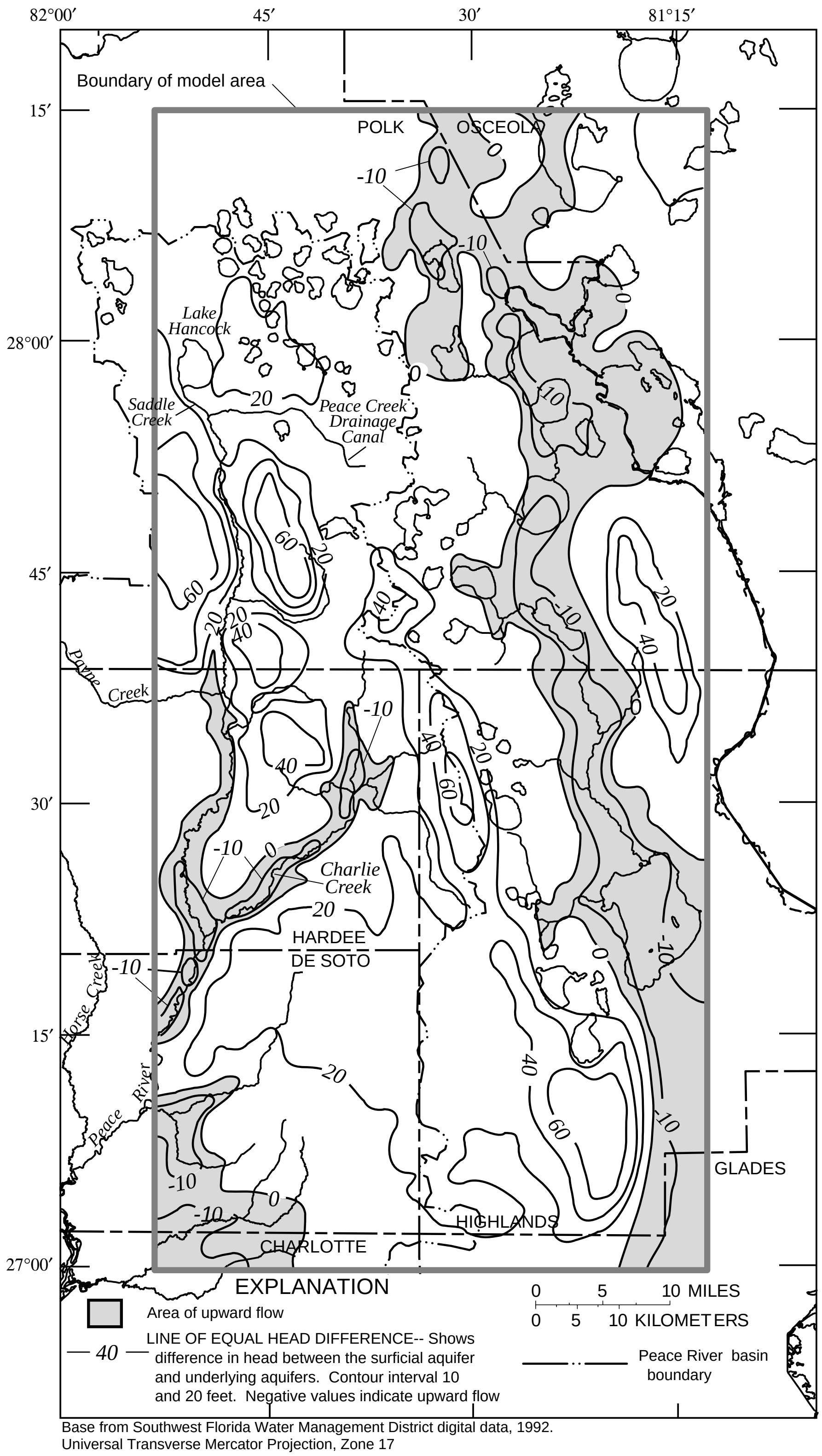
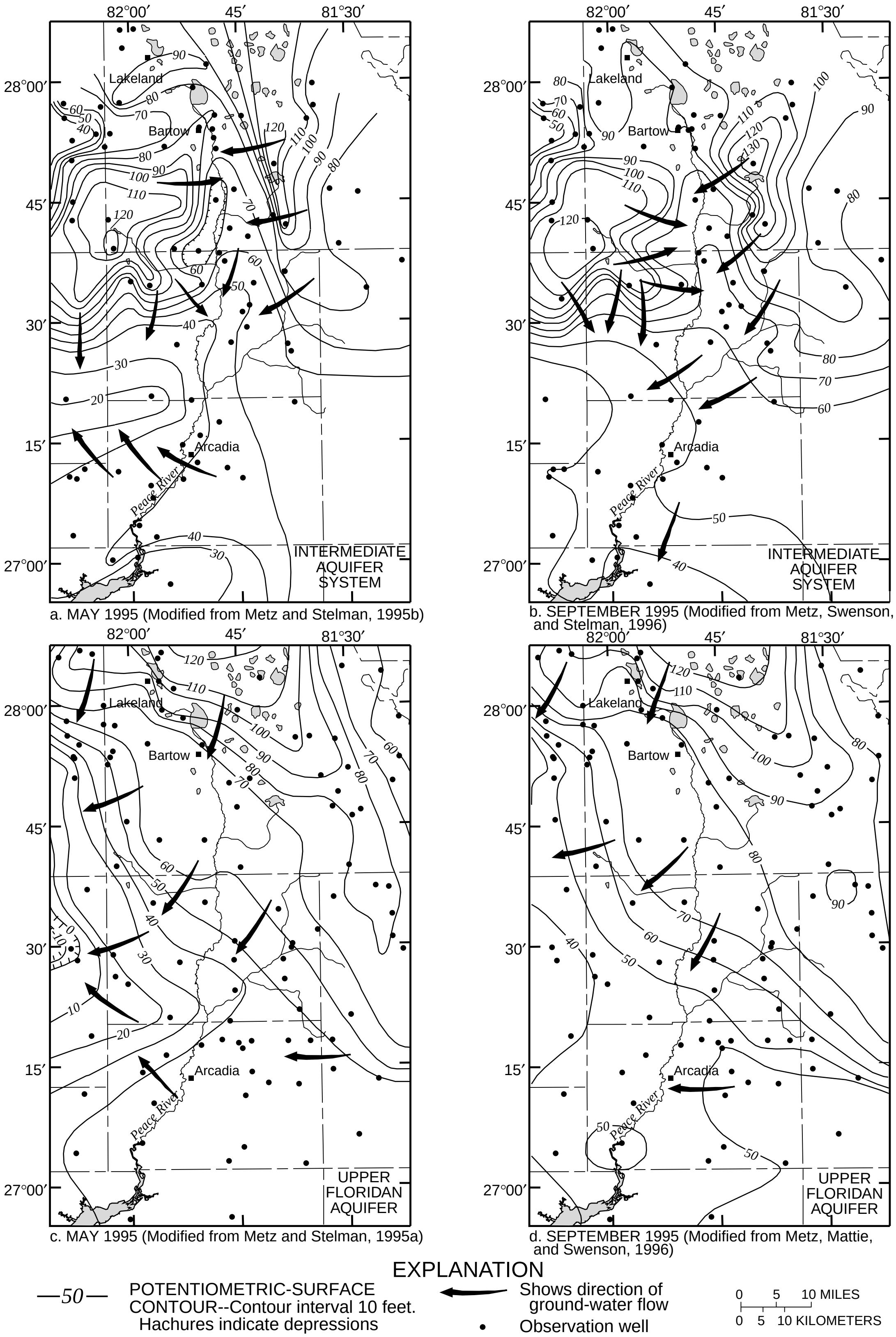


Figure 7. Head difference between the surficial aquifer and underlying aquifers and areas of upward flow, September 1989. (Modified from Yobbi, 1996.)



a. MAY 1995 (Modified from Metz and Stelman, 1995b)

b. SEPTEMBER 1995 (Modified from Metz, Swenson, and Stelman, 1996)

c. MAY 1995 (Modified from Metz and Stelman, 1995a)

d. SEPTEMBER 1995 (Modified from Metz, Mattie, and Swenson, 1996)

Figure 8. Potentiometric surfaces and regional ground-water flow of the intermediate aquifer system and the Upper Floridan aquifer, 1995.

basin and the regional ground-water system occur are determined by: (1) elevations of the potentiometric surfaces of the surficial aquifer, the intermediate aquifer system and the Upper Floridan aquifer; (2) the relative head differences between these hydrologic units; (3) the thickness, continuity, and hydrologic properties of confining units; and (4) the relation between the surface-water system and the potential and direction of ground-water movement within the Peace River basin.

The surficial aquifer is present throughout the study area. The water table is generally within 5 ft of land surface, except in ridge areas. Moderate water-table gradients exist along the major stream courses. In the upper Peace River basin, well-developed internal drainage provides effective avenues for recharge through the surficial aquifer, and little surface drainage exists. Further south, rainwater that does not directly infiltrate the surficial aquifer is generally diverted into streamflow, which becomes a dominant feature of the Peace River basin below the Polk-Hardee County line. The surficial aquifer, where exposed, discharges directly into streams and rivers. Hydrologic data for the surficial aquifer and underlying aquifers from September 1989 were used by Yobbi (1996) to calculate head differences between these hydrologic units. From Bartow to the Polk-Hardee County line, the Peace River dissects an area where the head difference between the surficial aquifer and underlying aquifers can be as large as 60 ft. In 1989, this head difference was approximately 20 ft along the course of the river. The head potential in this region is downward, indicating that the surficial aquifer probably recharges the underlying ground-water system. In Hardee and De Soto Counties, the head potential is upward along the Peace River basin, with head differences ranging from 0 to 10 ft between the surficial aquifer and underlying aquifers. In these areas, the surficial aquifer and adjacent surface-water features likely receive ground-water recharge from the underlying aquifers.

The Peace River bisects a regional potentiometric high in the intermediate aquifer system in Polk and Hardee Counties (fig. 8a and b). These potentiometric highs occur within topographic highs to the east and west of the Peace River basin. Based on gradients observed on potentiometric-surface maps, ground-water flow within the intermediate aquifer system is toward the Peace River basin from both the east and west within Polk and northern Hardee Counties. In central Hardee County, the general ground-water flow direction within the intermediate aquifer system is toward the southwest. The general flow pattern seasonally shifts direction in De Soto County north of Arcadia, which probably reflects the influence of ground-water withdrawals to the north and west.

Based on historical potentiometric data for the Upper Floridan aquifer, regional ground-water flow is generally from northeast to southwest through Polk, Hardee, and De Soto Counties (fig. 8c-d). In 1995, the general flow direction in De Soto County shifted to a more northwest direction due to the influence of large depressions in the Upper Floridan potentiometric surface caused by ground-water withdrawals in Sarasota and Manatee Counties.

HYDROLOGIC EFFECTS OF GROUND-WATER DEVELOPMENT

Hammett (1990) related the progressive long-term decline in Peace River discharge that occurred from 1931 to 1984 to the decline in the potentiometric surfaces of the underlying intermediate aquifer system and Upper Floridan aquifer. In the upper Peace River basin, an approximate 60-ft decline in the potentiometric surface of the Upper Floridan aquifer occurred over a 60-yr period (adapted from Stringfield, 1936). Historical and current potentiometric-surface profiles of the Upper Floridan aquifer relative to land surface along a line of wells in section *D-D′* for September 1934, 1994, and May 1995 are shown in figure 9.

Trend Analyses of Streamflow

According to Hammett (1990), a statistically significant decline in annual mean discharge occurred at the Bartow (1939-84), Zolfo Springs (1933-84), and Arcadia (1931-84) streamflow gaging stations. Hammett (1990) used the nonparametric Kendall tau procedure described by Hirsh and others (1982), which examines all possible pairs of chronologically ranked data to analyze for long-term trends. If the chronologically later measurement of each pair has a higher value than the earlier measurement, then the pair is concordant. Conversely, if the chronologically later measurement has a lower value than the earlier measurement, then the pair is discordant. If the number of concordant and discordant pairs are not statistically different, then no trend is discerned.

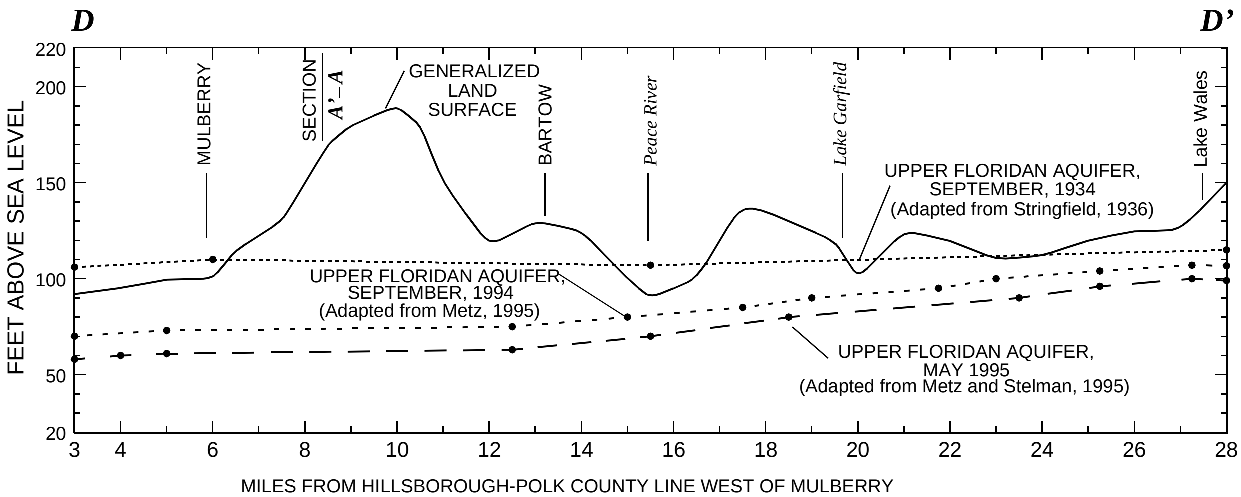


Figure 9. Comparison of historic and current potentiometric-surface profiles of the Upper Floridan aquifer along section *D-D′*, September 1934, September 1994, and May 1995. (Location of section *D-D′* is shown on figure 4.)

If the number of concordant pairs is statistically greater than the number of discordant pairs, then an upward (increasing) trend exists. If the opposite occurs, then the trend is downward (decreasing). A Kendall slope estimator describes the magnitude of a trend determined from a Kendall tau test as the median of the differences (expressed as slopes) of the ordered pairs of data values that are compared in the Kendall tau test. In the case of annual mean discharge, the magnitude of the slope is expressed in cubic feet per second. Table 1 shows the results of a trend analysis at three continuous-record Peace River streamflow stations for the period including Hammett's (1990) analysis (for data collected 1931-84) and the subsequent 10-yr period (1985-94). The trend is shown as an average change in discharge per year and as a percentage of long-term average discharge. Significance levels, ranging from 0.0004 to 0.008 for the three long-term stations, indicate that a decline in discharge occurred over the period of record. Table 2 presents discharge conditions during the 20-yr period from 1975 to 1994. The higher

Table 1. Long-term trend analyses of annual mean discharge for Peace River streamflow stations, 1932-94

Station name	Station no.	Period of record	Kendall tau	Significance level	Trend slope	
					Cubic feet per second per year	Percentage
Peace River at Bartow	02294650	1940-94	-0.33	0.0004	-3.46	-1.96
Peace River at Zolfo Springs	02295637	1934-94	-.30	.0007	-6.24	-1.08
Peace River at Arcadia	02296750	1932-94	-.23	.008	-8.89	-.88

Table 2. Twenty-year long-term trend analyses of annual mean discharge for Peace River streamflow stations, 1975-94

Station name	Station no.	Period of record	Kendall tau	Significance level	Trend slope	
					Cubic feet per second per year	Percentage
Peace River at Bartow	02294650	1940-94	0.05	0.77	1.65	1.22
Peace River at Fort Meade[1]	02294898	1975-94	.06	.74	1.34	.90
Peace River at Zolfo Springs	02295637	1934-94	.09	.58	4.18	1.10
Peace River at Arcadia	02296750	1932-94	.06	.72	6.18	.88

[1]Period of record for Peace River at Fort Meade is 20 years.

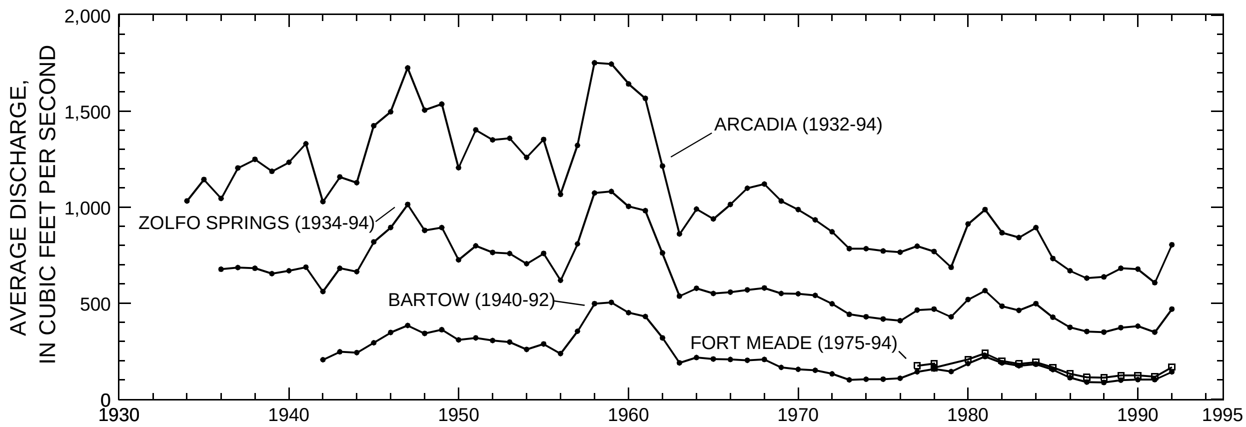


Figure 10. Five-year moving averages of annual mean discharge for the Peace River at Bartow, Fort Meade, Zolfo Springs, and Arcadia streamflow gaging stations. (Modified from Hammett, 1990.)

significance levels shown in table 2, ranging from 0.58 to 0.77, suggest that a 20-yr trend in annual mean discharge does not exist. This may be related to a recovery in ground-water levels since 1974, associated with improved water conservation practices implemented by the phosphate-mining industry which requires less ground-water withdrawal than prior to 1974. Five-year moving averages of annual mean discharge for the Peace River at Bartow, Fort Meade, and Arcadia, show a declining discharge trend until the mid-1970’s (fig. 10). The discharge trend since the mid-1970’s is relatively level.

Changes in Spring Flow

Areas of the upper Peace River basin exhibited artesian flow conditions prior to the regional lowering of potentiometric surfaces in the area (Peek, 1951; Stewart, 1966). Kissengen Spring, the only major spring in the area, and several minor springs along the upper Peace River, discharged from both the intermediate aquifer system and the Upper Floridan aquifer (fig. 1). At the headwaters of the Peace River, artesian flowing wells were reported by Stewart (1966) in 1948 near Saddle Creek. Stewart (1966) also reported discharge issuing from exposed outcrops along Saddle Creek during mining operations. Ground-water levels in the area were reported to have been about 2 ft above land surface in 1948, but decreased to 11 ft below land surface by 1956 (Stewart, 1966) as a result of the combined effects of a prolonged drought (1954-56) and ground-water withdrawals for phosphate mining. In 1959, water levels rose to near land surface for brief periods, but generally were about 2 ft below land surface.

Water-level data used in this study are from 29 wells throughout the study area (fig. 1). Descriptions of these wells are given in table 3. Ground-water levels at Kissengen Spring were interpolated from water levels over a continuous 47-yr period (fig. 11) in the Upper Floridan aquifer at the Claude Hardin well (site W1), located southwest of the city of Lakeland, the ROMP 60 well at Mulberry (site W3), and the ROMP 59 Avon Park well at Bartow (site W5a). Higher ground-water levels in the Claude Hardin well may reflect the higher heads beyond the influence of large ground-water withdrawals for phosphate mining. Correlations between ground-water levels in the Claude Hardin well and the ROMP 60 well (fig. 12a), and between the ROMP 60 well and the ROMP 59 well (fig. 12b) are excellent. Additionally, the correlation between ground-water levels in the Upper Floridan aquifer at the V.C. Corporation well (fig. 1, site W8), 2.2 miles south of Kissengen Spring, with those of the ROMP 59 Avon Park well (site W5a) is also excellent (figs. 12c and 13). Similar ground-water levels for the concurrent period of record (1976-95), shown in figure 13, indicate that a line of relatively equal potentiometric head may exist from the ROMP 59 Avon Park well (site W5a) to Kissengen Spring and to the V.C. Corporation well (site W8).

Table 3. Description of wells used in the study

[UFA, Upper Floridan aquifer; IAS, intermediate aquifer system; SA, surficial aquifer; --, no data]

Site no.	Well name	Aquifer	Station number	Period of record	Depth (feet)	Casing length (feet)
W1	Claude Hardin	UFA	275949081582401	1948-70	643	325
W2	Tillery Road Deep	UFA	275628081541201	--	542	231
W3	ROMP 60 Deep	UFA	275326081585801	1955-96	710	237
W4	Central Florida Truss Hawthorn	IAS	275440081493701	1988-96	60	47
W5a	ROMP 59 Avon Park	UFA	275314081514201	1977-96	1,050	200
W5b	ROMP 59 Hawthorn	IAS	275314081514202	1977-96	142	122
W5c	ROMP 59 Upper Hawthorn	IAS	275314081514203	1977-96	60	50
W6	L.B. Barnes	IAS	275301081495701	1986-96	120	60
W7	IMC Test Well (Homeland 8)	IAS	275040081493001	1975-96	227	68
W8	V.C. Corporation (Homeland (9)	UFA	274841081480901	1975-96	746	--
W9a	ROMP 45 Suwannee	UFA	274547081470902	1980-96	440	330
W9b	ROMP 45 Hawthorn	IAS	274547081470901	1976-96	192	110
W9c	ROMP 45 Avon Park	UFA	274547081470903	1976-96	757	680
W10	Mobil Well UF9 North	IAS	274108081474601	1986-96	--	--
W11	Bryan Hawthorn	IAS	273813081491201	1988-96	163	41
W12	Whitehurst Deep	UFA	273834081464701	--	850	--
W13	Payne Creek Historic Site	IAS	273714081483101	1990-96	130	119
W14	Rowell Deep Hawthorn	IAS	273156081451401	--	267	39
W15	W.D. Bond HA-89	IAS	273108081461301	1986-96	229	--
W16	City of Zolfo Springs Deep	UFA	272944081474001	--	1,002	350
W17a	ROMP 30 Avon Park	UFA	272728081474701	1981-96	1,266	380
W17b	ROMP 30 Tampa	IAS	272728081474702	1981-96	316	280
W17c	ROMP 30 Shallow	SA	272728081474703	1981-96	15	5
W18	Marshall Deep	UFA	272012081482501	1993-96	478	137
W19	Camp Chanyatah No. 49	IAS	271623081520101	1986-96	193	43
W20a	ROMP 26 Avon Park	UFA	271757081493002	1978-96	1,320	580
W20b	ROMP 26 Hawthorn	UFA	271757081493003	1978-96	180	140
W20c	ROMP 26 Shallow	SA	271757081493001	1978-96	15	10
W21	Arcadia Well No. 2	IAS	271308081522601	1964-96	372	263
W22	Minute Maid 43 FBG D-68	IAS	271109081541901	1986-96	325	90
W23	ROMP 17 Avon Park	UFA	271026081583601	1992-96	1,430	1,115

Ground-water levels in the intermediate aquifer system were compared between the ROMP 59 Hawthorn well (site W5b) and the IMC Test Well (site W7), located approximately 0.85 mi west of Kissengen Spring (fig. 14). These levels (at sites W5b and W7) were also compared with the ground-water levels in the Upper Floridan at the V.C. Corporation well (site W8) in figure 14. Correlations using both the annual maximum and minimum ground-water levels are only fair (fig. 12d). However, upon separately evaluating the correlation of maximum and minimum water levels at the two wells, a good correlation existed between sites during the period of annual maximum levels and only a fair correlation existed during the period of minimum levels (fig. 12e-f). The IMC Test Well (site W7), which is 227 ft in depth and cased to 68 ft, is open to both the intermediate aquifer system and the Upper Floridan aquifer, and reflects a composite ground-water level representing both aquifers. Maximum water levels at the well, and most likely at Kissengen Spring, are

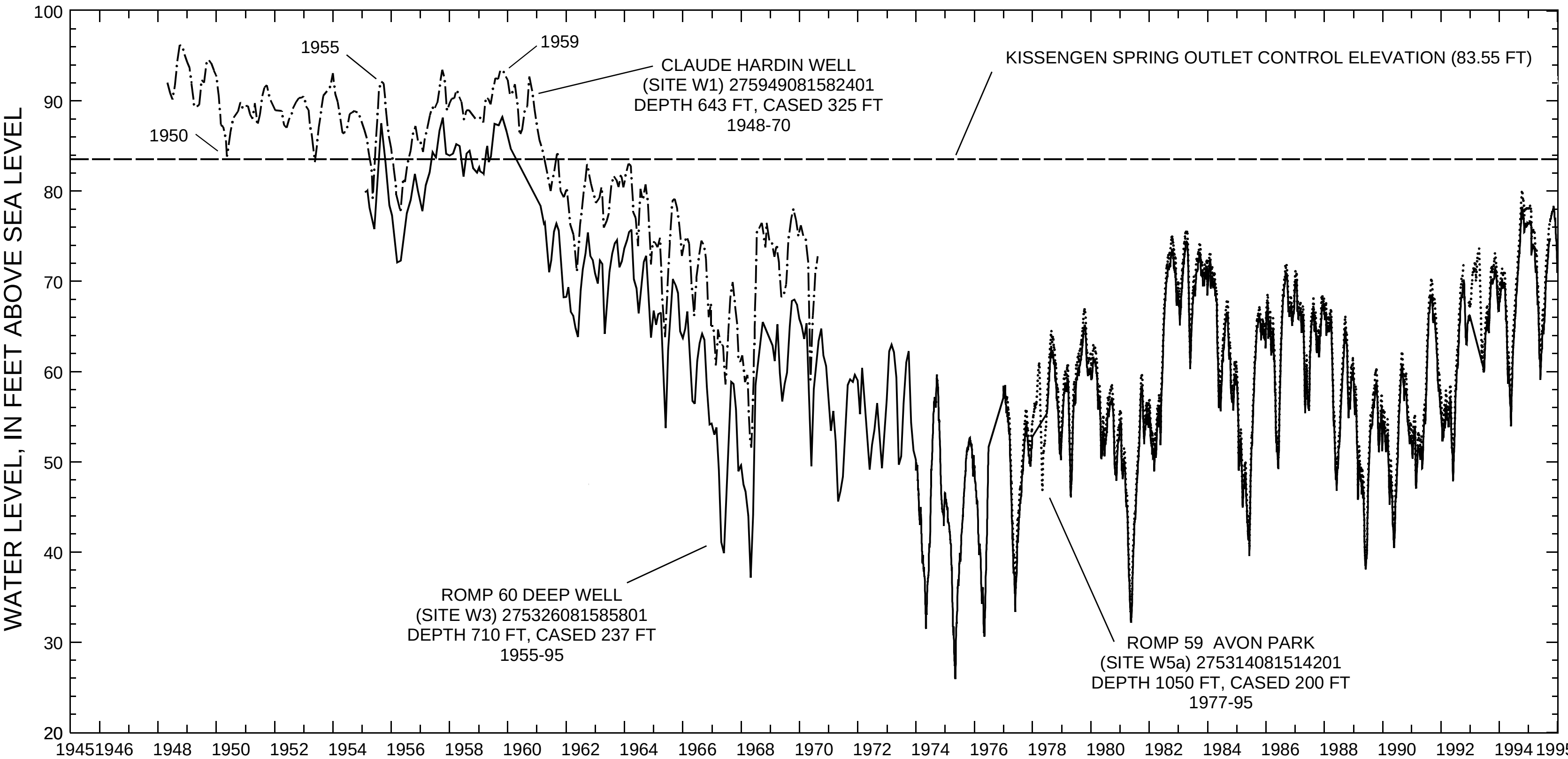


Figure 11. Ground-water levels in the Upper Floridan aquifer at the Claude Hardin, ROMP 59, and ROMP 60 wells, south-central Polk County, 1948-95. (Location of wells are shown in figure 1.)

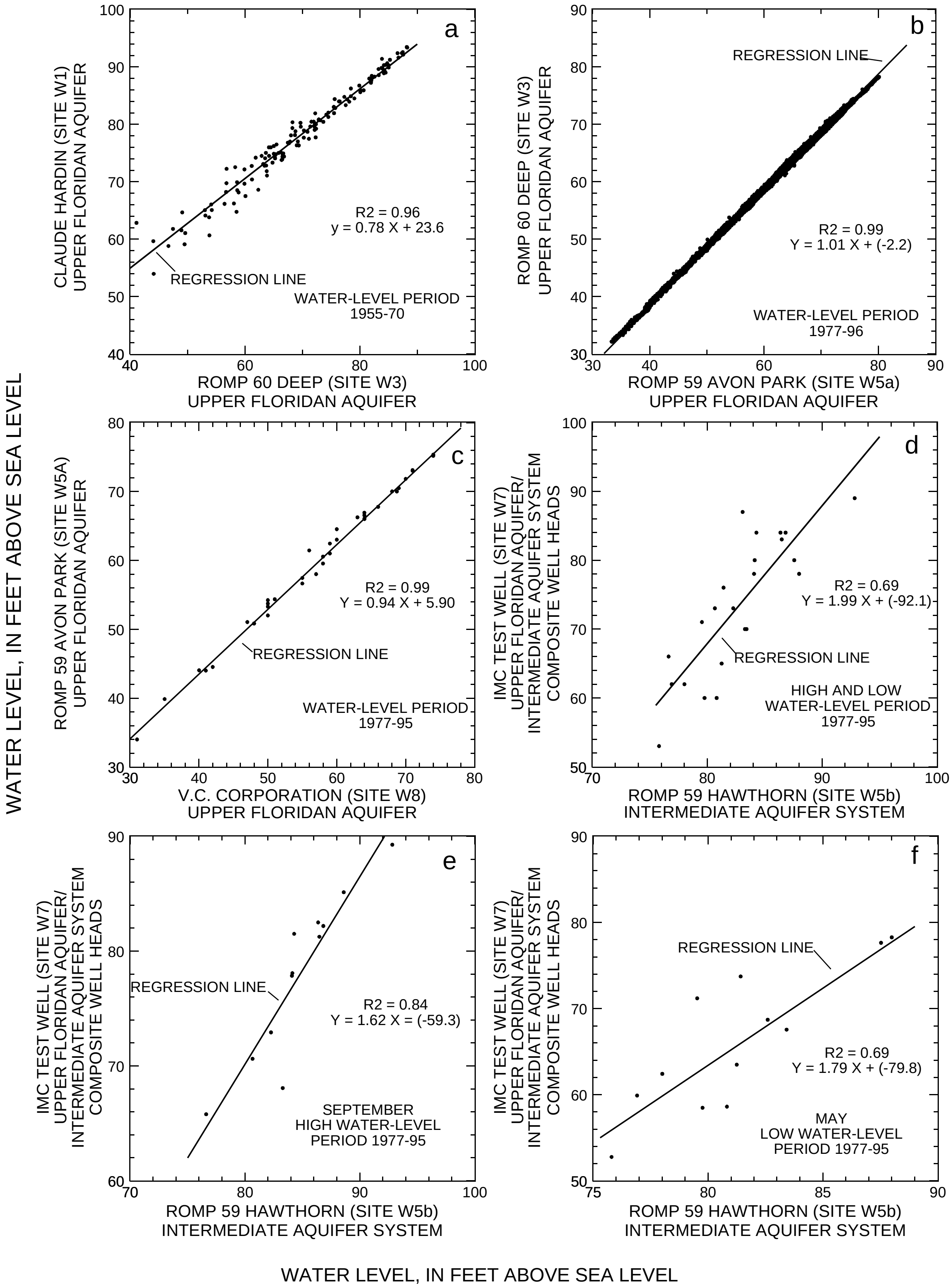


Figure 12. Relation between ground-water levels in wells in the Upper Floridan aquifer (a-c) and composite water levels in the intermediate aquifer system and Upper Floridan aquifer with water levels in the intermediate aquifer system (d-f). (Well depths and casing lengths are shown in table 3.)

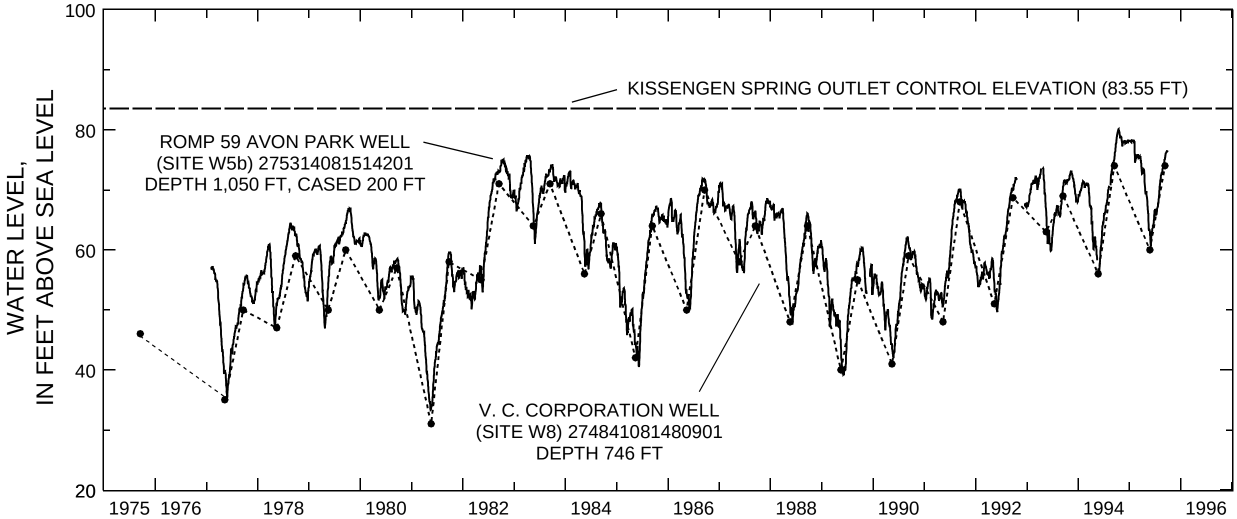


Figure 13. Ground-water levels in the Upper Floridan aquifer at the ROMP 59 Avon Park and the V.C. Corporation wells, 1975-95.

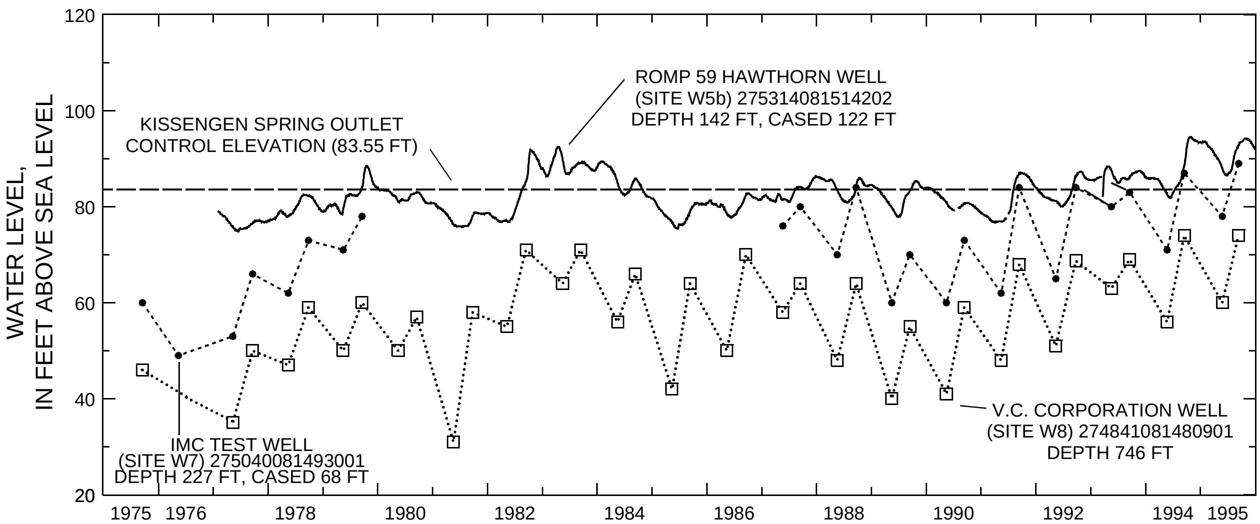


Figure 14. Ground-water levels in the intermediate aquifer system at the ROMP 59 Hawthorn well and in the Upper Floridan aquifer at the V.C. Corporation well, and composite ground-water levels in the intermediate aquifer system and Upper Floridan aquifer in the IMC Test Well, 1975-95.

similar to those of the intermediate aquifer system, and minimum levels are lower than those found in the intermediate aquifer system. The ground-water level in the Upper Floridan aquifer at the V.C. Corporation well (site W8) is approximately 20-ft lower than levels recorded in the intermediate aquifer system at the ROMP 59 well (site W5b). However, figure 14 shows that the IMC Test Well (W7) composite ground-water level (Upper Floridan aquifer and the intermediate aquifer system) is generally an average of the intermediate aquifer system levels at ROMP 59 (site W5b) and the Upper Floridan aquifer level at V.C. Corporation well (site W8).

The cessation of spring flow, both at Kissengen Spring and at many minor springs in the upper Peace River basin, was related to the regional lowering of the potentiometric surfaces of the intermediate aquifer system and the Upper Floridan aquifer from 1937 to 1950 (Peek, 1951; Stewart, 1966). Kissengen Spring was a major source of ground-water discharge to the Peace River and was used for recreational purposes for decades. The USGS made a total of 177 discharge measurements at Kissengen Spring from 1898 to 1960, of which 78 were observations of no-flow (fig. 15). The two initial discharge measurements, made in 1898 and 1917, were 31 ft^3/s (20 Mgal/d) and 21 ft^3/s (13.5

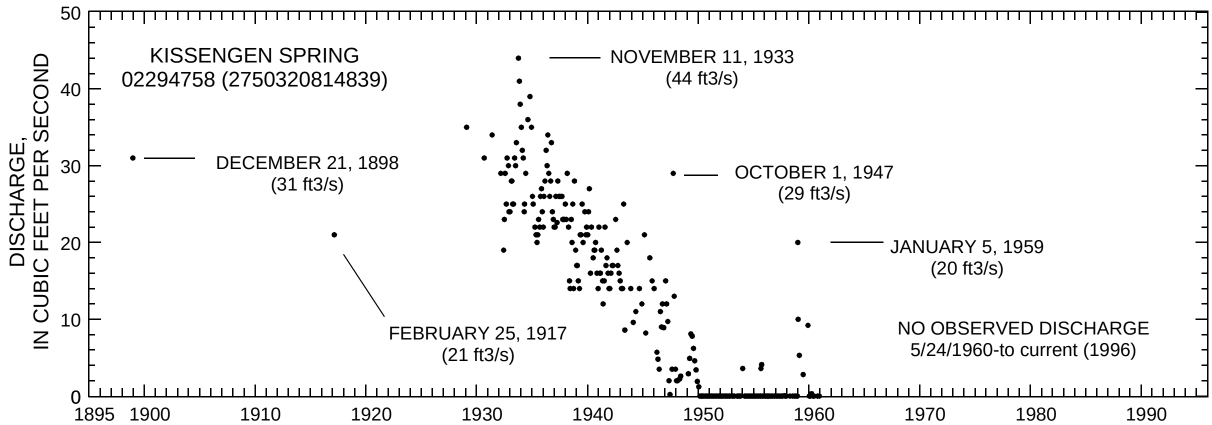


Figure 15. Periodic discharge measurements at Kissengen Spring, 1898-1960.

Mgal/d), respectively. Monthly measurements made during the 5-year period from 1932 to 1936 averaged 29 ft^3/s (19 Mgal/d). However, after the measurement period of 1932-36, discharge declined progressively until the spring ceased flowing in February 1950. Spring discharge recoveries occurred temporarily in 1955 and 1959; these recoveries were initiated by high ground-water level conditions in the Upper Floridan aquifer (fig. 11). Water-level decreases at the Claude Hardin well (site W1) correspond to approximately the same period Kissengen Spring first stopped flowing; water-level increases in 1955 and 1959 in the Upper Floridan aquifer at the ROMP 60 well (site W3) correlate with the period of flow recovery at Kissengen Spring. Permanent cessation of flow occurred in April 1960. For Kissengen Spring to flow again, a reversal of head gradients must occur, and the water-level elevation in the Upper Floridan aquifer at the spring must be above 83.55 ft (elevation of outflow control structure).

Effects of Mining Activities on Surface Drainage and Recharge

Much of the upper Peace River basin within Polk County has been surface mined for phosphate since the late 1800’s (fig. 16). Effects from mining and reclamation practices in this area may have contributed to the overall decline in streamflow in the Peace River. Two major effects on streamflow conditions that are related, in part, to mining activities are: (1) the lowering of the potentiometric surfaces in underlying aquifers by large ground-water withdrawals, resulting in the cessation of spring discharge and a reversal of natural head gradients, and (2) the significant alteration of local natural surface-drainage patterns. Furthermore, exposing the aquifer through mining has resulted in the lowering of ground-water head, ground-water impoundment, and loss of ground water to evaporation.

Reclamation practices commonly used by the phosphate-mining industry alter the natural surface-drainage patterns. Naturally incised streams drained by a dendritic network commonly are replaced by swales and other poorly defined drainage features during reclamation (Lewelling and Wylie, 1993). Soils of unmined areas tend to be well sorted and allow infiltration of rainfall and runoff, whereas soils altered by reclamation activities commonly are less pervious because of an increased clay content in the surface horizons. River base flow, derived from ground-water discharge from underlying aquifer systems, and in many cases directly through springs, has significantly been reduced or ceased along the upper reaches of the Peace River. This reduction or cessation of base flow could be a result of the widespread practice by the phosphate-mining industry of constructing large reclaimed clay-settling areas adjacent to the Peace River. Clay-settling areas, which generally cover hundreds of acres and can be more than 40 ft deep at times, are the dominant reclaimed landform produced during surface mining. In Polk County, these landforms are generally contiguous along both sides of the Peace River floodplain, from Bartow to Bowling Green. Typically, a reclaimed clay-settling area is built

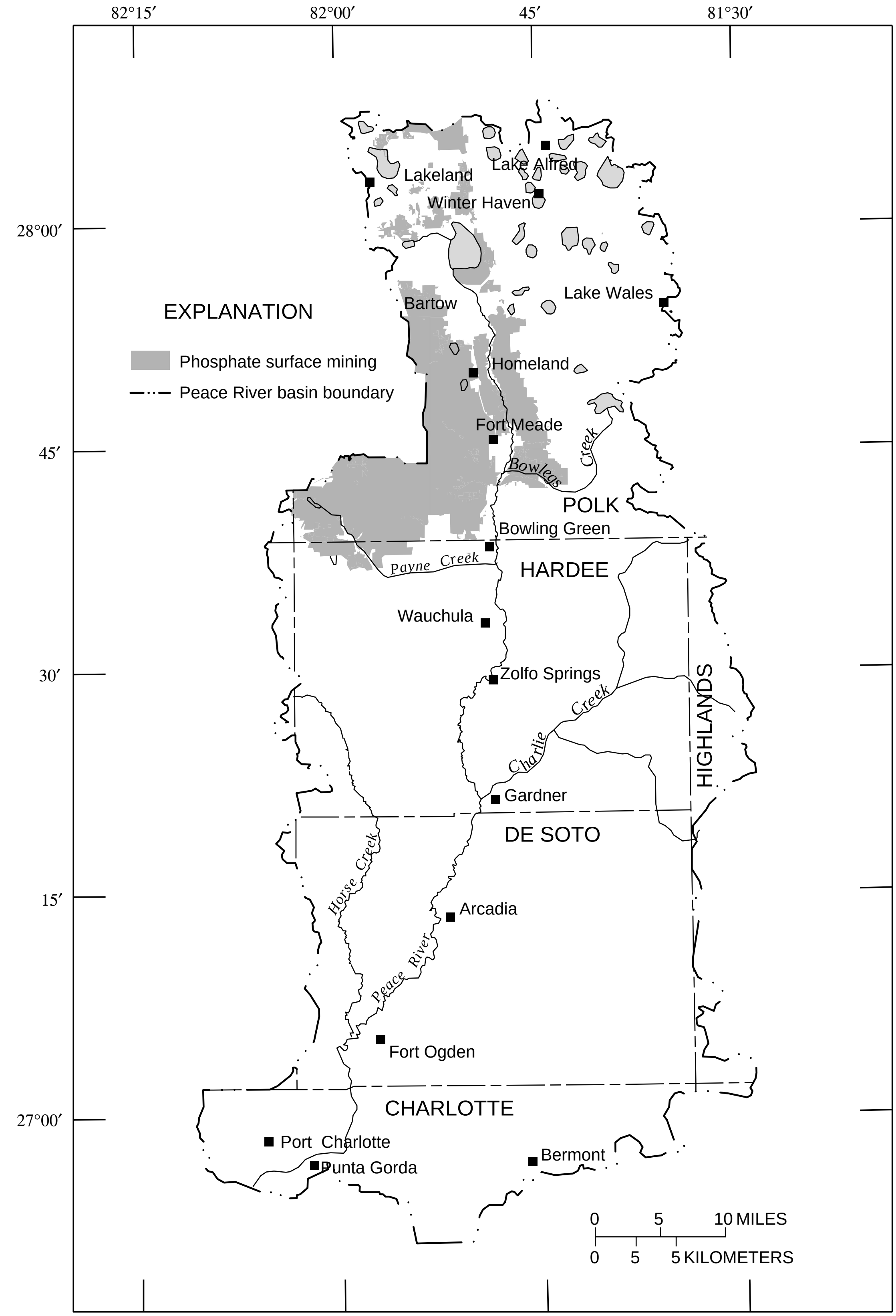


Figure 16. Extent of phosphate surface mining in the upper Peace River basin, 1990.

by constructing a high perimeter dam around a mined-out area, forming a containment to hold the clay-waste slurry. During construction of the clay-settling area, most of the disturbed overburden is removed from the mined pit to build the perimeter dam around it and to provide more room for clay storage. A clay slurry is separated from the phosphate matrix during the beneficiation process and is pumped into the newly formed clay-settling area to dewater, settle, and consolidate. The process of backfilling a clay-setting area is completed over a period of years. Once filled, the clay consolidation process can continue for decades before reaching the final design elevation. Because of the low hydraulic conductivity of clay, ground-water recharge and movement through a clay-settling area is significantly less than in natural conditions. Additionally, shrinkage of the consolidating clays can cause surface depressional features to form, increasing ponding and evaporation and reducing runoff (Lewelling and Wylie, 1993).

HYDROLOGIC CONDITIONS ALONG THE PEACE RIVER FROM BARTOW TO ARCADIA

Ground-water discharge from the surficial aquifer to the Peace River and its tributaries is a major source of base flow. Base flow is typically derived from precipitation which infiltrates the saturated zone of the surficial aquifer. Where the potentiometric surfaces of the intermediate aquifer system and the Upper Floridan aquifer rise above the water table in the surficial aquifer and a hydraulic connection exists, ground water can move upward through confining units and aquifers and discharge directly into the Peace River through springs or indirectly by diffuse leakage. Conversely, in areas along the river where these potentiometric surfaces are below the streambed, losses of river water may result from downward leakage. Seasonal high and low extremes of the potentiometric surfaces that occur along the Peace River affect head gradients between the river and the aquifers and control the areal extent and potential contribution to the river from the underlying confined aquifers. These extremes are due largely to a variability in precipitation and stresses resulting from ground-water withdrawals by agriculture, municipalities, industry, and domestic users. Metz (1995) and Yobbi (1996) identified areas of upward and downward leakage along the Peace River in southern Polk, Hardee, and De Soto Counties, based on the results of ground-water flow models. Areas of upward leakage through the confining unit of the intermediate aquifer system into the surficial aquifer and then to the Peace River are shown in figure 6. A potential exists for upward leakage from the Upper Floridan aquifer through the lower confining unit of the intermediate aquifer system along parts of the Peace River.

Areal Hydrologic Subdivisions

Based on the relation between the Peace River channelbed and ground-water levels at selected wells along the Peace River, the river was subdivided into three areas that reflect distinctive areal hydrologic conditions. These three subdivisions are: (1) the upper Peace River, area of downward head gradients; (2) the middle Peace River, area of reversal of head gradients; and (3) the lower Peace River, area of upward head gradients.

The potential for ground-water and surface-water interaction along the length of the Peace River is controlled by the relation between the Peace River and the potentiometric surfaces of hydrologic units within the ground-water system. Sections showing the potentiometric surfaces for both the intermediate aquifer system and the Upper Floridan aquifer were constructed by interpolating the potentiometric surface along the Peace River channel from Bartow to Arcadia for conditions during May and September 1995 (figs. 8 and 19). The historical range of ground-water level measurements made along this same section, compared to the Peace River stage and channelbed, is shown in figure 17. These data show relative changes in the potentiometric surfaces along the length of the Peace River from Bartow to Arcadia. Ground-water heads from Bartow to Fort Meade (upper Peace River area) are generally below the riverbed elevation. Ground-water heads fluctuate from below to above the elevation of the Peace River channel from near Fort Meade to below Zolfo Springs (middle Peace River area). Ground-water heads consistently are above the elevation of the river channel from below Zolfo Springs to the mouth (lower Peace River).

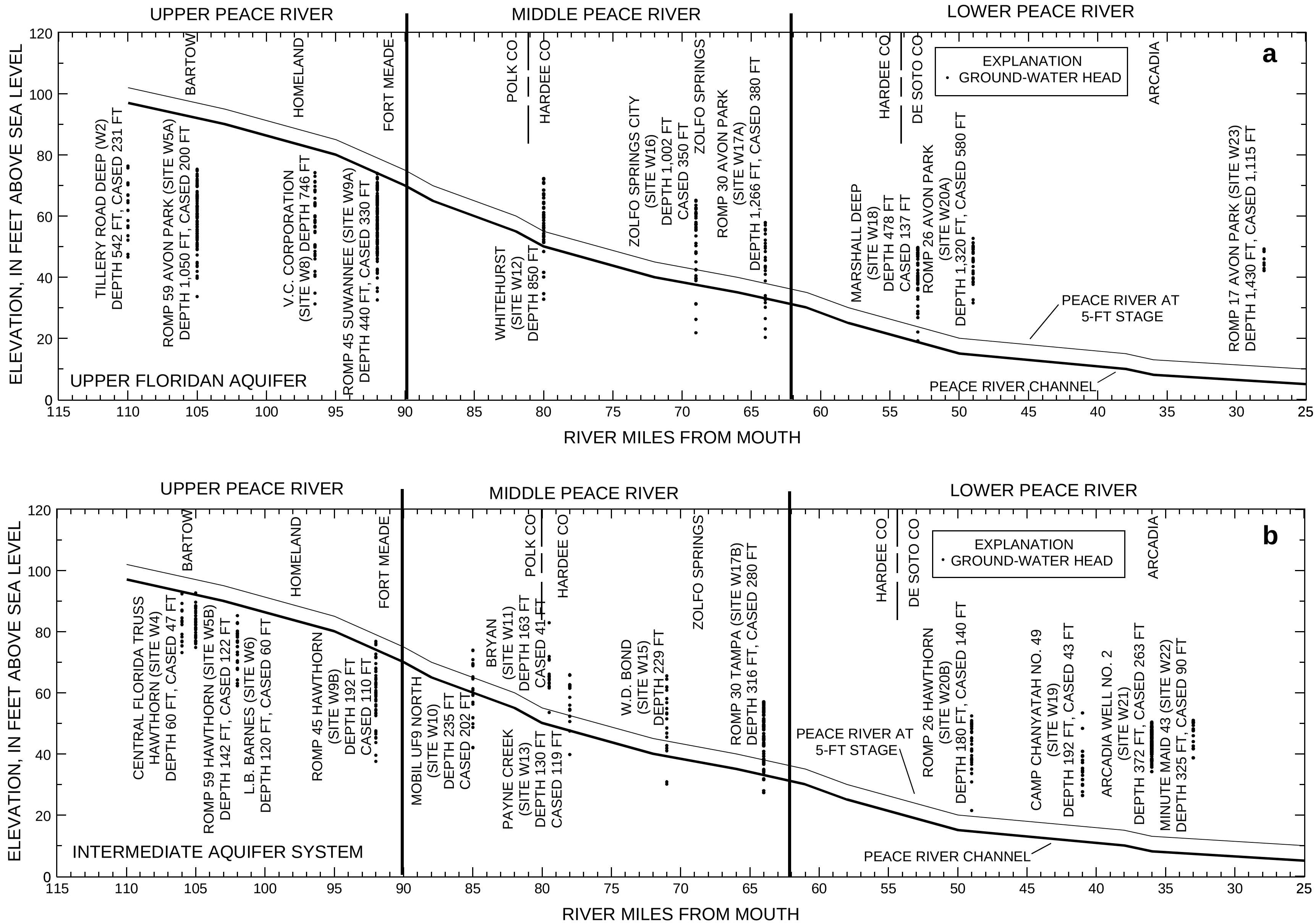


Figure 17. Historical ground-water levels in wells in the (a) Upper Floridan aquifer and (b) intermediate aquifer system compared to Peace River stage and channel elevations. (Well locations are shown in figure 1 and well descriptions are shown in table 3.)

Although ground-water head ultimately controls the direction of ground-water flow, the rates and volumes of ground-water flow are controlled by hydrogeologic conditions. Hydrologic interaction between the Peace River and the ground-water system varies along the length of the river from Bartow to Arcadia, ultimately affecting surface-water flow. Because the occurrence of recharge and discharge areas is controlled by the direction of head gradients in the surficial aquifer, the intermediate aquifer system, and the Upper Floridan aquifer, losses from and contributions to the Peace River system result as the river's hydrologic regime responds to ground-water head gradients. The presence or absence of breaches in confining units that separate the surficial aquifer, the intermediate aquifer system, and the Upper Floridan aquifer can be significant in controlling both the rate and the seasonal timing of these interactions. Calculated leakance values for confining units are low, but if significant head differences exist across hydrologic units, breaches within confining units can more rapidly transmit larger quantities of water between hydrologic units than can diffuse leakage. Breaches and structural features capable of providing direct conduits and preferential pathways for ground-water movement were identified along the Peace River based on seismic-reflection techniques. However, these features were not verified in the field.

Upper Peace River: Area of Downward Head Gradients

From Bartow to downstream of Fort Meade, the Peace River channel and floodplain is predominantly a ground-water recharge area (figs 17, 18, and 19), based on current conditions that reflect a reversal from the natural ground-water heads of the 1950's. Historically, several springs in the Bartow area discharged significant amounts of ground water into the Peace River. However, since 1960 these springs have ceased to flow (Stringfield, 1936; Peek, 1951; Kaufman, 1967). During the dry season (April-June), ground-water heads in both the intermediate aquifer system and the Upper Floridan aquifer are below the elevation of the river stage from upstream of Bartow to downstream of Fort Meade (figs. 19-21).

During wetter periods of the year, the ground-water heads in the intermediate aquifer system can be higher than the river stage for short periods. Because ground-water heads of the Upper Floridan aquifer are lower than for the intermediate aquifer system, the intermediate aquifer system may, during a short time period, simultaneously recharge the underlying Upper Floridan aquifer and discharge into the overlying Peace River. Ground-water heads at the upper Peace River streamflow gaging stations at Bartow and Fort Meade are based on data from ROMP wells 59 and 45, located approximately 3 and 0.25 mi from the gaging stations, respectively (fig. 1, sites W5a-c and W9a-c).

Continuous water levels in the lower Hawthorn well and intermittent water levels in the upper Hawthorn well of the intermediate aquifer system at the ROMP 59 monitoring site at Bartow (fig. 1, sites W5b-c) periodically exceed the elevation of the river stage (fig. 20). However, since this site is located approximately 3 mi to the southwest of the Peace River at Bartow gaging station, the potentiometric surface of the intermediate aquifer system is probably higher at the well than within the Peace River floodplain (fig. 8a and b). The correlation between maximum stage and maximum ground-water heads in the intermediate aquifer system is similar to that observed at Bartow in September 1995. Further downstream, continuous water levels in the intermediate aquifer system and the Upper Floridan aquifer at the ROMP 45 well at Fort Meade (sites W9a-b) show that ground-water heads in the two aquifers track approximately 4 ft apart and were below the stage of the river, creating a potential for downward movement from the Peace River and surficial aquifer to the intermediate aquifer system and the Upper Floridan aquifer between 1990 and 1992 (fig. 21). At the Fort Meade streamflow gaging station, the elevation of the maximum river stage was also similar to the elevation of the maximum ground-water heads in the intermediate aquifer system for September 1995 (fig. 19). Although continuous water-level data were not available for this study period (1994-96) at the ROMP 45 wells (site W9a-c), which were discontinued in October 1992, continuous water-level data were plotted in figure 21 for the final 2-year period (October 1990 through September 1992) along with hourly stage at the Peace River at Fort Meade. These data demonstrate that ground-water recharge conditions existed prior to this study.

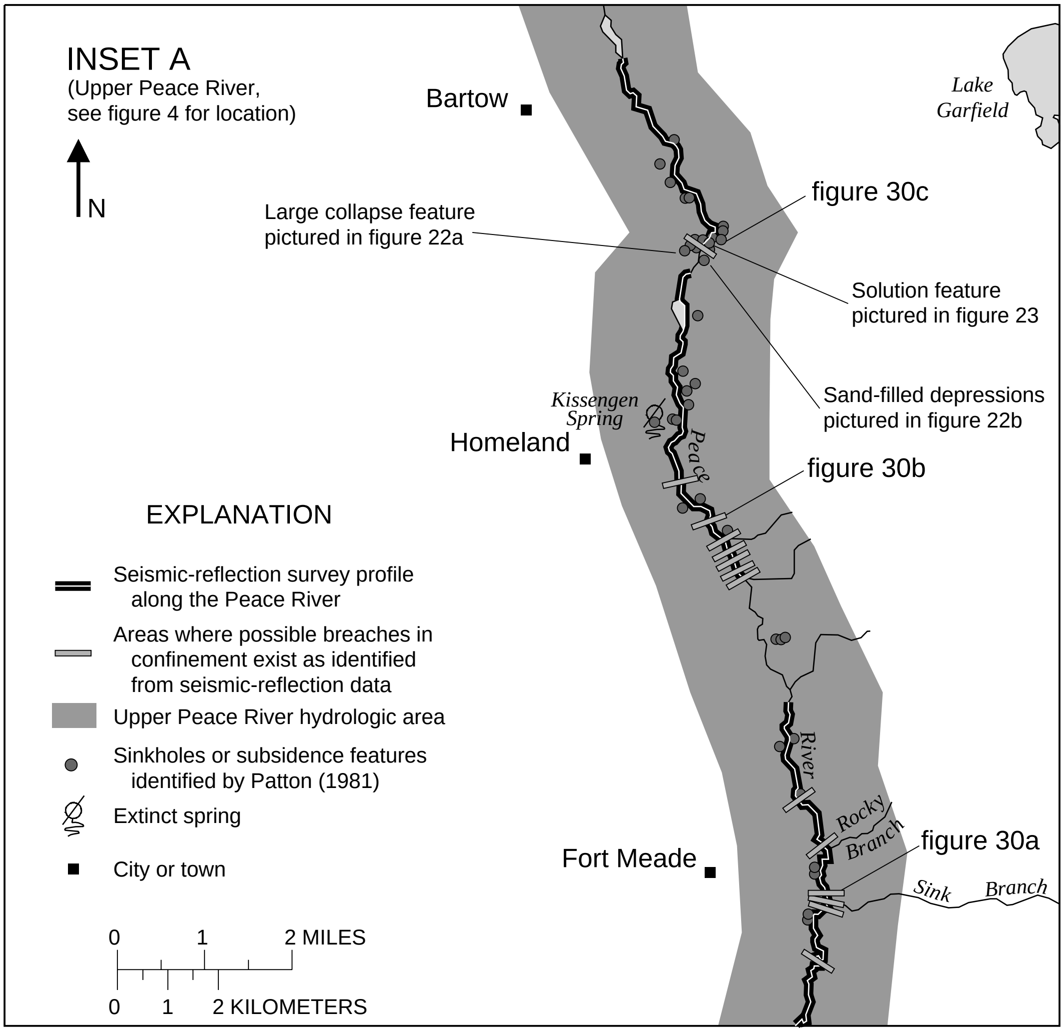


Figure 18. Upper Peace River hydrologic area with locations of seismic-reflection survey profiles, areas in seismic record where possible disruption of confinement exists, locations of interpreted seismic profiles shown in figures 30a, 30b, and 30c, and locations of sinkholes identified by Patton (1981) from Bartow to Fort Meade.

Hydraulic connection between the upper Peace River and underlying aquifers during flood stage may, in part, control the maximum flooding levels attained by the river during high-water conditions and provide significant recharge to the underlying ground-water system. The likelihood of this hydraulic connection is illustrated in figure 20. At the Bartow gage, flooding river levels are followed by a rise in the heads of the intermediate aquifer system and Upper Floridan aquifer in ROMP 59 wells (site W5a-c). Water levels in the Upper Floridan aquifer usually range between 10 and 20 ft below the water levels of the overlying system. The significant head difference and the relatively rapid response of ground-water levels following high-flow events along the river may indicate that recharge from the river to the ground-water system occurs. Further south at Fort Meade, ground-water levels (both in the intermediate aquifer system and the Upper Floridan aquifer) at ROMP 45 wells (site W9a-c) generally track major trends in river stage during the period of October 1990 to September 1992. Highest ground-water levels at the ROMP 45 wells slightly lag the maximum river stage levels. The increase in river stage, followed by the nearly uniform increase in ground-water levels in combination with the downward head gradients observed in this area, indicate that some significant ground-water recharge from the river occurs along this part of the Peace River.

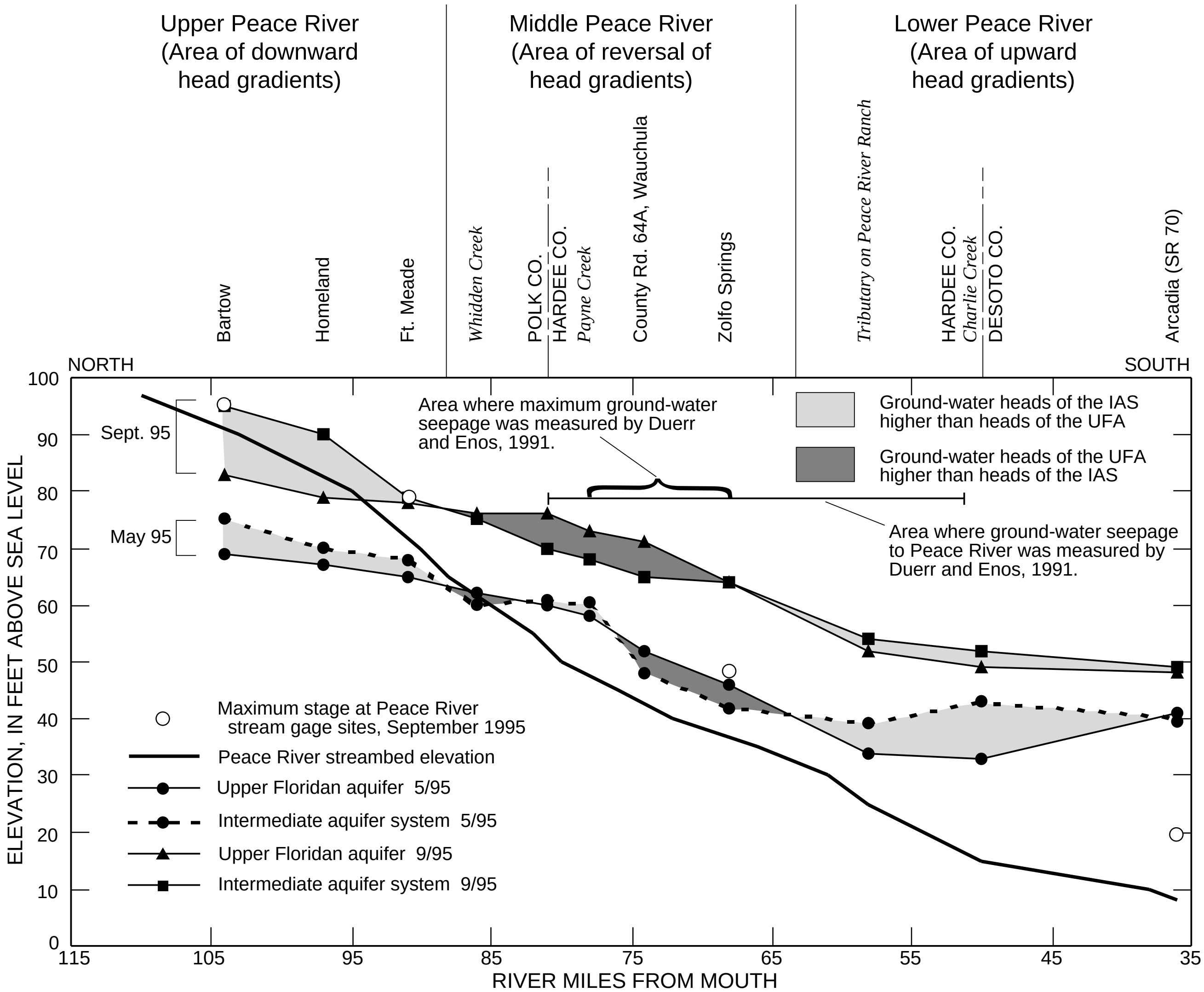


Figure 19. Cross-section of potentiometric surfaces of the intermediate aquifer system (IAS) and the Upper Floridan aquifer (UFA) for May and September 1995 in relation to the Peace River streambed from Bartow to Arcadia. (Adapted from Metz and Stelman, 1995a,b; Metz, Mattie, and Swenson, 1996; and Metz, Swenson, and Stelman, 1996.) (Potentiometric-surface maps are shown in figure 8.)

Recorded decreases in downstream discharge volumes between the Peace River at Bartow and Fort Meade provide further evidence of significant flow loss from the Peace River to the ground-water system. During seasonal dry conditions in the months of May 1995 and May 1996, negative flow differences in Peace River daily mean discharge between the Bartow and the Fort Meade gaging stations ranged from 1 to 9.6 ft^3/s and from 2 to 49 ft^3/s, respectively. The average negative flow difference was 5.1 ft^3/s for the 26 days of occurrence in May 1995 and was 13.1 ft^3/s for the 16 days in May 1996. In this area, little or no natural surface-water contributions occur, and the Peace River may cease flowing at places between Bartow and Homeland during these dry periods. The source of most surface-water contributions between Bartow and Fort Meade comes from either five phosphate-mine outfall control structures or from reclaimed phosphate-mined stream channels.

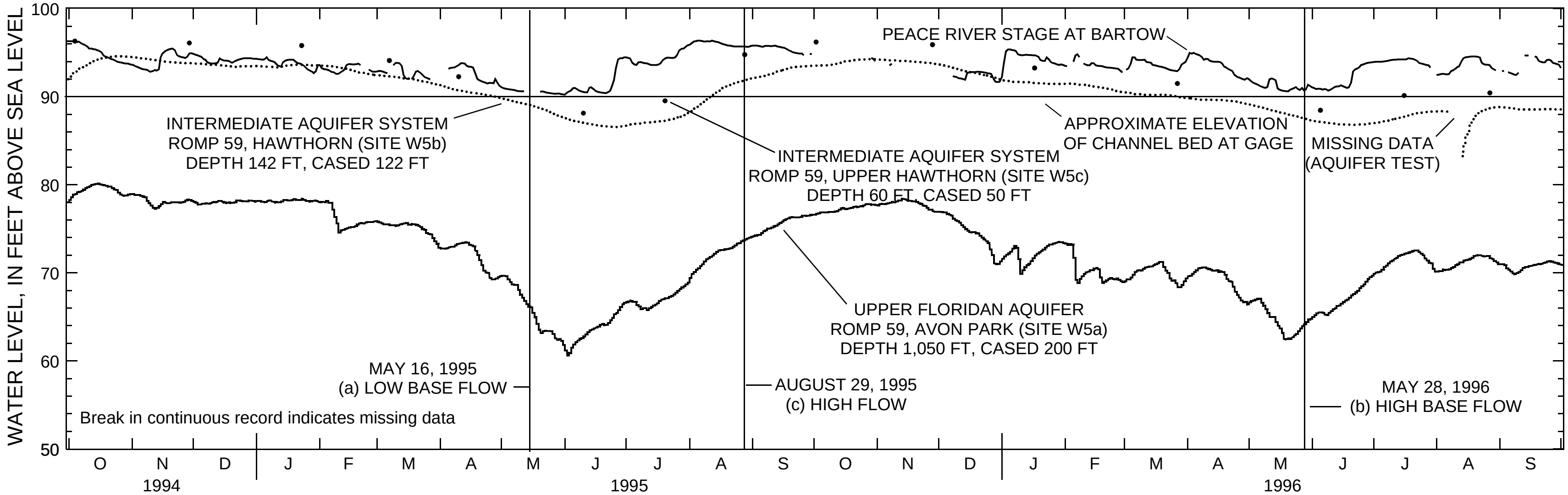


Figure 20. Comparison of Peace River hourly stage at the Bartow streamflow station and maximum daily water levels in the upper Hawthorn, Hawthorn, and Avon Park wells at the ROMP 59 monitoring site at Bartow, October 1994-September 1996, and dates of (a) low and (b) high base-flow and (c) high-flow seepage runs.

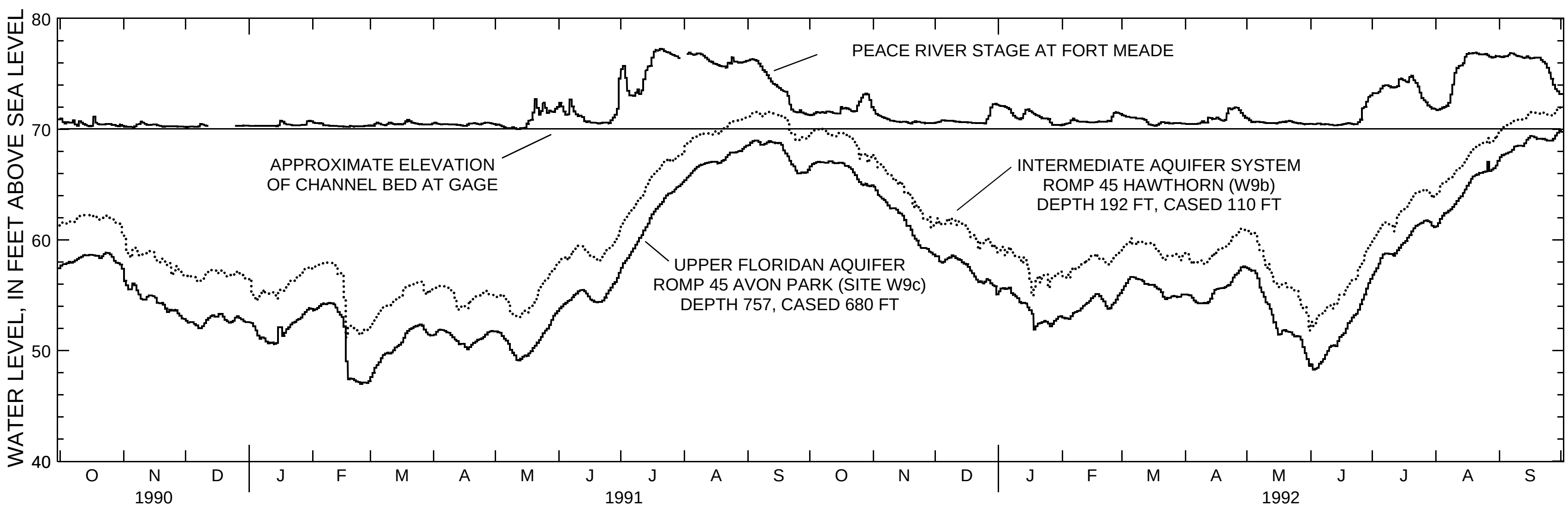


Figure 21. Comparison of Peace River hourly stage at the Fort Meade streamflow station and maximum daily water levels in the intermediate aquifer system and Upper Floridan aquifer at the ROMP 45 wells at Fort Meade, October 1990-September 1992.

Water movement from the Peace River to the aquifer systems has been observed occurring through sinkholes in places. Some of the sinkholes may have formed in response to the lowering of the potentiometric surfaces of the intermediate aquifer system and the Upper Floridan aquifer in recent decades (Patton and Klein, 1989). In some cases, the sinkholes may have served as spring vents during periods of higher ground-water levels. Sinclair and others (1985) classified this area as an internally drained region with numerous lakes and sinkholes. Limestone dissolution and downward piping of unconsolidated sediments frequently occur, as well as cover-collapse and cover-subsidence type sinkholes. Leakance values for the upper and lower confining units in the intermediate aquifer system are low and the generalized thickness of the intermediate aquifer system within the region ranges from 100 to 300 ft. However, the potential for ground-water movement from the overlying surficial aquifer to the intermediate aquifer system and to the Upper Floridan aquifer exists because of the downward head gradient and the prevalence of sinkholes (Barr, 1992).

Along the upper Peace River floodplain, from Bartow to Fort Meade, Patton (1981) and Patton and Klein (1989) mapped more than 90 sinkholes occurring within 50 identified sinkhole complexes (fig. 18). Breaches in the upper confining unit of the intermediate aquifer system in this area allow for nearly direct interaction of the Peace River and the surficial aquifer with the intermediate aquifer system and the Upper Floridan aquifer. The degree to which this interaction occurs depends on the head gradients between these hydrologic units, the lateral continuity of confining units, and the hydrologic properties of materials infilling the breaches.

Field reconnaissance during this study confirmed the existence of several of these same karst features. Two types of karst features observed in the Peace River floodplain are (a) large, cover-collapse, steep-walled sinkholes and (b) small sand-filled depressions (fig. 22a-b). Several sinkholes were observed diverting water from the river. Further evidence of ground-water recharge through sinkholes in the Peace River floodplain includes the identification of a slough connecting the river to the large sinkhole shown in figure 22a. The location of this sinkhole is shown in figure 18. A maximum slough channel depth of approximately 5 ft occurs at the junction with the sinkhole. Fluvial features indicating that water was diverted from the river to the sinkhole include ripple marks, gravel bars, and clean top-of-rock. These fluvial characteristics suggest that flow velocities within the slough may be significant. During the dry season, which corresponds to low-flow conditions, the Peace River also recharged the ground-water system through a solution-enlarged linear conduit located within the Peace River channel (fig. 23a-b). On several brief occasions during this study, the entire Peace River discharge was diverted into this conduit. This conduit is in the streambed to the east of the large sinkhole pictured in figure 22a and its location is shown in figure 18. Observations made in the Peace River floodplain during low-flow conditions identified additional locations where water has been diverted from the river into small, sand filled depressions (similar to those shown in figure 22b). Most likely, these are buried sinkholes infilled with unconsolidated materials.

Based on discussions with local construction crews, the underlying limestone formation in the Bartow area is near land surface, is highly cavernous, and recharges rapidly. Problems with constructing foundations and retention ponds are common. The loss of significant amounts of grout and a large plastic liner accompanying the rapid drainage of a retention pond was documented at a construction site 2 mi northwest of the Bartow gaging station. These observations reflect the high recharge potential and the cavernous nature of the buried limestone in this area.

Cavernous porosity in the underlying limestone has been described by Stewart (1966) and Barr (1992). McQuivey and others (1981) injected a dye tracer into three sinkhole complexes along the Peace River floodplain. Dye was observed in a water sample from an Upper Floridan aquifer well located in the Peace River floodplain, approximately 1 mi south of the injection sites. The maximum concentration of dye arrived within only 8 hours of injection, suggesting that there is a good hydraulic connection between hydrologic units within this area.

Middle Peace River: Area of Reversal of Head Gradients

The middle Peace River, extending roughly from Fort Meade to Zolfo Springs, drains an area with a well developed surface-water system, and is characterized by a seasonal reversal of head gradients (figs. 17, 19, and 24). In contrast to the downward head gradients within the largely internally drained area

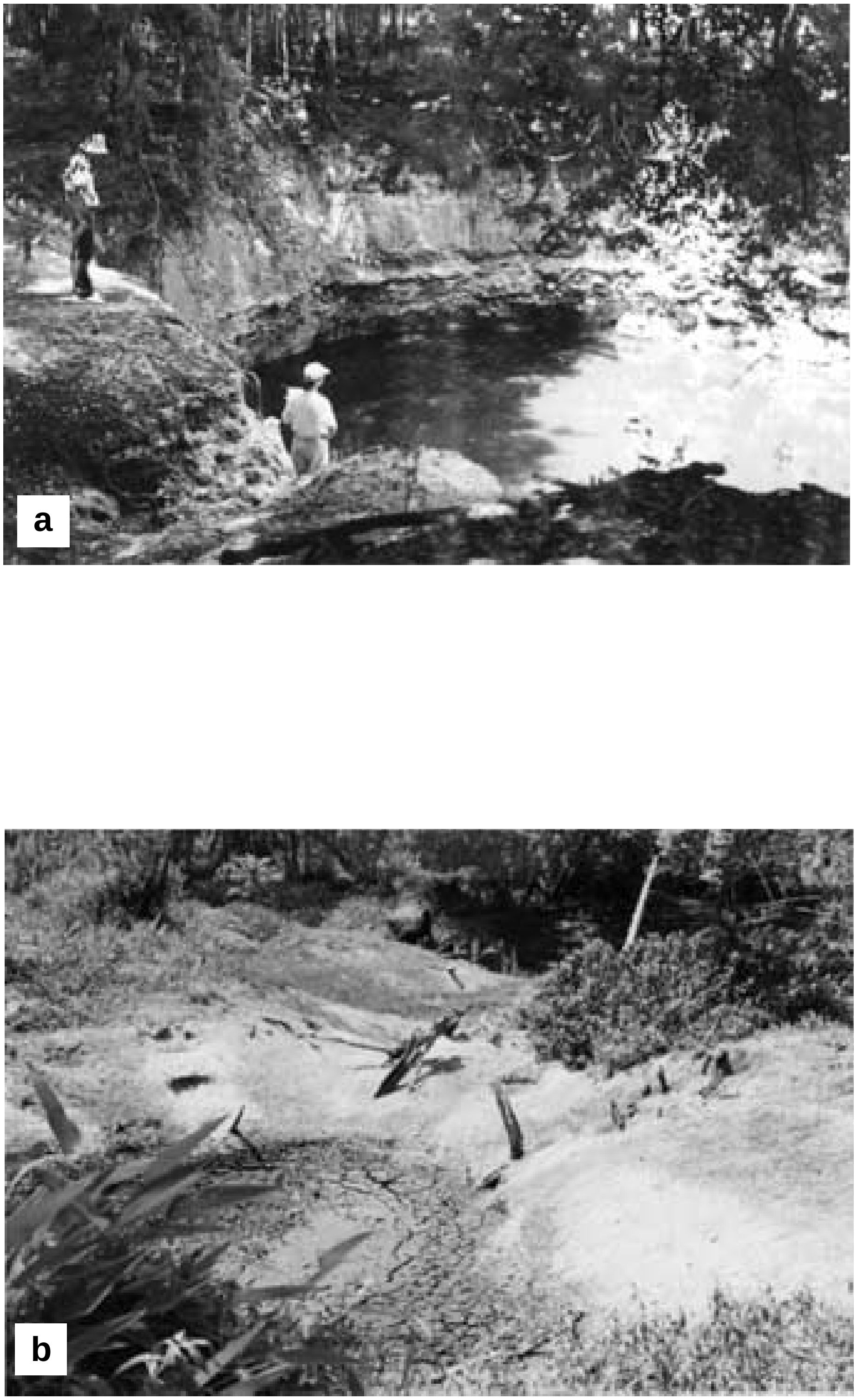


Figure 22. Examples of subsidence features observed in the upper Peace River floodplain: (a) large collapse feature with steep walls and (b) small sand-filled depressions. (Location of subsidence features are shown in figure 18.)

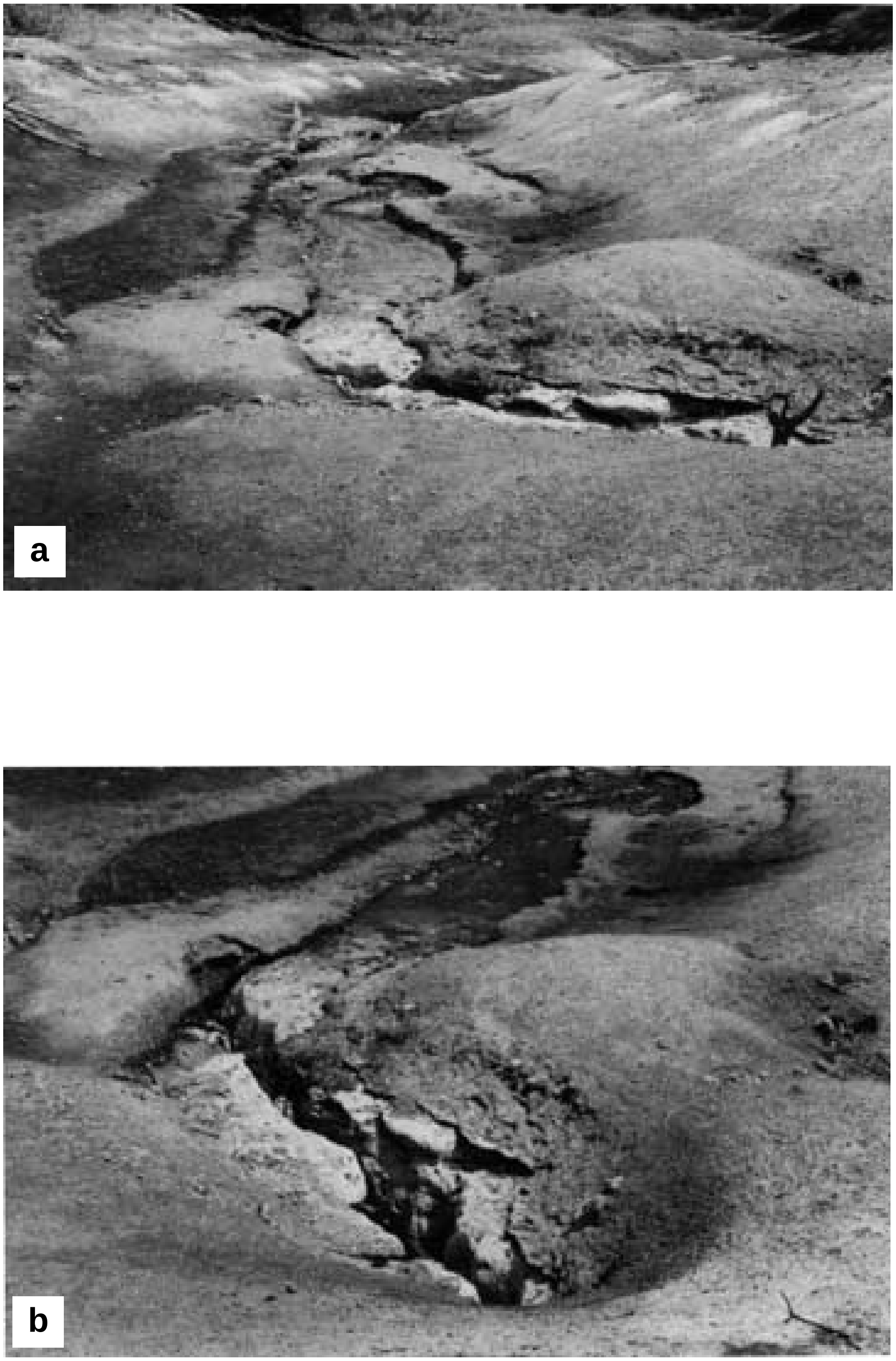


Figure 23. Example (a and b) of an enlarged linear solution feature capturing Peace River flow during low base-flow conditions, May 1995. (Location of solution feature is shown in figure 18.)

along the upper Peace River, this area reflects the seasonal transition from a ground-water recharge area to a ground-water discharge area. Ground-water heads in the intermediate aquifer system may be higher or lower than those in the Upper Floridan aquifer. Head differences vary in magnitude seasonally and annually (fig. 19). Heads also may be higher or lower than the Peace River channelbed (fig. 17). Ground-water heads below the elevation of the riverbed cause recharge conditions to occur (fig. 21). Ground-water discharged to the surficial aquifer and to the river in 1995 (fig. 19). In the middle Peace River, head gradients reverse seasonally between the intermediate aquifer system and the Upper Floridan aquifer. These reversals possibly affect the rate of recharge or discharge between the ground-water and riverine systems.

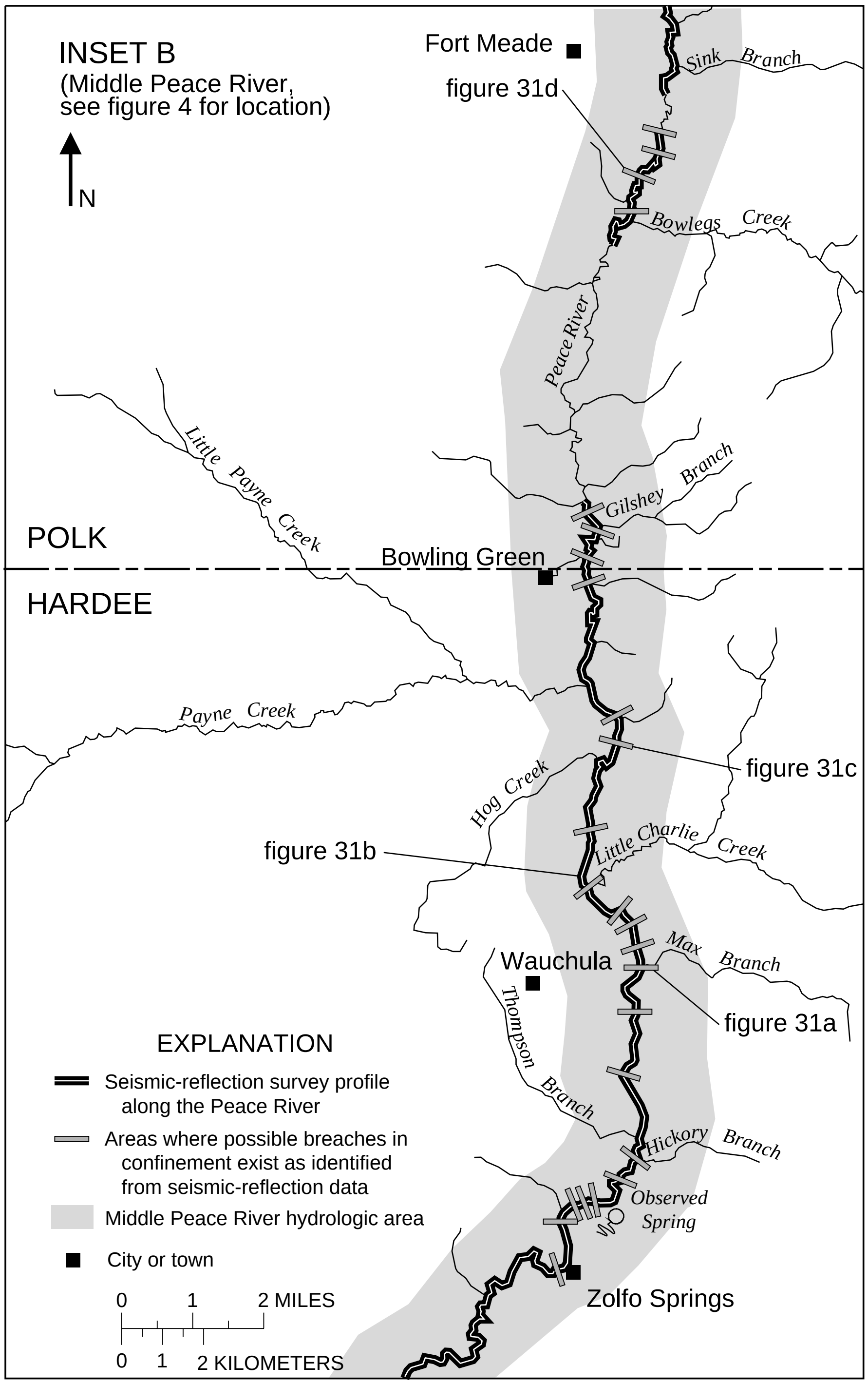


Figure 24. Middle Peace River hydrologic area with locations of seismic-reflection survey profiles, areas in seismic record where possible disruption of confinement exists, and locations of interpreted seismic profiles shown in figures 31a, 31b, 31c, and 31d from Fort Meade to Zolfo Springs.

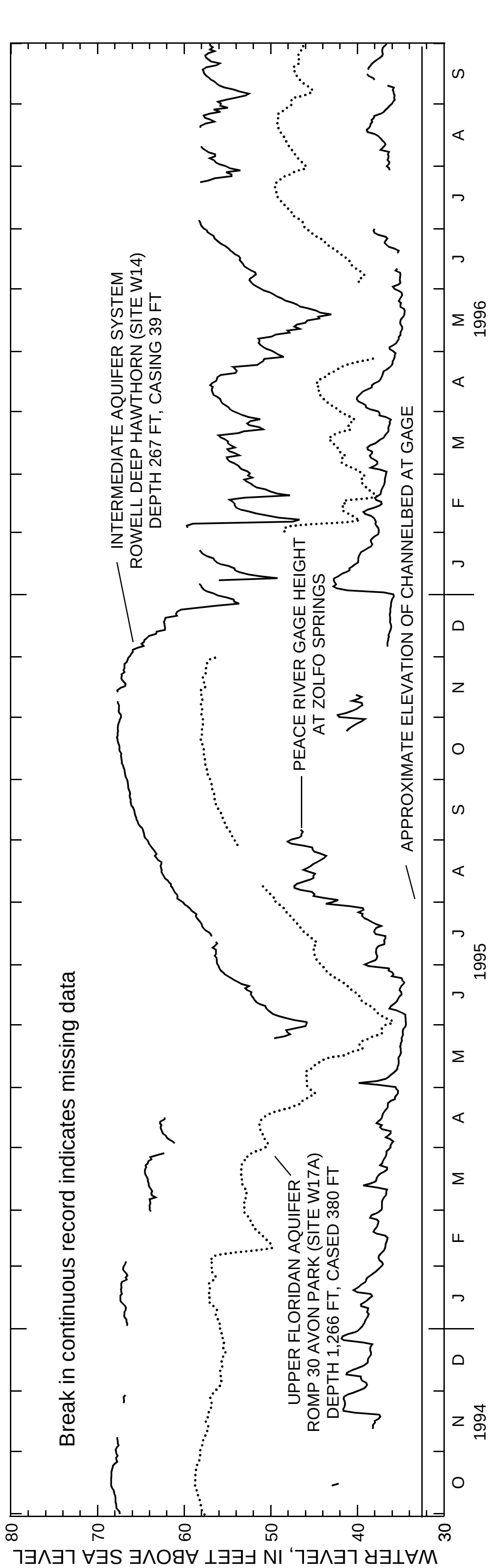


Figure 25. Comparison of Peace River hourly stage at the Zolfo Springs streamflow station and maximum daily water levels in the intermediate aquifer system and Upper Floridan aquifer, October 1994-September 1996.

Hydrographs in figures 21 and 25 show relative ground-water heads in relation to river stage at the uppermost (Fort Meade) and lowermost (Zolfo Springs) gaging stations along the middle Peace River reach, respectively. Ground-water heads in the intermediate aquifer system and in the Upper Floridan aquifer predominantly are below the elevation of the riverbed and stage at the Fort Meade gage and are above the elevation of the riverbed and stage at the Zolfo Springs gage. Ground-water systems discharge seasonally into the middle Peace River; contributions vary with respect to river stage and aquifer heads. In the area north of Wauchula, rainwater recharging the surficial aquifer moves downward to the intermediate aquifer system and laterally into the Peace River. South of Wauchula, potential upward leakage occurs from the intermediate aquifer system to the surficial aquifer or riverine system (Metz, 1995).

Seasonal variation in the ground-water levels and their relation to the riverine system is evidenced by Duerr and others (1988). In September 1985, the intermediate aquifer system had greater heads than those in the Upper Floridan aquifer from Bartow to Fort Meade. The area of zero head difference, between the intermediate aquifer system and the Upper Floridan aquifer, was located near Fort Meade. The heads in the Upper Floridan aquifer were higher than those in the intermediate aquifer system in the area downstream of Fort Meade. In May 1986, the area of zero head difference as mapped by Duerr and others (1988) had been located to the south, near the Hardee-De Soto County line, and ground-water heads in the intermediate aquifer system were above the Upper Floridan aquifer heads from Bartow to Gardner.

Metz (1995) delineated areas of upward and downward leakage through the upper confining unit of the intermediate aquifer system in Hardee and De Soto Counties using potentiometric data collected in September 1988 (fig. 6). Downward leakage occurred from Polk County to just south of the Hardee County line, at Payne Creek, and upward leakage from the intermediate aquifer system to the surficial aquifer occurred south of Payne Creek. Ground-water seepage contributions to the Peace River from the northern Hardee County line south to Charlie Creek were measured by Duerr and Enos (1991). The maximum seepage measured in 1991, between Payne Creek and Zolfo Springs, was 4 ft^3/s.

Based on an analysis of chemical data, Sacks and Tihansky (1996) delineated an area along the Peace River, from Zolfo Springs southward, as an area influenced by upward ground-water movement. Small springs, observed discharging from linear features in the uppermost rock within the Peace River streambed at Zolfo Springs, are additional evidence of the upward movement of ground water in this region.

Lower Peace River: Area of Upward Head Gradients

The lower Peace River, from below Zolfo Springs to Arcadia, is characterized by upward ground-water head gradients (figs. 17, 19, and 26). Upward-head gradients along the lower Peace River have caused discharging ground-water conditions as documented in historical records. The hydrographs in figure 27 show that the ground-water heads in the

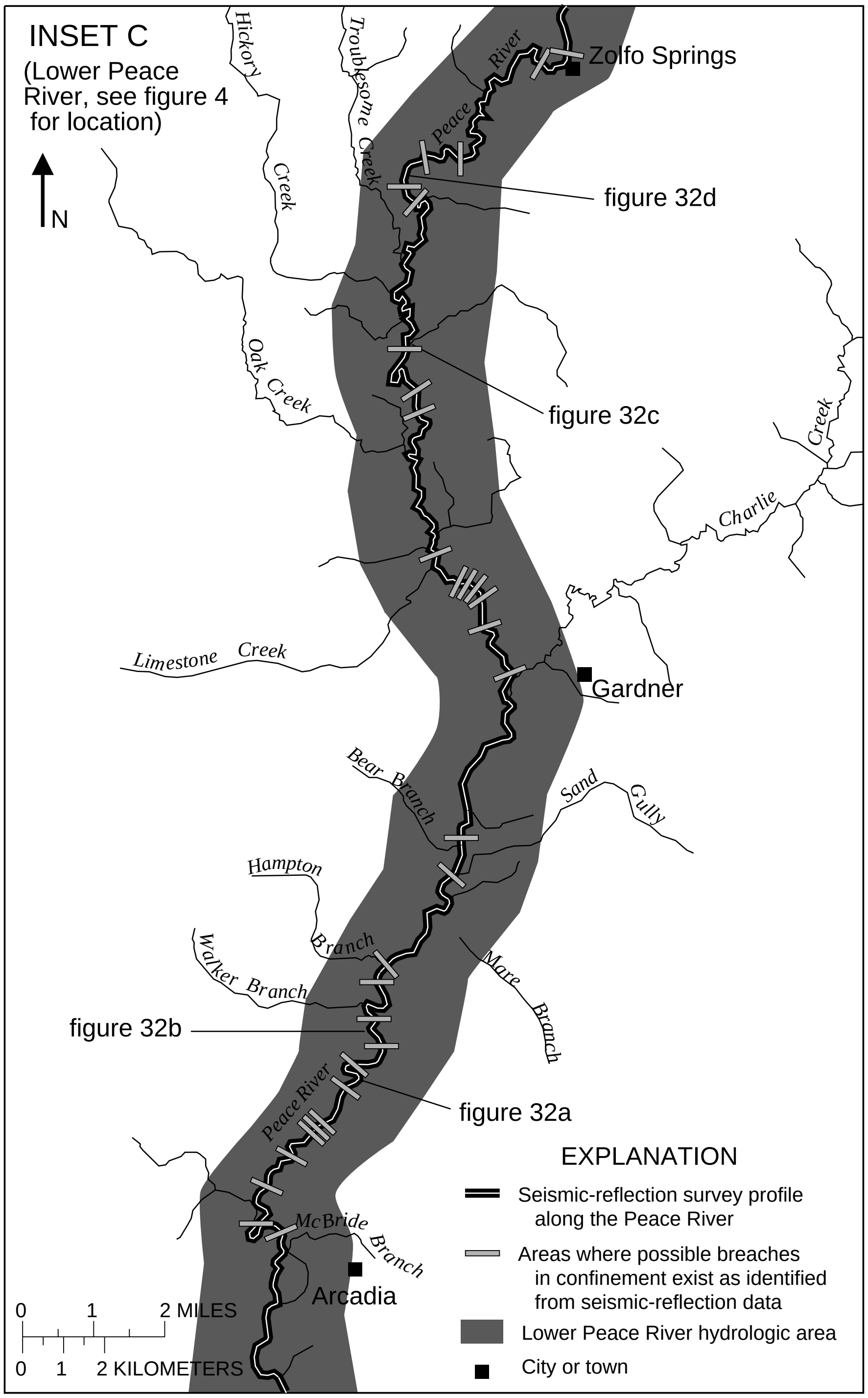


Figure 26. Lower Peace River hydrologic area with locations of seismic-reflection survey profiles, areas in seismic record where possible disruption of confinement exists, and locations of interpreted seismic profiles shown in figures 32a, 32b, 32c, and 32d from Zolfo Springs to Arcadia.

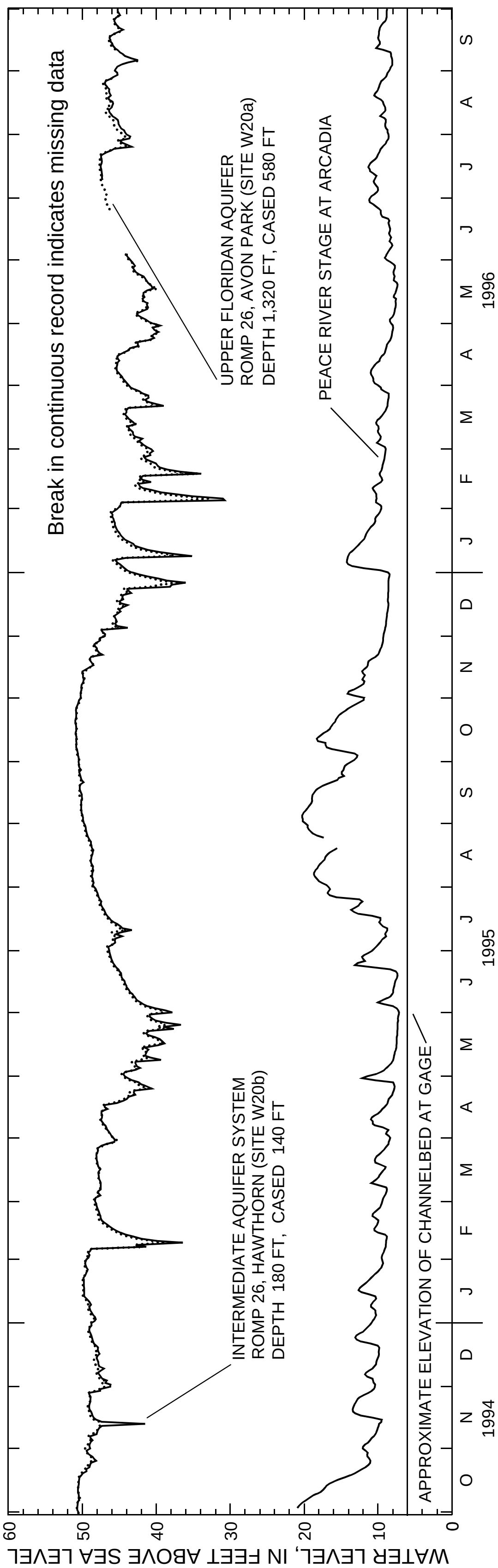


Figure 27. Comparison of Peace River hourly stage at the Arcadia streamflow station and maximum daily water levels in the intermediate aquifer system and Upper Floridan aquifer at the ROMP 26 wells at Gardner, October 1994-September 1996.

intermediate aquifer system and the Upper Floridan aquifer track closely, and are 20 ft or more above the maximum stage of the Peace River at Arcadia. Potentiometric data for May and September 1995 show that ground-water heads remain above the Peace River throughout the year (fig. 19).

The banks along the lower Peace River reach are generally more than 10 ft above the mean or average river stage and in places they expose sands of the surficial aquifer as well as clays and more indurated deposits of the upper Hawthorn Group units (fig. 3). These exposed units may be somewhat continuous, but disruptions and dissolution features in geologic units commonly are observed, especially at lower river stages when these units are exposed along the river banks (figs. 28a-d). The surficial aquifer

Figure 28a. Example of exposed geologic units along the banks of the lower Peace River.

Figure 28b. Example of exposed geologic units along the banks of the lower Peace River.

Figure 28c. Example of exposed geologic units along the banks of the lower Peace River.

Figure 28d. Example of exposed geologic units along the banks of the lower Peace River.

sands generally permit seepage to the river, and water is often observed seeping from the exposed sandy river banks that lie above the more lithified, clayey units of the Peace River Formation.

The ground-water head of the intermediate aquifer system in 1995 was consistently above that of the Upper Floridan aquifer in this reach of the river (fig. 19). In this area there is a potential for water to move downward from the intermediate aquifer system to the Upper Floridan aquifer. However, both ground-water systems generally have the potential to discharge to the river. Ground-water contributions to the Peace River from Zolfo Springs to Charlie Creek previously have been estimated to be 1.5 ft^3/s per river mile (Duerr and Enos, 1991).

ANALYSIS OF THE HYDRAULIC CONNECTION BETWEEN GROUND WATER AND THE PEACE RIVER

Analysis of the hydrologic connection between the Peace River and the underlying aquifers was done using three methods: (1) a seismic-reflection survey, (2) seepage investigations, and (3) thermal infrared imagery. The potential for surface-water and ground-water interactions along the Peace River was identified from potentiometric-surface data.

Geophysical Methods of Seismic-Reflection Survey

Seismic-reflection techniques were used to obtain subsurface records of the geologic framework beneath the Peace River. The seismic-reflection data were collected to determine lateral and vertical continuity of the geologic units, and to identify the presence of any structural or subsidence features that could be enhancing the hydraulic connection between the Peace River and ground-water systems. The extent of seismic-reflection data obtained along the Peace River from Bartow to Arcadia is shown in figure 4. Seismic-reflection records were not obtained in areas where access was limited. Overall, the quality of the seismic records ranged from poor to good, with the poor-quality data corresponding to areas with shallow water, thick organic deposits, and sharp turns in the river. Wolansky (1983) used similar techniques in the lower reaches of the Peace River, from Fort Ogden to Charlotte Harbor. The seismic-reflection data collected in the lower Peace River resemble some of the record published by Wolansky. Although there was no attempt to directly correlate the Wolansky data to that collected during this study, previously collected data by Wolansky were used to compare regional seismic-reflection characteristics.

Seismic-reflection surveys were conducted to gather continuous sub-bottom geologic data along the Peace River and to test the effectiveness of marine geophysical techniques in a shallow riverine system in Florida. Acquisition techniques were similar to those used in previous lake studies, with the exception of equipment modifications related to towing geometry and power supply. Data quality and field conditions varied among the three different hydrologic areas. As acquisition techniques were modified during this study, the general data quality improved.

An attempt was made to collect seismic-reflection data along the entire length of the Peace River, from Bartow to Arcadia, but access in the upper reaches was limited by low river stage, downed trees, and boat ramp availability. River reaches with the shallowest water depths were run during periods of high river stage to maximize accessibility for the boat and equipment and the quality of the data. In lakes and larger water bodies, seismic data are commonly run in grid patterns so that interpretations can be checked on several different profiles collected at the same locations. In this case, data were collected only along the length of the Peace River. Profiles were not run across the streambed due to the narrow channel width. The interpretation of the Peace River data set is limited because cross correlations between seismic lines were not possible.

Seismic profiles were collected with the Elics Delph2 high resolution seismic system with proprietary hardware and software (Delph2X Ver. 1.22). Digital data were stored on a Sony Magneto-Optical compact disk and a 1 gigabyte hard drive. Navigation data were collected using a proprietary PLGER global positioning system (military), logged into an Industrial Computer Corp. 486/33 personal computer and ported to the Delph2 seismic system. A Huntec Model 4425 Seismic Source Module was used to generate an underwater acoustical pulse. This module consisted of an Energy Storage/Power Control Unit and a catamaran sled with an electromechanical device (acoustical sound source). This unit was triggered by the Elics Delph2 system. An ORE GEOPULSE power supply was used at a setting of 60 or 135 joules, depending upon field conditions. An Innovative Transducers Incorporated ST-5 multi-element hydrophone was used to detect the return acoustical pulse. This pulse was fed directly into the Elics Delph2 system for storage and processing.

A velocity of 1,800 meters per second (m/s) was used to calculate approximate depth scales from two-way traveltimes for the seismic profiles. Measured site specific velocity data were not available for geologic units at these sites. Therefore, the velocity of 1,800 m/s was used, based on several correlations to lithologic units identified in logs from Florida Geological Survey boreholes near the Peace River profiles. Approximate depths for the seismic-reflection profiles were calculated from two-way travel times using the 1,800-m/s velocity.

Seismic-data interpretation was done using standard interpretation methods, where prominent sub-bottom reflectors and reflection characteristics were identified within the seismic-reflection profiles (Payton, 1977). Seismic-reflection characteristics, such as the continuity and amplitude of specific reflectors and their relation to identified reflection packages, were described. Probable geologic interpretation was related to specific identifiable seismic-facies characteristics throughout the record. The seismic-reflection characteristics and geologic interpretations are presented in figure 29. An attempt to correlate observed reflectors to calculated depths based on geologic contacts was made for parts of the record where seismic reflectors were laterally traceable and nearby borehole lithologic data were available. Although these correlations were somewhat successful in the lower reaches of the river, correlations in other reaches could not be made because of the complex stratigraphy and sparse geologic control. Instead, the

SEISMIC FACIES CHARACTERISTICS	GEOLOGIC INTERPRETATIONS	SYMBOL ON INTERPRETED PROFILES
Chaotic seismic facies	A-Disrupted sedimentary units B-Gas-charged or organic-rich material	**CF**
Continuous, high amplitude, concordant parallel reflectors, may be flat-lying or exhibit 'SAG' structure	Possibly clay or other unit capable of deformation associated with Hawthorn Group sediments, flexure structures indicate sediment deformation due to loss of support at depth	**HAR, SAG**
High amplitude ringing multiples	Gas-charged organic-rich river-bottom sediments	**RM**
Low- to high-amplitude continuous or disrupted clinoform reflectors	Infilling and prograding sedimentary units either regionally extensive or local paleochannel cut and fill units	**PCF**
Abrupt discontinuities or breaks in horizontal reflectors	Fractures or enlarged solution features	**FZ**

Figure 29. Descriptions of seismic-facies characteristics, geologic interpretations, and symbols used in interpreted profiles (figs. 30-32).

seismic-reflection record was interpreted using regional stratigraphic trends and physiographic characteristics. Seismic data throughout the study area were limited to a maximum depth resolution of approximately 100 ft below the river surface.

Line drawing interpretations were made of several seismic sections from each of the three hydrologic areas (upper, middle, and lower Peace River). High-amplitude reflectors and specific seismic facies produced by stratigraphic units were identified in the interpreted sections. Interpreted profiles represent cross-sectional views of the subsurface and define the relation between specific seismic facies. The profiles also identify structural features such as flexures, folds, faults, slumps, and other features associated with dissolution, subsidence, and sinkhole activity that may have disturbed the original stratigraphic structure.

Stratigraphic Control

Regional geologic trends, described in previous studies within the study area, were used as general stratigraphic controls for interpreting the seismic-reflection record because direct correlation between the seismic data and lithologic data was limited. Locations of wells where lithologic logs were used for velocity and depth calculations are shown in figure 4. Lithologic logs were obtained from the Florida Geological Survey. Most of these wells were located above the floodplain and may not directly reflect the geologic conditions present in the vicinity of the Peace River channel. The limited correlation is because the geologic units located in the floodplain and streambed have been eroded, sorted, transported, and dissolved by riverine processes and do not represent intact geologic units as described in cores. Therefore, during low-water conditions, geologic features along the river channel and floodplain were investigated on foot and by jonboat. More than 50 rock outcrop samples were collected from the river channel and floodplain between Bartow and Arcadia. Several specific samples were submitted to the Florida Geological Survey to identify rock types and possible geologic formations that were observed cropping out within the Peace River channel. Because of the lithologic complexity of these units, correlations to specific geologic formations were not possible. However, this reconnaissance effort did show where the Peace River is controlled and/or underlain by rock and where the rock units are buried by thicker unconsolidated materials.

Seismic-Reflection Interpretation

Many identified reflectors could not be traced laterally throughout the record because they (1) pinched out at the surface, (2) disappeared beneath the resolution depth, or were (3) separated by regions where no seismic data were collected. Specific lithologic packages appeared to correspond to identified reflectors, but the complex lithology of the Hawthorn Group sediments prevented correlations to geologic formations. Therefore, the interpretation of these reflection records was limited to identifying structural features, large-scale trends, and seismic-facies characteristics. Structural features, such as discontinuities and areas where units were breached by fractures or dissolution features, were identified in the seismic record. These features can be areas of surface- and ground-water interaction. The extent and direction of interaction depend on the hydraulic connection and head gradient between the Peace River and underlying aquifer systems.

The three hydrologic areas delineated along the Peace River have specific seismic-facies characteristics which could be identified on seismic profiles. The seismic-facies characteristics and their probable geologic origins are summarized in figure 29. Geologic features identified in the seismic record as possible breaches in confinement could represent: (1) large-scale subsidence features, (2) small localized fractures or, (3) enlarged conduits related to dissolution along these fractures. Locations where possible breaches in confinement exist in the seismic record are shown in figures 18, 24, and 26.

Upper Peace River: Area of Downward Head Gradients

Along the upper Peace River, shown in figure 18, the seismic record was poor. The Peace River was very shallow, full of organic-rich sediments which may be gas-charged, and most of the record was not interpretable. However, specific reflection characteristics and the mapped sinkhole features described by Patton (1981, fig. 18) were used to delineate areas where possible ground-water and surface-water interactions may occur along structural features in the geologic units. Interpretable seismic data helped identify an irregular top-of-rock that was partially buried and infilled by overlying unconsolidated materials. These overlying materials appear to have been modified by both subsidence and fluvial activity. Examples of seismic-reflection records and interpretation along the upper Peace River are shown in figures 30a-c. The seismic record shown in

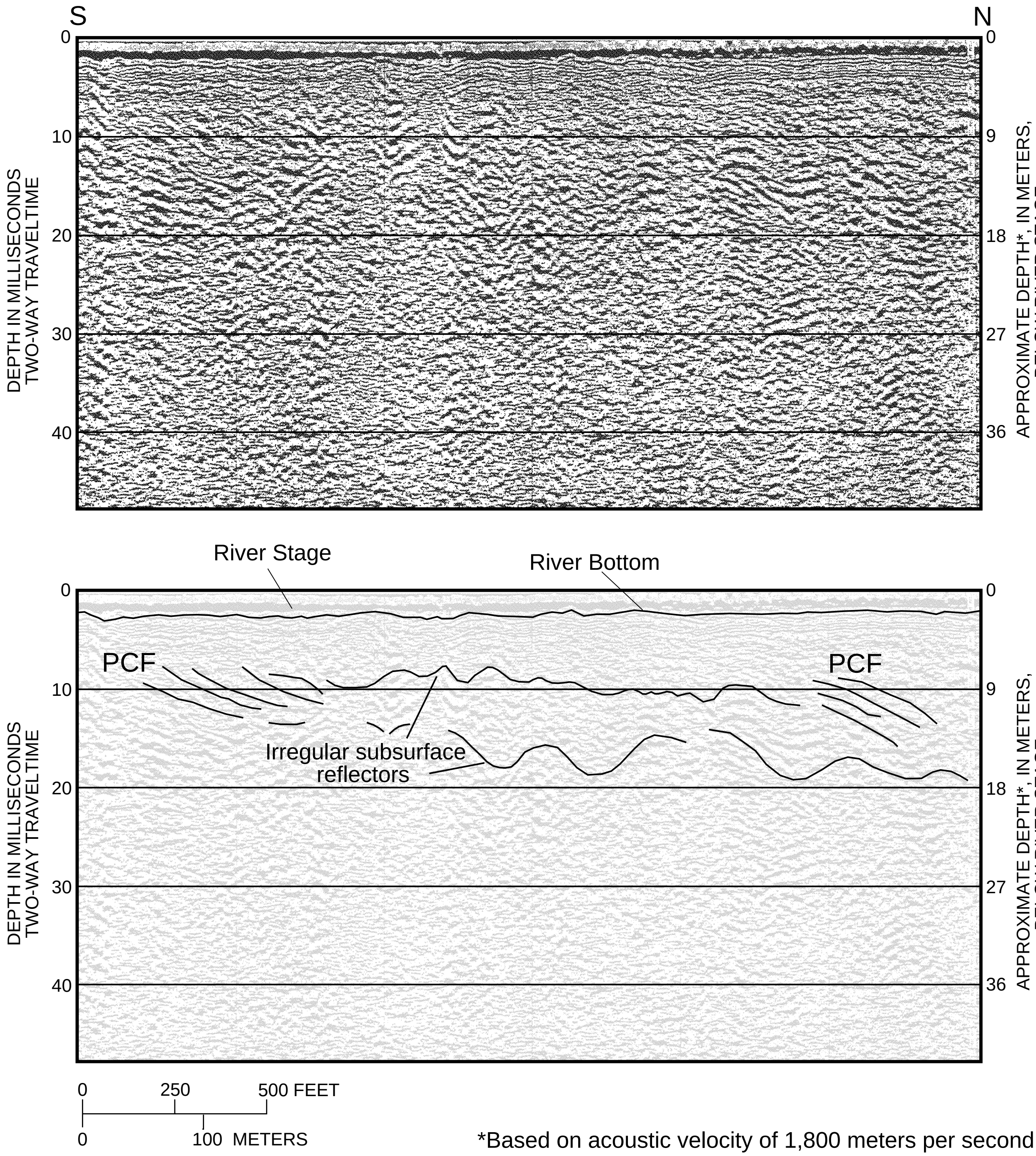


Figure 30a. Seismic-reflection profile and interpretation along the upper Peace River east of Fort Meade. (See figure 18 for location.)

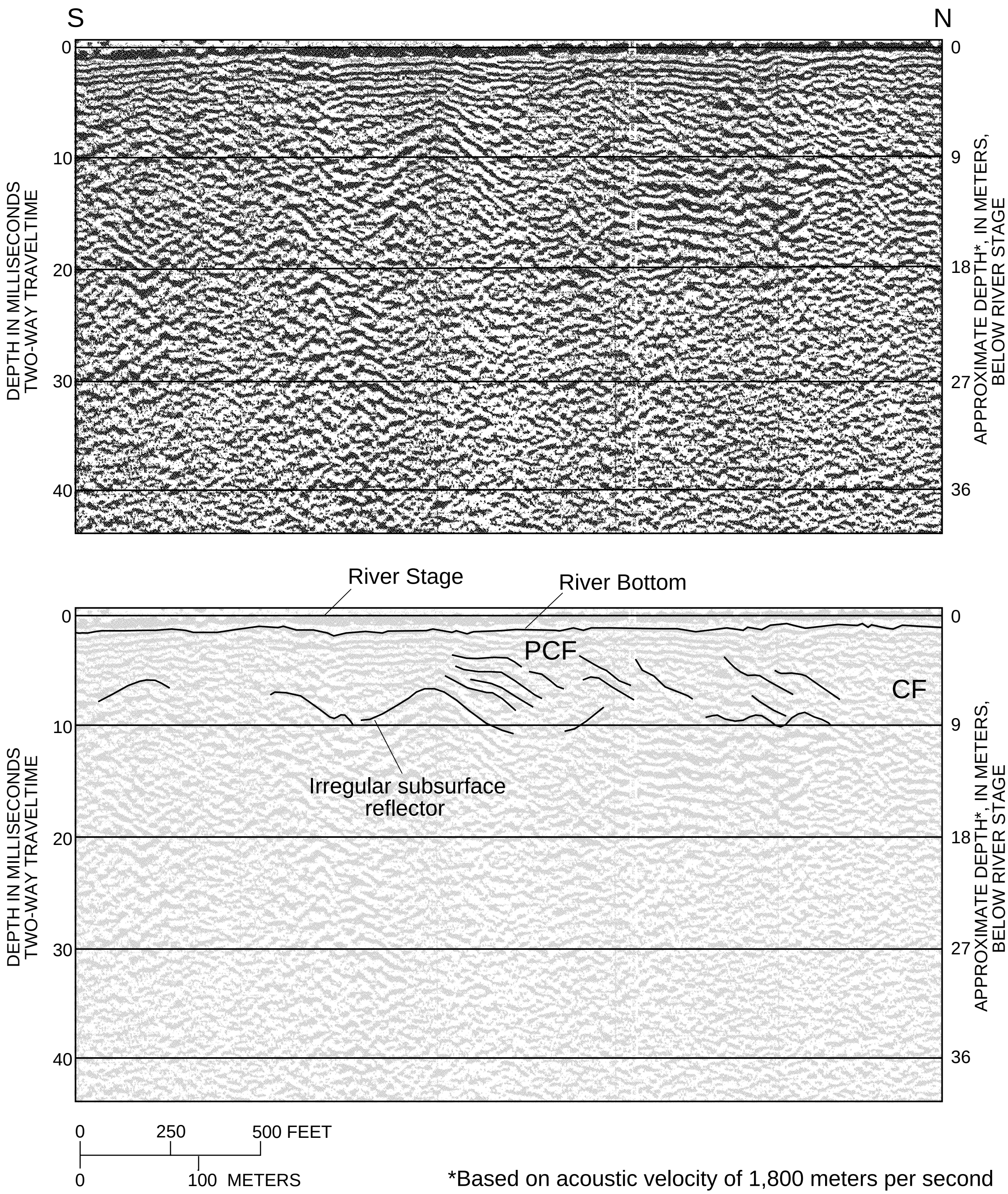
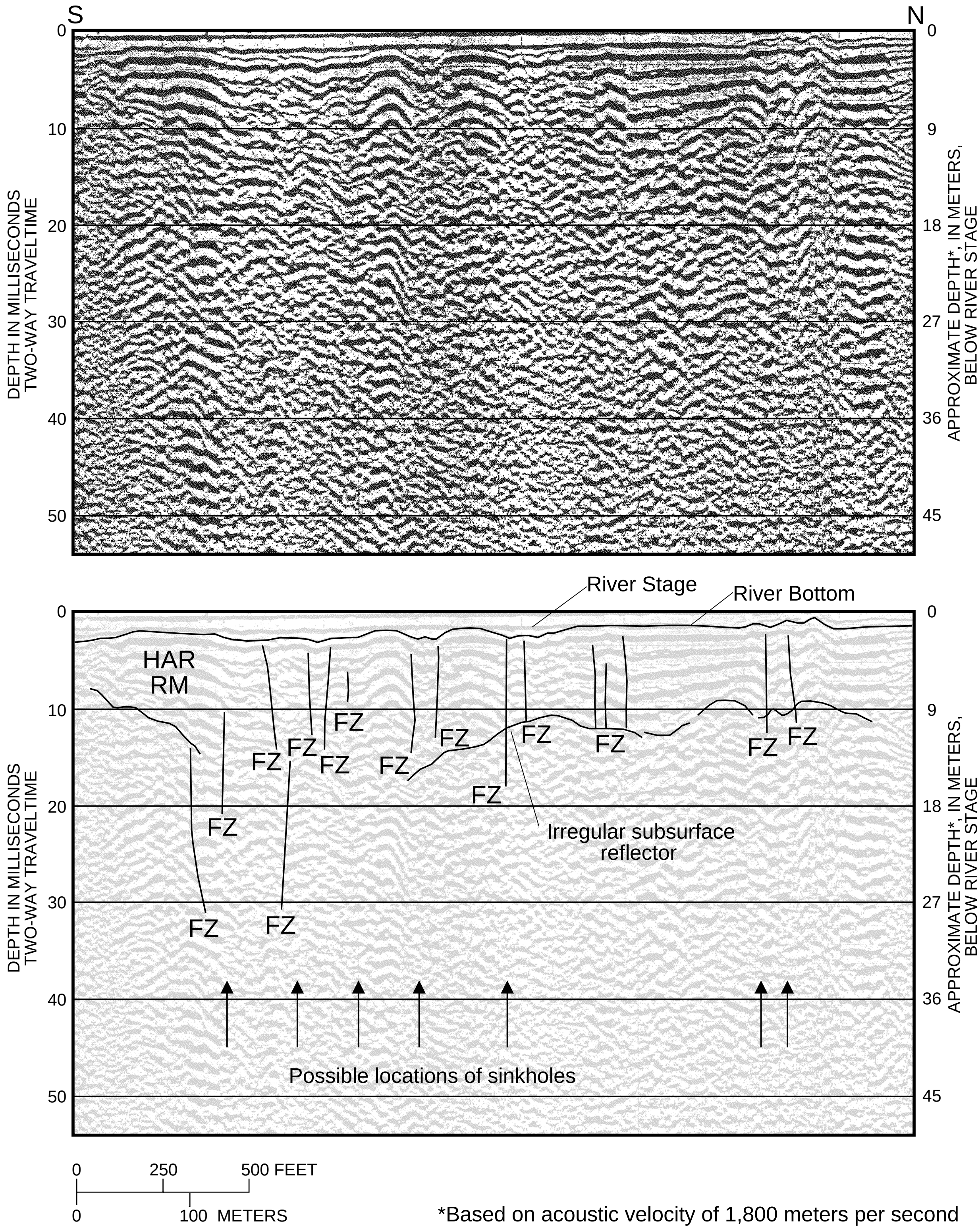


Figure 30b. Seismic-reflection profile and interpretation along the upper Peace River southeast of Kissengen Spring. (See figure 18 for location.)



*Based on acoustic velocity of 1,800 meters per second

Figure 30c. Seismic-reflection profile and interpretation along the upper Peace River southeast of Bartow. (See figure 18 for location.)

figures 30a and 30b illustrates the discontinuous nature of the seismic signal. Infilling, prograding clinoform (PCF) units appear to downlap onto a buried irregular subsurface reflector. These facies indicate that the buried reflector is the top of an erosional subsurface that is disrupted by paleochannels or subsidence structures that has subsequently been buried and infilled. Recent sediments are generally flat-lying but locally inclined reflectors and depressions are evidence of modern subsidence activity. Several subsurface reflectors identified in this area are irregular. Multiple occurrences of irregular subsurface reflectors suggest that this area may have been subject to repeated subsidence activity or multiple cut and fill depositional cycles. These infilling materials appear relatively intact. In contrast, undulations of the high-amplitude or ringing-multiple (HAR/RM) reflectors shown in figure 30c suggest that highly localized subsidence activity is modifying the units above another similar buried irregular reflector. This record was collected in a region where numerous sinkholes have been identified both within and adjacent to the Peace River channelbed. The presence of sinkholes substantiates the interpretation that subsidence features exist beneath the Peace River in this area.

Whereas much of the upper Peace River may be underlain by similar karst features, the poor quality and chaotic nature of the seismic signal limited the interpretation of the seismic-reflection data. However, a reasonable picture of the subsurface features was constructed by combining hydrologic information and geologic descriptions of the area with the seismic-reflection data. The upper Peace River is located in a karst region characterized by numerous sinkholes and a high recharge potential. Locations of the chaotic facies appear to correspond with locations of identified sinkhole complexes and karst features in the area. Sinkholes and solution conduits provide efficient avenues for ground-water recharge from the river.

Middle Peace River: Area of Reversal of Head Gradients

Along the middle Peace River, from Fort Meade to Zolfo Springs, the quality of the seismic data was moderate to good and seismic reflectors generally were flat-lying, and laterally continuous. Discontinuities in identified reflectors may be related to breaches, structural offsets, and subsidence structures. Buried prograding clinoforms, basinal infilling units, flexures and fractures were observed in localized areas presently occupied by tributaries of the Peace River (fig. 26). Examples of the seismic data in this area are shown in figures 31a-d. Throughout the data, flexures (SAG), fractures zones (FZ), and areas of chaotic infilling units (CF), have been interpreted as likely breaches in confinement and may correspond to areas where surface-water and ground-water interactions may occur (fig. 26). Figure 31a shows an infilled paleobasin that may originally have been controlled by subsidence features in an irregular subsurface reflector at depth prior to the deposition of the channel cut-and-fill (PCF) sequences. Multiple sequences of prograding clinoforms (PCF) that are relatively undisturbed illustrate the laterally continuous nature of PCF unit (fig. 31b). In the profile shown in figure 31c, the PCF units are thinner, and a small flexure (SAG) appears to be affecting the overlying units and increased the depth of the river above it. Neither of the profiles shown in figures 31b or 31c are located near any modern-day tributaries. In the profile shown in figure 31d, a larger flexure (SAG) similar to that shown in figure 31c, appears to affect the overlying units, although it does not appear to be affecting the modern river bottom.

In the study area, hydrogeologic units of the intermediate aquifer system thicken to the south (fig. 5). The morphology of seismic units identified in this region suggests that sediment transport and infilling of topographic lows have occurred in localized areas beneath the Peace River. These basinal areas have accumulated thicker and more complex infilling sequences; their origin may have been controlled by subsidence at depth. It is unknown how far these infilled basins extend beyond the modern Peace River channel. The infilling deposits are probably unconsolidated clastics derived from upland areas drained by a paleofluvial system that occupied the modern Peace River drainage basin.

Subsidence features, infilled with materials having greater permeability than the adjacent intact confining units, may actually create preferential ground-water flow paths. Lithologic variations typical of the Peace River Formation include both relatively insoluble clays and highly soluble carbonate units. Both lithologies vary in their degree of induration. The juxtaposition of poor and moderately indurated units with variable solubilities could also create zones along which ground water could preferentially flow. The complex interfingering of these units and their varying response to rock and ground-water chemical

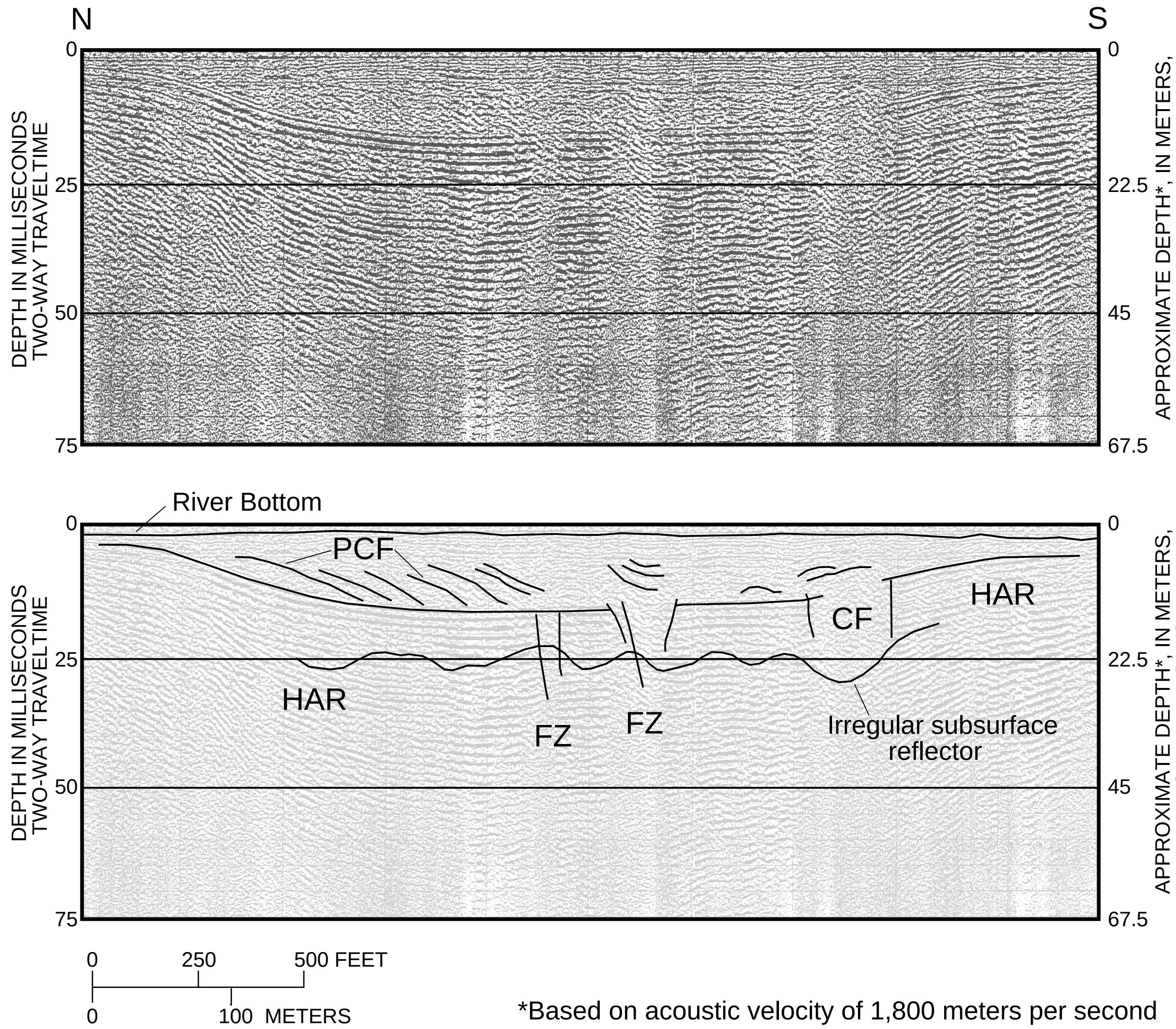


Figure 31a. Seismic-reflection profile and interpretation along the middle Peace River east of Wauchula. (See figure 24 for location.)

reactions may contribute to the development of the flexures and fractures observed in the seismic record. The breaches in confinement delineated in this interpretation may provide avenues for the upward or downward movement of surface- or ground-water during head-gradient reversals in the middle Peace River area.

Lower Peace River: Area of Upward Head Gradients

The seismic record along the lower Peace River was generally of good quality from Zolfo Springs to Arcadia (fig. 26). Technical problems related to the depth and width of the river and the presence of organic-rich material were minimal. The seismic data are characterized by thick traceable seismic units with moderate-to-high amplitude continuous reflectors. Seismic units were laterally continuous and could be traced from Arcadia north to Zolfo Springs, with several reflectors pinching out along the riverbed in the vicinity of Zolfo Springs. Because many seismic reflectors were coming to the surface in the riverbed, and a break in the seismic record occurred at Zolfo Springs, the seismic data from the lower Peace River could not be correlated with upstream record collected along the middle Peace River.

Continuous reflectors along the lower Peace River often were disrupted by offsets and/or large-scale subsidence features, but were traceable across them.

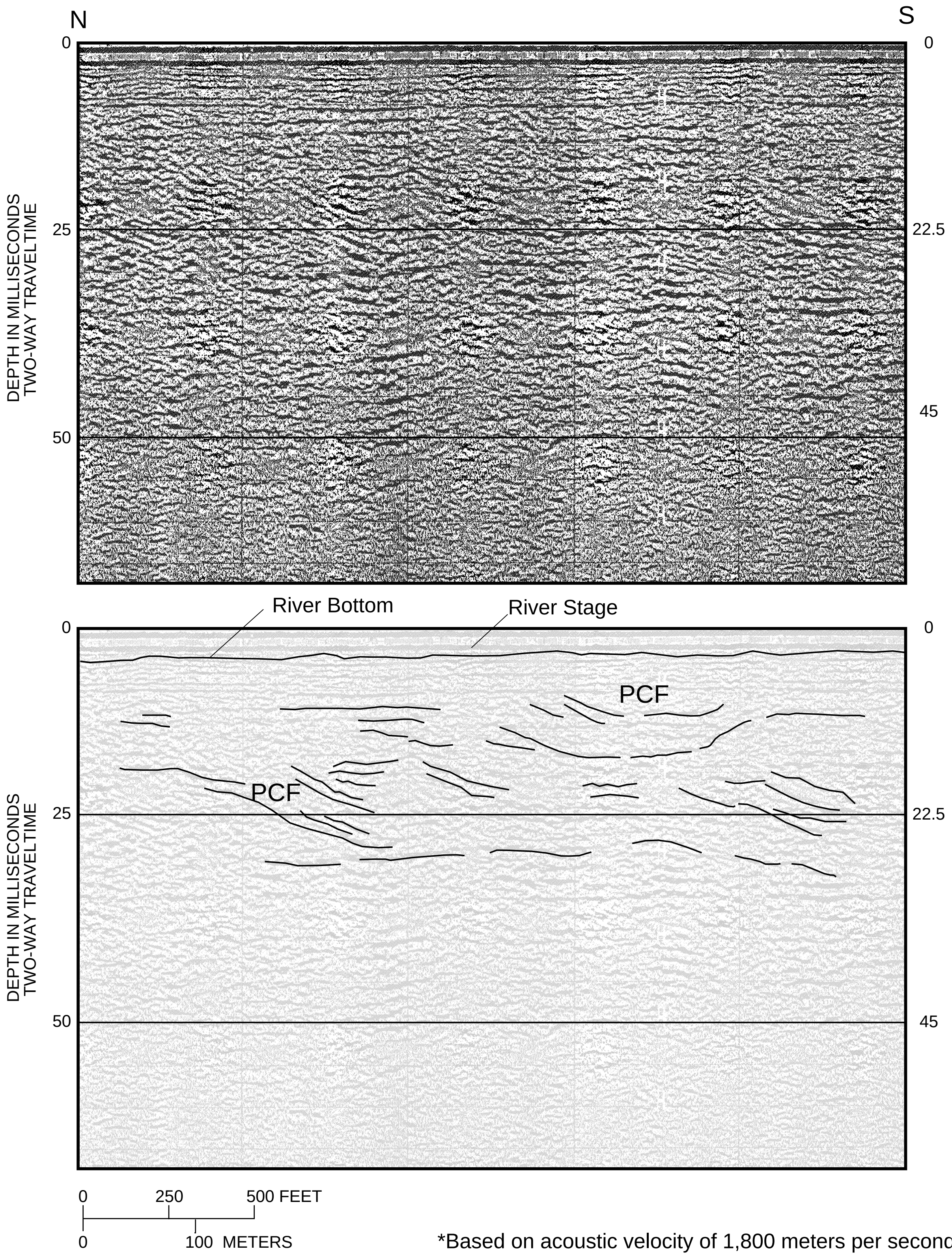


Figure 31b. Seismic-reflection profile and interpretation along the middle Peace River north of Wauchula. (See figure 24 for location.)

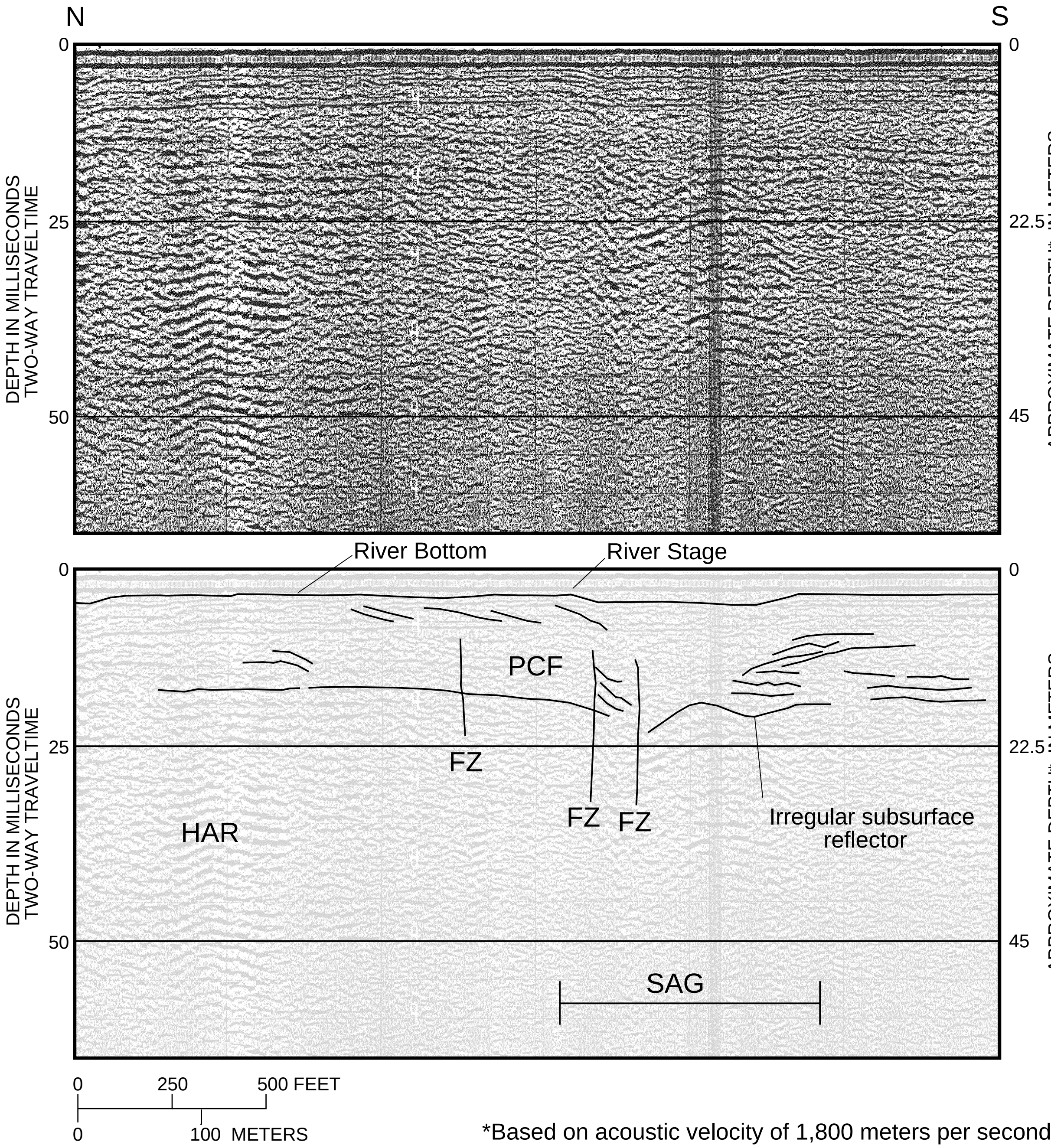


Figure 31c. Seismic-reflection profile and interpretation along the middle Peace River north of Wauchula. (See figure 24 for location.)

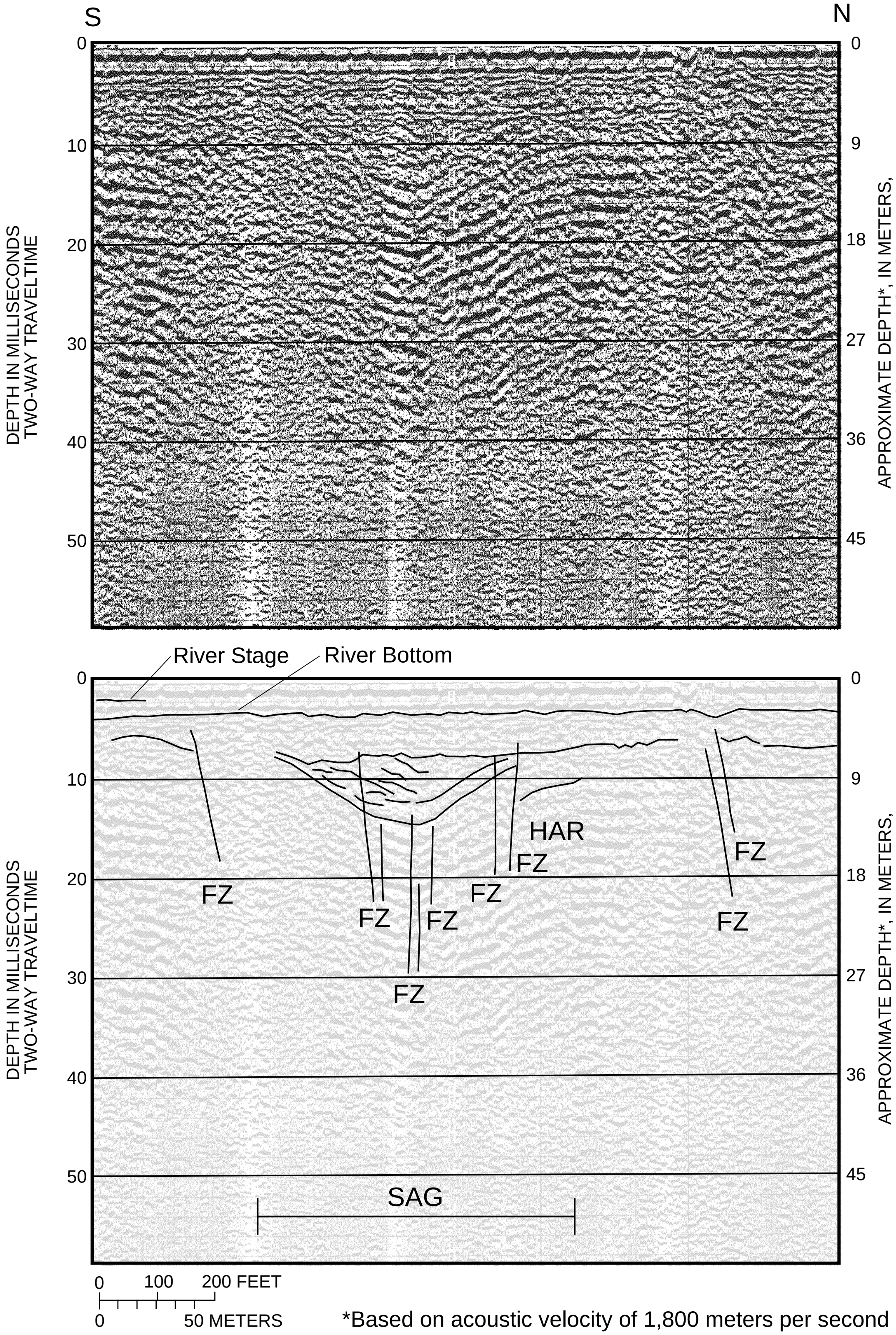


Figure 31d. Seismic-reflection profile and interpretation along the middle Peace River south of Fort Meade. (See figure 24 for location.)

Figures 32a-d illustrate the seismic-facies characteristics typical of the region. Several seismic units were identified in each figure as well as distinct flexures, fractures, and infilling clinoforms. The seismic record from this region contained more and thicker seismic sequences than were observed along the upper Peace River and the middle Peace River. These sequences appear to be modified by fractured areas (fig. 32a). Examples of large-scale flexures (SAG) are shown in figures 32b and 32c. Whereas the flexure observed in figure 32b appears to correspond to an increased river channel depth, a similar flexure in figure 32c has a more chaotic infilling, but does not appear to control the bathymetry of the riverbed to a large extent. Locations of possible breaches throughout the lower Peace River are shown in figure 26. Whereas these flexures and fractures clearly illustrate the effects of subsidence activity, the present upward-head gradient likely causes upward movement of ground water through these stratigraphic breaches. Depending on the hydraulic gradient, surface water and ground water may move along these karst features, causing the formation and/or enlargement of flexures, solution conduits, and sinkholes.

Flexures like those identified in figures 32b and 32c are common in seismic records obtained in Florida lakes, estuaries and coastal shelf regions. Although the origin of these flexures has not been confirmed, they are probably large-scale subsidence features that form in response to a loss of structural support at depth, resulting in fracturing of well lithified materials and flexures of softer sediments. Both fractures and flexures could create zones where preferential ground-water flow could occur. As in the middle Peace River, several of these observed flexures correspond to locations of modern tributaries. Features identified in figures 32a, 32b, and 32c correspond to greater river depths, and probably reflect sediment scour and channel cut and fill processes occurring where tributaries enter the Peace River. Topographic lows created by subsidence activity probably control the locations of drainage systems and lakes in the lower Peace River area and in many other regions of Florida.

Seepage Investigations

Three seepage runs were conducted along the Peace River to evaluate surface-water and ground-water exchanges, if any, between the river and underlying aquifers. A seepage run is a series of synoptic streamflow measurements made at selected cross sections along the length of a river and above the mouth of all tributaries. These measurements can be used to calculate streamflow gains and losses by determining the differences in stream discharges measured at the upper and lower ends of a reach, less any flow contribution from tributaries. Net increases or reductions in stream discharge along a particular reach could be interpreted as a net gain of ground water into the river or a net loss of river water into the aquifer(s). If stream discharge remains constant along a particular reach, then the river neither gained water from nor lost water to the underlying aquifers. Water losses in a river can result when ground-water levels in the underlying aquifers are lower than the stream-surface elevation (stage), thereby allowing for surface water to move into the underlying aquifers. When the potentiometric surface of the intermediate aquifer system is higher than the water level of the surficial aquifer, as in most of the low-lying areas of the Peace River, ground-water movement is upward from the intermediate aquifer system into the surficial aquifer, and discharges to the river (Duerr and Enos, 1991).

Base-flow seepage runs were performed at the end of the wet and the dry seasons, when annual rainfall was at a minimum and most streamflow was derived from ground-water seepage, rather than runoff. Using base-flow conditions simplifies seepage calculations because the only source of water along the river is from ground-water seepage. Typically, discharge measurements are subject to errors ranging from 5 to 8 percent of the measured flow (Slade and Buszka, 1994). The accuracy of computing gains or losses from a seepage run is subject to an error of similar magnitude. Seepage gains and losses for reaches on the Peace River were calculated using the following equation:

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

where

Q_s = gain (positive) or loss (negative) in streamflow between adjacent sites, in ft^3/s;

Q_d = streamflow at downstream site, in ft^3/s;

Q_u = streamflow at upstream site, in ft^3/s; and

Q_t = streamflow for all tributaries between upstream and downstream sites, in ft^3/s.

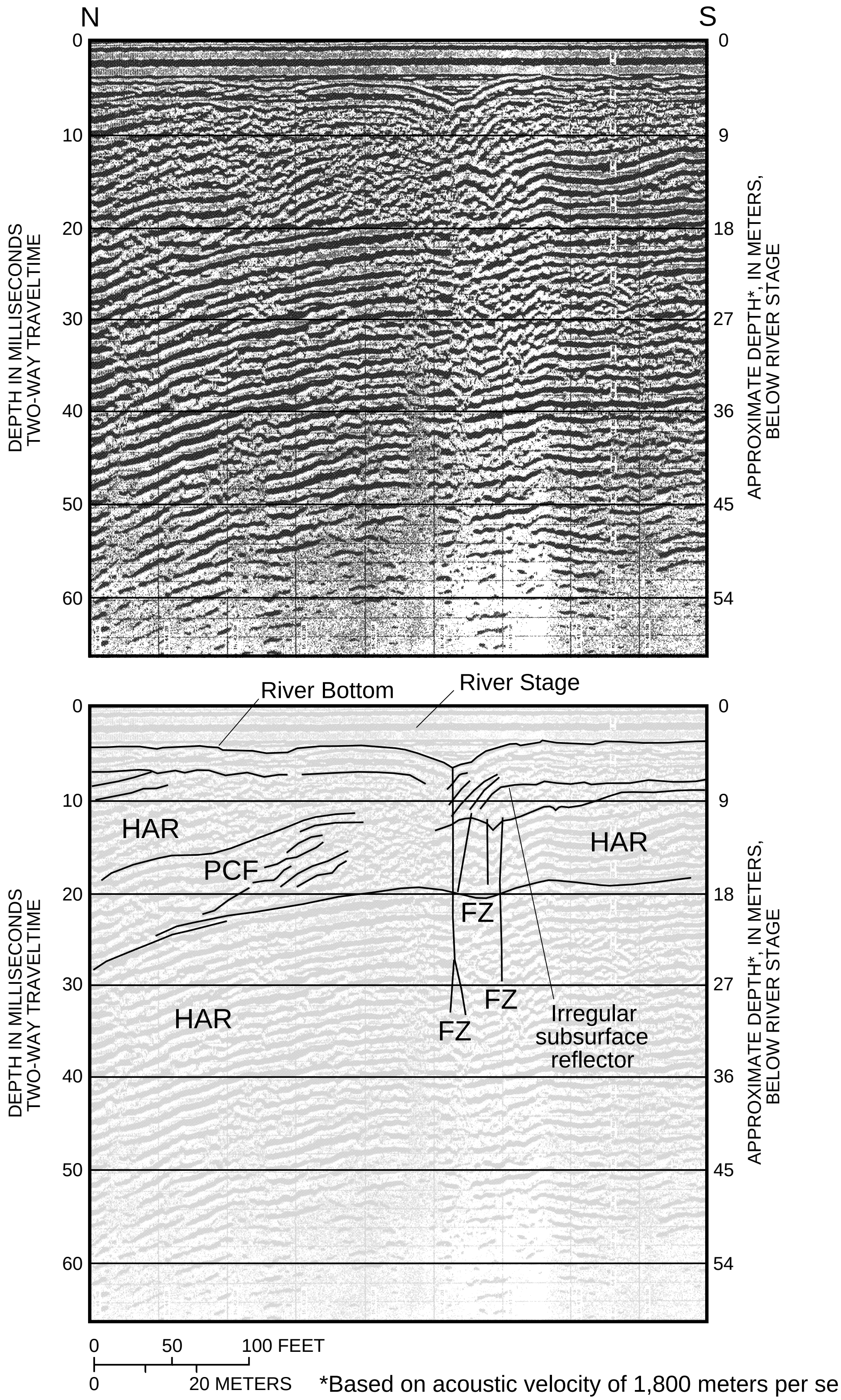


Figure 32a. Seismic-reflection profile and interpretation along the lower Peace River north of Arcadia. (See figure 26 for location.)

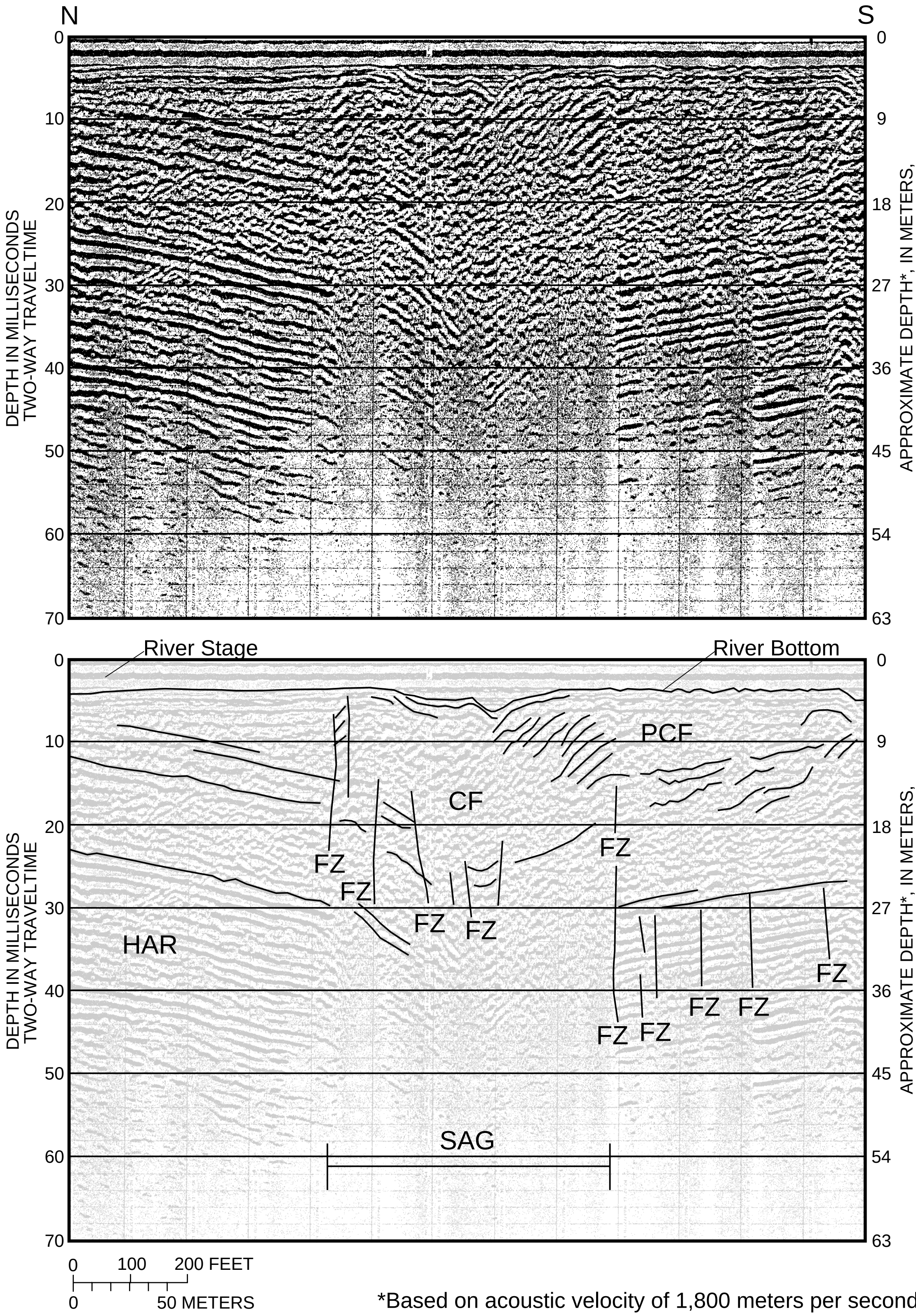


Figure 32b. Seismic-reflection profile and interpretation along the lower Peace River north of Arcadia. (See figure 26 for location.)

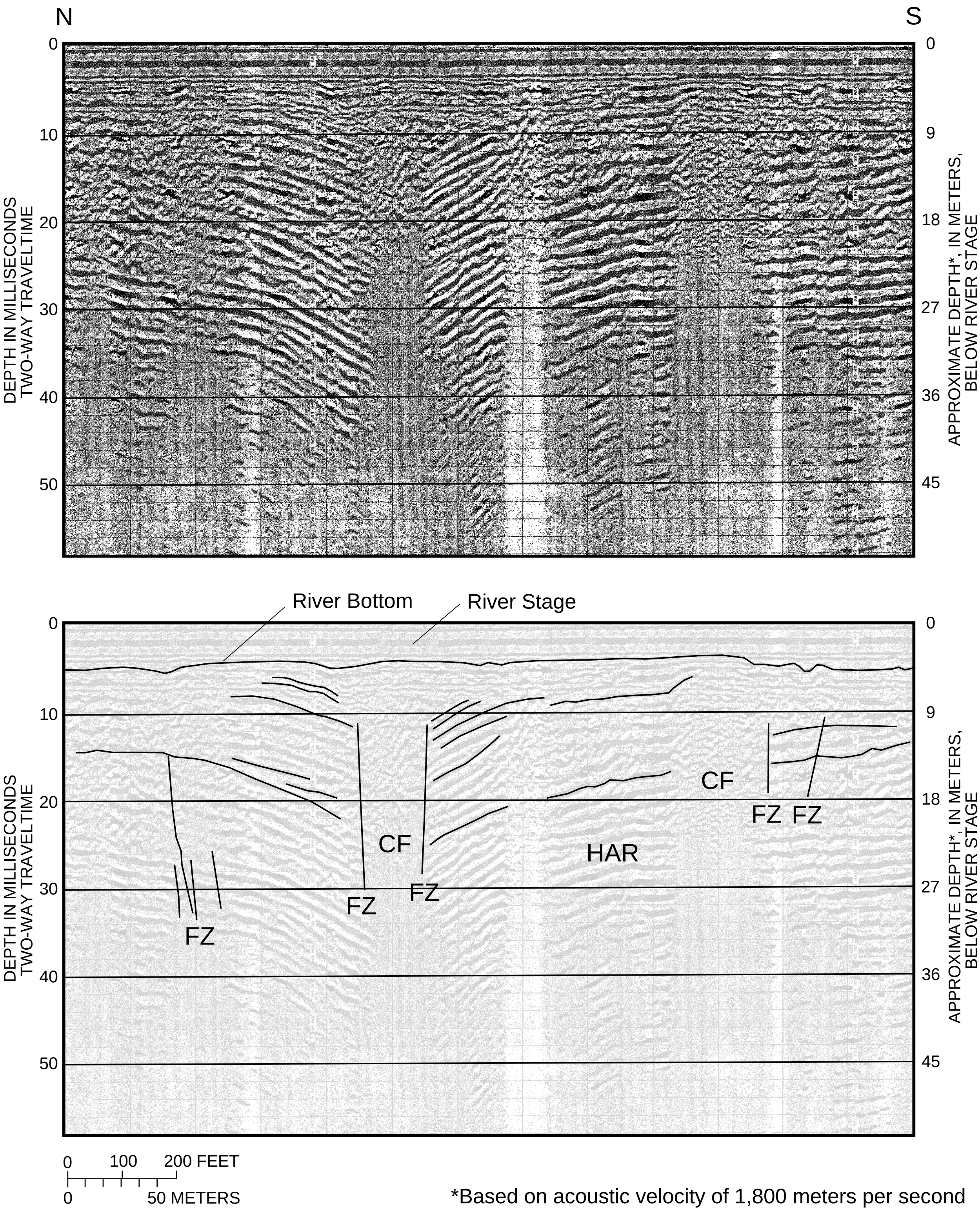


Figure 32c. Seismic-reflection profile and interpretation along the lower Peace River north of Arcadia. (See figure 26 for location.)

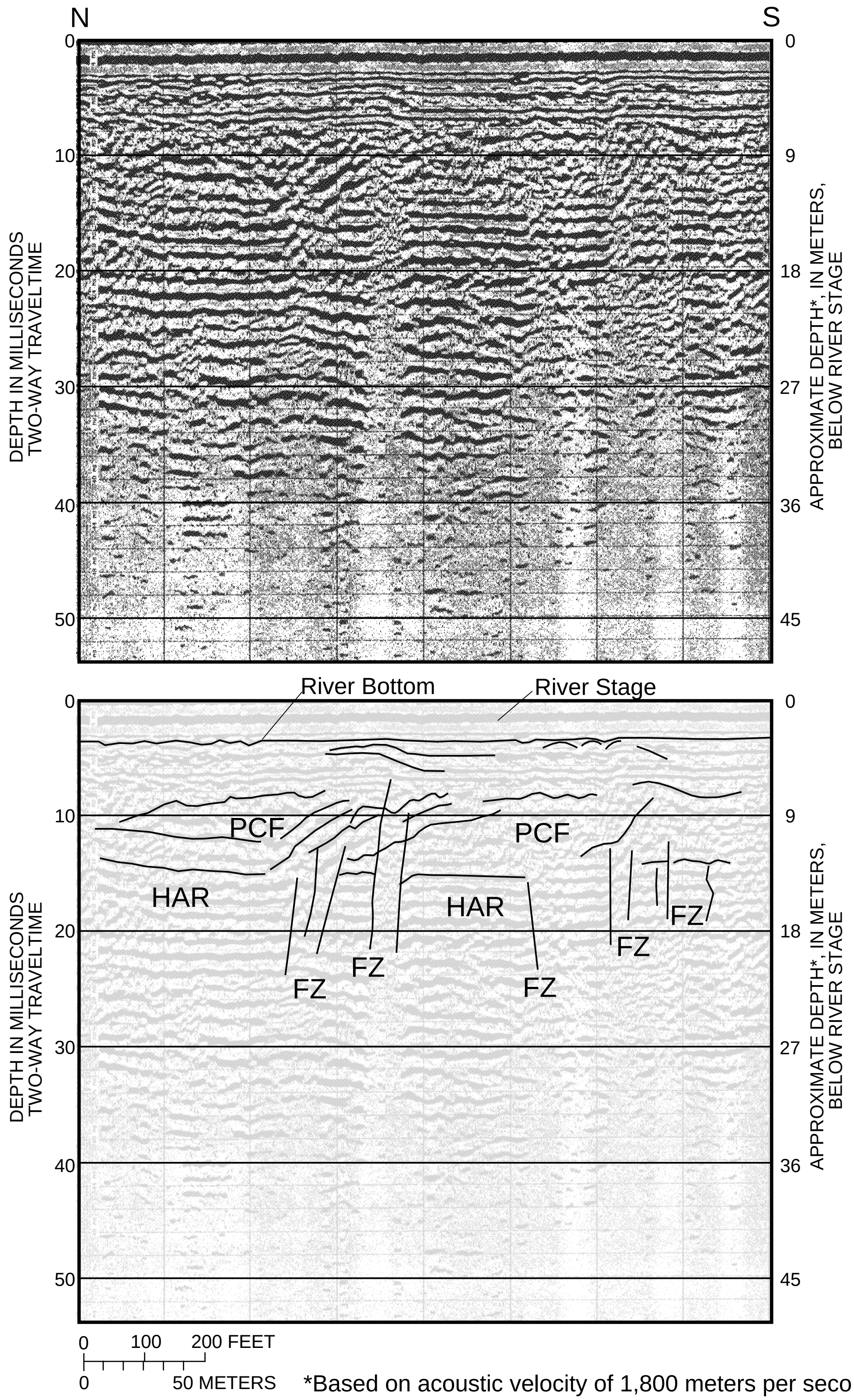


Figure 32d. Seismic-reflection profile and interpretation along the lower Peace River north of Arcadia. (See figure 26 for location.)

A previous seepage run investigation along the length of the Peace River in Hardee and De Soto Counties was conducted in 1988 by Duerr and Enos (1991) to define gains and losses during moderate base-flow conditions. McQuivey and others (1981) performed a limited seepage investigation that defined seepage losses along a 2.7-mi reach of the upper Peace River, from below Bartow to the Clear Springs Mine bridge, on January 9, 1981 (figs. 33 and 34). During this present investigation, low (May 1995) and high (May 1996) base-flow seepage runs were performed along the length of the Peace River, from the Bartow gaging station (figs. 33 and 34, site 1) to the tidally influenced reach at the State Highway 760 bridge (site 185) near Nocatee. In addition to these low and high base-flow seepage runs, a wet-season high-flow seepage run was performed from the Bartow gaging station to the Fort Meade gaging station on August 29, 1995, to quantify potential streamflow losses near peak seasonal high-flow conditions in the Peace River channel and floodplain. Patton (1981) and Patton and Klein (1989) documented approximately 90 sinkholes in the Peace River channel and floodplain of this reach where losses from the river may be occurring.

Low Base-Flow Conditions

The low base-flow seepage run was conducted during the 3 -day low-flow period of May 16-18, 1995, along a 74-mi length of the Peace River, from the Bartow gaging station (figs. 33 and 34, site 1) to the tidal-influenced reach near Nocatee (fig. 33, site 185). During the seepage run, a total of 175 discharge measurements were made, of which 74 were along the Peace River channel and 101 were near the mouths of tributaries (figs. 33 through 36). Low base-flow conditions typically occur in May and early June when ground-water levels in the underlying aquifers are at a seasonal low and ground-water withdrawals are high. During the seepage run, the (a) mean daily discharge at the four Peace River streamflow gaging stations, and the (b) maximum daily water levels in the surficial aquifer and the (c) intermediate aquifer system and Upper Floridan aquifer were near their seasonal low (fig. 37).

Peace River discharge measurements made during the low base-flow seepage run ranged from zero, along an approximate 2.6-mi reach southeast of Bartow (figs. 33 and 34, sites 10 through 15), to a maximum of 169 ft^3/s (fig. 33, site 183), southwest of Arcadia. Discharge from Peace River tributaries ranged from zero at many sites to a maximum of 62.4 ft^3/s at Payne Creek (fig. 35, site 96). The streamflow contribution from Payne Creek to the Peace River approximately tripled the discharge volume from 33 to 98.5 ft^3/s. Discharge from phosphate-mine outfalls to the Peace River ranged from less than 0.02 ft^3/s at outfall 001-Sixmile Creek (site 14) to 4.81 ft^3/s at outfall 002-Barber Branch (site 23) (figs. 35 and 36).

Because of differences in the chemical characteristics of surface and ground water, specific conductance was used as an indicator to locate potential areas of ground-water discharge. The specific conductance of water is directly related to the concentration of ions in solution. Water samples for specific conductance analysis were collected at most discharge measurement sites along the Peace River and tributaries. Specific-conductance values less than about 300 to 400 microsiemens per centimeter (μS/cm) are typically associated with stormwater runoff and water from the surficial aquifer that is primarily derived from rainfall. Specific conductance values greater than 500 μS/cm reflect mineral enrichment from deeper ground-water sources. Specific conductance values for samples collected along the Peace River ranged from 245 μS/cm at the Bartow gaging station (site 1) to 716 μS/cm at site 28, 0.5 mi downstream of the State Highway 640 bridge near Homeland (fig. 38). The relatively high specific conductance values of samples collected along the upper Peace River reflect the water chemistry from phosphate-mine outfalls. Specific conductance values of samples collected at tributaries ranged from 102 μS/cm at site 157 near Brownville to 1,217 μS/cm at site 175 near Arcadia (fig. 38).

The low base-flow seepage run was limited to a 3-day period to minimize potential changes in streamflow and climatic conditions. Reaches measured on the first day of the seepage run (May 16) included those between Bartow (site 1) and the Polk-Hardee County line at Bowling Green (site 89). Reaches measured on the second day of the seepage run (May 17) included those between Bowling Green (site 89) and the Peace River Ranch (site 142). Reaches measured on the third day of the seepage run

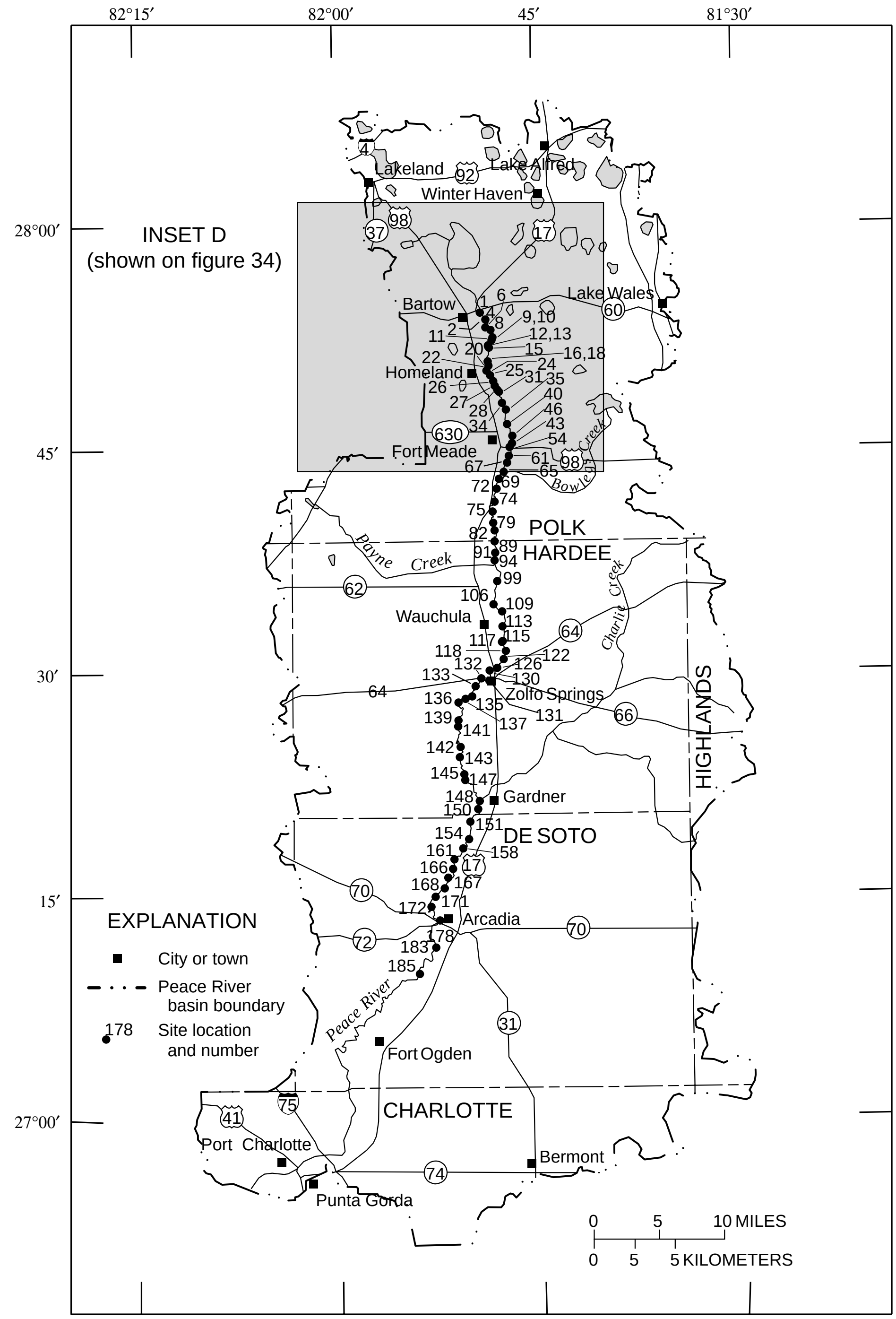


Figure 33. Location of discharge measurement sites along the Peace River during seepage runs.

(May 18) were those between the Peace River Ranch (site 142) and Nocatee (site 185). The hydrographs in figure 39 show a comparison between (a) discharge measurements made at the 74 river cross sections and (b) calculated seepage during the low base-flow seepage run. Seepage calculations for each reach were based on equation 1; the plot represents the seepage rate for the length of the contributing reach. Site descriptions, discharge measurements, and water-quality data are presented in the appendix.

Analysis of Low Base-Flow Conditions Along the Upper Peace River

On the first day of the low base-flow seepage run, the reaches where discharge measurements were made generally correspond to the upper Peace River hydrologic area of downward head gradient. That area extends from upstream of Bartow to approximately the Polk-Hardee County line at Bowling Green (fig. 4). The relation between the elevation of the Peace River streambed and the potentiometric surfaces of the intermediate aquifer system and Upper Floridan aquifer (Metz and Stelman, 1995a,b) in May 1995 is shown in figure 19. The elevations of the potentiometric surfaces were determined from wells measured during the week following the seepage run (May 22-26, 1995). Because the potentiometric surfaces of the intermediate aquifer system and Upper Floridan aquifer were below the elevation of the streambed along the length of the upper Peace River, ground-water discharge from the surficial aquifer to the streambed was the only source of base flow (fig. 20). During the seepage run, streamflow was observed flowing into sinkholes at two locations in the Peace River streambed southeast of Bartow. These streamflow losses to sinkholes confirmed that the potentiometric surface of the underlying intermediate aquifer system was below the level of the streambed at these locations.

Hydrographs in figure 40a and 40b show that relatively stable streamflow conditions existed at the Peace Creek Drainage Canal, Saddle Creek, and Bartow gaging stations during the period of May 14-21,

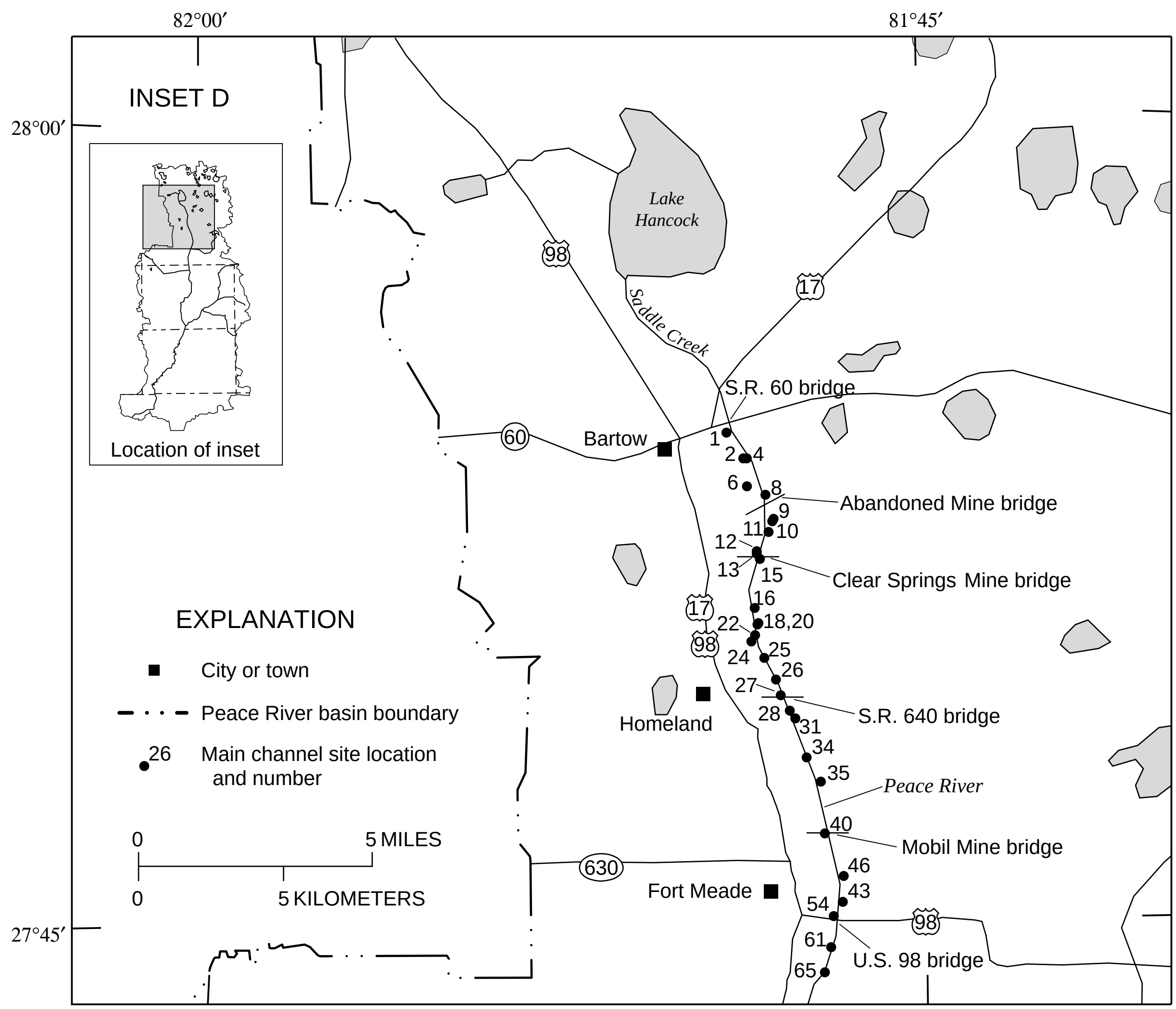


Figure 34. Location of discharge measurement sites along the upper Peace River during seepage runs.

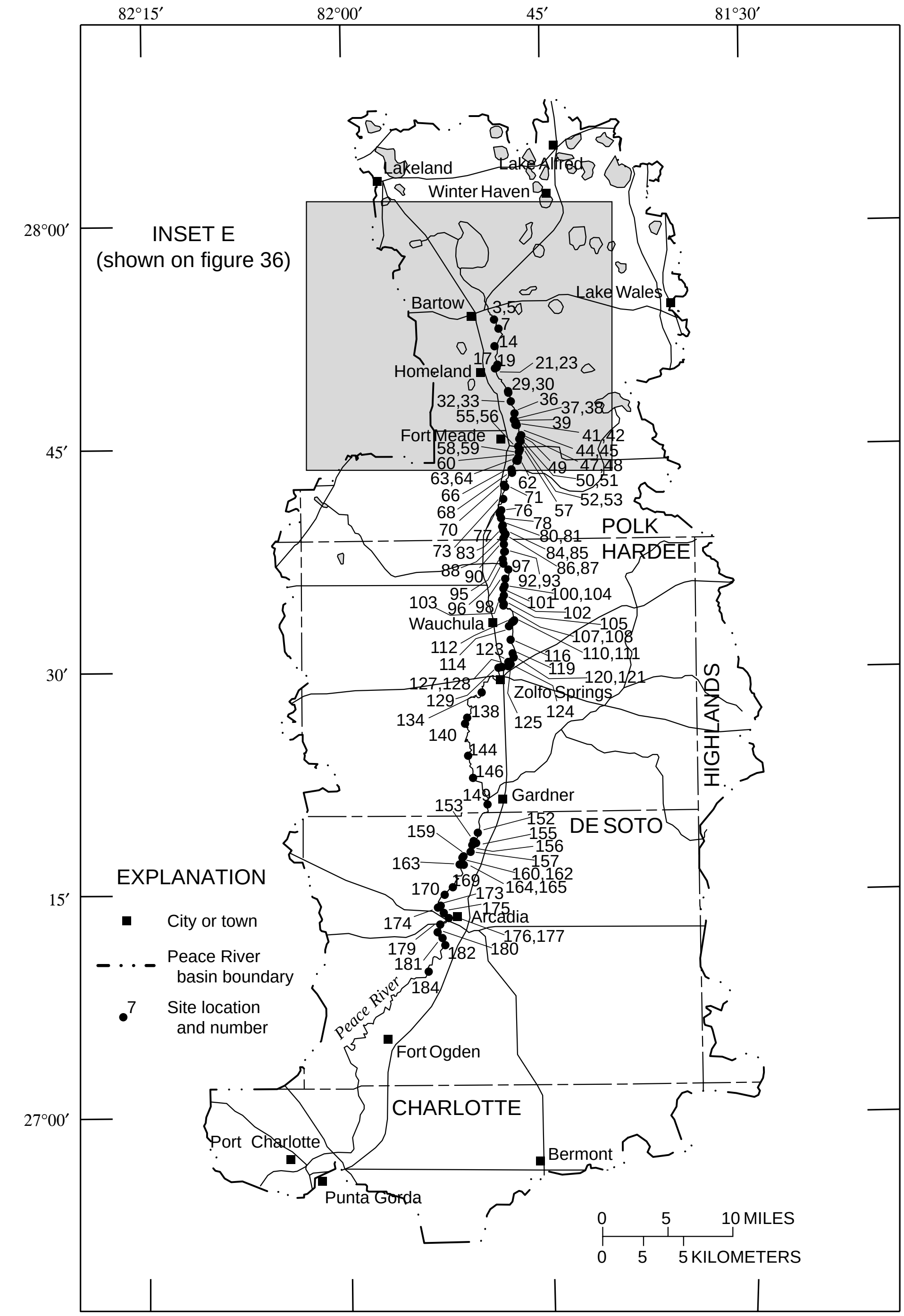


Figure 35. Location of discharge measurement sites on tributaries of the Peace River during seepage runs.

immediately prior to, during, and after the seepage run. Streamflow records from the Peace Creek Drainage Canal and the Saddle Creek gaging stations were used to estimate missing base-flow record for the period of May 14-18 at the Peace River at Bartow gaging station. Flow-duration curves in figure 41a and 41b show that the discharge measurements made at the Bartow and Fort Meade gaging stations during the seepage run represent discharges that are exceeded 98 and 88 percent of the time, respectively. These percentages indicate that base-flow conditions prevailed during the seepage run.

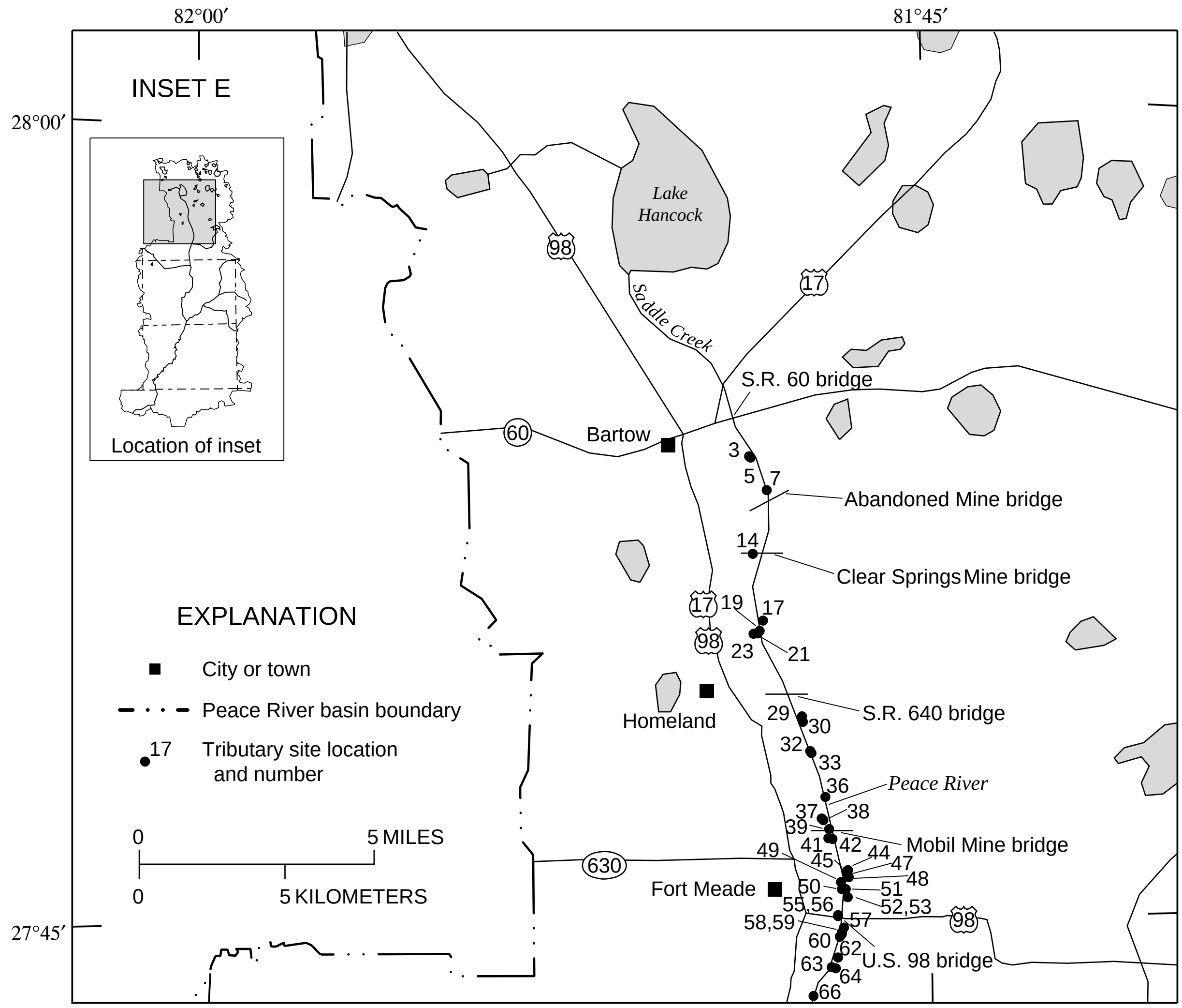


Figure 36. Location of discharge measurement sites on tributaries of the upper Peace River during seepage runs.

On the first day (May 16) of the seepage run, the uppermost Peace River discharge measurement was made at the Bartow gaging station (figs. 33 and 34, site 1) with 8.34 ft^3/s. This station is approximately 1 mi downstream from where the Peace River begins, at the confluence of the Peace Creek Drainage Canal and Saddle Creek. Peace River discharge at site 2, about 0.7 mi below the Bartow gaging station, was similar to that at site 1 with 8.4 ft^3/s. However, within the 1.6-mi reach between sites 2 and 9, the total discharge of 8.4 ft^3/s (5.43 Mgal/d) was lost through numerous sinkholes in the riverbed. Direct flow losses into sinkholes in the riverbed were measured at site 5 (1.15 ft^3/s) and site 9 (2.24 ft^3/s). The Peace River stopped flowing below site 9, and flow did not begin again until site 17, where discharges from a phosphate-mine outfall reached the river. Approximately 4 ft^3/s (2.6 Mgal/d) was lost within a 0.5 mi reach above an abandoned mine bridge (site 8). The sinkholes through which these streamflow losses occurred could not be located along the streambed as they were under 2-3 ft of water. The source of discharge along the lower 1.8-mi of the reach, downstream of site 17 to Homeland, was derived from surface-water releases at two phosphate-mine outfalls, 004 (site 17) and 002 (site 23), with 0.58 and 4.81ft^3/s, respectively (figs. 35 and 36). Discharges from these outfalls were determined from streamflow stage data provided to the USGS by IMC-Agrico. Unknown at the time, on May 14, 1995, regulated discharge releases from outfalls 004 (site 17) and 002 (site 23)

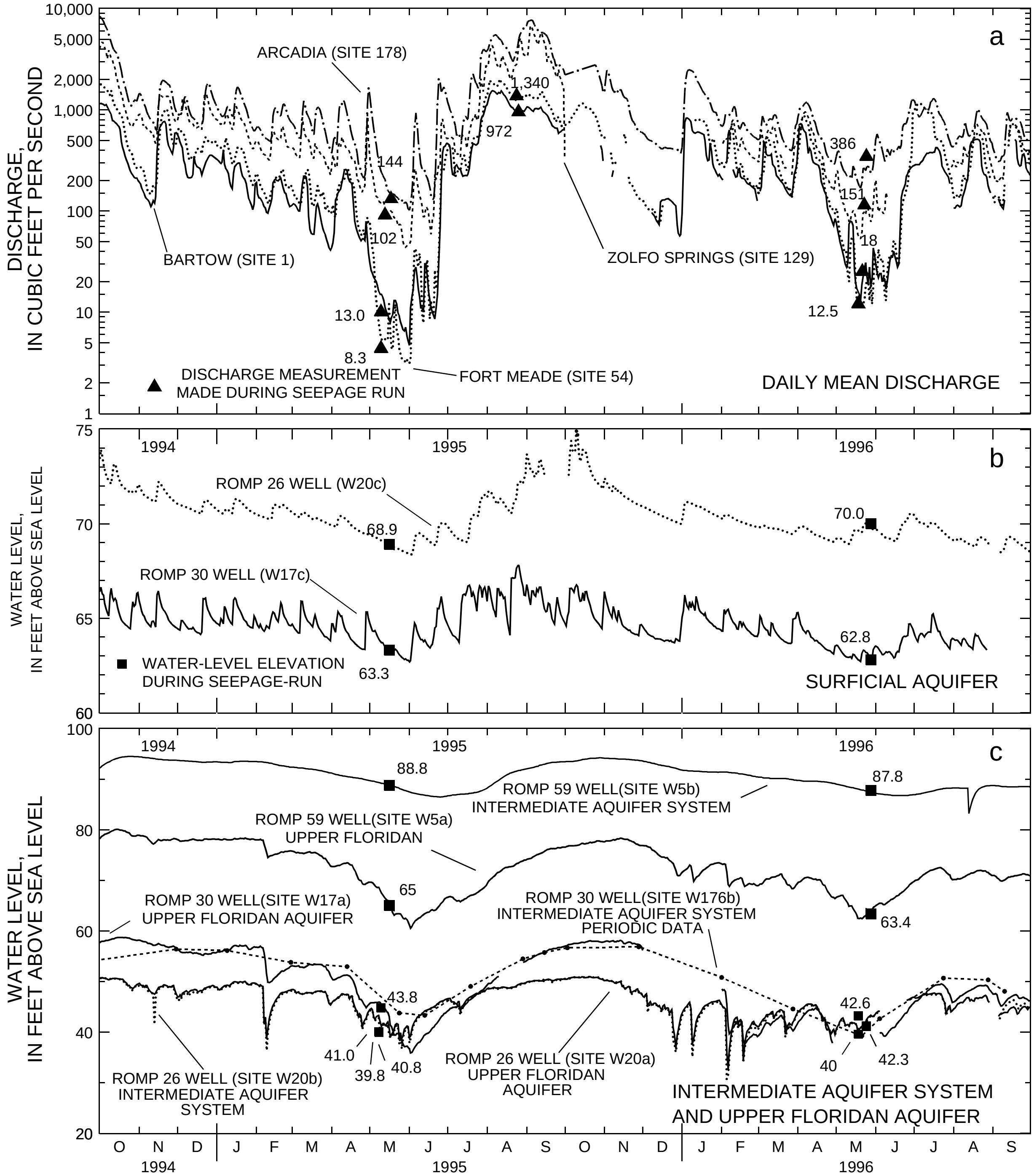


Figure 37. Daily mean discharge at (a) four Peace River streamflow stations, (b) maximum daily water levels in the surficial aquifer at ROMP wells 26 and 30, and (c) maximum daily water levels in the intermediate aquifer system and Upper Floridan aquifer at ROMP wells 26, 30, and 59, October 1994 through September 1996, and period of seepage runs. (Location of streamflow stations and wells are shown on figure 1.)

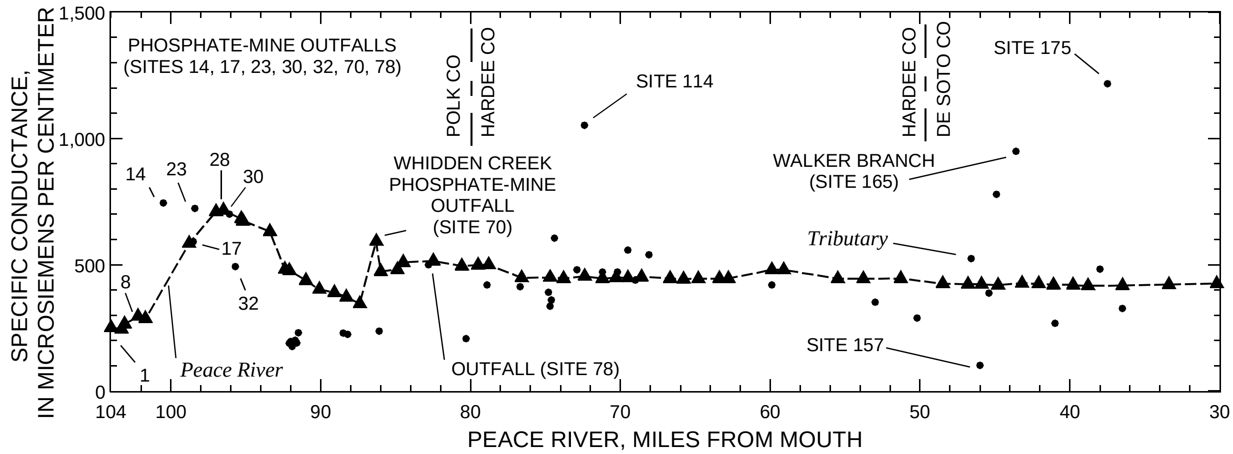


Figure 38. Comparison of specific conductance values measured along the Peace River to specific conductance values measured in tributaries during May 16-18, 1995.

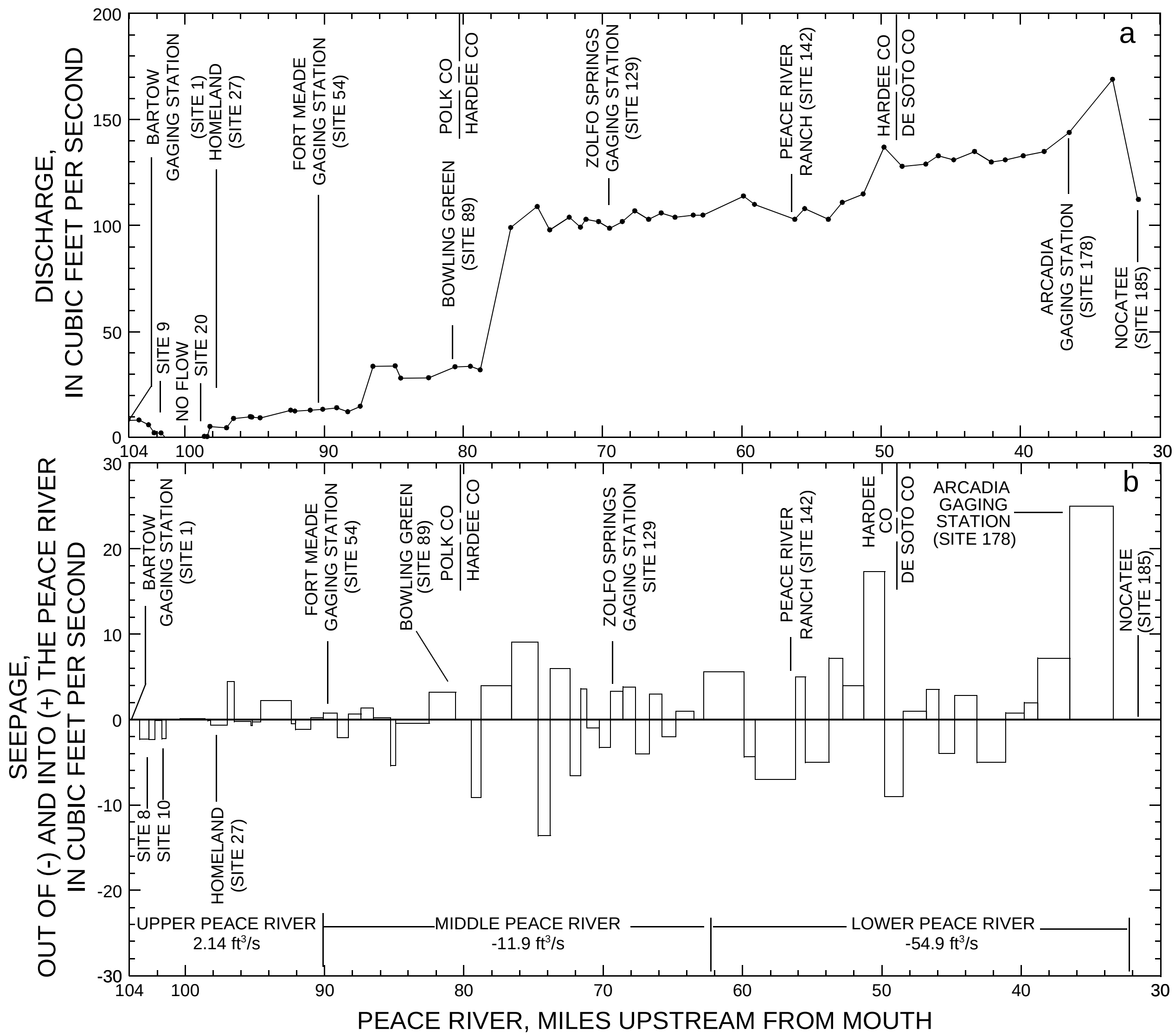


Figure 39. Comparison of (a) instantaneous discharge measurements and (b) calculated seepage along the Peace River during the low base-flow seepage run, May 16-18, 1995.

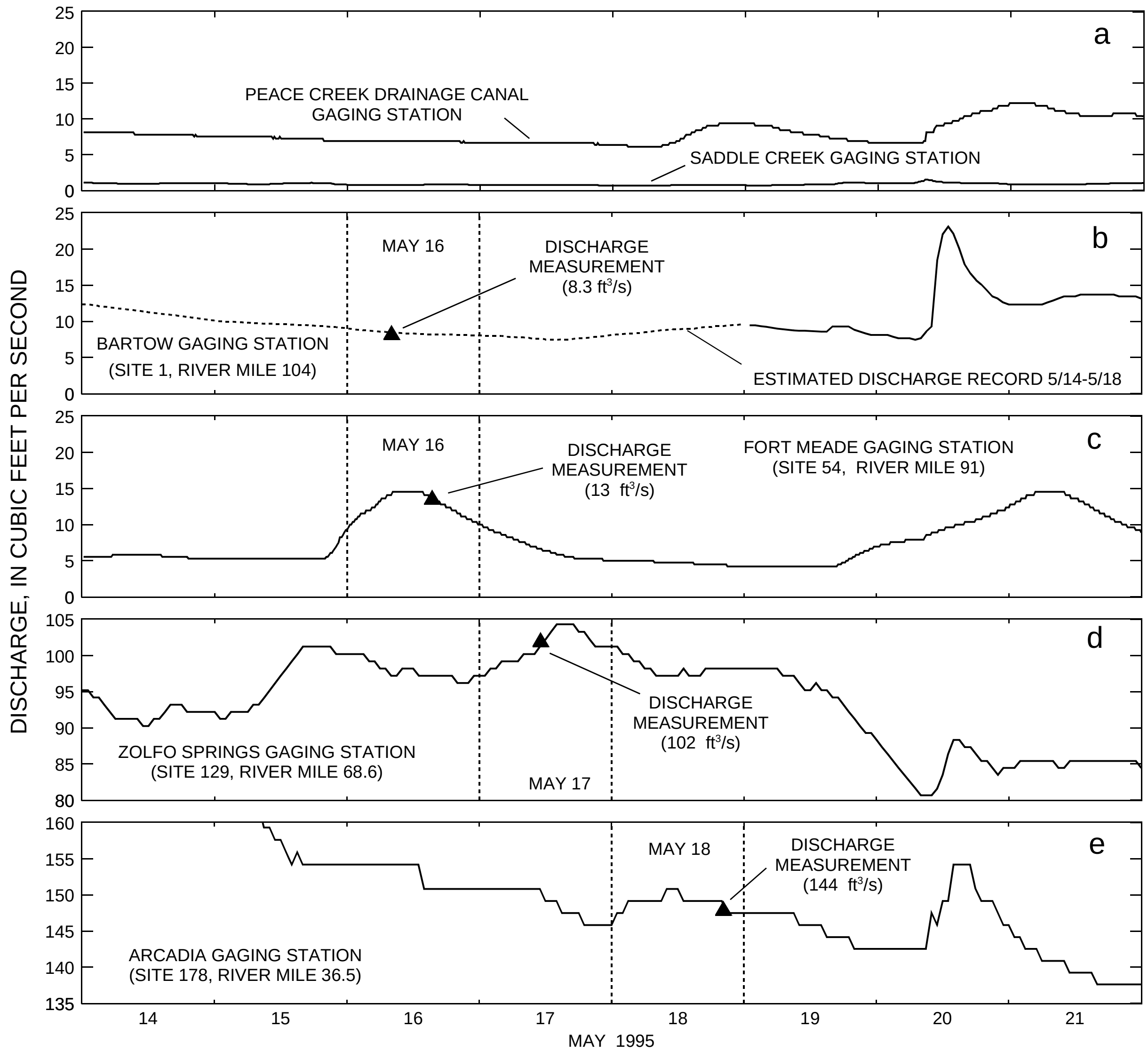


Figure 40. Discharge hydrographs for (a) Saddle Creek and Peace Creek Drainage Canal and the Peace River streamflow gaging stations at (b) Bartow, (c) Fort Meade, (d) Zolfo Springs, and (e) Arcadia, May 14-21, 1995.

had generated a pulse wave of water that flowed down the Peace River 1 day prior to the start of the seepage run. This wave, which peaked at approximately 21 ft^3/s (fig. 42), was recorded 7.4 mi downstream approximately 12 hours later at the Fort Meade gaging station (site 54) with a peak discharge of 15 ft^3/s. Seepage calculations from discharge measurements made at sites from Homeland to Bowling Green (sites 27 and 89) on May 16 were inconclusive because true seepage gains or losses could not be distinguished from flow associated with the pulse wave.

The calculated difference between the total tributary discharge of 31.4 ft^3/s and the lowermost Peace River discharge measurement of 33.5 ft^3/s made at site 89 near Bowling Green on May 16 revealed a net seepage gain of 2.1 ft^3/s. However, when discharge was adjusted for the phosphate-mine outfall releases to reflect a constant flow of approximately 2-3 ft^3/s that occurred over several days prior to the pulse wave, the actual seepage along the Peace River from Homeland to Bowling Green was probably closer to zero.

Specific conductance values from water samples collected between the Bartow gaging station (site 1) and site 8, directly upstream of the abandoned mine bridge, were similar and ranged from 245 to 296 μS/cm (fig. 38). These low specific conductance values suggest that base flow along this reach of the Peace River are derived from ground-water seepage

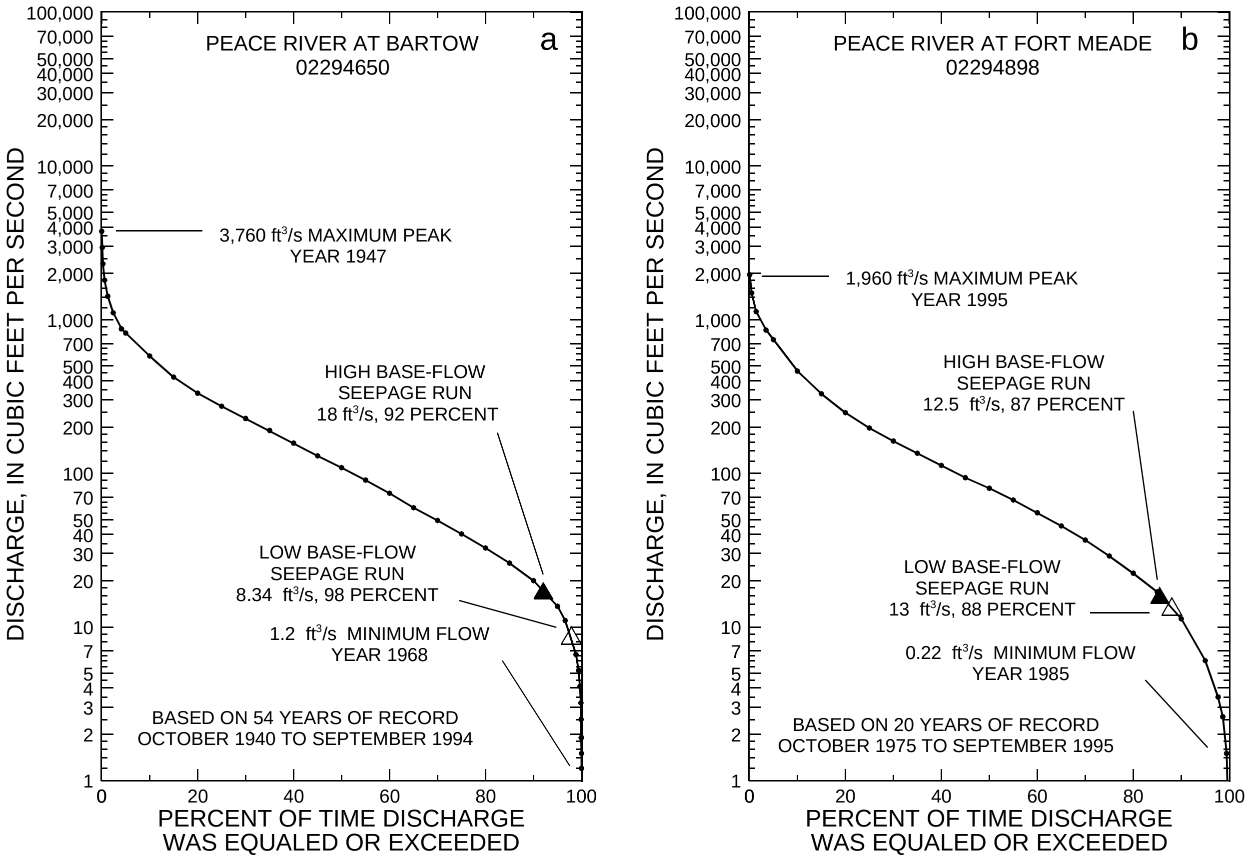


Figure 41. Flow-duration curves for the Peace River at (a) Bartow and (b) Fort Meade.

from the surficial aquifer. The only source of surface-water inflow to the Peace River along the 7-mi reach between the Clear Springs Mine bridge and the Mobil Mine bridge (sites 13 and 40) is from five phosphate-mine outfalls. The specific conductance values of water samples collected from these five outfalls ranged from 493 to 745 µS/cm. A water sample collected from the Peace River at the Mobil Mine bridge (site 40) had a specific conductance value of 632 µS/cm. Because the source of streamflow in the Peace River along this reach discharges only from five mine surface-water outfalls, the specific conductance value is the result of a composite sample. Generally, specific conductance values of samples collected along the Peace River from sites 43 to 185 had similar values, which typically ranged from 400-500 µS/cm.

Analysis of Low Base-Flow Conditions Along the Middle Peace River

Discharge measurements made along the Peace River during the second day (May 17) of the low base-flow seepage run ranged from 32 to 114 ft^3/s and included those reaches of the river that are approximately contiguous with the hydrologic area of ground-water head reversals that define the middle Peace River, from above Bowling Green to below Zolfo Springs (fig. 4). To evaluate continuity of streamflow between the first (May 16) and the second day (May 17) of the seepage run, the discharge measurement made at the farthest downstream site, Peace River at Bowling Green (site 89), on the evening of May 16 (33.5 ft^3/s) was compared to the discharge measurement at the same site on the morning of May 17 (33.7 ft^3/s). Because the two discharges were approximately equal, the outfall released wave pulse probably had either attenuated or had not yet reached site 89 by the morning of May 17.

Seepages calculated from discharge measurements made along the Peace River on May 17, from Bowling Green (site 89) to the Peace River Ranch (site 142), generally ranged from plus 3 ft^3/s to minus 3 ft^3/s (fig. 39b). However, the calculated seepages generally are within the range of the discharge measurement error of 5-8 percent, and therefore, indistinguishable from streamflow.

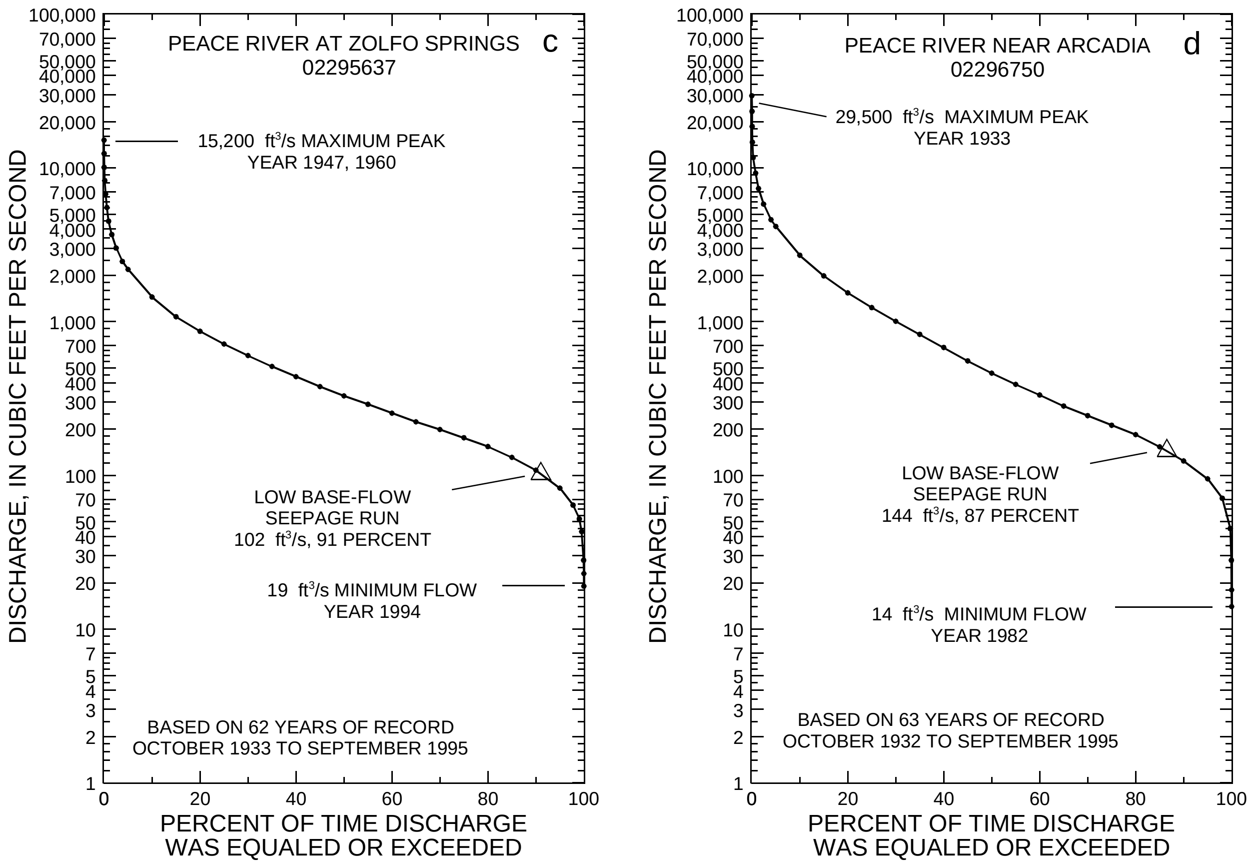


Figure 41.—Continued. Flow-duration curves for the Peace River at (c) Zolfo Springs and (d) Arcadia.

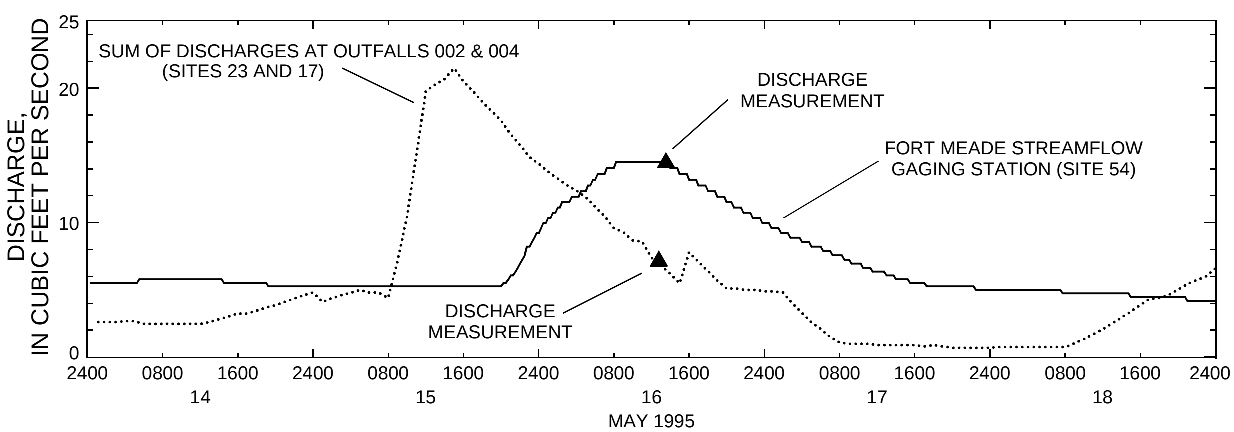


Figure 42. Sum of hourly discharge at the Clear Springs phosphate-mine outfalls 002 and 004 (sites 23 and 17) and discharge at the Peace River at Fort Meade streamflow gaging station (site 54), May 14-18, 1995. (Location of Fort Meade gaging station and outfalls 002 and 004 are shown on figures 34 and 36, respectively).

Calculated seepage losses along the Peace River on May 17 were identified at three reaches: (1) between the upper and the lower bridges of State Highway 664A (fig. 33, sites 94 and 106); (2) near the State Highway 652 bridge (fig. 33, site 115); and (3) near the Peace River Ranch (fig. 33, site 142). A comparison between the total tributary inflow (81.2 ft^3/s), measured during the second day of the seepage run, and the difference between streamflow discharge at the Peace River Ranch (103 ft^3/s) (site 142) and at Bowling Green (33.7 ft^3/s) (site 89), of 69.3 ft^3/s, revealed a net seepage loss of 11.9 ft^3/s.

Analysis of Low Base-Flow Conditions Along the Lower Peace River

During the third day of the low base-flow seepage run (May 18), gaining and losing seepages were calculated from discharge measurements made in the hydrologic area of upward-head gradients that define the lower Peace River, between the Peace River Ranch (site 142) and Nocatee (site 185)(fig. 4). Calculated seepage results indicated that potential gains occurred at two reaches. These two gaining reaches were located between Limestone Creek (site 147) and Charlie Creek (site 150) and between the railroad bridge near Arcadia (site 172) and site 183, about 2 mi below the Arcadia gaging station. Seepages along reaches below site 183 were undetermined because discharges measured at these sites were influenced by tidally affected backwater from Charlotte Harbor. A comparison between total tributary inflow (11.1 ft^3/s), measured on the third day, and the difference in stream discharges between the Peace River Ranch (103 ft^3/s) (site 142) and site 183 (169 ft^3/s) of 66 ft^3/s, revealed a net seepage gain of 54.9 ft^3/s.

Specific conductance values from water samples collected at the tributaries along the lower Peace River ranged from 102 µS/cm at site 157, a very small tributary near Brownville, to 1,217 µS/cm at site 175 near Arcadia. Ground-water discharge from underlying aquifers to tributaries may account for the higher specific conductance values.

High Base-Flow Conditions

A high base-flow seepage run was performed during May 28-31, 1996, along the same 74-mi length of the Peace River, between Bartow and Nocatee, used for the low base-flow seepage run. Base-flow conditions at most discharge measurement locations were higher than during the low base-flow seepage run in May 1995. During this four-day seepage run, base flow was mostly derived from ground-water seepage. In addition to natural tributary inflow, regulated discharges from both phosphate-mine outfalls and wastewater treatment plants contributed to the Peace River flow during the seepage run. In west-central Florida, high base-flow conditions typically occur in mid-to-late spring when ground-water heads in underlying aquifers are high and rainfall is limited. However, because many frontal storms occurred in the winter and spring of 1996, high base-flow conditions prevailed in the Peace River into late spring during the period of the May 1996 seepage run. Hydrographs in figure 37 show that during the May 1996 high base-flow seepage run the (a) daily mean discharges at the four Peace River continuous-record gaging stations were at high base-flow conditions and (b) maximum daily water-levels in the surficial aquifer and the (c) intermediate aquifer system and Upper Floridan aquifer were near seasonal high ground-water level conditions. The relation between the elevation of the Peace River streambed and water levels measured during May 20-24, 1996, in the surficial aquifer, intermediate aquifer system, and Upper Floridan aquifer, was similar to the relation that occurred between water levels and the streambed elevation of May 1995 (Mattie and others, 1996a) (figs. 20 and 37).

During the May 1996 high base-flow seepage run a total of 167 discharge measurements were made; 66 along the Peace River (figs. 33 and 34) and 101 along tributaries (figs. 35 and 36). Hydrographs in figure 43 show streamflow conditions along the Peace River at the Bartow, Fort Meade, Zolfo Springs, and Arcadia gaging stations (sites 1, 54, 126, and 148) during May 26-31, immediately prior, during, and after the seepage run. High base-flow conditions existed between the Bartow gaging station and Bowling Green (sites 1-89) during the first two days (May 28-29) of the seepage run. Unfortunately, seepage calculations determined from discharge measurements made along the Peace River between Bowling Green (site 89) and Nocatee (site 185), during the latter two days of the seepage run, proved to be inconclusive because of high-runoff conditions generated from an intense frontal storm that moved through the basin on the morning of May 30. Therefore, seepage calculations were limited to those reaches along the upper Peace River between Bartow and Bowling Green that were measured on May 28-29.

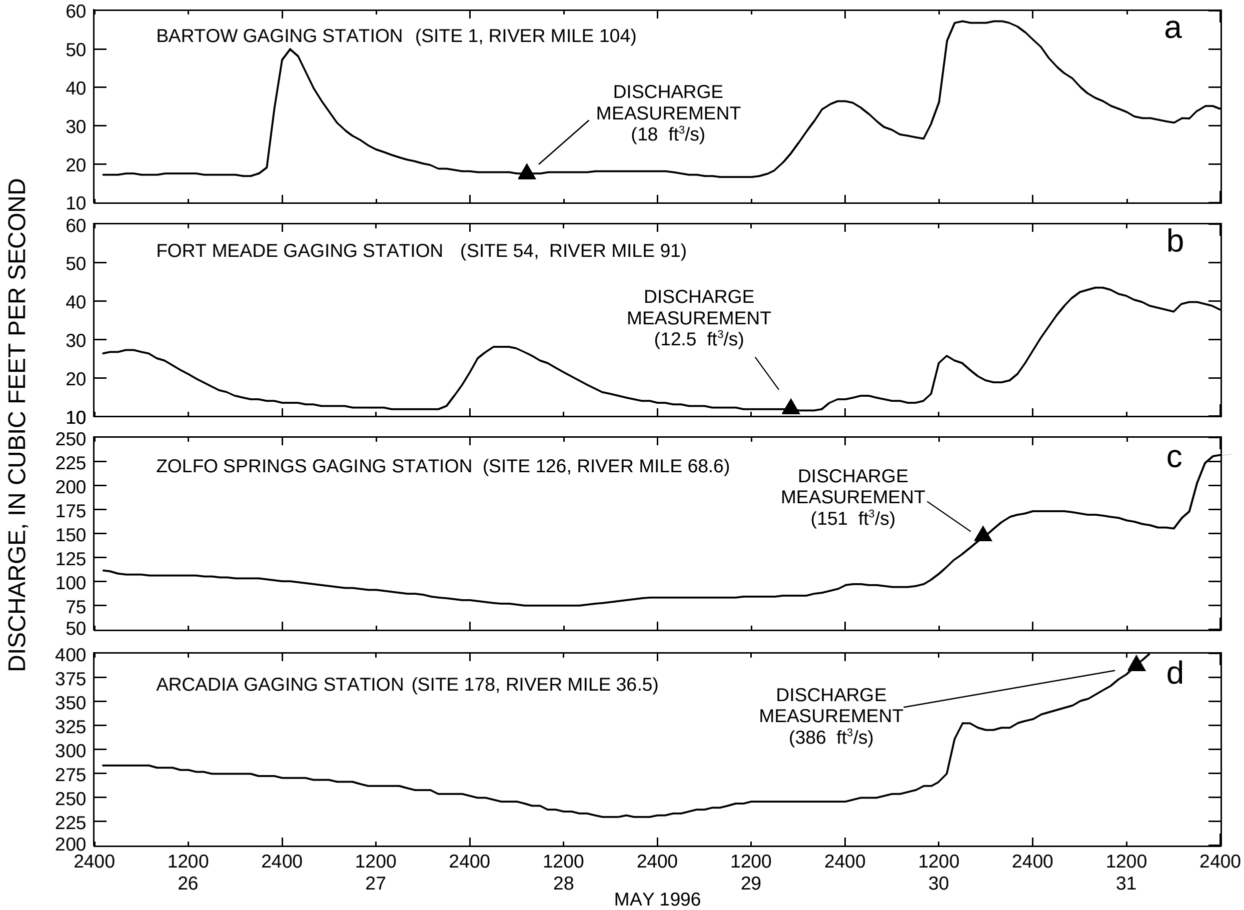


Figure 43. Discharge hydrographs for the Peace River at (a) Bartow, (b) Fort Meade, (c) Zolfo Springs, and (d) Arcadia gaging stations during the high base-flow seepage run, May 26-31, 1996.

Based on the period of record, flow-duration curves in figure 41a,b show that discharge measurements made at the two upper Peace River gaging stations, Bartow and Fort Meade, during the high base-flow seepage run were approximately equal to a flow that is exceeded 92 and 87 percent of the time, respectively. Figure 44a shows that discharge measurements made during May 28-29, 1996, along the upper Peace River ranged from 0.66 ft^3/s at site 11, above the Clear Springs Mine bridge, to 62.4 ft^3/s at site 89, near Bowling Green. Tributary flows to the Peace River ranged from zero at many sites to 32.7 ft^3/s at Whidden Creek (fig. 35, site 70). During this seepage run, the streamflow contribution from Whidden Creek to the Peace River accounted for approximately two-thirds of the total volume at the confluence (51.3 ft^3/s). Three major phosphate-mining companies, IMC-Agrico, Mobil Mining and Minerals Company, and Cargill Fertilizer, cooperated with the USGS during the seepage run by maintaining a constant rate of discharge at their outfalls. Discharge to the Peace River from phosphate-mine outfalls ranged from less than 0.01 ft^3/s at site 39 (figs. 35 and 36) to 7.79 ft^3/s at site 81 (fig. 35).

Seepage losses from the Peace River to underlying aquifers were calculated from discharge measurements made along the 1.8-mi reach between sites 4 and 11 (figs. 33 and 34). Total losses were calculated at 17.6 ft^3/s (11.4 Mgal/d) (fig. 44a and b). A direct loss of 1.2 ft^3/s was measured at an approximately 10-ft long natural diversion channel flowing perpendicular from the Peace River into a sinkhole at site 5. The sinkhole at site 5 becomes submerged under moderate-to-high flow conditions. Approximately 4.3 ft^3/s (2.8 Mgal/d) of river water was lost in a 0.4-mi reach between sites 6 and 8. No streamflow losses were measured along the 0.5-mi reach between sites 8 and 9. However, along the 0.3-mi reach between sites 9 and 10, streamflow losses were calculated at 2.7 ft^3/s (1.7 Mgal/d). These losses are probably the result of a sinkhole that was located approximately 100-ft upstream of site 10 during the low base-flow seepage run, when losses in May 1995

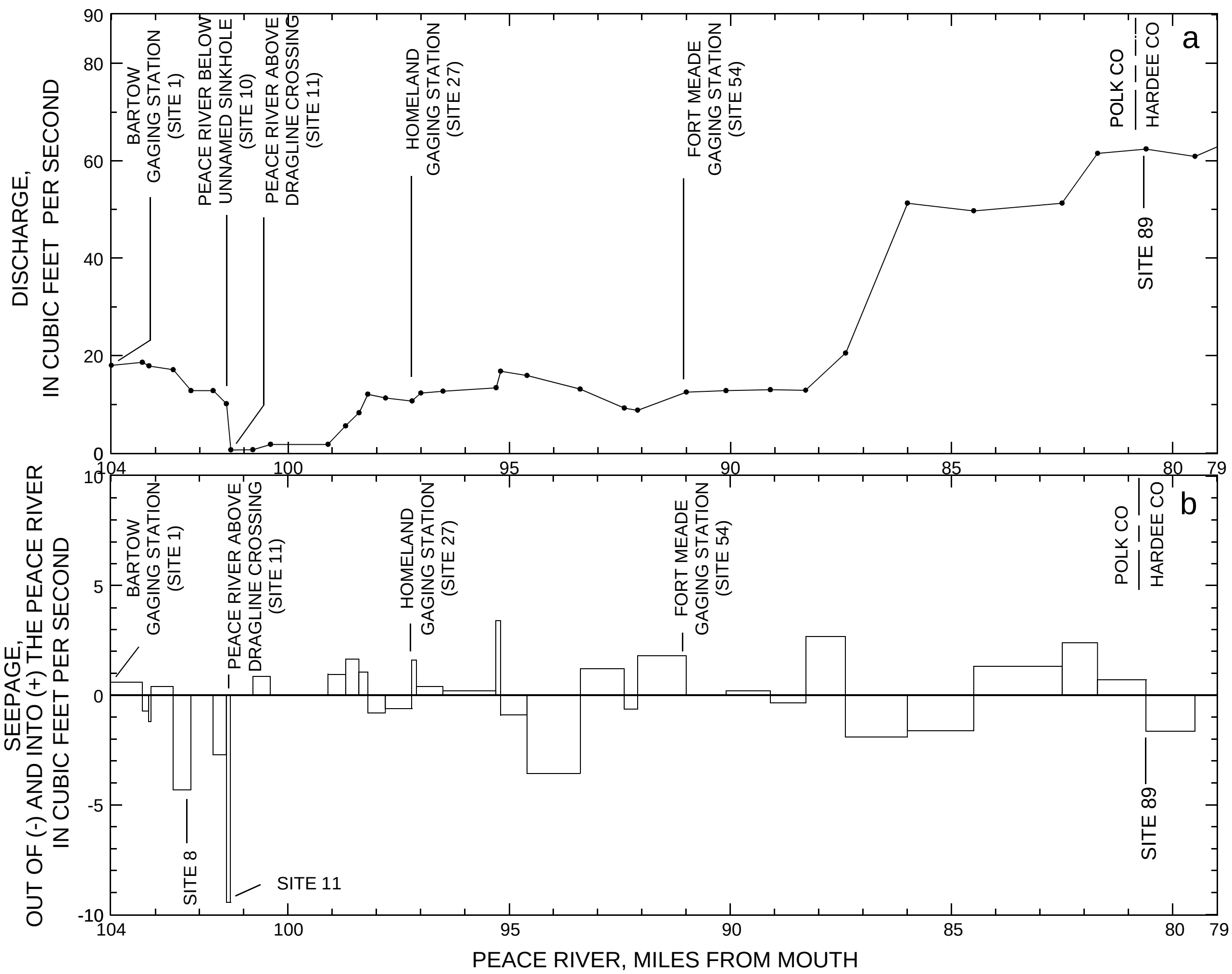


Figure 44. Comparison of (a) instantaneous discharge measurements and (b) calculated seepages along the upper Peace River during the high base-flow seepage run of May 28-29, 1996.

amounted to 2.24 ft^3/s. The greatest streamflow loss of 9.44 ft^3/s (6.1 Mgal/d) was recorded within the 0.1 mi reach between sites 10 and 11. Because the Peace River channel within this reach was heavily obstructed by many fallen trees and log jams, the sinkhole(s) could not be located.

Net streamflow seepage (gains and losses) on the first day of the high base-flow seepage run (May 28, 1996) along the 10.6-mi reach from the Bartow gaging station to the Mobil Mine bridge (figs. 33-34, sites 1 and 40) was calculated as a loss of 13.04 ft^3/s. On the second day of the seepage run, May 29, 1996, a net seepage gain of 4. 61 ft^3/s was calculated along the 14.6-mi reach from the Mobil Mine bridge to below Bowling Green (fig. 33, sites 40 and 91). The net seepage calculated during the 2-day high base-flow seepage run from Bartow to below Bowling Green was a loss of 8.43 ft^3/s.

Water-quality samples were collected and analyzed for specific conductance at most of the Peace River and tributaries discharge measurement sites during the high base-flow seepage run. Specific conductance values between Bartow (site 1) and Bowling Green (site 89) ranged from 247 µS/cm at site 16 to 521 µS/cm at site 35 (fig. 45). Specific conductance values of water samples collected from tributaries between Bartow and Bowling Green ranged from 193 µS/cm at Bowlegs Creek (site 68) to 630 µS/cm at mine outfall 002-Barber Branch (site 23). The high specific conductance values in the Peace River generally reflect the values of phosphate-mine outfall contributions. Specific conductance values from most natural tributaries in the upper Peace River are low,

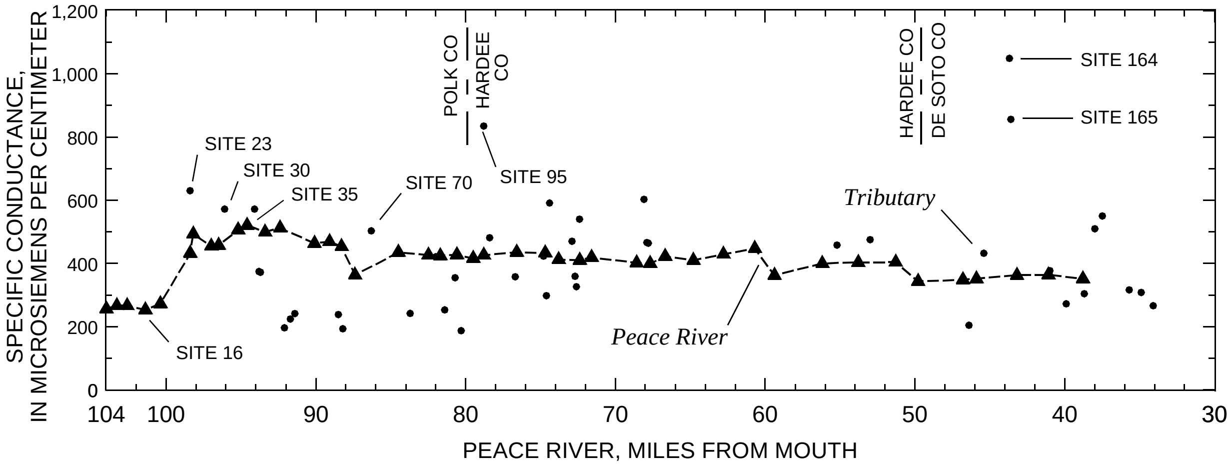


Figure 45. Comparison of specific conductance values for samples measured along the Peace River to specific conductance values measured in tributaries during May 28-29, 1996.

ranging from 224 to 421 µS/cm. However, in the middle and lower Peace River, higher specific conductance values in tributaries may indicate a ground-water discharge source. Site descriptions, discharge measurements, and water-quality data for the seepage runs are presented in the appendix.

Comparison of Low and High Base-Flow Conditions Along the Upper Peace River

A comparison between the low base-flow (May 1995) and the high base-flow (May 1996) seepage runs is shown in figure 46. Discharge measurements (fig. 46a) were made along a 74-mi length of the Peace

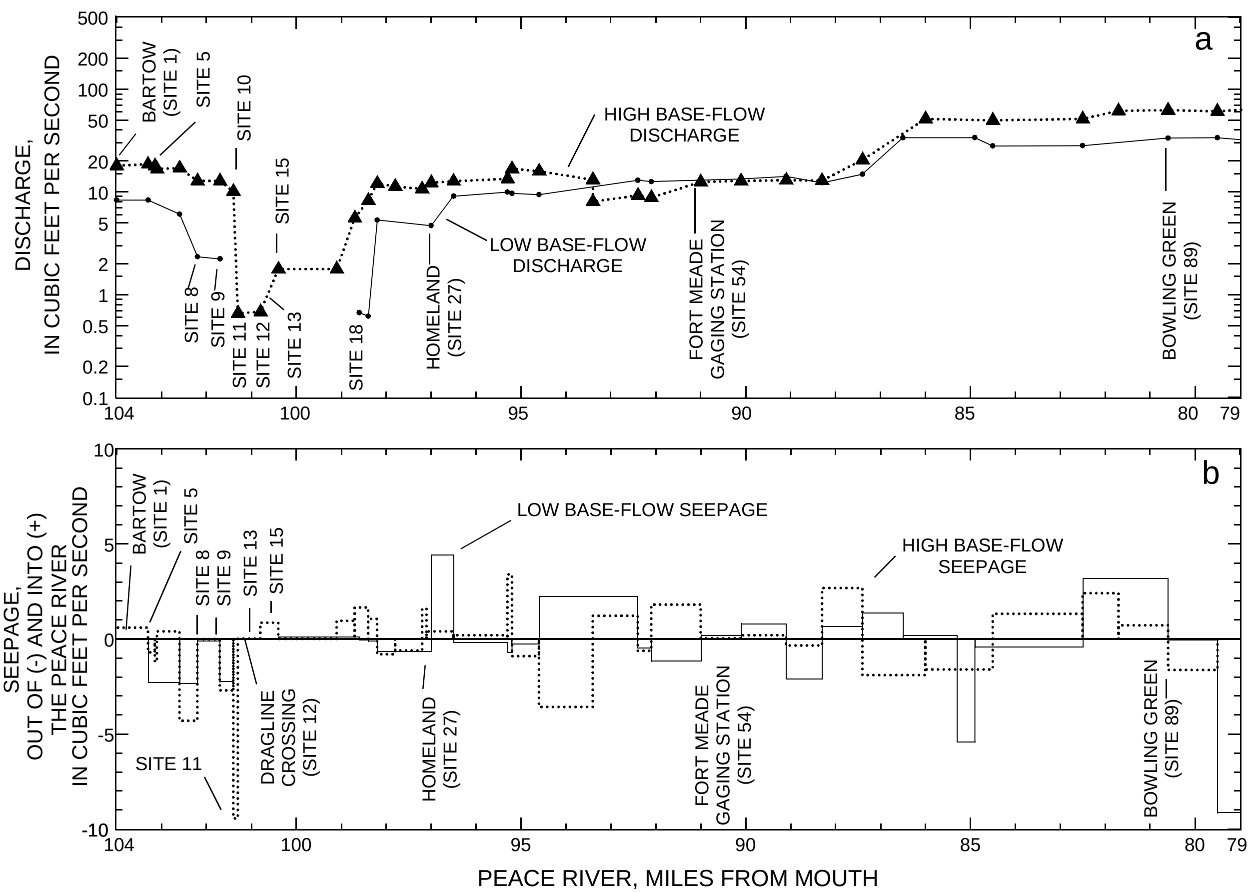


Figure 46. Comparison of (a) instantaneous discharge measurements and (b) calculated seepages along the upper Peace River during the May 1995 low base-flow and the May 1996 high base-flow seepage runs.

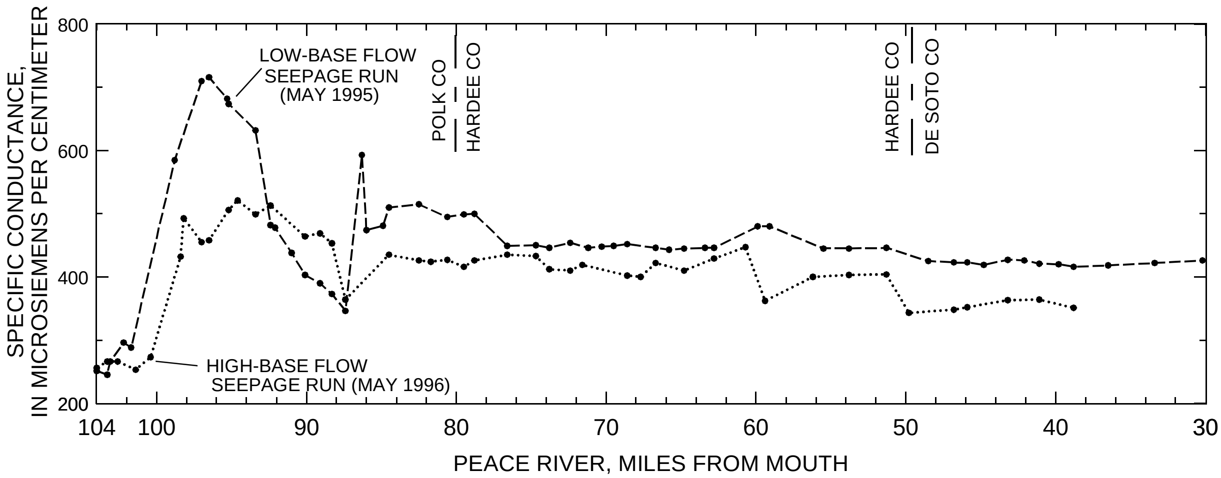


Figure 47. Comparison of specific conductance values from water samples measured along the Peace River during the May 1995-96 seepage runs.

River (fig. 33, sites 1-185). However, seepage comparisons (fig. 46b) were made only along the uppermost 25-mi reach of the Peace River, between Bartow and Bowling Green (figs. 33 and 34, sites 1 and 89), because of high-flow conditions produced by runoff from a frontal storm during the third day of the high base-flow seepage run (May 1996). The most accurate streamflow losses were documented along the 3.2-mi reach of the upper Peace River, between the Bartow gaging station (site 1) and the Clear Springs Mine bridge (site 12). This reach lacks inflow from either tributaries or mine outfalls and the occurrence of numerous sinkholes have been identified in the streambed. At the upstream site (Bartow gaging station (site 1)), discharges measured during the low and high base-flow seepage runs were 8.3 and 18.0 ft^3/s, respectively. During both seepage runs, no measurable losses occurred between sites 1 and 5. However, direct losses of approximately 1.2 ft^3/s were measured at site 5, where water leaves the Peace River along a natural diversion channel and disappears through a sinkhole. Cumulative streamflow losses along the upper 1.8-mi reach, from site 1 to site 8, during both the low- and high-flow seepage runs ranged from 5.2 to 6.05 ft^3/s, respectively. The sinkhole located directly downstream of site 9 drained the remaining 2.24 ft^3/s of river water in the Peace River channel during the low base-flow seepage run and is suspected of taking 2.7 ft^3/s of the river water during the high base-flow seepage run. During the high base-flow seepage run, the flow remaining in the river (9.44 ft^3/s) was lost to a sinkhole(s) within the 0.1-mi long reach between sites 10 and 11. Increases in streamflow between site 13 (Clear Springs Mine bridge) and site 54 (Fort Meade gaging station) during both seepage runs were attributed largely to mine outfall discharges.

Specific conductance values from water samples collected during the May 1995 and the May 1996 seepage runs are compared in figure 47. Specific conductance values from the May 1995 seepage run generally were higher than the May 1996 values along the Peace River, except for a 6.4-mi reach from sites 43 to 72 (figs. 33 and 34). Specific conductance values during the May 1996 seepage run were much lower than the May 1995 values along a 5.2-mi reach between sites 20 and 40, where much of the water was discharged from phosphate-mine outfalls. The lower specific conductance values in May 1996 may be the result of a seasonal rainfall increase to mine surface-water storage areas.

High-Flow Conditions Along the Upper Peace River

Direct streamflow losses from the upper Peace River to a number of known sinkholes in the low-water channel between Bartow and Fort Meade (figs. 33 and 34, sites 1 and 54) were observed during the two base-flow seepage runs. To further quantify these losses in the upper Peace River, a high-flow seepage run was conducted on August 29, 1995, along the 13-mi reach, from the Bartow gaging station to the Fort Meade gaging station. This reach generally is an undisturbed (unmined), environmentally protected corridor, bordered by phosphate-mined land that has been reclaimed with large clay-settling areas. During the period of the high-flow seepage run, much of the approximately one-half-mile wide, heavily forested Peace River floodplain was inundated with several feet of water. Discharge measurements along this reach were made using standard USGS high-flow techniques at five bridges that cross the Peace River. Seepage calculations at the four reaches were based on discharge measurements made at these bridges. Peace River daily mean discharge hydrographs in figures 20, 21, and 37 show that during the high-flow seepage run, streamflow conditions at the Bartow and Fort Meade (figs. 33 and 34, sites 1 and 54) gaging stations were near their seasonal high. Discharge measurements and calculated seepages at the five bridge sites are compared in figure 48 and summarized in table 4 by downstream order.

Discharge measurements made at the Bartow gaging station and the abandoned mine bridge (figs. 33 and 34, sites 1 and 8) define the first reach, and were 972 and 1,020 ft^3/s, respectively. This reach had no tributary inflows. The difference in discharge between the upstream and downstream sites along the reach indicated a net gain of about 48 ft^3/s. A gain in this reach of the river contradicted previous results where more precise seepage losses of approximately 6.0 and 5.2 ft^3/s were calculated during the low and high base-flow seepage runs in May 1995 and 1996, respectively. Discharge measurement errors associated with the high-flow measurements ranged from approximately plus or minus 5 to 8 percent, equivalent to a flow error of 50 to 80 ft^3/s. The gain in streamflow calculated along this reach, which falls within the discharge measurement error, may actually be (1) ground-water discharge from the intermediate aquifer system and/or (2) the result of reduced seepage losses along the reach from an upward head potential. Ground-water levels in the upper Hawthorn and lower Hawthorn Formations of the intermediate aquifer system at the ROMP 59 well site, located approximately 3 mi southwest of the Bartow gaging station, were above the elevation of the streambed, but were not above the river stage on August 29, 1995 (fig. 20).

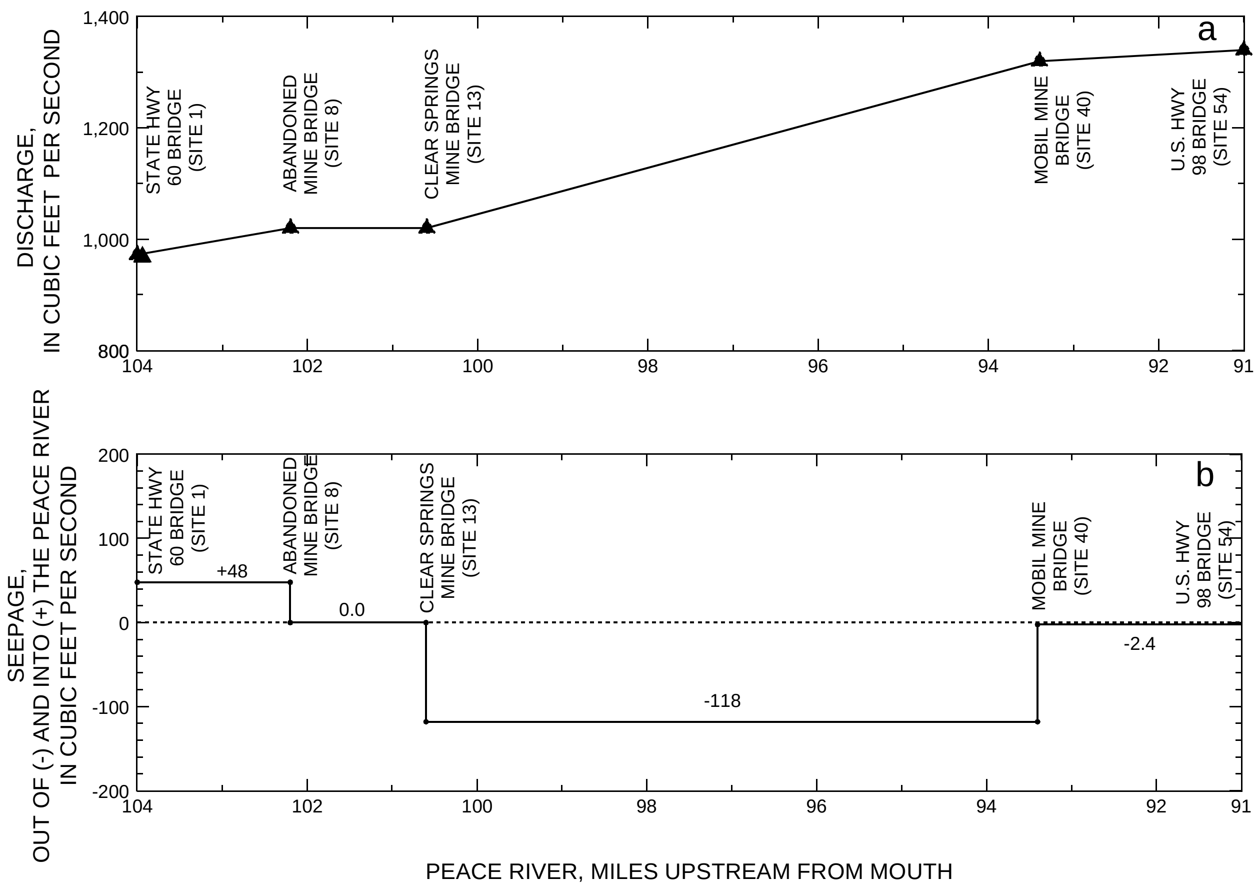


Figure 48. Comparison of (a) instantaneous discharge measurements and (b) calculated seepages along the upper Peace River during the high-flow seepage run of August 29, 1995.

Table 4. Instantaneous high-flow discharge and calculated seepage at five upper Peace River bridge cross sections, August 29, 1995

Site no.	River mile	Peace River bridge cross section	Peace River discharge (ft^3/s)	Reach sites	Tributary discharge (ft^3/s)	Seepage (ft^3/s)
1	104.0	Peace River at Bartow (State Hwy. 60 bridge)	972	--	--	--
8	102.2	Abandoned mine bridge	1,020	1-8	0	+48
13	100.6	Clear Springs Mine bridge	1,020	8-13	0	0
40	93.4	Mobil Mine bridge	1,320	13-40	418	-118
54	91.0	Peace River at Fort Meade (U.S. Hwy. 98 bridge)	1,340	40-54	22.4	-2.4

The second reach, located between the abandoned mine bridge and the Clear Springs Mine bridge (figs. 33 and 34, sites 8 and 13), is approximately 1.6 mi long. Similar to the first reach, this second reach had no tributary inflows or discharges from active surface-water mine outfalls. A discharge measurement of 1,020 ft^3/s was made at both the upstream (site 8) and the downstream (site 13) bridge sites. Quantifying seepage gains or losses in this reach may have been complicated by inherent discharge measurement errors associated with high-flow measurements and the presence of sinkholes. Losses of 12.1 ft^3/s occurred along this reach during the high base-flow seepage run in May 1996. Streamflow losses were expected to increase due to the presence of many sinkholes located in the floodplain during the high-flow conditions. However, similar to the flow gains in the first reach, upward head gradients in the intermediate aquifer system may control streamflow losses along this reach.

The 7.2-mi-long third reach was located between the Clear Springs Mine bridge and the Mobil Mine bridge (sites 13 and 40). This reach had six mine surface-water outfalls that discharge directly into the Peace River. Phosphate-mine outfall releases were held constant by mining companies during the seepage run. Total daily discharge data from the six outfalls were provided to the USGS from the phosphate-mining companies. The upper three outfalls included: Sixmile Creek (001), outfall (004), and Barber Branch (002) (figs. 35 and 36, sites 14, 17, and 23), and the lower three outfalls included: Camp Branch (002), Mobil Outfall 008, and Mobil outfall 001 (sites 30, 32, and 39). Discharges measured at the Clear Springs Mine bridge (site 13) and the Mobil Mine bridge (site 40) were 1,020 ft^3/s and 1,320 ft^3/s, respectively. A net seepage loss of 118 ft^3/s was calculated after subtracting the cumulative discharges from the six mine-outfalls (418 ft^3/s). Calculated seepage losses in this reach were probably the result of streamflow losses through sinkholes in the streambed and floodplain.

The fourth, and final reach was located between the Mobil Mine bridge and the Fort Meade gaging station (figs. 33 and 34, sites 40 and 54). This reach is approximately 2.4 mi long and has four small tributaries that drain reclaimed phosphate-mined land. In addition, many small ground-water seeps from the surficial aquifer were observed and measured during the base-flow seepage runs. However, these ground-water seeps could not be measured during the high-flow seepage run because they were submerged. A seepage loss of 2.4 ft^3/s was calculated by subtracting the total tributary inflow of 22.4 ft^3/s from the stream discharge difference between site 40 (1,320 ft^3/s) and site 54 (1,340 ft^3/s) of 20 ft^3/s. This low volume of calculated seepage is within the margin of discharge measurement error, and therefore may indicate that no significant seepage gains or losses occurred along this reach. The magnitude of most seepages calculated during the high-flow seepage run along the 13-mi reach between Bartow and Fort Meade may be within the range of discharge measurement error.

Thermal Infrared Imagery

Prior to the seismic-reflection survey and the three seepage runs, two thermal infrared imagery reconnaissance surveys were performed in January 1995 along the 105-mi length of the Peace River (fig. 1). The thermal infrared imagery surveys were conducted to locate areas where ground-water discharge (springs) may be occurring in the Peace River. These surveys used a remote sensing technique that can identify and differentiate water parcels of different temperatures. Spring flow is generally of constant temperature, whereas waters of rivers and streams fluctuate seasonally. Spechler (1996) successfully used this remote sensing technique to identify spring flow along the St. Johns River in northeast Florida. Ideal field conditions are needed to identify spring flow using the thermal infrared imagery technique. In the study area, optimum field conditions for utilizing thermal infrared imagery techniques occur during the winter months because (1) the potentiometric surfaces in the intermediate aquifer system and Upper Floridan aquifer are usually high, depending on rainfall, (2) the greatest contrast in relative temperature occurs between the colder river water and the warmer spring water that rises to the surface, and (3) a good potential for base-flow conditions to occur along the Peace River. The volume of warmer ground water discharging from the aquifer through a spring vent in the streambed has to be sufficiently large enough to displace the colder river water and rise to the surface. Additionally, the magnitude of the ground-water discharge is dependent upon the potentiometric head in the underlying aquifers and the degree of hydraulic connection between the spring and underlying aquifers. These thermal infrared surveys, conducted aerially at altitudes of approximately 500 to 1,000 ft above the Peace River, were used to detect plumes of warmer ground water discharging into the colder river water.

Because effects from the high-streamflow conditions that prevailed during the first thermal infrared imagery reconnaissance survey on January 18, 1995, may have obscured the location of springs, a second survey was performed on January 27, 1995. Although performed under more ideal field conditions, the second survey also failed to identify ground-water sources discharging into the Peace River. The inability to identify ground-water discharge sources in the Peace River using this technique could be because: (1) major springs are absent along the Peace River, (2) spring flow and ground-water seepage is below the resolution of the thermal-infrared imaging capability, or (3) infrared imaging cannot be used to detect small hydrologic features from aerial elevations.

ANALYSIS OF GROUND-WATER AND SURFACE-WATER INTERACTION

The following discussion focuses on the specific hydrogeology of the Peace River and the possibility of interactions between the Peace River, its adjacent floodplain, and the ground-water system. Ground-water recharge along the upper Peace River appears to be primarily a function of the hydrologic conditions, as well as the existence of sinkholes and enlarged solution features within the Peace River channel and floodplain. In the upper Peace River, recharging conditions are predominant and water moves from the Peace River and the surficial aquifer into the intermediate aquifer system and into the Upper Floridan aquifer in response to downward head gradients. However, under extreme conditions, when the head gradients in the intermediate aquifer system are higher than the river stage, a potential for some ground-water flow to the river may occur. Downward moving recharge waters may accelerate the rate and extent of carbonate dissolution within the intermediate aquifer system and the Upper Floridan aquifer. The maximum streamflow losses to sinkholes measured directly during the high base-flow seepage run along the upper Peace River were 17.6 ft^3/s (11.4 Mgal/d), which occurred when heads in the intermediate aquifer system were below the elevation of the riverbed. During periods of low heads in the intermediate aquifer system and during high-flow conditions when the floodplain is inundated, the net losses may be much greater. However, during periods of high-flow conditions and when heads in the intermediate aquifer system are above the riverbed, streamflow losses may be significantly reduced.

Along the middle Peace River, the physiography changes from an internally drained basin to a poorly drained upland. Ground-water movement in the intermediate aquifer system in the Peace River basin is towards the river and along a southwesterly flow path. Ground-water movement within the Upper Floridan aquifer is to the southwest. The intermediate aquifer system thickens and becomes more confined towards the southwest. Although surface-water drainage systems become more established in response to improved confinement between the surficial aquifer and the intermediate aquifer system, seasonal fluctuations in ground-water heads may affect the recharge and discharge potential between these hydrologic units. Ground-water head reversals were observed along the middle Peace River where recharge and discharge conditions alternate seasonally (fig. 19).

Along the middle Peace River, ground-water heads in the Upper Floridan aquifer were greater than heads in the intermediate aquifer system during both May and September 1995. During the wet season, the area of upward head gradients extends further north. The presence of confining units within the intermediate aquifer system effectively creates confining conditions between the intermediate aquifer system and the Upper Floridan aquifer. Depressions in ground-water heads in the intermediate aquifer system (fig. 8) along the middle Peace River could be attributed to ground-water withdrawals from wells tapping the intermediate aquifer system. Water levels in wells tapping the intermediate aquifer system probably are depressed more by ground-water withdrawals than water levels in wells tapping the Upper Floridan aquifer. Hydrogeologic sections of these areas constructed from historical data collected at both high- and low-water conditions and for maximum and minimum ground-water levels may help further describe the relation between ground water and Peace River flow conditions. Structural features, flexures, and stratigraphic breaches identified in the seismic-reflection data correspond to areas where Duerr and Enos (1991) measured maximum ground-water seepages to the Peace River during low-flow conditions. These seepages suggest that upward moving ground water contributes to the Peace River flow. Most calculated seepages in this zone during the May 1995 low base-flow seepage run were smaller than the standard range of measurement error and could not accurately be quantified. In the southern part of the middle Peace River, the Upper Floridan aquifer heads are above the heads of the intermediate aquifer system resulting in an upward head gradient between the two aquifers.

In the southern part of the lower Peace River, the intermediate aquifer system increases in thickness as well as lithologic complexity. The potential for increased ground-water discharge to the Peace River prevails as a result of upward head gradients from the underlying aquifers to the Peace River. The maximum stage of the Peace River for the period of record at Arcadia was at least 10 ft below the minimum ground-water head measured in 1995. Ground-water discharge, in the form of springs, was not observed during this study but ground-water seepages may occur at specific local areas where breaches or fractures exist. In the seismic records, the lithologic units appear to be generally continuous suggesting that confining units are intact. Movement of rainfall-recharged ground water from the surficial aquifer into the Peace River occurs along the river banks where the surficial aquifer is exposed. Because the confinement between the surficial aquifer and the intermediate aquifer system is well established and the head gradient in the surficial aquifer is toward the Peace River, water from the surficial aquifer discharges from the banks of the Peace River and into well-developed surface-water drainage systems that ultimately flow to the Peace River. Seepage gains were observed along this region of the Peace River and are attributable to seepage from the surficial aquifer along exposed river banks and from upward movement of ground water from the intermediate aquifer system into the surficial aquifer and ultimately into the Peace River.
This upward seepage is predominantly by diffuse intergranular flow through confining units rather than by movement along breaches and enlarged dissolution features such as spring vents. The lack of observed spring flow and the presence of laterally continuous confining units identified in the seismic-reflection data further supports seepage by diffuse intergranular flow.

SUMMARY AND CONCLUSIONS

The Peace River drains a 2,350-mi^2 area of west-central Florida where regional ground-water withdrawals have stressed the capacity of the aquifers to supply the municipal, agricultural, and industrial needs of this rapidly developing area. Alternative surface-water sources, such as the Peace River, are being used to augment ground-water use.
The hydraulic connection between the Peace River and the underlying aquifers was assessed to evaluate flow exchanges between the systems. Along the upper Peace River, a progressive decline in discharge has occurred since the 1940's. This decline has resulted from a lowering of the potentiometric surface of the Upper Floridan aquifer by as much as 60 ft, from intensive ground-water withdrawals for phosphate-mining and agriculture. One of the effects of lowered potentiometric surfaces has been a cessation of spring flow in the upper Peace River basin. The largest spring to stop flowing was Kissengen Spring, which once flowed at an average rate of about 29 ft^3/s (19 Mgal/d). Spring flows to the Peace River were significant at one time and their cessation reflects a reversal in ground-water gradients; where ground-water seepages once augmented streamflow, the river now loses water to the underlying aquifers.

A continuous seismic-reflection survey was conducted along the length of the Peace River. This survey identified several karst structures and features, typical of those identified in other areas of Florida. The karst features vary in type and size and include sinkholes, dissolution pipes, and enlarged fractures. These features have the potential to provide direct preferential paths of hydraulic connection between the river and the underlying aquifer systems.

Low and high base-flow seepage runs were conducted along a 74-mi length of the Peace River between Bartow and Nocatee to identify gaining and losing reaches. Maximum losses along the upper 3.2 mi of the river channel were 17.3 ft^3/s (11.2 Mgal/d). These losses are attributed to the existence of numerous sinkholes, identified both on seismic-reflection surveys and field reconnaissances, and to a prevailing downward head gradient between the river and the underlying aquifers. Seepage losses along the riverbed and floodplain were calculated from the results of a high-flow seepage run along a 7.2-mi reach of the Peace River below Clear Springs. These losses were approximately 10 percent, or 118 ft^3/s (76.3 Mgal/d), of the total river flow during this measurement period. Ground-water seepages further south, in areas of potential upward head gradient, increased river discharge. Continuous seismic reflectors pinching out within the streambed along the Peace River near Zolfo Springs coincided with an area where several springs discharge to the river. These springs were small and their flow was not significant compared to the total river discharge. The Peace River along Hardee and De Soto Counties gains water from ground-water seepage contributions, but flow measurements were generally within the range of discharge measurement error (5 to 8 percent) and the contributions could not be determined with certainty.

Two continuous aerial thermal infrared imagery surveys were conducted to locate areas of ground-water discharge along the Peace River. Although both temperature and hydrologic conditions were ideal to observe spring flow using thermal infrared imaging techniques, no sources of ground-water discharge were identified. This could be because: (1) major springs are absent along the Peace River, (2) spring flow and ground-water seepage is below the resolution of the thermal-infrared imaging capability, or (3) infrared imaging cannot be used to detect small hydrologic features from aerial elevations.

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APPENDIX

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
1	02294650	Peace River at Bartow	Lat 27º54’07’’, long 81º49’03’’, Polk County, Hydrologic Unit 03100101, on State Highway 60 bridge, 0.6 mi east of Bartow, and 104 mi upstream from mouth.	05-16-95 08-29-95 05-28-96	251 --- 259	8.3 972 18.0
2	2753380814842	Peace River above Wabash Street Drainage Ditch at Bartow	Lat 27º53’38”, long 81º48’42”, Polk County, Hydrologic Unit 03100101, 300 ft above Wabash Street Drainage Ditch, 0.8 mi below State Highway 60 bridge, 2.0 mi southeast of post office in Bartow, and 103.3 mi upstream from mouth.	05-16-95 05-28-96	245 266	8.4 18.6
3	2753360814840	Wabash Street Drainage Ditch to the Peace River at Bartow WTP at Bartow	Lat 27º53’36”, long 81º48’40”, Polk County, Hydrologic Unit 03100101, on right bank, on north side of Wabash Street, 0.9 mi below State Highway 60 bridge, 2.1 mi southeast of post office in Bartow, and 103.2 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-28-96	--- --- ---	.00 .00 .00
4	2753380814838	Peace River below Wabash Street Drainage Ditch at Bartow	Lat 27º53’38”, long 81º48’38”, Polk County, Hydrologic Unit 03100101, 100 ft below Wabash Street Drainage Ditch, 0.8 mi below State Highway 60 bridge, 2.0 mi southeast of post office in Bartow, and 103.15 mi upstream from mouth.	05-28-96	266	17.9
5	2753340814838	Unnamed Sinkhole Diversion channel from the Peace River near Wabash Street Drainage Ditch at Bartow	Lat 27º53’34”, long 81º48’38", Polk County, Hydrologic Unit 03100101, on left bank, 200 ft downstream from Wabash Street Drainage Ditch, 2.2 mi southeast of post office in Bartow, and 103.1 mi upstream from mouth of Peace River.	05-16-95 05-28-96	--- 266	-1.15 -1.20
6	2753070814838	Peace River above Mine Dragline Crossing near Bartow	Lat 27º53’07”, long 81º48’38", Polk County, Hydrologic Unit 03100101, 200 ft above dragline crossing, 1.3 mi below State Highway 60 bridge, 2.2 mi southeast of Bartow, and 102.6 mi upstream from mouth.	05-16-95 05-28-96	266 266	6.10 17.1
7	2752580814818	Unnamed Tributary to the Peace River above abandoned mine bridge in Section 10 near Bartow	Lat 27º52’58”, long 81º48’18", Polk County, Hydrologic Unit 03100101, on left bank, 50 ft above abandoned mine bridge, 2.6 mi southeast of post office in Bartow, and 102.3 mi upstream from mouth of Peace River.	05-16-95 05-28-96	--- ---	.03 .00
8	2752570814815	Peace River above abandoned mine bridge in Section 10 near Bartow	Lat 27º52’57”, long 81º48’15", Polk County, Hydrologic Unit 03100101, 200 ft above abandoned mine bridge, 2.7 mi east of post office in Bartow, and 102.2 mi upstream from mouth.	05-16-95 08-29-95 05-28-96	296 --- 264	2.35 1,020 12.8
9	2752300814805	Peace River above Unnamed Sinkhole in Channel near Clear Springs Mine bridge near Bartow	Lat 27º52’30”, long 81º48’05", Polk County, Hydrologic Unit 03100101, 250 ft above sinkhole, 0.75 mi above Clear Springs Mine bridge southeast of Bartow, and 101.7 mi upstream from mouth.	05-16-95 05-28-96	288 ---	2.24 12.8
10	2752270814807	Peace River Below Unnamed Sinkhole in Channel near Clear Springs Mine bridge near Bartow	Lat 27º52’27’’, long 81º48’07”, Polk County, Hydrologic Unit 03100101, 100 ft below sinkhole, 0.75 mi above Clear Springs Mine bridge, 1.2 mi east of Bartow city boundary, and 101.4 mi upstream from mouth.	05-16-95 05-28-96	--- 253	.00 10.1

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Dis-charge (ft^3/s)
11	2752150814812	Peace River above Dragline Crossing above Clear Springs Mine bridge near Bartow	Lat 27º52'15", long 81º48'12", Polk County, Hydrologic Unit 03100101, 0.5 mi above drag line crossing, 0.75 mi southeast of Bartow city boundary, and 101.3 mi upstream from mouth.	05-28-96	---	.66
12	2751540814827	Peace River at Dragline Crossing above Clear Springs Mine bridge near Bartow	Lat 27º51'54", long 81º48'27", Polk County, Hydrologic Unit 03100101, 300 ft above Clear Springs Mine bridge, 1.0 mi southeast of Bartow city boundary, and 100.8 mi upstream from mouth.	05-16-95 05-28-96	--- ---	.00 .68
13	2751510814827	Peace River at Clear Spring Mine bridge near Bartow	Lat 27º51'51'', long 81º48'27'', Polk County, Hydrologic Unit 03100101, at Clear Springs Mine bridge, 1.0 mi southeast of Bartow city boundary, and 100.6 mi upstream from mouth.	08-29-95	---	1,020
14	2751470814837	Sixmile Creek near Bartow (IMC-Agrico Outfall 001)	Lat 27º51'47'', long 81º48'37'', Polk County, Hydrologic Unit 03100101, on right bank, 100 ft below Clear Springs Mine bridge, 200 feet above mouth, 1.0 mi southeast of Bartow, and 100.5 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-28-96	745 --- ---	.02 **17.2 .23
15	2751450814823	Peace River below Sixmile Creek near Bartow	Lat 27º51'45'', long 81º48'23'', Polk County, Hydrologic Unit 03100101, 250 ft below Sixmile Creek, 1.2 mi southeast of Bartow city boundary, and 100.4 mi upstream from mouth.	05-16-95 05-28-96	--- 273	.00 1.77
16	2750500814830	Peace River above Upper Canal near Bartow	Lat 27º50'50'', long 81º48'30'', Polk County, Hydrologic Unit 03100101, 500 ft above upper canal, 1.4 mi southeast of Bartow city boundary, and 99.1 mi upstream from mouth.	05-16-95 05-28-96	--- 247	.00 1.78
17	2750320814825	Unnamed Tributary to Peace River near Bartow (IMC Agrico Outfall 004)	Lat 27º50'32'', long 81º48'25'', Polk County, Hydrologic Unit 03100101, on left bank, 0.25 mi below canal, 2.6 mi southeast of Bartow city boundary, and 98.8 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-28-96	585 --- ---	.58 **6.9 2.82
18	2750330814826	Peace River above Unnamed Tributary to Peace River near Bartow	Lat 27º50'33'', long 81º48'26'', Polk County, Hydrologic Unit 03100101, 2.6 mi southeast of Bartow city boundary, and 98.7 mi upstream from mouth.	05-16-95 05-28-96	--- ---	.56
19	2750180814832	Unnamed Tributary to Peace River near Bartow	Lat 27º50'18'', long 81º48'32'', Polk County, Hydrologic Unit 03100101, on left bank, 0.4 mi below canal, 2.9 mi southeast of Bartow city boundary, and 98.6 mi upstream from mouth of Peace River.	05-16-95 05-28-96	--- ---	.00 1.03
20	2750320814827	Peace River above Mouth of Kissengen Spring Run near Bartow	Lat 27º50'32'', long 81º48'27'', Polk County, Hydrologic Unit 03100101, 0.2 mi above mouth of Kissengen Spring run, 2.6 mi southeast of Bartow city boundary, and 98.6 mi upstream from mouth.	05-16-95 05-28-96	585 ---	.67 ---

Appendix. Peace River and Tributary Discharge Measurements

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Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
21	2750210814829	Unnamed Tributary to Peace River above Barber Branch near Bartow	Lat 27º50'21'', long 81º48'29'', Polk County, Hydrologic Unit 03100101, on left bank, 500 ft upstream from mouth of Barber Branch, 2.8 mi southeast of Bartow city boundary, and 98.5 mi upstream from mouth of Peace River.	05-16-95 05-28-96	592 ---	.03 ---
22	2750200814830	Peace River above Barber Branch near Bartow	Lat 27º50'20'', long 81º48'30'', Polk County, Hydrologic Unit 03100101, 0.25 mi upstream from mouth of Barber Branch, 2.6 mi southeast of Bartow city boundary, and 98.4 mi upstream from mouth.	05-16-95 05-28-96	--- 432	.62 8.25
23	2750180814837	Barber Branch near Homeland (IMC-Agrico Outfall 002)	Lat 27º50'18'', long 81º48'37'', Polk County, Hydrologic Unit 03100101, on right bank, 0.2 mi upstream from mouth, 1.2 mi above State Highway 640 bridge, 1.6 mi northeast of Homeland, and 98.4 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-28-96	723 --- 630	4.81 **134 2.79
24	2750130814835	Peace River below Mouth of Barber Branch near Homeland	Lat 27º50'13'', long 81º48'35'', Polk County, Hydrologic Unit 03100101, below mouth of Barber Branch, 1.6 mi northeast of Homeland, and 98.2 mi upstream from mouth.	05-16-95 05-28-96	--- 493	5.34 12.1
25	2749540814819	Peace River below Barber Branch near Homeland	Lat 27º49'54'', long 81º48'19'', Polk County, Hydrologic Unit 03100101, 0.5 mi below Barber Branch, 1.9 mi northeast of Homeland, and 97.8 mi upstream from mouth.	05-28-96	477	11.3
26	2749300814805	Peace River above Homeland	Lat 27º50'13'', long 81º48'35'', Polk County, Hydrologic Unit 03100101, below Barber Branch, 1.6 mi northeast of Homeland, and 97.2 mi upstream from mouth.	05-28-96	475	10.7
27	02294781	Peace River near Homeland	Lat 27º49'12'', long 81º 47'59'', Polk County, Hydrologic Unit 03100101, on State Highway 640 bridge, 1.6 mi east of U.S. Highway 17 in Homeland, and 97 mi upstream from mouth.	05-16-95 08-29-95 05-28-96	710 --- 455	4.70 1,540. 12.3
28	2748550814748	Peace River below State Highway 640 bridge near Homeland	Lat 27º48'55'', long 81º 47'48'', Polk County, Hydrologic Unit 03100101, 0.5 mi below State Highway 640 bridge, 1.8 mi southeast of Homeland, and 96.5 mi upstream from mouth.	05-16-95 05-28-96	716 458	9.14 12.7
29	2748450814738	Unnamed Tributary to Peace River near Homeland	Lat 27º48'45'', long 81º47'38'', Polk County, Hydrologic Unit 03100101, on right bank, 0.6 mi below State Highway 640 bridge, 1.9 mi southeast of Homeland, and 96.3 mi upstream from mouth of Peace River.	05-28-96	---	.02
30	2748390814737	Camp Branch near Homeland (Mobil Outfall 002)	Lat 27º48'39'', long 81º47'37'', Polk County, Hydrologic Unit 03100101, on right bank, 0.8 mi below State Highway 640 bridge, 2.0 mi southeast of Homeland, and 96.1 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-28-96	700 --- 572	.67 **5.9 0.48
31	2748220814728	Peace River at Old Mine Pipeline Crossing near Homeland	Lat 27º48'22'', long 81º 47'28'', Polk County, Hydrologic Unit 03100101, 1.4 mi below State Highway 640 bridge, 2.4 mi southeast of Homeland, and 95.3 mi upstream from mouth.	05-16-95 05-28-96	682 ---	10.0 13.4

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Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Dis-charge (ft^3/s)
32	2748060814728	Unnamed Tributary to Peace River near Pembroke (Mobil Outfall 008)	Lat 27º48’06’’, long 81º47’28’’ Polk County, Hydrologic Unit 03100101, on right bank, 1.2 mi northeast of Pembroke, and 95.7 mi up-stream from mouth of Peace River.	05-16-95 08-29-95 05-28-96	493 --- ---	.38 .66 .00
33	2748040814727	Unnamed Tributary to Peace River near Pembroke	Lat 27º48’04’’, long 81º47’27’’, Polk County, Hydrologic Unit 03100101, on left bank, 1.2 mi northeast of Pembroke, and 95.2 mi upstream from mouth of Peace River.	05-16-95 05-28-96	--- ---	e.02 ---
34	274802814728	Peace River near Homeland	Lat 27º48’02’’, long 81º47’28’’, Polk County, Hydrologic Unit 03100101, 1.75 mi below State Highway 640, 2.0 mi above Mobil Mine bridge, 2.5 mi southeast of Homeland, and 95.2 mi upstream from mouth.	05-16-95 05-28-96	674 506	9.70 16.8
35	2747350814710	Peace River near Pembroke	Lat 27º47’35’’, long 81º 47’10’’, Polk County, Hydrologic Unit 03100101, 1.0 mi east of Pem-broke, 1.3 mi north of Mobil Mine bridge, and 94.6 mi upstream from mouth.	05-16-95 05-28-96	--- 521	9.44 15.9
36	2747150814710	Unnamed Tributary to Peace River near Pembroke	Lat 27º47’15’’, long 81º47’10’’, Polk County, Hydrologic Unit 03100101, on right bank, 1.0 mi east of Pembroke, and 94.1 mi upstream from mouth of Peace River.	05-28-96	572	.02
37	2746510814715	Unnamed Tributary to Peace River near Pembroke	Lat 27º46’51’’, long 81º47’15’’, Polk County, Hydrologic Unit 03100101, on right bank, 1.0 mi southeast of Pembroke, and 93.8 mi upstream from mouth of Peace River.	05-16-95 05-28-96	--- 374	.32 .60
38	2746490814713	Unnamed Tributary to Peace River near Pembroke	Lat 27º46’49’’, long 81º47’13’’, Polk County, Hydrologic Unit 03100101, on left bank, 1.0 mi southeast of Pembroke, and 93.7 mi upstream from mouth of Peace River.	05-28-96	372	.14
39	2746390814706	Unnamed Tributary to the Peace River above Mobil Mine bridge (Mobil Outfall-001)	Lat 27º46’39’’, long 81º47’06’’, Polk County, Hydrologic Unit 03100101, on left bank, 0.75 ft above Mobil Mine bridge, 1.0 mi southeast of Pembroke, and 93.5 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-28-96	--- --- ---	**1.0 **253 <.01
40	2746370814706	Peace River at Mobil Mine bridge near Fort Meade	Lat 27º46’37’’, long 81º47’06’’, Polk County, Hydrologic Unit 03100101, 100 ft below Mobil Mine bridge,1.2 mi southeast of Pembroke, 1.7 mi northeast of Fort Meade city boundary, and 93.4 mi upstream from mouth.	05-17-95 05-18-95 08-29-95 05-28-96 05-29-96	632 --- --- 510 499	4.42 2.34 1,320 13.1 8.03
41	2746290814706	Unnamed Tributary to Peace River below Mobil Mine bridge near Fort Meade (Mobil West Catchment 004)	Lat 27º46’39’’, long 81º47’06’’, Polk County, Hydrologic Unit 03100101, on right bank, 500 ft south of Mobil Mine bridge, 1.6 mi northeast of Fort Meade city boundary, and 93.3 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-29-96	--- --- ---	.00 .00 .00
42	2746280814702	Unnamed Tributary to Peace River near Fort Meade	Lat 27º46’28’’, long 81º47’02’’, Polk County, Hydrologic Unit 03100101, on right bank, 1.4 mi northeast of Fort Meade city boundary, and 93.1 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-29-96	--- --- ---	.00 .23 .00

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Dis-charge (ft^3/s)
43	2746040814652	Peace River above power line near Fort Meade	Lat 27º46'04'', long 81º46'52'', Polk County, Hydrologic Unit 03100101, 1,000 ft above power line, 0.9 mi below Mobil Mine bridge, 1.2 mi northeast of Fort Meade city boundary, and 92.4 mi upstream from mouth of Peace River.	05-16-95 05-29-96	482 513	13.0 9.25
44	2745530814643	Unnamed Tributary to Peace River lower near Fort Meade	Lat 27º45'53'', long 81º46'43'', Polk County, Hydrologic Unit 03100101, on left bank, 600 ft below power line, 1.2 mi northeast of Fort Meade city boundary, and 92.2 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
45	2745520814645	Unnamed Tributary to Peace River near Fort Meade	Lat 27º45'52'', long 81º46'45'', Polk County, Hydrologic Unit 03100101, on right bank, 1.0 mi northeast of Fort Meade city boundary, and 92.1 mi upstream from mouth of Peace River.	05-16-95 05-29-96	189 196	.05 .18
46	2745490814643	Peace River above Rocky Branch near Fort Meade	Lat 27º45'49'', long 81º46'43'', Polk County, Hydrologic Unit 03100101, 0.7 mi above Rocky Branch, 1.1 mi northeast of Fort Meade city boundary, and 92.1 mi upstream from mouth.	05-16-95 05-29-96	478 ---	12.6 8.81
47	2745470814643	Unnamed Tributary to Peace River near Fort Meade	Lat 27º45'47'', long 81º46'43'', Polk County, Hydrologic Unit 03100101, on left bank, 0.1 mi northeast of Fort Meade city boundary, 0.2 mi below power line, 0.65 mi upstream from Rocky Branch, and 92.1 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-29-96	--- --- ---	.00 .40 .00
48	2745450814642	Unnamed Tributary to Peace River near Fort Meade	Lat 27º45'45'', long 81º46'42'', Polk County, Hydrologic Unit 03100101, on right bank, 200 ft north of Fort Meade city boundary, 0.4 mi downstream from power line, and 92.0 mi upstream from mouth of Peace River.	05-16-95 05-29-96	196 ---	<.01 .02
49	2745400814652	Unnamed Tributary to Peace River near Fort Meade	Lat 27º45'40'', long 81º46'52'', Polk County, Hydrologic Unit 03100101, on right bank, at east Fort Meade city boundary, 0.4 mi upstream from Rocky Branch, and 91.9 mi upstream from mouth of Peace River.	05-16-95 05-29-96	176 ---	e<.01 e.02
50	2745320814651	Unnamed Tributary to Peace River near Fort Meade	Lat 27º45'32'', long 81º46'51'', Polk County, Hydrologic Unit 03100101, on right bank, at east Fort Meade city boundary, 0.2 mi upstream from Rocky Branch, and 91.7 mi upstream from mouth of Peace River.	05-16-95 05-29-96	201 224	.17 .22
51	2745320814646	Unnamed Tributary to Peace River near Fort Meade	Lat 27º45'32'', long 81º46'46'', Polk County, Hydrologic Unit 03100101, on right bank, at Fort Meade city boundary, 0.1 mi upstream from Rock Branch, and 91.6 mi upstream from mouth of Peace River.	05-16-95 05-29-96	191 ---	.13 .00
52	2745230814644	Rocky Branch near Fort Meade	Lat 27º45'23'', long 81º46'44'', Polk County, Hydrologic Unit 03100101, on left bank, 0.7 mi above mouth, 0.75 mi east of Fort Meade, and 91.5 mi upstream from mouth of Peace River.	05-16-95 08-29-95 05-29-96	231 --- ---	1.24 8.87 .00

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
53	2745230814644	Sink Branch near Fort Meade	Lat 27º45'23'', long 81º46'44'', Polk County, Hydrologic Unit 03100101, on left bank, 0.5 mi upstream from U.S. Highway 98 bridge, 0.9 m east of Fort Meade city boundary, 91.4 mi upstream from mouth.	05-16-95 08-29-95 05-29-96	--- --- 241	.00 12.9 1.62
54	02294898	Peace River at Fort Meade	Lat 27º45'04'', long 81º 46'56'', Polk County, Hydrologic Unit 03100101, on U.S. Highway 98 bridge, 0.4 mi downstream from Sink Branch, 1.2 mi east of U.S. Highway 17 in Fort Meade, and 91.0 mi upstream from mouth.	05-16-95 08-29-95 05-29-96	438 --- ---	13.0 1,340 12.5
55	2745030814656	Unnamed Tributary to Peace River at Fort Meade	Lat 27º45'03'', long 81º46'56'', Polk County, Hydrologic Unit 03100101, on right bank, 100 ft below U. S. Highway 98 bridge at east Fort Meade city boundary, and 90.9 mi upstream from mouth of Peace River.	05-29-96	---	e0.02
56	2745020814656	Unnamed Tributary to Peace River above boat ramp near Fort Meade	Lat 27º45'02'', long 81º46'56'', Polk County, Hydrologic Unit 03100101, on right bank, 300 ft below U. S. Highway 98 bridge at east Fort Meade city boundary, and 90.9 mi upstream from mouth of Peace River.	05-29-96	---	0.01
57	2744490814649	Unnamed Tributary to Peace River at boat ramp near Fort Meade	Lat 27º44'49'', long 81º46'49'', Polk County, Hydrologic Unit 03100101, on left bank, at boat ramp, 0.2 mi below U. S. Highway 98 bridge at east Fort Meade city boundary, and 90.8 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	e0.2 .00
58	2744420814652	Unnamed Tributary to Peace River near Fort Meade	Lat 27º44'42'', long 81º46'52'', Polk County, Hydrologic Unit 03100101, on left bank, at Fort Meade city boundary, 0.3 mi downstream from U.S. Highway 98 bridge, and 90.8 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .24
59	2744440814652	Unnamed Tributary to Peace River near Fort Meade	Lat 27º44'44'', long 81º46'52'', Polk County, Hydrologic Unit 03100101, on right bank, at Fort Meade city boundary, 0.3 mi downstream from U.S. Highway 98 bridge, and 90.8mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
60	2744390814654	Unnamed Tributary to Peace River near Fort Meade	Lat 27º44'39'', long 81º46'54'', Polk County, Hydrologic Unit 03100101, on right bank, at Fort Meade city boundary, 0.7 mi downstream from U.S. Highway 98 bridge, and 90.4 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
61	2744290814700	Peace River below U.S. Highway 98 bridge near Fort Meade	Lat 27º44'29'', long 81º47'00'', Polk County, Hydrologic Unit 03100101, at east Fort Meade city boundary, 1.0 mi downstream from U.S. Highway 98 bridge, and 90.1 mi upstream from mouth.	05-16-95 05-29-96	403 464	13.4 12.8

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
62	2744160814657	Unnamed Tributary to Peace River below power line near Fort Meade	Lat 27º44’16’’, long 81º46’57", Polk County, Hydrologic Unit 03100101, on left bank, 0.2 mi below power line, 0.25 mi southeast of Fort Meade city boundary, 1.4 mi south of U.S. Highway 98 bridge, and 89.7 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
63	2744050814705	Unnamed Tributary to Peace River near Fort Meade	Lat 27º44’05’’, long 81º47’05’’, Polk County, Hydrologic Unit 03100101, on right bank, 0.4 mi below power line, 0.4 mi south of Fort Meade city boundary, and 89.6 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
64	2744040814700	Unnamed Tributary to Peace River near Fort Meade	Lat 27º44’04’’, long 81º47’00’’, Polk County, Hydrologic Unit 03100101, on left bank, 0.5 mi below power line, 0.5 mi south of Fort Meade city boundary, and 89.5 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
65	2744010814708	Peace River above State Highway 657 bridge near Fort Meade	Lat 27º44’01’’, long 81º47’08’’, Polk County, Hydrologic Unit 03100101, 0.6 mi south of Fort Meade city boundary, 1.3 mi above State Highway 657 bridge, and 89.1 mi upstream from mouth.	05-16-95 05-29-96	390 469	14.2 13.0
66	2743290814728	Unnamed Tributary to Peace River above State Highway 657 bridge near Fort Meade	Lat 27º43’29’’, long 81º47’28’’, Polk County, Hydrologic Unit 03100101, on right bank, 0.3 mi above State Highway 657 bridge, 1.0 mi south of Fort Meade city boundary, and 88.5 mi upstream from mouth of Peace River.	05-16-95 05-29-96	229 238	e0.2 .24
67	2743240814724	Peace River on State Highway 657 bridge near Fort Meade	Lat 27º43’24’’, long 81º47’24’’, Polk County, Hydrologic Unit 03100101, on State Highway 657 bridge, 1.3 mi south of Fort Meade city boundary, and 88.3 mi upstream from mouth.	05-16-95 05-29-96	373 453	12.3 12.9
68	2743160814725	Bowlegs Creek near Fort Meade	Lat 27º43’16’’, long 81º47’25’’, Polk County, Hydrologic Unit 03100101, 100 ft above mouth, 500 ft downstream from State Highway 657 bridge, 1.4 mi south of Fort Meade city boundary, and 88.2 mi upstream from mouth of Peace River.	05-16-95 05-29-96	225 193	1.94 4.92
69	2742560814746	Peace River below Bowlegs Creek near Fort Meade	Lat 27º42’56’’, long 81º47’46’’, Polk County, Hydrologic Unit 03100101, 1.0 mi above Whidden Creek, 1.8 mi south of Fort Meade city boundary, and 87.4 mi upstream from mouth.	05-16-95 05-29-96	346 364	14.9 20.5
70	2742280814803	Whidden Creek near Fort Meade	Lat 27º42’28’’, long 81º48’03’’, Polk County, Hydrologic Unit 03100101, on right bank, 1,300 ft southwest of power line, 2.4 mi south of Fort Meade city boundary, and 86.3 mi upstream from mouth of Peace River.	05-16-95 05-29-96	593 503	17.4 32.7
71	2742190814756	Unnamed Tributary to Peace River below Whidden Creek near Fort Meade	Lat 27º42’19’’, long 81º47’56’’, Polk County, Hydrologic Unit 03100101, on left bank, 0.2 mi south of Whidden Creek, 2.6 mi south of Fort Meade, and 86.1 mi upstream from mouth of Peace River.	05-16-95 05-29-96	237 ---	e<0.01 e<0.01

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
72	2742160814757	Peace River below Whidden Creek near Fort Meade	Lat 27º42'16'', long 81º47'57'', Polk County, Hydrologic Unit 03100101, below Whidden Creek, 1,600 ft southwest of power line, 2.4 mi downstream from State Highway 657 bridge, 2.6 mi south of Fort Meade, and 86.0 mi upstream from mouth.	05-16-95 05-29-96	474 441	33.7 51.3
73	2741300814806	Unnamed Tributary to Peace River near Bowling Green	Lat 27º41'30'', long 81º48'06'', Polk County, Hydrologic Unit 03100101, on right bank, 3.3 mi northeast of Bowling Green city boundary, 4.3 mi upstream of State Highway 664 bridge, and 85.0 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00l .00
74	2741240814807	Peace River above Cargill Park near Bowling Green	Lat 27º41'24'', long 81º48'07'', Polk County, Hydrologic Unit 03100101, 3.2 mi northeast of Bowling Green city boundary, 4.2 mi upstream from State Highway 664 bridge, and 84.9 mi upstream from mouth.	05-16-95 05-29-96	481 ---	33.9 ---
75	2741120814816	Peace River near Cargill Park near Bowling Green	Lat 27º41'12'', long 81º48'16'', Polk County, Hydrologic Unit 03100101, 750 ft above Cargill Park, 2.9 mi northeast of Bowling Green city boundary, 3.9 mi upstream from State Highway 664 bridge, and 84.5 mi upstream from mouth.	05-16-95 05-29-96	510 435	28.1 49.7
76	2740450814815	Unnamed Tributary to Peace River near Bowling Green	Lat 27º40'45'', long 81º48'15'', Polk County, Hydrologic Unit 03100101, on left bank, 2.6 mi northeast of Bowling Green city boundary, 3.3 mi upstream from State Highway 664 bridge, and 83.7 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- 242	.00 .27
77	2740310814823	Unnamed Tributary to Peace River at Cargill Park near Bowling Green	Lat 27º40'31'', long 81º48'23'', Polk County, Hydrologic Unit 03100101, on right bank, at Cargill Park, 2.2 mi northeast of Bowling Green city boundary, 3.0 mi upstream from State Highway 664 bridge, and 83.4 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
78	2740130814817	Phosphate Mine Outfall near Bowling Green	Lat 27º40'13'', long 81º48'17'', Polk County, Hydrologic Unit 03100101, on left bank, 2.2 mi upstream from State Highway 664 bridge, 2.2 mi northeast of Bowling Green city boundary, and 82.8 mi upstream from mouth of Peace River.	05-16-95 05-29-96	500 ---	.21 .00
79	2740000814813	Peace River above Mobil Mining railroad bridge near Bowling Green	Lat 27º40'00'', long 81º48'13'', Polk County, Hydrologic Unit 03100101, 0.9 mi above Mobil Mining railroad bridge, 1.8 mi northeast of Bowling Green city boundary, and 82.5 mi upstream from mouth.	05-16-95 05-29-96	515 426	28.3 51.3
80	2739450814810	Unnamed Tributary to Peace River near Bowling Green	Lat 27º39'45'', long 81º48'10'', Polk County, Hydrologic Unit 03100101, on left bank, 0.7 mi upstream of Gilshey Branch, 1.4 mi upstream from State Highway 664 bridge, 1.6 mi northeast of Bowling Green city boundary, and 82.2 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
81	2739380814813	Unnamed Tributary to Peace River above Mine Railroad bridge near Bowling Green (Cargill Phosphate-Mine Outfall)	Lat 27º39'38'', long 81º48'13'', Polk County, Hydrologic Unit 03100101, on right bank, 70 ft above mine railroad bridge, 1.4 mi northeast of Bowling Green city boundary, and 82 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- 421	.00 7.79
82	2739280814808	Peace River below Mobil Mining Railroad bridge near Bowling Green	Lat 27º39'28'', long 81º48'08'', Polk County, Hydrologic Unit 03100101, 0.25 mi below Mobil Mine railroad bridge, 1.8 mi northeast of Bowling Green city boundary, and 81.7 mi upstream from mouth.	05-16-95 05-29-96	--- 424	--- 61.5
83	2739230814808	Unnamed Tributary to Peace River at Mobil railroad bridge near Bowling Green	Lat 27º39'23'', long 81º48'08'', Polk County, Hydrologic Unit 03100101, on right bank, 500 ft below bridge, 1.0 mi north of State Highway 664, 1.3 mi northeast of Bowling Green city boundary, and 81.7 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
84	2739150814757	Mobil Outfall 001 below railroad bridge near Bowling Green	Lat 27º39'15'', long 81º47'57'', Polk County, Hydrologic Unit 03100101, on left bank, 15 ft above mouth, 0.1 mi above Gilshey Branch, 0.8 mi north of State Highway 664, 1.3 mi northeast of Bowling Green city boundary, and 81.5 mi upstream from mouth of Peace River.	05-16-95 05-29-96	410 ---	2.01 .00
85	2739130814756	Gilshey Branch near Bowling Green	Lat 27º39'13'', long 81º47'56'', Polk County, Hydrologic Unit 03100101, on left bank, 0.7 mi upstream from State Highway 664, 1.2 mi northeast of Bowling Green, and 81.4 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- 253	.00 e0.08
86	2739080814757	Outfall below Gilshey Branch near Bowling Green	Lat 27º39'08'', long 81º47'57'', Polk County, Hydrologic Unit 03100101, on left bank, 0.1 mi below Gilshey Branch, 0.6 mi upstream from State Highway 664, 1.2 mi northeast of Bowling Green city boundary, and 81.3 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
87	2739030814800	Phosphate Mine Outfall above State Highway 664 near Bowling Green	Lat 27º39'03'', long 81º48'00'', Polk County, Hydrologic Unit 03100101, on left bank, 0.6 mi upstream from State Highway 664, 1.2 mi northeast of Bowling Green city boundary, and 81.2 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- ---	.00 .00
88	2738510814808	Unnamed Tributary to Peace River above State Highway 664 bridge near Bowling Green	Lat 27º38'51'', long 81º48'08'', Polk County, Hydrologic Unit 03100101, on right bank, 500 ft north of State Highway 664, 1.0 mi northeast of Bowling Green, and 80.7 mi upstream from mouth of Peace River.	05-16-95 05-29-96	--- 355	.00 .10
89	02295194	Peace River at Bowling Green	Lat 27º38'45'', long 81º48'09'', Hardee County, Hydrologic Unit 03100101, on State Highway 664 bridge, 1.0 mi northeast of Bowling Green, and 80.6 mi upstream from mouth.	05-16-95 05-17-95 05-29-96	495 --- 427	33.5 33.7 62.4

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
90	2738280814807	Unnamed Tributary to Peace River near Bowling Green	Lat 27º38'28'', long 81º48'07'', Hardee County, Hydrologic Unit 03100101, on left bank, 80 ft above mouth, 0.4 mi downstream from State Highway 664 bridge, 1.3 mi east of Bowling Green, and 80.3 mi upstream from mouth of Peace River.	05-17-95 05-29-96	207 187	.05 .13
91	2737590814807	Peace River below Bowling Green	Lat 27º37'59'', long 81º48'07'', Hardee County, Hydrologic Unit 03100101, above split in channel, 1.0 mi east of Bowling Green city boundary, 1.3 mi below State Highway bridge 664, and 79.5 mi upstream from mouth.	05-17-95 05-29-96	499 416	33.7 60.9
92	2737570814806	Unnamed Tributary to Peace River near Bowling Green	Lat 27º37'57'', long 81º48'06'', Hardee County, Hydrologic Unit 03100101, 200 ft above split channel in Peace River, 1.0 mi east of Bowling Green city boundary, and 79.5 mi upstream from mouth of Peace River.	05-17-95 05-29-96	--- ---	3.68 .00
93	2737580814801	Unnamed Tributary to Peace River near Bowling Green	Lat 27º37'58'', long 81º48'01'', Hardee County, Hydrologic Unit 03100101, on left bank, 1.1 mi east of Bowling Green, and 79.4 mi upstream from mouth of Peace River.	05-17-95 05-29-96	--- ---	3.72 .00
94	02295203	Peace River at State Highway 664A bridge (upper) near Bowling Green	Lat 27º37'28'', long 81º48'10'', Hardee County, Hydrologic Unit 03100101, at State Highway 664A bridge (upper), 1.6 mi southeast of Bowling Green, and 78.8 miles upstream from mouth.	05-17-95 05-30-96	500 426	32.0 63.6
95	2737270814812	Unnamed Tributary to Peace River below State Highway 664A (upper) bridge near Bowling Green	Lat 27º37'08'', long 81º48'12'', Hardee County, Hydrologic Unit 03100101, 200 ft downstream from State Highway 664A (upper) bridge, 1.6 mi southeast of Bowling Green, and 78.8 mi upstream from mouth of Peace River.	05-18-95 05-30-96	--- 835	.17 .48
96	2737090814809	Payne Creek at State Park near Bowling Green	Lat 27º37'09'', long 81º48'09'', Hardee County, Hydrologic Unit 03100101, at boat ramp, 0.2 mi above mouth, 1.8 mi southeast of Bowling Green, and 78.4 mi upstream from mouth of Peace River.	05-17-95 05-30-96	420 481	62.4 37.2
97	2736450814747	Unnamed Tributary to Peace River near Bowling Green	Lat 27º36'45'', long 81º47'47'', Hardee County, Hydrologic Unit 03100101, on left bank, 0.6 mi downstream from Payne Creek, 2.4 mi southeast of Bowling Green, and 77.6 mi upstream from mouth of Peace River.	05-17-95 05-30-96	--- ---	.00 e<0.01
98	2736080814801	Hog Branch near Wauchula	Lat 27º36'08'', long 81º48'01'', Hardee County, Hydrologic Unit 03100101, at mouth, 2.0 mi upstream from State Highway 664A bridge (lower), 3.6 mi north of Wauchula city boundary, and 76.7 mi upstream from mouth of Peace River.	05-17-95 05-30-96	413 358	.54 7.43
99	2736040814759	Peace River below Hog Branch near Wauchula	Lat 27º36'04'', long 81º47'59'', Hardee County, Hydrologic Unit 03100101, 0.1 mi downstream from confluence with Hog Branch, 2.0 mi upstream from State Highway 664A (lower) bridge, 3.7 mi north of Wauchula, and 76.6 mi upstream from mouth.	05-17-95 05-30-96	449 435	99.1 127

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
100	2735410814804	Unnamed Tributary to Peace River near Wauchula	Lat 27º35'41'', long 81º48'04'', Hardee County, Hydrologic Unit 03100101, 1.4 mi upstream from State Road 664 (lower) bridge, 2.5 mi north of Wauchula, and 76.1 mi upstream from mouth of Peace River.	05-30-96	---	.44
101	2735340814808	Unnamed Tributary to Peace River above State Road 664 (lower) near Wauchula	Lat 27º35'34'', long 81º48'08'', Hardee County, Hydrologic Unit 03100101, on right bank, 1.3 mi upstream from State Road 664 (lower) bridge, 2.7 mi north of Wauchula, and 76.0 mi upstream from mouth of Peace River.	05-30-96	---	e0.25
102	2735280814810	Unnamed Tributary to Peace River near Wauchula	Lat 27º35'28'', long 81º48'10'', Hardee County, Hydrologic Unit 03100101, on right bank, 1.1 mi upstream from State Road 664 (lower) bridge, 2.5 mi north of Wauchula, and 75.8 mi upstream from mouth of Peace River.	05-30-96	---	e0.45
103	2735010814810	Unnamed Tributary to Peace River near Wauchula	Lat 27º35'01'', long 81º48'10'', Hardee County, Hydrologic Unit 03100101, on right bank, 0.6 mi upstream from State Road 664 (lower) bridge, 2.0 mi north of Wauchula, and 75.3 mi upstream from mouth of Peace River.	05-30-96	---	e0.50
104	2735400814805	Unnamed Tributary to Peace River near Wauchula	Lat 27º35'40'', Long 81º48'05'', Hardee County, Hydrologic Unit 03100101, at mouth, on right bank, 0.1 mi upstream from State Highway 664A (lower) bridge, 2.0 mi north of Wauchula, and 74.8 mi upstream from mouth of Peace River.	05-17-95 05-30-96	391 423	.27 2.12
105	2734430814817	Unnamed Tributary to Peace River at State Highway 664A bridge near Wauchula	Lat 27º34'43'', long 81º48'17'', Hardee County, Hydrologic Unit 03100101, at mouth, on right bank, 20 ft upstream from State Highway 664A bridge (lower), 1.9 mi north of Wauchula, and 74.7 mi upstream from mouth of Peace River.	05-17-95 05-30-96	336 ---	.54 2.77
106	02295440	Peace River at State Highway 664A bridge (lower) near Wauchula	Lat 27º34'32'', long 81º48'17'', Hardee County, Hydrologic Unit 03100101, at bridge on State Highway 664A (lower), 2.0 mi north of Wauchula, and 74.7 mi upstream from mouth.	05-17-95 05-30-96	450 433	109 97.4
107	2734270814810	Little Charlie Creek at mouth below State Highway 664 near Wauchula	Lat 27º34'27'', long 81º48'10'', Hardee County, Hydrologic Unit 03100101, at mouth, 0.1 mi downstream from State Highway 664A (lower) bridge, 1.9 mi north of Wauchula, and 74.6 mi upstream from mouth of Peace River.	05-17-95 05-30-96	361 298	2.3 14.2
108	2734200814811	Wauchula WTP outfall to Peace River near Wauchula	Lat 27º34'20'', long 81º48'11'', Hardee County, Hydrologic Unit 03100101, at mouth, on right bank, 0.2 mi downstream from State Highway 664A bridge (lower), 1.8 mi north of Wauchula, and 74.4 mi upstream from mouth of Peace River.	05-17-95 05-30-96	605 591	.32 .40
109	2734030814739	Peace River above State Highway 64A near Wauchula	Lat 27º34'03'', long 81º47'39'', Hardee County, Hydrologic Unit 03100101, 0.8 mi below State Highway 664A, 1.25 mi northeast of Wauchula, 1.5 mi above State Highway 64A, and 73.8 mi upstream from mouth.	05-17-95 05-30-96	446 412	98.0 128

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Dis-charge (ft^3/s)
110	2733200814724	Max Branch at mouth near Wauchula	Lat 27º33'20'', long 81º47'24'', Hardee County, Hydrologic Unit 03100101, at mouth, 0.5 mi up-stream from State Highway 64A bridge, 1.5 mi east of Wauchula, and 72.9 mi upstream from mouth of Peace River.	05-17-95 05-30-96	480 470	.02 .25
111	2733150814728	Unnamed Tributary to Peace River below Max Branch near Wauchula	Lat 27º33'15'', long 81º47'28'', Hardee County, Hydrologic Unit 03100101, at mouth, 0.3 mi up-stream from State Highway 64A bridge, 1.4 mi east of Wauchula, and 72.7 mi upstream from mouth of Peace River.	05-30-96	359	1.16
112	2733120814733	Unnamed Tributary to Peace River above State Road 64A near Wauchula	Lat 27º33'12'', long 81º47'33'', Hardee County, Hydrologic Unit 03100101, at mouth, 0.2 mi up-stream from State Highway 64A bridge, 1.3 mi east of Wauchula, and 72.6 mi upstream from mouth of Peace River.	05-30-96	326	2.05
113	02295607	Peace River at Wauchula	Lat 27º33'01'', long 81º47'38'', Hardee County, Hydrologic Unit 03100101, on State Highway 64A bridge, 1.1 mi east of Wauchula, and 72.4 mi upstream from mouth.	05-17-95 05-30-96	454 410	104 182
114	2732570814747	Unnamed Tributary to Peace River near Wauchula	Lat 27º32'57'', long 81º47'47'', Hardee County, Hydrologic Unit 03100101, on right bank, 50 ft below State Highway 64A bridge, 1.1 mi east of Wauchula, and 72.4 mi upstream from mouth of Peace River.	05-17-95 05-30-96	1053 540	1.85 5.07
115	2732030814738	Peace River at State Highway 652 bridge near Wauchula	Lat 27º32'03'', long 81º47'38'', Hardee County, Hydrologic Unit 03100101, on State Highway 652 bridge, 0.6 mi east of Wauchula city bound-ary, and 71.6 mi upstream from mouth.	05-17-95 05-30-96	454 419	99.3 144
116	2732020814742	Unnamed Tributary to Peace River near Wauchula	Lat 27º32'02'', long 81º47'42'', Hardee County, Hydrologic Unit 03100101, on right bank, 0.5 mi downstream from State Highway 652 bridge, 0.5 mi southeast of Wauchula city boundary, and 71.2 mi upstream from mouth of Peace River.	05-17-95 05-30-96	472 ---	.11 .46
117	2731590814741	Peace River below rock out-Crop near Wauchula	Lat 27º31'59'', long 81º47'41'', Hardee County, Hydrologic Unit 03100101, below rock outcrop, 0.5 mi downstream from State Highway 652 bridge, 0.5 mi southeast of Wauchula city bound-ary, and 71.2 mi upstream from mouth.	05-17-95 05-30-96	446 ---	103 ---
118	2731230814724	Peace River above Hickory Branch	Lat 27º31'23'', long 81º47'24'', Hardee County, Hydrologic Unit 03100101, 0.7 mi above Hickory Branch, 1.1 mi southeast of Wauchula city bound-ary, 1.4 mi below State Highway 652, and 70.3 mi upstream from mouth.	05-17-95 05-30-96	448 ---	102 117
119	2731070814732	Unnamed Tributary to Peace River near Wauchula	Lat 27º31'07'', long 81º47'32'', Hardee County, Hydrologic Unit 03100101, on left bank, 1.1 mi southeast of Wauchula city boundary, 1.4 mi downstream from State Highway 652 bridge, and 70.2 mi upstream from mouth of Peace River.	05-17-95 05-30-96	472 ---	.01 .01

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
120	2730510814728	Hickory Branch at mouth near Zolfo Springs	Lat 27º30’51’’, long 81º47’28’’, Hardee County, Hydrologic Unit 03100101, at mouth, 1.0 mi north of Zolfo Springs city boundary, 1.2 mi upstream from U.S. Highway 17 bridge, and 69.5 mi upstream from mouth of Peace River.	05-17-95 05-30-96	558 ---	.05 .00
121	2730500814728	Unnamed Tributary to Peace River near Zolfo Springs	Lat 27º30’50’’, long 81º47’28’’, Hardee County, Hydrologic Unit 03100101, at mouth, 0.9 mi north of Zolfo Springs city boundary, 1.1 mi upstream from U.S. Highway 17 bridge, and 69.5 mi upstream from mouth of Peace River.	05-30-96	---	.01
122	2730480814734	Peace River below Hickory Branch near Zolfo Springs	Lat 27º30’48’’, long 81º47’34’’, Hardee County, Hydrologic Unit 03100101, 150 ft below Hickory Branch, 1.0 mi north of Zolfo Springs city boundary, 1.1 mi upstream from U.S. Highway 17 bridge, and 69.5 mi upstream from mouth.	05-17-95 05-30-96	449 ---	98.8 132
123	2730320814752	Thompson Branch at mouth near Zolfo Springs	Lat 27º30’32’’, long 81º47’52’’, Hardee County, Hydrologic Unit 03100101, at mouth, 0.5 mi upstream from U.S. Highway 17 bridge, 0.6 mi downstream from Hickory Branch, 0.6 mi north of Zolfo Springs city boundary, and 69.0 mi upstream from mouth of Peace River.	05-17-95 05-30-96	439 ---	.88 5.09
124	2730220814743	Unnamed Tributary to Peace River above U.S. Highway 17 bridge near Zolfo Springs	Lat 27º30’22’’, long 81º47’43’’, Hardee County, Hydrologic Unit 03100101, on left bank, 0.1 mi northeast of Zolfo Springs city boundary, 0.4 mi upstream from U.S. Highway 17 bridge, and 68.8 mi upstream from mouth of Peace River.	05-17-95 05-30-96	--- ---	.01 .00
125	2730150814753	Unnamed Tributary to Peace River above U.S. Highway 17 bridge near Zolfo Springs	Lat 27º30’15’’, long 81º47’53’’, Hardee County, Hydrologic Unit 03100101, on left bank, at Zolfo Springs city boundary, 0.2 mi upstream from U. S. Highway 17 bridge, and 68.7 mi upstream from mouth of Peace River.	05-17-95 05-30-96	--- ---	.01 e<0.01
126	02295637	Peace River at Zolfo Springs	Lat 27º30’15’’, long 81º48’04’’, Hardee County, Hydrologic Unit 03100101, on downstream side of bridge on U.S. Highway 17, 0.8 mi north of Zolfo Springs, and 68.6 mi upstream from mouth.	05-17-95 05-30-96	452 402	102 151
127	2730110814821	Spring to Peace River at boat ramp in Pioneer Park at Zolfo Springs	Lat 27º30’11’’, long 81º48’21’’, Hardee County, Hydrologic Unit 03100101, on left bank, at boat ramp, 0.4 mi downstream from U.S. Highway 17 bridge at Zolfo Springs city boundary, and 68.1 mi upstream from mouth.	05-17-95 05-30-96	540 603	.15 .06
128	2730110814825	Unnamed Tributary to Peace River near Zolfo Springs	Lat 27º30’11’’, long 81º48’25’’, Hardee County, Hydrologic Unit 03100101, at Zolfo Springs city boundary, 0.2 mi above State Highway 64 bridge, 0.7 mi below U.S. Highway 17 bridge, and 67.9 mi upstream from mouth of Peace River.	05-17-95 05-30-96	--- 466	--- .05
129	2730090814837	Unnamed Tributary to Peace River near Zolfo Springs	Lat 27º30’09’’, long 81º48’37’’, Hardee County, Hydrologic Unit 03100101, at Zolfo Springs city boundary, 0.2 mi above State Highway 64 bridge, 0.7 mi below U.S. Highway 17 bridge, and 67.8 mi upstream from mouth of Peace River.	05-17-95 05-30-96	--- 464	.05 .72

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
130	2730040814839	Peace River at State Highway 64 bridge at Zolfo Springs	Lat 27º30'04'', long 81º48'39'', Hardee County, Hydrologic Unit 03100101, at Zolfo Springs city boundary, 1,000 ft upstream from State Highway 64 bridge, and 67.7 mi upstream from mouth.	05-17-95 05-30-96	--- 400	107 152
131	2729230814840	Peace River in southeast quarter of Section 28 west of Zolfo Springs	Lat 27º29'23'', long 81º48'40'', Hardee County, Hydrologic Unit 03100101, 0.15 mi west of Zolfo Springs city boundary, 0.8 mi below State Highway 64 bridge, and 66.7 mi upstream from mouth.	05-17-95 05-30-96	446 422	103 124
132	2729320814916	Peace River below State Highway 64 near Zolfo Springs	Lat 27º29'32'', long 81º49'16'', Hardee County, Hydrologic Unit 03100101, 0.6 mi west of Zolfo Springs city boundary, 1.7 mi below State Highway 64 bridge, and 65.8 mi upstream from mouth.	05-17-95 05-30-96	443 ---	106 ---
133	2729020814943	Peace River above Alligator Branch near Zolfo Springs	Lat 27º29'02'', long 81º49'43'', Hardee County, Hydrologic Unit 03100101, 1.2 mi above Alligator Branch, 1.3 mi west of Zolfo Springs city boundary, and 64.8 mi upstream from mouth.	05-17-95 05-30-96	445 410	104 128
134	2728290814954	Alligator Branch near Zolfo Springs	Lat 27º28'29'', long 81º49'54'', Hardee County, Hydrologic Unit 03100101, at mouth, 2.5 mi southwest of Zolfo Springs, 3.5 mi downstream from State Highway 64 bridge, and 63.9 mi upstream from mouth of Peace River.	05-17-95 05-30-96	--- ---	.00 .00
135	2728210814958	Peace River below Alligator Branch near Zolfo Springs	Lat 27º28'21'', long 81º49'58'', Hardee County, Hydrologic Unit 03100101, 0.3 mi below Alligator Branch, 1.6 mi southwest of Zolfo Springs, 4.7 mi downstream from State Highway 63.5 bridge, and 63.4 mi upstream from mouth.	05-17-95 05-30-96	446 ---	105 ---
136	2727560815059	Peace River above Mud Lake near Zolfo Springs	Lat 27º27'56'', long 81º50'59'', Hardee County, Hydrologic Unit 03100101, 1.2 mi below Alligator Branch, 2.3 mi southwest of Zolfo Springs city boundary, and 62.8 mi upstream from mouth.	05-17-95 05-30-96	446 429	105 124
137	2728110815028	Peace River below Mud Lake near Zolfo Springs	Lat 27º28'11'', long 81º50'28'', Hardee County, Hydrologic Unit 03100101, 1.0 mi below Mud Lake, 0.5 mi above confluence of Peace River and Troublesome Creek, 3.75 mi southwest of Zolfo Springs, 60.7 mi upstream from mouth.	05-17-95 05-30-96	--- 447	--- 112
138	2726480815101	Troublesome Creek at mouth near Zolfo Springs	Lat 27º26'48'', long 81º51'01'', Hardee County, Hydrologic Unit 03100101, on right bank, 0.6 mi above Hickory Creek, 3.8 mi southwest of Zolfo Springs city boundary, 8.1 mi downstream from State Highway 64 bridge, and 59.9 mi upstream from mouth of Peace River.	05-17-95 05-30-96	420 ---	3.4 12.4
139	2726440815100	Peace River below Troublesome Creek near Zolfo Springs	Lat 27º26'44'', long 81º51'00'', Hardee County, Hydrologic Unit 03100101, 300 ft below Troublesome Creek, 0.6 mi above Hickory Creek, 3.8 mi southwest of Zolfo Springs city boundary, 8.1 mi downstream from State Highway 64 bridge, and 59.9 mi upstream from mouth.	05-17-95 05-30-96	480 ---	114 116

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
140	2726240815110	Unnamed Tributary to Peace River below Troublesome Creek near Zolfo Springs	Lat 27º26’24’’, long 81º51’10’’, Hardee County, Hydrologic Unit 03100101, on right bank, 50 ft above mouth, 8.7 mi downstream from State Road 64 bridge, 4.1 mi southwest of Zolfo Springs city boundary, 59.4 mi upstream from mouth.	05-17-95 05-30-96	460 362	.36 3.07
141	2726200815102	Peace River below Hickory Creek near Buchanan	Lat 27º26’20’’, long 81º51’02’’, Hardee County, Hydrologic Unit 03100101, 0.4 mi downstream from Hickory Creek, 2.6 mi above Peace River Ranch bridge, 4.1 mi northwest of Buchanan, and 59.1 mi upstream from mouth.	05-17-95 05-30-96	480 ---	110 ---
142	2724570815052	Peace River at Peace River Ranch bridge near Buchanan	Lat 27º24’57’’, long 81º50’52’’, Hardee County, Hydrologic Unit 03100101, 200 ft below bridge, 0.9 mi west of Peace River Ranch headquarters, 3.6 mi west of Buchanan, and 56.2 mi upstream from mouth.	05-17-95 05-30-96 05-31-96	--- 427 400	103 133 201
143	2724160815057	Peace River above Oak Creek near Gardner	Lat 27º24’16’’, long 81º50’57’’, Hardee County, Hydrologic Unit 03100101, above Oak Creek, 1.3 mi below Peace River Ranch bridge, 4.6 mi northwest of Gardner, and 55.5 mi upstream from mouth.	05-18-95 05-31-96	445 ---	108 ---
144	2724150815058	Oak Creek at mouth near Gardner	Lat 27º24’15’’, long 81º50’58’’, Hardee County, Hydrologic Unit 03100101, on right bank, 1.2 mi downstream from Peace River Ranch bridge, 5.0 northwest of Gardner, 5.2 mi upstream from Gardner bridge, and 55.2 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- 458	e.01 9.36
145	2723060815038	Peace River above Limestone Creek near Buchanan	Lat 27º23’06’’, long 81º50’38’’, Hardee County, Hydrologic Unit 03100101, 1.1 mi upstream from Limestone Creek, 2.3 mi below Peace River Ranch bridge, 3.9 mi southwest of Buchanan, and 53.8 mi upstream from mouth.	05-18-95 05-31-96	445 403	103 219
146	2722450815037	Limestone Creek at mouth near Gardner	Lat 27º22’45’’, long 81º50’37’’, Hardee County, Hydrologic Unit 03100101, on right bank, 400 ft above mouth, 3.2 mi northwest of Gardner, and 53.0 mi upstream from mouth of Peace River.	05-18-95 05-31-96	352 475	.80 1.20
147	2722440815034	Peace River below Limestone Creek near Gardner	Lat 27º22’44’’, long 81º50’34’’, Hardee County, Hydrologic Unit 03100101, below Limestone Creek, 3.1 mi northwest of Gardner, and 52.8 mi upstream from mouth.	05-18-95 05-31-96	--- ---	111 ---
148	2721190814930	Peace River above Charlie Creek near Gardner	Lat 27º21’19’’, long 81º49’30’’, Hardee County, Hydrologic Unit 03100101, 0.6 mi above mouth of Charlie Creek, 0.8 mi above boat ramp, 1.6 mi west of Gardner, and 51.3 mi upstream from mouth.	05-18-95 05-31-96	446 404	115 215
149	2720580814934	Charlie Creek at mouth near Gardner	Lat 27º20’58’’, long 81º49’34’’, Hardee County, Hydrologic Unit 03100101, on left bank, 0.3 mi above Gardner boat ramp, 1.8 mi west of Gardner, and 50.2 mi upstream from mouth of Peace River.	05-18-95 05-31-96	289 ---	4.6 207

Appendix. Peace River and Tributary Discharge Measurements

[μS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (μS/cm)	Dis-charge (ft^3/s)
150	02296525	Peace River below Charlie Creek near Gardner	Lat 27º20'46'', long 81º49'37'', Hardee County, Hydrologic Unit 03100101, 15 ft below boat ramp, 0.6 mi above county line, 1.8 mi west of Gardner, and 49.8 mi upstream from mouth.	05-18-95 05-31-96	--- 343	137 369
151	2719560815013	Peace River below Gardner boat ramp near Brownville	Lat 27º19'56'', long 81º50'13'', De Soto County, Hydrologic Unit 03100101, 0.8 mi below county line, 1.4 mi below boat ramp, 2.7 mi northwest of Brownville, and 48.5 mi upstream from mouth.	05-18-95 05-31-96	425 ---	128 ---
152	2719030815020	Bear Branch near Brownville	Lat 27º19'03'', long 81º50'20'', De Soto County, Hydrologic Unit 03100101, on right bank, 1.6 mi above Brownville Road bridge, 1.6 mi northwest of Brownville, 2.1 mi below county line, and 47.4 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- ---	.00 e<0.10
153	2718210815027	Sand Gully at mouth near Brownville	Lat 27º18'21'', long 81º50'27'', De Soto County, Hydrologic Unit 03100101, on left bank, 100 ft above mouth, 200 ft above power line, 0.5 mi below Bear Branch, 1.2 mi northwest of Brownville, and 46.9 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- ---	.00 .00
154	2718450815020	Peace River below Bear Branch at power line near Brownville	Lat 27º18'45'', long 81º50'20'', De Soto County, Hydrologic Unit 03100101, below power line, 0.4 mi below Bear Branch, 1.1 mi above Brownville Road, 1.3 mi west of Brownville, and 46.8 mi upstream from mouth.	05-18-95 05-31-96	423 348	129 377
155	2718300815038	Unnamed Tributary to Peace River below power line near Brownville	Lat 27º18'30'', long 81º50'38'', De Soto County, Hydrologic Unit 03100101, on right bank, 0.15 mi below power line, 0.6 mi below Bear Branch, 0.9 mi above Brownville Road, 1.3 mi west of Brownville, and 46.6 mi upstream from mouth of Peace River.	05-18-95 05-31-96	525 ---	.45 e>1.0
156	2718210815027	Unnamed Tributary to Peace River near Brownville	Lat 27º18'21'', long 81º50'27'', De Soto County, Hydrologic Unit 03100101, on left bank, 100 ft above mouth, 0.6 mi above Brownville Road bridge, 1.2 mi northwest of Brownville, and 46.4 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- 204	.001 4.68
157	2718140815046	Unnamed Tributary to Peace River above Brownville Road bridge near Brownville	Lat 27º18'14'', long 81º50'46'', De Soto County, Hydrologic Unit 03100101, on right bank, 500 ft above bridge, 1.5 mi west of Brownville, and 46.0 mi upstream from mouth of Peace River.	05-18-95 05-31-96	102 ---	.02 .00
158	02295977	Peace River near Brownville	Lat 27º18'08'', long 81º50'47'', De Soto County, Hydrologic Unit 03100101, at Brownville Road bridge, 1.3 mi west of Brownville, and 45.9 mi upstream from mouth.	05-18-95 05-31-96	423 352	133 358
159	2717470815053	Mare Branch at mouth near Brownville	Lat 27º17'47'', long 81º50'53'', De Soto County, Hydrologic Unit 03100101, on left bank, 0.6 mi below from Brownville Road bridge, 1.6 mi west of Brownville, and 45.4 mi upstream from mouth of Peace River.	05-18-95 05-31-96	388 432	1.7 8.90

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
160	2717280815124	Unnamed Tributary to Peace River near Brownville	Lat 27º17'28'', long 81º51'24'', De Soto County, Hydrologic Unit 03100101, at mouth, on right bank, 0.1 mi above Hampton Branch, 1.1 mi below Brownville Road bridge, 1.9 mi southwest of Brownville, and 44.9 mi upstream from mouth of Peace River.	05-18-95 05-31-96	779 ---	.20 .49
161	2717250815126	Peace River above Hampton Branch near Brownville	Lat 27º17'25'', long 81º51'26'', De Soto County, Hydrologic Unit 03100101, 0.25 mi above Hampton Branch, 1.4 mi below Brownville Road bridge, 2.3 mi west of Brownville, and 44.8 mi upstream from mouth.	05-18-95 05-31-96	419 ---	131 395
162	2717230815130	Hampton Branch at mouth near Brownville	Lat 27º17'23'', long 81º51'30'', De Soto County, Hydrologic Unit 03100101, at mouth, on right bank, 1.2 mi below Brownville Road bridge, 2.0 mi southwest of Brownville, and 44.6 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- ---	.80 2.67
163	2716550815123	Unnamed Tributary to Peace River below Hampton Branch near Brownville	Lat 27º16'55'', long 81º51'23'', De Soto County, Hydrologic Unit 03100101, at mouth, on left bank, 0.6 mi below Hampton Branch, 1.8 mi below Brownville Road bridge, 2.2 mi southwest of Brownville, and 44.0 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- ---	.01 1.12
164	2716580815140	Unnamed Tributary to Peace River above Walker Branch near Brownville	Lat 27º16'58'', long 81º51'40'', De Soto County, Hydrologic Unit 03100101, at mouth, on right bank, 300 ft above Walker Branch, 2.4 mi southwest of Brownville, and 43.7 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- 1049	.00 .22
165	2716560815143	Walker Branch at mouth near Brownville	Lat 27º16'56'', long 81º51'43'', De Soto County, Hydrologic Unit 03100101, at mouth, on right bank, 2.2 mi below Brownville Road bridge, 2.5 mi southwest of Brownville, and 43.6 mi upstream from mouth of Peace River.	05-18-95 05-31-96	949 856	.39 2.82
166	2716460815134	Peace River below Walker Branch near Brownville	Lat 27º16'46'', long 81º51'34'', De Soto County, Hydrologic Unit 03100101, 0.2 mi below Walker Branch, 2.5 mi southwest of Brownville, and 43.2 mi upstream from mouth.	05-18-95 05-31-96	427 363	135 346
167	2716100815155	Peace River in Section 12 near Cubitis	Lat 27º16'10'', long 81º51'55'', De Soto County, Hydrologic Unit 03100101, 1.3 mi above McBride Branch, 1.5 mi below Walker Branch, 1.7 mi northwest of Cubitis, and 42.1 mi upstream from mouth.	05-18-95 05-31-96	426 ---	130 ---
168	2715280815212	Peace River above McBride Branch near Cubitis	Lat 27º15'28'', long 81º52'12'', De Soto County, Hydrologic Unit 03100101, above McBride Branch, 1.9 mi west of Cubitis, 2.5 mi above railroad bridge, and 41.1 mi upstream from mouth.	05-18-95 05-31-96	421 364	131 378

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Dis-charge (ft^3/s)
169	2715240815214	McBride Branch near Arcadia	Lat 27º15’24’’, long 81º52’14’’, De Soto County, Hydrologic Unit 03100101, at mouth, on left bank, 1.0 mi upstream from old mouth, 2.0 mi above railroad near center of section 13, 2.7 mi north of Arcadia, and 41.0 mi upstream from mouth of Peace River.	05-18-95 05-31-96	268 377	.21 1.34
170	2714540815250	Unnamed Tributary to Peace River near Arcadia	Lat 27º14’54’’, long 81º52’50’’, De Soto County, Hydrologic Unit 03100101, at mouth, on left bank, 1.2 mi above railroad, near former mouth of McBride Branch (may actually be part of McBride Branch), 2.4 mi northwest of Arcadia, and 39.9 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- 272	.00 1.73
171	2714540815252	Peace River below McBride Branch near Arcadia	Lat 27º14’54’’, long 81º52’52’’, De Soto County, Hydrologic Unit 03100101, 0.6 mi below mouth of McBride Branch, 1.2 mi north of Arcadia city boundary, 1.3 mi above railroad bridge, and 39.8 mi upstream from mouth.	05-18-95 05-31-96	420 ---	133 ---
172	2714140815312	Peace River above railroad bridge near Arcadia	Lat 27º14’14’’, long 81º53’12’’, De Soto County, Hydrologic Unit 03100101, 450 ft above railroad bridge, 0.6 mi northwest of Arcadia city boundary, and 38.8 mi upstream from mouth.	05-18-95 05-31-96	416 351	135 305
173	2714100815309	Unnamed Tributary to Peace River above railroad bridge near Arcadia	Lat 27º14’10’’, long 81º53’09’’, De Soto County, Hydrologic Unit 03100101, at mouth, on left bank, 200 ft above railroad bridge, 0.7 mi northwest of Arcadia city boundary, and 38.7 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- 304	.00 1.67
174	2714030815321	Unnamed Tributary to Peace River below railroad bridge near Arcadia	Lat 27º14’03’’, long 81º53’21’’, De Soto County, Hydrologic Unit 03100101, at mouth, on right bank, 0.2 mi below railroad bridge, 0.9 mi north west of Arcadia city boundary, and 38.0 mi upstream from mouth of Peace River.	05-18-95 05-31-96	483 510	1.0 4.35
175	2713420815256	Unnamed Tributary to Peace River near Arcadia	Lat 27º13’42’’, long 81º52’56’’, De Soto County, Hydrologic Unit 03100101, at mouth, on left bank, 0.4 mi west of Arcadia city boundary, 0.9 mi above State Highway 70 bridge, and 37.5 mi upstream from mouth of Peace River.	05-18-95 05-31-96	1217 550	.61 2.63
176	2713210815235	Unnamed Tributary to Peace River at Arcadia	Lat 27º13’21’’, long 81º52’35’’, De Soto County, Hydrologic Unit 03100101, at mouth, on left bank, 300 ft above State Highway 70 bridge, 1.0 mi west of Arcadia, and 36.5 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- ---	.00 .00
177	2713200815234	Unnamed Tributary to Peace River above State Highway 70 bridge near Arcadia	Lat 27º’13’20’’, long 81º52’34’’, De Soto County, Hydrologic Unit 03100101, at mouth, on left bank, 200 ft above State Highway 70 bridge, (between old and new bridges), 1.0 mi west of Arcadia, and 36.5 mi upstream from mouth of Peace River.	05-18-95 05-31-96	327 ---	.16 1.15

Appendix. Peace River and Tributary Discharge Measurements

[µS/cm, microsiemens per centimeter; ft^3/s, cubic feet per second; ---, no data; <, less than; >, more than; e, estimated; *, from rating; **, reported by phosphate company; WTP, waste treatment plant. Location for Peace River sites are shown in figures 33 and 34 and tributary sites in figures 35 and 36]

Site	Station No.	Site name and location	Site identification	Date	Specific conductance (µS/cm)	Discharge (ft^3/s)
178	02296750	Peace River at Arcadia	Lat 27º13’19’’, long 81º52’34’’, De Soto County, Hydrologic Unit 03100101, on left bank, 500 ft upstream from State Highway 70 bridge, 1.0 mi west of post office in Arcadia, and 36.5 mi upstream from mouth.	05-18-95 05-31-96	418 ---	144 *386
179	2712550815313	Unnamed Tributary to Peace River below State Highway 70 bridge near Arcadia	Lat 27º12’55’’, long 81º53’13’’, De Soto County, Hydrologic Unit 03100101, on right bank, 50 ft above mouth, 0.6 mi west of Arcadia city boundary, 0.8 mi downstream from State Highway 70 bridge, and 35.7 mi upstream from mouth of Peace River.	05-18-98 05-31-96	--- 316	.00 2.57
180	2712240815324	Unnamed Tributary to Peace River near Arcadia	Lat 27º12’24’’, long 81º53’24’’, De Soto County, Hydrologic Unit 03100101, at mouth, on right bank, 0.8 mi west of Arcadia city boundary, 1.5 mi below State Highway 70 bridge, and 34.9 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- 308	.00 2.17
181	2712000815302	Unnamed Tributary to Peace River near Arcadia	Lat 27º12’00’’, long 81º53’02’’, De Soto County, Hydrologic Unit 03100101, on left bank, 50 ft above mouth, 0.7 mi southwest of Arcadia city boundary, 2.4 mi below State Highway 70 bridge, and 34.1 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- 266	.00 2.42
182	2711310815251	Unnamed Tributary to Peace River near Arcadia	Lat 27º11’31’’, long 81º52’51’’, De Soto County, Hydrologic Unit 03100101, on left bank, 5 ft above mouth, 0.9 mi southwest of Arcadia city boundary, 3.0 mi below State Highway 70 bridge, and 33.6 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- ---	.00 ---
183	2711290815252	Peace River near Arcadia	Lat 27º11’29’’, long 81º52’52’’, De Soto County, Hydrologic Unit 03100101, 0.9 mi southwest of Arcadia city boundary, 3.2 mi below State Highway 70 bridge, and 33.4 mi upstream from mouth.	05-18-95 05-31-96	422 ---	169 ---
184	02297100	Joshua Creek at mouth at Nocatee	Lat 27º09’44’’, long 81º54’06’’, De Soto County, Hydrologic Unit 03100101, on left bank, 300 ft above mouth, 400 ft above State Highway 760 bridge, 1.0 mi west of Nocatee, and 30.2 mi upstream from mouth of Peace River.	05-18-95 05-31-96	--- ---	12 *76
185	02297105	Peace River at Nocatee	Lat 27º09’43", long 81º54’06’’, De Soto County, Hydrologic Unit 03100101, 500 ft below State Highway 760 bridge, 1.0 mi west of Nocatee, and 30.2 miles from mouth.	05-18-95 05-31-96	426 ---	>112 ---