Hydrogeologic and Hydraulic Characterization of the Surficial Aquifer System, and Origin of High Salinity Groundwater, Palm Beach County, Florida

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Prepared in cooperation with the

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Conversion Factors, Acronyms, Abbreviations, and Datums

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per day (ft/d)	7.48	gallon per day per feet squared (gal/d/ ft^2)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09294	meter squared per day (m^2/d)
foot squared per day (ft^2/d)	7.48	gallon per day per foot (gal/d/ft)
	Leakance	
foot per day per foot [(ft/d)/ft]	1	meter per day per meter
foot per day per foot [(ft/d)/ft]	7.48	gallon per day per cubic foot (gal/d/ft^3)

CERP	Comprehensive Everglades Restoration Plan
DBHYDRO	South Florida Water Management District database
GMWL	Global Meteoric Water Line
GR	Gamma-ray
GWSI	Groundwater Site Inventory
SFWMD	South Florida Water Management District
SPT	Standard penetration test
USGS	U.S. Geological Survey
WCA	Water-Conservation Area

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

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

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27) and North American Datum of 1983 (NAD 83).

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

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Chemical concentration units are in milligrams per liter (mg/L)

Isotropic rations are expressed using the delta (δ) notation, which are in units of per mill (parts per thousand)

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Abstract

Previous studies of the hydrogeology of the surficial aquifer system in Palm Beach County, Florida, have focused mostly on the eastern one-half to one-third of the county in the more densely populated coastal areas. These studies have not placed the hydrogeology in a framework in which stratigraphic units in this complex aquifer system are defined and correlated between wells. Interest in the surficial aquifer system has increased because of population growth, westward expansion of urbanized areas, and increased utilization of surface-water resources in the central and western areas of the county. In 2004, the U.S. Geological Survey, in cooperation with the South Florida Water Management District, initiated an investigation to delineate the hydrogeologic framework of the surficial aquifer system in Palm Beach County, based on a lithostratigraphic framework, and to evaluate hydraulic properties and characteristics of units and permeable zones within this framework.

A lithostratigraphic framework was delineated by correlating markers between all wells with data available based primarily on borehole natural gamma-ray geophysical log signatures and secondarily, lithologic characteristics. These correlation markers approximately correspond to important lithostratigraphic unit boundaries. Using the markers as guides to their boundaries, the surficial aquifer system was divided into three main permeable zones or subaquifers, which are designated, from shallowest to deepest, zones 1, 2, and 3. Zone 1 is above the Tamiami Formation in the Anastasia and Fort Thompson Formations. Zone 2 primarily is in the upper part or Pinecrest Sand Member of the Tamiami Formation, and zone 3 is in the Ochopee Limestone Member of the Tamiami Formation or its correlative equivalent. Differences in the lithologic character exist between these three zones, and these differences commonly include differences in the nature of the pore space.

Zone 1 attains its greatest thickness (50 feet or more) and highest transmissivity in coastal areas. Zone 2, the most transmissive and extensive zone, is thickest (80 feet or more) and most transmissive in the inland eastern areas near Florida's Turnpike. In this area, zone 1 is absent, and the semiconfining unit above zone 2 extends to the land surface with a thickness commonly ranging from 50 to 100 feet. The thickness of zone 2 decreases to zero in most wells near the coast. Zone 3 attains its greatest thickness (100 feet or more) in the southwestern and south-central areas; zone 3 is equivalent to the gray limestone aquifer.

The distribution of transmissivity was mapped by zone; however, zones 2 and 3 were commonly combined in aquifer tests. Maximum transmissivities for zone 1, zones 2 and 3, and zone 3 were 90,000, 180,000, and 70,000 ft^2/d (feet-squared per day), respectively. The northern extent of the area with transmissivity greater than 50,000 ft^2/d for zones 2 and 3 in the inland northeastern area along Florida's Turnpike has not been defined based on available data and could extend 5 to 10 miles farther north than mapped. Based on the thickness of zone 2 and a limited number of aquifer tests, a large area of zone 2 with transmissivity greater than 10,000 ft^2/d, and possibly as much as 30,000 ft^2/d, extends to the west across Water Conservation Area 1 from the inland southeastern area into the south-central area and some of the southwestern area.

In contrast to the Biscayne aquifer present to the south of Palm Beach County, zones 2 and 3 are interpreted to be present principally in the Tamiami Formation and are commonly overlain by a thick semiconfining unit of moderate permeability. These zones have been referred to as the "Turnpike" aquifer in the inland eastern areas of Palm Beach County, and the extent of greatest thickness and transmissivity follows, or is adjacent to, Florida's Turnpike. Where it is thick and transmissive, zone 1 may be considered equivalent to the Biscayne aquifer.

Areas of high salinity groundwater in the surficial aquifer system in the central and western areas of the county have been identified and mapped in previous studies, and water samples were collected in this study to gain a better understanding of the origin of this water. Based primarily on strontium concentration and isotope data, as well as hydrogen and oxygen isotope data, evidence for upwelling and invasion of the surficial aquifer system with brackish or saline water from the Floridan aquifer system or deeper was not found. The seawater age indicated by strontium isotope ratios measured in water produced from wells sampled in the central and western areas correlates with the expected age of the sediments open in a well, which indicates that the residual invaded or relict seawater theory for the origin of this high salinity water is most probable.

Introduction

The surficial aquifer system is the major source of freshwater for public water supply in Palm Beach County, Florida, yet many previous studies of the hydrogeology of this aquifer system have focused only on the eastern one-half to one-third of the county in the more densely populated coastal area (Land and others, 1973; Swayze and others, 1980; Swayze and Miller, 1984; Shine and others, 1989). Population growth in the county has resulted in the westward expansion of urbanized areas into agricultural areas and has created new demands on the water resources of the county. Additionally, interest in surface-water resources of the central and western areas of the county has increased. In these areas, plans for additional surface-water storage reservoirs are being made under the Comprehensive Everglades Restoration Plan (CERP), originally proposed by the U.S. Army Corps of Engineers and the South Florida Water Management District (1999). Stormwater-treatment areas already have been constructed by the South Florida Water Management District (SFWMD). Surface-water and groundwater interactions in the Everglades are thought to be important to water budgets, water quality, and ecology (Harvey and others, 2002).

Most of the previous hydrogeologic and groundwater flow simulation studies of the surficial aquifer system in Palm Beach County have not utilized a hydrostratigraphic framework, in which stratigraphic or sequence stratigraphic units, such as those proposed in Cunningham and others (2001), are delineated in this stratigraphically complex aquifer system. A thick zone of secondary permeability, mapped by Swayze and Miller (1984), was not subdivided and was identified only as being within the Anastasia Formation of Pleistocene age. Miller (1987) published 11 geologic sections of the surficial aquifer system but did not delineate any named stratigraphic units in these sections. This limited interpretation has resulted, in part, from the complex facies changes within rocks and sediments of the surficial aquifer system, and in some places, the indistinct and repetitious nature of the most common lithologies, which include sand, shell, sandstone, and limestone.

Model construction and layer definition in a simulation of groundwater flow within the surficial aquifer system of Palm Beach County utilized only the boundaries of one or two major hydrogeologic zones, such as the “Biscayne aquifer” and the “production zone”; otherwise, layers were defined by average altitudes rather than geologic structure or stratigraphy (Shine and others, 1989). Additionally, the major permeable zones in the model were assumed to have constant hydraulic conductivity with no allowance for the possibility of thin, preferential flow zones within the model layer.

The key to understanding the spatial distribution and hydraulic connectivity of permeable zones in the surficial aquifer system beneath Palm Beach County is the development of a stratigraphic framework based on a consistent method of countywide correlation. Variability in hydraulic properties in the system needs to be linked to the stratigraphic units delineated in this framework, and proper delineation of the hydrogeologic framework should provide a better understanding and simulation of the groundwater flow system. For the purpose of gaining this understanding and in order to better manage this groundwater resource, the U.S. Geological Survey (USGS), in cooperation with the SFWMD, initiated an investigation in 2004 to develop a hydrogeologic framework for the surficial aquifer system in Palm Beach County.

Purpose and Scope

The purpose of this report is to delineate the hydrogeologic framework of the surficial aquifer system in Palm Beach County, based on a lithostratigraphic framework developed in the initial report for this study (Reese and Wacker, 2007), and to evaluate hydraulic properties and characteristics of units and permeable zones within this framework. Specifically, this report: (1) divides the surficial aquifer system into three main permeable zones and delineates the configuration, thickness, and extent of these zones and the semiconfining units that separate them; (2) estimates and delineates the hydraulic properties of these zones (transmissivity, hydraulic conductivity, and characteristics of confinement); and (3) discusses water-quality data collected that relate to the origin of high salinity in the aquifer system in the central and southwestern parts of the county. Two hydrogeologic sections were constructed to show the relation of hydrostratigraphic units to the lithostratigraphic framework.

Five test wells were drilled for this study, and in three of these, continuous cores were collected; four of these test wells were constructed as monitoring wells. Standard borehole geophysical logs were run in 13 wells, flowmeter logs were run in 6 wells, and aquifer tests were run in 9 wells. Data from 150 wells were synthesized and used for mapping the litho- and hydrostratigraphic frameworks. Including the tests run in this study and previously conducted tests, data from 63 aquifer tests conducted in other studies were compiled and used to map the distribution of transmissivity by zone.

Description of Study Area

The study area includes all of Palm Beach County and parts of Martin, Glades, Hendry, Collier, and Broward Counties (fig. 1) and is divided into four physiographic provinces, which from east to west are the Atlantic Coastal Ridge, the Sandy Flatlands, the Everglades, and the Big Cypress Swamp. The western boundary of the Atlantic Coastal Ridge province roughly parallels the coast and extends inland from 1 to 3 mi. The water-conservation areas (WCA) and stormwater-treatment areas are in the Everglades province (fig. 1). Most of the Everglades province north of the water-conservation areas encompasses the Everglades Agricultural Area.

For the purpose of this report, the study area was divided into eight areas (fig. 1). These areas are grouped into two western areas (the northwestern and southwestern areas), two central areas (the north-central and south-central areas), and four eastern areas (the inland and coastal northeastern areas and the inland and coastal southeastern areas). Most of the boundaries between the areas were chosen to follow main highways or roads. The boundaries of the inland eastern areas, however, were chosen, in part, because of hydrogeologic changes found along them.

Previous Investigations

Test-well drilling and hydrogeologic studies were conducted by the USGS and SFWMD in Palm Beach County during the 1970s and 1980s. Data collected and inventoried during this period include lithologic and geophysical logs from 110 test wells (Schneider, 1976; Swayze and others, 1980). In eastern Palm Beach County, Swayze and Miller (1984) mapped the extent of a zone of high secondary permeability in the surficial aquifer system that represents the northern extension of the Biscayne aquifer. Miller (1987) mapped the base of the surficial aquifer system for the entire county and compiled 11 lithologic sections. Causaras (1985) defined stratigraphic units in the surficial aquifer system in Broward County adjacent to and south of Palm Beach County (fig. 1). Fish (1988) divided the aquifer system in Broward County into the Biscayne aquifer and an underlying or adjacent new and informally named “gray limestone” aquifer. Shine and others (1989) completed a groundwater resource assessment of the surficial aquifer system in eastern Palm Beach County, including groundwater flow models and detailed mapping of the Biscayne aquifer and a related production zone. Harvey and others (2002) conducted a more recent hydrogeologic study of the surficial aquifer system in and adjacent to the water-conservation areas in southeastern Palm Beach County, including test well drilling, borehole geophysical logging, and hydraulic conductivity testing.

Mapping of the gray limestone aquifer was conducted by Reese and Cunningham (2000). This aquifer was found to extend from Broward, Collier, and Hendry Counties into southwestern Palm Beach County. Depositional sequences within and beneath the surficial aquifer system were mapped in southern Florida, including Palm Beach County, by Cunningham and others (2001). Some generalized sequence stratigraphic data in the upper part of the Biscayne aquifer of the surficial aquifer system of southeastern Florida are included in Cunningham and others (2004).

The Pleistocene deposits of southeastern Florida, including Palm Beach County, were subdivided into five units or stratigraphic cycles that, from oldest to youngest, are referred to as Q1, Q2, Q3, Q4, and Q5 (Perkins, 1977). These units are predominantly marine in origin but are separated by subaerial exposure surfaces. In another proposed nomenclature for the southern Florida stratigraphy, all the Pleistocene age formations are grouped and referred to as the “Okeechobee Formation” (Scott, 1992).

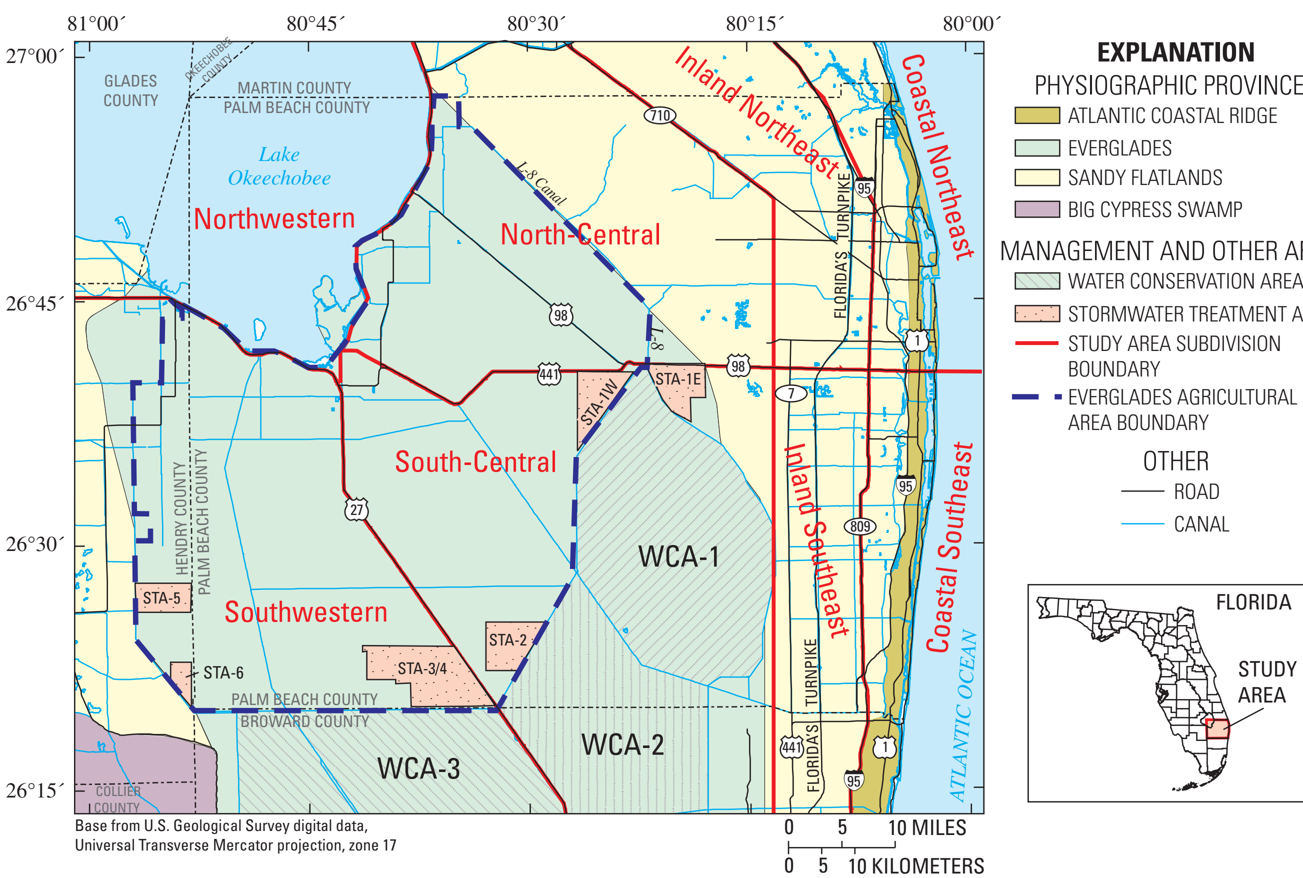


Figure 1. Study area and physiographic provinces and subdivisions of the study area.

Methods of Investigation

To meet the objectives of this study, work included test well drilling, coring, and construction; borehole geophysical logging; lithologic description; aquifer testing; water-quality sampling and analysis; and data analysis. Prior to well drilling, a lithostratigraphic framework was established based on data collected from 105 previously drilled wells (Reese and Wacker, 2007).

Well Drilling and Construction and Inventory of Wells

Test wells were drilled at five sites (table 1, fig. 2). Two wells (PB-1804 and PB-1805) were drilled in the south-central area, two (PB-1806 and PB-1807) were in the inland southeastern area, and one (PB-1808) was in the inland northeastern area.

Continuous coring was the preferred method of sample collection and was used in three of the test wells (table 1). Continuous core was collected using the wireline core drilling method. Other sample collection methods included the standard penetration test (SPT) method and collection of rock cuttings from mud-rotary drilling. The SPT method employs a split-barrel sampler that collects *in situ* formation samples in 2-ft intervals during drilling; however, the upper part of the sample collected in each barrel often contains material sloughed into the hole during the process of retrieving the barrel and drill string out of the hole for each 2-ft run.

Four of the five wells drilled in this study were constructed as monitoring wells. These wells were constructed with 4-in.-diameter polyvinyl chloride casing and screen (20-slot size), with the screened interval sandpacked with 6/20 sand within an 8-in.-diameter mud-drilled hole (except for PB-1806, which had a 10-in.-diameter hole). The sandpack extended several feet above the top of the screened interval and was sealed above with several feet of bentonite. Above the bentonite, the casing was filled with portland cement to the surface.

Identification, source study or owner, location, and total hole depth data for 161 wells used in this report, including the wells drilled during this study, are presented in table 1–1 (appendix 1). This information and other details such as construction data are stored in the USGS Groundwater Site Inventory (GWSI) database and can be accessed using the USGS local well name given in table 1–1. Of the 161 wells, 150 were used in defining the litho- and hydrostratigraphic frameworks, and their locations are shown in figure 2. The locations of additional wells used in this study from which hydraulic test and water-quality data were collected are not shown in figure 2, but are shown in a later figure in this report.

Table 1. Wells drilled and data collected for this study.

USGS local well no.	Other identifier	Drilled for this study	Continuous core collected	Borehole geophysical logs collected		Aquifer test
				Standard open hole[1]	Constructed well[2]	
PB-880				X		
PB-1545	APT site 9 production well			X		X
PB-1547	APT site 15 production well			X		
PB-1605	APT site 3 deep test well			X		
PB-1608	APT site 17 production well			X	X	
PB-1761	B-6 Core Test		X[3]	X	X	
PB-1769	PBC-2			X		X
PB-1792	CP02-EAARS-CB-0010					X
PB-1801	BP-DMW-W			X		X
PB-1803	HASR-SASMW-1			X		X
PB-1804	LEC 7, S-6 Pump Station	X		X	X	X
PB-1805	LEC 8, US 27, bend to north	X	X	X	X	X
PB-1806	LEC 9, US 441 and C-51 Canal	X	X	X	X	X
PB-1807	LEC 10 APT site 8, Turnpike and Lantana Rd	X	X	X	X	X
PB-1808	SR 710 and C-18 Canal	X				Not completed

[1]Includes gamma ray, caliper, induction resistivity, and spontaneous potential.

[2]Includes single-point resistance, borehole fluid resistivity and temperature, heat-pulse flowmeter, and electromagnetic or spinner flowmeter.

[3]Collected in a previous study

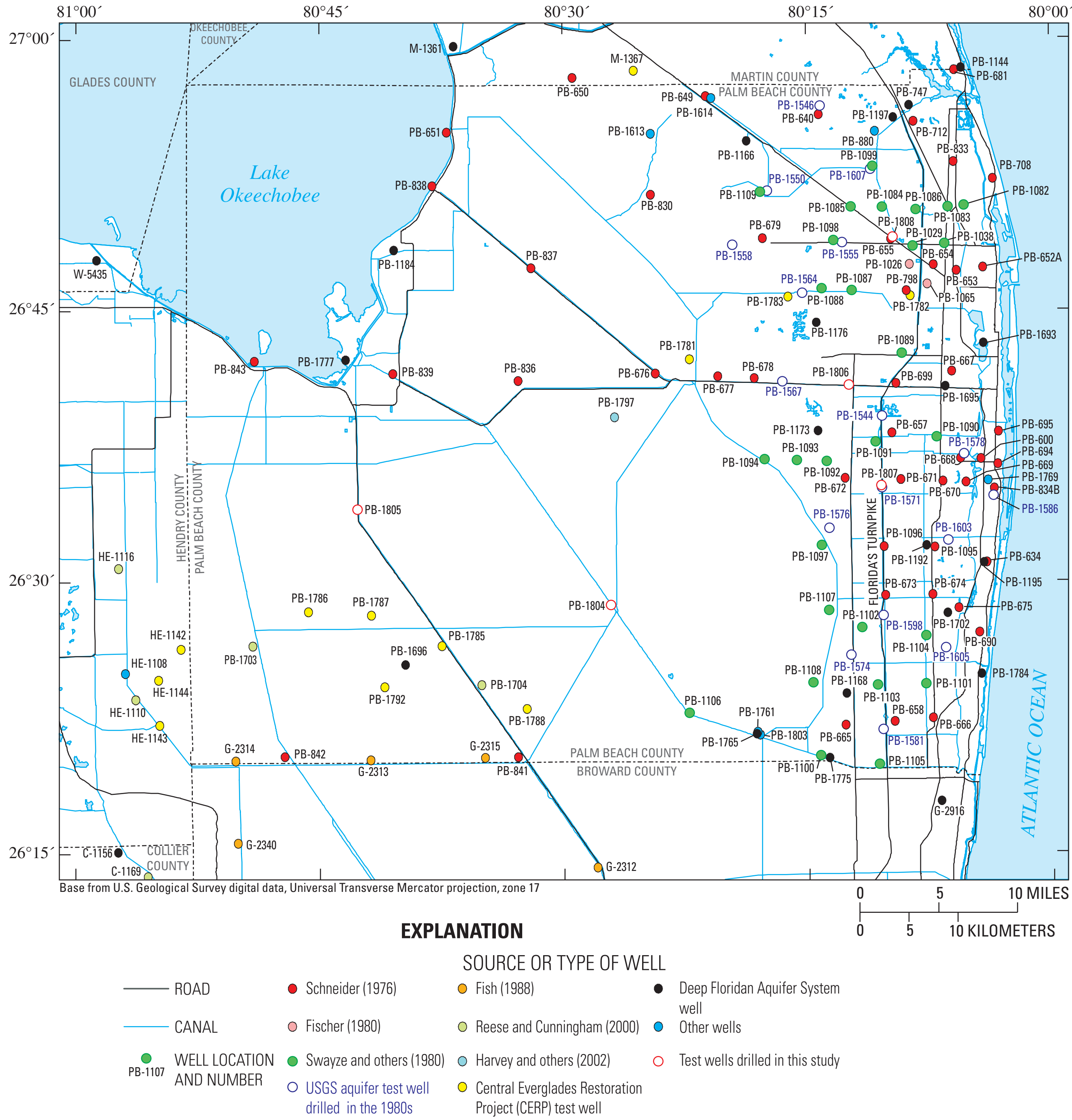


Figure 2. All wells used to define the litho- and hydrostratigraphic frameworks in the study, Palm Beach County, Florida.

Previously drilled USGS test wells with continuously collected core include HE-1110 and HE-1116 in Hendry County and PB-1703, PB-1704, and PB-1761 in southern Palm Beach County (fig. 2). Previously drilled CERP program wells used in this study include four wells in northern parts of the study area (U.S. Army Corps of Engineers, 2005) and 10 wells in the southwestern and south-central parts of the study area (Ardaman & Assoc., Inc., 2003) (fig. 1; table 1–1).

Borehole Geophysical Logging

Borehole geophysical measurements collected in this study were useful in determining the depth interval to screen in a well, defining litho- and hydrostratigraphic boundaries including flow zones, and determining relative changes in formation water salinity. For four of the test wells drilled during this study, standard open-hole borehole geophysical logs were run, including natural gamma ray (GR), caliper, induction resistivity, and spontaneous potential (table 1). Standard logs also were run in nine previously drilled wells, because borehole geophysical logs had not been collected when they were originally drilled (table 1).

Additional geophysical logs were run in constructed wells, including the four wells drilled in this study and two of the previously drilled wells, primarily to define and quantify flow zones present in the constructed screened interval (table 1). The additional logs included single-point resistance, fluid resistivity, fluid temperature, heat-pulse flowmeter, and electromagnetic or spinner flowmeter. Heat-pulse flowmeter data were collected in the stationary mode under ambient conditions to quantify ambient vertical flow between flow zones, if present. The electromagnetic flowmeter was run under ambient and stressed conditions (pumping the well at several different rates), both in the stationary and trolling mode. The fluid resistivity and fluid temperature logs, run on the same tool as the electromagnetic flowmeter, were also run under ambient and stressed conditions. The single-point resistance log was used to confirm the depths of the screened interval and screen pipe joints.

Geophysical logs for 115 wells used in this study are shown on montages in appendix 2. Included on these montages are both the standard and constructed well geophysical logs.

Description of Lithologic Samples

Core, SPT, and cuttings samples from test wells drilled in this study were described using a hand lens and binocular microscope. Included in the descriptions were the primary rock type, rock colors of dry samples by comparison to a rock-color chart with Munsell color chips (Geological Society of America, 1991), grain size of the predominant grains and the matrix, minor components such as phosphate grain content, qualitative porosity and permeability, and other characteristics such as sedimentary structures and the nature of bed or sequence boundaries.

Additionally, rock samples from some previously drilled test wells were obtained and described. These included continuous core samples from well PB-1761, and SPT and minor continuous core samples from four CERP test wells drilled by the U.S. Army Corps of Engineers in northern Palm Beach County (wells M-1367, PB-1781, PB-1782, and PB-1783; U.S. Army Corps of Engineers, 2005). Borehole geophysical logs were collected previously for these four CERP wells by the USGS as part of a different study. Lithologic descriptions done for this study for PB-1761 and four of the five wells drilled for this study (PB-1804 through PB-1807) are given in tables 1–2 through 1–6, and geologic units and flow zones are provided in table 1–7.

Aquifer Testing

Single-well constant rate aquifer tests were performed at nine sites, including the four wells drilled in this study (table 1). Well size dictated the maximum pumping rate that could be obtained, and diameters ranged from 2 to 6 in. Water-level changes were recorded during drawdown and recovery using a self-contained, data logging pressure transducer placed down a drop pipe in the well. The pumping rate was continuously measured and recorded using an in-line vortex flowmeter placed in a flow pipe on the discharge side of the pump. Both drawdown and recovery water-level data were analyzed to provide values for aquifer transmissivity. Tests of two of the wells were repeated using a larger pump to provide a higher pumping rate.

Water-Quality Data Collection

To better characterize the nature of brackish-to-saline groundwater in the surficial aquifer system in central and southwestern areas, water samples from 19 wells were collected and analyzed. Specific conductance and temperature were measured in the field. Laboratory analyses included concentrations of selected major ions, dissolved solids, strontium, boron, and isotopic ratios for strontium-87 to -86 ($^{87}Sr/^{86}Sr$), hydrogen-2 to -1 ($^{2}H/^{1}H$) and oxygen-18 to -16 ($^{18}O/^{16}O$). The boron-11 to -10 ratio ($^{11}B/^{10}B$) was also measured for samples from seven wells that produced high salinity groundwater.

Wells were purged with a suction-lift pump of at least three well volumes. Samples were then collected from 0.25-in.-diameter plastic tubing attached to a sampling port on the discharge hose of the pump. All samples, except for the $^{2}H/^{1}H$ and $^{18}O/^{16}O$ samples, were filtered using a 0.45-micron filter capsule.

Lithostratigraphic Framework Delineation

The method used in establishing the lithostratigraphic framework used for this study was described in a previous report (Reese and Wacker, 2007). Borehole natural GR geophysical logs and lithologic descriptions from 118 wells were used. Most of these wells penetrated at least to the base of the surficial aquifer system, which ranges in depth in the study area from about 140 to 360 ft below NGVD 29 (Miller, 1987).

Borehole natural GR geophysical log patterns were compared to lithostratigraphic boundaries determined using continuously drilled core collected from test coreholes, and log correlation markers were selected that approximately correspond to important lithostratigraphic unit boundaries. These GR markers were then correlated to all of the wells, primarily using GR log signatures and, secondarily, lithologic characteristics. Fourteen cross sections that extended east to west and north to south were constructed to assist in this effort.

Hydrostratigraphic Framework Delineation

The surficial aquifer system was divided into three main permeable zones or subaquifers, and the boundaries of these zones were determined using all available information collected on each well drilled in this study and in previous studies. The previously developed lithostratigraphic framework (Reese and Wacker, 2007) was used as a guide in determining these zone boundaries. Information used for each well in determining boundaries included lithologic descriptions, drilling characteristics, and borehole geophysical logs. Drilling characteristics include loss circulation zones during mud-rotary drilling and rate of penetration. Flowmeter and borehole fluid resistivity and temperature logs used in defining flow zones in constructed wells were the most conclusive geophysical logs used to determine permeable zone boundaries (a permeable zone contains one or more flow zones), but the other geophysical logs, such as induction resistivity and spontaneous potential, also provided indications of the depths of permeable zone boundaries. The presence of permeable zone boundaries was inconclusive in some wells because of poor or incomplete data. After reviewing data collected in previously drilled wells, permeable zone boundaries determined in the previous studies under which wells were drilled were usually accepted.

Hydrogeologic Framework

This section describes the hydrogeologic framework of the surficial aquifer system in Palm Beach County through the description and mapping of lithostratigraphic and hydrostratigraphic units. The surficial aquifer system is divided into three permeable zones or subaquifers.

Lithostratigraphic Framework

The lithostratigraphic framework used in this report for the surficial aquifer system was previously defined through the use of four natural GR borehole geophysical log correlation markers (Reese and Wacker, 2007). These markers approximately correspond to important lithostratigraphic unit boundaries (fig. 3). They are referred to, from deepest to shallowest, as the H, O, T, and F correlation markers. The markers approximate, respectively, the tops of the Hawthorn Group, Ochopee Limestone Member of the Tamiami Formation, the Pinecrest Sand Member of the Tamiami Formation, and Fort Thompson Formation. Initially, these four correlation markers were selected through comparison of GR geophysical logs to lithostratigraphic boundaries determined in cores from continuously drilled test coreholes in southeastern Hendry County and southern Palm Beach County. The markers were then correlated to all other key wells in the study area, as described previously. The continuity of these markers from west to east across the southern part of the study area (from the southwestern to the southeastern coastal area), and from south to north in the coastal areas, is shown by two hydrostratigraphic sections that include GR geophysical log curves and lithology for each well (Reese and Wacker, 2007, figs. 4, 5). A more complete description of lithologic characteristics that define lithostratigraphic units, particularly the two members of the Tamiami Formation, is given in Reese and Wacker (2007). Lateral changes within the lithostratigraphic units as defined by the correlation markers in the study area can lead to lithologies that may not always be characteristic of the formation or member as originally defined.

Eight wells in which standard borehole geophysical logs were run were added to the lithostratigraphic framework defined by Reese and Wacker (2007). Four of these wells were wells drilled in this study, and the other four were at sites at which multiwell aquifer tests were conducted by the USGS in the late 1980s (PB-1545 to PB-1608, table 1).

Also, in two areas some additional confirmation for the top of the Tamiami Formation (T marker) defined by Reese and Wacker (2007) was found based on paleontological identification of mollusks. The top of the Pliocene age Tamiami Formation is indicated to be at the depth of the T marker or shallower, based on fossil identification in the northern part of the south-central area, in Stormwater Treatment Area 1W (fig. 1; Harvey and others, 2000). A specific well used in the present study, from which fossils were recovered and identified from sieve samples in the Harvey and others (2000) study, is PB-1797 (fig. 2). The age of species identified in the Harvey and others (2000) study was provided by G.L. Wingard (U.S. Geological Survey, written commun., 2007).

Paleontological identification of mollusks was done as part of a USGS study in the late 1980s, using samples obtained from wells drilled by the dual tube reverse-air method. These wells were test wells drilled at 17 sites for the purpose of conducting multiwell aquifer tests. Using mollusk identification, the top of the Pliocene age Tamiami Formation was placed at a depth of 57 ft below land surface in well PB-1544 (fig. 2; site 9) in the northern part of the inland southeastern area (R. Kane, U.S. Geological Survey, written commun., 1988). The T marker was placed at a depth of 81 ft below land surface in the same well.

The depths of all four of the correlation markers are given in table 1–8, and the altitudes of the T, O, and H markers were mapped (figs. 1–1, 1–2, 1–3). The O and H markers are the most reliable indicators of true structure in the surficial aquifer system, because strata in the lower part of the surficial aquifer system are more continuous and because GR peak(s) or characteristic patterns tend to be more laterally persistent, providing better correlation (Reese and Wacker, 2007).

Hydrostratigraphic Units

Important hydrostratigraphic units in the study area include the zone of secondary permeability (Swayze and Miller, 1984), the Biscayne aquifer (Shine and others, 1989), and the gray limestone aquifer (Fish, 1988; Reese and Cunningham, 2000) (fig. 3). The top of the zone of secondary permeability approximately coincides with the T marker in the inland southeastern area. The H correlation marker is generally at or close to the base of the surficial aquifer system; however, intervals of sand of low to moderate hydraulic conductivity that are still considered to be in the surficial aquifer system can, in some places, be present below this marker.

In this study, the surficial aquifer system was divided into three main permeable zones, or subaquifers, usually separated by semiconfining units. These zones, which are from shallowest to deepest, zones 1, 2, and 3, contain one or more flow zones, whereas the intervening semiconfining units do not. The boundaries of the permeable zones were determined using the depths of the H, O, and T correlation markers as a guide (fig. 3). Zone 1 is above the T marker in Pleistocene age formations, such as the Anastasia and Fort Thompson Formations. Zone 2 generally is between the T and O markers in the Pinecrest Sand Member of the Tamiami Formation or an equivalent interval, and zone 3 generally is restricted by the O and H markers and is in the Ochopee Limestone Member of the Tamiami Formation or an equivalent interval. None of these three zones are present in all of the study area, and in some areas the semiconfining unit separating them is absent or poorly confining. Depths of the top and base of each of the three permeable zones were determined in all wells with adequate data (table 1–8; app. 2), and maps of the altitude and thickness of each were constructed.

The distribution of the three permeable zones and the relation of these zones to the correlation markers are shown by two hydrostratigraphic sections (figs. 4, 5). Section *A–A′* extends from south to north in the inland eastern areas, and section *B–B′* extends from west to east across the southern part of the study area.

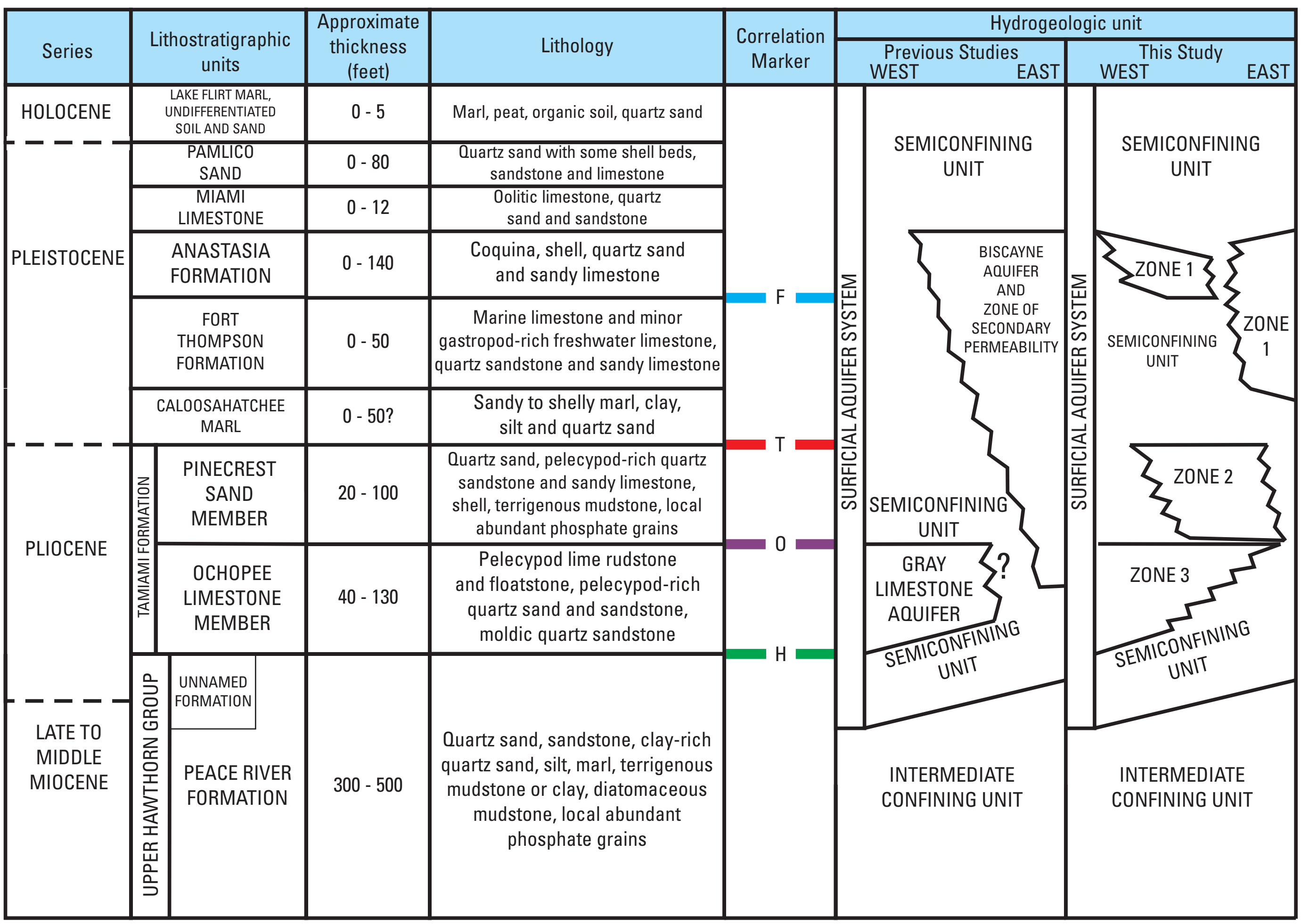


Figure 3. Lithostratigraphic units recognized in the study area, their generalized geology, and relation with hydrogeologic units. Modified from Reese and Cunningham (2000) and Cunningham and others (2001). Changes in hydrogeologic units are shown from west to east. References for hydrogeologic units from previous studies are “Biscayne aquifer” (Shine and others, 1989), “gray limestone aquifer” (Reese and Cunningham, 2000), and “zone of secondary permeability” (Swayze and Miller, 1984).

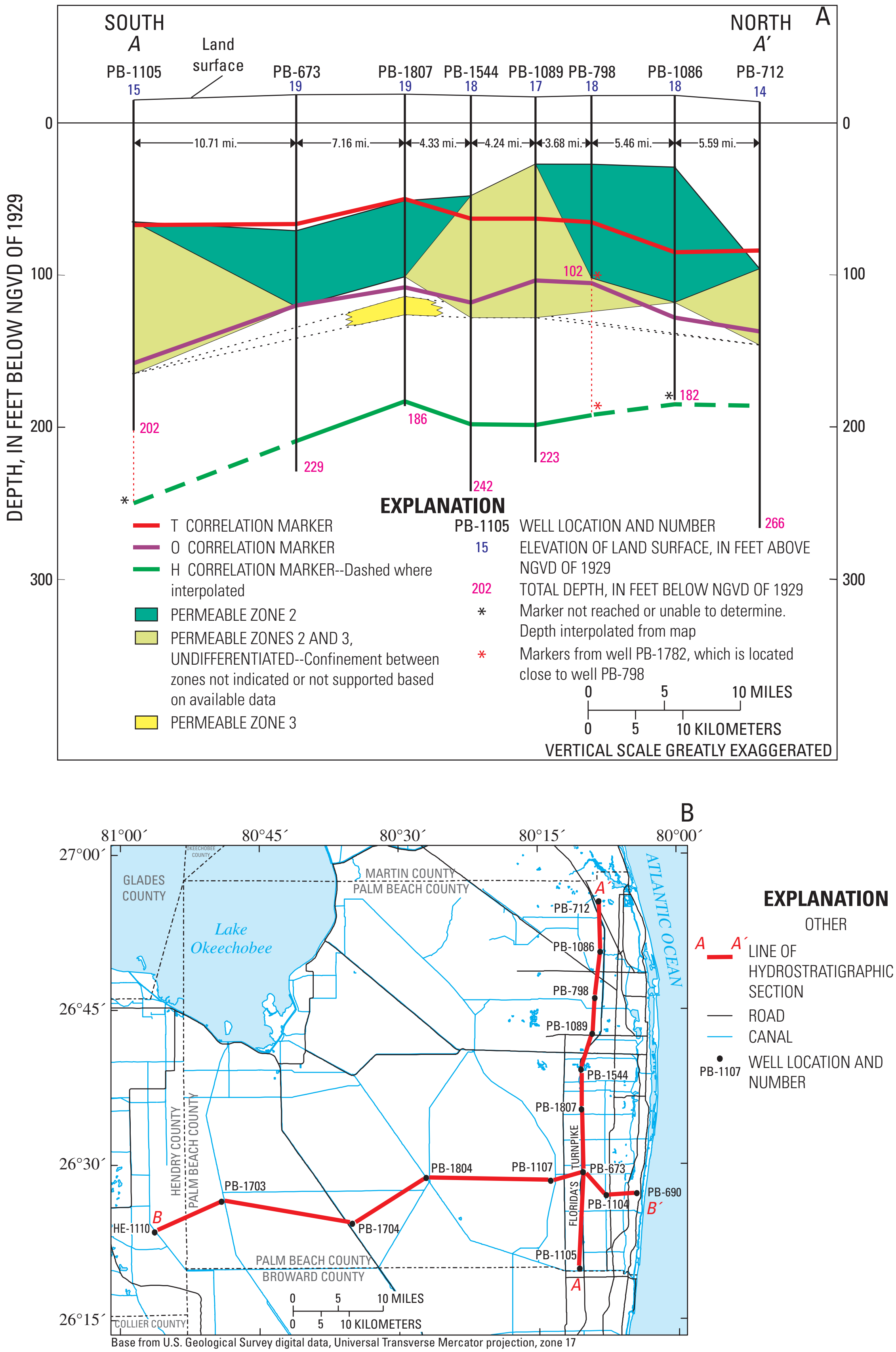


Figure 4. *A*, Hydrostratigraphic section *A-A′*. *B*, location of hydrostratigraphic section lines.

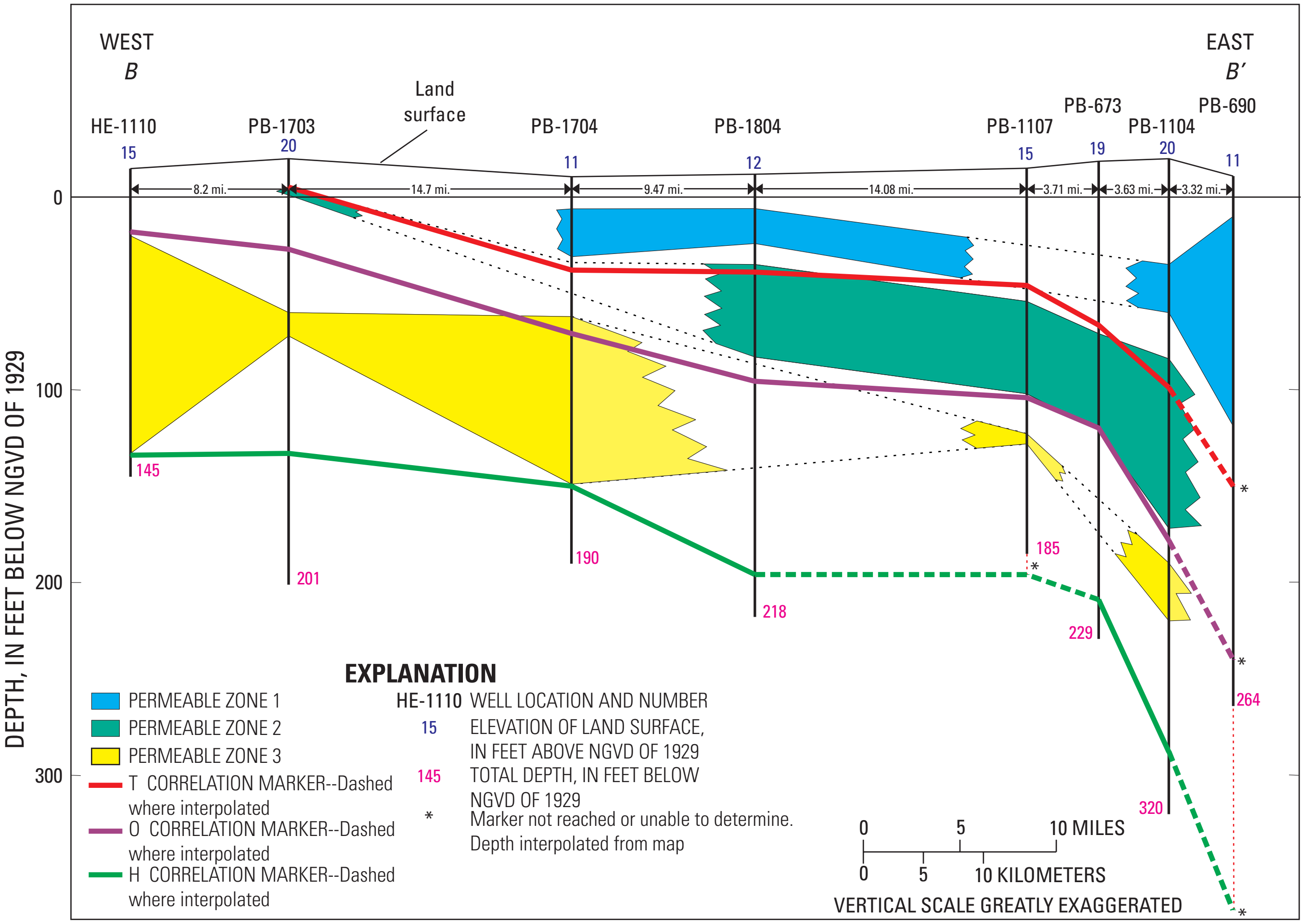


Figure 5. Hydrostratigraphic section *B-B′*.

The lithologic character, distribution, thickness, and confinement of the three permeable zones is discussed in the following sections. Characterization of each zone includes core photographs and maps showing zone boundary altitudes and the thicknesses of zones and confining units.

Zone 1

The lithology of zone 1 commonly includes cemented or loosely cemented whole shell or shell fragments (lime grainstone to rudstone) with high intergrain porosity and permeability. An example of this lithology is the interval from 17 to 30 ft below land surface in continuously cored well PB-1761 (fig. 6; app. 2). Vuggy limestone or calcareous sandstone can also be present. A permeable lithology often described in zone 1 in the coastal southeastern area, based on rotary cutting samples, is friable sandstone with cavities, shell fragments and calcite crystals; thin zones of lost circulation are sometimes reported during drilling in this lithology and in the permeable limestone.

Zone 1 is present in most of the study area, and commonly forms the water-table aquifer. In the coastal southeastern area, however, the altitude of the top of the zone decreases to as deep as 55 ft below NGVD 29, and the zone may be semiconfined due to thick deposits of overlying sand (fig. 7). The thickness of zone 1 is less than 20 ft in most of the study area, but thickness increases to 50 ft or greater in the coastal southeastern and northeastern areas and in one well in north-central Broward County (fig. 8). Zone 1 is interpreted to be absent in a large area along and west of Florida's Turnpike in the inland eastern areas (figs. 4, 8).

In a previous study (Land, 1977), a shallow permeable zone was defined as being separate from a deeper more permeable zone, and these zones roughly correspond to zone 1 and zones 2/3 (zones 2 and 3) defined in this study, respectively. The Land (1977) study encompassed inland and coastal northeastern areas, and wells common to that study and the present study are PB-652A, PB-653, and PB-654 (fig. 2). In wells PB-652A and PB-653, which are in the coastal northeastern area, the shallow zone is described as being overlain by a 20- to 40-ft thick unit composed of sand, some muck, and layers of shell, and separated from the deeper zone by a 50-ft thick unit of very fine sand and shell.

Figure 6. Core photographs of PB-1761 for the interval from 10 to 40 feet below land surface, including zone 1. Permeable zone 1 is present from 10 to 30 feet, and a major flow zone is present from 17 to 23 feet. Porosity and permeability are present between whole shells and shell fragments in this permeable zone.

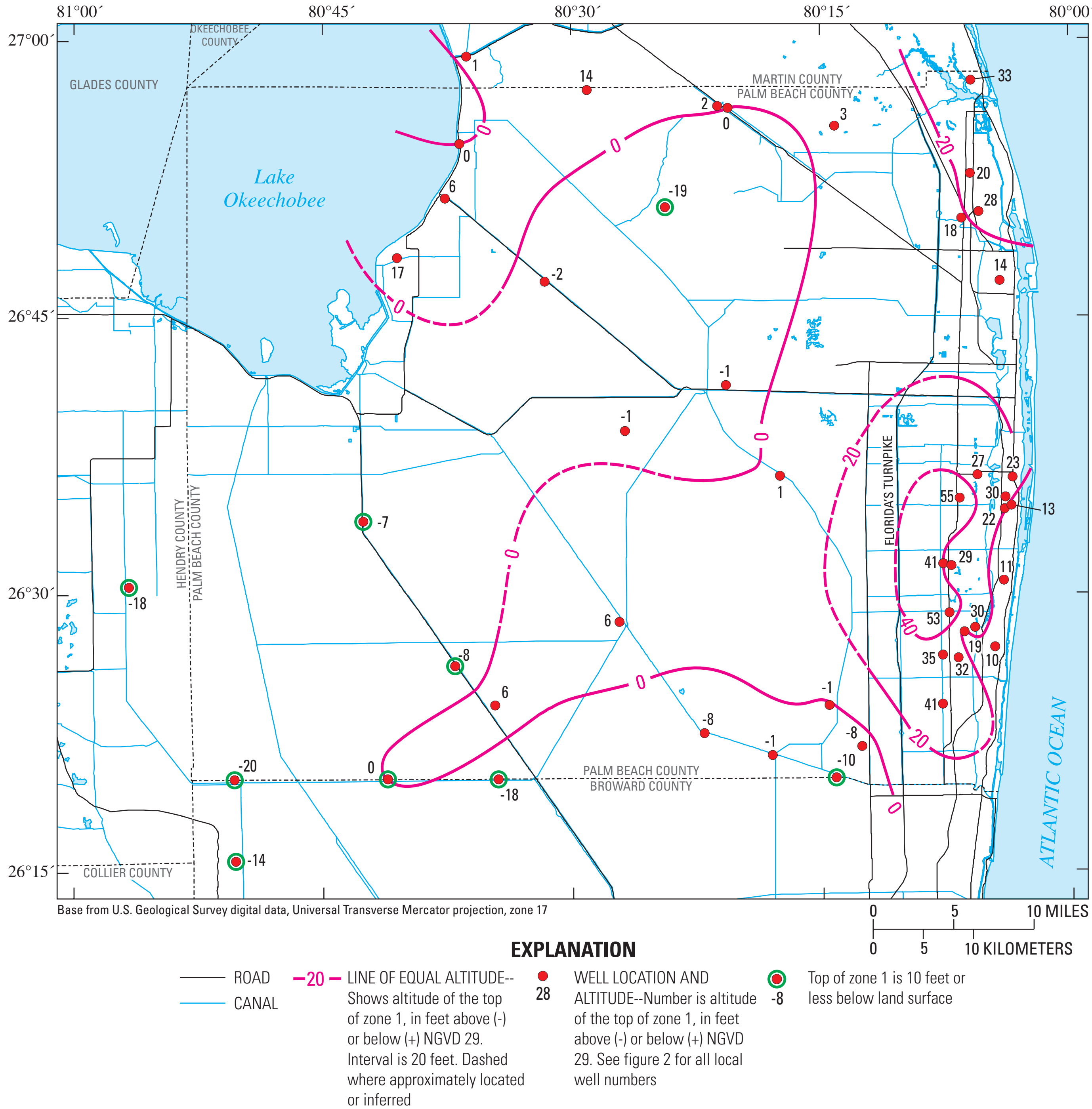


Figure 7. Altitude of the top of zone 1.

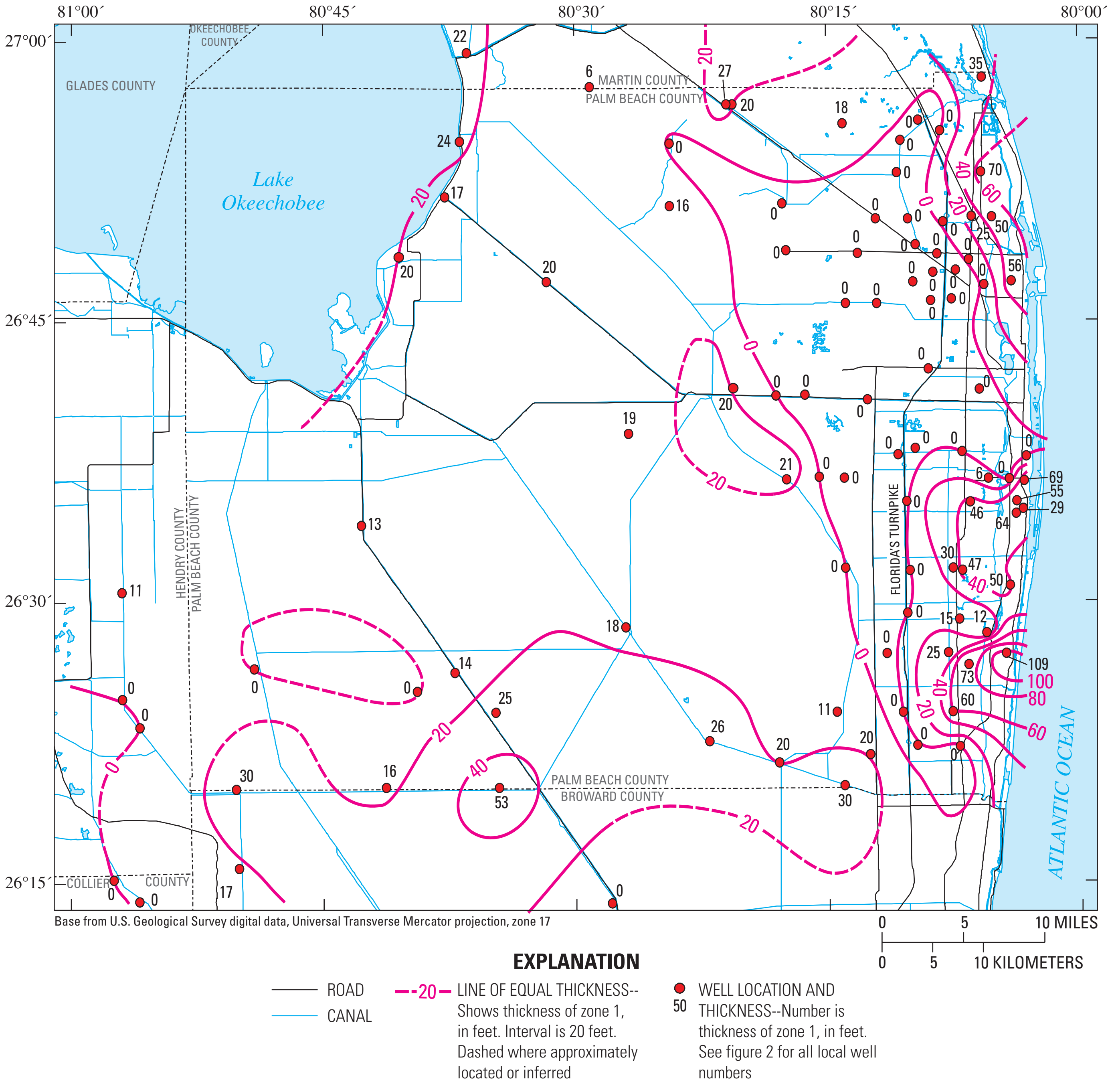


Figure 8. Thickness of zone 1.

Zone 2

The lithology of zone 2 includes shelly, highly permeable, well cemented, gray limestone (lime rudstone, floatstone, and grainstone) and calcareous, quartz-rich sandstone. Large pore spaces are common, and rock is often characterized as "solution-riddled" or as having interconnected vugs or cavities. For example, the cavities described by Fischer (1980) in zone 2 in the inland northeastern area have a "probable average diameter of 1 to 2 inches." Pore spaces up to 0.5-in. diameter were described in this zone in core from well PB-1807 drilled in this study (fig. 9; table 1–6). Moldic and intergrain porosity are also present. Interbedded layers of loose quartz sand are common, particularly in the lower part of the zone, and vugs can be partially filled with sand (Fischer, 1980). Pore space in flow zones in this permeable zone may be classified as pore class I (Cunningham and others, 2006), which is dominated by touching vugs through which conduit flow can occur.

Zone 2 is interpreted as being present in virtually all of the study area; however, the zone of secondary permeability (Swayze and Miller, 1984) that includes zone 2 was mapped as being present in only the eastern part of the county (approximately the same as the northeastern and southeastern areas as defined in this study). The extent of the zone of secondary permeability was based on drilling characteristics and lithology (Swayze and Miller, 1984), but hydraulic properties indicate that zone 2 is more extensive. The altitude of the top of zone 2 is highest in extreme southwestern Palm Beach County and eastern Hendry County, where it is as shallow as 20 ft above NGVD 29, and lowest along the eastern coast, where it is as deep as 151 ft below NGVD 29 (fig. 10).

Zone 2 is thickest in the inland southeastern and northeastern areas close to Florida's Turnpike, where it can be greater than 80 ft; thickness decreases to zero in most wells located close to the coast in the coastal southeastern and northeastern areas (figs. 5 and 11). An area where thickness is greater than 40 ft roughly coincides with WCA 1 (fig. 2) and extends to the northwest toward Lake Okeechobee (fig. 11). The extent of zone 2 to the west into this area and the west-to-east spatial relation of zone 2 to zones 1 and 3 are shown by section *B–B'* (fig. 5). A large area of high altitude of the top of zone 2, as shallow as 17 ft below NGVD 29, is in the inland northeastern area along and to the west of Florida's Turnpike; in this area, the top of the zone is placed substantially above the T correlation marker (fig. 1–1). This shallow altitude is shown by wells PB-1089, PB-798, and PB-1086 in hydrostratigraphic section *A–A'* (fig. 4), where a thick interval of permeable gray sandstone and limestone extends as much as 50 ft above the top of the T marker. This section above the T marker is included in zone 2 in this area because no evidence of a confining unit within it was found. This upper permeable section may contain rocks of Pleistocene age (fig. 3).

Zone 2 is semiconfined in most of the study area. The semiconfining unit between zones 1 and 2 generally ranges in thickness from 10 to 40 ft, but is as thick as 60 ft in the inland southeastern area (fig. 12). The confining nature of this unit is variable with a lithologic composition that ranges from fine to medium sand, to hard sandstone or limestone, to sandy limestone, to marl or clay, or to sandy broken shell. In a large area located mostly in the inland southeastern and northeastern areas, zone 1 is absent and the semiconfining unit above zone 2 extends to the land surface (fig. 12). In this area, the thickness of this semiconfining unit commonly ranges from 50 to 100 ft.

Zone 3

The lithology of zone 3 commonly includes gray, sandy, lime rudstone or floatstone, calcareous, quartz-rich sandstone, and quartz or carbonate sand. Porosity in the zone is primarily intergrain and moldic, and solution-enlarged pore spaces are only locally distributed. The lime rudstone to floatstone lithology with moldic porosity is best exhibited in the southwestern and south-central areas, where zone 3 is equivalent to the gray limestone aquifer. Core photographs of this lithology from wells southwest of the study area in Collier County are shown in figure 13. In some areas, such as the eastern and northern areas of the study area, thin, hard, limestone or sandstone layers one to several feet thick are present in the upper to middle parts of this zone and may be interbedded with thick layers of sand. In some cases, these hard layers may be associated with either subaerial exposure surfaces, thin zones of lost circulation during drilling, or both (Reese and Wacker, 2007).

The altitude of the top of zone 3 is as deep as 220 ft below NGVD 29 in the coastal southeastern area (fig. 14), and the thickness of the zone is over 100 ft in extreme southwestern Palm Beach County, southeastern Hendry County, and extreme northwestern Broward County (fig. 15). The thickness of the semiconfining unit between zones 2 and 3 generally ranges from 10 to 20 ft in the eastern half of Palm Beach County (fig. 16), but the thickness of this unit can be greater than 60 ft in the southwestern area (for example, well PB-1703, fig. 5). In a small area in the northern part of the coastal southeastern area, confinement above zone 3 is as thick as 147 ft. Zone 2 is not present in this area, and the confining unit extends up to the base of zone 1.

The gray limestone aquifer, as previously mapped, can include zone 2 in addition to zone 3. For example, the top of the gray limestone aquifer was placed at the same depth as the top of zone 2 in well G-2313 in the southwestern area (Fish, 1988).

Because the thickness of the confining unit separating zones 2 and 3 is limited or difficult to define in much of the study area, the thicknesses of zones 2 and 3 were combined (fig. 17), and this combined unit is referred to as zones 2/3. In many of the wells used to determine this combined thickness, a confining unit separating zones 2 and 3 was not indicated or not supported based on available data, and the combined thickness is a total thickness (red dots, fig. 17). Only the top of zone 2 and base of zone 3 were determined in these wells (table 1–8). In the other wells used to determine the combined thickness, this thickness is a net thickness that excludes the confining unit separating zones 2 and 3 (blue dots, fig. 17). The thickness of zones 2/3 is 100 ft or greater in 10 wells in the inland southeastern and northeastern areas (fig. 17), including both net and total thickness wells.

Figure 9. Core photograph of PB-1807 for the interval from approximately 76 to 83 feet below land surface within zone 2. Photograph shows both uncut side of core pieces (left column) and slabbed side of same pieces (right column). Some cross-bedding and dissolution along bedding planes is evident. A major flow zone within permeable zone 2 in this well is from 70 to 92 feet below land surface. Red and black marks were used to maintain correct orientation of samples.

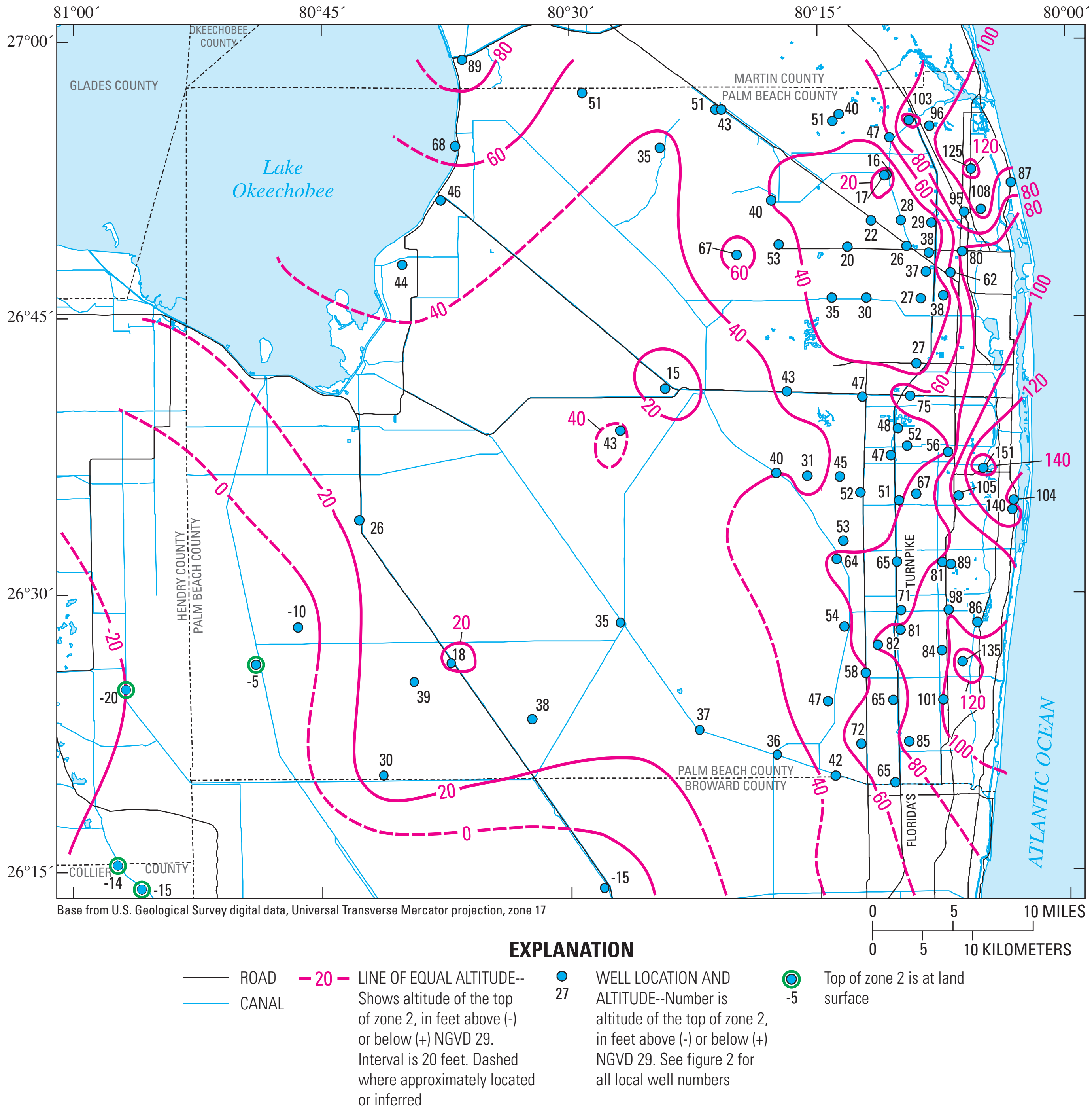


Figure 10. Altitude of the top of zone 2.

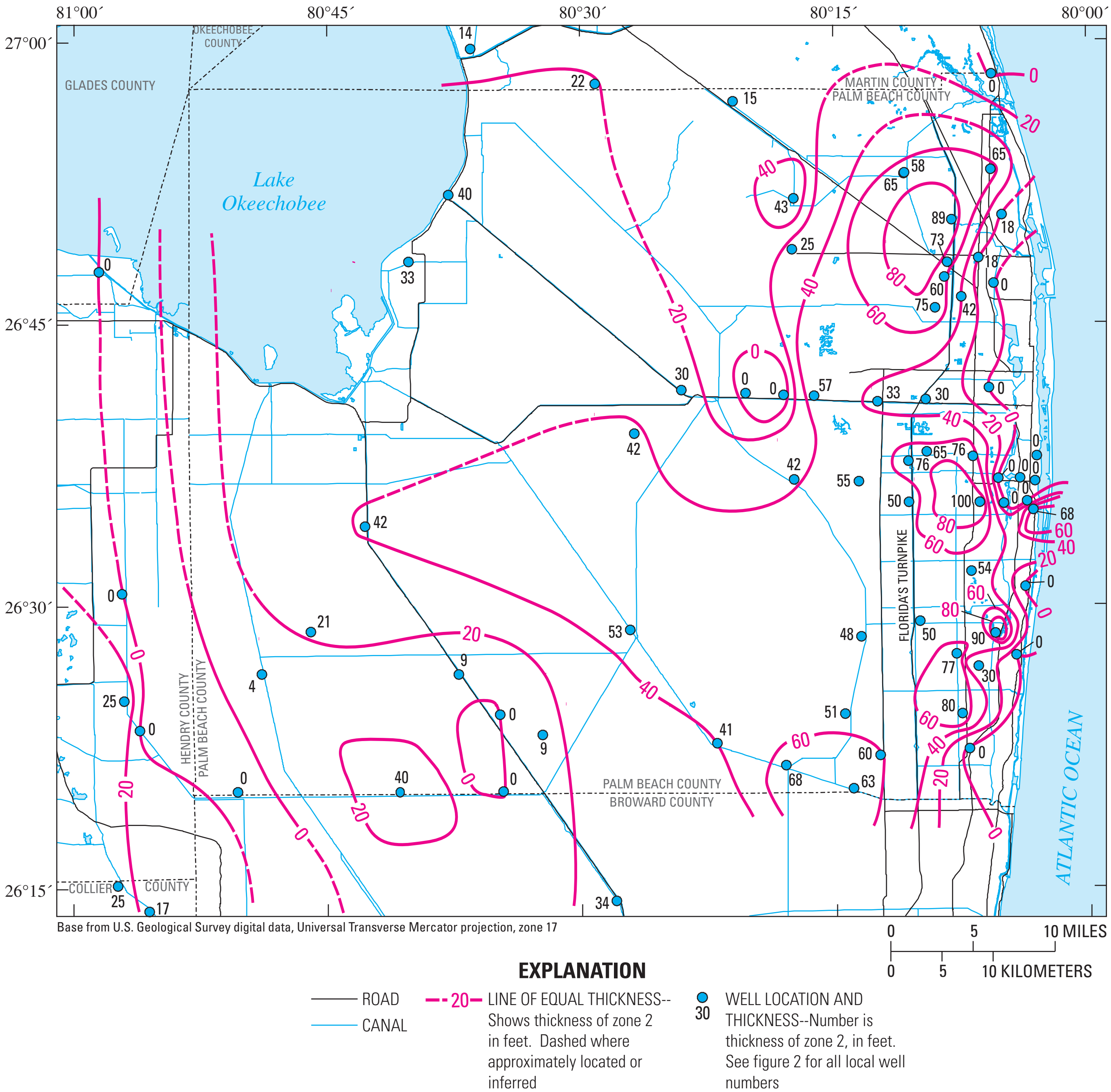


Figure 11. Thickness of zone 2.

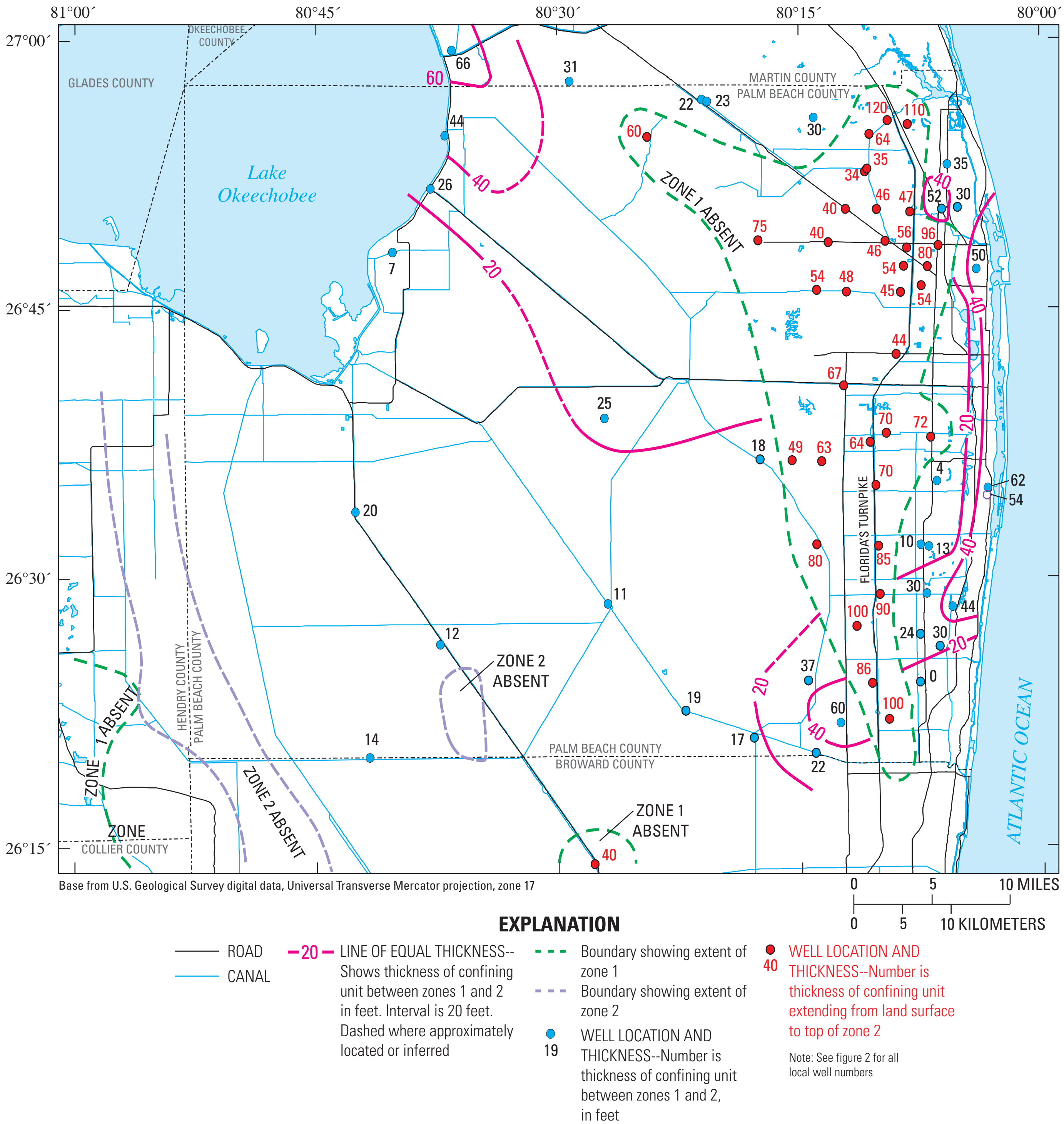


Figure 12. Thickness of the confining unit between zones 1 and 2.

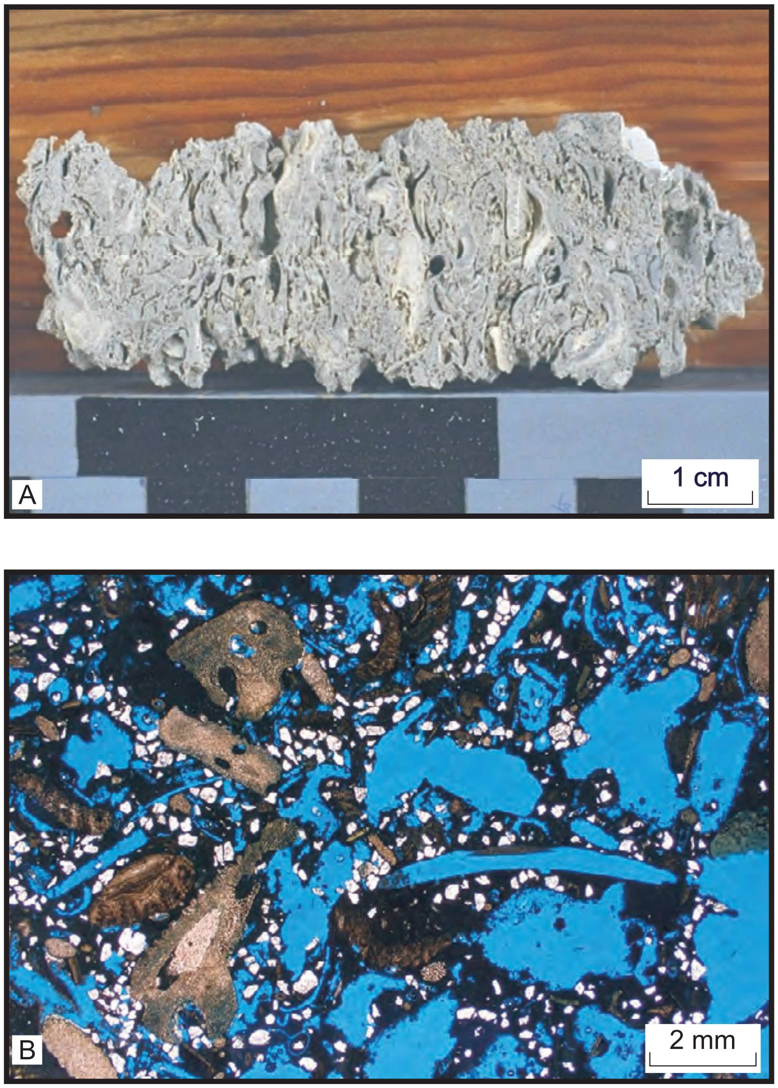


Figure 13. Core photograph and thin-section photomicrograph from zone 3 in the gray limestone aquifer. Samples are in the pelecypod lime rudstone facies of the Ochopee Limestone Member of the Tamiami Formation. Wells are located to the southwest of the study area in Collier County. *A*, Core-slab photograph showing moldic porosity in a pelecypod lime rudstone facies from a depth of 73.5 feet below land surface in the Nobles Farm core test, C-1142. *B*, Thin-section photomicrograph of sample HHW-20 taken from the pelecypod lime rudstone facies from a depth of 96 feet below land surface in the Cypress Lane core test, C-1181. Plane-polarized light; blue epoxy highlights porosity in *B*. Modified from Reese and Cunningham (2000, fig. 7).

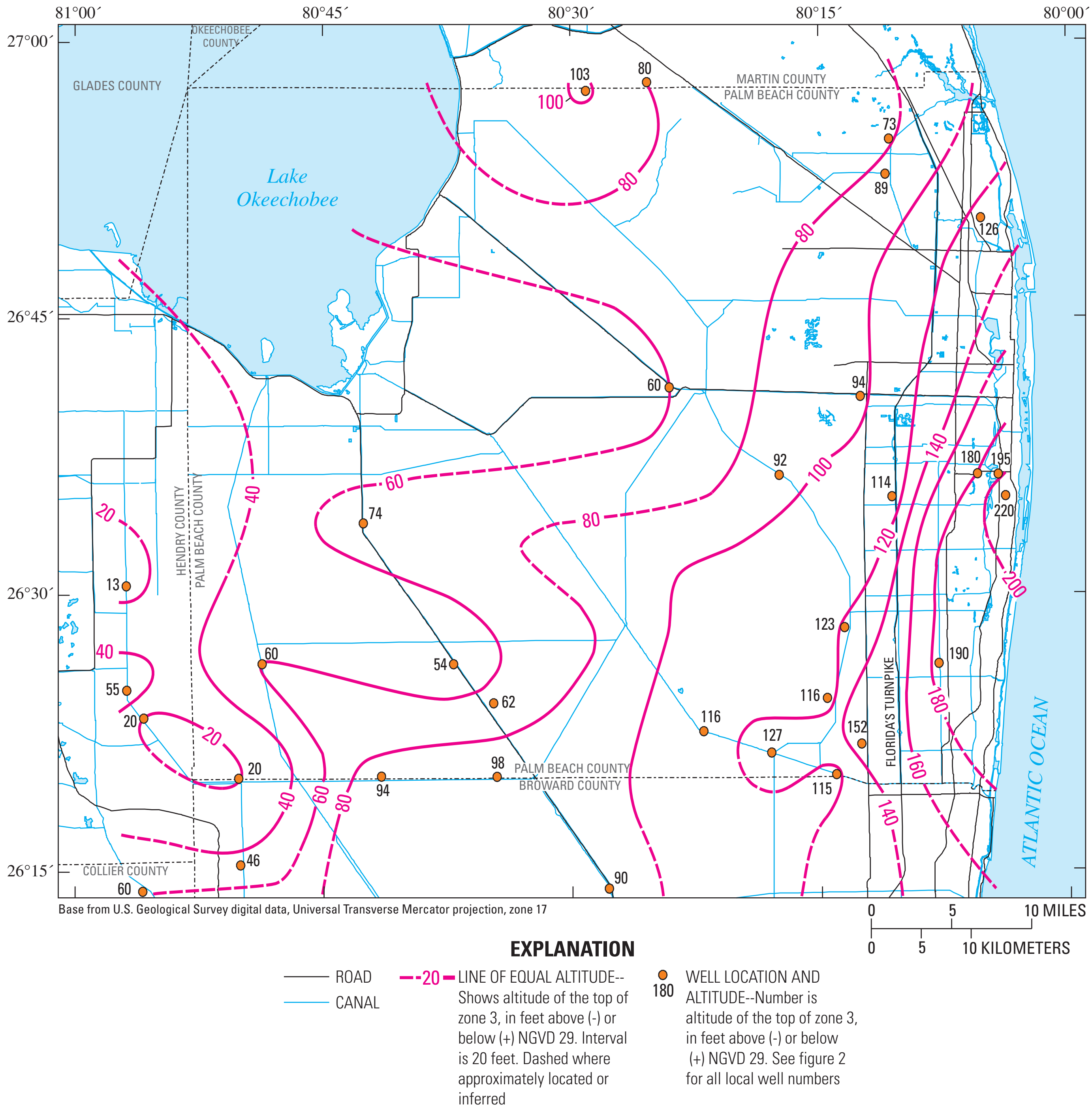
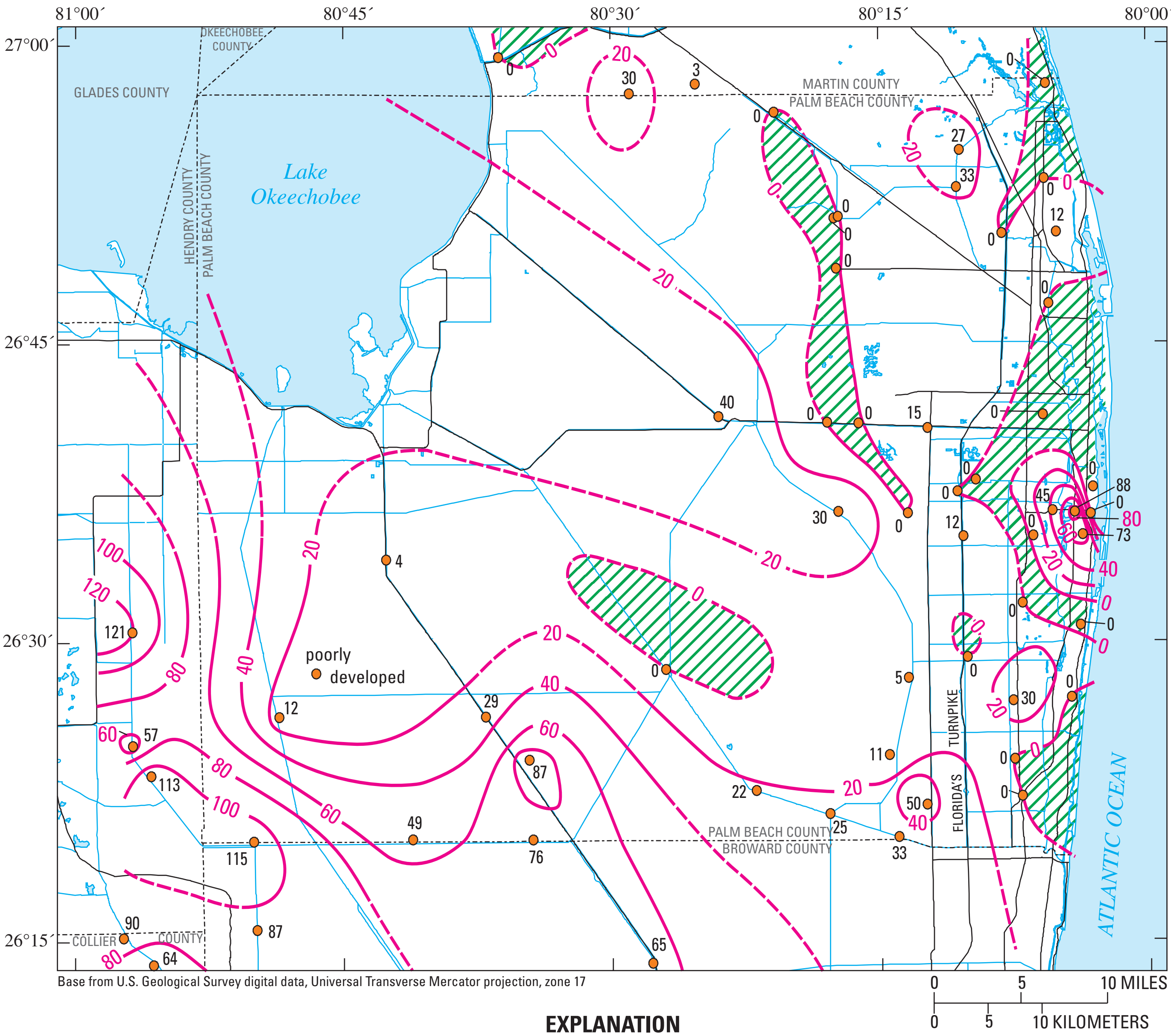


Figure 14. Altitude of the top of zone 3.



EXPLANATION

AREAS WITH ZERO THICKNESS

ROAD

CANAL

–20– LINE OF EQUAL THICKNESS--Shows thickness of zone 3, in feet. Interval is 20 feet. Dashed where approximately located or inferred

50 WELL LOCATION AND THICKNESS--Number is thickness of zone 3, in feet. See figure 2 for all local well numbers

Figure 15. Thickness of zone 3.

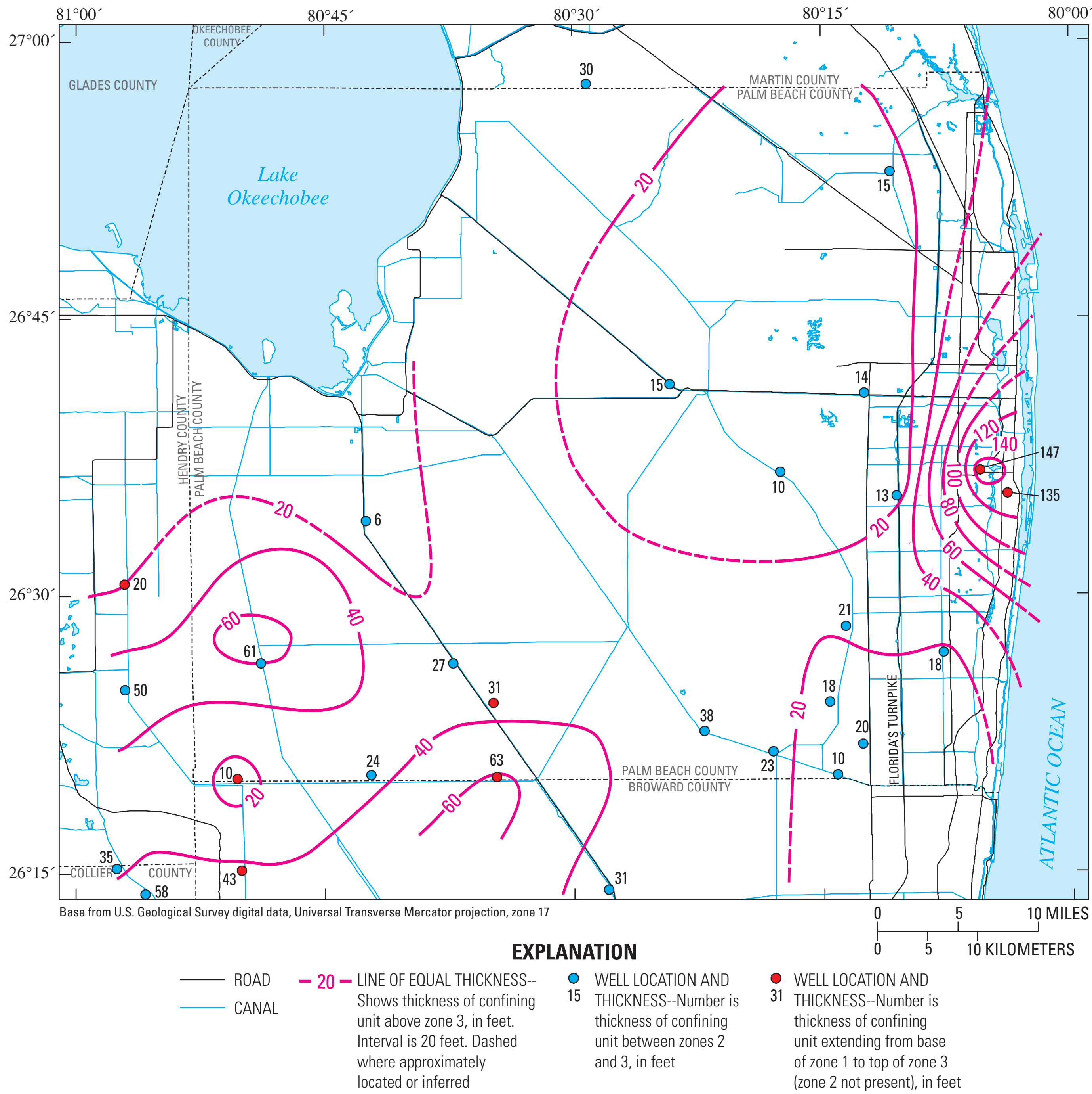


Figure 16. Thickness of the confining unit above zone 3.

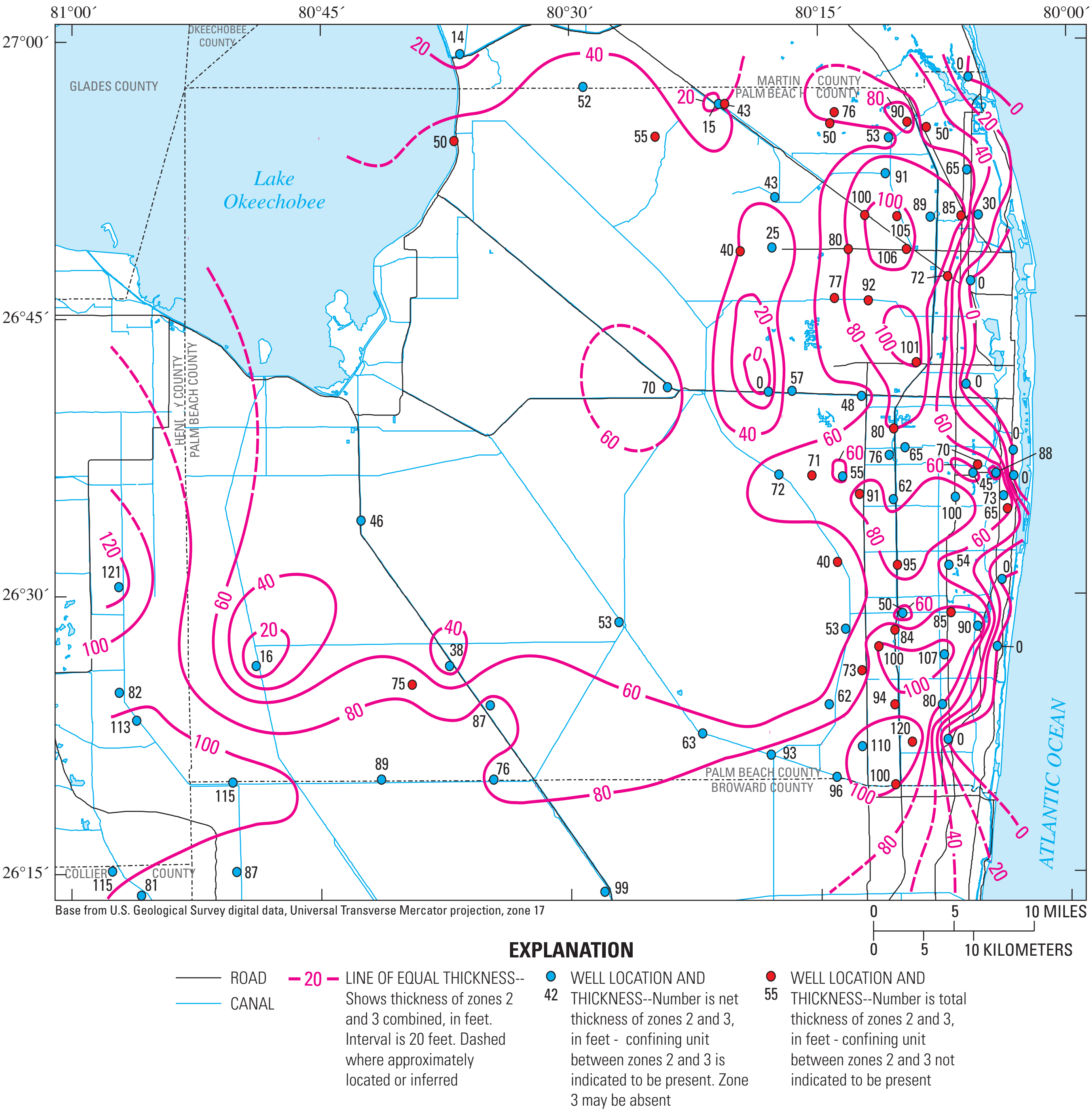


Figure 17. Combined thickness of zones 2 and 3.

Hydraulic Properties and Characteristics

Historical aquifer tests and aquifer tests conducted during this study were compiled (tables 1–9*A* and 1–9*B*) and are described in the following sections. Hydraulic test data used in this study include data derived from single and multiple well aquifer tests and specific capacity tests. Based on these data, the distribution of transmissivity within the study area is described for each of the three permeable zones.

Hydraulic Test Data

Included in table 1–9*A* are the production well identifier and diameter, test date and test type, sources and references, operator, test description and site number, monitoring well identifier, latitude and longitude, and horizontal datum. Included in table 1–9*B* are the production well identifier, test date, land-surface altitude, depths of the open interval in the production well, zone(s) interpreted to be open in the tested well, pumping rate, length of pumping period, specific capacity, resulting transmissivity, method of analysis, estimated depths of total interval tested (if reported), and problems or comments. Fifteen of the tests in tables 1–9*A* and 1–9*B* were multiwell tests conducted by the USGS in the late 1980s (PB-1545 to PB-1608; sites 1–2, 4–5, and 7–17, table 1–9*A*). These test results were not previously reported by the USGS, but transmissivity values were reported for 14 of these sites in a SFWMD publication (Shine and others, 1989). In addition, 23 of the tests in tables 1–9*A* and 1–9*B* are from the SFWMD hydrologic database (DBHYDRO), and the production well identifier is referred to as a station name in this database. The DBHYDRO database is available at *http://glades.sfwmd.gov/pls/dbhydro_pro_plsql/show_dbkey_info.main_page*

Most of the hydraulic tests shown in tables 1–9*A* and 1–9*B* are in eastern Palm Beach County (fig. 18). These tests are usually referred to as sites as opposed to wells, because more than one well was typically open to the tested interval at a site; sites are identified using the production well number. Many of the sites in figure 18 are not shown by wells in figure 2, but in some cases the initial test well at a site is shown in figure 2. The transmissivity values reported in table 1–9*B* for most of the tests listed are from analysis of water-level changes in production or monitoring wells during pumping (drawdown) or recovery, but also included are tests in which transmissivity was estimated from specific capacity test data. Specific capacity is calculated from pumping a production well at a constant rate after a constant drawdown of water level is obtained. Transmissivity can be proportional to specific capacity in large-diameter water-supply wells, which have low well losses, and the average factor of proportionality was found to be 270 in the surficial aquifer system of Broward County (Fish, 1988; transmissivity equal to 270 times specific capacity). An average factor of 200 was determined for the surficial aquifer system in eastern Palm Beach County (Mark Stewart, U.S. Geological Survey, written commun., 1989), and this factor was used for the specific capacity values reported for 10 wells at 10 sites in table 1–9*B* (reference nos. 12–21). These values are from Swayze and Miller (1984, table 3.2–1), and for most of these sites, the reported value is from the well with the maximum value at a well field. The site numbers in table 1–9*A* for these specific capacity test wells can have the same site numbers as for the 15 multiwell aquifer performance tests conducted by the USGS in the late 1980s that are described above, but they are not the same sites.

Comparison of Transmissivity Derived by Different Methods

The productive zones, or subaquifers, in the surficial aquifer system in the study area generally are expected to behave as “leaky confined” or “semiconfined,” as opposed to “well confined” during aquifer tests, given the nature of the confining units above and below the zones (Fischer, 1980). The method of analysis commonly used for aquifer tests in the study area, however, assumes a confined aquifer (table 1–9*B*). The approved values for transmissivity for 14 of the 15 multiwell tests conducted by the USGS in the late 1980s (PB-1545 to PB-1608; sites 1–2, 4–5, 7, and 9–17, table 1–9*A*) were based on the Cooper and Jacob (1946) confined aquifer method of analysis of early time monitoring well drawdown data (table 1–9*B*). Although this method may overestimate transmissivity, it can be more reliable for early time data compared to a leaky confined aquifer solution (L.C. Murray, U.S. Geological Survey, written commun., 2008)

Two commonly used methods of analysis used for leaky confined aquifer tests are the Hantush and Jacob (1955) and the Hantush (1960) methods. In the former method, vertical leakage is assumed to pass through the overlying confining unit and be derived from a water-table aquifer; in the latter method, leakage is assumed to be derived from the release of water from storage in the confining unit(s). In the eastern parts of the study area, the Hantush (1960) method may be most applicable; the confining unit overlying zone 2 consists predominantly of unconsolidated sand that could release water from storage.

Transmissivity determined from drawdown data measured in the production well was compared to the transmissivity determined from monitoring well drawdown data at the same site, with the same method of analysis used for both cases. Transmissivity based on analysis of production well drawdown data using the Cooper and Jacob (1946) method for 14 out the 15 multiwell tests conducted by the USGS in the late 1980s was reported (table 1–9*B*). In most cases, these results are from step-drawdown tests of the production well, with analysis of the data from the step with the highest pumping rate. This rate was usually comparable to the rate used in the ensuing multiwell test at the site. Except for two of these sites, the ratio of the production well transmissivity value to the monitoring well transmissivity value ranged from about 0.4 to 1.4 (fig. 19*A*). For the other two sites (PB-1572, site 8 and PB-1557, site 13) this ratio was 0.06 and 0.17, respectively. The reason for the anomalously low production well value for these two sites, and perhaps for some of the other low values, is unknown.

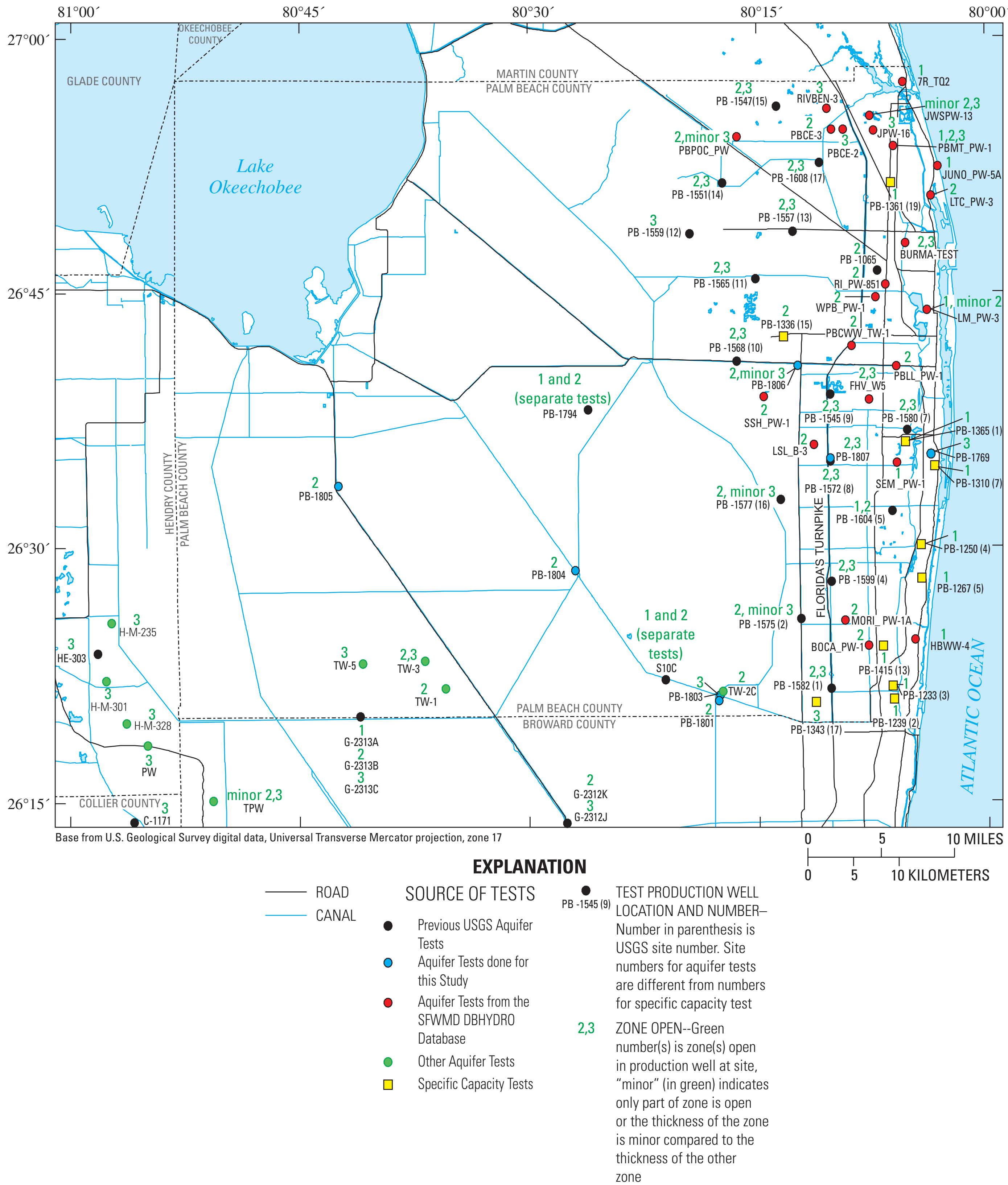


Figure 18. Hydraulic test sites, production well number, and zone(s) open.

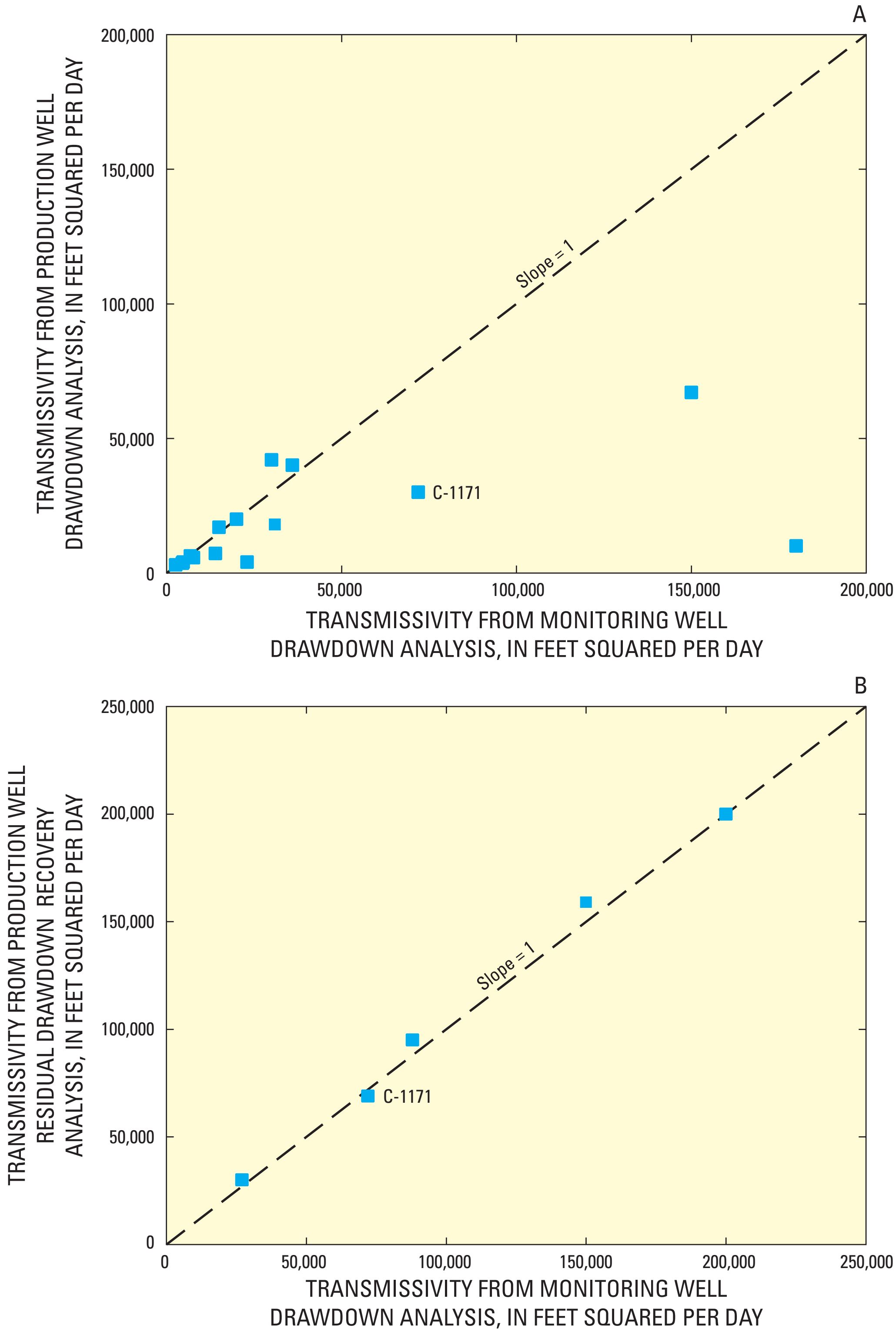


Figure 19. Comparison of transmissivity from production well to monitoring well water-level analyses at the same site. *A*, All analyses were of drawdown data by the Cooper and Jacob (1946) method, except for the C-1171 test, for which the monitoring well data were analyzed by the Hantush and Jacob (1955) method. *B*, Transmissivity from production well analyses use the Theis (1935) residual drawdown recovery method. Transmissivity from monitoring well analyses are from various methods (see text).

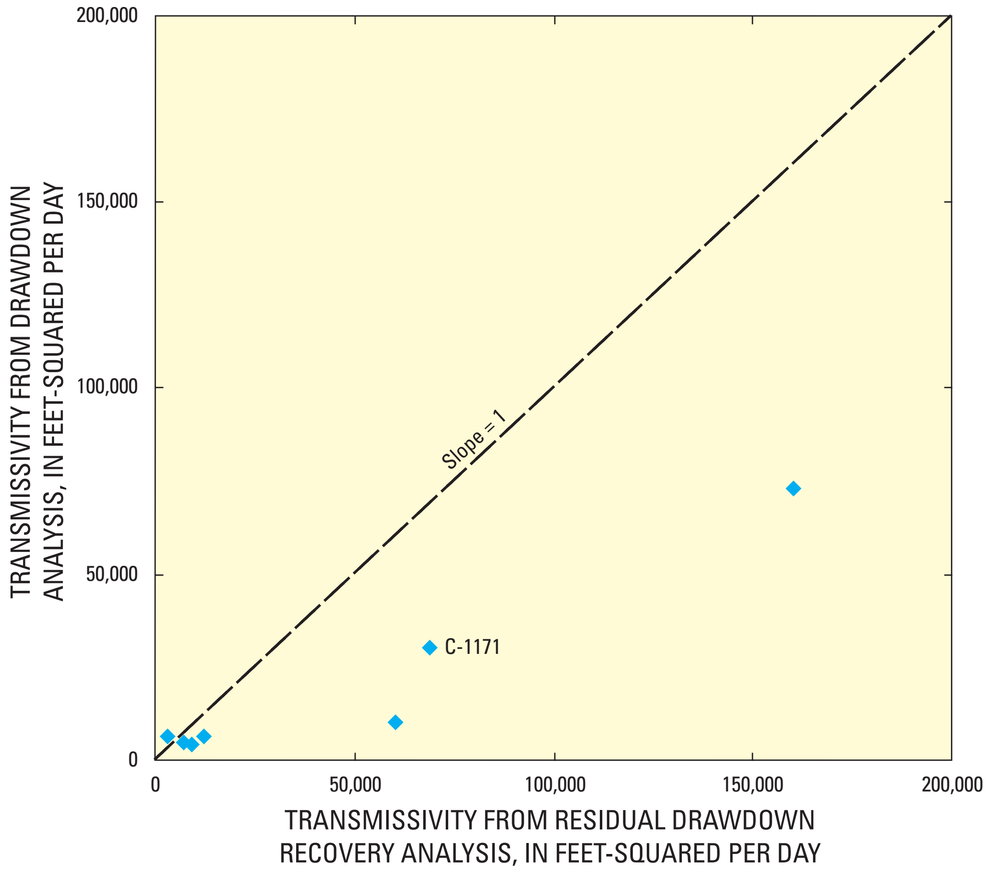


Figure 20. Comparison of transmissivity derived from drawdown data to recovery data for single-well tests.

Transmissivity determined using the Theis (1935) residual drawdown recovery method for production well data was also compared with a value determined from monitoring well drawdown data at the same site for five tests, and the results for all five tests agreed to within one significant figure (fig. 19*B*). Three of these tests are listed in table 1–9*B* and are C-1171, PB-1545 (site 9), and TW-3 (Montgomery Watson Americas, Inc., 1999); the methods used for analysis of the monitoring well data for these tests were the Thiem (1906), Cooper and Jacob (1946), and the Hantush and Jacob (1955) constant time methods, respectively. The test of C-1171 in the southwestern part of the study area is of the gray limestone aquifer (Reese and Cunningham, 2000). The additional two tests were at sites to the south and west of the study area and are of the gray limestone aquifer (Reese and Cunningham, 2000, table 9, sites 38 and 42). The monitoring well data from these additional two tests were analyzed using the Hantush and Jacob (1955) method, which could be more applicable for analysis of gray limestone aquifer tests than the Hantush (1960) method. The semiconfining unit above the gray limestone aquifer contains sand and finer-grained material, including clay, silt, and lime mud, and is more consolidated than the loose, relatively clean sand in the semiconfining unit in eastern Palm Beach County. Assuming that transmissivity determined from analysis of monitoring well drawdown data is the most representative of the aquifer, a comparison of figures 19A and 19B indicates that transmissivity determined from production well recovery data is more reliable than from production well drawdown data.

In the single-well tests conducted in this study, transmissivity values derived from analysis of drawdown data commonly are substantially lower than those from analysis of recovery data (table 1–9*B*), and here again, the recovery analysis values could be more reliable. The ratio of the Cooper and Jacob (1946) drawdown value to the Theis (1935) recovery value was about 0.4, on average, and as low as 0.17 in six of the single-well tests that were run in this study and in one previously run test (fig. 20). This ratio was about 0.4 for the previous test, which was of well C-1171 in the gray limestone aquifer in the southwestern part of the study area, and for this test, the production well recovery value agrees well with the leaky confined aquifer analysis of monitoring well drawdown data (fig. 19*B*). The recovery analysis values from these single-well tests are considered in this study for mapping the distribution of transmissivity, in addition to the values derived from drawdown analysis, because of the relatively good comparison of the recovery values with monitoring well drawdown results.

Confinement above Zone 2 or 3

The very fine- to medium-grained, relatively clean quartz sand common in the semiconfining unit above zone 2 in the eastern areas probably has moderate (horizontal) hydraulic conductivity (10 to 100 ft/d, Fish, 1988, table 7). A value of 50 ft/d is considered to be a reasonable estimate of the average hydraulic conductivity of nonproduction zone sediments in eastern Palm Beach County (Shine and others, 1989). These estimates are high, however, compared to vertical hydraulic conductivity derived from aquifer test results.

As discussed previously, the semiconfining units above zone 2 or 3 generally have finer-grained material in the southwestern area than in eastern areas; accordingly, these units may have lower hydraulic conductivity in the southwestern area. In the southeastern Hendry County and extreme northwestern Broward County parts of the study area, the average vertical hydraulic conductivity in the confining unit above the gray limestone aquifer can be 0.05 ft/d or less, based on thickness of the upper confining unit and leakance values from aquifer tests (Reese and Cunningham, 2000). The average vertical hydraulic conductivity of the confining unit above zone 2 in the eastern areas may be an order of magnitude or two greater than this value. Aquifer test results indicate that the average vertical hydraulic conductivity of the overlying confining unit at site PB-1557 (site 13) in the inland northeastern area (PB-1555 in fig. 2) is 3 ft/d. This value is based on the Hantush (1960) analytical solution for the monitoring well drawdown data and a thickness of the confining unit of 40 ft (fig. 21*A*). The approved solution for transmissivity for this test, using the Cooper and Jacob (1946) method, is shown in figure 21*B*.

Characteristics of Flow Zones as Determined by Borehole Geophysical Logs

The depths of flow zones and the percentage of total flow for each zone during pumping were determined in six constructed wells (table 2). Zone boundaries were determined based on the fluid temperature and resistivity log curve deviations or breaks, in addition to the flowmeter logs. In most cases, the pumping rate used for the stressed condition was about 10 gal/min.

In wells PB-1608 and PB-1761, the percentage of total flow for each flow zone was determined using a spinner flowmeter log lowered into the well during pumping. This was done by setting the readings in casing and at total depth, or in a section of blank pipe at the bottom of the well, at 100 and 0 percent of total flow, respectively. A similar approach was used for wells PB-1804 through PB-1807, but an electromagnetic flowmeter was run under both ambient and pumping (stressed) conditions. For both of these conditions, the tool was lowered at the same speed, and the analysis was based on a computed curve produced by subtracting the flow rate values of the ambient run from those of the stressed run.

The flow zones open in each well were compared with the depths of the three permeable zones mapped and discussed previously (table 2). The flow zones and permeable zones determined in each of the six wells are also shown on the montages for the well included in appendix 2. Except for well PB-1761, which was open to both zones 1 and 2, the flow zone contributing the most flow (as much as 60 percent) was within permeable zone 2. The total percent flow from the flow zone(s) open and included in permeable zone 2 ranged from 60 to 100 percent, and in permeable zone 3, from less than 1 (PB-1804) to 22 percent (PB-1608). The depths of the permeable zone boundaries are not always the same as the flow zone boundaries, because the permeable zone boundaries were determined using additional data, including lithologic descriptions and standard geophysical logs.

Distribution of Transmissivity by Zone

The distribution of transmissivity by zone was mapped and is discussed in the following sections. The greatest transmissivity for each zone is in a different areal location than those for other zones.

Zone 1

Hydraulic tests were conducted at 15 sites where the production well is interpreted to be open to only zone 1 (fig. 18), and transmissivity determined from these tests ranged from 1,000 to 90,000 ft^2/d (fig. 22). All but three sites were in the coastal eastern areas, where transmissivity ranged from 6,000 to 90,000 ft^2/d. The other three sites are in the south-central and southwestern areas, and transmissivity at these sites ranged from only 1,000 to 18,000 ft^2/d. In the coastal eastern areas, well LM_PW-3 is open to both zones 1 and 2, but the thickness of zone 2 in this area is indicated to be zero (fig. 11).

Zone 2 or Zones 2 and 3 Combined

An area of high transmissivity in zone 2 or zones 2/3 extends along Florida's Turnpike in the inland eastern areas; transmissivity in this area is the highest in the study area and is as high as 180,000 ft^2/d in the northern part of the inland southeastern area and the southern part of the inland northeastern area (fig. 23). This area of high transmissivity generally coincides with areas of high thickness of zones 2/3 (greater than 80 ft) (fig. 17). At many of the sites where a well is open to both zones, the well is open to only a minor part of zone 3, or the thickness of zone 3 is minor relative to zone 2. At one site in the coastal southeastern area, well PB-1604 (site 5) is open to both zones 1 and 2, but the value for this site fits with the distribution of transmissivity shown for zone 2 in figure 23.

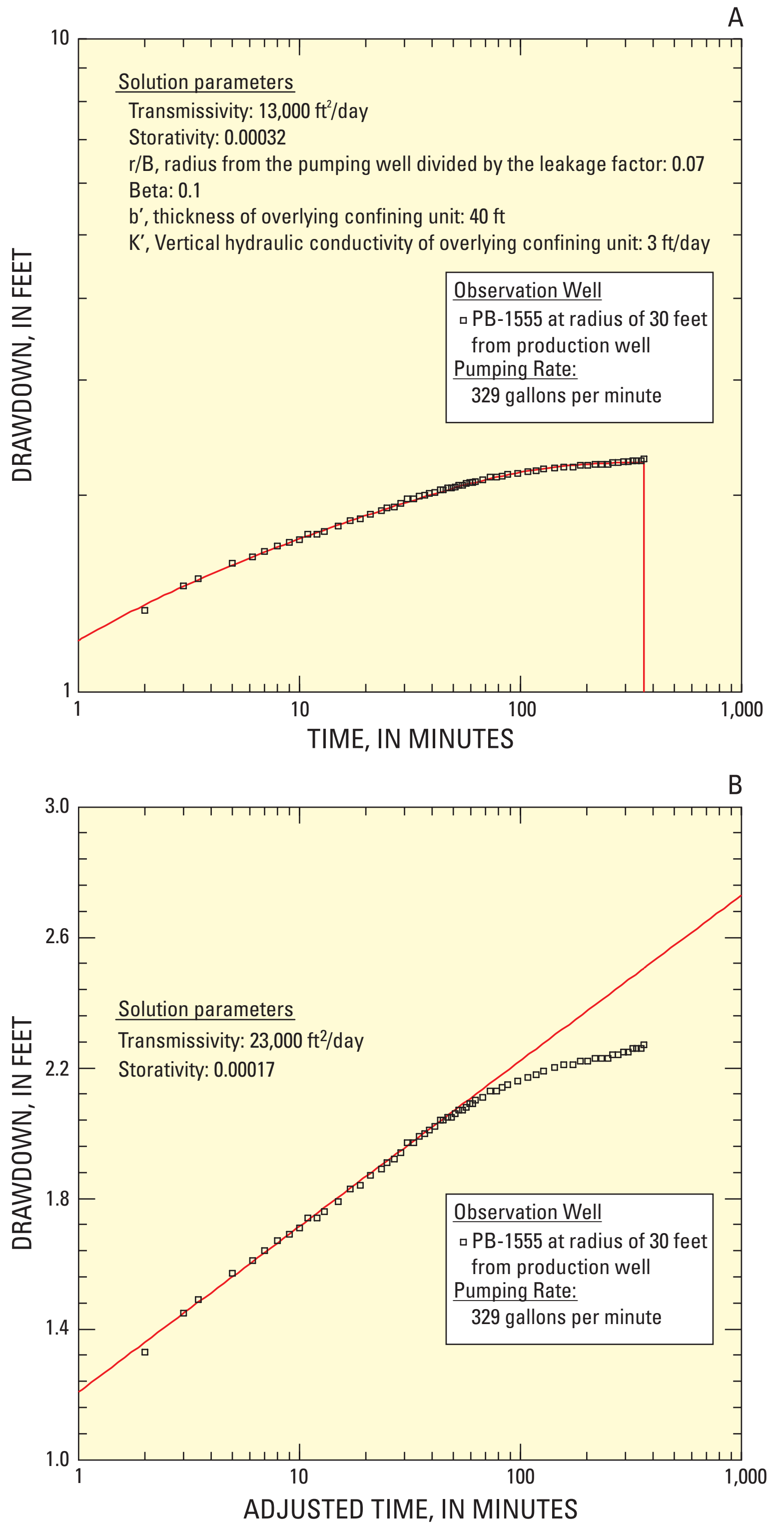


Figure 21. Two methods of analysis of monitoring well drawdown data for production well PB-1557, site 13, in the inland northeastern area. *A*, Hantush (1960) method for a leaky aquifer. *B*, Cooper and Jacob (1946) method for a confined aquifer.

Table 2. Depths of flow zones and percentage of total flow based on analyses of flowmeter and fluid properties logs run in six wells.

[Depths of the three mapped permeable zones in the wells are shown for comparison. All depths are in feet below land surface; NP, not present; <, less than; --, not applicable]

USGS well name	Screened interval in well (feet below land surface)	Flow zone			Permeable zone	
		Number	Depth (feet below land surface)	Percent of total flow	Number	Depth (feet below land surface)
PB-1608	50–150	--	--	--	1	NP
		1	53–57	44	2	34–92
		2	82–86	34		
		3	106–110	6	3	107–140
		4	120–123	6		
		5	133–140	10		
PB-1761	0–111	1	17–23	40	1	10–30
		2	47–58	17	2	47–115
		3	69–76	13		
		4	83–85	15		
		5	91–93	5		
		6	98–103	10		
		--	--	--	3	138–163
PB-1804	38–188	--	--	--	1	18–36
		1	45–60	40	2	47–100
		2	67–73	50		
		3	90–100	10		
		4	140–143	<1	3	NP
PB-1805	40–90	--	--	--	1	5–18
		1	40–43	35	2	38–80
		2	69–80	50		
		3	86–90	15	3	86–90
PB-1806	68–123	--	--	--	1	NP
		1	68–73	20	2	67–100
		2	87–93	52		
		3	97–100	11		
		4	113–120	17	3	114–129
PB-1807	70–140	--	--	--	1	NP
		1	70–92	60	2	70–120
		2	108–120	20		
		3	133–140	20	3	133–145

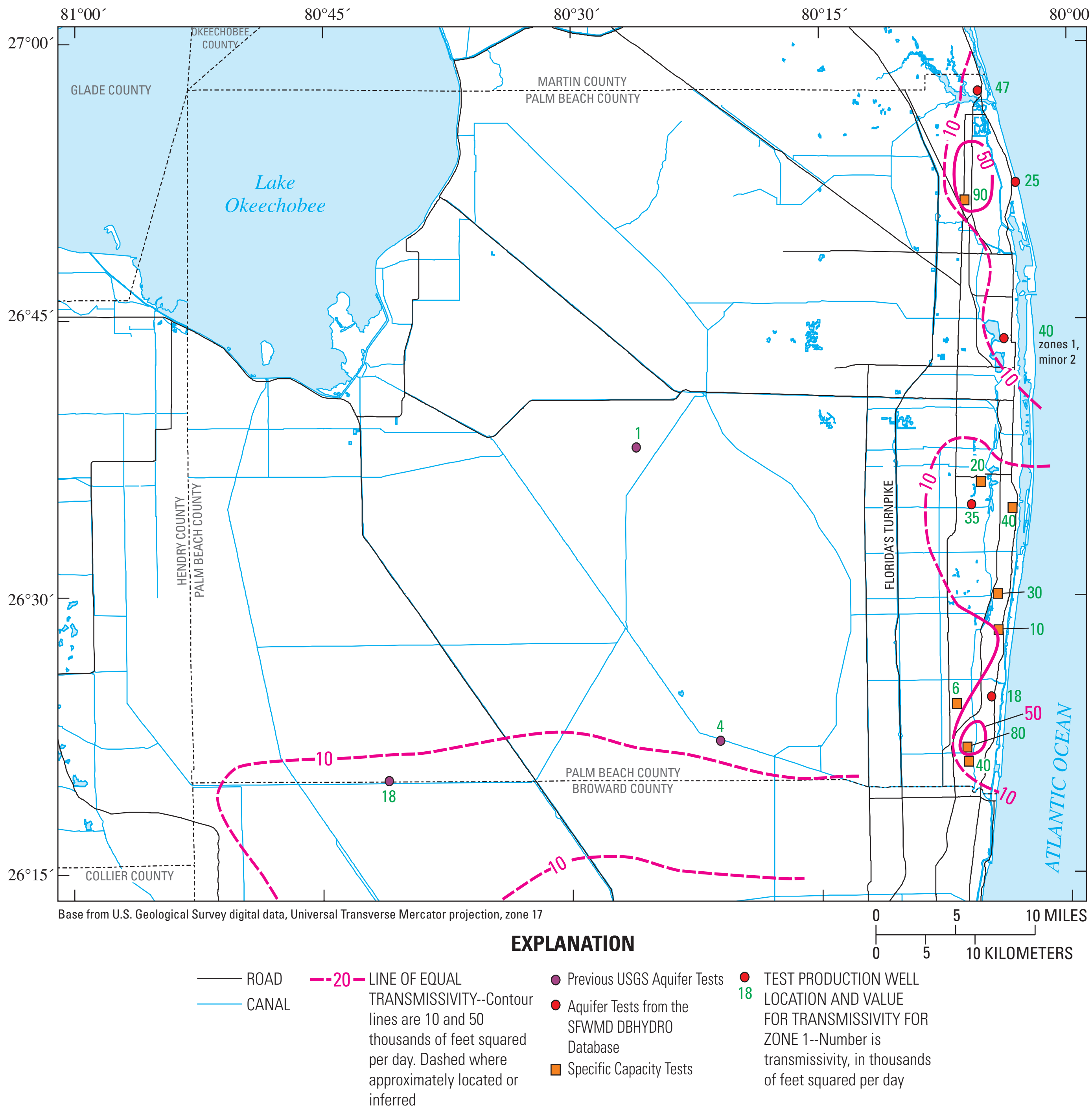


Figure 22. Distribution of transmissivity for zone 1.

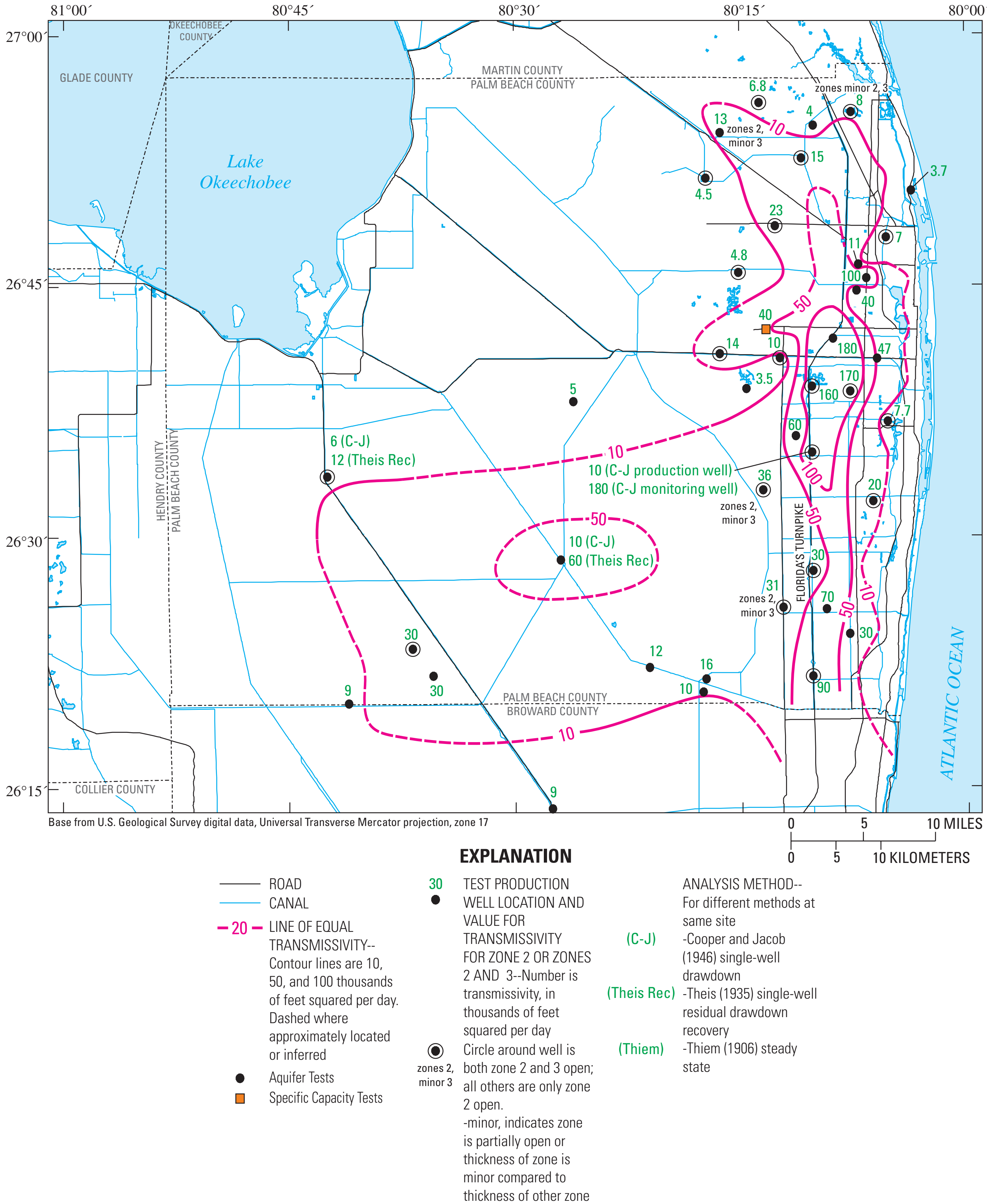


Figure 23. Distribution of transmissivity for zone 2 or zones 2 and 3 combined.

The northern extent of high transmissivity in zones 2/3 in the inland northeastern area along Florida's Turnpike has not been defined based on available tests; the area with transmissivity greater than 50,000 ft^2/d could extend 5 to 10 mi farther north in this area, as indicated by the thickness of zones 2/3 (figs. 17, 23). The northernmost site in this area with high transmissivity is site RI_PW-851 (fig. 18), where transmissivity was reported to be 100,000 ft^2/d (fig. 23). Transmissivity at the next site to the north and approximately 1 mi away, well PB-1065 (figs. 2, 18), was reported to be only 11,000 ft^2/d. The bottom of the open interval at well PB-1065, however, extended to only 79 ft below NGVD 29, and this interval in PB-1065 is interpreted to include only zone 2, which is 42-ft thick in the well (fig. 11) and is referred to as the "cavity zone" by Fischer (1980). The section extending below this cavity zone to a depth of approximately 134 ft below NGVD 29 is interpreted by Fischer (1980) to be "quite permeable," even though it is not cavity-riddled. The base of zone 3 in PB-654, located in this same area (fig. 2), also extends to 134 ft below NGVD 29, and the open interval in RI_PW-851 extends from 53 to 113 ft below NGVD 29.

The large difference between the transmissivity values reported for RI_PW-851 compared to PB-1065 may be due to more than partial penetration in PB-1065. The method of analysis used for PB-1065 was the leaky aquifer solution by Hantush (1960), and this solution can give a value lower than the value determined using the Cooper and Jacob (1946) confined aquifer solution. The method of analysis used for RI_PW-851 was not reported in DBHYDRO.

Transmissivity of zones 2/3 decreases toward the coast in the coastal areas to less than 10,000 ft^2/d (fig. 23), and in most areas along the coast the combined thickness of zones 2/3 is zero (fig. 17). The transmissivity at site LTC_PW-3 (fig. 18), which is close to the coast in the coastal northeastern area and is open only to zone 2, was only 3,700 ft^2/d.

A large area in zone 2 has a transmissivity greater than 10,000 ft^2/d, possibly as great as 60,000 ft^2/d, and extends from the inland southeastern area to the west into the south-central area and some of the southwestern area (fig. 23). Most of this area coincides with the area where the thickness of zone 2 is greater than 40 ft extending to the west covering WCA 1, and to the northwest toward Lake Okeechobee (fig. 11). Zone 2 is 53-ft thick at PB-1804, located on the west side of WCA 1. Farther to the west, in the southwestern area, the transmissivity of zone 3 increases.

Zone 3

Hydraulic test sites open only to, or predominantly to, zone 3 indicate high transmissivity in northwestern Broward County, southwestern Palm Beach County, and southeastern Hendry County (fig. 24); as previously discussed, zone 3 in this area is the gray limestone aquifer (Reese and Cunningham, 2000). Transmissivity in this area is as high as 70,000 ft^2/d, and the thickness of zone 3 is as great as 115 ft (fig. 15). This area of high transmissivity in zone 3 is part of a larger area of high transmissivity in the gray limestone aquifer that extends northwest to southeast and is more fully delineated in Reese and Cunningham (2000, fig. 28); the origin of this larger area is described as possibly related to a depositional trend in the Ochopee Limestone.

A substantial east-west transition in the thickness and transmissivity from zone 2 to 3 is present between the south-central and southwestern areas; the hydraulic connection, however, between these zones in this area is probably good. Between wells PB-1804 and PB-1704, the thickness of zone 2 decreases to zero, whereas the thickness of zone 3 increases from zero to 87 ft as shown on hydrostratigraphic section *B–B′* (fig. 5). A transition in the zone with the dominant transmissivity is indicated by aquifer tests at three sites, TW-1, TW-3, and TW-5 in the southwestern area, (table 1–9*B*; fig. 18). Site TW-1 is located approximately 2 mi southeast of TW-3, the central site, and is open only to zone 2. At TW-3 the open interval tested includes zones 2 and 3, but at TW-5, the site approximately 4 mi to the west, the open interval tested includes only zone 3. A transmissivity value of about 30,000 ft^2/d, however, was reported for all three sites (figs. 23; 24). The depths of zones 2 and 3 at these three sites was determined by correlation of GR logs, run in the production well at the sites under the Montgomery Watson Americas, Inc. (1999) study, with wells used to establish the lithostratigraphic framework in this study (fig. 2).

Relatively few hydraulic tests exclusive to zone 3 have been done in the eastern areas, but most indicate a transmissivity of less than 10,000 ft^2/d (fig. 24). Most hydraulic test sites in this area that include zone 3 also include zone 2 (fig. 18). For two tests with wells open only to zone 3 (PB-1803 and PB-1769), evidence was found for separation of zone 3 from shallower permeable zones. In well PB-1803, water produced during the test had a specific conductance of 4,730 µS/cm. Specific conductance did not substantially decrease during the test, even though the specific conductance of water from a shallower well (PB-1761) at the same site and open only to zone 2 was more than three times lower than the measured value at well PB-1803. In well PB-1769, zone 2 is not present, and the thickness of the confining unit above zone 3 is 135 ft (fig. 16), including a 120-ft thick interval of sand directly overlying zone 3.

Aquifer Nomenclature and Definition

A review of previous definitions of the Biscayne and gray limestone aquifers is needed for comparison of that nomenclature with the zones of high permeability mapped in this study (fig. 3). The Biscayne aquifer was originally shown as extending only into the southern part of southeastern Palm Beach County (Klein and others, 1975, p. 31). Fish (1988) and Fish and Stewart (1991) define the Biscayne aquifer in nearby Broward and Miami-Dade Counties as the contiguous, highly permeable section of Pliocene (Tamiami Formation) and Pleistocene age

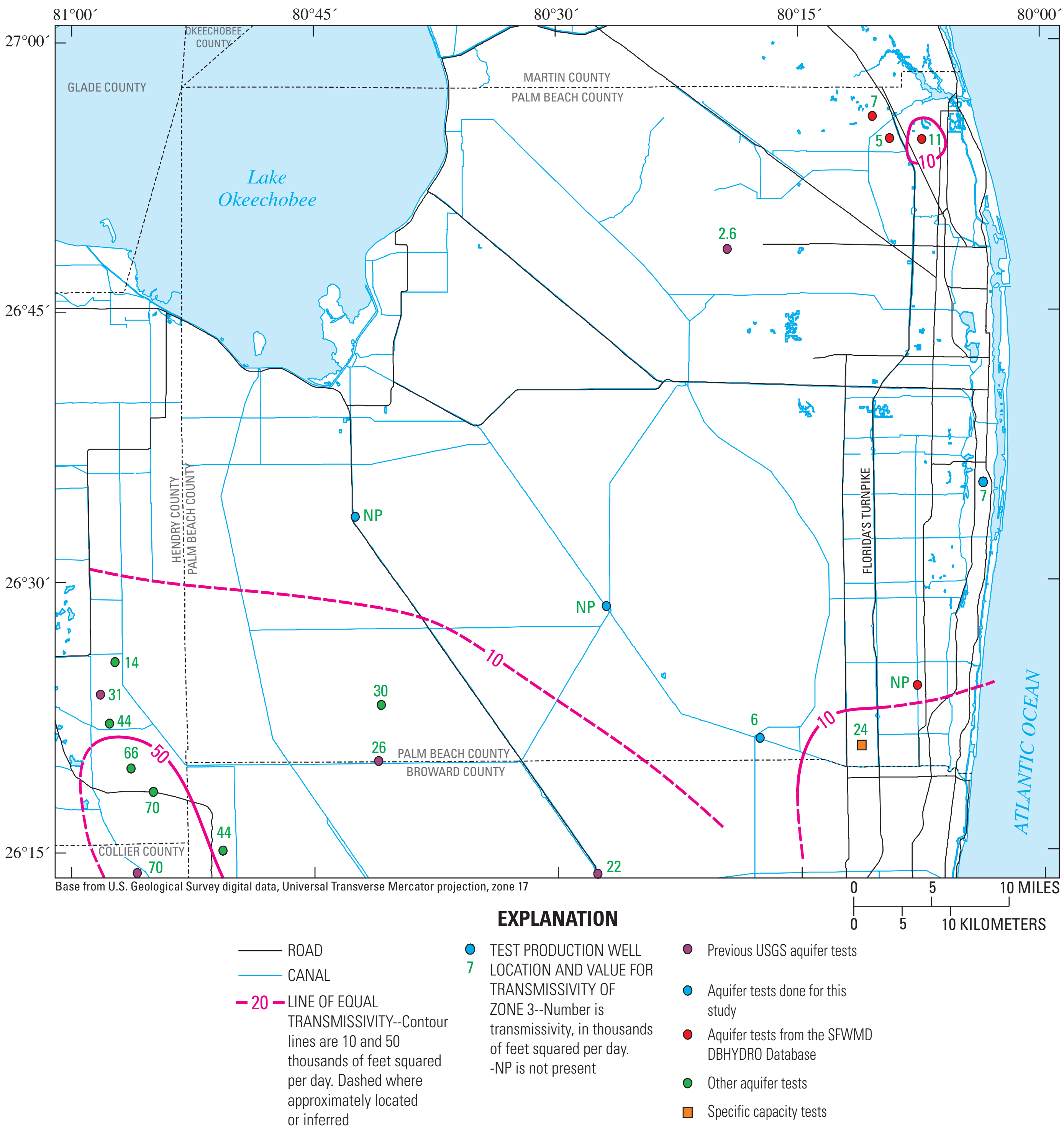


Figure 24. Distribution of transmissivity for zone 3.

formations from land surface downward, where at least 10 ft of the section has hydraulic conductivity of 1,000 ft/d or more. Their definition, however, includes the following statement: "The key criterion for defining the Biscayne aquifer apparently is the presence of highly permeable limestone or calcareous sandstone in the Fort Thompson Formation, Anastasia Formation, or the Key Largo Limestone." These three formations are all of Pleistocene age. This definition allows for the inclusion of "contiguous highly permeable limestone or calcareous sandstone beds of the Tamiami Formation," even if these beds have a hydraulic conductivity as low as 100 ft/d. In northeastern Broward County, in two of the test wells drilled in the Fish (1988) study, the upper part of the Tamiami Formation is included in the lower part of the Biscayne aquifer (Fish, 1988, wells G-2323 and G-2344).

The Biscayne aquifer in eastern Palm Beach County was defined by Shine and others (1989) as an interval within the surficial aquifer system with a thickness of at least 10 ft, and as having a hydraulic conductivity of at least 500 ft/d within at least 50 percent of this interval. Accordingly, the Biscayne aquifer was mapped as being present in southeastern and northeastern Palm Beach County (Shine and others, 1989, pl. 5). Their definition does not include a requirement for the inclusion of Pleistocene age formations and does not include the semiconfining unit above the aquifer.

Fish (1988) defines the gray limestone aquifer as "that part of the limestone beds (usually gray) and contiguous coarse clastic beds of the lower to middle part of the Tamiami Formation that are highly permeable (having a hydraulic conductivity of about 100 ft/d or more) and at least 10-ft thick." By this definition, the gray limestone aquifer also must be separated from the Biscayne aquifer by sediments having relatively low to moderate permeability.

Zone 2, the primary permeable zone mapped in this study, may not be included in the Biscayne aquifer as defined by Fish (1988), because it is interpreted to be principally in the Tamiami Formation and commonly overlain by a thick (50 to 100 ft) semiconfining unit of moderate permeability (fig. 12). This semiconfining unit commonly provides some separation from zone 1, where zone 1 is present (fig. 8). Zone 1 may be part of the Biscayne aquifer in parts of the coastal areas where the zone is thick and transmissive (figs. 5, 8, and 22), based on an average hydraulic conductivity of at least 1,000 ft/d.

Although a case can be made for classifying zone 2 of this study in the inland eastern areas as the "gray limestone" aquifer, the nature of the pore space in this zone is not consistent with this aquifer. Zone 2 is interpreted to be present in the Tamiami Formation, composed of shelly, highly permeable gray limestone and calcareous sandstone, and semiconfined and thus, similar to the gray limestone aquifer. Additionally, as discussed previously, zones 2 and 3 in the south-central and southwestern parts of the study area may be well connected, and the gray limestone aquifer as previously mapped in northwestern Broward County can include zone 2 in addition to zone 3. The nature of the pore space in the gray limestone aquifer, however, is different from that for zone 2 in the inland eastern areas where the zone is thick and highly transmissive. The porosity in the gray limestone aquifer is primarily intergrain and moldic (Reese and Cunningham, 2000). Solution-enlarged pore spaces are only locally distributed. In zone 2 of the inland eastern areas of this study, porosity commonly includes large pore spaces and is often characterized as "solution-riddled" or as having interconnected vugs or cavities. This difference in the nature of the porosity probably resulted from a difference in the environment of deposition or from the timing of dissolution relative to deposition, or both.

Based on the inconsistencies noted here, perhaps it would be beneficial to use a local name for zone 2 or zones 2/3 in the inland eastern areas. This zone(s) is referred to locally as the "Turnpike" aquifer (Palm Beach Post, 1987). The extent of greatest thickness and transmissivity in these zones follows or is adjacent to Florida's Turnpike in the inland eastern areas, as shown by the thickness of zone 2 (fig. 11) and zones 2/3 (fig. 17), and by the high transmissivity of these zones in these areas (fig. 23).

Origin of High Salinity Groundwater in Central and Western Parts of the Study Area

Areas of high salinity in the surficial aquifer system in the central and western areas have been identified and mapped in previous studies (Parker and others, 1955; Scott, 1977; Swayze and Miller, 1984; Reese and Cunningham, 2000). These areas of high salinity appear to be related to Lake Okeechobee, because many are present around the southern and southeastern shores of the lake and extend to the south or southeast (Parker and others, 1955, fig. 221). Groundwater with a dissolved-solids concentration (a measure of salinity) of 21,600 mg/L was measured in one well on the southeast shore of Lake Okeechobee in the north-central area (Scott, 1977). Samples collected from six wells in the central and western areas had measured chloride concentrations of over 1,000 mg/L (Scott, 1977; Reese and Cunningham, 2000). The most commonly accepted theory for the origin of this high salinity groundwater is that the groundwater is residual in nature and results from incomplete flushing of invaded seawater (Parker and others, 1955). If this water is residual, it could also have originated from the seawater present during deposition (connate seawater). Harvey and others (2002) refer to the high salinity, surficial aquifer system groundwater in the in the south-central area as *relict seawater* or *transitional relict seawater*, and they classify this water as sodium-chloride or sodium chloride-bicarbonate type water, respectively.

Another theory that could explain the origin of this high salinity water is that it results from localized upwelling of brackish or saline water from a depth equal to or greater than that of the Floridan aquifer system. Evidence for upwelling of brackish or saline water from deeper aquifers and invasion of the surficial aquifer system in southwestern Florida is primarily based on strontium isotope data, but also on major ion and hydrogen and oxygen isotope data (Schmerge, 2001).

Water samples were collected from 19 wells in this study to gain a better understanding of the origin of the high salinity water in the central and western areas, and the analytical results for these samples are given in table 1–10. Five of these wells are located in the inland eastern areas, and the rest are in the central and western areas (fig. 25). Although Lake Okeechobee could be related to the source(s) of high salinity water, previously drilled and constructed wells close to the lake could not be located for sampling. The measured chloride concentrations, however, in 7 of the 19 samples collected from the study area exceeded 1,000 mg/L (fig. 25).

Strontium concentration and the $^{87}Sr/^{86}Sr$ ratio can be used as indicators of groundwater movement and in determining the origin of salinity. The $^{87}Sr/^{86}Sr$ ratio measured in marine carbonate sediments and rocks of Cenozoic age indicates a strong variation during the late Cenozoic Erathem, providing a high-resolution dating tool (Elderfield, 1986; Howarth and McArthur, 1997). Cenozoic sediments contain strontium derived from the seawater present during deposition, and if the $^{87}Sr/^{86}Sr$ ratio of groundwater has equilibrated with the $^{87}Sr/^{86}Sr$ ratio of the rock or sediment containing this water, then an indication of the source of the water can be determined, provided the ages of potential source rocks are known. The $^{87}Sr/^{86}Sr$ ratio decreases as the age of seawater increases.

Review of the $^{87}Sr/^{86}Sr$ ratios measured in 18 of the samples indicates a seawater age no older than late Miocene and as young as Holocene or recent (fig. 26). Samples from zone 2 or zones 2/3 in the inland eastern area indicate an age of Pleistocene or younger, but the $^{87}Sr/^{86}Sr$ ratio for these samples could be influenced by mixing with modern recharge water. The increase in the inverse concentration of strontium for these samples (fig. 26) indicates dilution with recharge water.

The estimated seawater age generally correlates with the expected age of the sediments based on the zone to which a well is open. The lithostratigraphic and hydrogeologic units mapped in this study in the surficial aquifer system are Pliocene in age or younger (fig. 3), but sand in the lower part of the surficial aquifer system can be as old as late Miocene (Reese and Cunningham, 2000; Cunningham and others, 2001). Pleistocene or younger sediments present above zone 2 in the inland eastern area could also affect the $^{87}Sr/^{86}Sr$ ratio as the recharged water moves downward into zone 2. Therefore, the strontium data support the hypothesis for the origin of high salinity as residual invaded or relict seawater in the central and western areas; a source deeper than the surficial aquifer system is not indicated.

The stable isotopes of hydrogen and oxygen in water are affected by meteorological processes and can be helpful in understanding the origin of the water. The isotopic ratios of hydrogen ($^2H/^1H$) and oxygen ($^{18}O/^{16}O$) are commonly expressed using the delta (δ) notation, delta deuterium (δ^2H or δD) and delta oxygen ($\delta^{18}O$), respectively, and the units of this notation are parts per thousand or per mil. The δ^2H and $\delta^{18}O$ in freshwater are linearly correlated on a global scale, and the relation is known as the “global meteoric water line” (GMWL; Craig, 1961). The position of data relative to this line can indicate important information on waters that have undergone evaporation, recharge during different climatic conditions, and mixing of waters from different sources, such as recharged downgradient groundwater and saltwater.

Generally, the δ^2H and $\delta^{18}O$ values measured in the 19 samples from the study area plot along a trend below the GMWL, and this trend probably represents a progression in evaporation and mixing (fig. 27). The residual water at or near the surface after evaporation is isotopically heavier (greater δ^2H and $\delta^{18}O$ values) than the initial rain water; therefore, the progression in evaporation results in a linear trend with a lesser slope than the GMWL (Clark and Fritz, 1997). A similar but more extensive trend for δ^2H and $\delta^{18}O$ data collected from surface water and groundwater in wetland areas in the south-central area was found by Harvey and others (2002), and this trend was attributed to evaporation from surface water in wetlands. Mixing of fresh recharge water with saltwater is indicated by a trend for the δ^2H value of samples with a chloride concentration of greater than 250 mg/L (fig. 28).

Most of the samples in figure 27 plot in two separate groups: one for the central and western areas, and one for the inland eastern areas. The separation of these groups could be related to the nature of recharge in these areas. In the inland eastern areas, recharge could be more direct and rapid with less evaporation at or near the surface. This separation is not due to groundwater flow and mixing from west to east in zone 2 or 2/3, because a horizontal hydraulic gradient in this direction from the central and western areas to the inland eastern areas is not indicated (Swayze and Miller, 1984; Harvey and others, 2002).

Comparison of the δ^2H and $\delta^{18}O$ values to results of samples taken from the Floridan aquifer system in nearby areas indicates that the source of the higher salinity groundwater is not from this deeper aquifer system. Thirty one samples collected from the Floridan aquifer system from inland areas of Martin, St. Lucie, and Okeechobee Counties to the north of the study area (Reese, 2004, fig. 29) plot as a group shown on figure 27. The chloride concentration of these 31 samples ranged from about 300 to 2,000 mg/L. This Floridan aquifer system group of values is at least 2 per mil and 6 per mil heavier in $\delta^{18}O$ and δ^2H, respectively, than the data collected in this study; this difference is even more pronounced for the values collected from the central and western areas in this study. These areas are more likely to be where localized upwelling of brackish or saline water from the Floridan aquifer system would be expected to occur.

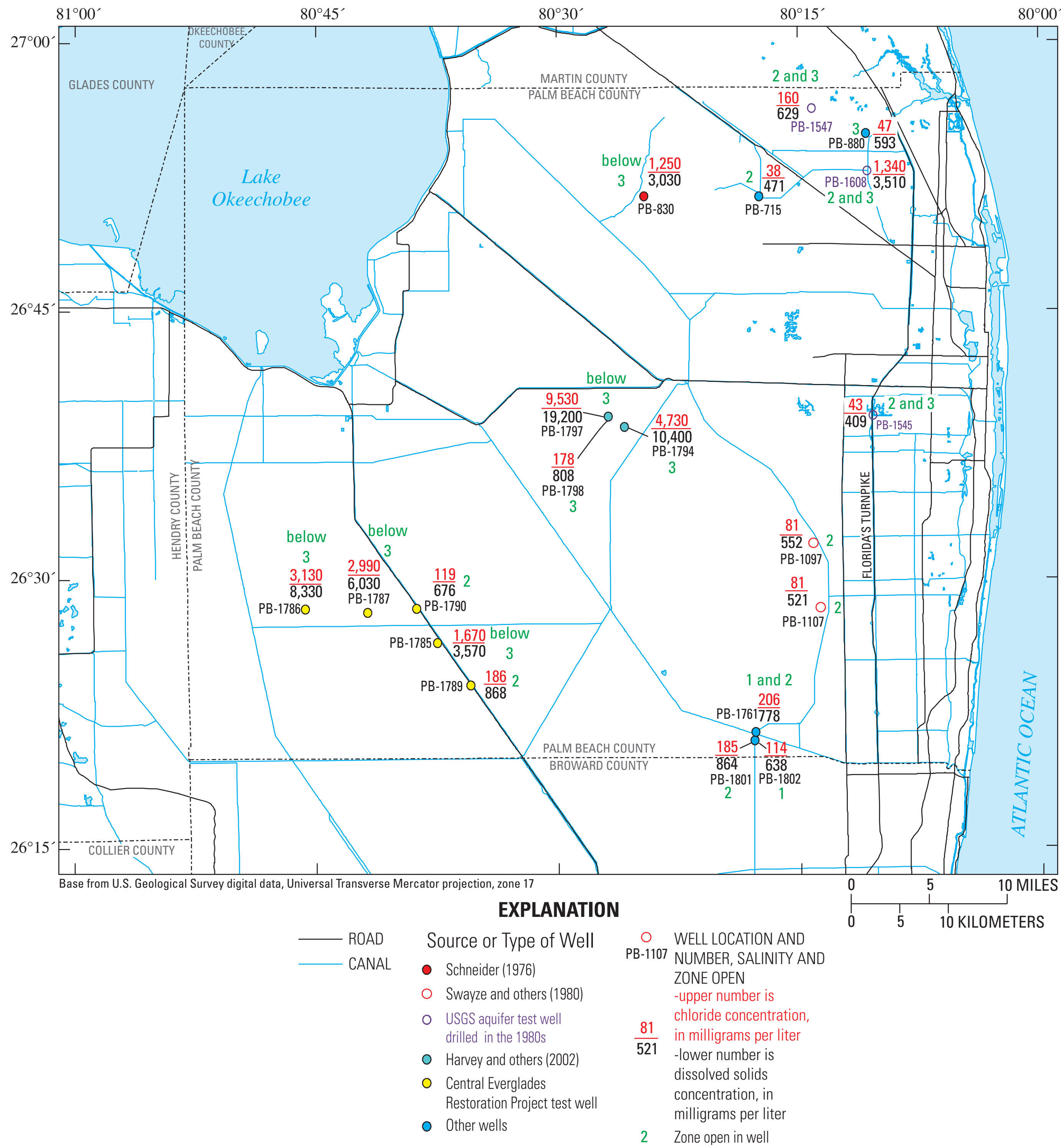


Figure 25. Wells sampled in this study, and chloride and dissolved solids concentrations measured.

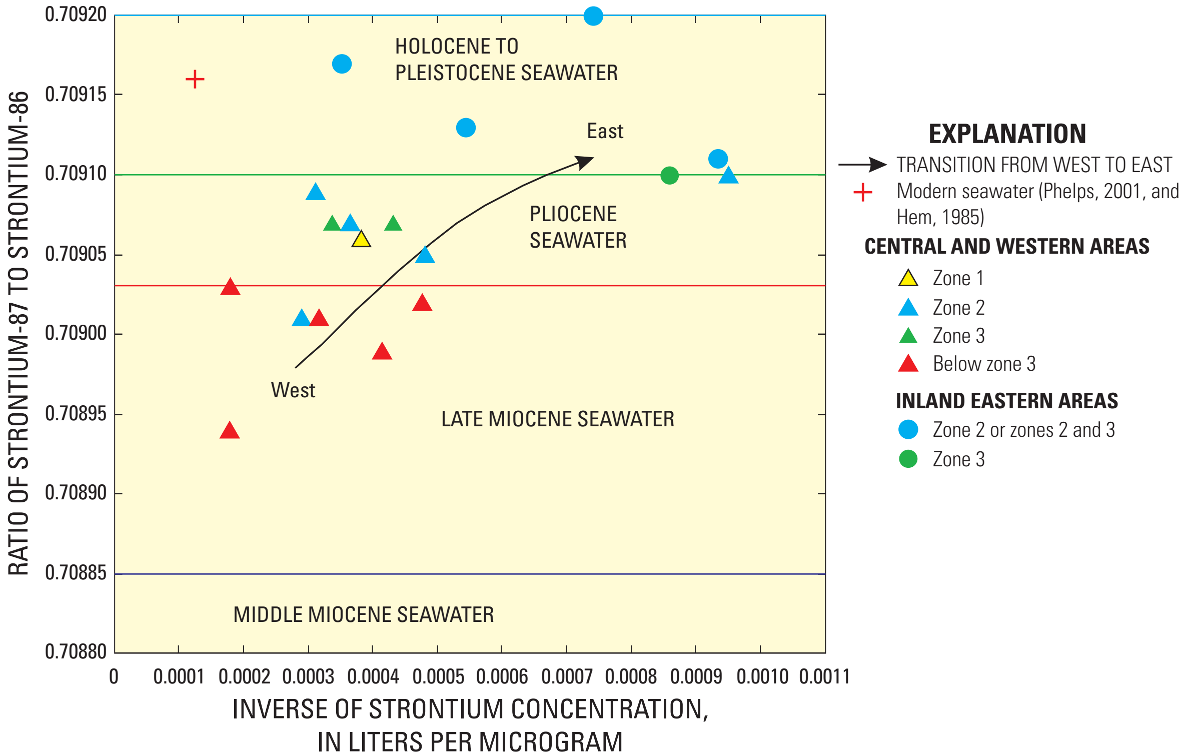


Figure 26. Relation between the ratio of strontium-87 to strontium-86 and the inverse of strontium concentration in groundwater within the study area. The indicated age of seawater based on ratio is also shown.

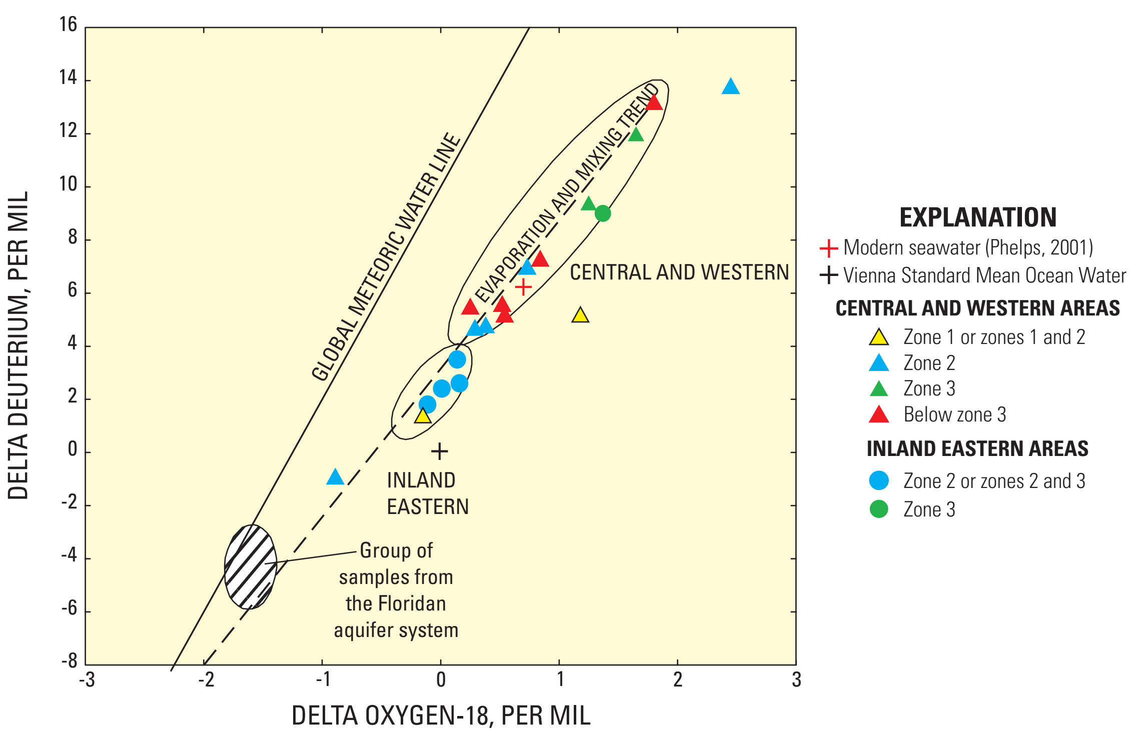


Figure 27. Relation between delta deuterium and delta oxygen-18 in groundwater within the study area. Shown for comparison is the location of a group of 31 samples from the Floridan aquifer system from nearby areas of inland Martin, St. Lucie, and Okeechobee Counties to the north of the study area (from Reese, 2004; fig. 29)

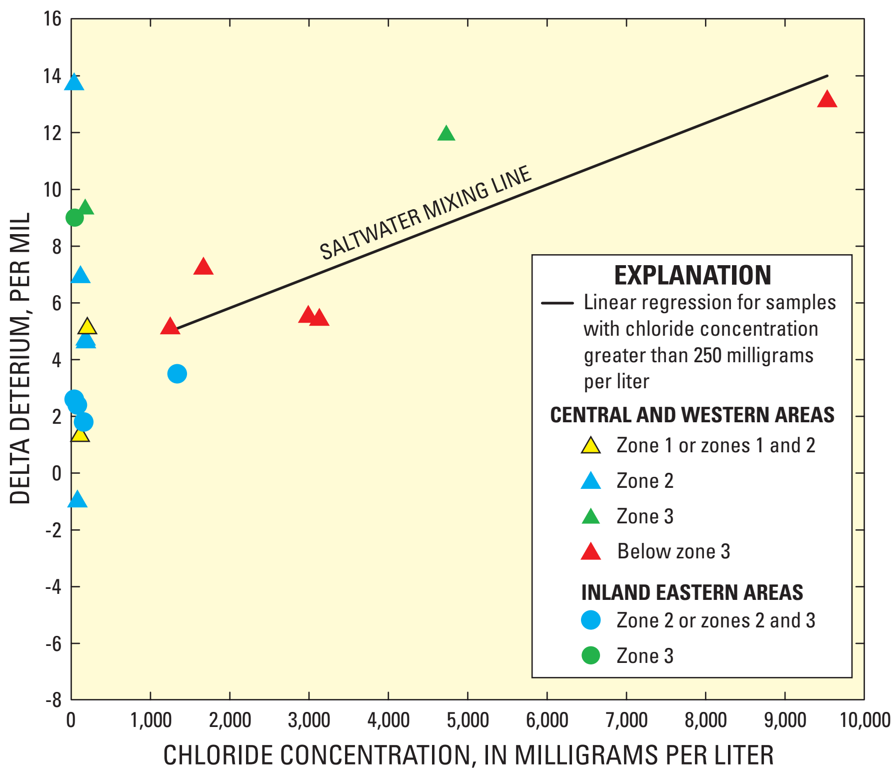


Figure 28. Relation between delta deuterium and chloride concentration in groundwater within the study area.

Summary and Conclusions

Population growth in Palm Beach County has resulted in the westward expansion of urbanized areas into agricultural areas and has created new demands on the surficial aquifer system, which is the major source of freshwater for public water supply in the county. Additionally, interest in surface-water resources in the central and western areas of the county has increased, and surface-water and groundwater interactions in this area are thought to be important to water budgets. Previous studies of the hydrogeology of this aquifer system have focused mostly on the eastern one-half to one-third of the county in the more densely populated coastal areas. These studies have not placed the hydrogeology in a framework in which stratigraphic units in this complex aquifer system are defined and correlated between wells.

Meaningful simulation of groundwater flow in the surficial aquifer system in Palm Beach County requires model construction based on lithostratigraphic unit delineation. The purpose of this study was to delineate the hydrogeologic framework of the surficial aquifer system in Palm Beach County based on a lithostratigraphic framework and to evaluate hydraulic properties and characteristics of units and permeable zones within this hydrogeologic framework.

For this purpose, five test wells were drilled, and in three of these, continuous core was collected. Standard borehole geophysical logs were run in 13 wells, flowmeter and fluid logs were run in 6 constructed wells, and single-well aquifer tests were run in 9 wells. Including the wells drilled in this study and previously drilled wells, data from 150 wells were synthesized and used for defining and mapping the lithostratigraphic framework and hydrostratigraphic units.

A lithostratigraphic framework was delineated through correlation of borehole natural GR geophysical log markers between all the wells with GR logs and lithologic descriptions. These correlation markers approximately correspond to important lithostratigraphic unit boundaries, and were selected through comparison of GR logs to lithostratigraphic boundaries determined in cores collected from test coreholes. The markers approximate the tops of the Hawthorn Group, the Ochopee Limestone Member of the Tamiami Formation, the Pinecrest Member of the Tamiami Formation, and the Fort Thompson Formation.

The surficial aquifer system was divided into three main permeable zones or subaquifers, which are, from shallowest to deepest, zones 1, 2, and 3; the correlation markers were used as guides to the top or base of zones. Zone 1 is present above the Tamiami Formation in the Anastasia and Fort Thompson Formations, zone 2 primarily is present in the upper part of the Tamiami Formation in the Pinecrest Sand Member or its correlative equivalent, and zone 3 is present in the Ochopee Limestone Member of the Tamiami Formation or its correlative equivalent. Differences in lithologic character exist among these three zones, and commonly include differences in the nature of the pore space. High intergrain porosity (between shells or shell fragments) is common in zone 1, interconnected vugs or cavities are common in zone 2, and moldic and intergrain porosity are common in zone 3.

Zone 1, which commonly forms the water-table aquifer, attains its greatest thickness (50 ft or more) in coastal areas. Zone 2, the most transmissive and extensive zone, is thickest (80 ft or more) in the inland eastern areas close to Florida's Turnpike. The thickness of zone 2 decreases to zero in most wells located close to the coast. Zone 3 attains its greatest thickness (100 ft or more) in the southwestern and south-central areas, where it is equivalent to the gray limestone aquifer.

The thickness of semiconfining units between zones is variable and commonly ranges from 10 to 60 ft. In a large area located mostly in the inland southeastern and northeastern areas, however, zone 1 is absent, and the semiconfining unit above zone 2 extends to the land surface and has a thickness that commonly ranges from 50 to 100 ft. In some areas, confinement between zones 2 and 3 probably is not effective because of the limited thickness of the confining unit or the nature of the material in the unit. Because the thickness of the confining unit separating zones 2 and 3 is limited or difficult to define in much of the study area, the thicknesses of zones 2 and 3 were combined and mapped as one unit. The combined thickness of zones 2 and 3 reaches 100 ft or greater in the inland eastern areas.

Data on 68 aquifer tests were compiled, including tests run in this study and previously conducted tests. Additionally, data for 10 specific capacity tests were compiled. These data were used to define hydraulic properties, compare transmissivity values derived by different methods, and map the distribution of transmissivity in the surficial aquifer system. Transmissivity values determined from both drawdown and recovery data measured in production wells were compared to the transmissivity determined from monitoring well drawdown data at the same site, with all analysis methods assuming confined aquifer conditions.

The semiconfining unit above zone 2 in the eastern areas is predominantly composed of very fine- to medium-grained, relatively clean quartz sand, which indicates moderate horizontal hydraulic conductivity in the range of 10 to 100 ft/d. The vertical hydraulic conductivity of this unit based on an aquifer tests, however, is less than 10 ft/d.

The depths of flow zones and the percentage of total flow for each zone were determined in six constructed wells, based on fluid temperature and resistivity log curve deviations and flowmeter logs run under ambient and pumping conditions. Analyses of these logs and comparison of the results with the depths of the three mapped permeable zones indicated that zone 2 contained the largest flow zones. A flow zone in zone 2 in one well in the inland eastern area contributed 60 percent of the total flow from the well.

The distribution of transmissivity was mapped by zone; however, for many aquifer tests, wells were open to both zones 2 and 3, and the resulting transmissivity values represent a composite value for both zones. Maximum transmissivities for zone 1, zones 2 and 3, and zone 3 were 90,000, 180,000, and 70,000 ft^2/d (feet-squared per day), respectively, in the coastal areas, the inland eastern areas, and the southwestern area, respectively. The northern extent of high transmissivity for the composite of zones 2 and 3 in the inland northeastern area along Florida's Turnpike has not been defined based on available tests; the area with transmissivity greater than 50,000 ft^2/d could extend 5 to 10 mi farther north than mapped in this area, as indicated by the combined thickness of zones 2 and 3. Based on the thickness of zone 2 and a limited number of aquifer tests, a large area within zone 2 that has an associated transmissivity greater than 10,000 ft^2/d, and possibly as much as 30,000 ft^2/d, extends to the west across Water-Conservation Area 1 from the inland southeastern area into the south-central area and some of the southwestern area. An east-west transition in thickness and transmissivity from zone 2 to 3 is present between the south-central and southwestern areas, but the hydraulic connection between these two zones in the area of this transition is probably good. Most tests in the eastern areas where only zone 3 was tested indicate a transmissivity of about 10,000 ft^2/d or less.

Previous definitions of the Biscayne and gray limestone aquifers were reviewed for comparison to the zones of high permeability mapped in this study. The Biscayne aquifer was originally shown as extending only into the southern part of southeastern Palm Beach County. The surficial aquifer system in the area of greatest thickness and transmissivity of combined zones 2 and 3 in the inland eastern areas may not be included in the Biscayne aquifer, because these zones are interpreted to be present principally in the Tamiami Formation and are commonly overlain by a thick semiconfining unit of moderate permeability. Perhaps use of the local name "Turnpike" aquifer for zones 2 and 3, mapped in the inland eastern areas, would be beneficial, because the extent of greatest thickness and transmissivity in these zones follows, or is adjacent to, Florida's Turnpike. In parts of the coastal areas where it is thick and transmissive, zone 1 may be considered equivalent to the Biscayne aquifer.

Areas of high salinity in the surficial aquifer system in the central and western areas of the county have been identified and mapped in previous studies, and water samples were collected from 19 wells in this study to gain a better understanding of the origin of this high salinity water. Evidence for upwelling of brackish or saline water from the Floridan aquifer system or deeper was not found, based on strontium concentration and isotope data, as well as hydrogen and oxygen isotope data. The seawater age indicated by strontium isotope ratios measured in water produced from wells sampled in the central and western areas correlates with the expected age of the sediments, which ranges from Pliocene to late Miocene. These data support a hypothesis of residual invaded or relict seawater for the origin of this high salinity groundwater; nevertheless, the number of wells sampled was limited and large areas near Lake Okeechobee were not sampled.

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Appendix 1.

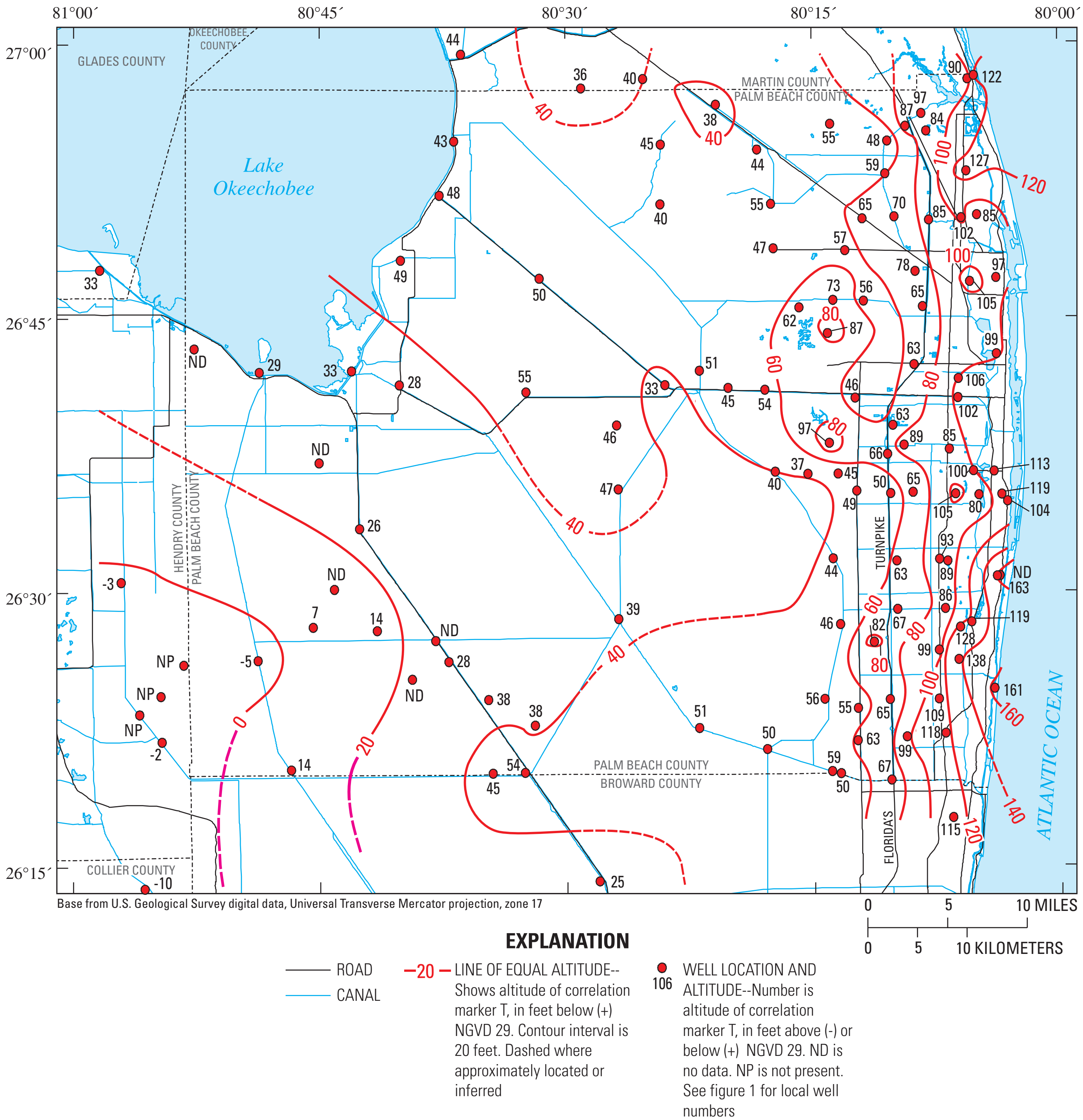
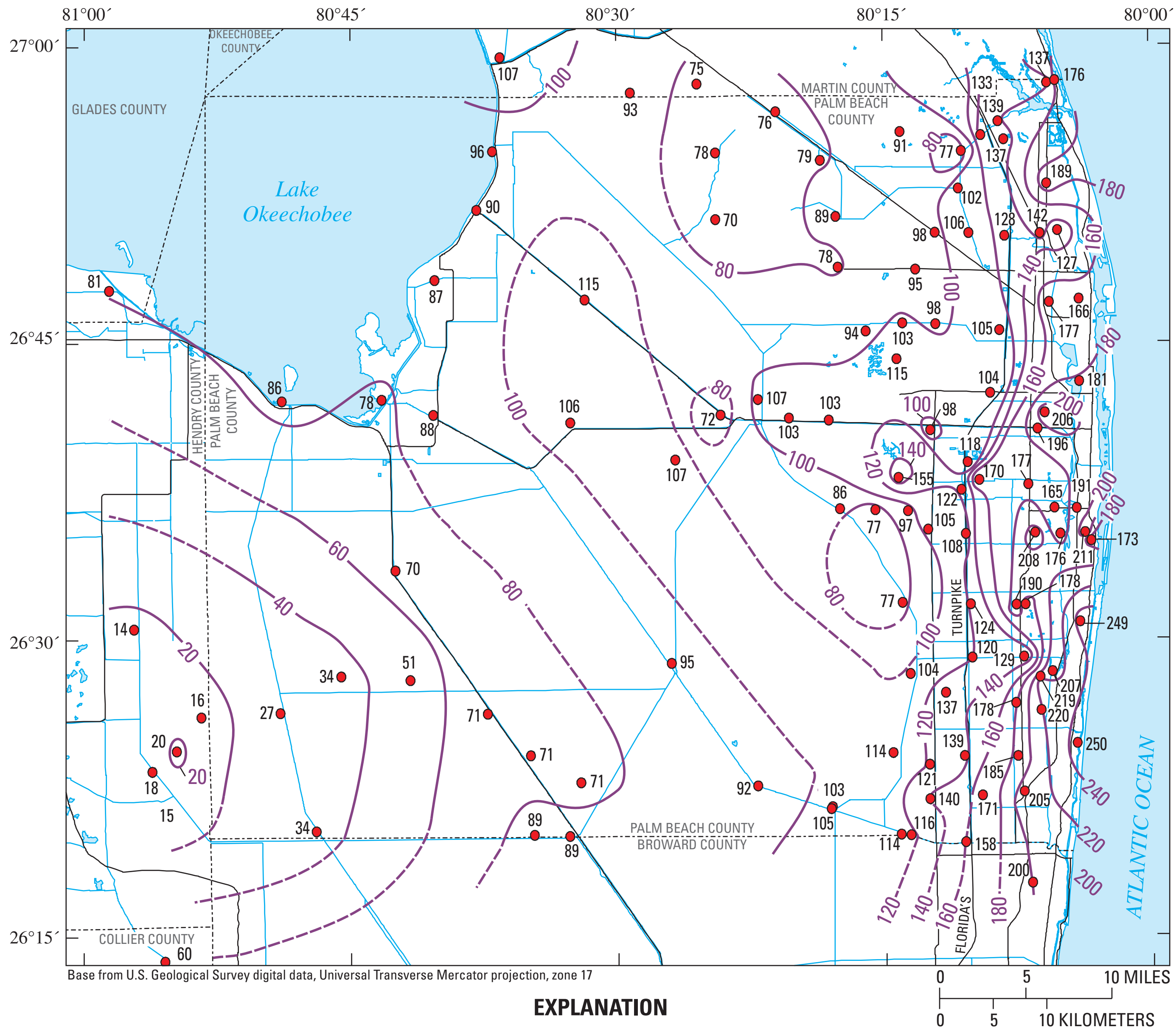


Figure 1–1. Altitude of the T marker correlation.



EXPLANATION

ROAD

CANAL

20 LINE OF EQUAL ALTITUDE--Shows altitude of correlation marker O, in feet below (+) NGVD 29. Contour interval is 20 feet. Dashed where approximately located or inferred

103 WELL LOCATION AND ALTITUDE--Number is altitude of correlation marker O, in feet below (+) NGVD 29. See figure 1 for local well numbers

Figure 1–2. Altitude of the O correlation marker.

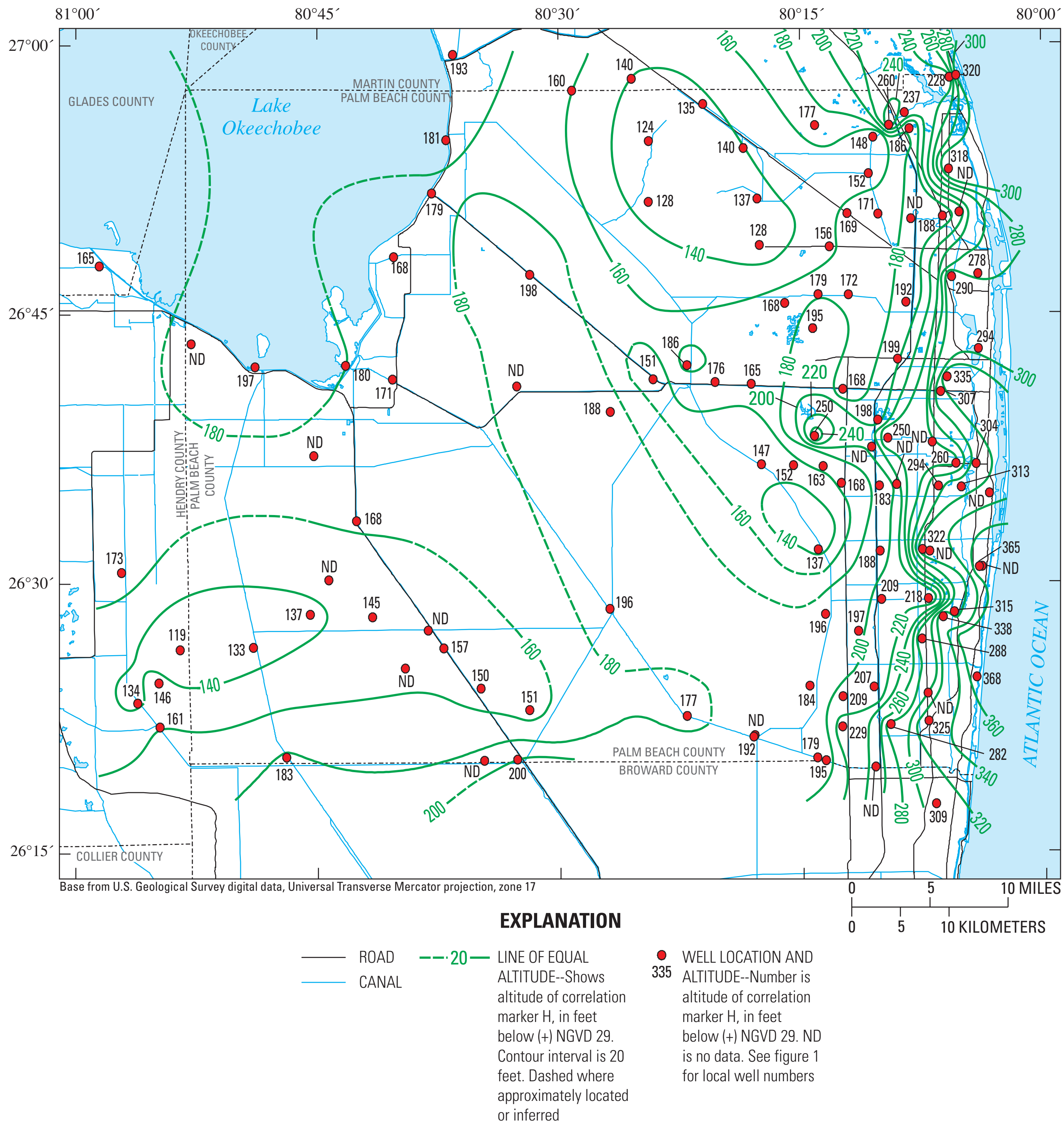


Figure 1–3. Altitude of the H correlation marker

Table 1–1. Inventory of all wells used in this study.

[Total hole depth is in feet below land surface; ASR, aqufier storage and recovery; CERP, Comprehensive Everglades Restoration Plan; NR, not reported; PBCWUD, Palm Beach County Water Utilities Department; RO, reverse osmosis; SFWMD, South Florida Water Management District; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WTP, wastewater treatment plant]

USGS local well name	Other identifier	Source study or owner	Latitude north (dd mm ss.ss)	Longitude west (dd mm ss.ss)	Horizontal datum	Total hole depth (feet)	Altitude of land surface (feet NGVD 29)
C-1156	W-10018		26 15 00	80 57 20	NAD 27	1,000	14
C-1169	W-17614, Big Cypress Sanctuary	Reese and Cunningham (2000)	26 13 17	80 55 52	NAD 27	195	15
G-2312	BRT-19	Fish (1988)	26 13 47	80 27 37	NAD 27	229	15
G-2313	BRT-14	Fish (1988)	26 19 58	80 41 06	NAD 27	219	12
G-2314	BRT-13	Fish (1988)	26 19 52	80 50 02	NAD 27	199	20
G-2315	BRT-15	Fish (1988)	26 19 58	80 34 21	NAD 27	249	18
G-2340	BRT-20	Fish (1988)	26 14 58	80 49 47	NAD 27	199	14
G-2916	MW-1	Broward County WTP 2A ASR	26 17 36	80 06 24	NAD 27	1,200	17
HE-1108	HY-301, HM-265	SFWMD	26 24 40	80 56 50	NAD 27	132	20
HE-1110	L-3 Deep	Reese and Cunningham (2000)	26 23 09	80 55 48	NAD 27	160	15
HE-1116	W-17868, L-2 Deep	Reese and Cunningham (2000)	26 30 23	80 56 52	NAD 83	195	18
HE-1142	CP02-EAARS-CB-0005	CERP, USACE	26 25 55.6	80 53 04.4	NAD 27	184	14.09
HE-1143	CP02-EAARS-CB-0006	CERP, USACE	26 21 42.7	80 54 22.8	NAD 27	181	14.63
HE-1144	CP02-EAARS-CB-0014	CERP, USACE	26 24 12.7	80 54 27.2	NAD 27	182	15.85
M-1361	EXPM-1	Port Mayaca ASR, SFWMD	26 59 17	80 36 20	NAD 83	1,380	22.20
M-1367	CP02-NPBP1-CB-0055	CERP, USACE	26 57 57.2	80 25 17.4	NAD 83	206	27.10
PB-600		Schneider (1976)	26 36 33	80 03 57	NAD 27	345	15
PB-634		Schneider (1976)	26 30 50	80 03 35	NAD 27	188	10
PB-640		Schneider (1976)	26 55 32	80 13 56	NAD 27	236	19
PB-649		Schneider (1976)	26 56 33	80 20 52	NAD 27	205	26
PB-650		Schneider (1976)	26 57 28	80 29 00	NAD 27	193	7
PB-651		Schneider (1976)	26 54 32	80 36 45	NAD 27	236	22
PB-652A		Schneider (1976)	26 47 08	80 03 51	NAD 27	314	20
PB-653		Schneider (1976)	26 46 56	80 05 29	NAD 27	314	12
PB-654		Schneider (1976)	26 47 08	80 06 58	NAD 27	282	18
PB-655		Schneider (1976)	26 48 38	80 09 20	NAD 27	267	20
PB-657	Palm Beach County	Schneider (1976)	26 37 58	80 09 25	NAD 27	281	18
PB-658		Schneider (1976)	26 22 01	80 09 13	NAD 27	365	15
PB-665		Schneider (1976)	26 21 47	80 12 13	NAD 27	225	18

Table 1–1. Inventory of all wells used in this study.—Continued

[Total hole depth is in feet below land surface; ASR, aqufier storage and recovery; CERP, Comprehensive Everglades Restoration Plan; NR, not reported; PBCWUD, Palm Beach County Water Utilities Department; RO, reverse osmosis; SFWMD, South Florida Water Management District; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WTP, wastewater treatment plant]

USGS local well name	Other identifier	Source study or owner	Latitude north (dd mm ss.ss)	Longitude west (dd mm ss.ss)	Horizontal datum	Total hole depth (feet)	Altitude of land surface (feet NGVD 29)
PB-666		Schneider (1976)	26 22 13	80 06 52	NAD 27	415	13
PB-667		Schneider (1976)	26 41 23	80 05 45	NAD 27	357	15
PB-668		Schneider (1976)	26 36 34	80 05 12	NAD 27	358	10
PB-669		Schneider (1976)	26 35 15	80 04 52	NAD 27	345	12
PB-670		Schneider (1976)	26 35 18	80 06 17	NAD 27	325	15
PB-671		Schneider (1976)	26 35 23	80 08 52	NAD 27	119	18
PB-672		Schneider (1976)	26 35 27	80 12 17	NAD 27	234	18
PB-673		Schneider (1976)	26 28 59	80 09 48	NAD 27	248	19
PB-674		Schneider (1976)	26 29 02	80 06 54	NAD 27	302	17
PB-675		Schneider (1976)	26 28 18	80 05 18	NAD 27	387	14
PB-676		Schneider (1976)	26 41 13	80 23 56	NAD 27	175	15
PB-677		Schneider (1976)	26 41 04	80 20 06	NAD 27	190	16
PB-678		Schneider (1976)	26 40 58	80 17 52	NAD 27	189	20
PB-679		Schneider (1976)	26 48 42	80 17 22	NAD 27	174	22
PB-681		Schneider (1976)	26 58 02	80 05 38	NAD 27	248	12
PB-690		Schneider (1976)	26 27 12	80 04 07	NAD 27	275	11
PB-694		Schneider (1976)	26 36 27	80 03 04	NAD 27	249	8
PB-695		Schneider (1976)	26 37 46	80 02 56	NAD 27	249	6
PB-699		Schneider (1976)	26 40 43	80 09 27	NAD 27	357	20
PB-708		Schneider (1976)	26 52 00	80 03 20	NAD 27	154	18
PB-712		Schneider (1976)	26 55 10	80 08 07	NAD 27	280	14
PB-715		USGS	26 51 14.7	80 17 30.8	NAD 27	81	23
PB-747	PB-733, injection	SFWMD	26 56 06	80 08 24	NAD 83	1,280	13
PB-798		Schneider (1976)	26 45 37	80 08 56	NAD 27	120	18
PB-830		Schneider (1976)	26 51 04.5	80 24 42.8	NAD 27	220	22
PB-833		Schneider (1976)	26 52 58	80 05 40	NAD 27	520	10
PB-834B		Schneider (1976)	26 34 55	80 03 08	NAD 27	201	8
PB-836		Schneider (1976)	26 40 49	80 32 22	NAD 27	240	12
PB-837		Schneider (1976)	26 47 02	80 31 34	NAD 27	200	12
PB-838		Schneider (1976)	26 51 34	80 37 38	NAD 27	240	14

Table 1–1. Inventory of all wells used in this study.—Continued

[Total hole depth is in feet below land surface; ASR, aqufier storage and recovery; CERP, Comprehensive Everglades Restoration Plan; NR, not reported; PBCWUD, Palm Beach County Water Utilities Department; RO, reverse osmosis; SFWMD, South Florida Water Management District; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WTP, wastewater treatment plant]

USGS local well name	Other identifier	Source study or owner	Latitude north (dd mm ss.ss)	Longitude west (dd mm ss.ss)	Horizontal datum	Total hole depth (feet)	Altitude of land surface (feet NGVD 29)
PB-839		Schneider (1976)	26 41 12	80 40 03	NAD 27	220	15
PB-841		Schneider (1976)	26 20 00	80 32 20	NAD 27	250	20
PB-842		Schneider (1976)	26 20 00	80 46 40	NAD 27	240	16
PB-843		Schneider (1976)	26 41 53	80 48 33	NAD 27	575	13
PB-880		Other	26 54 37.2	80 10 30.8	NAD 27	118	17.06
PB-1026		Fischer (1980)	26 47 15	80 08 23	NAD 27	114	17
PB-1029		Swayze and others (1980)	26 48 02	80 08 13	NAD 27	129	18
PB-1038		Swayze and others (1980)	26 48 17	80 06 23	NAD 27	123	17
PB-1065	APT production well	Fischer (1980)	26 46 10	80 07 25	NAD 27	115	16
PB-1082		Swayze and others (1980)	26 50 34	80 05 01	NAD 27	200	12
PB-1083		Swayze and others (1980)	26 50 27	80 06 00	NAD 27	200	12
PB-1084		Swayze and others (1980)	26 50 27	80 10 02	NAD 27	200	18
PB-1085		Swayze and others (1980)	26 50 27	80 11 57	NAD 27	200	18
PB-1086		Swayze and others (1980)	26 50 18	80 07 58	NAD 27	200	18
PB-1087		Swayze and others (1980)	26 45 55	80 11 52	NAD 27	200	18
PB-1088		Swayze and others (1980)	26 45 55	80 13 44	NAD 27	200	19
PB-1089		Swayze and others (1980)	26 42 25	80 08 47	NAD 27	240	17
PB-1090		Swayze and others (1980)	26 37 45	80 06 40	NAD 27	200	16
PB-1091		Swayze and others (1980)	26 37 28	80 10 25	NAD 27	160	17
PB-1092		Swayze and others (1980)	26 36 23	80 13 25	NAD 27	200	18
PB-1093		Swayze and others (1980)	26 36 26	80 15 15	NAD 27	200	18
PB-1094		Swayze and others (1980)	26 36 29	80 17 14	NAD 27	180	18
PB-1095		Schneider (1976)	26 31 38	80 06 47	NAD 27	300	17
PB-1096		Schneider (1976)	26 31 38	80 09 52	NAD 27	220	20
PB-1097		Swayze and others (1980)	26 31 45.2	80 13 42.4	NAD 27	160	16
PB-1098		Swayze and others (1980)	26 48 36	80 13 01	NAD 27	180	20
PB-1099		Swayze and others (1980)	26 52 50	80 10 36	NAD 27	180	18
PB-1100		Swayze and others (1980)	26 20 07	80 13 45	NAD 27	200	15
PB-1101		Swayze and others (1980)	26 24 05	80 07 18	NAD 27	220	19
PB-1102		Swayze and others (1980)	26 27 11	80 11 14	NAD 27	235	18

Table 1–1. Inventory of all wells used in this study.—Continued

[Total hole depth is in feet below land surface; ASR, aqufier storage and recovery; CERP, Comprehensive Everglades Restoration Plan; NR, not reported; PBCWUD, Palm Beach County Water Utilities Department; RO, reverse osmosis; SFWMD, South Florida Water Management District; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WTP, wastewater treatment plant]

USGS local well name	Other identifier	Source study or owner	Latitude north (dd mm ss.ss)	Longitude west (dd mm ss.ss)	Horizontal datum	Total hole depth (feet)	Altitude of land surface (feet NGVD 29)
PB-1103		Swayze and others (1980)	26 24 03	80 10 16	NAD 27	240	21
PB-1104		Swayze and others (1980)	26 26 45	80 07 18	NAD 27	340	20
PB-1105		Swayze and others (1980)	26 19 39	80 10 09	NAD 27	217	15
PB-1106		Swayze and others (1980)	26 22 28	80 21 49	NAD 27	217	23
PB-1107		Swayze and others (1980)	26 28 07.9	80 13 16.7	NAD 27	200	15
PB-1108		Swayze and others (1980)	26 24 03	80 14 13	NAD 27	200	14
PB-1109		Swayze and others (1980)	26 51 15	80 17 31	NAD 27	171	23
PB-1144	PBF-1	BRDVW CONDOS, SFWMD	26 58 11	80 05 13	NAD 83	1,038	13
PB-1166	IW-1	Pratt & Whitney	26 54 06	80 18 22	NAD 27	3,310	25
PB-1168	IW-1	PBCWUD System 9 North	26 23 34	80 12 11	NAD 27	3,300	20
PB-1173	MW-1	ACME Improvement District	26 38 04	80 13 57	NAD 27	2,010	17
PB-1176	IW-1	Royal Palm Beach	26 44 04	80 14 04	NAD 27	3,300	17.83
PB-1184	IW-1	Pahokee	26 48 01	80 39 59	NAD 27	3,510	13.03
PB-1192	RO IW-1	Boynton Beach RO Reject	26 31 44	80 07 17	NAD 27	3,312	19.42
PB-1195	ASR MW-1	Boynton Beach East WTP	26 30 49	80 03 45	NAD 27	435	18.90
PB-1197	RO-5	Jupiter RO	26 55 24	80 09 22	NAD 27	1,665	17
PB-1544	APT site 9 deep test well	USGS	26 38 57.9	80 10 09.5	NAD 83	260	18
PB-1545	APT site 9 production well	USGS	26 38 57.9	80 10 09.5	NAD 83	160	18
PB-1546	APT site 15 deep test well	USGS	26 56 06	80 13 55	NAD 27	170	20
PB-1547	APT site 15 production well	USGS	26 56 06	80 13 55	NAD 27	120	20
PB-1550	APT site 14 deep test well	USGS	26 51 34	80 17 27	NAD 27	180	23
PB-1555	APT site 13 deep test well	USGS	26 48 43	80 12 50	NAD 27	190	19
PB-1558	APT site 12 deep test well	USGS	26 48 34	80 19 34	NAD 27	200	20
PB-1564	APT site 11 deep test well	USGS	26 45 55	80 15 17	NAD 27	220	20
PB-1567	APT site 10 deep test well	USGS	26 41 01	80 16 30	NAD 27	190	17
PB-1571	APT site 8 deep test well	USGS	26 35 09	80 10 22	NAD 27	260	19
PB-1574	APT site 2 deep test well	USGS	26 25 53	80 12 15	NAD 27	240	19
PB-1576	APT site 16 deep test well	USGS	26 32 55	80 13 36	NAD 27	190	17
PB-1578	APT site 7 deep test well	USGS	26 37 02	80 05 19	NAD 27	270	10
PB-1581	APT site 1 deep test well	USGS	26 21 47	80 10 16	NAD 27	320	17

Table 1–1. Inventory of all wells used in this study.—Continued

[Total hole depth is in feet below land surface; ASR, aqufier storage and recovery; CERP, Comprehensive Everglades Restoration Plan; NR, not reported; PBCWUD, Palm Beach County Water Utilities Department; RO, reverse osmosis; SFWMD, South Florida Water Management District; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WTP, wastewater treatment plant]

USGS local well name	Other identifier	Source study or owner	Latitude north (dd mm ss.ss)	Longitude west (dd mm ss.ss)	Horizontal datum	Total hole depth (feet)	Altitude of land surface (feet NGVD 29)
PB-1586	APT site 6 deep test well	USGS	26 34 43	80 03 30	NAD 27	420	18
PB-1598	APT site 4 deep test well	USGS	26 28 05	80 10 16	NAD 27	270	19
PB-1603	APT site 5 deep test well	USGS	26 32 16	80 06 17	NAD 27	390	15
PB-1605	APT site 3 deep test well	USGS	26 26 36	80 06 21	NAD 27	430	15
PB-1607	APT site 17 deep test well	USGS	26 52 48	80 10 38	NAD 27	220	18
PB-1608	APT site 17 production well	USGS	26 52 48	80 10 38	NAD 27	150	18
PB-1613		USGS	26 54 27	80 24 15	NAD 27	162	25
PB-1614		USGS	26 56 33	80 20 30	NAD 27	155	24
PB-1693	ASR MW-1	West Palm Beach ASR	26 42 58	80 03 49	NAD 83	1,191	18.97
PB-1695	PBF-3,4,5; Lake Lytal	SFWMD	26 40 34	80 06 09	NAD 27	2,490	15
PB-1696	W-7500	Sugar Cane Growers Coop	26 25 06	80 39 15	NAD 27	1,705	11
PB-1702	ASR-1	Delray Beach North Storage Reservoir	26 28 01	80 05 59	NAD 27	1,200	21.20
PB-1703	W-17554, G-200	Reese and Cunningham (2000)	26 26 07	80 48 37	NAD 27	221	20
PB-1704	W-17747, Sod Farm	Reese and Cunningham (2000)	26 23 59	80 34 34	NAD 27	201	11
PB-1761	B-6 Core Test	USGS	26 21 19.1	80 17 41.8	NAD 27	120	10
PB-1765	ASR EXW-1, Hillsboro Canal West Site 1	SFWMD	26 21 19	80 17 42	NAD 83	1,225	10
PB-1769	PBC-2	SFWMD (Saltwater monitoring network)	26 35 22	80 03 30	NAD 27	337	15
PB-1775	ASR FAMW, Hillsboro Canal East	PBCWUD	26 20 00	80 13 13	NAD 27	1,650	16.33
PB-1777	PBF-7, South Bay	SFWMD	26 41 58	80 42 57	NAD 27	2,504	10
PB-1781	CP02-NPBP1-CB-0056	CERP, USACE	26 42 00.2	80 21 50.6	NAD 83	205	13.90
PB-1782	CP02-NPBP1-CB-0057	CERP, USACE	26 45 32.6	80 08 18	NAD 83	206	17.80
PB-1783	CP02-NPBP1-CB-0058	CERP, USACE	26 45 28.1	80 15 48	NAD 83	205	21.60
PB-1784	DMW-2	Highland Beach RO Reject	26 24 40	80 03 54	NAD 83	425	8
PB-1785	CP02-EAARS-CB-0001	CERP, USACE	26 26 07.3	80 37 00.4	NAD 27	180	11.84
PB-1786	CP02-EAARS-CB-0002	CERP, USACE	26 28 00.1	80 45 13.7	NAD 27	182	13.38
PB-1787	CP02-EAARS-CB-0003	CERP, USACE	26 27 49	80 41 21	NAD 27	183	12.15
PB-1788	CP02-EAARS-CB-0004	CERP, USACE	26 22 39	80 31 46	NAD 27	180	11.39
PB-1789	CP02-EAARS-CB-0007	CERP, USACE	26 23 52.9	80 35 16.6	NAD 27	76	11.82
PB-1790	CP02-EAARS-CB-0008	CERP, USACE	26 28 13.1	80 38 38.4	NAD 27	67	11.56
PB-1792	CP02-EAARS-MW-0010	CERP, USACE	26 23 58.3	80 40 52.5	NAD 27	73	11.92

Table 1–1. Inventory of all wells used in this study.—Continued

[Total hole depth is in feet below land surface; ASR, aqufier storage and recovery; CERP, Comprehensive Everglades Restoration Plan; NR, not reported; PBCWUD, Palm Beach County Water Utilities Department; RO, reverse osmosis; SFWMD, South Florida Water Management District; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WTP, wastewater treatment plant]

USGS local well name	Other identifier	Source study or owner	Latitude north (dd mm ss.ss)	Longitude west (dd mm ss.ss)	Horizontal datum	Total hole depth (feet)	Altitude of land surface (feet NGVD 29)
PB-1794	MP2-A, ENR	Harvey and others (2002)	26 38 19.4	80 25 38.3	NAD 27	101.9	15.6
PB-1797	MP3-A, ENR	Harvey and others (2002)	26 38 54.5	80 26 40.1	NAD 27	191	17.20
PB-1798	MP3-B, ENR	Harvey and others (2002)	26 38 54.5	80 26 40.1	NAD 27	190.9	17.2
PB-1801	BP-DMW-W	SFWMD	26 20 54.27	80 17 49.33	NAD 83	107	12.44
PB-1802	BP-SMW-W	SFWMD	26 20 54.36	80 17 49.33	NAD 83	32	12.48
PB-1803	HASR-SASMW-1	SFWMD	26 21 17.7	80 17 41.5	NAD 27	208	11
PB-1804	LEC 7, S-6 Pump Station	This study	26 28 29.4	80 26 54.2	NAD 83	230	12
PB-1805	LEC 8, US 27, bend to north	This study	26 33 59	80 42 35.7	NAD 83	200	12
PB-1806	LEC 9, US 441 & C-51	This study	26 40 46.5	80 12 10.7	NAD 83	205	20
PB-1807	LEC 10, APT site 8, Turnpike and Lantana Rd	This study	26 35 12.3	80 10 21.4	NAD 83	205	19
PB-1808	LEC 11, SR 710 & C-18	This study (data not used)	26 48 47.6	80 09 21.4	NAD 83	200	18
W-5435			26 47 28	80 58 14	NAD 27	1,200	5

Table 1–2. PB-1761 (B-6 core test) lithologic description.

[Descriptions by R.S. Reese, March 2006. All references to “sandstone,” “sand” or “sandy” imply dominantly quartz sand unless otherwise specified, such as carbonate or shell sand. Color is according to the Rock-color chart based on the Munsell system (1948). Continuous core from surface to total depth of 120 ft]

Top (feet)	Bottom (feet)	Thickness (feet)	Recovered (feet)	Primary rock type	Color	Grain size	Notes
0.0	5.0	5.0	0.5	Sandy limestone	Light gray	Fine-medium quartz sand	Abundant quartz sand in matix. May be more of a sandstone.
5.0	9.0	4.0	3.5	Sandy floatstone-rudstone	White to yellowish-gray to light gray		Abundant quartz sand (fine-medium) in places. High moldic porosity. Many shells dissolved; schizoporella bryozoan
9.0	10.0	1.0	0.3	Sandstone	Yellowish-gray	Fine-medium	Quartzose, with abundant shells
10.0	15.0	5.0	No recovery	Cuttings: sandstone	Pinkish gray	Fine-medium	Quartzose, no shells
15.0	17.0	2.0	~2	Sandstone	Yellowish-gray to light gray	Fine-coarse	Quartzose; abundant large shells; more abundant lime grains in lower part; light to medium light gray mottling which could be infilling or burrowing
17.0	20.0	3.0	< 1.0	Limestone	Light to medium-light gray	Abundant shell fragments	Matrix is quartz sandstone and gray mottled sandy micrite
20.0	25.0	5.0	4.0	Limestone	Similar to above	More shells than above	Laminated calcrete at 21 ft (light and gray layers); gastropod rich layer with abundant lime mud infilling at 21.5 ft; lower part is mostly stacked whole molusk shells—most shells are not leached out (original shell material); high porosity
25.0	30.0	5.0	2.0	Limestone-grainstone	As above	Coarse shell coquina	Solidary coral fragments at 26.5 ft
30.0	35.0	5.0	<1.0	Sand	Yellowish-gray	Fine, well sorted	Loose; occasional quarter to penny-sized calm shells similar to above; trace black grains
35.0	40.0	5.0	<1.0	Sand	Yellowish-gray	Fine-coarse, mostly fine	Loose; more shells than above; rare black grains; Lower part grades to brown blebs imbedded in matrix; (could be organic matter or FeO in soil zone)
40.0	44.5	4.5	4.0	Sand	Very light gray to yellowish-gray	Fine, well sorted	Abundant coarse shell fragments; black grains—trace to 1 or 2%; may grade into lime sand in places
44.5	45.0	0.5	0.4	Lime mudstone	Light brownish gray		
45.0	47.0	2.0	1.5	Sand	Yellowish-gray	Fine, poorly sorted	Silty to muddy; grades down to abundant large shells
47.0	48.0	1.0	1.0	Lime mudstone to shell hash	Very light gray		
48.0	49.0	1.0	1.0	Floatstone	Very light gray to light gray	Very coarse whole shells (original material)	Dense, low porosity; some fine quartz sand in matix; steep irregular dissolution surface at top with some infilling of brownish material from above; solidary coral on top of slope

Table 1–2. PB-1761 (B-6 core test) lithologic description.—Continued

[Descriptions by R.S. Reese, March 2006. All references to “sandstone,” “sand” or “sandy” imply dominantly quartz sand unless otherwise specified, such as carbonate or shell sand. Color is according to the Rock-color chart based on the Munsell system (1948). Continuous core from surface to total depth of 120 ft]

Top (feet)	Bottom (feet)	Thickness (feet)	Recovered (feet)	Primary rock type	Color	Grain size	Notes
49.0	50.0	1.0	0.0	Assumes two feet recovered from 47–50 ft is from top of interval			
50.0	53.0	3.0	1.5	Floatstone, similar to above	Very light gray to light gray	May be more of a sandstone at top (upper few inches)	Shell fragments are dense; another steep dissolution surface a few inches from top with conch shells on top; trace black grains
53.0	54.5	1.5	1.5	Floatstone, similar to above		May be more fine quartz sand	Areas of mottled darker gray limestone; may be bioturbated; looks like areas of dissolution coated with darker gray limestone
54.5	55.0	0.5	0.5	Floatstone, same as above	Grades to medium or medium dark gray in places	Very coarse shell fragments	Large monastria coral at bottom
55.0	57.0	2.0	1.0	Floatstone, similar to above	Mottled yellowish-gray to medium or medium dark gray		Dense; large whole pelypod shells in lower part, also monastria coral fragments; lower part is sandstone to mudstone, yellowish-gray, muddy, silty with medium grained quartz common
57.0	60.0	3.0	0.7	Laminated calcrete	Yellowish-gray to medium or medium dark gray		Mostly mudstone grading down to sandstone(?), brecciated layers and shell material; medium gray layer at top (surface coating with crinulated bottom); at bottom—piece of monastria coral and shell coquina
60.0	65.0	5.0	0.1 to 0.2	Mudstone	White to medium gray		Hard, dense, abundant shell fragments; pin point porosity
65.0	70.0	5.0	0.9	Sand	Yellowish-gray	Fine (silty to coarse), poorly to moderate sorted	Shell fragments common; fine grained black grains common (trace to 2 or 3%); some coarse quartz grains
70.0	75.0	5.0	1.3	Mudstone		Abundant shell fragments	Trace fine black grains; pinpoint porosity
		Grades down to:		Shell		Muddy	Unconsolidated; some whole shells; lime sand to mud matrix; shell fragments increase with depth
75.0	76.0	1.0	0.4	Sand, as above at 65 ft			
76.0	80.0	4.0	1.9	Sand, same as above	Gray color increasing		Abundant coarse grain shell flakes; black grains more common (5–10%); in lower part abundant whole or mostly whole small to medium molusk shells
80.0	85.0	5.0	1.8	Sandstone to sandy grainstone	Light gray	Fine-coarse	50–50 quartz grains(?); lime grains are limestone and shell; quartz grains tend to be finer; phosphatic; coarser grained and less quartz toward bottom
85.0	90.0	5.0	1.3	Grainstone to wackstone	Similar to above		Overall less quartz sand than above; grades down to lime mud matrix with some large original clam shells

Table 1–2. PB-1761 (B-6 core test) lithologic description.—Continued

[Descriptions by R.S. Reese, March 2006. All references to "sandstone," "sand" or "sandy" imply dominantly quartz sand unless otherwise specified, such as carbonate or shell sand. Color is according to the Rock-color chart based on the Munsell system (1948). Continuous core from surface to total depth of 120 ft]

Top (feet)	Bottom (feet)	Thickness (feet)	Recovered (feet)	Primary rock type	Color	Grain size	Notes
90.0	91.0	1.0	0.5	Packstone to wackstone	White to very light gray	Medium to coarse	Minor quartz grains; trace phosphate
91.0	95.0	4.0	0.7?	Packstone, similar to above			Quartz grains may be 10–20%, but may dominate in lower part
95.0	96.0	1.0	0.9	Floatstone down to grainstone-packstone	Very light to light gray	Medium to coarse	Dense; quartzose; phosphatic; grainstone in lower part is less dense and coarser grained (pinkish gray color at bottom)
96.0	100.0	4.0	1.9	Sandstone	Very light to light. gray	Medium to coarse	Trace up to 2% phosphate; limestone and shell fragments common
		Grades down to:		Shelly sandstone or grainstone		Coarse (pea size) shell fragments	Less dense and more porous; more phosphate; quartzose matrix; more lime mud in matrix; high porosity in shelly layers
100.0	103.0	3.0	1.8	Floatstone	Light gray	Medium to coarse	Matrix is medium-coarse and quartose (up to 50%) with some limestone fragments as well as shell fragments; some lm mud in matrix, also trace of phosphate
103.0	105.0	2.0	1.0	Floatstone, similar to above			Abundant small shells in layers; eroded and dissolved large (up to 3-in. thick) pieces of remanent limestone which are dense and have an abundant micrite matrix—they are sitting at an angle with large holes infilled with mostly shell material
105.0	110.0	5.0	0.0	No recovery			
110.0	111.0	1.0	0.6	Shell hash	White to yellowish-gray	Fine quartz sd matrix	Shells are mostly pea size with common gastropods
111.0	111.7	0.7	0.7	Shell hash, as above	Assumes 1.8 ft recovered from 111 to 115 ft is from top of interval		
111.7	115.0	3.3	1.1	Grainstone to packstone	Very light to light gray	Medium to coarse (quartz)	Dense; abundant quartz grains;lime mud matrix; trace phosphate; ranges to floatstone as at 100 ft; quartz grains and lime mud matrix is variable; some moldic porosity in lower part
115.0	120.0	5.0	1.7	Grainstone to packstone	Similar to above		Less dense, friable, soft, higher porosity; quartz grain rich in places; trace phosphate;
		Lower part:					Has prevalent dense micrite pieces (eroded limestone chunks similar to pieces at 103 ft)
		Lowest piece		Similar to friable grainstone at top			Has coarse, gray limestone fragments floating in matrix

Table 1–3. PB-1804 (LEC-7) lithologic description.

[Descriptions by R.S. Reese, August 4, 2006. All references to “sandstone,” “sand” or “sandy” imply dominantly quartz sand unless otherwise specified, such as calcareous or shell sand. Color is according to the Rock-Color chart based on the Munsell system (1948); source of samples: 2-ft intervals taken by SPT or rotary cuttings down to 200 ft and cuttings at 5-ft intervals down to total depth of 230 ft. SPT, standard penetration test methodology using split barrel sampler. A more detailed description of the lithology for this well is on file with the U.S. Geological Survey]

Depth interval (feet)	Recovery method	Primary rock type	Color	Grain size and modifiers	Notes
0–4	SPT	Fill	Light gray		
4–8	All SPT	Peat	Dark brown to black		
8–18	All SPT	Mudstone to sand	White to light to yellowish-gray and pale yellowish-brown	Very fine-fine quartz	Clay rich—occurring as beds(?) and matrix; common large shell fragments; large limestone fragments
18–40	SPT for 18-22 ft; remainder is cuttings	Floatstone to rudstone to wackstone	Very light to yellowish to light olive gray	Fine sand	Abundant coarse shell fragments and small gastropods in carbonate mud matrix; well cemented; variable sand content; good porosity from 24 to 30 ft; common spar pieces or cement in places
40–50	Cuttings except SPT for 42-44 and 48-50	Marl to sandstone	Light to medium light gray to light olive gray	Fine quartz	Also mudstone and wackstone; abundant clay with fine black specs and lime mud matrix; limestone and large shell fragments; trace dark sand grains
50–62	All cuttings	Wackstone to sandstone	White to light gray to light olive gray	Fine quartz (?)	Common shell fragments; spar pieces; some brown mudstone pieces
62–68	Cuttings except SPT for 64-66	Wackstone to mudstone	Light gray to yellowish-gray	Fine quartz	Common large white shell fragments and large fossils; clay/lime mud as grain coatings and some pieces; one piece has dark organic matter in pits
68–70	Cuttings	Clay and sandstone	Light olive gray	Very fine-fine	With very fine dark flecks
70–98	SPT for 70-74,76-78, 86-88, 92-96; remainder is cuttings	Mudstone-wackstone-floatstone-packstone-sandstone	Yellowish-gray to light gray to light olive gray	Very fine-fine quartz	Abundant shell fragments; some clay/mud coatings in upper part; some blackening of surfaces; moldic and vuggy porosity from 70 to 80 ft and 86 to 98 ft
98–100	SPT	Sand and shell	Light gray to dark gray	Medium-coarse quartz	Clear quartz grains; 20% dark limestone fragments; 30–40% shell fragments; 1–3% phosphate grains; floating fine-grained sandstone pieces
100–110	All cuttings	Mudstone	Very light to light gray	Fine-medium quartz	Hard; variable quartz; some moldic porosity, increasing toward base
110–130	All SPT	Rudstone to floatstone	Light to medium gray	Medium-coarse quartz	Quartz in matrix (10–20%); good moldic porosity; trace to 2% phosphate grains, very fine to fine; vugs filled with quartz and limestone grains and lime mud; in lower part matrix has 50–50 quartz and carbonate grains along with carbonate mud; spar at bottom

Table 1–3. PB-1804 (LEC-7) lithologic description.—Continued

[Descriptions by R.S. Reese, August 4, 2006. All references to "sandstone," "sand" or "sandy" imply dominantly quartz sand unless otherwise specified, such as calcareous or shell sand. Color is according to the Rock-Color chart based on the Munsell system (1948); source of samples: 2-ft intervals taken by SPT or rotary cuttings down to 200 ft and cuttings at 5-ft intervals down to total depth of 230 ft. SPT, standard penetration test methodology using split barrel sampler. A more detailed description of the lithology for this well is on file with the U.S. Geological Survey]

Depth interval (feet)	Recovery method	Primary rock type	Color	Grain size and modifiers	Notes
130–160	Cuttings for 132-134; remainder is SPT	Sand	Light gray to light olive gray to gray-olive	Very fine-fine	Well sorted; has silt and clay or lime mud matrix that increases downward; 3–5% phosphate grains, very fine to fine; some coarse shell fragments (5%)
160–180	SPT for 162-164; remainder is cuttings	Mudstone	Light olive gray	Fine-coarse	Variable fine to coarse quartz sand; some sandstone; moldic to pinpoint porosity; some coarse white shell fragments; clay/mud matrix from 176 to 178 ft
180–182	Cuttings	Mudstone to crystalline limestone	Light gray to light olive gray	Fine-coarse spar	Similar to 160–162 ft; good vuggy porosity(?)
182–200	All SPT	Sand	Light to yellowish- to light olive gray	Very fine to fine, silty	Phosphate grains, very fine, 5–10% increasing to 10–20% downward; in middle to lower part: some pieces of sandstone of similar composition; trace to minor clay in matrix in places
200–230	All cuttings	Sand	Dusky yellowish-green to dark greenish gray	Very fine to fine, clayey	Abundant clay matrix;10% very fine phosphate grains; clay increasing to 30–50% at 215 ft; common large white pelecypod shell fragments in upper part

Table 1–4. PB-1805 (LEC-8) lithologic description.

[Descriptions by R.S. Reese, November 8, 2008. All references to “sandstone,” “sand” or “sandy” imply dominantly quartz sand unless otherwise specified, such as lime sandstone or shell sandstone. Color is according to the Rock-Color chart based on the Munsell system (1948); Continuous core to 73 ft; SPT to 200 ft. S, only a small portiion of the core barrel content was saved; SPT, standard penetration test methodology using split barrel sampler. A more detailed description of the lithology for this well is on file with the U.S. Geological Survey]

Depth interval (ft)	Recovered (feet)	Primary rock type	Color	Grain size and modifiers	Notes
0–8	No recovery				
8–13	2.8	Mudstone	Light to medium-light gray	Pebble-sized shell infills	Karst surface at 8 ft. Large vertical dissolution feature at 9 ft infilled with coarse broken shell debris; common vertical root marks (holes)
13–23	5.2	Mudstone	White	Chalky at 13 ft	Common vertical root marks (holes); dense at top down to soft and crumbly
23–28	4.0	Mudstone to marl	White to yellowish-gray	Clay to fine-coarse shell	Soft and plastic when wet. Ubiquitous fine to coarse shell fragments
28–33	3.0	Floatstone	Yellowish-gray to white	Mud to pebble-sized shell	Irregular surface at top lined with gray matirix; upper part has abundant floating smooth-shelled gastropods (1/4 in.); lower part has common large shells with matrix of mud and fine shell fragments
33–43	4.1	Floatstone	Light to medium gray	Mud to granule and pebble-sized shell	Dense with gray micrite matrix, mottled appearance; irregular infilling of dissolution features with yellowish-gray mudstone constaining some medium quartz grains; shell lag(?) in top 0.3 ft; low to moderate permeability
43–53	No recovery				
53–73	2.3	Floatstone to sandstone	Medium light gray to grayish yellowish green	Mud to pebble-sized shell	Irregular to rounded pieces with prevalent dissolution; common moldic porosity; patches of calcite spar lining vugs; some whole large shells
				and fine to medium quartz sand	May border on quartz sandstone in places; more mud (micrite) matrix in lower part and trace of fine to medium phosphate grains; overall, high permeability and porosity in upper part and decreasing downward
73–200	SPT only	Samples missing			

Table 1–5. PB-1806 (LEC-9) lithologic description.

[Descriptions by R.S. Reese, August 29, 2007. All references to “sandstone,” “sand” or “sandy” imply dominantly quartz sand unless otherwise specified, such as calcareous or shell sand. Color is according to the Rock-Color chart based on the Munsell system (1948); SPT samples from 63 to 69 ft and below 138 ft to total depth of 205 ft, remainder was continuous core; SPT samples below 138 to 150 ft were continous 2-ft intervals, and below 150-ft samples were 2 ft out every 5-ft interval. S, only a small portiion of the core barrel content was saved; SPT, standard penetration test methodology using split barrel sampler. A more detailed description of the lithology for this well is on file with the U.S. Geological Survey]

Depth interval (feet)	Recovered (feet)	Primary rock type	Color	Grain size and modifiers	Notes
0–38	S	Sand	Yellowish-gray to pale brown	Fine-coarse	Moderately to well sorted
38–53	2.0	Sand	Very light gray to light olive gray	Fine-coarse	Silty to muddy matrix; trace dark minerals or phosphate grains; lost circulation at 51 ft
53–58	4.0	Sand	Light to medium gry	Medium-coarse	Moderately well sorted; loose; phosphate or dark minerals grains 5 to 10%; common limestone grains in lower part
58–69	3 by core and 6 by SPT	Sand to interbedded sandstone or limestone	Yellowish-gray	Fine-coarse	Poorly sorted; carbonate silt-mud matrix; sandstone to packstone; 5% phosphate grains
69–74	1.0	Sandstone to limestone	Very light gray	Fine-medium	Well cemented to loose and rotten; concretions near top; silty, muddy sand matrix packed around hard pieces; up to 5% phosphate grains; some porosity
74–84	2.3	Shell sand to sandstone	Very light to yellowish-gray	Medium-coarse	Abundant coarse shell fragments; 1–5% phosphate grains
84–99	4.9	Rudstone	Light to medium light gray	Fine to very coarse	Pelecypod rich; high moldic to vuggy porosity; coarse sand infilling some vugs; concretions at top; trace to 2% phosphate grains
99–109	3.0	Floatstone to sandstone	Very light gray to light gray	Fine-coarse	Broken to rotten and vuggy; high porosity; spar to lime mud matrix; up to 3% phosphate grains
109–124	5.5	Sandstone to floatstone	Very light gray to light gray	Medium-coarse	Rubbly and broken, concretions at top; very high porosity that may be due to borrowing; micrite to spar matrix
124–134	7.6	Sand, carbonate to minor packstone	Yellowish-gray	Fine-coarse	Shell fragments and variable quartz grains; carbonate mud-silt matrix increasing downward; Minor fine to coarse phosphate grains; plastic in lower part
134–138	No recovery				
138–160	SPT	Sand, carbonate to quartzose	Yellowish-gray	Fine-coarse	Variable carbonate silt-mud matrix; trace to 2% medium-coarse phosphate grains
163–180	SPT	Sand	Light olive gray	Fine	Poorly- to moderately well-sorted; mud-silt matrix; 1–2% fine phosphate grains
183–190	SPT	Sand	Yellowish-gray	Fine-medium	Less mud-silt matrix; trace to 2% phosphate grains
193–200	SPT	Sand	Light olive gray	Fine	Occasional mottled green clay patches; trace to occasional fine to very fine and very coarse phosphate grains
200–205	No recovery				

Table 1–6 PB-1807 (LEC-10) lithologic description.

[Descrioptions by R.S. Reese, November 22, 2008. All references to “sandstone,” “sand,” or “sandy” imply dominantly quartz sand unless otherwise specified, such as carbonate or shell sand. Color is according to the Rock-Color chart based on the Munsell system (1948); Continuous core to 125 ft; SPT to 190 ft; SPT were continuous 2-ft intervals from 123 to 143 ft and 2-ft sample for every 5-ft interval from 143 to 190 ft; total well depth 205 ft. SPT, standard penetration test methodology using split barrel sampler. A more detailed description of the lithology for this well is on file with the U.S. Geological Survey]

Dept interval (feet)	Recovered (feet)	Primary rock type	Color	Grain size and modifiers	Notes
0–9	No Recovery		Ran roller bit to fit core barrel		
9–13	No Recovery				
13–18	0.3	Sand	Pale yellowish-brown	Medium to coarse	Well sorted; some white shell fragments
18–33	3.1	Sand	Pale brown	Fine to medium	Well sorted, loose, trace shell fragments
33–53	5.1	Sand	Yellowish-gray to pale yellowish-orange to dark yellowish-brown	Very fine to coarse	Poorly sorted, silty; dark brown color may be due to organic material and can occur in layers
53–68	1.5	Sand	Very pale orange	Medium to coarse	Moderate to well sorted; has rock fragments from 53 to 58 ft and 63 to 68 ft, medium to light gray, medium-grained, sandstone to rudstone
68–78	3.3	Sandstone to grainstone(?)	Very light to light gray	Fine to medium-coarse	Dense; common dissolution vugs, subhorizontal and tabular in shape—probably represent cross-bedding with dissolution of shell layers; moderate to good permeability
78–93	3.6	Sandstone to rudstone	Very light gray to very light olive gray	Very fine to coarse	Dense; dissolution vugs similar to above indicating some cross-bedding, vugs up to 1/4 to 1/2-in. diamater; abundant coarse flat shell fragments in places; rounded to broken pebble sized pieces in places; trace to 1% phosphate grains in lower 5 ft; low to high permeability, high permeability in upper 5 ft; layer of loose sand in top 0.4 ft, fine to medium grained
93–118	No Recovery				May have been mostly sand, but in old test well at same site (PB-1571) in this interval predominantly limestone (but interbedded with sand) was recovered
118–123	0.4	Floatstone to grainstone	Very light to light gray	Fine to pebble	Abundant medium-coarse rounded quartz grains and limestone to shell grains, white; common 1/8 to 1/4-in. vugs, one vug up to 1/2 in.; 1–3% very fine phosphate grains; moderate to good permeability
123–125	1.3	Upper part: sand	Yellowish-gray	Fine	Approx 50% carbonate grains; 1% very fine to fine phosphate grains
	0.8	Lower part: floatstone to grainstone	Very light to light gray	Fine quartz to pebble	Dense; abundant fine quartz and shell fragments in micrite matrix; common vug poroosity (up to 1/4-in. diameter); moderate permeability
125–133	SPT	Sand with rock layers	Yellowish-gray to light gray	Fine to medium	Poorly to moderate well sorted; predominantly carbonate grains; 1–8% very fine to fine phosphate grains; rock pieces are coarse-grained sandstone to mudstone to floatstone—may occur as thin layes
133–141	SPT	Floatstone to rudstone	White to light gray to yellowish-gray	Coarse to pebble	Predominantly carbonate grains, but abundant coarse, rounded quartz grains; 1% fine to coarse phosphate grains; abundant small to pinpoint vugs; moderate to good permeability (highest permeability from 137 to 139 ft)

Table 1–6 PB-1807 (LEC-10) lithologic description.—Continued

[Descrioptions by R.S. Reese, November 22, 2008. All references to “sandstone,” “sand,” or “sandy” imply dominantly quartz sand unless otherwise specified, such as carbonate or shell sand. Color is according to the Rock-Color chart based on the Munsell system (1948); Continuous core to 125 ft; SPT to 190 ft; SPT were continuous 2-ft intervals from 123 to 143 ft and 2-ft sample for every 5-ft interval from 143 to 190 ft; total well depth 205 ft. SPT, standard penetration test methodology using split barrel sampler. A more detailed description of the lithology for this well is on file with the U.S. Geological Survey]

Dept interval (feet)	Recovered (feet)	Primary rock type	Color	Grain size and modifiers	Notes
141–143	SPT	Sand	Light olive gray	Medium to coarse	Predominantly carbonate grains; some gray limestone grains; 1% fine phosphate grains
143–148	No recovery				
148–180	SPT	Sand	Yellowish-gray to light olive gray to greenish gray	Fine to coarse	Predominantly carbonate grains; poorly sorted; silt to mud matrix that generally increases downward; occasional pebble-sized rock or shell fragments; 1–3% phosphate grains; from 168 to 180 ft: predominantly medium-coarse grained, but sticky and clumpy
180–183	No recovery				
183–190	SPT	Sand to floatstone	Greenish gray	Medium to pebble	Abundant pebble-sized shell fragments; still has mud matrix; sample from 188 to 190 ft: predominantly floastone, which may have some vuggy permeability; moderate to high permeability

Table 1–7. Summary of geologic units and flow zones for wells with lithologic descriptions.

[Descriptions by R.S. Reese on the following dates: PB-1761, Mar. 2006; PB-1804, Aug. 4, 2007; PB-1805, Nov. 8, 2008; PB-1806, Aug. 29, 2007; PB-1807, Nov. 22, 2008. Depths are in feet below land surface]

Geologic units	Depth (feet)	Flow zones[1]	Depth (feet)	Comments
PB-1761 (B-6 core test)				
Miami Limestone	0–9	Major	17–23	Screened interval depth is from 0 to 111 ft.
Ft Thompson Formation	9–30	Major	47–58	
Caloosahatchee Marl	30–60	Minor	69–76	
Pinecrest Sand Member of the Tamiami Formation	60–113	Minor	83–85	
Ochopee Limestone Member of the Tamiami Formation	[2]113–120	Minor	91–93	
		Minor	98–103	
PB-1804 (LEC-7)				
Fill and Peat	0–8	Minor	[3]24–30	Screened interval depth is from 38 to 188 ft and top of sand pack is at 33 ft.
Lake Flirt Marl	8–18	Major	45–73	
Ft. Thompson	18–40	Minor	90–100	
Caloosahatchee Marl?	40–50	Minor	[4]140–143	
Pinecrest Sand Member of the Tamiami Formation	50–110			
Ochopee Limestone Member of the Tamiami Formation	110–200			
Peace River Formation of the Hawthorrn Group	[2]200–230			
PB-1805 (LEC-8)				
Fill and Soil	0–8	Minor	[3]8–13(?)	Screened interval depth is from 40 to 90 ft and top of sand pack is at 36 ft.
Ft. Thompson? Formation	8–23	Major	40–43	
Calooshatchee Marl?	23–33	Major	69–80	
Pinecrest Sand Member of the Tamiami Formation	[5]33–82	Minor	86–90	
Ochopee Limestone Member of the Tamiami Formation	82–180(?)			
Peace River Formation of the Hawthorrn Group	[2,6]180(?)-200			
PB-1806 (LEC-9)				
Fill and Soil	0–8?	None?		Screened interval depth is from 68 to 123 ft and top of sand pack is at 66 ft.
Undifferentiated shallow sand	8–53	Minor	68–73	
Pinecrest Sand Member of the Tamiami Formation	53–109	Major	87–93	
Ochopee Limestone Member of the Tamiami Formation	109–160	Minor	97–100	
Peace River Formation of the Hawthorrn Group	[2]160–200	Minor	113–120	
PB-1807 (LEC-10)				
Fill and Soil	Unknown	Minor	[7]13–18(?)	Screened interval depth is from 70 to 140 ft and top of sand pack is at 68 ft.
Undifferentiated shallow sands	Down to 68	Major	70–92	
Pinecrest Sand Member of the Tamiami Formation	68–118	Minor	108–120	
Ochopee Limestone Member of the Tamiami Formation	[2]118–205	Minor	133–140	
Peace River Formation of the Hawthorrn Group	Not reached (interpreted to be at 210 to 220 ft in PB-1571 at same site)			

[1]Flow zone characterizations based on flow and fluid properties geophysical logs unless noted otherwise in comments.

[2]Base not reached.

[3]Based on lithologic samples.

[4]Based mostly on fluid logs and ambient heat pulse flowmeter.

[5]Top of the Tamiami Formation could be higher (at 30 ft based on bipass surface at this depth and change to marine conditions).

[6]Top of Hawthorn uncertain because of missing samples.

[7]Based on lithologic samples (medium to coarse well sorted sand)

Table 1–8. Hydrogeologic unit boundaries and correlation marker depths determined in this study.

[All depths are in feet below land surface; Land surface altitude is feet above NGVD 29; Abbreviations: IC, inconclusive; ISD, inadequate sample description; ND, not determined; NP, not present; NR, not reached at total depth; QGL, questionable geophysical logs; PSQ, poor sample quality; --, evidence for separation of zone 2 from zone 3 not found. Cells shaded in dark gray in first column indicate lithologic and geophysical log plot is available for well in appendix 2. Cells shaded in light gray in last four columns indicate borehole gamma ray log was not available for determining depth of marker]

USGS local well name	Total hole depth	Land surface altitude	Zone 1 depth		Zone 2 depth		Zone 3 depth		Depths of gamma ray and lithologic correlation markers			
			Top	Bottom	Top	Bottom	Top	Bottom	F (blue)	T (red)	O (purple)	H (green)
C-1156	1,000	14	NP	NP	0	25	60	150	ND	ND	ND	ND
C-1169	195	15	NP	NP	0	17	75	139	NP	[1]5	[1]75	ND
G-2312	229	15	NP	NP	40	74	105	170	ND	[2]40	ND	ND
G-2313	219	12	12	28	42	82	106	155	ND	ND	ND	ND
G-2314	199	20	0	30	NP	NP	40	155	ND	ND	ND	ND
G-2315	249	18	0	53	NP	NP	116	192	28	63	107	ND
G-2340	199	14	0	17	NP	NP	60	147		[3]21	ND	ND
G-2916	1,200	17	IC	IC	IC	IC	IC	IC	42	132	217	326
HE-1108	132	20	NP	NP	0	25	75	132	NP	[4]NP		
HE-1110	160	15	NP	NP	NP	NP	35	148	NP	[4]NP	33	149
HE-1116	195	18	0	11	NP	NP	31	152	NP	15	32	191
HE-1142	184	14.09	ND	ND	ND	ND	ND	ND	NP	NP	30	133
HE-1143	181	14.63	ND	ND	ND	ND	ND	ND	NP	13	30	176
HE-1144	182	15.85	ND	ND	ND	ND	ND	ND	NP	NP	36	162
M-1361	1,380	22.20	23	45	111	125	NP	NP	41	66	129	216
M-1367	206	27.10	IC	IC	IC	IC	107	110	26	68	102	167
PB-600	345	15	NP	NP	NP	NP	210	298	57	128	206	319
PB-634	188	10	IC	IC	NP	NP	NP	NP	118	NR		
PB-640	236	19	22	40	70	--	--	120	25	74	110	196
PB-649	205	26	28	55	77	92	NP	NP	22	64	102	161
PB-650	193	7	21	27	58	80	110	140	34	43	100	167
PB-651	236	22	22	46	90	--	--	140	40	65	118	203
PB-652A	314	20	34	90	IC	IC	IC	IC	65	117	186	298
PB-653	314	12	NP	NP	NP	NP	NP	NP	67	117	189	302
PB-654	282	18	NP	NP	80	--	--	152	ND	ND	ND	ND
PB-655	267	20	NP	NP	46	--	--	152	ND	ND	ND	ND
PB-657	281	18	NP	NP	70	135	NP	NP	53	107	188	268
PB-658	365	15	NP	NP	100	--	--	220	42	114	186	297
PB-665	225	18	10	30	90	150	170	220	41	81	158	247
PB-666	415	13	NP	NP	NP	NP	NP	NP	39	131	218	338
PB-667	357	15	NP	NP	NP	NP	NP	NP	47	121	221	350
PB-668	358	10	37	43	NP	NP	190	235	51	110	175	270
PB-669	345	12	IC	IC	NP	NP	IC	IC	38	92	188	325

Table 1–8. Hydrogeologic unit boundaries and correlation marker depths determined in this study.—Continued

[All depths are in feet below land surface; Land surface altitude is feet above NGVD 29; Abbreviations: IC, inconclusive; ISD, inadequate sample description; ND, not determined; NP, not present; NR, not reached at total depth; QGL, questionable geophysical logs; PSQ, poor sample quality; --, evidence for separation of zone 2 from zone 3 not found. Cells shaded in dark gray in first column indicate lithologic and geophysical log plot is available for well in appendix 2. Cells shaded in light gray in last four columns indicate borehole gamma ray log was not available for determining depth of marker]

USGS local well name	Total hole depth	Land surface altitude	Zone 1 depth		Zone 2 depth		Zone 3 depth		Depths of gamma ray and lithologic correlation markers			
			Top	Bottom	Top	Bottom	Top	Bottom	F (blue)	T (red)	O (purple)	H (green)
PB-670	325	15	70	116	120	220	NP	NP	62	120	223	309
PB-671	119	18	IC	IC	85	NR at 119	NR	NR	29	83	NR	
PB-672	234	18	IC	IC	70	--	--	161	27	67	123	186
PB-673	248	19	NP	NP	90	140	NP	NP	25	86	139	228
PB-674	302	17	70	85	115	--	--	200	36	103	146	235
PB-675	387	14	44	56	100	190	NP	NP	69	133	221	329
PB-676	175	15	IC	IC	30	60	75	115	19	48	87	166
PB-677	190	16	15	35	NP	NP	IC	IC	29	61	119	192
PB-678	189	20	NP	NP	NP	NP	NP	NP	33	74	123	185
PB-679	174	22	NP	NP	75	100	NP	NP	26	69	100	150
PB-681	248	12	45	80	NP	NP	NP	NP	46	102	149	240
PB-690	275	11	21	130	NP	NP	NP	NP	ND	ND	ND	ND
PB-694	249	8	31	100	NP	NP	NP	NP	ND	ND	ND	ND
PB-695	249	6	NP	NP	NP	NP	NP	NP	ND	ND	ND	ND
PB-699	357	20	IC	IC	95	125	IC	IC	ND	ND	ND	ND
PB-708	154	18	IC	IC	105	NR	NR	NR	ND	ND	ND	ND
PB-712	280	14	NP	NP	110	--	--	160	57	98	151	200
PB-747	1,280	13	PSQ	PSQ	PSQ	PSQ	PSQ	PSQ	54	110	152	250
PB-798	120	18	NP	NP	45	120	NR	NR	ND	ND	ND	ND
PB-830	220	22	3	19	ISD	ISD	ISD	ISD	27	62	92	150
PB-833	520	10	30	100	135	200	NP	NP	58	137	199	328
PB-834B	201	8	21	50	112	180	NR	NR	41	112	181	NR
PB-836	240	12	ISD	ISD	ISD	ISD	ISD	ISD	35	67	118	NR
PB-837	200	12	10	30	ISD	ISD	ISD	ISD	28	62	127	[5]210
PB-838	240	14	20	37	60	100	IC	IC	30	62	104	193
PB-839	220	15	ISD	ISD	ISD	ISD	ISD	ISD	28	43	103	186
PB-841	250	20	ISD	ISD	ISD	ISD	ISD	ISD	30	74	109	220
PB-842	240	16	ISD	ISD	ISD	ISD	ISD	ISD	4	30	50	199
PB-843	575	13	ISD	ISD	ISD	ISD	ISD	ISD	24	42	99	210
PB-880	118	17.06	NP	NP	64	90	90	117	29	65	94	166
PB-1026	114	17	NP	NP	54	114	NR	NR	42	95	NR	NR
PB-1029	129	18	NP	NP	56	129	NR	NR	ND	ND	ND	ND
PB-1038	123	17	NP	NP	96	114	NR	NR	ND	ND	ND	ND

Table 1–8. Hydrogeologic unit boundaries and correlation marker depths determined in this study.—Continued

[All depths are in feet below land surface; Land surface altitude is feet above NGVD 29; Abbreviations: IC, inconclusive; ISD, inadequate sample description; ND, not determined; NP, not present; NR, not reached at total depth; QGL, questionable geophysical logs; PSQ, poor sample quality; --, evidence for separation of zone 2 from zone 3 not found. Cells shaded in dark gray in first column indicate lithologic and geophysical log plot is available for well in appendix 2. Cells shaded in light gray in last four columns indicate borehole gamma ray log was not available for determining depth of marker]

USGS local well name	Total hole depth	Land surface altitude	Zone 1 depth		Zone 2 depth		Zone 3 depth		Depths of gamma ray and lithologic correlation markers			
			Top	Bottom	Top	Bottom	Top	Bottom	F (blue)	T (red)	O (purple)	H (green)
PB-1065	115	16	NP	NP	54	96	NR	NR	ND	ND	ND	ND
PB-1082	200	12	40	90	120	138	138	150	61	97	139	NR
PB-1083	200	12	30	55	107	--	--	192	56	114	154	200
PB-1084	200	18	NP	NP	46	--	--	151	40	88	124	189
PB-1085	200	18	NP	NP	40	--	--	140	38	83	116	187
PB-1086	200	18	NP	NP	47	136	NP	NP	47	103	146	NR
PB-1087	200	18	NP	NP	48	--	--	140	37	74	116	190
PB-1088	200	19	NP	NP	54	--	--	131	48	92	122	198
PB-1089	240	17	NP	NP	44	--	--	145	38	80	121	216
PB-1090	200	16	NP	NP	72	148	NR	NR	48	101	193	NR
PB-1091	160	17	NP	NP	64	140	NP	NP	52	83	139	NR
PB-1092	200	18	NP	NP	63	118	NP	NP	30	63	115	181
PB-1093	200	18	NP	NP	49	--	--	120	27	55	95	170
PB-1094	180	18	19	40	58	100	110	140	33	58	104	165
PB-1095	300	17	46	93	106	160	NP	NP	56	106	195	NR
PB-1096	220	20	NP	NP	85	--	--	180	36	83	144	208
PB-1097	160	16	NP	NP	80	--	--	120	21	60	93	153
PB-1098	180	20	NP	NP	40	--	--	120	35	77	115	176
PB-1099	180	18	NP	NP	35	100	IC	IC	35	77	120	170
PB-1100	200	15	5	35	57	120	130	163	34	74	129	194
PB-1101	220	19	60	120	120	200	NP	NP	80	128	204	NR
PB-1102	235	18	NP	NP	100	--	--	200	49	100	155	215
PB-1103	240	21	NP	NP	86	--	--	180	42	86	160	228
PB-1104	340	20	55	80	104	192	210	240	52	119	198	308
PB-1105	217	15	IC	IC	80	--	--	180	46	82	173	NR
PB-1106	217	23	15	41	60	101	139	161	35	74	115	200
PB-1107	200	15	IC	IC	69	117	138	143	36	61	119	211
PB-1108	200	14	13	24	61	112	130	141	27	70	128	198
PB-1109	171	23	NP	NP	IC	IC	NP	NP	31	78	112	160
PB-1144	1,038	13	PSQ	PSQ	PSQ	PSQ	PSQ	PSQ	63	130	189	333
PB-1166	3,310	25	ISD	ISD	ISD	ISD	ISD	ISD	32	69	104	165
PB-1168	3,300	20	QGL, ISD	QGL, ISD	QGL, ISD	QGL, ISD	QGL, ISD	QGL, ISD	32	75	141	229
PB-1173	2,010	17	NP?	NP?	NP?	NP?	NP?	NP?	61	114	172	267

Table 1–8. Hydrogeologic unit boundaries and correlation marker depths determined in this study.—Continued

[All depths are in feet below land surface; Land surface altitude is feet above NGVD 29; Abbreviations: IC, inconclusive; ISD, inadequate sample description; ND, not determined; NP, not present; NR, not reached at total depth; QGL, questionable geophysical logs; PSQ, poor sample quality; --, evidence for separation of zone 2 from zone 3 not found. Cells shaded in dark gray in first column indicate lithologic and geophysical log plot is available for well in appendix 2. Cells shaded in light gray in last four columns indicate borehole gamma ray log was not available for determining depth of marker]

USGS local well name	Total hole depth	Land surface altitude	Zone 1 depth		Zone 2 depth		Zone 3 depth		Depths of gamma ray and lithologic correlation markers			
			Top	Bottom	Top	Bottom	Top	Bottom	F (blue)	T (red)	O (purple)	H (green)
PB-1176	3,300	17.83	ISD	ISD	ISD	ISD	ISD	ISD	46	105	133	213
PB-1184	3,510	13.03	30	50	57	90	IC	IC	31	63	101	181
PB-1192	3,312	19.42	60	90	100	IC	IC	IC	60	112	209	341
PB-1195	435	18.90	30	80	IC	IC	IC	IC	118	182	268	384
PB-1197	1,665	17	NP	NP	120	--	--	210	58	104	150	277
PB-1544	260	18	NP	NP	66	--	--	146	42	81	136	216
PB-1546	170	20	NP	NP	60	--	--	136	23	76	110	ND
PB-1550	180	23	NP	NP	63	106	NP	NP	ND	ND	ND	ND
PB-1555	190	19	[6]PB-1098	[6]PB-1098	[6]PB-1098	[6]PB-1098	[6]PB-1098	[6]PB-1098	ND	ND	ND	ND
PB-1558	200	20	NP	NP	87	--	--	127	ND	ND	ND	ND
PB-1564	220	20	[6]PB-1088, [6]PB-1783	[6]PB-1088, [6]PB-1783	[6]PB-1088, [6]PB-1783	[6]PB-1088, [6]PB-1783	[6]PB-1088, [6]PB-1783	[6]PB-1088, [6]PB-1783	ND	ND	ND	ND
PB-1567	190	17	NP	NP	60	117	NP	NP	ND	ND	ND	ND
PB-1571	260	19	[7]PB-1807	[7]PB-1807	[7]PB-1807	[7]PB-1807	[7]PB-1807	[7]PB-1807	ND	ND	ND	ND
PB-1574	240	19	NP	NP	77	--	--	150	ND	ND	ND	ND
PB-1576	190	17	NP	NP	70	IC	IC	IC	ND	ND	ND	ND
PB-1578	270	10	NP	NP	161	--	--	231	ND	ND	ND	ND
PB-1581	320	17	[6]PB-658	[6]PB-658	[6]PB-658	[6]PB-658	[6]PB-658	[6]PB-658	ND	ND	ND	ND
PB-1586	420	18	40	104	158	--	--	223	ND	ND	ND	ND
PB-1598	270	19	NP	NP	100	--	--	184	ND	ND	ND	ND
PB-1603	390	15	[6]PB-1095	[6]PB-1095	[6]PB-1095	[6]PB-1095	[6]PB-1095	[6]PB-1095	ND	ND	ND	ND
PB-1605	430	15	47	120	150	180	IC	IC	83	153	235	ND
PB-1607	220	18	NP	NP	34	92	107	140	38	73	102	169
PB-1613	162	25	NP	NP	60	--	--	115	24	70	103	149
PB-1614	155	24	24	44	67	--	--	110	ND	ND	ND	ND
PB-1693	1,191	18.97	ISD	ISD	ISD	ISD	ISD	ISD	51	118	200	313
PB-1695	2,490	15	ISD	ISD	ISD	ISD	ISD	ISD	50	117	211	322
PB-1696	1,705	11	IC	IC	50	--	--	125	ND	ND	ND	ND
PB-1702	1,200	21.20	IC	IC	IC	IC	IC	IC	80	149	240	360
PB-1703	221	20	NP	NP	15	19	80	92	NP	15	47	153
PB-1704	201	11	17	42	NP	NP	73	160	18	49	82	161
PB-1761	[8]120	10	[7]PB-1803	[7]PB-1803	[7]PB-1803	[7]PB-1803	[7]PB-1803	[7]PB-1803	22	60	113	NR
PB-1765	1,225	10	[7]PB-1803	[7]PB-1803	[7]PB-1803	[7]PB-1803	[7]PB-1803	[7]PB-1803	28	60	115	202

Table 1–8. Hydrogeologic unit boundaries and correlation marker depths determined in this study.—Continued

[All depths are in feet below land surface; Land surface altitude is feet above NGVD 29; Abbreviations: IC, inconclusive; ISD, inadequate sample description; ND, not determined; NP, not present; NR, not reached at total depth; QGL, questionable geophysical logs; PSQ, poor sample quality; --, evidence for separation of zone 2 from zone 3 not found. Cells shaded in dark gray in first column indicate lithologic and geophysical log plot is available for well in appendix 2. Cells shaded in light gray in last four columns indicate borehole gamma ray log was not available for determining depth of marker]

USGS local well name	Total hole depth	Land surface altitude	Zone 1 depth		Zone 2 depth		Zone 3 depth		Depths of gamma ray and lithologic correlation markers			
			Top	Bottom	Top	Bottom	Top	Bottom	F (blue)	T (red)	O (purple)	H (green)
PB-1769	337	15	45	100	NP (all sand)		235	308	67	137	229	NR
PB-1775	1,650	16.33	ND, close to PB-1100		ND, close to PB-1100		ND, close to PB-1100		41	66	132	211
PB-1777	2,504	10	ISD	ISD	ISD	ISD	ISD	ISD	28	43	88	190
PB-1781	205	13.90	PSQ	PSQ	PSQ	PSQ	PSQ	PSQ	29	65	121	200
PB-1782	206	17.80	PSQ	PSQ	PSQ	PSQ	PSQ	PSQ	42	83	123	210
PB-1783	205	21.60	PSQ	PSQ	PSQ	PSQ	PSQ	PSQ	43	84	116	190
PB-1784	425	8	ISD	ISD	ISD	ISD	ISD	ISD	68	169	258	376
PB-1785	180	11.84	4	18	30	39	66	95	13	40	83	169
PB-1786	182	13.38	NP	NP	3	24	Poorly developed		NP	20	47	150
PB-1787	183	12.15	ND	ND	ND	ND	ND	ND	4	26	63	157
PB-1788	180	11.39	ND	ND	49	58	ND	ND	14	49	82	162
PB-1797	191	17.20	16	35	60	102	IC	IC	28	63	124	205
PB-1803	208	11	10	30	47	115	138	163	Same site as PB-1761 and PB-1765			
PB-1804	[8]230	12	18	36	47	100	NP	NP	22	51	107	208
PB-1805	[8]200	12	5	18	38	80	86	90	13	38	82	[5]180
PB-1806	[8]205	20	NP	NP	67	100	114	129	28	66	118	188
PB-1807	[8]205	19	NP	NP	70	120	133	145	38	69	127	[5]202
PB-1808	200	18							ND	ND	ND	ND
W-5435	1,200	5	NP	NP	IC	IC	IC	IC	10	38	86	170

[1]Depths for T and O markers from Reese and Cunningham (2000).

[2]T marker is top of Tamiami Formation (from Fish 1988, section B-B′).

[3]T marker is top of Tamiami Formation (from Fish 1988, section E-E′).

[4]Tamiami Formation at land surface.

[5]Marker not reached at total depth, but estimated.

[6]Use boundaries from this well, which is located nearby.

[7]Use boundaries from this well, which is located at same site.

[8]Detailed lithologic description available for well in appendix tables.

[9]Samples collected but no geophysical logs run

Table 1–9*A*. Hydraulic well test descriptions and locations.

[Sources and references for this appendix table are given in table 1–9*C*. Abbreviations: dd mm ss.s, degrees, minutes, and seconds; APT, aquifer performance test; LWDD, Lake Worth Drainage District; NA, not applicable; NR, not reported; SFWMD, South Florida Water Management District; USGS; U.S. Geological Survey. Test type: M, multiwell constant rate; P, Packer test; R, single well constant rate; S, step drawdown; SC, specific capacity]

Table 1–9*A*, 1–9*B* cross reference	Production well identifier	Production well diameter (inches)	Test date	Test type	Source and references	Operator	Test description and site number	Monitoring well identifier	Latitude north (dd mm ss.s)	Longitude west (dd mm ss.s)	Horizontal datum
1	C-1171	6	04/29/98	M	1a	USGS	Big Cypress Sanctuary	2 wells	26 13 17	80 55 51	NAD 27
2	G-2312J	6	NR	M	1b	USGS	Twenty Six Mile Bend	NR	26 13 47	80 27 37	NAD 27
3	G-2312K	6	NR	SC	1b	USGS	Twenty Six Mile Bend	None	26 13 47	80 27 37	NAD 27
4	G-2313A	6	NR	SC	1b	USGS	North Everglades central	None	26 19 58	80 41 06	NAD 27
5	G-2313B	6	NR	SC	1b	USGS	North Everglades central	None	26 19 58	80 41 06	NAD 27
6	G-2313C	6	NR	S	1b	USGS	North Everglades central	None	26 19 58	80 41 06	NAD 27
7	HE-303	NR	06/03/58	M	1c	USGS	S & M Farms; Reese and Cunningham, 2000, fig. 23, site 7	2 wells	26 23 47	80 58 16	NAD 27
8	H-M-235	NR	02/27/86	M	9	Missimer	U.S Sugar Corporation, South Division Ranch; Smith and Adams, 1988, fig. 66, site 15	4 wells	26 25 41	80 57 59	NAD 27
9	H-M-301	NR	11/06/86	M	9	Missimer	U.S Sugar Corporation, South Division Ranch; Smith and Adams, 1988, fig. 66, site 16	3 wells	[1]NR	[1]NR	NA
10	H-M-328	NR	04/17/87	M	9	Missimer	U.S Sugar Corporation, South Division Ranch; Smith and Adams, 1988, fig. 66, site 17	3 wells	26 17 43	80 56 36	NAD 27
11	PB-1065	6	05/03/78	M	1d	USGS	Riviera Beach	8 wells	26 46 10	80 07 25	NAD 27
12	PB-1233	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 3	None	26 22 04.0	80 06 39	NAD 27
13	PB-1239	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 2	None	26 20 48.0	80 07 45	NAD 27
14	PB-1250	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 4	None	26 30 47.0	80 04 05	NAD 27

Table 1–9*A*. Hydraulic well test descriptions and locations.—Continued

[Sources and references for this appendix table are given in table 1–9*C*. Abbreviations: dd mm ss.s, degrees, minutes, and seconds; APT, aquifer performance test; LWDD, Lake Worth Drainage District; NA, not applicable; NR, not reported; SFWMD, South Florida Water Management District; USGS; U.S. Geological Survey. Test type: M, multiwell constant rate; P, Packer test; R, single well constant rate; S, step drawdown; SC, specific capacity]

Table 1–9*A*, 1–9*B* cross reference	Production well identifier	Production well diameter (inches)	Test date	Test type	Source and references	Operator	Test description and site number	Monitoring well identifier	Latitude north (dd mm ss.s)	Longitude west (dd mm ss.s)	Horizontal datum
15	PB-1267	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 5	None	26 28 05.0	80 04 27	NAD 27
16	PB-1310	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 7	None	26 34 53.0	80 03 19	NAD 27
17	PB-1336	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 15	None	26 42 23.0	80 12 57	NAD 27
18	PB-1343	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 17	None	26 20 35.0	80 11 45	NAD 27
19	PB-1361	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 19	None	26 50 54.0	80 07 44	NAD 27
20	PB-1365	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1, site 1	None	26 36 08.0	80 05 25	NAD 27
21	PB-1415	NR	NR	SC	1f	USGS	Specific capacity test, Swayze and Miller, 1984, table 3.2–1,site 13	None	26 24 58.0	80 07 00	NAD 27
22	PB-1545	6	07/03/86	M	1e	USGS	USGS, site 9	PB-1544	26 38 58	80 10 09.5	NAD 83
23	PB-1545	6	07/20/07	R	2	USGS	USGS, site 9	None	26 38 58	80 10 09.5	NAD 83
24	PB-1545	6	08/31/87?	M	10	SFWMD	USGS, site 9	PB-1544? (D-1A)	26 38 58	80 10 09.5	NAD 83
25	PB-1547	6	07/16/86	M	1e	USGS	USGS, site 15	PB-1546	26 56 06	80 13 55	NAD 27
26	PB-1551	6	07/30/86	M	1e	USGS	USGS, site 14	PB-1550	26 51 34	80 17 27	NAD 27
27	PB-1557	6	08/07/86	M	1e	USGS	USGS, site 13	PB-1555	26 48 43	80 12 50	NAD 27
28	PB-1559	6	11/19/86	M	1e	USGS	USGS, site 12	PB-1558	26 48 34	80 19 34	NAD 27
29	PB-1565	6	11/04/86	M	1e	USGS	USGS, site 11	PB-1564	26 45 55	80 15 17	NAD 27
30	PB-1568	6	12/08/86	M	1e	USGS	USGS, site 10	PB-1569	26 41 01	80 16 30	NAD 27

Table 1–9*A*. Hydraulic well test descriptions and locations.—Continued

[Sources and references for this appendix table are given in table 1–9*C*. Abbreviations: dd mm ss.s, degrees, minutes, and seconds; APT, aquifer performance test; LWDD, Lake Worth Drainage District; NA, not applicable; NR, not reported; SFWMD, South Florida Water Management District; USGS; U.S. Geological Survey. Test type: M, multiwell constant rate; P, Packer test; R, single well constant rate; S, step drawdown; SC, specific capacity]

Table 1–9*A*, 1–9*B* cross reference	Production well identifier	Production well diameter (inches)	Test date	Test type	Source and references	Operator	Test description and site number	Monitoring well identifier	Latitude north (dd mm ss.s)	Longitude west (dd mm ss.s)	Horizontal datum
31	PB-1572	6	11/11/86	M	1e	USGS	USGS, site 8	PB-1571	26 35 09	80 10 22	NAD 27
32	PB-1575	6	11/05/86	M	1e	USGS	USGS, site 2	PB-1574	26 25 53	80 12 15	NAD 27
33	PB-1577	6	12/02/86	M	1e	USGS	USGS, site 16	PB-1576	26 32 55	80 13 36	NAD 27
34	PB-1577	6	07/09/87	M	10	SFWMD	USGS, site 16	PB-1576	26 32 55	80 13 36	NAD 27
35	PB-1580	6	11/13/86	M	1e	USGS	USGS, site 7	PB-1578	26 37 02	80 05 19	NAD 27
36	PB-1582	6	11/04/86	M	1e	USGS	USGS, site 1	PB-1581	26 21 47	80 10 16	NAD 27
37	PB-1582	6	07/01/87	M	10	SFWMD	USGS, site 1	PB-1581	26 21 47	80 10 16	NAD 27
38	PB-1599	6	02/12/87	M	1e	USGS	USGS, site 4	PB-1600	26 28 05	80 10 16	NAD 27
39	PB-1604	6	02/17/87	M	1e	USGS	USGS, site 5	PB-1603	26 32 16	80 06 17	NAD 27
40	PB-1608	6	02/23/87	M	1e	USGS	USGS, site 17	PB-1607	26 52 48	80 10 38	NAD 27
41	PB-1769	2	09/20/07	R	2	USGS	A. G. Holly Rehabilitation Center	None	26 35 22	80 03 30	NAD 27
42	PB-1792	4	04/05/07	R	2	USGS	CP02-EAARS-CB-0010	None	26 23 58	80 40 52.5	NAD 27
43, 44	PB-1794	2	Various dates	R	3	USGS	ENR MP2-A	None	26 38 19	80 25 38	NAD 27
45	PB-1801	2	04/18/07	M	2	USGS	BP-DMW-W	PB-1802 in shallower zone	26 20 54	80 17 49.3	NAD 83
46	PB-1803	4	04/17/07	R	2	USGS	HASR-SAS-MW-1	None	26 21 18	80 17 41.5	NAD 27
47	PB-1804	4	04/09/07	R	2	USGS	Hillsboro Canal near pump station S-6	None	26 28 29	80 26 54.2	NAD 83
48	PB-1805	4	05/25/07	R	2	USGS	U.S. Hwy 27 at bend to the north	None	26 33 59	80 42 35.7	NAD 83
49	PB-1806	4	01/15/08	R	2	USGS	Southern Blvd and U.S. 441 at S-155A	None	26 40 47	80 12 10.7	NAD 83
50	PB-1807	4	03/28/08	R	2	USGS	Lantana Rd and Florida Turnpike on LWDD canal E-2E	None	26 35 12	80 10 22	NAD 83
51	PW	4	05/24/87	M	7	Murray-Milleson, Inc	Seminole Tribe; Smith and Adams, 1988, fig. 66, site 18	3 wells	[1]NR	[1]NR	NA

Table 1–9*A*. Hydraulic well test descriptions and locations.—Continued

[Sources and references for this appendix table are given in table 1–9*C*. Abbreviations: dd mm ss.s, degrees, minutes, and seconds; APT, aquifer performance test; LWDD, Lake Worth Drainage District; NA, not applicable; NR, not reported; SFWMD, South Florida Water Management District; USGS; U.S. Geological Survey. Test type: M, multiwell constant rate; P, Packer test; R, single well constant rate; S, step drawdown; SC, specific capacity]

Table 1–9*A*, 1–9*B* cross reference	Production well identifier	Production well diameter (inches)	Test date	Test type	Source and references	Operator	Test description and site number	Monitoring well identifier	Latitude north (dd mm ss.s)	Longitude west (dd mm ss.s)	Horizontal datum
52, 53	S10C	2	Various dates	R	3	USGS	WCA-2A	None	26 22 15	80 21 4.1	NAD 27
54	TPW	6	05/10/89	M	8	Murray-Milleson, Inc	Miccosuke Tribe (North site); Murray-Milleson, Inc., 1989, fig. 2	3 wells	[2]NR	[2]NR	NA
55	TW-1	4	06/03/99	R	6	Montgomery Watson for SFWMD	Stormwater Treatment Area 3 and 4	None	[3]NR	[3]NR	NA
56	TW-2C	8	04/27/99	M	5	Montgomery Watson for SFWMD	ASR pilot test site, Site 1	4 wells	26 21 24	80 17 19.3	NAD 83
57	TW-3	4	08/04/99	M	6	Montgomery Watson for SFWMD	Stormwater Treatment Area 3 and 4	6 wells	[4]26 22 28	[4]80 35 47	NAD 83
58	TW-3	4	06/10/99	R	6	Montgomery Watson for SFWMD	Stormwater Treatment Area 3 and 4	None	[4]26 22 28	[4]80 35 47	NAD 83
59	TW-5	4	06/17/99	R	6	Montgomery Watson for SFWMD)	Stormwater Treatment Area 3 and 4	None	[4]26 22 27	[4]80 40 02	NAD 83
60	7R_TQ2	10	07/10/80	M	4	Gee & Jensen	Pumping well for Tequesta wellfield APT (7/10/80)	4 wells	26 57 34	80 05 35	NAD 27
61	BOCA_PW-1	NR	01/10/85	NR	4	Camp, Dresser, & McKee	Boca Raton test production well for wellfield expansion near Clint Moore Road	NR	26 24 14	80 07 46	NAD 27
62	BURMA-TEST	NR	02/03/88	M	4	Geraghty & Miller, Inc.	Burma Road Parcel test well	3 wells	26 48 01	80 05 23	NAD 27
63	FHV_W5	8	04/13/83	M	4	CH2M-HILL	Palm Springs Forest Hill Village Wellfield	5 wells	26 38 48	80 07 47	NAD 27
64	HBWW-4	NR	10/20/78	NR	4	Camp, Dresser, & McKee	Highland Beach West Wellfield well #4	NR	26 24 36	80 04 44	NAD 27

Table 1–9*A*. Hydraulic well test descriptions and locations.—Continuedd

[Sources and references for this appendix table are given in table 1–9*C*. Abbreviations: dd mm ss.s, degrees, minutes, and seconds; APT, aquifer performance test; LWDD, Lake Worth Drainage District; NA, not applicable; NR, not reported; SFWMD, South Florida Water Management District; USGS; U.S. Geological Survey. Test type: M, multiwell constant rate; P, Packer test; R, single well constant rate; S, step drawdown; SC, specific capacity]

Table 1–9*A*, 1–9*B* cross reference	Production well identifier	Production well diameter (inches)	Test date	Test type	Source and references	Operator	Test description and site number	Monitoring well identifier	Latitude north (dd mm ss.s)	Longitude west (dd mm ss.s)	Horizontal datum
65	JPW-16	NR	12/25/82	S	4	Geraghty & Miller, Inc.	Jupiter Water Plant production well #16	None	26 54 44	80 07 31	NAD 27
66	JUNO_PW-5A	NR	05/15/79	M	4	Barker, Osha, & Anderson, Inc.	Town of Juno Beach pumping well 5A	5 wells	26 52 36	80 03 18	NAD 27
67	JWSPW-13	NR	11/29/78	M	4	Geraghty & Miller, Inc.	Jupiter	4 wells	26 55 34	80 07 45	NAD 27
68	LM_PW-3	NR	07/29/82	M	4	Geraghty & Miller, Inc.	Lake Magnolia pumping well #3	3 wells	26 44 06	80 03 59	NAD 27
69	LSL_B-3	NR	08/20/85	NR	4	PBS&J, Inc.	Lantana Sanitary Landfill discharge well B-3	NR	26 36 06	80 11 23	NAD 27
70	LTC_PW-3	NR	03/10/80	M	4	NR	Lost Tree Club	3 wells	26 50 50	80 03 45	NAD 27
71	MORI_PW-1A	6	03/23/87	M	4	SFWMD	Morikami Park (SFWMD)	3 wells	26 25 43	80 09 19	NAD 27
72	PBCE-2	2	11/01/86	NR	4	Geraghty & Miller, Inc.	Palm Beach Country Estates well #2	NR	26 54 44	80 09 29	NAD 27
73	PBCE-3	2	11/01/86	NR	4	Geraghty & Miller, Inc.	Palm Beach Country Estates #3	NR	26 54 45	80 10 16	NAD 27
74	PBCWW_TW-1	6	01/01/79	M	4	Russel & Axom	Palm Beach County proposed Western Well Field site test well 1	2 wells	26 41 58	80 08 55	NAD 27
75	PBLL-PW1	6	05/01/87	M	4	SFWMD	Lake Lytal Park surficial aquifer test	16 wells	26 40 35	80 06 07.9	NAD 27
76	PBMT_PW-1	NR	08/03/87	M	4	SFWMD	Military Trail APT production well 1 (SFWMD)	4 wells	26 53 47	80 06 12	NAD 27
77	PBPOC_PW	NR	12/25/81	M	4	H.L. Searcy, Consulting Engineer, Inc.	Pumping well for Palm Beach Park of Commerce APT (1981)	1 well	26 54 18	80 16 28	NAD 27
78	RIVBEN-3	2	11/01/86	NR	4	Geraghty & Miller, Inc.	Riverbend Park well #3	NR	26 55 39	80 10 33	NAD 27

Table 1–9*A*. Hydraulic well test descriptions and locations.—Continued

[Sources and references for this appendix table are given in table 1–9*C*. Abbreviations: dd mm ss.s, degrees, minutes, and seconds; APT, aquifer performance test; LWDD, Lake Worth Drainage District; NA, not applicable; NR, not reported; SFWMD, South Florida Water Management District; USGS; U.S. Geological Survey. Test type: M, multiwell constant rate; P, Packer test; R, single well constant rate; S, step drawdown; SC, specific capacity]

Table 1–9*A*, 1–9*B* cross reference	Production well identifier	Production well diameter (inches)	Test date	Test type	Source and references	Operator	Test description and site number	Monitoring well identifier	Latitude north (dd mm ss.s)	Longitude west (dd mm ss.s)	Horizontal datum
79	RI_PW-851	NR	12/25/85	M	4	Barker, Osha, & Anderson, Inc.	City of Riviera Beach pumping well 851	3 wells	26 45 36	80 06 42	NAD 27
80	SEM_PW-1	8	11/04/83	M	4	NR	Seminole Manor Water Treatment Plant pumping well 1	1 well	26 34 48	80 05 56	NAD 27
81	SSH_PW-1	6	08/09/87	NR	4	SFWMD	South Shore pumping well #1 (SFWMD)	NR	26 38 55	80 14 40	NAD 27
82	WPB_PW-1	NR	06/10/82	M	4	Geraghty & Miller, Inc.	West Palm Beach Regional Wastewater Treatment Plant pumping well #1	5 wells	26 44 51	80 07 21	NAD 27

[1]Location not reported, estimated from Smith and Adams (1988 fig. 66);

[2]Location not reported, estimated from Murray-Milleson, Inc. (1989, fig. 2);

[3]Location not reported, estimated from Montgomery Watson Americas, Inc. (1999, fig. 4.1).

[4]Location not reported, estimated from Montgomery Watson Americas, Inc. (1999, fig. 4.1) and aerial photographs.

Table 1–9*B*. Hydraulic well test results.

[Depths are in feet below land surface. Altitude of land surface is feet above NGVD 29 (numbers in boldface type are estimated from topographic map). Method of analysis: SC, specific capacity; Theis, Theis (1935) confined aquifer; Theis Rec, Theis (1935) residual drawdown recovery; Bouwer, Bower (1989) and Bouwer and Rice (1976) slug test; C-J, Cooper and Jacob (1946) confined aquifer; H-J, Hantush and Jacob (1955) leaky aquifer; Hantush, Hantush (1960) leaky aquifer. Other annotations: K, hydraulic conductivity; MW, monitoring well; NR, not reported; PW, production well; SFWMD, South Florida Water Management District; USGS, U.S. Geological Survey; WTP, water treatment plant; --, not applicable]

Table 1–9*A*, 1–9*B* cross reference	Production-well identifier	Test date	Altitude of land surface (feet)	Depth of open interval tested (feet)	Permeable zones interpreted to be open in PW [1](Z1, Z2, Z3)	Pumping rate (gallons per minute)	Length of pumping period (hours) or step test number	Specific capacity (gallons per minute per foot)	Transmissivity (square feet per day)	Method of analysis	Estimated depths of total interval tested (feet)	Problems and comments
1	C-1171	04/29/98	15	75–135	3	222	5.0		[2]70,000	H-J for MWs and Theis Rec for PW	75–140	
									30,000	C-J for PW		
2	G-2312J	NR	15	110–140	3	NR	NR		[2]22,000	Theis; C-J; H-J; Cooper (1963)	106–140	
3	G-2312K	NR	15	40–50	2	NR	NR	NR	[2]9,000	SC	40–62	
4	G-2313A	NR	12	12–22	1	NR	NR	NR	[2]18,000	SC	12–22	
5	G-2313B	NR	12	46–81	2	NR	NR		[2]9,000	SC	46–82	
6	G-2313C	NR	12	106–146	3	NR	NR		[2]26,000	Step drawdown	106–146	
7	HE-303	06/03/58	**15**	NR-120	3	1,400	43		[2]31,000	Cooper (1963)		
8	H-M-235	02/27/86	**15**	65–125	3	754	72		14,000	H-J		
9	H-M-301	11/06/86	**15**	76–124	3	831	72		44,000	H-J		
10	H-M-328	04/17/87	**15**	75–133	3	508	71		66,000	H-J		
11	PB-1065	05/03/78	16	55–95	2	220	24		[2]11,000	Hantush		
12	PB-1233	NR	**17**	100–120	1	2,435	NR	406	[3]81,200	SC		
13	PB-1239	NR	**17**	108–124	1	2,440	NR	222	[3]44,400	SC		
14	PB-1250	NR	**17**	50–70	1	1,050	NR	131	[3]26,200	SC		
15	PB-1267	NR	**17**	57–108	1	1,000	NR	60	[3]12,000	SC		
16	PB-1310	NR	**17**	50–80	1	1,500	NR	188	[3]37,600	SC		
17	PB-1336	NR	**17**	64–70	2	450	NR	192	[3]38,400	SC		
18	PB-1343	NR	**17**	160–170	3	580	NR	118	[3]23,600	SC		
19	PB-1361	NR	**17**	72–102	1	700	NR	467	[3]93,400	SC		
20	PB-1365	NR	**17**	95–117	1	500	NR	100	[3]20,000	SC		
21	PB-1415	NR	**17**	63–69	1	100	NR	31	[3]6,200	SC		
22	PB-1545	07/03/86	18	70–160	2 and 3	433	4.65		[2]150,000	C-J for MW	56–180	Good fit for all MW data
						434	Step 4		67,000	C-J for PW		
23	PB-1545	07/20/07	18	70–153	2 and 3	307.46	2.9		[2]160,000	Theis Rec for PW		Retest
									73,000	C-J for PW		

Table 1–9*B*. Hydraulic well test results.—Continued

[Depths are in feet below land surface. Altitude of land surface is feet above NGVD 29 (numbers in in boldface type are estimated from topographic map). Method of analysis: SC, specific capacity; Theis, Theis (1935) confined aquifer; Theis Rec, Theis (1935) residual drawdown recovery; Bouwer, Bower (1989) and Bouwer and Rice (1976) slug test; C-J, Cooper and Jacob (1946) confined aquifer; H-J, Hantush and Jacob (1955) leaky aquifer; Hantush, Hantush (1960) leaky aquifer. Other annotations: K, hydraulic conductivity; MW, monitoring well; NR, not reported; PW, production well; SFWMD, South Florida Water Management District; USGS, U.S. Geological Survey; WTP, water treatment plant; --, not applicable]

Table 1–9*A*, 1–9*B* cross reference	Production-well identifier	Test date	Altitude of land surface (feet)	Depth of open interval tested (feet)	Permeable zones interpreted to be open in PW [1](Z1, Z2, Z3)	Pumping rate (gallons per minute)	Length of pumping period (hours) or step test number	Specific capacity (gallons per minute per foot)	Transmissivity (square feet per day)	Method of analysis	Estimated depths of total interval tested (feet)	Problems and comments
24	PB-1545	08/31/87?	18	70–160	2 and 3	824	2.81		220,000	C-J for MW		Reported well: USGS9_S-1
25	PB-1547	07/16/86	20	75–115	2 and 3	214	8.4		[2]6,800	C-J for MW	60–156	Early time (100 min) fit for MW data
						238	Step 4		6,300	C-J for PW		
26	PB-1551	07/30/86	23	70–130	2 and 3	212	4.95		[2]4,500	C-J for MW	63–146	Good early time (20 min) fit for MW data
						88	Step 1		3,600	C-J for PW		
27	PB-1557	08/07/86	19	50–120	2 and 3	329	6.13		[2]23,000	C-J for MW	30–130	Good early time (50 min) fit for MW data
						360	Step 4		4,000	C-J for PW		
28	PB-1559	11/19/86	20	93–153	3	109	5.97		[2]2,600	C-J for MW	87–144	Good early time (40 min) fit for MW data
						80	Step 3		3,000	C-J for PW		
29	PB-1565	11/04/86	20	68–128	2 and 3	180	3.83		[2]4,800	C-J for MW	40–154	Good early time (170 min) fit for MW data
						210	Step 4		4,000	C-J for PW		
30	PB-1568	12/08/86	17	84–164	2 and 3	160	5.57		[2]14,000	C-J for MW	10–170	Good early time (60 min) fit for MW data
						189	Step 4		7,200	C-J for PW		
31	PB-1572	11/11/86	19	106–206	2 and 3	403	2.16		180,000	C-J for MW	60–220	Early time (65 min) fit for MW data
						406	Step 4		[2]10,000	C-J for PW		
32	PB-1575	11/05/86	19	80–180	2, minor 3	318	3		[2]31,000	C-J for MW	77–183	Good early time (60 min) fit for MW data
						360	Step 4		18,000	C-J for PW		
33	PB-1577	12/02/86	17	56–146	2, minor 3	398	2		[2]36,000	C-J for MW	54–150	Early time (30 min) fit for MW data
						326	Step 3		40,000	C-J for PW		

Table 1–9*B*. Hydraulic well test results.—Continued

[Depths are in feet below land surface. Altitude of land surface is feet above NGVD 29 (numbers in in boldface type are estimated from topographic map). Method of analysis: SC, specific capacity; Theis, Theis (1935) confined aquifer; Theis Rec, Theis (1935) residual drawdown recovery; Bouwer, Bower (1989) and Bouwer and Rice (1976) slug test; C-J, Cooper and Jacob (1946) confined aquifer; H-J, Hantush and Jacob (1955) leaky aquifer; Hantush, Hantush (1960) leaky aquifer. Other annotations: K, hydraulic conductivity; MW, monitoring well; NR, not reported; PW, production well; SFWMD, South Florida Water Management District; USGS, U.S. Geological Survey; WTP, water treatment plant; --, not applicable]

Table 1–9*A*, 1–9*B* cross reference	Production-well identifier	Test date	Altitude of land surface (feet)	Depth of open interval tested (feet)	Permeable zones interpreted to be open in PW [1](Z1, Z2, Z3)	Pumping rate (gallons per minute)	Length of pumping period (hours) or step test number	Specific capacity (gallons per minute per foot)	Transmissivity (square feet per day)	Method of analysis	Estimated depths of total interval tested (feet)	Problems and comments
34	PB-1577	07/09/87	17	56–146	2, minor 3	726	1.93		38,000	C-J for MW		Early time (33 min) fit for MW data
									33,000	Theis Rec for MW		
35	PB-1580	11/13/86	10	151–221	2 and 3	337	5.12		7,700	C-J for MW	150–250	Good early time (20 min) fit for MW data
						172	Step 1		[2]5,700	C-J for PW		
36	PB-1582	11/04/86	17	90–220	2 and 3	332	5		[2]56,000	C-J for MW	87–220	Early time (100 min) fit for MW data
37	PB-1582	07/01/87	17	90–220	2 and 3	536	3.93		86,000	Theis Rec for MW		
									90,000	C-J for MW		Good fit for all MW data
38	PB-1599	02/12/87	19	110–230	2 and 3	408	6		[2]30,000	C-J for MW	100–250	?, Only very early time fit (10 to 20 min) for MW data
						401	Step 4		42,000	C-J for PW		
39	PB-1604	02/17/87	15	60–170	1 and 2	335	6		[2]20,000	C-J for MW	57–180	Good early time (60 min) fit for MW data
						271	Step 3		20,000	C-J for PW		
40	PB-1608	02/23/87	18	50–150	2 and 3	332	6		[2]15,000	C-J for MW	34–150	Early time (30 min) fit for MW data
						332	Step 4		17,000	C-J for PW		
41	PB-1769	09/20/07	15	232–337	3	39	3.01		[2]7,000	Theis Rec for PW	235–308	Theis Rec—good trend; C-J—High scatter in data (2 in. well)
									4,600	C-J for PW		
42	PB-1792	04/05/07	11.92	61.5–71.5	3	18.5	2.24		Not approved	Theis Rec for PW	57–87	Results of test not approved because of low drawdown in aquifer
									Not approved	C-J for PW		

Table 1–9*B*. Hydraulic well test results.—Continued

[Depths are in feet below land surface. Altitude of land surface is feet above NGVD 29 (numbers in in boldface type are estimated from topographic map). Method of analysis: SC, specific capacity; Theis, Theis (1935) confined aquifer; Theis Rec, Theis (1935) residual drawdown recovery; Bouwer, Bower (1989) and Bouwer and Rice (1976) slug test; C-J, Cooper and Jacob (1946) confined aquifer; H-J, Hantush and Jacob (1955) leaky aquifer; Hantush, Hantush (1960) leaky aquifer. Other annotations: K, hydraulic conductivity; MW, monitoring well; NR, not reported; PW, production well; SFWMD, South Florida Water Management District; USGS, U.S. Geological Survey; WTP, water treatment plant; --, not applicable]

Table 1–9*A*, 1–9*B* cross reference	Production-well identifier	Test date	Altitude of land surface (feet)	Depth of open interval tested (feet)	Permeable zones interpreted to be open in PW [1](Z1, Z2, Z3)	Pumping rate (gallons per minute)	Length of pumping period (hours) or step test number	Specific capacity (gallons per minute per foot)	Transmissivity (square feet per day)	Method of analysis	Estimated depths of total interval tested (feet)	Problems and comments
43	PB-1794	Various dates	15.6	18.6–40.3	1	10–12	NR		1,100	Bouwer for PWs	13–35	Uses average K from tests of 10 wells in vicinity
44	PB-1794	Various dates	15.6	58–101	2	10–12	NR		5,200	Bouwer for PWs	35–100	Uses average K from test of 6 wells in vicinity
45	PB-1801	04/18/07	12.4	85–105	2	49	0.5		[2]10,000	Theis Rec for PW	77–122	Tested twice with same results; estimated depths of total interval tested are from Bennett, M.W., 2006 (unpublished report), Hydrogeologic investigataion and seepage analysis, Bishop Property Excavation Project, Palm Beach County, Florida: South Florida Water Management District.
									10,000	C-J for PW		
46	PB-1803	04/17/07	11	155–175	3 (well confined)	7.7	1.74		3,000	Theis Rec for PW	138–163 (gray limestone aquifer)	Good fit for late time data for Theis Rec; good fit for all data for C-J
									[2]6,000	C-J for PW		
47	PB-1804	04/09/07	12	38–188	2	72	3.5		60,000	Theis Rec for PW	47–95	For Theis Rec -weak to moderate fit, but repeated in earlier test; C-J, good fit for all data except early time; correction made for steady background decline
									[2]10,000	C-J for PW		

Table 1–9*B*. Hydraulic well test results.—Continued

[Depths are in feet below land surface. Altitude of land surface is feet above NGVD 29 (numbers in in boldface type are estimated from topographic map). Method of analysis: SC, specific capacity; Theis, Theis (1935) confined aquifer; Theis Rec, Theis (1935) residual drawdown recovery; Bouwer, Bower (1989) and Bouwer and Rice (1976) slug test; C-J, Cooper and Jacob (1946) confined aquifer; H-J, Hantush and Jacob (1955) leaky aquifer; Hantush, Hantush (1960) leaky aquifer. Other annotations: K, hydraulic conductivity; MW, monitoring well; NR, not reported; PW, production well; SFWMD, South Florida Water Management District; USGS, U.S. Geological Survey; WTP, water treatment plant; --, not applicable]

Table 1–9*A*, 1–9*B* cross reference	Production-well identifier	Test date	Altitude of land surface (feet)	Depth of open interval tested (feet)	Permeable zones interpreted to be open in PW [1](Z1, Z2, Z3)	Pumping rate (gallons per minute)	Length of pumping period (hours) or step test number	Specific capacity (gallons per minute per foot)	Transmissivity (square feet per day)	Method of analysis	Estimated depths of total interval tested (feet)	Problems and comments
48	PB-1805	05/25/07	12	40–90	2 and 3	33.6	3.03		12,000	Theis Rec for PW	38–73	Theis Rec—early time fit, C-J—late time fit, well confined; well poorly developed with high drawdown (17 ft)
									[2]6,000	C-J for PW		
49	PB-1806	01/15/08	20	68–123	2 and 3	20	3.04		[2]10,000	Theis Rec for PW	67–129	Low pumping rate resulted from high drawdown and lift
									[2]4,000	C-J for PW		
50	PB-1807	03/28/08	19	70–140	2 and 3	85	3.02		Not approved	Theis Rec for PW	68–148	Results of test not approved because of large difference in results for drawdown and recovery analyses and high well loss.
									Not approved	C-J for PW		
51	PW	05/24/87	**15**	63–120	3	197	12		70,000	Glover; Jacob for MWs		
52	S10C	Various dates	22.4	12.6–34	1	10–12	NR		3,900	Bouwer for PWs	14–46	Uses average K from tests of 5 wells in vicinity
53	S10C	Various dates	22.4	62.6–101.4	2	10–12	NR		12,000	Bouwer for PWs	46–118	Uses average K from tests of 2 wells in vicinity
54	TPW	05/10/89	**15**	55–135	Minor 2, 3	440	69		44,000	H-J distance drawdown for MWs		
55	TW-1	06/03/99	**12**	35–65	2	186	8		27,000	Theis Rec for PW		

Table 1–9*B*. Hydraulic well test results.—Continued

[Depths are in feet below land surface. Altitude of land surface is feet above NGVD 29 (numbers in in boldface type are estimated from topographic map). Method of analysis: SC, specific capacity; Theis, Theis (1935) confined aquifer; Theis Rec, Theis (1935) residual drawdown recovery; Bouwer, Bower (1989) and Bouwer and Rice (1976) slug test; C-J, Cooper and Jacob (1946) confined aquifer; H-J, Hantush and Jacob (1955) leaky aquifer; Hantush, Hantush (1960) leaky aquifer. Other annotations: K, hydraulic conductivity; MW, monitoring well; NR, not reported; PW, production well; SFWMD, South Florida Water Management District; USGS, U.S. Geological Survey; WTP, water treatment plant; --, not applicable]

Table 1–9*A*, 1–9*B* cross reference	Production-well identifier	Test date	Altitude of land surface (feet)	Depth of open interval tested (feet)	Permeable zones interpreted to be open in PW [1](Z1, Z2, Z3)	Pumping rate (gallons per minute)	Length of pumping period (hours) or step test number	Specific capacity (gallons per minute per foot)	Transmissivity (square feet per day)	Method of analysis	Estimated depths of total interval tested (feet)	Problems and comments
56	TW-2C	04/27/99	**11**	85–115	2	798	72		16,000	Thiem (1906) and C-J constant time (average) for MWs	85–115	Results from different wells varied greatly
57	TW-3	08/04/99	**12**	50–80	2 and 3	200	96		27,000	Thiem (1906) and C-J constant time (average) for MWs	50–80	Rainfall event and background level changes during test
58	TW-3	06/10/99	**12**	50–80	2 and 3	210	7		30,000	Theis Rec for PW		
59	TW-5	06/17/99	**12**	55–85	3	210	8		30,000	Theis Rec for PW		
60	7R_TQ2	07/10/80	**17**	50–90	1	457	72		47,000	Boulton (1963?)		Only late-time estimates included
61	BOCA_PW-1	01/10/85	**17**	135–185	2	1,400	73		28,000	NR		
62	BURMA-TEST	02/03/88	**17**	132–162	2 and 3	213	24		7,000	Jacob (probably C-J)		
63	FHV_W5	04/13/83	**17**	123–170	2 and 3	1,600	2,880		170,000	Hantush		
64	HBWW-4	10/20/78	**17**	85–105	1	322	24.7		18,000	NR		Water table aquifer; found report
65	JPW-16	12/25/82	**17**	130–165	3	668	NR		11,000	Step drawdown		
66	JUNO_PW-5A	05/15/79	**17**	40–55	1	NR	71.25		25,000	NR		
67	JWSPW-13	11/29/78	**17**	136–200	Minor 2, 3	568	24		8,000	Boulton (1963?)		Found report
68	LM_PW-3	07/29/82	**17**	85–155	1, minor 2	600	NR		40,000	Theis Rec		
69	LSL_B-3	08/20/85	**17**	70–120	2	446	24		61,000	NR		Found report
70	LTC_PW-3	03/10/80	**17**	144–159	2	155	3.17		3,700	Boulton (1963?)		Reported value in disagreement with values for the 3 MWs. Used value representative of the 3 MWs.

Table 1–9*B*. Hydraulic well test results.—Continued

[Depths are in feet below land surface. Altitude of land surface is feet above NGVD 29 (numbers in in boldface type are estimated from topographic map). Method of analysis: SC, specific capacity; Theis, Theis (1935) confined aquifer; Theis Rec, Theis (1935) residual drawdown recovery; Bouwer, Bower (1989) and Bouwer and Rice (1976) slug test; C-J, Cooper and Jacob (1946) confined aquifer; H-J, Hantush and Jacob (1955) leaky aquifer; Hantush, Hantush (1960) leaky aquifer. Other annotations: K, hydraulic conductivity; MW, monitoring well; NR, not reported; PW, production well; SFWMD, South Florida Water Management District; USGS, U.S. Geological Survey; WTP, water treatment plant; --, not applicable]

Table 1–9*A*, 1–9*B* cross reference	Production-well identifier	Test date	Altitude of land surface (feet)	Depth of open interval tested (feet)	Permeable zones interpreted to be open in PW [1](Z1, Z2, Z3)	Pumping rate (gallons per minute)	Length of pumping period (hours) or step test number	Specific capacity (gallons per minute per foot)	Transmissivity (square feet per day)	Method of analysis	Estimated depths of total interval tested (feet)	Problems and comments
71	MORI_PW-1A	03/23/87	**17**	116–185	2	890	74		70,000	C-J		
72	PBCE-2	11/01/86	**17**	140–170	3	75	0.5		5,000	C-J		
73	PBCE-3	11/01/86	**17**	50–80	2	120	0.5		4,000	C-J		
74	PBCWW_TW-1	01/01/79	**17**	80–120	2	1,450	72		180,000	NR		
75	PBLL-PW1	05/01/87	16	94–120	2	1,000	72		47,000	C-J		Early time (10 min) fit only
76	PBMT_PW-1	08/03/87	**17**	40–250	1,2, and 3	189	72		27,000			
77	PBPOC_PW	12/25/81	**17**	74–94	2, minor 3(?)	225	24		13,000	Neuman partial penetration (probably Neuman (1974))		
78	RIVBEN-3	11/01/86	**17**	140–170	3	75	0.5		7,000	Jacob (probably C-J)		
79	RI_PW-851	12/25/85	**17**	70–130	2	1,380	4.42		100,000	Time-drawdown		Method not reported, but a leakance value was reported, indicating a leaky aquifer solution
80	SEM_PW-1	11/04/83	**17**	100–120	1	1,000	2.87		35,000	Hantush and C-J		
81	SSH_PW-1	08/09/87	**17**	50–91	2	92	44.2		3,500	Neuman (1972)		
82	WPB_PW-1	06/10/82	**17**									

[1]Minor indicates only part of zone is open or thickness of zone is minor compared to thickness of other zone(s).
[2]Approved value for USGS test.
[3]Uses a factor of 200 to compute transmissivity from specific capacity.

Table 1–9*C*. Sources and references for hydraulic well tests

[Hydraulic well test information provided in tables 1–9*A* and 1–9*B*]

Citatlion number	Source or reference
1a	Tests run in previous USGS study; Reese, R.S., and Cunningham, K.J., 2000, Hydrogeology of the gray limestone aquifer in souhern Florida: U.S. Geological Survey Water-Resources Investigations Report 99–4213, 244 p.
1b	Tests run in previous USGS study; Fish, J.E., 1988, Hydrogeology, aquifer characteristics, and ground-water flow of the surficial aquifer system, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 87–4034, 92 p.
1c	Tests run in previous USGS study; Klein, Howard, Schroeder, M.C., and Lichtler, W.F., 1964, Geology and ground-water resources of Glades and Hendry Counties, Florida: Florida Geological Survey Report of Investigations 37, 101 p.
1d	Tests run in previous USGS study; Fischer, J.N., Jr., 1980, Evaluation of a cavity-riddled zone of the shallow aquifer near Riviera Beach, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 80–60, 39 p.
1e	Tests run in previous USGS study; unpublished by the USGS, test approved by internal memo dated 4/8/1988.
1f	Tests run in previous USGS study; Swayze, L.J., and Miller, W.L., 1984, Hydrogeology of a zone of secondary permeability in the surficial aquifer of eastern Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 83–4249, 39 p.
2	Tests done in this study
3	Tests run in previous USGS study; Harvey, J.W., Krupa, S.L., Gefvert, Cynthia, and others, 2000, Interaction between ground water and surface water in the northern Everglades and relation to water budget and mercury cycling: study methods and appendixes: U.S. Geological Survey Open-File Report 00–168, 411 p.
	and Harvey, J.W., Krupa, S.L., Gefvert, Cynthia, and others, 2002, Interactions between surface water and ground water and effects on mercury transposrt in the north-central Everglades: U.S. Geological Survey Water-Resources Investigations Report 02–4050, 82 p.
4	Data from SFWMD DBHYDRO database; production well identifier is station name.
5	Montgomery Watson, 1999, Final report on Site 1 detailed analysis: SFWMD Contract No. C-9765, submittal memo on 9–22–1999, 20 p. and appendixes.
6	Montgomery Watson Americas, Inc., 1999, Stormwater Treatment Area No. 3 and 4, field investigations and seepage analysis report: SFWMD contract, 48 p. and appendixes.
7	Murray-Milleson, Inc., 1987, Hydrogeologic study for the Seminole Tribe of Florida, 15 p. and appendix.
8	Murray-Milleson, Inc., 1989, Hydrogeologic study of Miccosukee Indian Reservation in Broward County, Florida, 27 p. and appendix.
9	Smith, K.R. and Adams, K.M., 1988, Ground water resource assessment of Hendry County, Florida: South Florida Water Management District Technical Publication 88–12: 109 p. and appendixes.
10	Repeat tests run by SFWMD.

Table 1–10. Water-quality data collected in this study.

[All depths are below land surface, in feet. Abbreviations: deg, degrees; NM, not measured; mg/L, milligrams per liter; µg/l, micrograms per liter; wf, water filtered; wu, water unfiltered; ROE, residue on evaporation]

USGS local well name	Date (mm/dd/yyyy)	Time (hhmm)	Depth of open interval (feet)	Zone open	Specific conductance at 25 deg C (µS/cm)	Water temperature, (deg C)	Residue ROE at 180 deg C, wf (mg/L)	Chloride, wf (mg/L)	Sulfate, wf (mg/L)	Calcium, wf (mg/L)	Strontium, wf (µg/L)	H-2/H-1, wu (per mil)	O-18/O-16, wu (per mil)	Sr-87/Sr-86, wf ratio	Boron, wf (µg/L)	Boron-11/Boron-10 (per mil)
PB-715	05/23/06	1529	72-81	2	764	NM	471	38	3.31	121	1,052	13.8	2.45	0.70910	20	NM
PB-830	05/23/06	1355	120–129	Below 3	5,130	NM	3,030	1,250	277	174	2,100	5.2	0.54	0.70902	508	32.3
PB-880	06/15/06	1123	90–117	3	949	25.1	593	46.5	25.9	111	1,165	9.0	1.37	0.70910	67	NM
PB-1097	05/23/06	1030	80–83	2	923	NM	552	81.3	1.95	124	2,078	-0.9	-0.89	0.70905	20	NM
PB-1107	05/23/06	1119	95–103	2	837	NM	521	80.7	11.1	105	1,350	2.4	0.01	0.70920	18	NM
PB-1545	05/18/06	1119	67–153	2 and 3	668	NM	409	43	7.29	106	1,838	2.6	0.16	0.70913	10	NM
PB-1547	05/24/06	1051	75–112	2 and 3	1,040	NM	629	160	7.01	114	1,071	1.8	-0.11	0.70911	20	NM
PB-1608	05/24/06	1157	50–145	2 and 3	5,770	NM	3,510	1,340	386	271	2,846	3.5	0.14	0.70917	329	33.0
PB-1761	06/06/06	1508	0–111	1 and 2	1,370	24.2	778	206	48.7	81.6	1,800	5.2	1.18	NM	NM	NM
PB-1785	05/30/06	1132	166–174	Below 3	7,460	NM	3,570	1,670	147	99.4	3,155	7.3	0.84	0.70901	630	24.0
PB-1786	06/01/06	1334	170–180	Below 3	12,300	NM	8,330	3,130	1,790	491	5,557	5.5	0.25	0.70903	1,130	33.8
PB-1787	06/01/06	1440	176–187	Below 3	10,500	24.7	6,030	2,990	338	93.8	2,412	5.6	0.52	0.70899	1,162	29.0
PB-1789	06/01/06	1057	64–74	2	1,500	25.5	868	186	20.8	86.7	3,438	4.7	0.29	0.70901	114	NM
PB-1790	06/01/06	1142	55–65	2	1,110	25.8	676	119	56.6	81.4	2,740	7.0	0.73	0.70907	42	NM
PB-1794	06/02/06	1231	99–101	3	16,800	24.8	10,400	4,730	838	79	2,318	12.0	1.65	0.70907	1,205	36.5
PB-1797	06/02/06	1124	176–191	Below 3	29,700	NM	19,200	9,530	1,540	269	5,588	13.2	1.8	0.70894	2,640	32.6
PB-1798	06/02/06	1148	98–100	3	1,310	25.3	808	178	75	93.1	2,970	9.4	1.25	0.70907	98	NM
PB-1801	06/06/06	1217	85–105	2	1,480	24.6	864	185	24.6	134	3,211	4.8	0.38	0.70909	73	NM
PB-1802	06/06/06	1236	20–30	1	1,060	25.1	638	114	9.06	98.2	2,620	1.4	-0.15	0.70906	32	NM

Appendix 2. Montages showing lithology, geophysical logs, geologic and hydrostratigraphic units, flow zones, and well construction for all wells with data available

Included in appendix 2 are log montages in WellCAD™ (WCL) file format showing data plots for 115 wells. Included are wells drilled prior to this study and four of the five wells drilled for this study. These wells are identified in table 1–8 of this report. In addition to all geophysical logs run and lithology, data included in the log montages and their column heading identifiers are geologic (FM) and hydrostratigraphic (HYD) units, if determined, flow zones (HYD-FZ), if determined, and well construction (CONST). Flow zones were determined by flow meter logs for four of the wells drilled in this study (PB-1804 though PB-1807) and two previously drilled wells (PB-1608 and PB-1761). The percentage of total flow during pumping is labeled for each flow zone in the HYD-FZ column. The lithology is shown by a lithologic symbols column (LITH) and a brief lithologic description column (Lithofacies). A more detailed lithologic description for five wells is provided by tables 1–2 through 1–6, including four of the wells drilled in this study and PB-1761.

The WellCAD™ files in this appendix can be opened, viewed, and printed by installing the WellCAD Reader™ software included in this appendix. This software is non proprietary; however, the only modifications allowed that can be saved are scale changes. If a full version of WellCAD™ is available, these files may be opened, modified, and saved as usual.

All of the plots in the appendix are saved in WellCAD™ at a vertical scale of 1 in. = 20 ft (except for PB-1761). Because of this scale, upon opening a file in WellCAD™, the full lithologic description may not be visible for all intervals. In particular, the lithologic descriptions for thin intervals (3 ft or less thick) do not appear. To view the lithologic description for all intervals, the vertical scale can be expanded in WellCAD Reader™, for example from 1 in. = 20 ft to 1 in. = 10 ft. Expansion of the vertical scale will also be required to view the digital borehole image included for PB-1807.