Hydrogeology of the Surficial and Intermediate Aquifer Systems in Sarasota and Adjacent Counties, Florida

By G.L. Barr

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
Suite 3015
227 North Bronough Street
Tallahassee, Florida 32301

Copies of this report can be purchased from:

U.S. Geological Survey
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CONVERSION FACTORS, VERTICAL DATUM, ABBREVIATED WATER-QUALITY UNITS, AND ACRONYMS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
inch (in.)	25,400	micrometer
cubic inch (in^3)	16.39	cubic centimeter
foot (ft)	0.3048	meter
foot per day (ft/d)	1.0	meter per day
foot per day per foot [(ft/d)/ft]	1.0	meter per day per meter
mile (mi)	1.609	kilometer
foot squared per day (ft^2/d)	0.0929	meter squared per day
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
gallon per day (gal/d)	3.785	liter per day
gallon per minute (gal/min)	0.06308	liter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Temperature in degrees Fahrenheit (^oF) can be converted to degrees Celsius (^oC) as follows:

$$^oC = 5/9\ (^oF - 32)$$

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

ABBREVIATED WATER-QUALITY UNITS

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

ACRONYMS

SAS	Surficial aquifer system
IAS	Intermediate aquifer system
PZ1	Intermediate aquifer system, permeable zone 1
PZ2	Intermediate aquifer system, permeable zone 2
PZ3	Intermediate aquifer system, permeable zone 3
UFA	Upper Floridan aquifer
CU SAS/PZ1	Confining unit between SAS and PZ1
CU PZ1/PZ2	Confining unit between PZ1 and PZ2
CU PZ2/PZ3	Confining unit between PZ2 and PZ3
CU PZ3/UFA	Confining unit between PZ3 and UFA
EWD	Englewood Water District
FGS	Florida Geological Survey
MCL	Maximum concentration level
QWIP	Quality of Water Improvement Program
RO	Reverse osmosis
ROMP	Regional Observation and Monitor-Well Program
SWFWMD	Southwest Florida Water Management District
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WRAP	Water Resources Assessment Program

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ABSTRACT

From 1991 to 1995, the hydrogeology of the surficial aquifer system and the major permeable zones and confining units of the intermediate aquifer system in southwest Florida was studied. The study area is a 1,400-square-mile area that includes Sarasota County and parts of Manatee, De Soto, Charlotte, and Lee Counties. Lithologic, geophysical, hydraulic property, and water-level data were used to correlate the hydrogeology and map the extent of the aquifer systems. Water chemistry was evaluated in southwest Sarasota County to determine salinity of the surficial and intermediate aquifer systems.

The surficial aquifer is an unconfined aquifer system that overlies the intermediate aquifer system and ranges from a few feet to over 60 feet in thickness in the study area. Hydraulic properties of the surficial aquifer system determined from aquifer and laboratory tests, and model simulations vary considerably across the study area.

The intermediate aquifer system, a confined aquifer system that lies between the surficial and the Upper Floridan aquifers, is composed of alternating confining units and permeable zones. The intermediate aquifer system has three major permeable zones that exhibit a wide range of hydraulic properties. Horizontal flow in the intermediate aquifer system is northeast to southwest. Most of the study area is in a discharge area of the intermediate aquifer system.

Water ranges naturally from fresh in the surficial aquifer system and upper permeable zones of the intermediate aquifer system to moderately saline in the lower permeable zone.Water-quality data collected in coastal southwest Sarasota County indicate that ground-water withdrawals from major pumping centers have resulted in lateral seawater intrusion and upconing into the surficial and intermediate aquifer systems.

INTRODUCTION

Demand for public, industrial, and domestic water-supply is increasing in southwest Florida largely due to an influx of new residents and increased development in coastal regions. In southwest Florida, ground water is the main source of potable water. In 1992, a variety of community potable water systems, ranging from county-owned water systems to independent businesses in Sarasota County were permitted by the Southwest Florida Water Management District (SWFWMD) to withdraw ground water. The SWFWMD also requires permits by other independent businesses that withdraw ground water for agricultural, industrial, mining, and recreational purposes when the outside diameter of the well casing is 6-in. or greater, total withdrawal capacity from any source or combined sources is greater than or equal to 1 million gal/d, or the annual average withdrawal from any source or combined sources is greater than or equal to 100,000 gal/d (SWFWMD, 1994). Withdrawals reported by these permitted water systems ranged from hundreds of gallons to more than 2 million gallons per month. Domestic homes and private companies do not require water-use permits when the outside diameter of the well casings is smaller than 6-in. and withdraws are less than threshold pumpage rates.

Ground water is withdrawn from three main aquifer systems in Sarasota County and neighboring counties: the surficial aquifer system (SAS), intermediate aquifer system (IAS), and Upper Floridan aquifer (UFA). Manatee County withdraws much of its potable water from the UFA. Southern Sarasota County and counties to the south rely heavily on the surficial and intermediate aquifer systems for their potable water. Limited supplies of potable ground water can be pumped from thin layers of the SAS and the upper two permeable zones of the IAS in those areas. Limited amounts of water can be withdrawn from these potable water zones because they are thin and have limited areal extent. Slightly saline to very saline water is available in larger quantities from the deeper permeable zones in the area. Slightly saline to moderately saline water can be converted to potable water by desalinization but at a relatively large expense. Because of the need for large quantities of potable water, 42 facilities for public water supply were permitted for desalinization operations in the Sarasota-Charlotte County area in 1993; 19 of the facilities produced more than 100,000 gal/d (Mark Hammond, SWFWMD, oral commun., 1994).

The IAS has a series of permeable zones and confining units. Water quality in the zones depends on the hydrogeologic setting, flow dynamics, well construction, and pumping stresses on the aquifer system. The confining units of the IAS limit movement of water between the various permeable zones. Many production wells are open to several permeable zones of the IAS, allowing for an interchange of water with significantly different water-quality properties. Consequently, potable water in upper zones can be degraded by saline water from deeper permeable zones. Wells with corroded casings also can allow interchange of water among the zones. The withdrawal of ground water from production wells near the coast increases the possibility of lateral seawater intrusion because of the proximity to the seawater/freshwater interface at the coast. Intense pumping of an upper permeable zone also can cause upconing of water with higher dissolved solids from lower permeable zones.

A better understanding of the hydrogeology of the SAS and the IAS is needed to evaluate the effects of pumping on the entire aquifer system. Because of insufficient hydrogeologic information of the individual permeable zones and confining units of the IAS, the potentiometric surfaces of the individual permeable zones of the IAS and the UFA is not well defined. In October 1991, the U.S. Geological Survey (USGS), in cooperation with the SWFWMD, began a 3-year study to define the hydrogeology of the surficial and intermediate aquifer systems in Sarasota County and adjacent counties (fig. 1). In 1993, Sarasota County became a cooperator and the study was extended through September 1995 and expanded to include an evaluation of ground-water quality and seawater intrusion along coastal Sarasota County, from Osprey to Englewood (fig. 1).

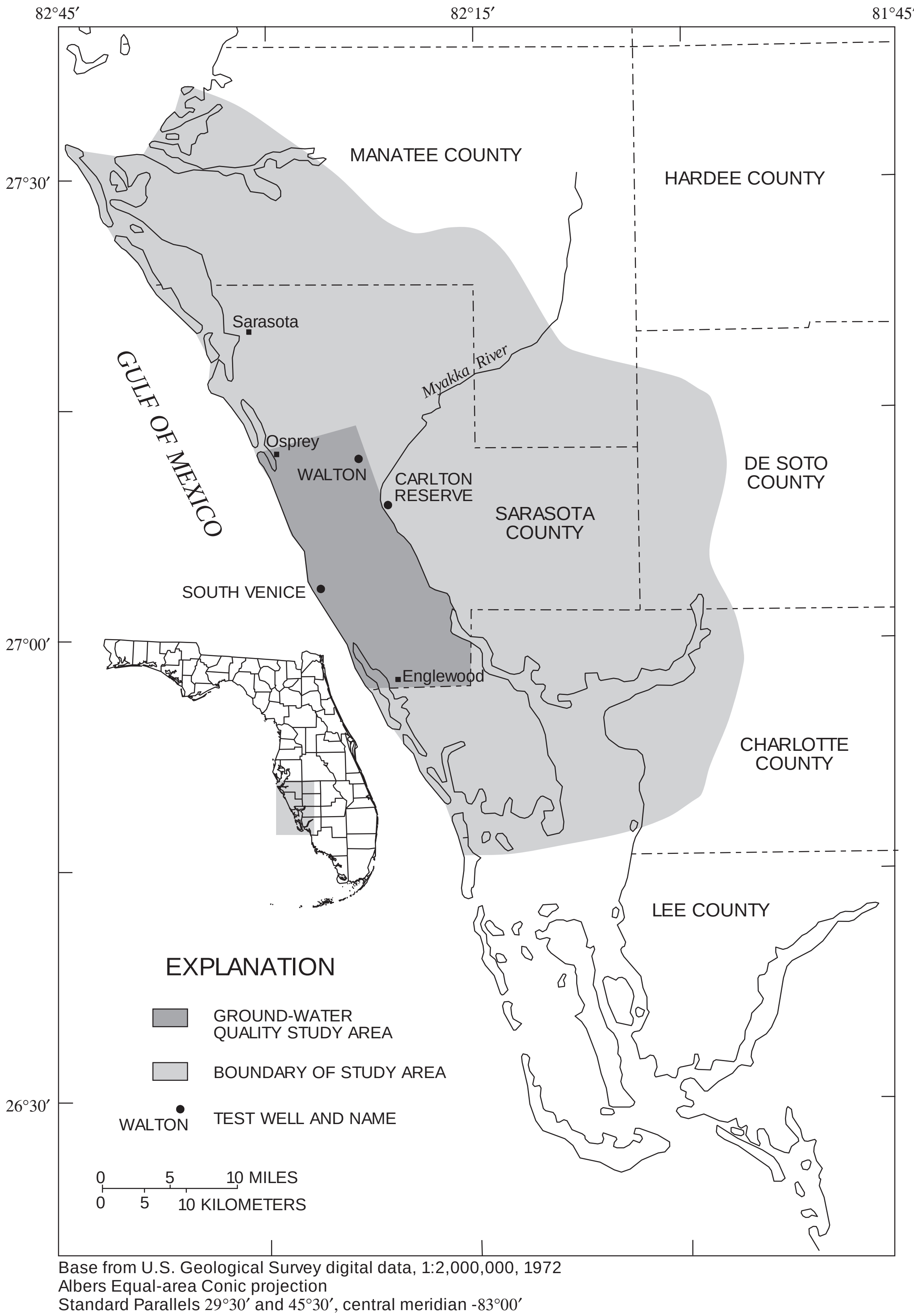
Purpose and Scope

This report describes the hydrogeology of the surficial and intermediate aquifer systems in southwest Florida, focusing on the area where the Venice Clay exists. The hydrogeologic framework is based upon lithologic, geophysical, head, water-quality, and hydraulic property data from many existing wells and three test wells constructed in Sarasota County during the study. Data from existing wells were from the files of the USGS, SWFWMD, Florida Geological Survey (FGS), Sarasota County Utility and Water Departments, and private consultants' reports. Ground-water quality and the potential for seawater intrusion in coastal Sarasota County between Osprey and Englewood were determined from water collected from wells open to the SAS and IAS.

Description of the Study Area

The study area is about 1,400 mi^2 and includes Sarasota County and parts of Manatee, De Soto, Charlotte, and Lee Counties (fig. 1). The areal extent of the study area was selected by evaluating the hydrogeologic framework and defining the landward extent of the Venice Clay, a member of a confining unit in the upper part of the IAS. A smaller part of the study area in southwest Sarasota County, between Osprey and Englewood and to the east in the general vicinity of the Myakka River, was selected for evaluation of ground-water quality, seawater intrusion, and a general discussion of ground-water flow.

The study area lies in parts of the Gulf Coastal Lowlands, the lagoons and barrier chain, and the De Soto Plain, all minor divisions of the Florida central or



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 1. Location of the study area, ground-water quality study area, and test wells.

midpeninsula physiographic zone described by White (1970). Land-surface altitude ranges from sea level along Gulf coastal regions to over 100 ft above sea level in southeast Manatee County. The area is characterized by gradually sloping plains and terraces formed in shallow marine environments by advances and retreats of the sea during Tertiary and Quaternary periods. Most inland areas are dry upland habitats with an assortment of palustrine forested, scrub-shrub, or palustrine emergent wetland habitats (U.S. Fish and Wildlife Service, 1985). The area is marked with springs and karst features including, sinkholes, depressions, and relict-sink lakes.

Previous Investigations

Early reconnaissance reports of Florida before the mid-1980’s, which described geology or ground water in the study area, reported the surficial or intermediate aquifer systems in geologic or hydraulic terms. These proposed descriptions and names for the surficial and intermediate aquifer systems as hydrogeologic units were acknowledged by the Southeastern Geological Society (1986). Terminology for the SAS has generally undergone few changes and has usually been called the non-artesian aquifer, unconfined aquifer, water-table aquifer, or the surficial aquifer.

Descriptions of sediments of the IAS by investigators have undergone a progression of terminology. Stringfield (1936, p. 131) combined the IAS with the Floridan aquifer in his investigation of artesian water in Tertiary deposits of the southeastern States and referred to both as “the main body of water.” In 1966, Stringfield described the geology in Florida and called the IAS the “local artesian aquifers” of middle Miocene and younger aged sediments. Parker and others (1955, p. 189) defined the Hawthorn and Tamiami Formations as the “Florida aquiclude.” Peek (1958) completed the first detailed geologic study of Manatee County, noting that the Hawthorn Formation serves as a confining bed for the Floridan aquifer. Clark (1964) investigated the hydrologic conditions near Venice, Fla., and called the upper Hawthorn sediments the “first and second artesian aquifers,” an early attempt to distinguish individual permeable zones of the IAS.

Later, investigators began describing the IAS as an aquifer system with discrete permeable zones. Sutcliffe (1975), investigating the water resources of Charlotte County, divided the Tamiami Formation and other Miocene sediments into three discrete aquifer zones. The hydrogeology and water quality of the three discrete aquifer zone system of the Tamiami Formation and Miocene sediments were further described by Joyner and Sutcliffe (1976) for Sarasota County and parts of Manatee, Hardee, De Soto, Charlotte, and Lee Counties. Geraghty and Miller (1974, 1975) investigated the hydrogeology of the “water table aquifer” and the “upper artesian aquifer” at the Verna well field in northeast Sarasota County, the hydrogeology in central Sarasota County at the MacArthur tract (1981), and at Venice Gardens (1985), where the IAS was termed the “secondary artesian aquifer.” Wolansky (1978) reported the hydrogeology of the unconfined aquifer in Charlotte County. In Brown’s reports of the water resources of Manatee County (1981) and the Manasota basin (1982), he called part of the IAS the “minor artesian aquifer.” In the study by Sutcliffe and Thompson (1983), in the Venice-Englewood area, Sarasota and Charlotte Counties, the hydrogeology and water quality of five aquifer zones were described for the surficial, intermediate, and Upper Floridan aquifer systems.

A report by Wolansky (1983) describing the hydrogeology of the Sarasota-Port Charlotte area divides the Miocene and lower Pliocene sediments into two hydrogeologic units called the lower Hawthorn-upper Tampa aquifer and the Tamiami-upper Hawthorn aquifer. These two hydrogeologic units are called the “intermediate aquifers,” and correspond to the upper two permeable zones of the present day IAS. In a study of the hydrogeology of the Verna well field in Sarasota County, Hutchinson (1984) also used Wolansky’s terminology for the Miocene and lower Pliocene sediments of the IAS. Campbell reported the geology of Sarasota County (1985a) and De Soto County (1985b). A water supply and development study by Dames and Moore (1985) that included hydrogeology of central Sarasota County (Ringling-MacArthur Reserve) notes a “secondary artesian aquifer” within the Hawthorn and Tampa Limestone. Duerr and Wolansky (1986) reported the hydrogeology and water quality in the surficial and intermediate aquifers in central Sarasota County (Ringling-MacArthur Reserve).

Since 1987, the USGS has published biannual potentiometric-surface map reports of the IAS in southwest Florida. Potentiometric surfaces are contoured based upon Wolansky’s (1983) two permeable zones of the IAS. Reports show general head relations, but insufficient areal coverage and composite-head data have resulted due to a paucity of single permeable-zone head data. The first effort to map the areal extent and upper and lower bounds of the IAS was in a study of the geohydrology and water withdrawals of the aquifer systems in southwest Florida by Duerr and others (1988). Lithostratigraphic work by Scott (1988) lead to an accurate understanding of the Hawthorn sediments and subsequent revision to group status. The SWFWMD (1990) presented ground-water quality results in Manatee, Hardee, Highlands, Sarasota, De Soto, and Charlotte Counties of water samples from wells open to the surficial, intermediate, and Upper Floridan aquifer systems; all water-quality data from IAS wells, however, were reported as composite data because some wells were open to several permeable zones. Hutchinson (1992) assessed the hydrogeology of southwest Sarasota and west Charlotte Counties, and reported on water quality of samples from springs and wells open to the IAS and Upper Floridan aquifer; some water-quality data were of samples from wells open to several zones of the IAS.

Information about the hydraulic properties of the SAS and IAS was also obtained from reports by CH2M Hill (1978), Post, Buckley, Schuh, and Jernigan (1981, 1982a, and 1982b), and Ardaman and Associates, Inc. (1992). Hydrogeologic and well-construction data from the SWFWMD Regional Observation Monitoring Program (ROMP), Water Resources Assessment Program (WRAP), Quality of Water Improvement Program (QWIP), and information from the data-resources, water-use, and well-permitting departments were also used.

Methods for Describing the Hydrogeology

Files of the USGS, SWFWMD, FGS, Sarasota County, and consultants' reports were the sources of lithologic, hydraulic, borehole geophysical, and head data. From all the well data available, 61 wells were selected to evaluate the hydrogeologic properties of the SAS, Venice Clay, and the permeable zones and confining units of the IAS in the study area.

The areal extent of the permeable zones of the IAS has not been determined. In 1992, the Carlton Reserve and South Venice test wells were drilled by the FGS to collect hydrogeologic data that could be used to provide benchmark information for the SAS, Venice Clay, and the IAS. The Walton test well was drilled in 1991 by the USGS for geologic reconnaissance. At all three test wells (fig. 1), continuous sediment and core samples were collected using split-spoon (upper 10 to 30 ft) and wire-line techniques. The Carlton Reserve, South Venice, and Walton test wells were drilled to depths of 580, 701, and 304 ft below land surface, respectively. The Carlton Reserve and South Venice test wells penetrated the UFA, and the Walton test well was completed into the IAS. The Carlton Reserve test well was converted into a 4-in. monitor well with an open hole interval of 175 to 190 ft below land surface. Personnel from the FGS and USGS provided lithostratigraphic and paleontologic descriptions from samples collected at the test wells (Campbell and others, 1993; Wingard and others, 1995). The FGS conducted laboratory tests on selected cores of the Carlton Reserve and South Venice wells using falling-head permeameters to determine vertical hydraulic conductivities. Borehole geophysical data were collected at the three test wells by the USGS.

Correlation techniques were used to construct hydrogeological sections across the study area. The data acquired during this study were used to construct isopach maps of the surficial, intermediate, and Upper Florida aquifer systems. At the three test wells, depth intervals of hydrogeologic units were determined and correlated with lithologic descriptions and signatures on the geophysical logs. Correlations subsequently were made with log data from other wells on the section line. Head data from 15 ROMP sites and 1 FGS well were used to define the depth intervals for permeable zones and confining units of the IAS; however, head data were interpreted with caution because of well construction techniques and seasonal head changes that occurred during drilling periods that sometimes exceeded 6 months.

Other well data used in the correlation of hydrogeologic units included reliable lithologic descriptions from core or cutting samples, geophysical logs, and heads collected during drilling. Natural gamma and electric logs were used to establish geophysical profiles for the SAS and IAS. The most comprehensive data for defining the Venice Clay were from the Carlton Reserve, South Venice, and Walton test wells, and from ROMP sites 22, TR 5-1, and TR 7-2. Samples of the Venice Clay at these sites were age dated by fossil identification, and mineral content was analyzed by x-ray diffraction in samples at the three test wells. Selected data from the key wells, presented

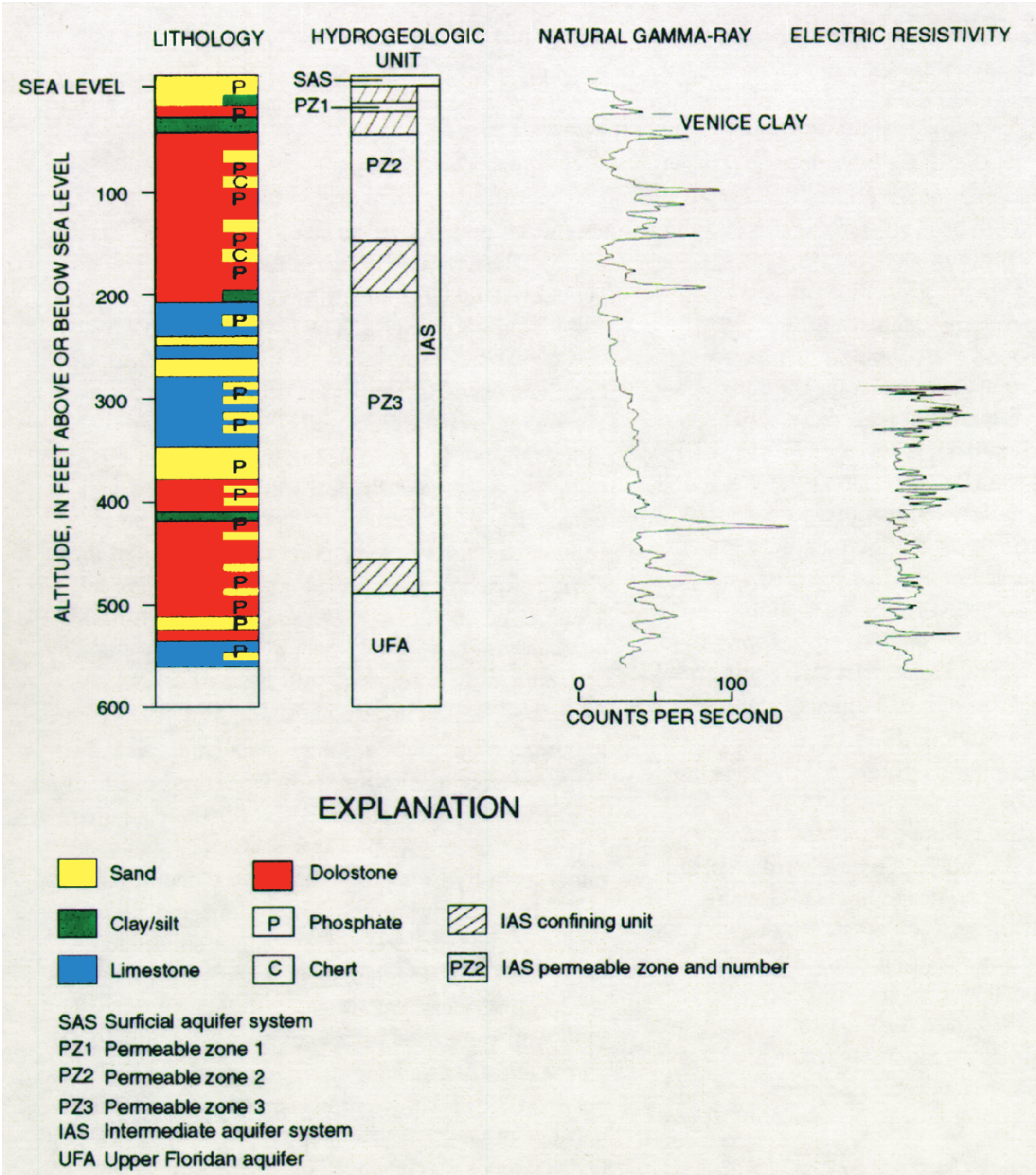


Figure 2. Lithologic, hydrogeologic, and geophysical data at the Carlton Reserve test well.

in figures 2-4, include lithology, hydrogeologic unit, head, and borehole geophysical logs.

Acknowledgments

The author gratefully acknowledges the support of the SWFWMD and Sarasota County. Sarasota County and the U.S. Army Corps of Engineers allowed the drilling of test wells on their properties. Special thanks are extended to the following individuals: Frank T. Manheim, USGS, for providing the core-squeezing apparatus and technical advice on sampling methods; Amleto A. Pucci, Lafayette College, Easton, Pa., who also advised on core-squeezing, water sampling, and laboratory analytical techniques; Roger Quick, Englewood Water District; Robert Money, Plantation Utility; Steven F. Park, City of Venice; and Betty Thomas, Venice Gardens Utility, for providing production-well and water-quality data at the respective well fields; George Ulrich, USGS, retiree, who voluntarily assisted in identifying lithologies at the test wells. Thanks also are given to the many residents in Sarasota County who allowed water samples to be

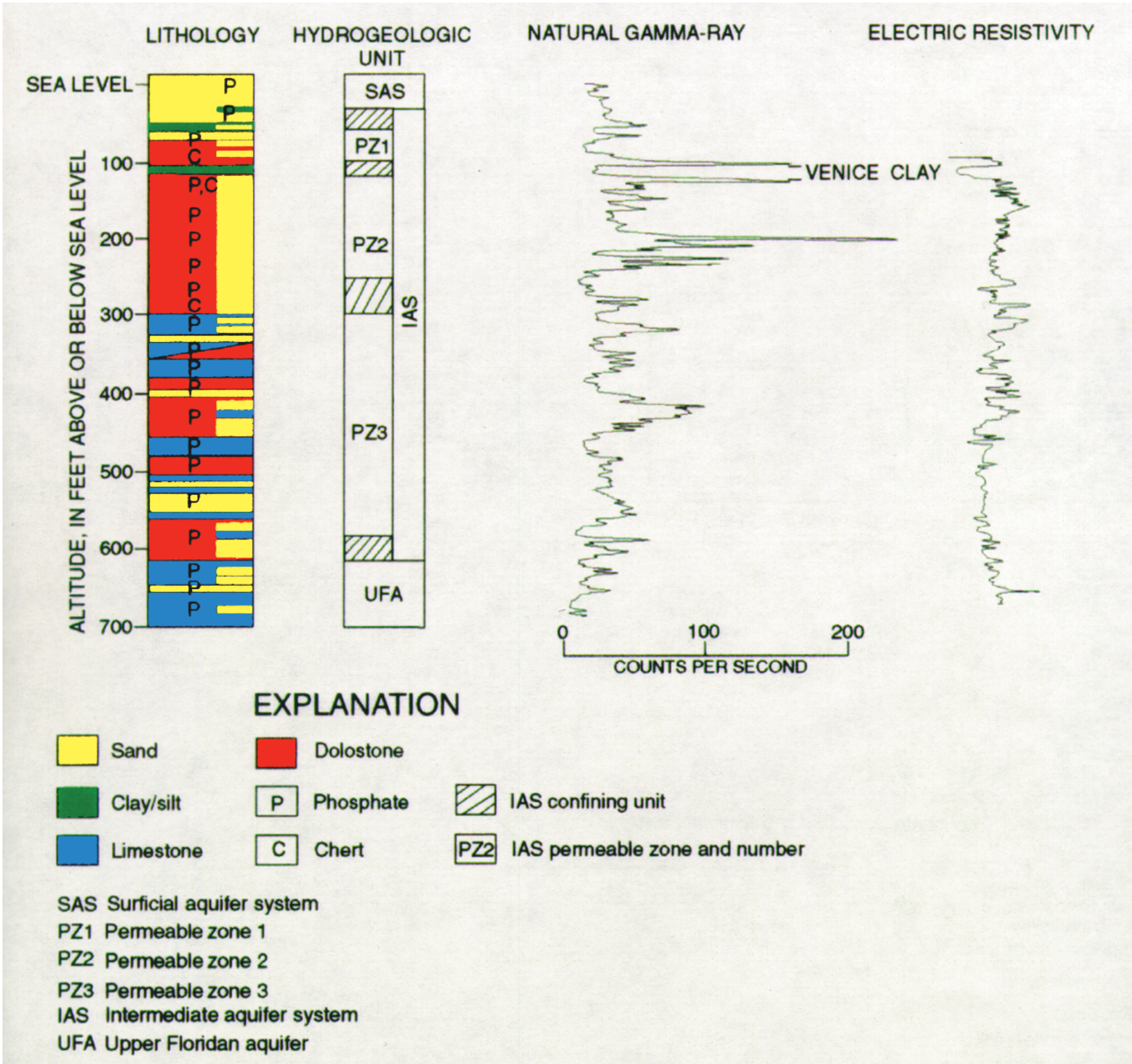


Figure 3. Lithologic, hydrogeologic, and geophysical data at the South Venice test well.

collected from their wells. The author is grateful to Jonathan D. Arthur and Thomas M. Scott, Florida Geological Survey, for their insightful comments and technical review of the Florida geology.

HYDROGEOLOGIC FRAMEWORK

The surficial and intermediate aquifer systems, a series of unconsolidated and consolidated marine sediments from the land surface downward are more than 700 ft thick in the study area. The hydrogeologic units in these sediments range in age from Quaternary to early Tertiary. The hydrogeologic framework of the study area is presented in figure 5. The locations of 10 hydrogeologic sections are shown in figure 6 and the sections are shown in figures 7-16. A summary of well records, vertical hydraulic conductivities, and hydraulic properties of the SAS and IAS are listed in table 1.

Surficial Aquifer System

The SAS consists of permeable, unconsolidated, clastic sediments and some locally consolidated basal carbonates that range in age from Holocene to Pliocene. The sediments are composed of fine to medium quartz and phosphatic sand, clayey sand, clay, sandy clay, shells, limestone, and dolostone, and become increasingly phosphatic and clayey with depth. Carbonate sediments usually are components of

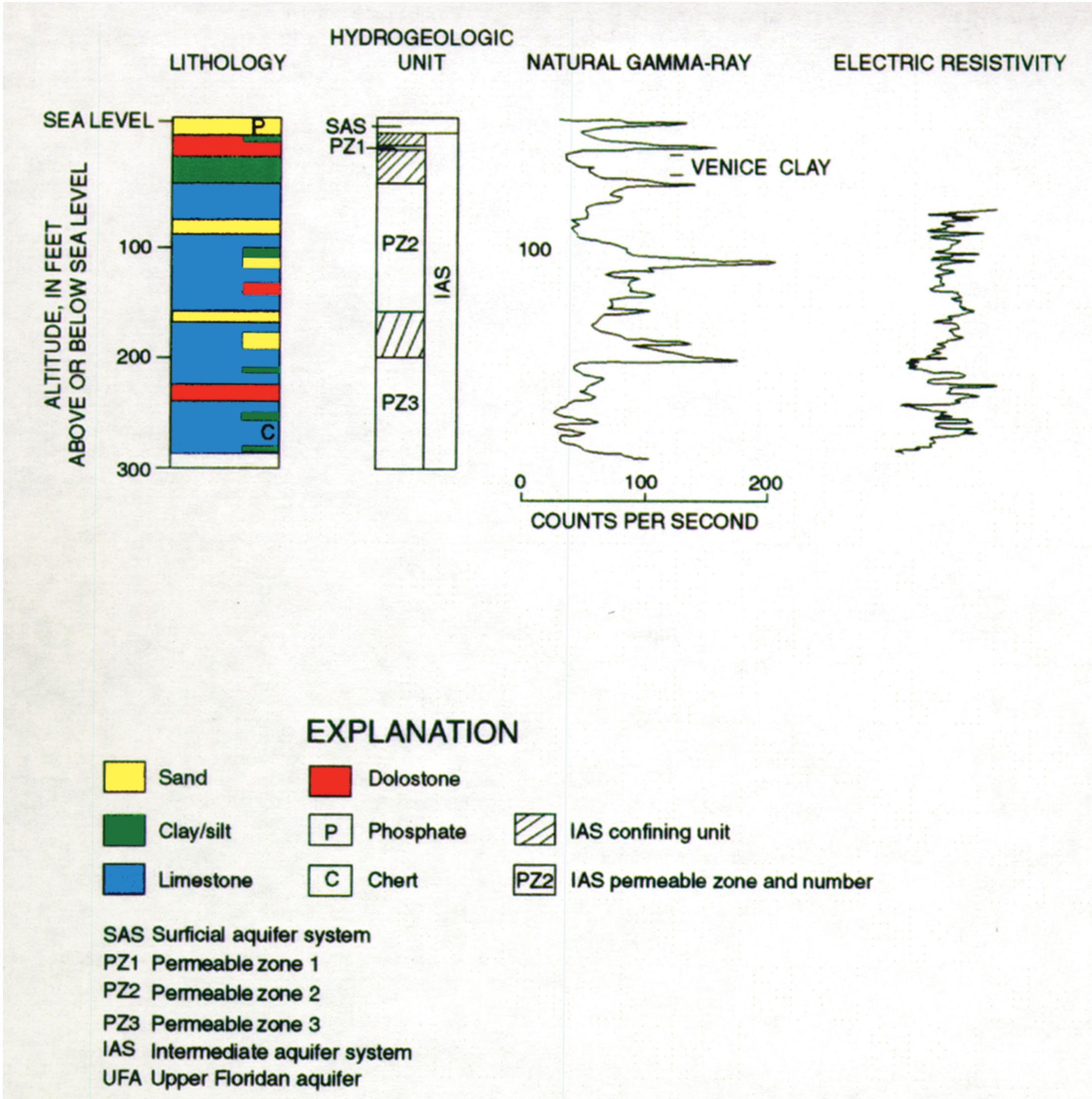
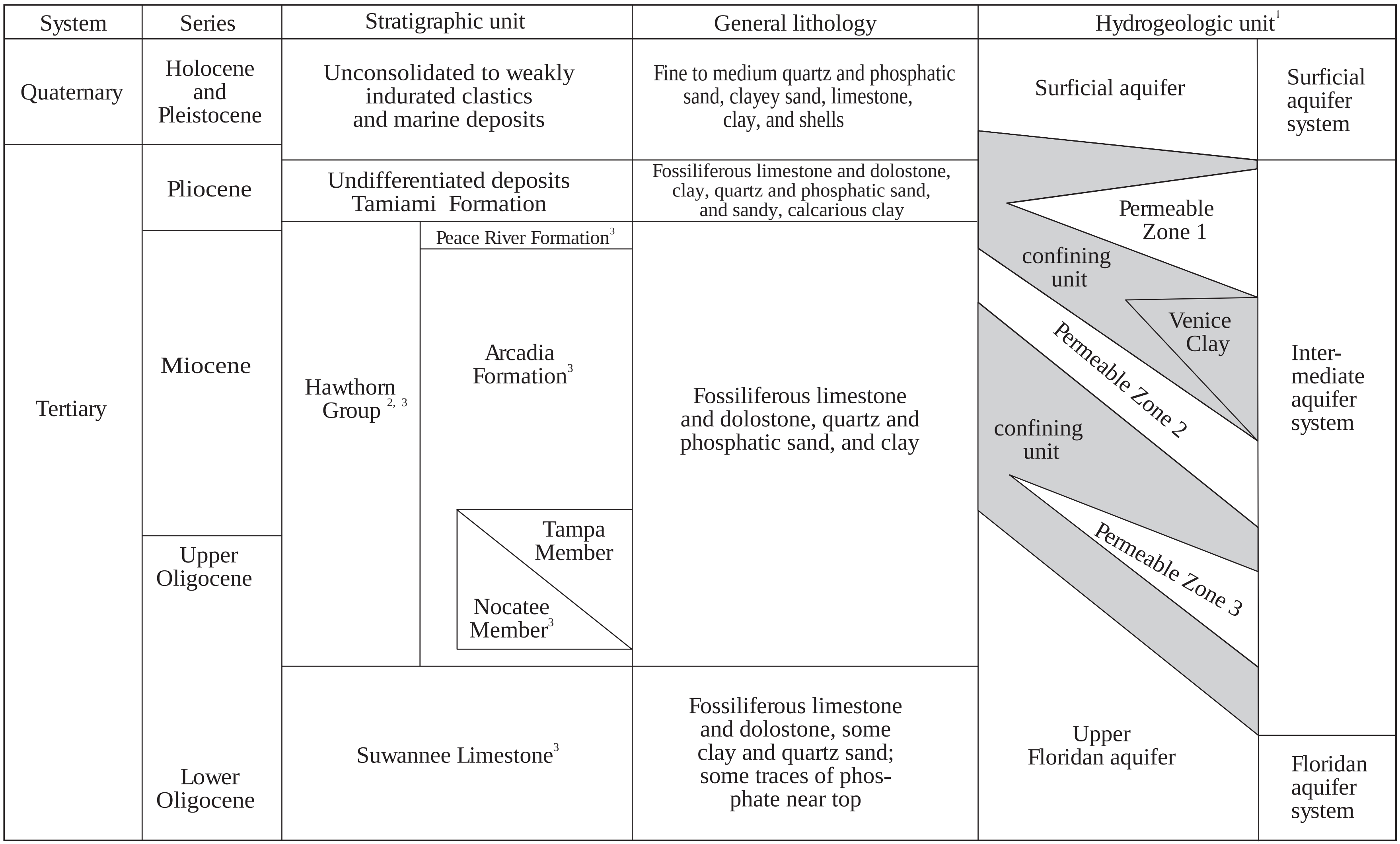


Figure 4. Lithologic, hydrogeologic, and geophysical data at the Walton test well.

deeper aquifers, but when clay and confining materials are not present, the carbonates may be part of the base of the SAS. The SAS is contiguous with land surface and extends to the top of laterally extensive and vertically persistent sediments of much lower permeability (Southeastern Geological Society, 1986). Data collected during this study indicate that the SAS ranges in thickness from a few feet to more than 60 ft (fig. 17).

Sediments of the SAS have a wide range of hydraulic properties because of variations in grain size and texture, porosity, depositional environment, and degree of fluid saturation. Previous investigations show the hydraulic properties vary considerably across the study area (table 1). Transmissivities from aquifer tests at eight wells in Sarasota County range from 150 to 1,800 ft^2/d, and in western and northwestern Charlotte County from 1,340 to greater than 3,340 ft^2/d (table 1). Storage coefficients in Sarasota County from aquifer tests at two wells in the Carlton Reserve and the Verna well field 2E7 range from 0.1 to 0.19. Horizontal hydraulic conductivity values from 15 wells in Sarasota County range from 2×10^{-3} to 159 ft/d and in western and northwest Charlotte County ranges from 47 to 60 ft/d.

The water table of the SAS generally follows land-surface topography; however, the water table varies in altitude seasonally because of recharge from precipitation and the effects of pumping. The water table is generally 0 to 5 ft below land surface, and is at land surface where surface-water bodies such as lakes, streams, and swamps exist.



[1] Based on nomenclature of Southeastern Geological Society (1986).
[2] Based on nomenclature of Scott (1988).
[3] Based on age determination by Covington (1993), Missimer and others (1994), Scott and others (1994), Wingard and others (1993), and Wingard and others (1995).

Figure 5. Hydrogeologic framework in the study area.

Intermediate Aquifer System

The IAS “includes all rocks that lie between and collectively retard the exchange of water between the overlying surficial aquifer system and the underlying Floridan aquifer system” (Southeastern Geological Society, 1986, p. 5). Three major permeable zones are recognized within the study area (fig. 5). Permeable zones 1, 2, and 3 (PZ1, PZ2, PZ3), respectively, are in the upper, middle, and lower parts of the IAS. The zones are distinguished as separate units by intervening confining units, and by differences in water quality and water levels. The major permeable zones of the complex IAS may be thick sequences of permeable sediments, or successive layers of permeable and semi-permeable sediments that function as a single hydrogeologic unit. Boundaries of the major permeable zones and their confining units also may transverse chronohorizons (sediments of the same age). Some layers of clastic or carbonate sediments within major confining units are more permeable and are capable of producing small quantities of water to wells than other layers of sediments; however, the layers may be thin or not areally extensive, and incapable of sustaining long-term ground-water withdrawals.

Lithology and Age

Sediments of the IAS in the study area include fossiliferous limestone and dolostone, quartz and phosphate sand, clayey sand, clay, sandy clay, and chert, ranging in age from Pliocene to Oligocene (fig. 5). The relation between the stratigraphic and hydrogeologic units shown in figure 5 is developed based on limited lithologic control in the study area and is, therefore, subject to change with more data.

The confining unit below the SAS, the upper confining unit, is the top of the IAS (fig. 5). The upper confining unit consists mostly of clay with varying percentages of quartz and phosphatic sand, silt, carbonates, and micro- to macrofossils, and sometimes dense, low-to-very-low-permeability carbonates. Permeable zone 1 lies below the upper confining unit (fig. 2) and consists primarily of limestone, dolostone, and sand with varying percentages of quartz and phosphatic sand, silt, clay, fossils, and accessory minerals.

The confining unit below PZ1 consists primarily of clay with varying percentages of quartz and phosphatic sand, silt, and accessory minerals, chert, and low permeability sandstone and carbonates. Within this confining unit and sometimes composing the entire confining unit (figs. 10 and 16) is the Venice Clay (fig. 5). The name Venice Clay was probably first used by Joyner and Sutcliffe (1976), and later by Sutcliffe and Thompson (1983), and Miller and Sutcliffe (1985) to describe a previously unnamed clay unit. No outcrops of the Venice Clay exist, but presumably, below-water-surface exposures are present at about 50 ft below land surface in Warm Mineral Springs in southern Sarasota County (about 9 mi northeast of Englewood) where Pleistocene to Miocene sediments are exposed along the open spring vent wall.

For this study, the Venice Clay is defined as a green to gray, magnesian clay composed of illite-smectite, sepiolite, and palygorskite with little or no quartz, phosphate, or carbonates. Due to sampling techniques, previous descriptions may have included materials in contact above and below the Venice Clay. The USGS conducted x-ray diffraction analyses of Venice Clay samples from the Carlton Reserve, South Venice, and Walton test wells. Analyses showed that the primary components of the Venice Clay are magnesian clays composed of illite-smectite, sepiolite and palygorskite, containing little or no carbonate or quartz (Lucy McCartan, USGS, Reston, Va., written commun., 1992). The Venice Clay possesses swelling properties; several core samples collected at the South Venice test well expanded about two times the length of the collection interval upon removal from the core barrel. Substantial amounts of quartz, phosphate, and carbonates were observed in sediments suprajacent and subjacent the Venice Clay. Mixing of the Venice Clay with these sediments during previous sampling could explain earlier descriptions of the Venice Clay as being dolomitic.

Geophysical data can indicate lithologic characteristics of the sediments. Natural gamma and electric geophysical log data for 3 wells are given in figures 2 to 4. The Venice Clay is identified on the natural gamma log at the area of low intensity. Natural gamma radioactivity is relatively low (25-30 counts per second) in the Venice Clay because of low or no phosphate content.

Based on FGS and USGS evaluations of the cores from the Carlton Reserve, South Venice, and Walton test wells and lithologic data from selected wells, Scott (1992) proposed that the Venice Clay be recognized as a member of the Arcadia Formation, Hawthorn Group. The Venice Clay previously was defined as the basal part of the Tamiami Formation. Paleopalynologic evaluations of Venice Clay samples from the Carlton Reserve, South Venice, Walton, ROMP 22, and TR 5-1 wells by Lucy E. Edwards (USGS, Reston, Va., written commun., 1994); Wingard and others (1993) reported the presence of dinoflagellate assemblages that range in age from early or middle Miocene.

Permeable zone 2 underlies the confining unit that contains the Venice Clay (fig. 5) and is composed primarily of limestone and dolostone with varying percentages of quartz and phosphate sand, silt, clay, fossils, and accessory minerals. The confining unit below PZ2 is composed primarily of clay with varying percentages of quartz and phosphate sand, silt, and dense, low-to-very-low permeability carbonates.

Permeable zone 3 underlies the confining unit below PZ2 (fig. 5) and is composed primarily of limestone and dolostone, and varying percentages of quartz and phosphate sand, silt, clay, fossils, and accessory minerals. The confining unit below PZ3, the lower confining unit, is the base of the IAS. The lower confining unit is composed of clay with varying percentages of quartz and phosphate sand, silt, and dense, low-to-very-low permeability carbonates.

Areal Extent and Thickness

The IAS exists throughout the entire study area; however, some hydrogeologic units of the system are not areally extensive. The IAS is thinnest in Manatee County and thickest in Lee County, ranging in thickness from 221 to 745 ft (figs. 7-16). The altitude of the top of the IAS can be extrapolated from the SAS thickness map (fig. 17); for example, where the SAS is 20 ft thick, the top of the IAS is at 20 ft below land surface. The bottom of the IAS coincides with the top of the UFA and ranges in altitude from less than 300 to greater than 700 ft below sea level (fig. 18). Structurally, the IAS and its associated hydrogeological units have a gentle slope and dip one degree or less generally toward the south in the study area.

Permeable zone 1 is not extensive throughout the study area but exists in a part of western Manatee, southern and western Sarasota, and western Charlotte Counties (fig. 19). Permeable zone 1 may exist in eastern Charlotte and Lee Counties, although the extent of it in those counties was not determined during this study. This is generally the thinnest permeable zone of the IAS, averaging 80 ft or less (fig. 19). Where present, PZ1 always overlies the Venice Clay.

Permeable zone 2 extends throughout the study area and beyond, ranging in thickness from 20 ft to greater than 190 ft (fig. 20); the zone is thickest in eastern and southern Sarasota, and eastern Manatee Counties. Permeable zone 2 is always below the Venice Clay.

Permeable zone 3 extends throughout most of the study area except in northern and eastern Manatee County (fig. 21); it probably extends beyond the study area to the south. Thickness ranges from 0 feet in central and western Manatee County to greater than 300 ft in southwest Sarasota County. Permeable zone 3 is generally the thickest permeable zone of the IAS in the study area.

Upper, lower, and intervening confining units always separate the permeable zones of the IAS. In some locations however, the various confining units merge and function as a single confining unit (figs. 7-16). This condition is most prevalent in the northern part of the study area, where permeable zones narrow progressively to extinction in Manatee County. The result may be very thick confining units between thin permeable zones. The upper confining unit generally is thickest in the southern part of the study area, ranging in thickness from about 5 to 150 ft. Various middle confining units that separate PZ1, PZ2, and PZ3 range in thickness from about 15 to 240 ft, depending on whether or not they merge with other confining units. Because the Venice Clay is an important hydrogeologic unit, it is delineated as a discrete unit within the study area. The Venice Clay is a convenient marker bed that separates PZ1 from PZ2; the Venice Clay's stratigraphic position helps drillers to locate these zones. The Venice Clay occurs in southern and western Manatee, Sarasota, western De Soto and western Charlotte Counties, and probably extends under the Gulf of Mexico (fig. 22). The Venice Clay ranges from 0 to 29 ft thick and averages about 11 ft thick. The lower confining unit, generally thickest in the southern part of the study area and where it merges with middle confining units (figs. 7-9, 16), ranges in thickness from about 10 to 240 ft.

Hydraulic Properties

The IAS is a heterogeneous unit because of local variations in sediment composition and depositional environments, and in the diagenetic (physical, chemical, and biological) processes that have altered those sediments since they were deposited. As a result of these variations, hydraulic properties of the hydrogeologic units of the IAS vary greatly among and also within hydrogeologic units. Hydraulic properties of the IAS reported by previous investigators were sometimes determined from wells that were open to several permeable zones. Only values representative of discrete permeable zones and confining units are given in table 1.

The principal hydraulic properties summarized in table 1 for the permeable zones and confining units are transmissivity, leakance coefficient, storage coefficient, and vertical and horizontal hydraulic conductivities. Some values of leakance coefficients for various confining units are given as values for a permeable zone reported by other investigators; their intent was to report leakage away from the permeable zone. Permeable zone 1 has transmissivities ranging from 1,100 to 8,000 ft^2/d, leakance coefficients ranging from 3.6×10^{-5} to 1.2×10^{-1} (ft/d)/ft, and storage coefficients ranging from 1.6×10^{-5} to 6.5×10^{-4}. Few hydraulic conductivity values are available for permeable material in any of the major permeable zones, except on the Carlton Reserve tract where horizontal hydraulic conductivity for two wells in PZ1 ranged from 17 to 56 ft/d; the wells were reported to be SAS wells, but well construction data suggest these wells are open to PZ1. Permeable zone 2 has transmissivities ranging from 200 to 5,000 ft^2/d, leakance coefficients ranging from 2×10^{-5} to 1.1×10^{-3} (ft/d)/ft, and storage coefficients ranging from 6×10^{-6} to 6.2×10^{-4}. Permeable zone 3 has transmissivities ranging from 5,600 to 15,400 ft^2/d, one reported leakance coefficient of 3.5×10^{-5} (ft/d)/ft, and storage coefficients ranging from 8.5×10^{-5} to 6.4×10^{-4}. All hydraulic conductivity values for sediments from the three test wells constructed during the study were determined by the FGS using a falling-head permeameter. Vertical hydraulic conductivity values for confining material within PZ1, PZ2, and PZ3 in the three test wells ranged from less than 3.6×10^{-10} to 2.4×10^{-3} ft/d. Vertical hydraulic conductivity values of the various confining units between PZ1, PZ2, and PZ3 ranged from 1×10^{-3} to less than 3.6×10^{-10} ft/d. The hydraulic conductivity values of less than 3.6×10^{-10} ft/d noted above were from samples that did not saturate in the permeameter after 31 days or more; the sediments have very low hydraulic conductivity, and the values should be used with caution. Vertical hydraulic conductivity for the confining units above and below permeable zone 3 at well TR 5-2 were 0.1 ft/d and 10 ft/d, respectively, and were estimated by model simulations (Hutchinson and Trommer, 1992).

Geologic Faulting

Geologic faulting has been reported in the IAS and the UFA (Hutchinson, 1992) in southern parts of the study area and may have important implications for ground-water quality and movement in the IAS. If faulting extends into the IAS, results could include: 1) breaks in confining units and direct paths for upward flow of ground water from lower permeable zones; 2) major permeable zones may be in direct contact with each other and water quality of one permeable zone may be affected by the chemical properties of water in an adjacent permeable zone; and 3) conduit flow may occur and natural ground-water flow rates and directions may differ from estimates derived from aquifer tests and model simulations that assume porous media flow. Hutchinson (1992) presents evidence for an east-west fault extending from the lower IAS to the base of the Suwannee Limestone in southern Sarasota and northern Charlotte Counties. Based on observations during this study, faulting appears to extend into the upper parts of the IAS between the South Venice and TR 4-2 wells and nearby areas (fig. 7). The Venice Clay gently slopes in the study area usually from 0.01 to 0.1 degree. In southern Sarasota County a slight deviation of the slope to about 0.3 degree between the wells may be an indication of faulting that extends to shallow depths. The South Venice well is on the down-thrown side, and the TR 4-2 well is on the up-thrown side of the fault described by Hutchinson (1992). The Venice Clay appears to be at the expected depths. Data from wells near TR 4-2, although not included in the section lines, were used to corroborate depths of the Venice Clay and showed inconsistency with the expected fault displacement. Although not conclusive evidence, the depths of the Venice Clay at these wells suggest additional fault lines or more complex faulting has taken place in the region north of Englewood.

GROUND-WATER USE

In coastal southwest Sarasota County, ground-water withdrawals from individual aquifers is reported to the SWFWMD by major pumping centers and permitted users, to aid the evaluation of water quality and ground-water flow in that area. Ground water is primarily used for domestic, agricultural irrigation, and public supply. A large part of ground-water use in southwest Sarasota County is for public supply. Major pumping centers are defined by this report as community potable water systems that pumped 50,000 gal/d or more. The water systems were either a utility company with a consolidated network of production wells, or a municipality with several dispersed well fields. Many private wells used for domestic supply in southwest Sarasota County pump less than 50,000 gal/d. In 1992, there were four major pumping centers in southwest Sarasota County that produced 50,000 gal/d or more from either the SAS or the IAS for public supply (fig. 23 and table 2). Average daily withdrawal rates for 1992 ranging from about 90,000 to 4,038,000 gal/d from these pumping centers are shown in table 2 (SWFWMD, written commun., 1993). The major pumping centers, due to development preferences and population density in southwest Sarasota County, have been constructed within 5 mi of the Gulf of Mexico.

Table 2. Ground-water withdrawals from the surficial and intermediate aquifer systems at major pumping centers, southwest Sarasota County, 1992

[Major pumping centers are community potable water supply systems where accumulated ground-water pumpage exceeded 50,000 gal/d in 1992. Withdrawal rates were reported as average values (Southwest Florida Water Management District data files). SAS, surficial aquifer system; IAS PZ1, intermediate aquifer system, permeable zone 1; IAS PZ2, intermediate aquifer system, permeable zone 2; IAS PZ3, intermediate aquifer system, permeable zone 3; gal/d, gallons per day]

Major pumping center	Production zone	Withdrawal rate (gal/d)
Englewood Water District:		
..........Well field 1	SAS	93,000
..........Well field 1	IAS PZ1	90,400
..........Well field 2	IAS PZ1	103,100
..........Well field 3	IAS PZ1	722,400
..........Well field 4	IAS PZ3	1,655,300
Plantation Utility	IAS PZ3	278,900
City of Venice well field	IAS PZ2	27,000
	IAS PZ3	4,038,000
Venice Gardens Utility	IAS PZ2	268,100
	IAS PZ3	2,176,100

The SAS yields freshwater, which is used primarily for public and domestic supply, and lawn and agricultural irrigation. Because of low transmissivity of the SAS and because most wells are small in diameter, withdrawal rates usually are less than 50 gal/min. If the wells are located close to the coast, withdrawal rates are intentionally decreased to reduce the possibility of seawater intrusion. Use of water from the SAS varies among the communities in the study area depending on the availability of other water sources. In Englewood and areas to the south, the SAS is used mostly for public and domestic supply; north of Englewood, the SAS is used more extensively for lawn and agricultural irrigation. Water from the SAS usually requires treatment to remove dissolved solids. The IAS yields larger quantities of freshwater than the SAS or the UFA, although the UFA yields larger quantities but with greater concentrations of dissolved solids in southwest Sarasota County. Water from the lower part of the IAS is more saline than water in the upper part; consequently, community potable water systems and other public facilities use desalinization or reverse-osmosis processes to treat the water.

GROUND-WATER QUALITY

Ground-water quality was evaluated in this study over a 155-mi^2 area of coastal southwest Sarasota County between Osprey and Englewood, and at the Carlton Reserve and South Venice test wells (fig. 1); this was done because of potential ground-water degradation from upconing and lateral intrusion of seawater. Southwest Sarasota County had a sufficient number of wells in which water could be sampled and evaluated from discrete permeable zones; other parts of the study area lacked the required data sites. Lateral intrusion of seawater in Florida's aquifer systems within this century has become a derivative of coastal metropolitan development, and Sarasota County is no exception. Ground-water withdrawals from the IAS in the county also have caused upconing of saline water from the UFA. Ground-water flow in the IAS in the study area at most times has an upward flow component, and consequently, pumping from one aquifer allows water in the next lower aquifer to move up through the system at a faster rate. Deeper hydrogeologic units are the source of vertically intruded water containing higher dissolved-solids concentration.

Constituents that included chloride, sulfate, and dissolved-solids concentrations, and temperature, pH, and specific conductance measurements were used as precursors to evaluate lateral seawater intrusion from the Gulf of Mexico and upconing of saline water from the UFA into the IAS. In order to characterize the ground-water quality in southwest Sarasota County between Osprey and Englewood, 96 wells open to the SAS, and individual permeable zones and confining units of the IAS were sampled from June to November 1993 (fig. 24).

Only water from wells open to discrete permeable zones as defined by this study was sampled. Well records and ground-water quality data for 96 wells (26 SAS, 23 PZ1, 28 PZ2, and 19 PZ3 wells) are given in table 3. Water samples from 85 of these wells, including five SAS wells drilled by the USGS using a solid-stem auger rig in areas where data were not available, were collected by USGS personnel. During the period June to November 1993, the USGS, using production pumps, water taps, and portable centrifugal and submersible pumps, collected one water sample from each of the 85 wells. Water samples were collected after 2 to 3 casing volumes of water were evacuated and field measurements had stabilized. Field measurements included temperature, pH, and specific conductance. Water samples were then sent to the USGS Water-Quality Laboratory, Ocala, Florida, and analyzed for chloride, sulfate, dissolved solids, and nitrogen. Selected water-quality data for samples from 11 wells, collected and analyzed by private sources, also were evaluated and are given in table 3. The water-quality data were evaluated with respect to secondary maximum contaminant levels (SMCL) of the recommended secondary drinking-water regulations (U.S. Environmental Protection Agency, 1988) for chloride, sulfate, and dissolved solids as follows:

Constituent	Secondary maximum contaminant level
Chloride	250 mg/L
Dissolved solids	500 mg/L
Sulfate	250 mg/L

Water samples were collected from the IAS at selected intervals of clay within the major permeable zones and from the confining units between major permeable zones at the Carlton Reserve and South Venice test wells (fig. 24). The water samples were collected from cores during drilling of the test wells. The purpose of collecting the samples was to evaluate interstitial water quality in confining material and to demonstrate the capacity of a pore-squeezing apparatus to extrude water from sediments in Florida. The pore-squeezing technique and apparatus used in this study were adapted from techniques used in the petroleum industry and described by various investigators including Swarzenski (1959), Lusczynski (1961), Manheim (1966), Manheim and others (1985), Pucci and Owens (1989), and Pucci and others (1992).

The pore-squeezing apparatus used in this study included a stainless-steel hollow cylinder (3 in. in length by 2.5 in. in diameter) with matching piston, seals, gaskets, and a 0.45 μm filter. A small sediment sample, about 1.5 in^3, was taken from the interior of the unconsolidated core material immediately upon removal from the well bore, inserted into the cylinder, and pressed into the chamber by the piston. A manually cranked bar-clamp was used to apply the force needed to extrude interstitial water from the core sample in the apparatus into a polyethylene tube or collector syringe. Volumes of water collected from each core sample ranged from 3 to 14 mL. Extraction times ranged from 5 to 50 minutes.

Water samples were analyzed by the USGS Ocala Laboratory for cations, anions, iron, strontium, nitrogen, hardness, specific conductance, pH, and alkalinity. No field measurements were made. Standard laboratory analytical procedures and induced coupled plasma/mass spectrometry methods were used. Water samples were collected from eight core samples at the Carlton Reserve test well and 6 samples at the South Venice test well. Some analyses were not made when limited volumes of sample water were available; laboratory alkalinity and pH measurements were performed only on water from the Carlton Reserve test well. Alkalinity concentrations for the South Venice test well were not analyzed by field or laboratory titrations, but were approximated by calculating the difference between cations and anions in milliequivalents per liter and converting to milligrams per liter of calcium carbonate.

Surficial Aquifer System

Most of the 26 SAS wells from which water samples were collected produce water with chloride and sulfate concentrations below U.S. Environmental

Protection Agency (USEPA) recommended secondary drinking-water regulations SMCL (figs. 25 and 26). About half the water samples exceeded the SMCL for dissolved solids; all water samples analyzed except one have dissolved-solids concentrations greater than or equal to 300 mg/L and specific conductances greater than 500 mg/L (fig. 27). Nitrogen concentrations were also analyzed in water from wells open to the SAS. Nitrogen (NO_2+NO_3) concentrations from most samples were less than the detection limit of laboratory analytical equipment (less than 0.02 mg/L). The pH of SAS water ranged from 4.8 to 8.9. Water in the SAS is usually acidic due to contact with carbon dioxide in the air and sediments; however, some SAS water is alkaline because of dissolution of accessory shell and calcium materials. Temperatures of the water samples ranged from 23.6 to 32.4^{o}C.

Wells within 2 mi of coastal or estuarine environments have concentrations of chloride, sulfate, and dissolved solids that approach or exceed the USEPA recommended secondary drinking-water regulations. Water from wells in the study area more than 2 mi from coastal or estuarine environments usually had chloride and sulfate concentrations within the recommended limits. Water samples from the SAS in the central region of the water-quality study area had dissolved-solids concentrations less than 500 mg/L. The dissolved-solids concentrations greater than 500 mg/L that were detected more than 2 mi inland were in an area centered around major pumping centers that include the Englewood Water District, Plantation Utility, and the City of Venice well fields (fig. 27). Coastal and estuarine areas occasionally are subjected to short durations of flooding by high tides that result in inundation by sea water with high dissolved-solids concentrations. Inlets, creeks, and canals allow further contamination by seawater into areas beyond coastal margins. Chloride concentrations on some barrier islands such as at the Casperson Beach well (fig. 25; index no. 10) may be less than expected due to local recharge. Detectable nitrite plus nitrate nitrogen concentrations (0.09 to 0.85 mg/L, table 3) in water from four wells may be due to fertilizers in inland areas, or natural concentration levels in coastal areas.

Intermediate Aquifer System

Ground water from wells tapping all permeable zones of the IAS is predominately calcium bicarbonate, calcium sulfate, or sodium chloride type (Hutchinson, 1992), although water of other types exists in the study area. Water from the IAS is slightly saline with chloride and dissolved-solids concentrations generally increasing with depth. Water in the IAS in most parts of the water-quality study area is not suitable for drinking without treatment because the water exceeds the SMCL for dissolved solids (USEPA, 1988).

Permeable Zone 1

Twenty-three wells open to PZ1 were sampled during the study (table 3). The distribution of chloride, sulfate and dissolved-solids concentrations, and specific conductance measurements in PZ1 are shown in figures 29-32. Chloride concentrations ranged from 45 to 1,520 mg/L. Sulfate concentrations ranged from less than 0.2 to 1,200 mg/L. Dissolved-solids concentrations ranged from 431 to 3,410 mg/L. Temperatures ranged from 23.6 to 28.1^{o}C. The pH ranged from 6.6 to 7.8. Specific conductances ranged from 674 to 5,250 μS/cm. Chloride concentrations exceeded USEPA regulations at five wells (index nos. 103, 107, 164, 168, and 169), sulfate at five wells (index nos. 90, 93, 164, 176, and 183), and dissolved solids for all wells except for three wells (index nos. 97, 105, and 188).

Wells at or near coastal and estuarine environments and major pumping centers generally produce water that exceeds USEPA regulations for chloride, sulfate, and dissolved solids (figs. 29-31). Water from PZ1 wells within 2 mi of coastal and estuarine environments usually exceeded USEPA regulations for chloride and sulfate; wells within 5 mi had dissolved-solids concentrations greater than 500 mg/L. Water from PZ1 wells that were 2 mi or more from coastal and estuarine environments had specific conductance measurements that were less than 1,000 μS/cm; some of the highest specific conductance measurements (table 3) were in water from wells at or near coastal or estuarine environments (fig. 32).

Chloride, sulfate, and dissolved-solids concentrations have been determined for water samples from well 164 (EWD EPZ 9) since 1987 (fig. 41). Although a variety of sampling techniques have been used by the Englewood Water District personnel over the years, the effects of varying pumping rates are also apparent. Concentrations of chloride, sulfate, and dissolved solids are relatively stable when pumping rates are low, but increase during periods of increased pumping (Roger Quick, the

Englewood Water District, oral commun., 1993), such as in 1991. Water from the area around the EWD well field generally exceeds the USEPA regulations for chloride and dissolved solids (figs. 29 and 31). In the area of the Englewood Water District well fields, high chloride and sulfate concentrations probably result from a combination of lateral seawater intrusion and upconing of saline water from deeper permeable zones.

High chloride, sulfate, and dissolved-solids concentrations in ground water from an area centered at the Venice well field could be related to lateral seawater intrusion induced by pumping. Pumping from PZ2 and PZ3 in the Venice well field (table 3) may also cause upconing of saline water that migrates into PZ1 because of an upward hydraulic gradient.

Permeable Zone 2

Most of the 28 PZ2 wells evaluated and sampled are in the northern half of the study area; few wells open to PZ2 were available in the southern half of the area. Chloride concentrations in water from these wells ranged from 48 to 4,920 mg/L. Sulfate concentrations ranged from 16 to 1,600 mg/L. Dissolved-solids concentrations ranged from 316 to 10,300 mg/L. Temperatures ranged from 24.4 to 27.5 ^{o}C. The pH ranged from 6.5 to 7.7. Specific conductances ranged from 515 to 15,100 μS/cm. Chloride concentrations exceeded USEPA regulations at five wells (index nos. 56, 74, 108, 192, and 194, table 3 and fig. 33), for sulfate from all except 9 wells (index nos. 70, 97, 146, 158, 182, 185, 187, 197, and 221, table 3, and fig. 33), and for dissolved solids from all except 3 wells (index nos. 182, 185, and 193, table 3, and fig. 34).

Concentrations of chloride, sulfate, and dissolved solids generally are highest along the coast and at major pumping centers (figs. 33-35). Lateral intrusion of seawater probably takes place in coastal regions. Wells located more than 2 mi from coastal or estuarine environments generally have concentrations of chloride, sulfate, and dissolved solids less than USEPA regulations. Maps showing concentrations of water-quality parameters indicate upconing of saline water from PZ3 in the Venice well field.

High concentrations of dissolved solids in inland areas is due to the interchange of water among several permeable zones through multiple-zone wells. Water from many multiple-zone wells in the study area can have local or regional effects on water quality. An example of possible local effect is water from well 74 (table 3 and figs. 33-35) which had higher than expected concentrations of chloride, sulfate, and dissolved solids, and high specific conductance. A well with high dissolved-solids concentration, about 400 ft away from well 74, may be open to PZ2 and deeper permeable zones, thus allowing saline water to enter PZ2 and into well 74.

Water quality at some pumping centers can fluctuate widely due to changes in withdrawal rates from the pumping wells. Long-term concentrations of chloride, sulfate, and dissolved solids in water from three wells open to PZ2 are shown in figures 42-44. Well locations are shown in fig. 24. Increases in concentrations of chloride, sulfate, or dissolved-solids concentration in water from Venice Gardens (VG 9) and Plantation MW4 coincided with increases in pumping rates on one or more occasions. Data from VG 9 (index no. 185, figs. 33-35) and MW4 (index no. 182, figs. 33-35) indicate that water-quality changes in inland areas probably are the result of upconing of saline water from deeper aquifer units. At the Southbay Utility well PZ2 (fig. 44) both lateral seawater intrusion and upconing probably are occurring due to elevated concentrations of chloride, sulfate, and dissolved solids.

Permeable Zone 3

Nineteen wells tapping PZ3 were sampled in the northern half of the study area. Wells in the water-quality study area used for public supply commonly are not completed in PZ3, except for those wells used for reverse-osmosis treatment and agricultural irrigation, because the water has high concentrations of sulfate and dissolved solids. Chloride concentrations ranged from 33 to 4,200 mg/L. Sulfate concentrations ranged from 388 to 2,500 mg/L. Dissolved-solids concentrations ranged from 1,120 to 7,700 mg/L. Temperatures ranged from 25.6 to 28.4^{o}C. The pH ranged from 6.4 to 7.5. Specific conductances ranged from 1,347 to 10,370 μS/cm. Chloride concentrations in water samples exceeded USEPA regulations for drinking water for all except six wells (index nos. 109, 112, 114, 123, 124, and 308, table 3 and fig. 37). Sulfate and dissolved-solids concentrations in water from all the wells exceeded the standards.

Water with the highest concentrations of chloride and dissolved solids was generally from wells in the southern part of the study area (figs. 37 and 39). However, sulfate concentrations were much lower in the southern part of the area. Specific conductance measurements of more than 2,000 µS/cm were common in water from wells in the study area (fig. 40); the distribution of specific conductance followed the same pattern as concentrations of dissolved solids.

Water in PZ3 has naturally higher concentrations of chloride, sulfate, and dissolved solids than water in PZ1 and PZ2 in the study area. Pumping from PZ3 causes lateral seawater intrusion in coastal regions and upconing from the UFA, resulting in increased mineral concentration. Plots of chloride, sulfate, and dissolved-solids concentration from 1983 to 1994 for water from four wells open to PZ3 are shown in figures 45-48. In southern Sarasota County, chloride, sulfate, and dissolved-solids concentrations in water from EWD RO Production well 1 (index no. 147 in table 3 and figs. 37-39) generally increased from 1983 to 1993. Pumpage from PZ3 at the Englewood Water District well field 4 increased from about 585 Mgal/d in 1983 to about 1,358 Mgal/d in 1993 (a 132-percent increase). The increases in chloride, sulfate, and dissolved-solids concentrations at the Englewood Water District RO Production well 1 in late 1992 and early 1993 are probably due to a pumpage increase at the Englewood Water District well field 4 from 1.4 Mgal/d in September 1992 to 1.9 Mgal/d in January 1993 (EWD data files). Monthly fluctuations of chloride, sulfate, and dissolved-solids concentrations in water from Plantation MW3 (fig. 46), Sarasota County Utilities PZ3 (fig. 47), and Southbay Utilities PZ3 (fig. 48) are similar to concentration changes in water from well EWD RO 1 (fig. 45) and probably are related to changes in pumping rates.

Carlton Reserve and South Venice Test Wells

Comparisons were made between chloride, sulfate, and specific conductance data for water samples from the IAS at different intervals in each borehole (figs. 49 and 50). Major-ion diagrams for water samples from the Carlton Reserve and South Venice test wells are shown in figure 51 and the data are shown in table 4.

Water from the IAS at the Carlton Reserve test well is a calcium bicarbonate type in the upper confining unit through the upper part of permeable zone 2, a magnesium bicarbonate type in the lower part of permeable zone 2, and a calcium sulfate type in permeable zone 3 through the lower confining unit (fig. 51). Water from the IAS at the South Venice test well is a calcium bicarbonate type in the upper confining unit between permeable zones 2 and 3, a sodium-magnesium chloride-bicarbonate type in the lower part of the confining unit between permeable zones 2 and 3, and a calcium sulfate type in permeable zone 3 (fig. 51).

Chloride, sulfate, and hardness concentrations, and specific-conductance values generally increased with depth in the IAS at both test wells (table 4 and figs. 49-51). At both test wells, chloride concentrations were below the USEPA SMCL in all evaluated hydrogeologic units of the IAS. Whereas most sulfate concentrations were below the SMCL in PZ2 and upper zones at both test wells, sulfate concentrations of 270 and 280 mg/L were detected in water from the Venice Clay at the Carlton Reserve test well. The highest sulfate concentrations at both test wells were detected in water at depths below PZ2. The higher chloride, sulfate, and hardness concentrations, and specific conductance in the lower permeable zones can be attributed to upward ground-water flow from the UFA at both test wells, and also to lateral flow due to proximity to the Gulf of Mexico at the South Venice test well. Specific conductance measurements ranged between 920 and 2,120 µS/cm at the Carlton Reserve test well and 550 and 2,080 µS/cm at the South Venice test well; the highest specific conductance measurements were in water from PZ3 at both test wells (table 4 and figs. 49-51). Generally, the water is slightly acidic or slightly alkaline at the Carlton Reserve test well and pH ranged from 6.3 to 7.9. Iron concentrations were usually less than the USEPA SMCL (0.3 mg/L) at both test wells, but were 1.1 mg/L in permeable zone 2 and 0.4 mg/L in the lower confining unit at the Carlton Reserve test well. Strontium concentrations, ranging from 1,200 to 14,000 µg/L at the Carlton Reserve test well, and 620 to 13,000 µg/L at the South Venice test well, increased with depth, but some exceptions were detected. Nitrite plus nitrate showed no discernible trend with depth; concentrations as nitrogen ranged from 0.14 to 2.8 mg/L at the Carlton Reserve test well and less than 0.02 to 0.42 mg/L at the South Venice test well, and were always below the USEPA SMCL (10 mg/L).

The chemical composition of water samples from various depths in the two test wells was also compared to the composition of water from other wells tapping the same hydrogeologic units. Although the Carlton Reserve test well is slightly east of the water-quality study area (fig. 24), chloride, sulfate, and specific-conductance values for water from the Carlton Reserve test well were similar to or slightly lower than the values for water from well 70 in PZ2 and wells 114 and 124 in PZ3 (tables 3 and 4). Chloride, sulfate, and specific-conductance values at the South Venice test well were similar or slightly lower than values for regional PZ1 and PZ3 water (tables 3 and 4).

GROUND-WATER FLOW

Ground-water flow, described for the IAS in the study area, occurs under confined conditions. Horizontal ground-water flow through the IAS in the study area is generally from northeast to southwest, as indicated in the composite potentiometric surface maps in May and September 1993 (fig. 52). Data used to define head altitudes on the potentiometric maps were from wells open to all or only parts of the IAS. The seasonal low (May) and high (September) water-level periods, typical for the study area are also shown in figure 52. The potentiometric surface fluctuates in response to hydraulic characteristics of the sediments, recharge, discharge, and pumping stresses. A recharge area can be defined as that part of a ground-water flow system that has downward head gradients, whereas a discharge area has upward head gradients. A two-dimensional conceptual model of the flow system, shown in figure 53, represents a discharge area of the IAS in southwest Sarasota County. All IAS confining units in the study area allow vertical leakance. Most of the study area is in the discharge area of the IAS. Some parts of the study area in Manatee, Hardee, and De Soto Counties may be recharge or intermittent discharge areas of the IAS.

The IAS has vertical ground-water flow in the study area. An upward flow in the major permeable zones of the IAS results in hydraulic heads that generally increase with depth in the study area. The general head relation between the SAS, IAS, and UFA at ROMP TR 5-2 in Sarasota County is shown in figure 54. Head data from the wells shown in figures 2-4 indicate a gradual head increase in the IAS with depth, and sometimes significant head increases occur when major permeable zones are penetrated during drilling. Water-level relations between the SAS, major permeable zones of the IAS, and the UFA are not completely understood in the study area due to insufficient head data for discrete permeable zones of the IAS.

Water withdrawn from the IAS will probably result in changes in the chemical composition and availability of the ground water. The ability of ground-water managers to detect these changes can be enhanced by the use of numerical models. Conceptual ground-water flow models, used to design numerical models, may sometimes use simplified assumptions about the hydrogeology. If the hydrogeology is complex, as in the case of the IAS in the study area, more complex assumptions should be employed. The following assumptions should be considered when numerical models are used to evaluate ground-water flow of the IAS in the study area:

1. The IAS is heterogeneous. Although this study shows that a broad range of hydraulic properties exist for major permeable zones of the IAS, values reported by this and previous reports appear reasonable and could be used for modeling purposes.
2. Two or three major permeable zones of the IAS exist in the study area. The IAS should be evaluated as a multilayer flow system.
3. Permeable zones 1 and 2 are only several tens of feet thick in some areas; thus, pumping may have a greater effect on water-level drawdowns in these areas. Models should be designed that consider the effects of ground-water withdrawals from major pumping centers that withdraw 50,000 gal/d or more.
4. Major permeable zones of the IAS have unique water chemistry. Different concentrations of dissolved solids in the zones are important if particle-tracking simulations are performed.
5. Adequate head data of major permeable zones of the IAS are lacking in the study area because of nonuniform distribution of monitor wells. Observation wells outside the study area also are needed for the collection of head data. Head data are necessary for evaluating model assumptions, boundary conditions, water budgets, and ground-water fluxes in and out of the aquifer units.

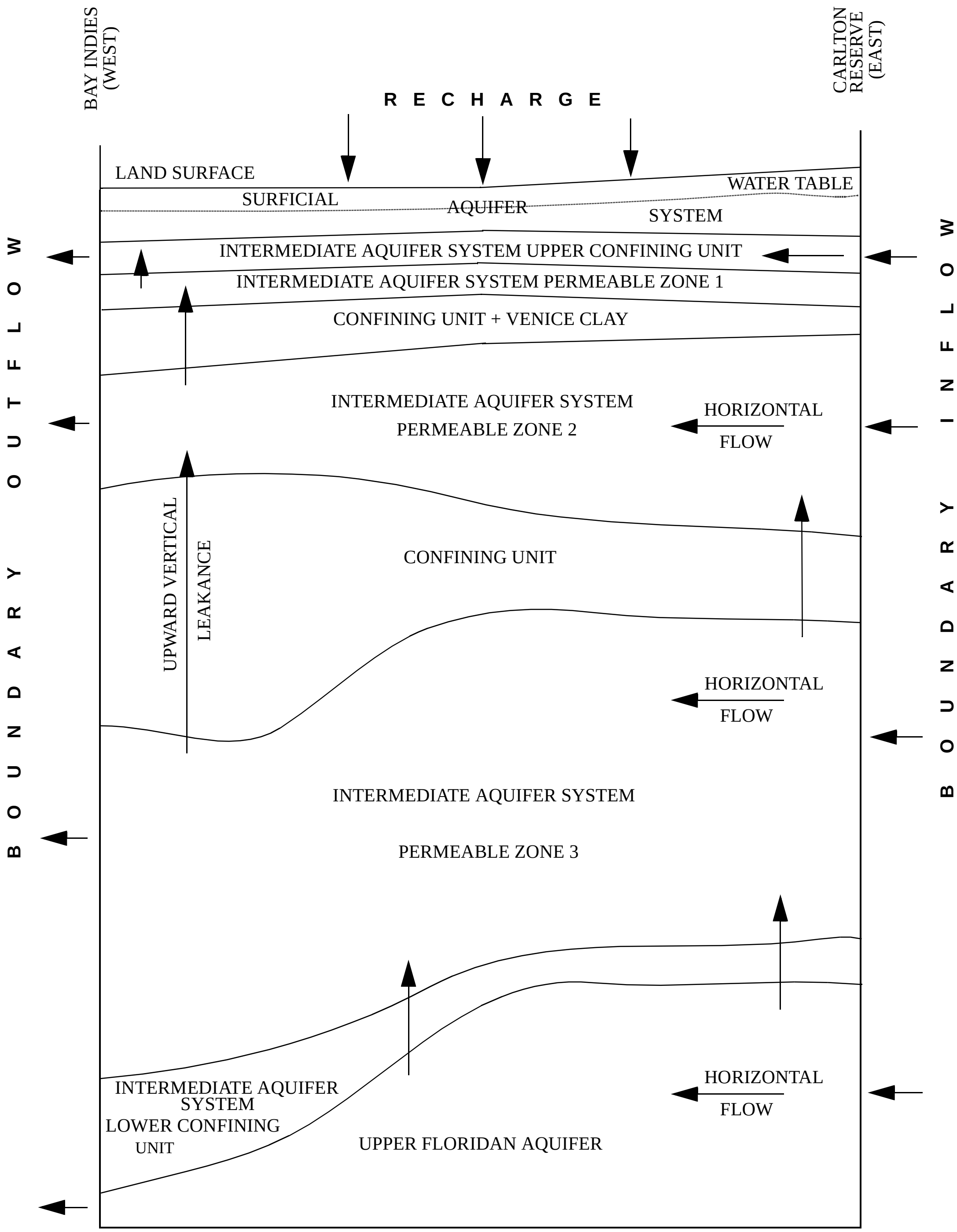


Figure 53. Two-dimensional conceptual model of the intermediate aquifer system, southwest Sarasota County. (The section is part of hydrogeologic section H-H', figure 14, from the Bay Indies well to the Carlton Reserve test well.)

SUMMARY

Demand for ground water for public, industrial, agricultural irrigation, and domestic use has intensified the need to understand the hydrogeology of the dan aquifers are the main aquifer systems in Sarasota County and neighboring counties. In southern Sarasota surficial and the intermediate aquifer systems in southwest Florida. The surficial, intermediate, and Upper FloriCounty and counties to the south, limited supplies of potable water can be pumped from the surficial and intermediate aquifer systems.

An investigation was conducted in southwest Florida from 1991 to 1995 to evaluate the hydrogeology of the surficial aquifer system and the major permeable zones and confining units of the intermediate aquifer system in a 1,400-square-mile area that includes Sarasota County and parts of Manatee, De Soto, Charlotte, and Lee Counties. Lithologic, geophysical, hydraulic property, and water-level data from 61 wells were used to correlate the hydrogeology and map the extent of the surficial and intermediate aquifer systems in the study area. In southwest Sarasota County, water chemistry was evaluated to determine salinity or saline character of the surficial and intermediate aquifer systems. Furthermore, ground-water flow within the major permeable zones of the intermediate aquifer system was described.

The surficial aquifer is an unconfined aquifer system that overlies the intermediate aquifer system and ranges from a few feet to over 60 feet in thickness in the study area. Pliocene and younger surficial aquifer system sediments are composed mainly of unconsolidated clastics and carbonates. Hydraulic properties of the surficial aquifer system determined from aquifer and laboratory tests, and model simulations vary considerably across the study area.

The intermediate aquifer system is a series of Pleistocene to Oligocene age sediments composed of fossiliferous limestone and dolostone, quartz and phosphatic sand, clayey sand, clay, sandy clay, and chert. The intermediate aquifer system, a confined aquifer system that lies between the surficial and the Upper Floridan aquifers, is composed of alternating confining units and permeable zones. The intermediate aquifer system, a complex heterogeneous system, has three major permeable zones that exhibit a wide range of hydraulic properties.

The surficial aquifer system and major permeable zones of the intermediate aquifer system have distinct water-quality characteristics that range naturally from fresh in the surficial aquifer system and upper permeable zones of the intermediate aquifer system to moderately saline in the lower permeable zone.Water-quality data collected in coastal southwest Sarasota County indicate that ground-water withdrawals from major pumping centers have caused lateral seawater intrusion and upconing into the surficial and intermediate aquifer systems.

Water-level data indicate that horizontal flow in the intermediate aquifer system is northeast to southwest. Most of the study area is in a discharge area of the intermediate aquifer system. Data from this study indicate an upward head gradient in the intermediate aquifer system, where heads increase with depth.

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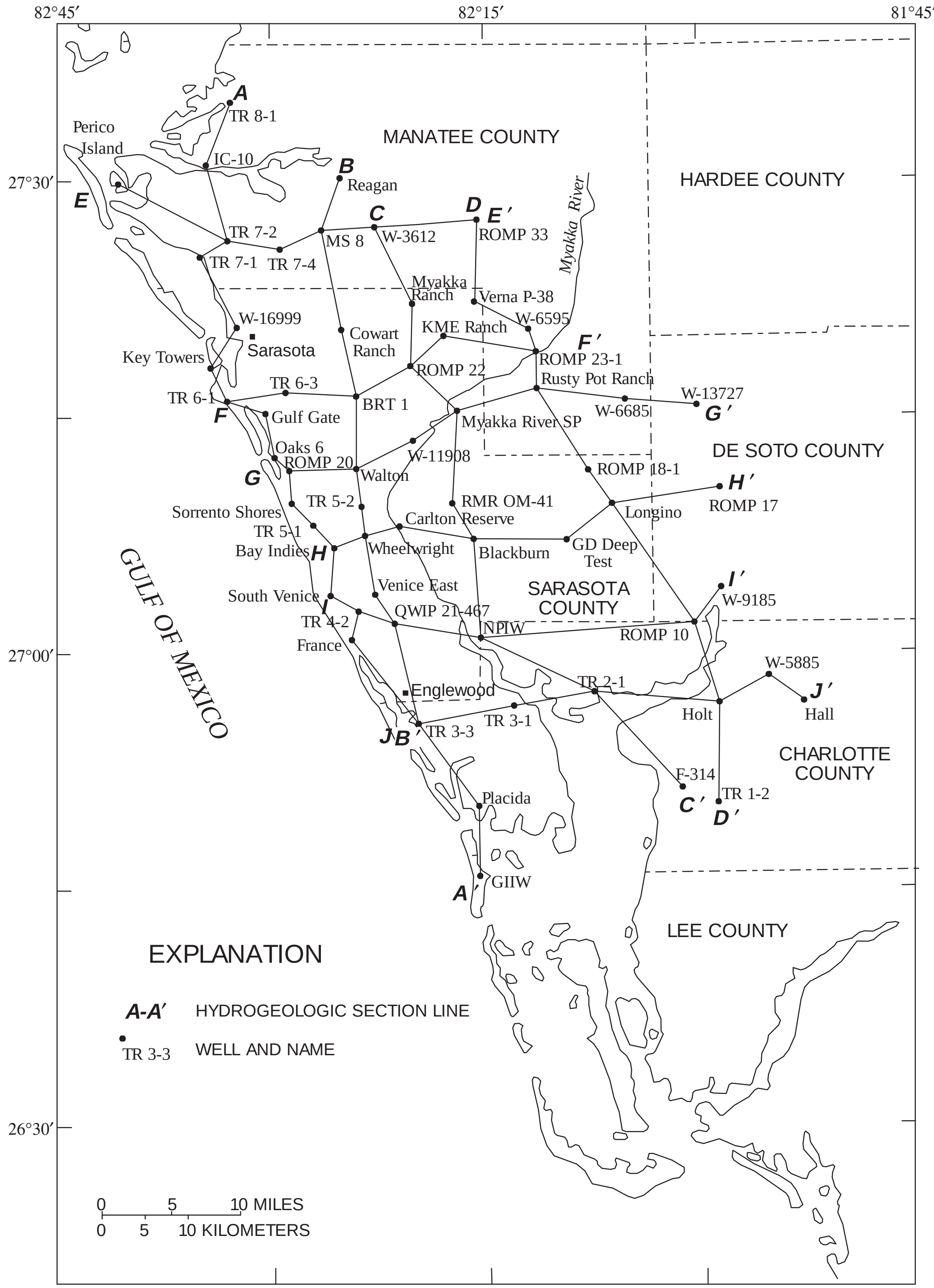

Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 6. Location of hydrogeologic sections in the study area.

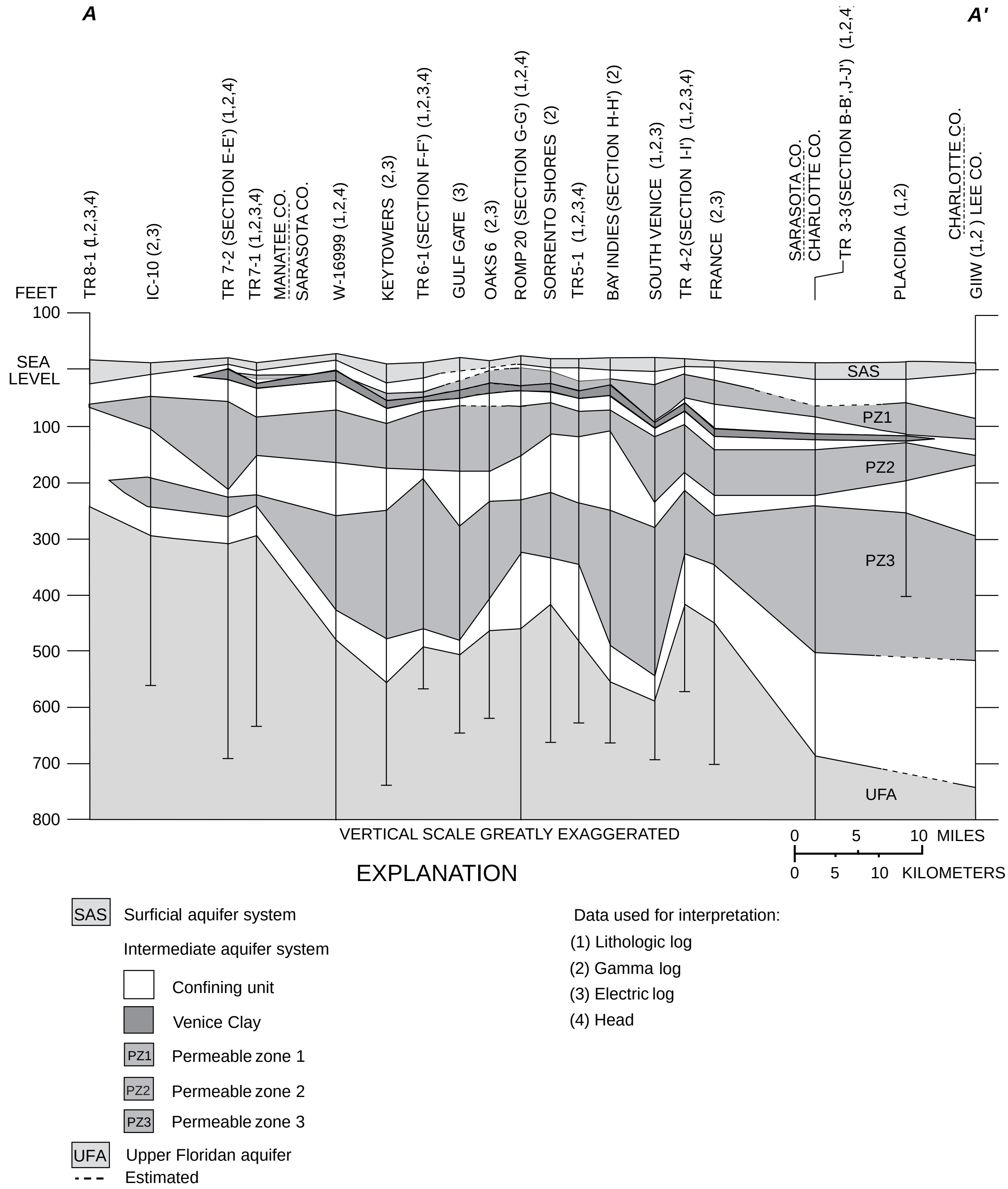

Figure 7. Hydrogeologic section A-A′ in southwest Florida. (Line of section is shown in figure 6.)

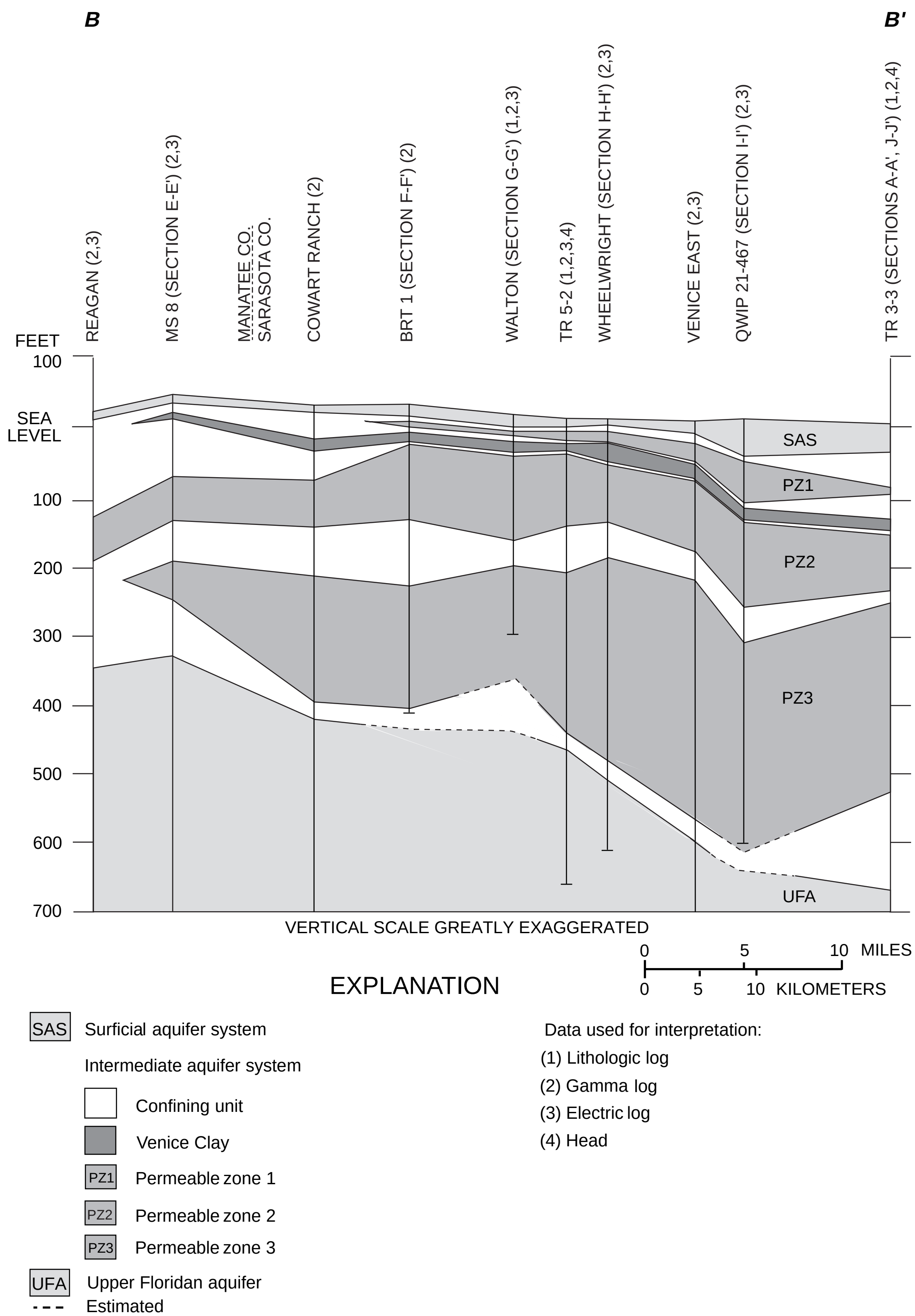

Figure 8. Hydrogeologic section B-B′ in southwest Florida. (Line of section is shown in figure 6.)

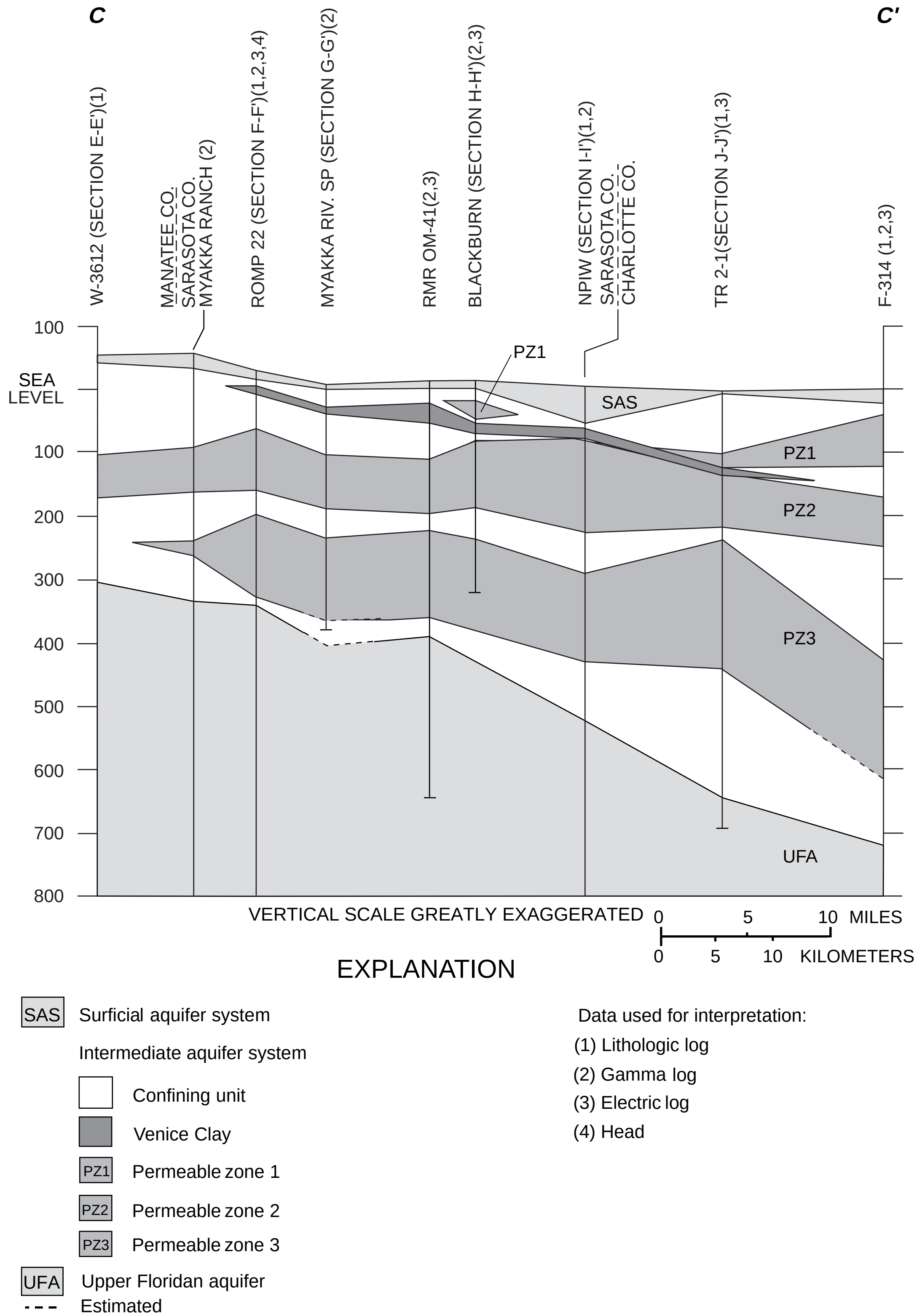

Figure 9. Hydrogeologic section C-C′ in southwest Florida. (Line of section is shown in figure 6.)

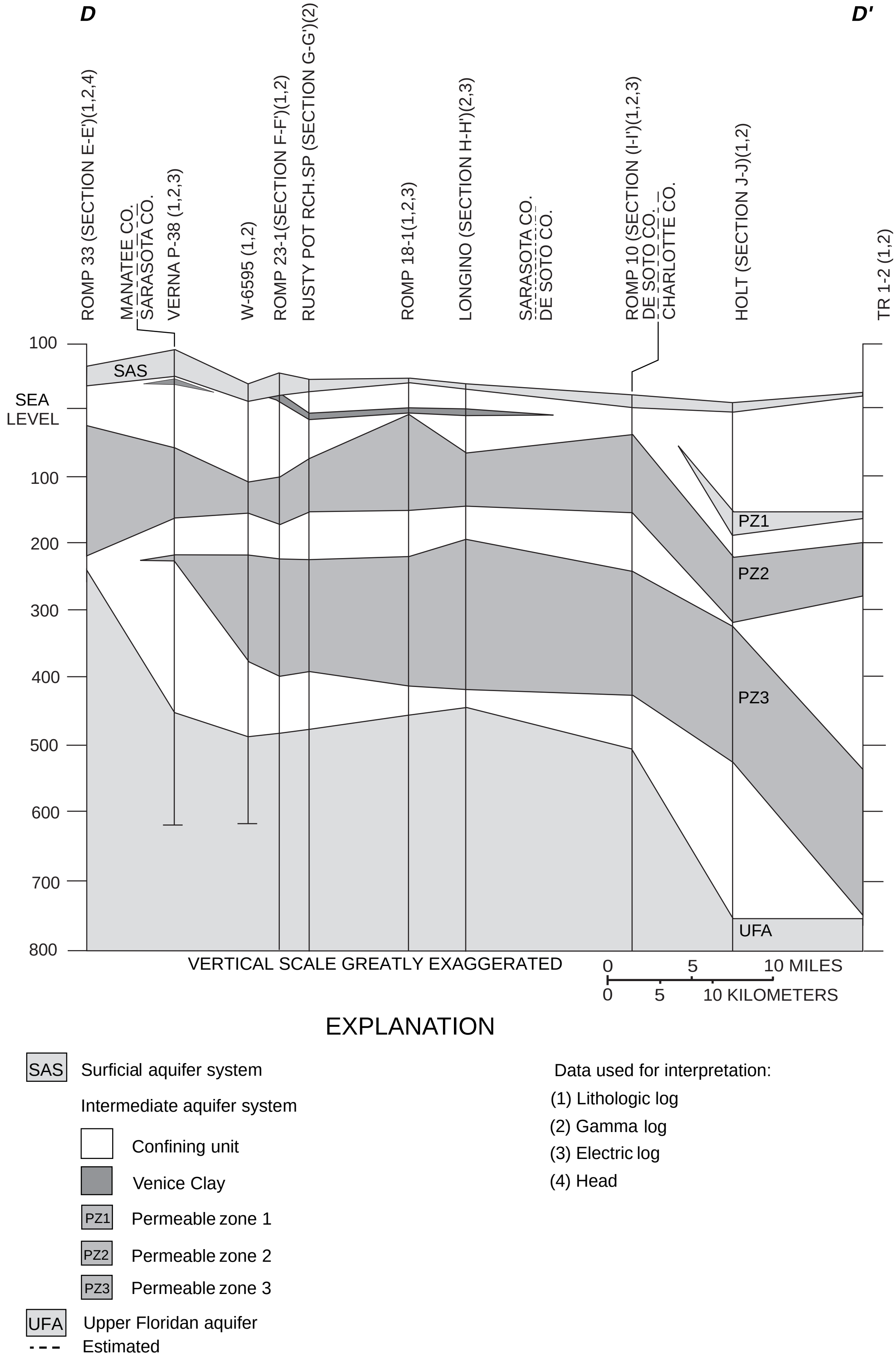

Figure 10. Hydrogeologic section D-D′ in southwest Florida. (Line of section is shown in figure 6.)

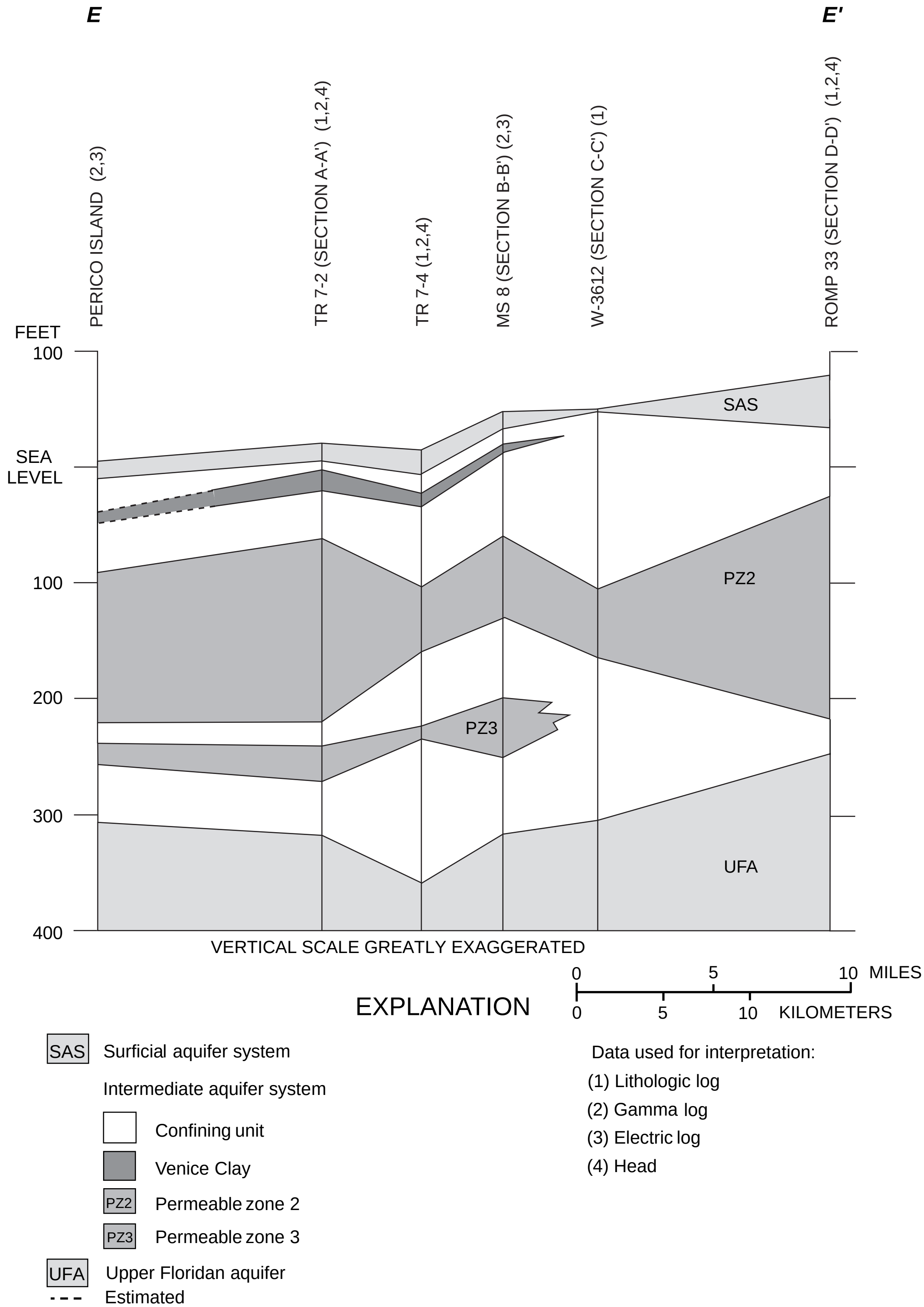

Figure 11. Hydrogeologic section E-E′ in southwest Florida. (Line of section is shown in figure 6.)

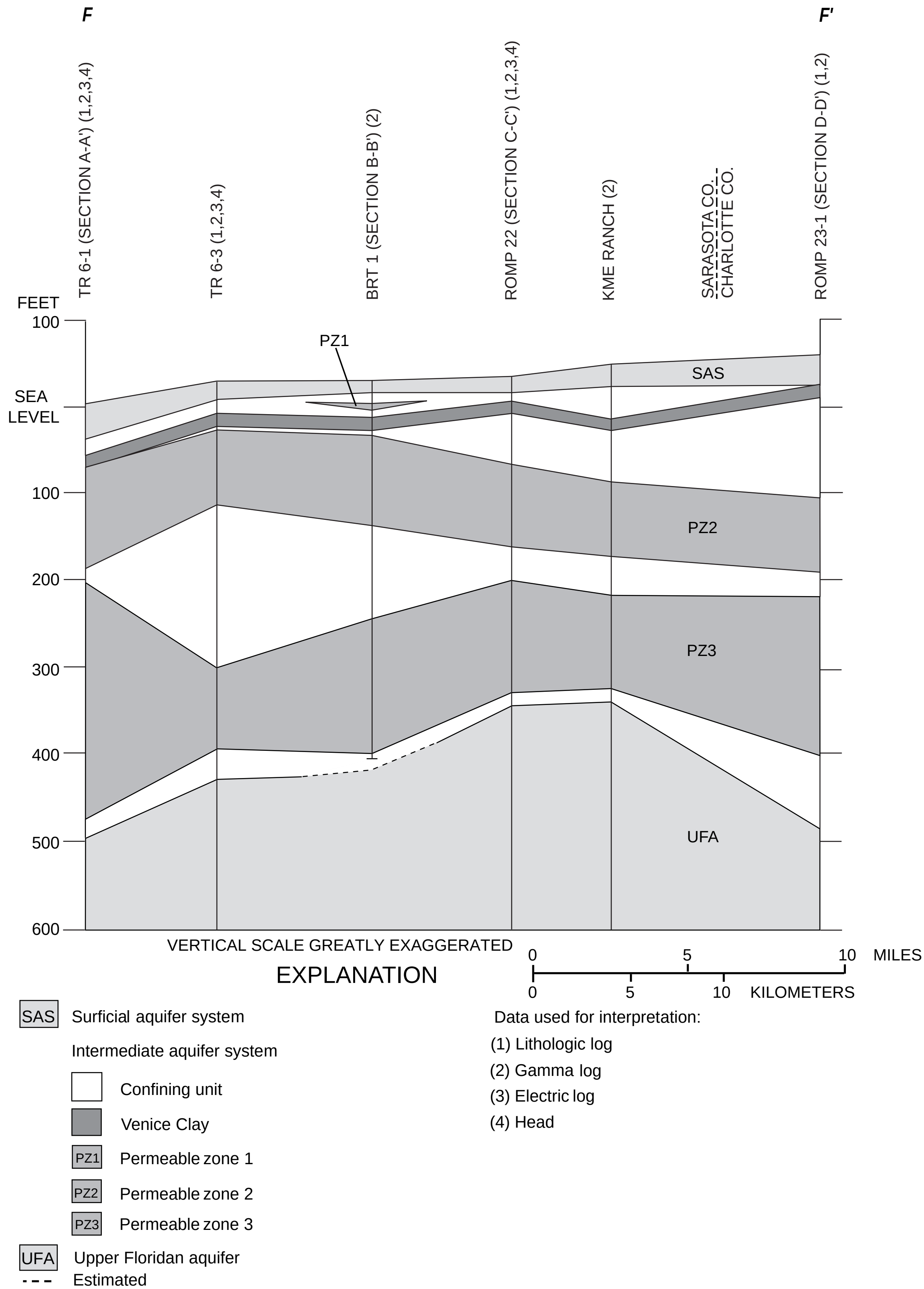

Figure 12. Hydrogeologic section F-F′ in southwest Florida. (Line of section is shown in figure 6.)

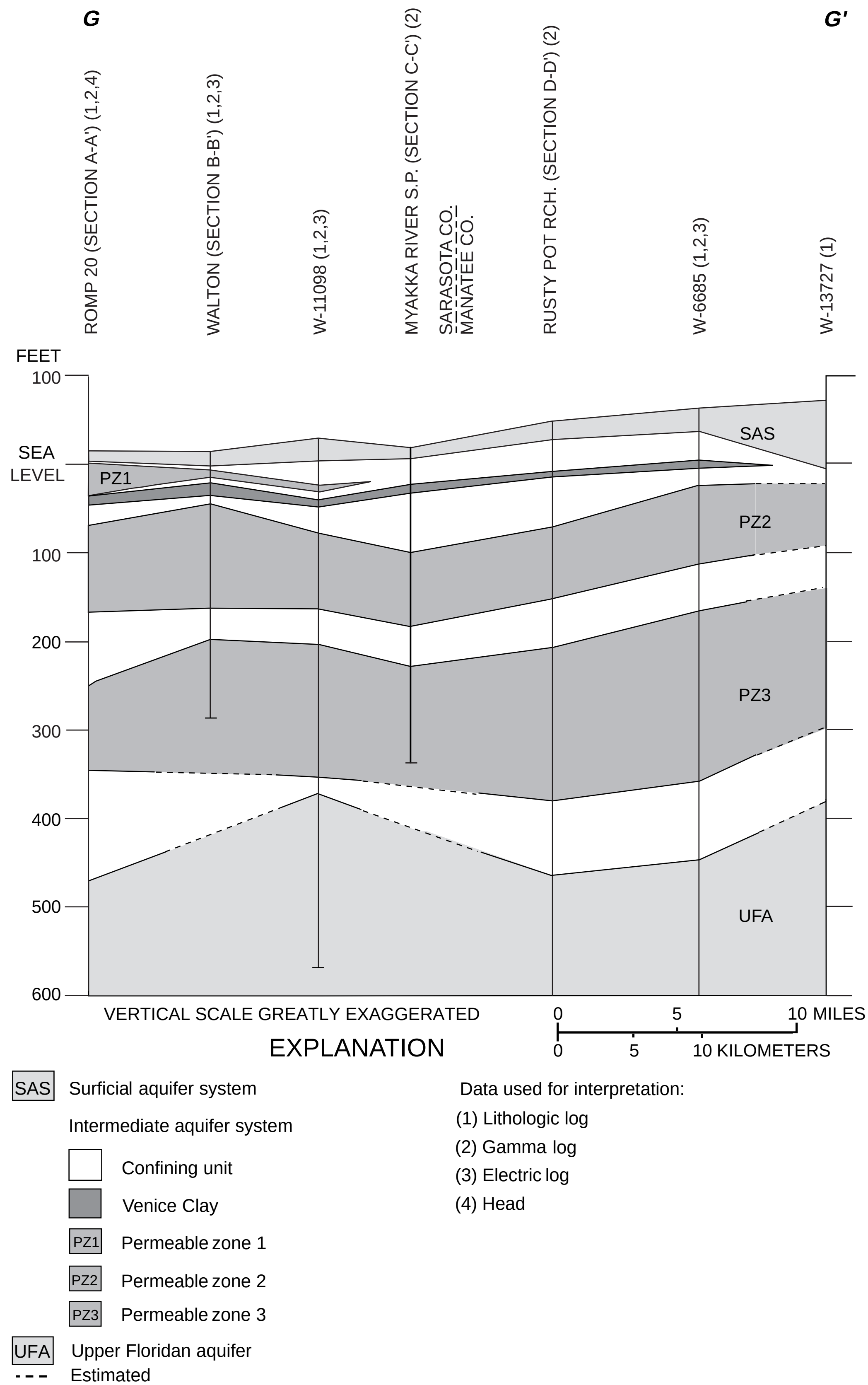

Figure 13. Hydrogeologic section G-G′ in southwest Florida. (Line of section is shown in figure 6.)

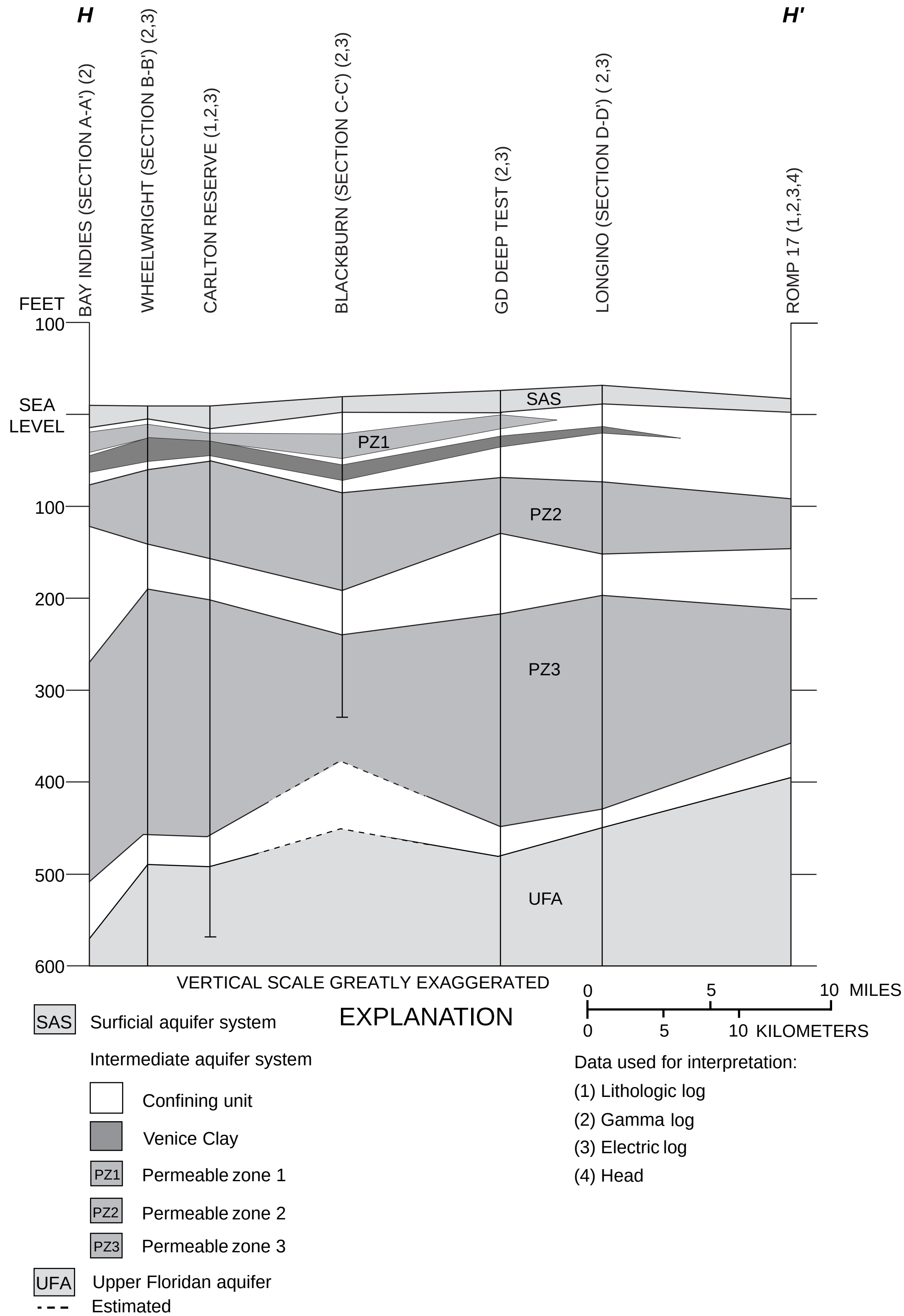

Figure 14. Hydrogeologic section H-H′ in southwest Florida. (Line of section is shown in figure 6.)

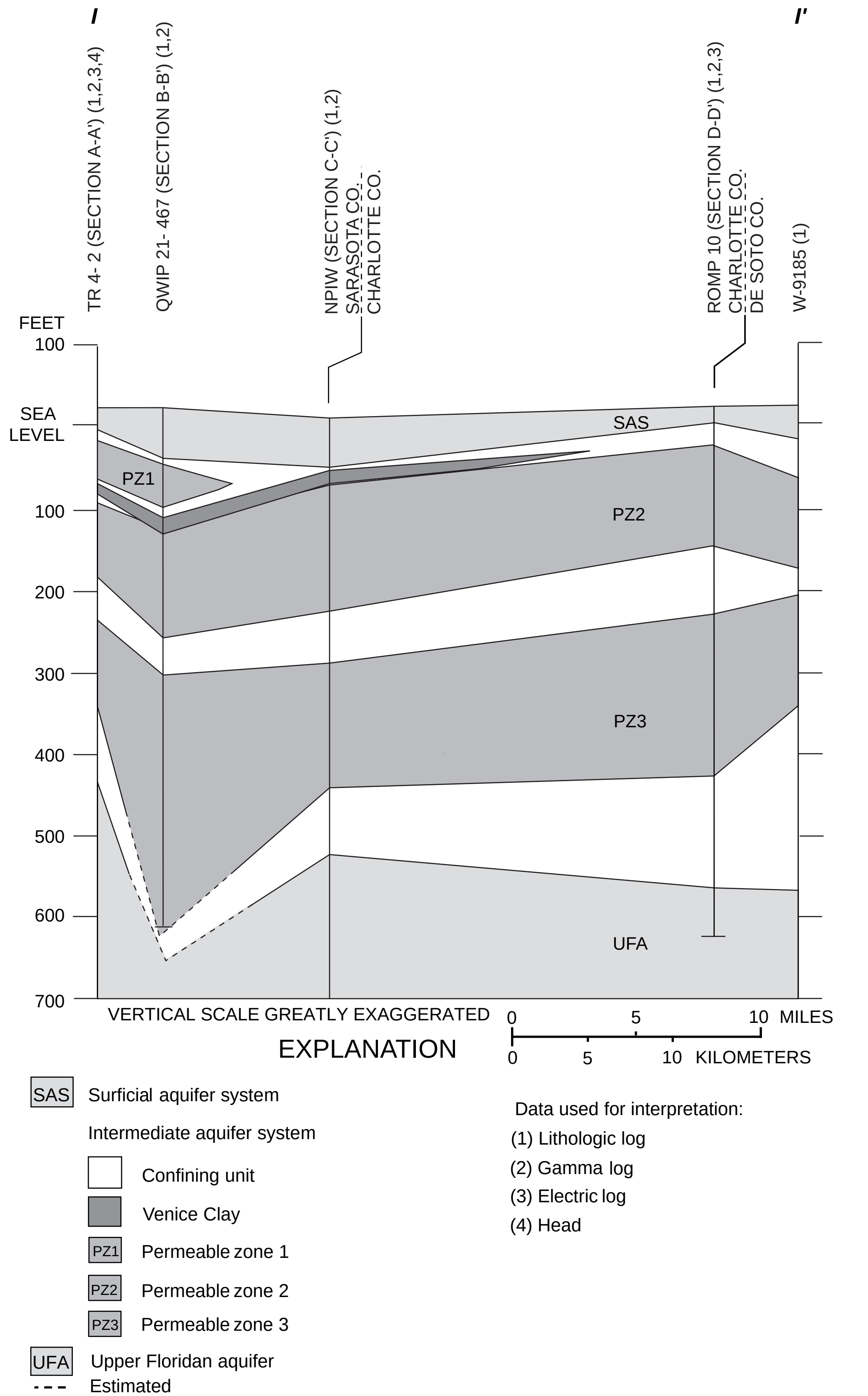

Figure 15. Hydrogeologic section I-I′ in southwest Florida. (Line of section is shown in figure 6.)

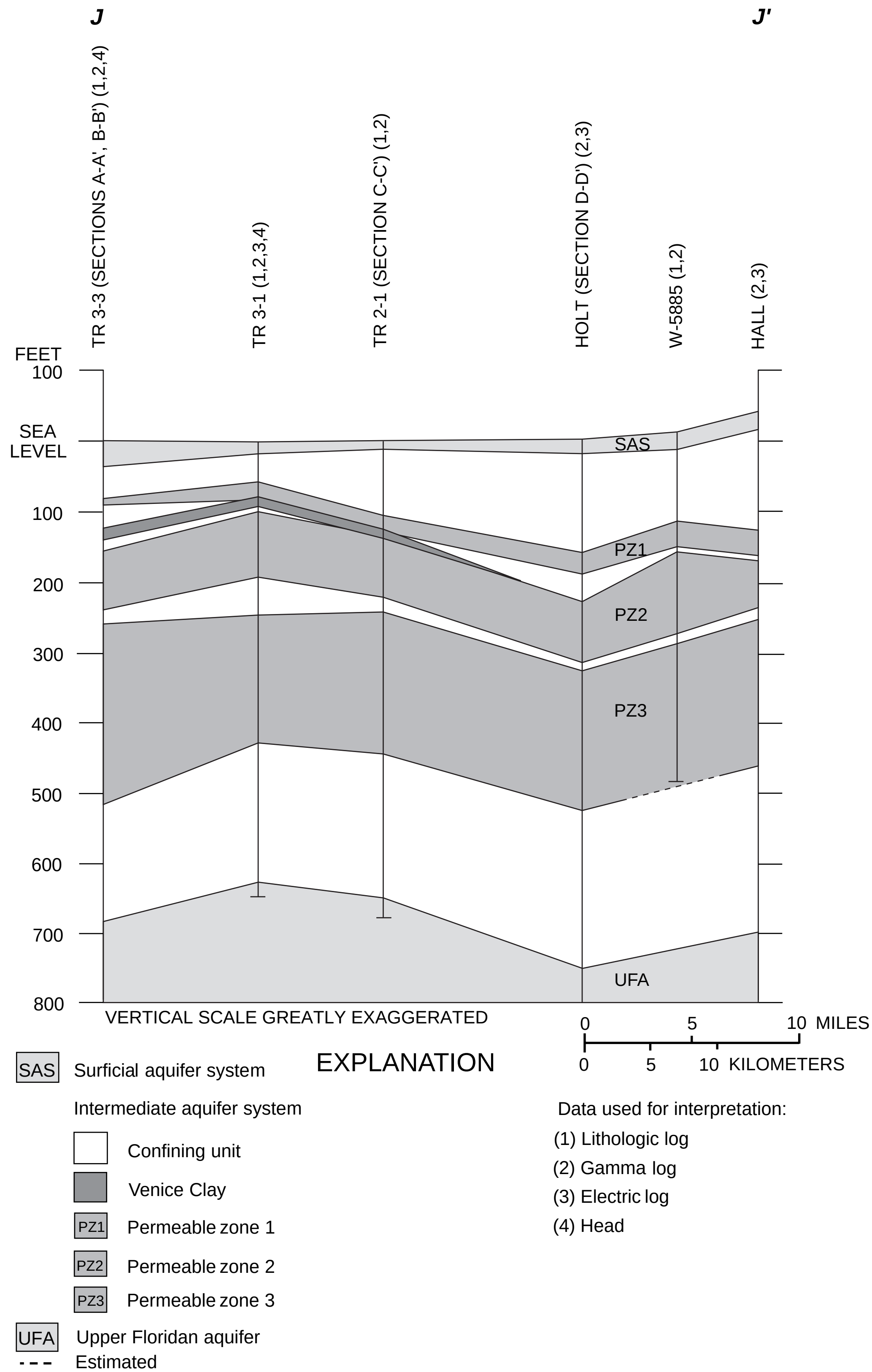

Figure 16. Hydrogeologic section J-J′ in southwest Florida. (Line of section is shown in figure 6.)

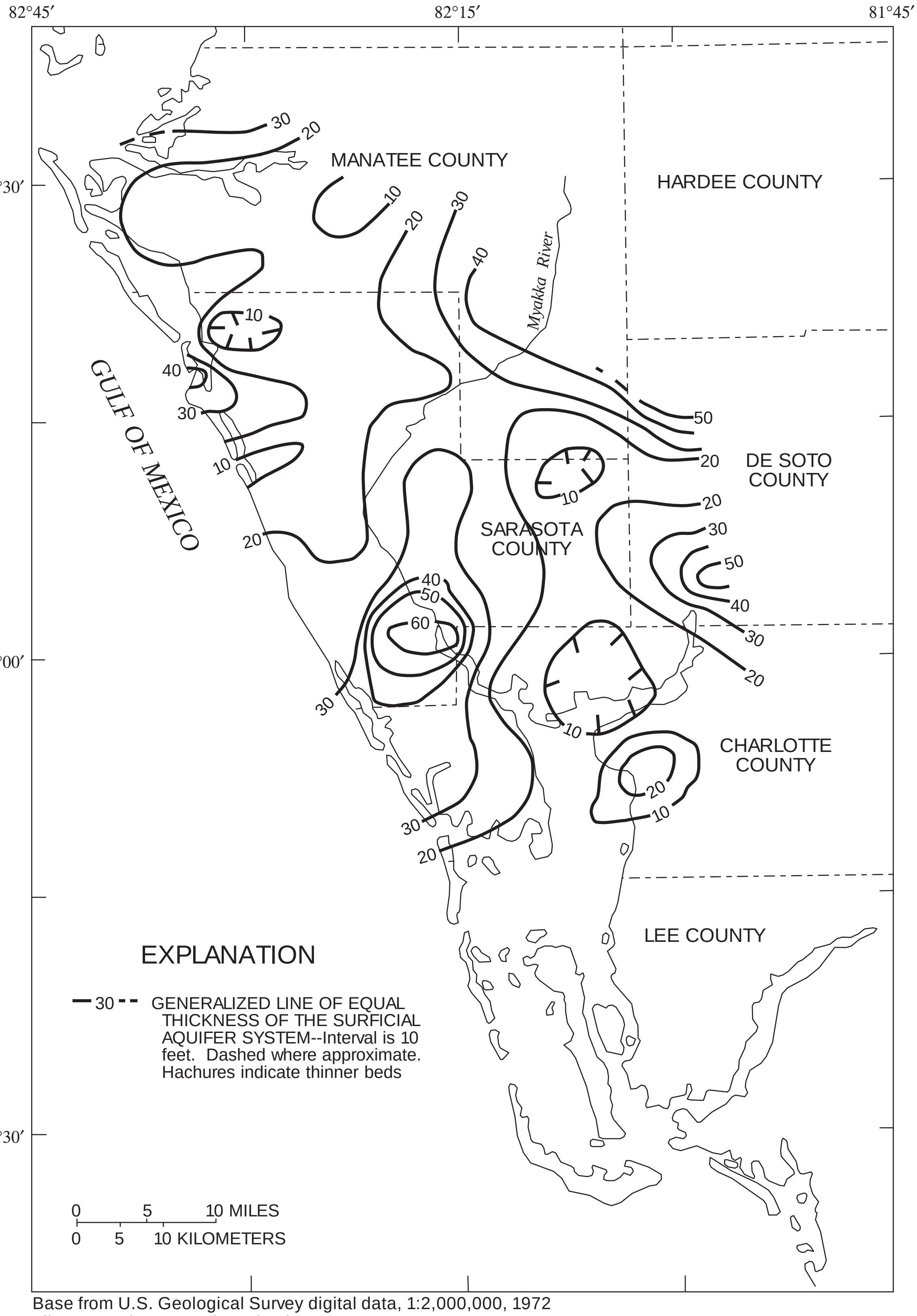

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Figure 17. Generalized thickness of the surficial aquifer system in southwest Florida.

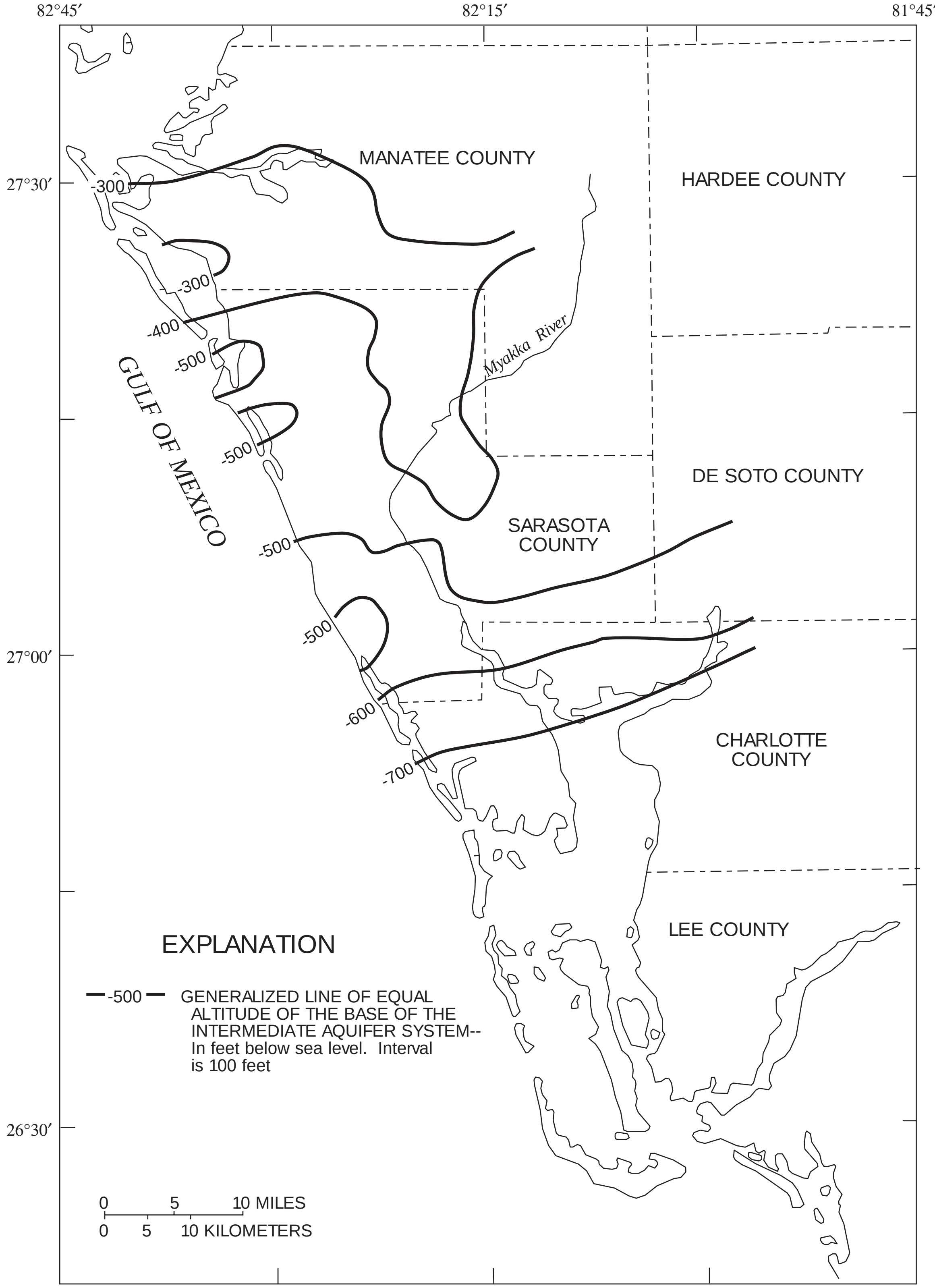

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Figure 18. Generalized altitude of the base of the intermediate aquifer system in southwest Florida.

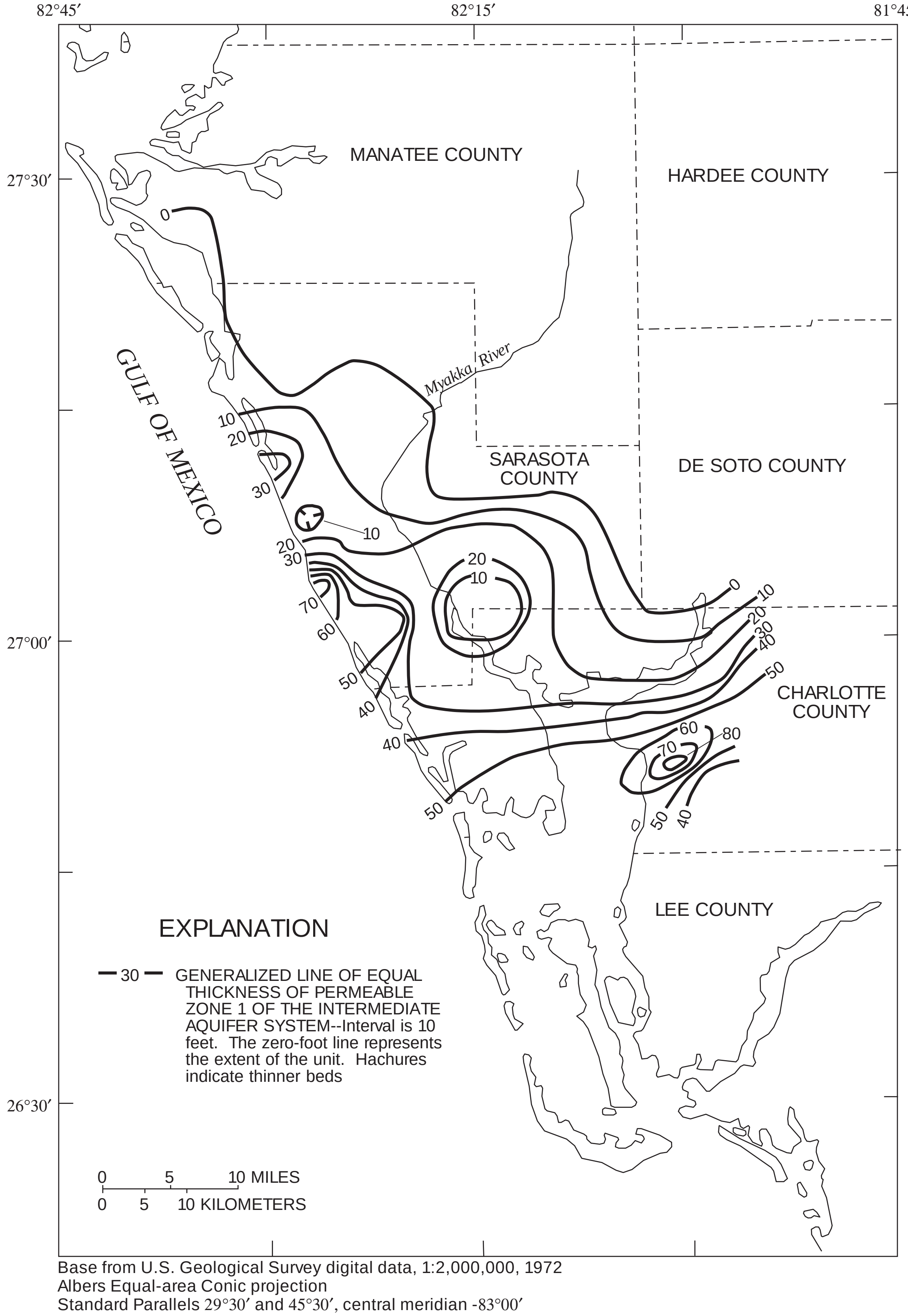

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Figure 19. Generalized thickness and extent of permeable zone 1 of the intermediate aquifer system in southwest Florida.

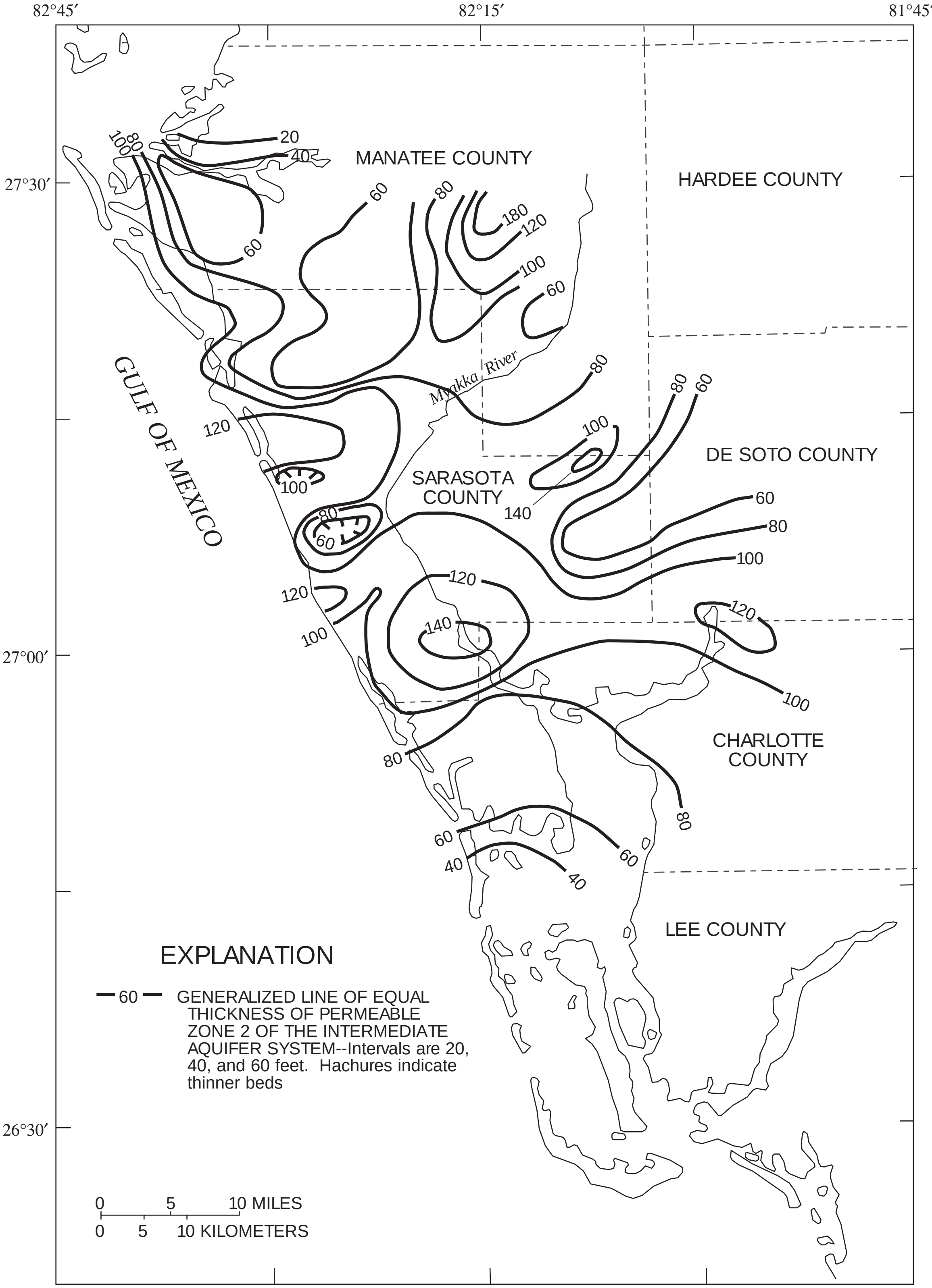

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Figure 20. Generalized thickness of permeable zone 2 of the intermediate aquifer system in southwest Florida.

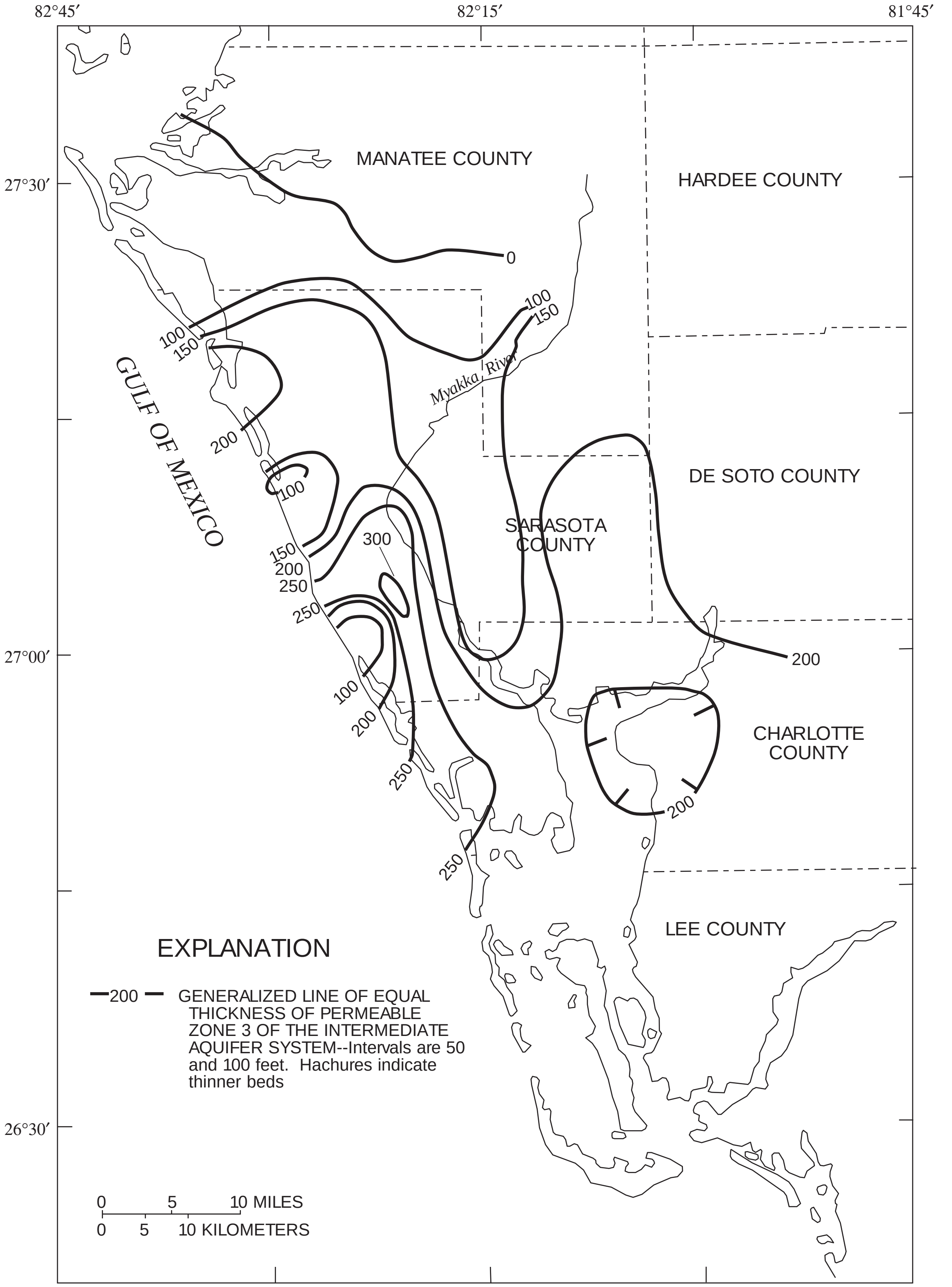

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Figure 21. Generalized thickness of permeable zone 3 of the intermediate aquifer system in southwest Florida.

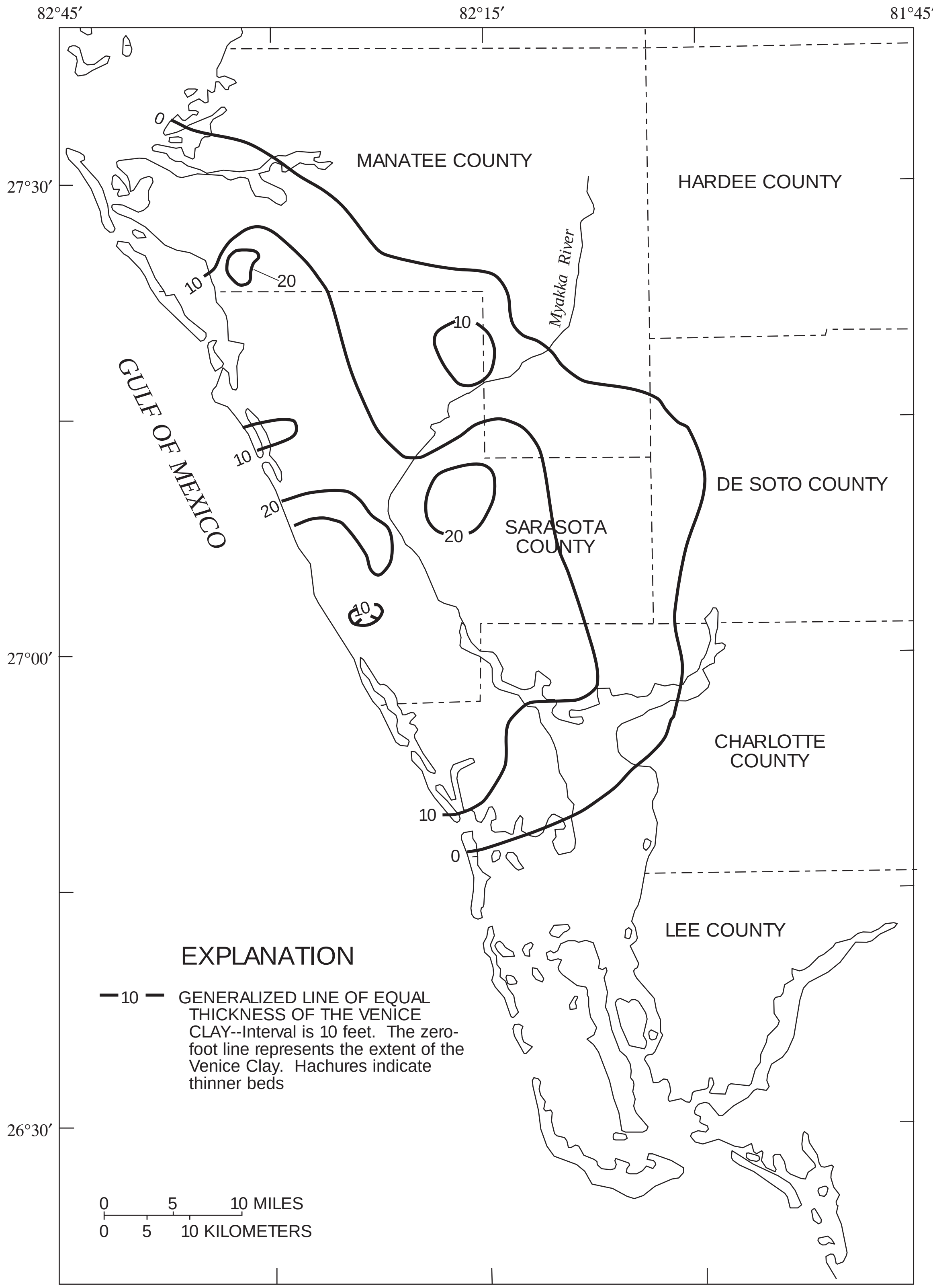

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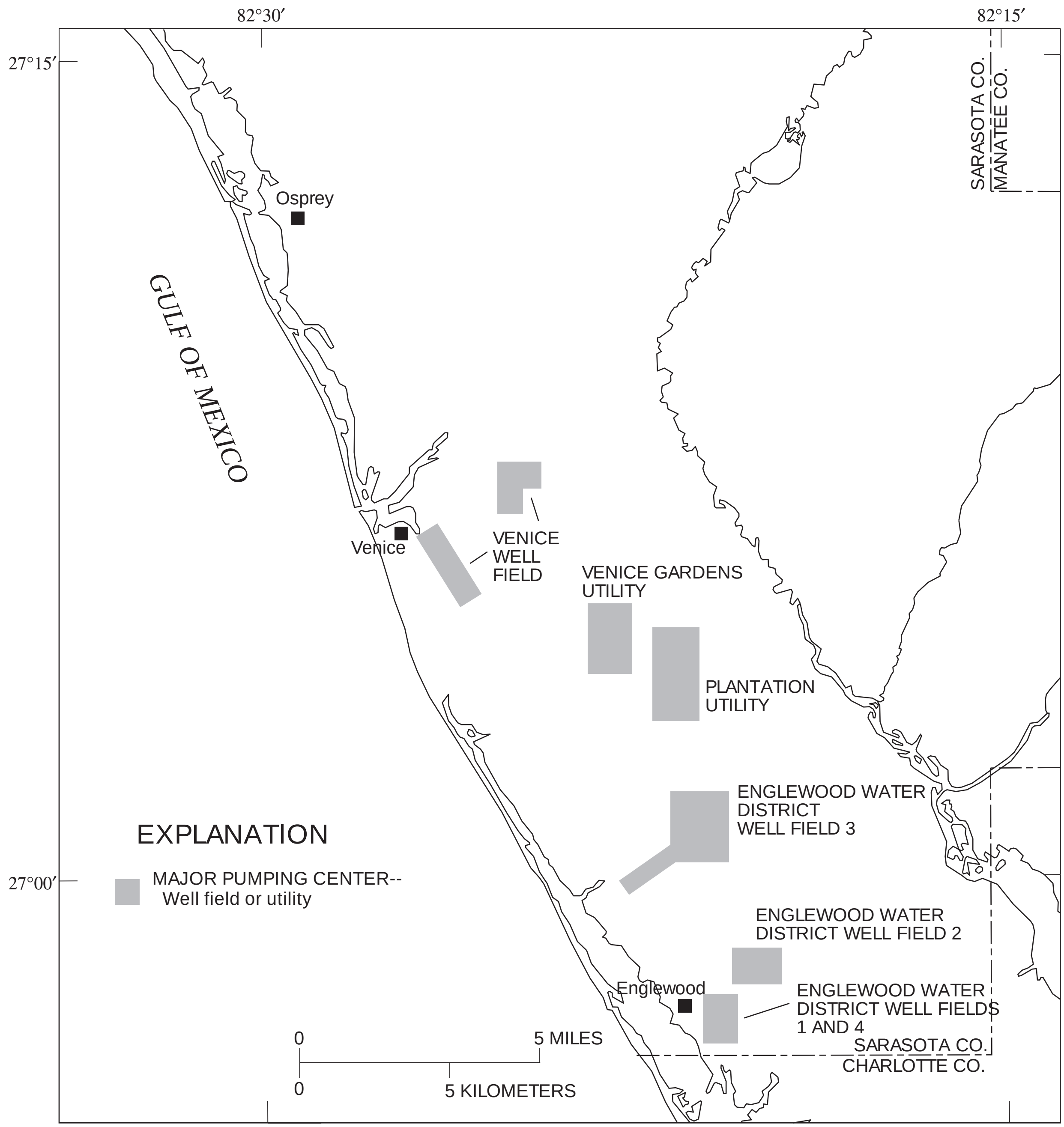
Figure 22. Generalized thickness and extent of the Venice Clay in southwest Florida.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
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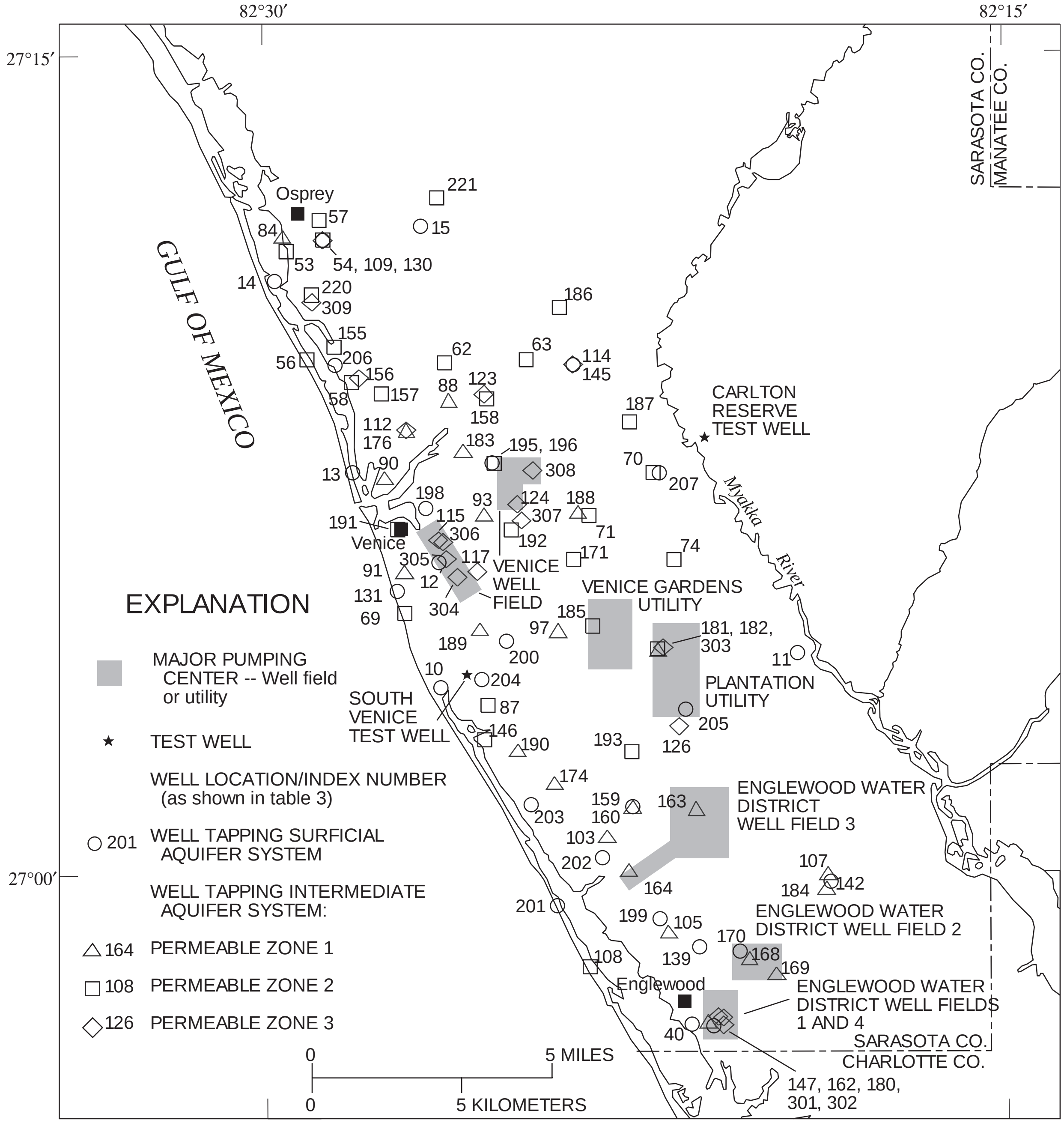
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 23. Major pumping centers in southwest Sarasota County.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
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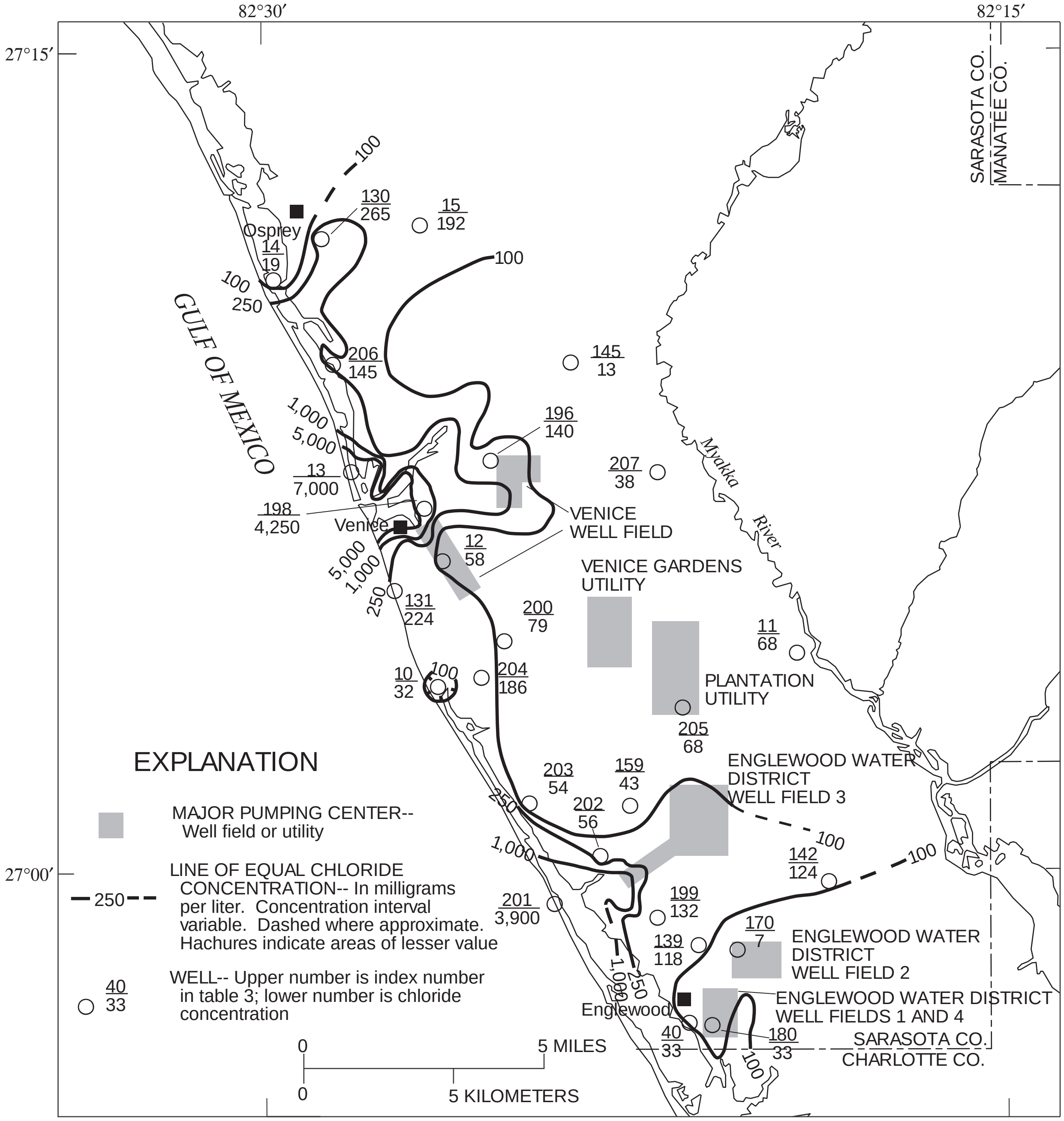
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 24. Surficial and intermediate aquifer system ground-water quality monitor wells in southwest Sarasota County.



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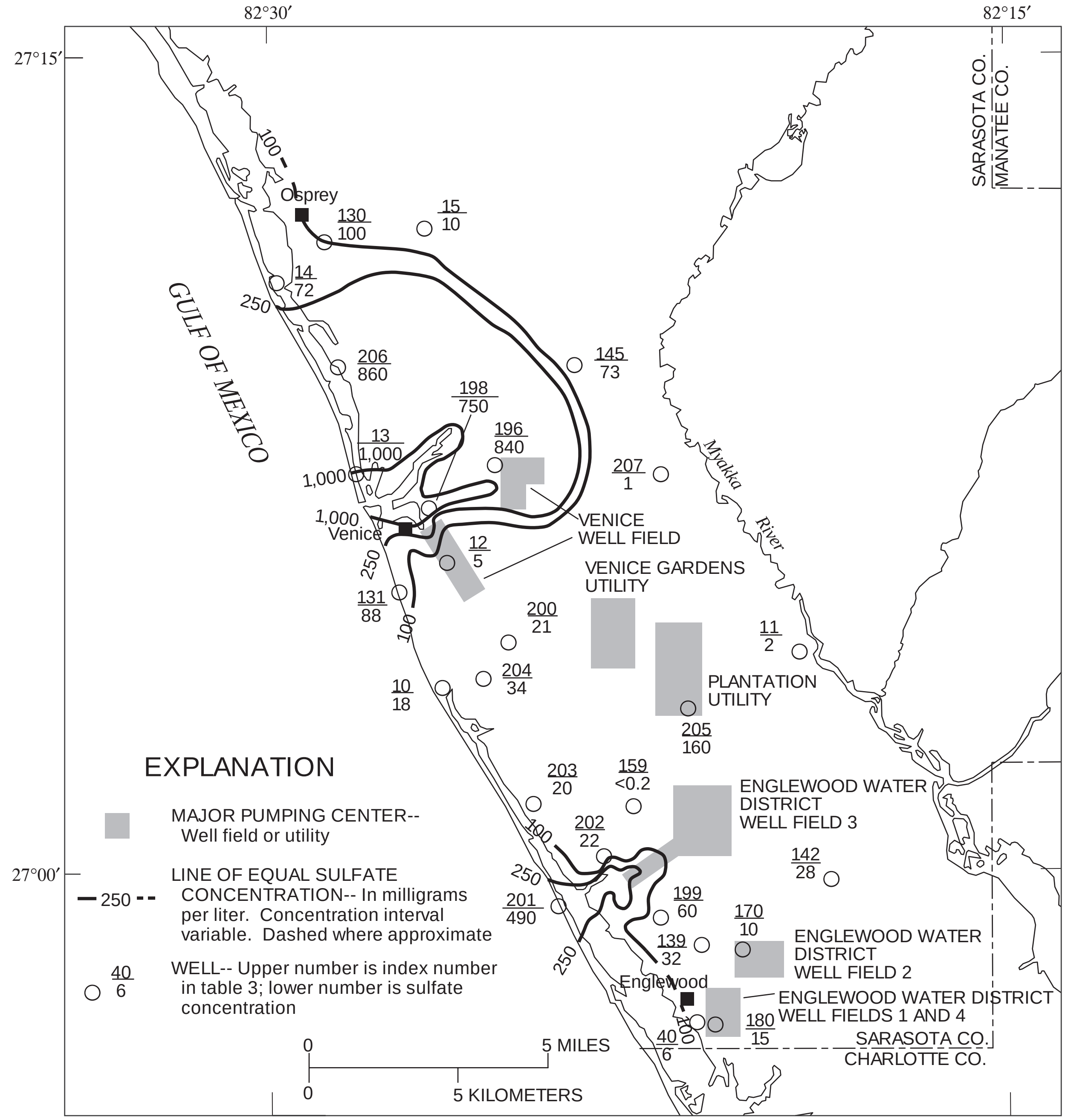
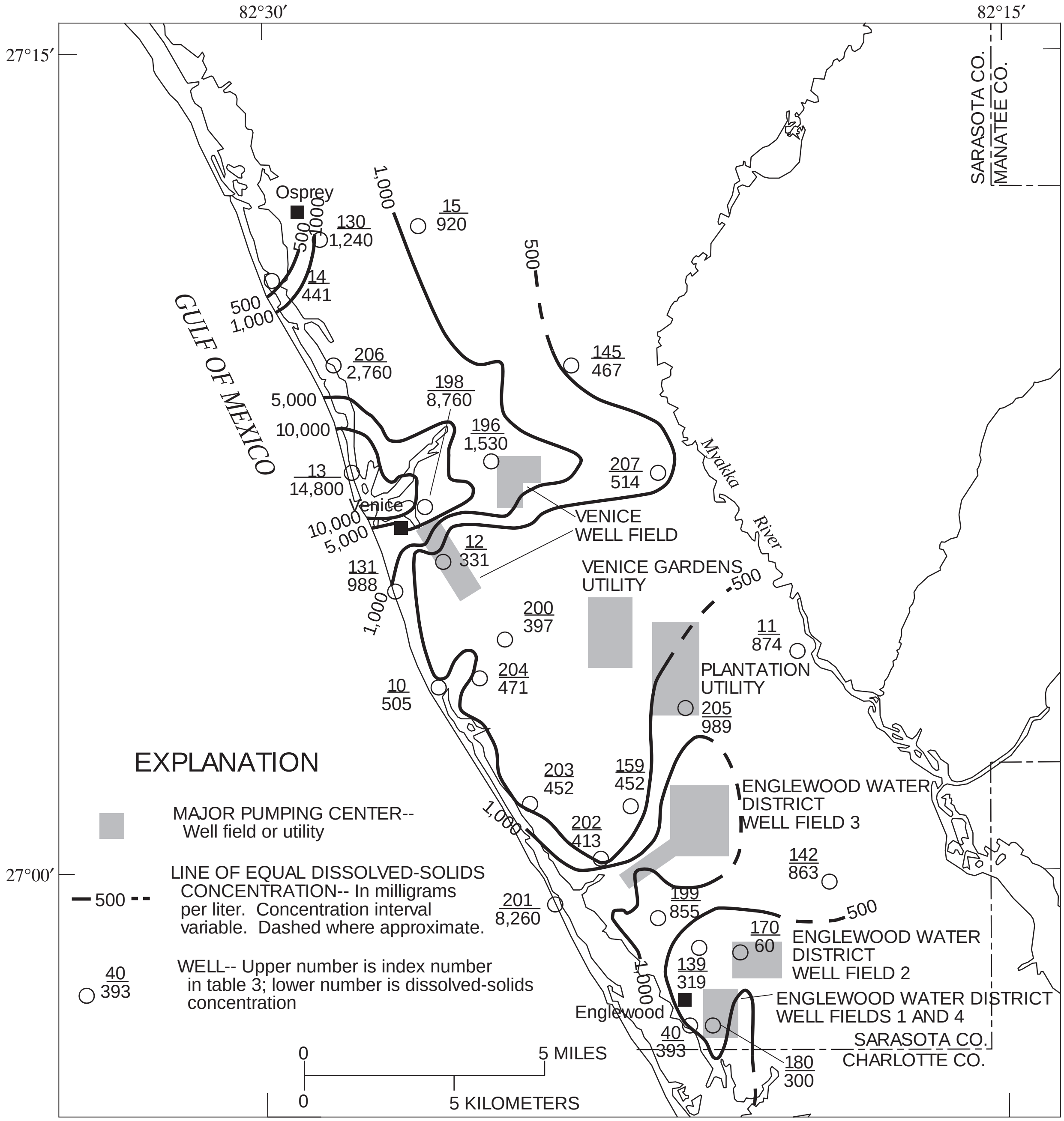
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 25. Chloride concentration in water from wells open to the surficial aquifer system in southwest Sarasota County.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 26. Sulfate concentration in water from wells open to the surficial aquifer system in southwest Sarasota County.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
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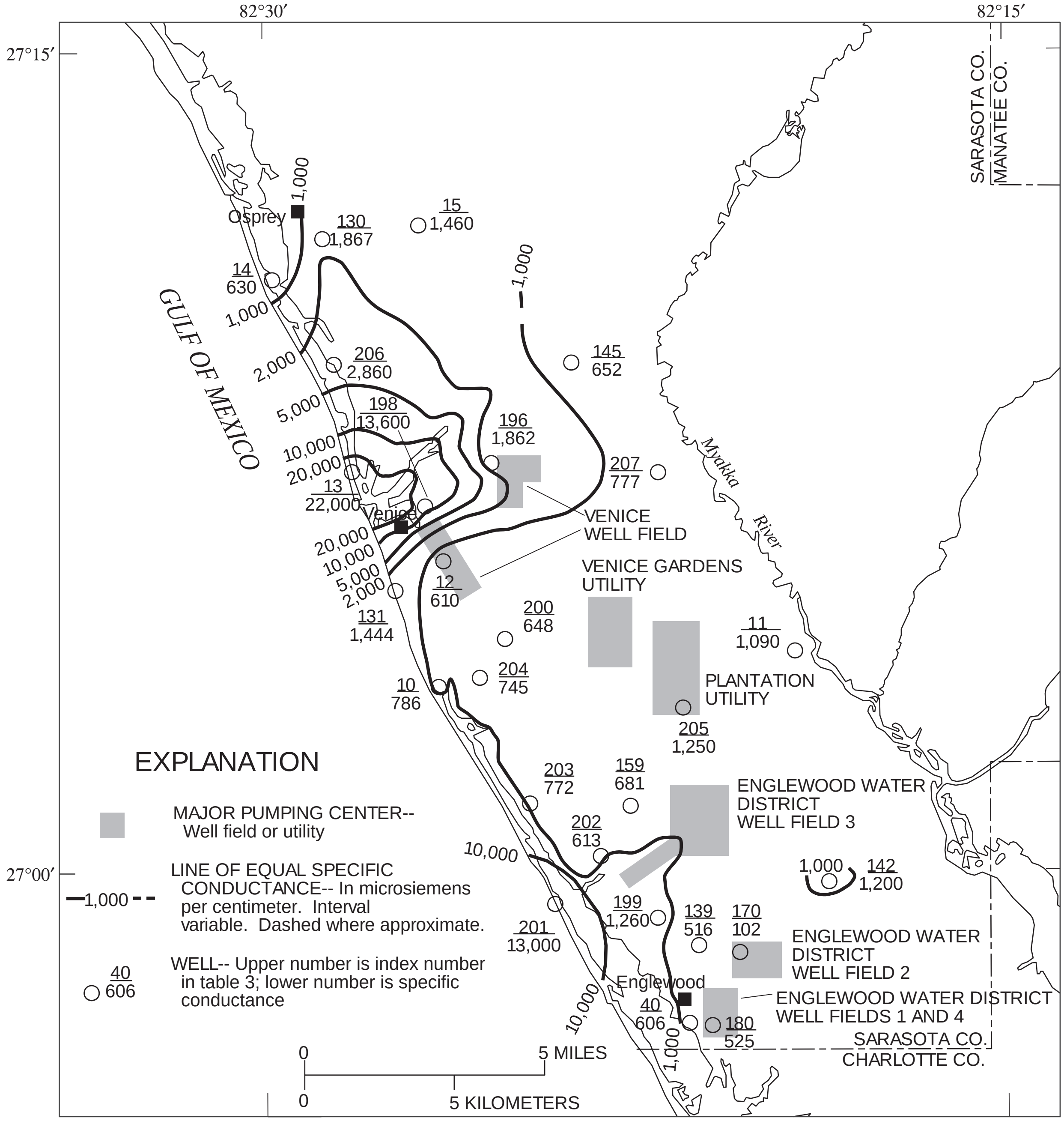
Figure 27. Dissolved-solids concentration in water from wells open to the surficial aquifer system in southwest Sarasota County.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
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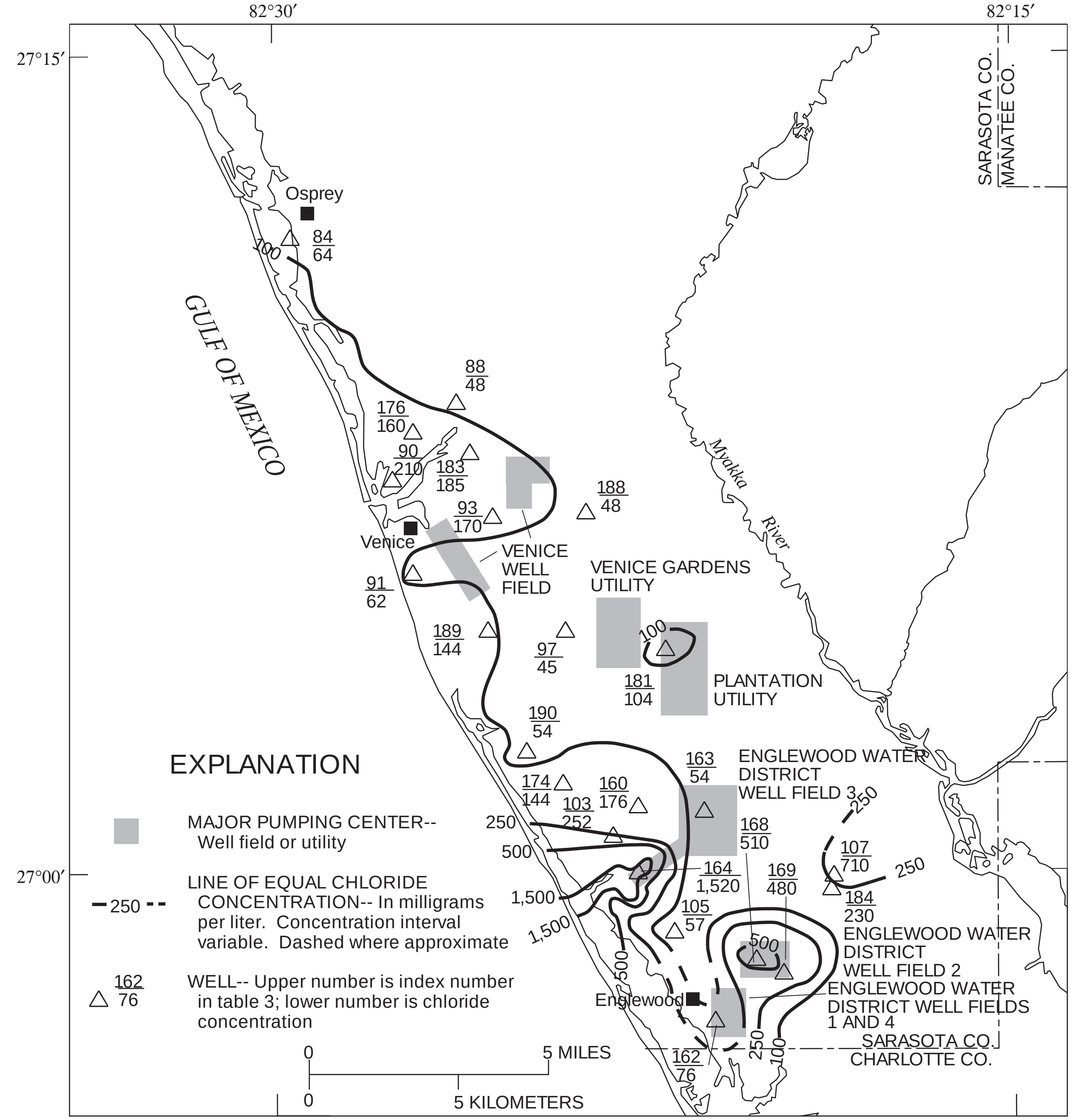
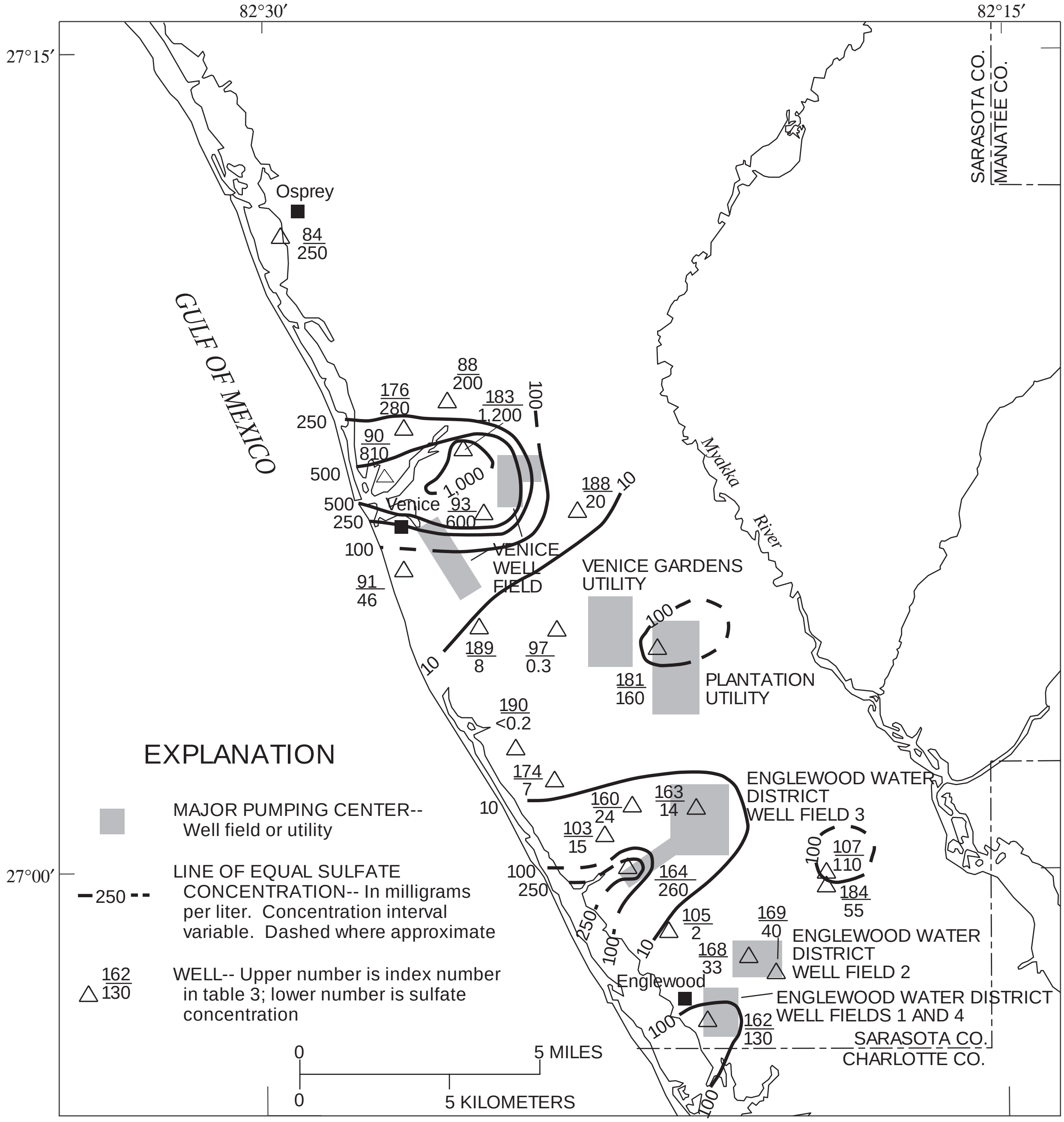
Figure 28. Specific conductance of water from wells open to the surficial aquifer system in southwest Sarasota County.



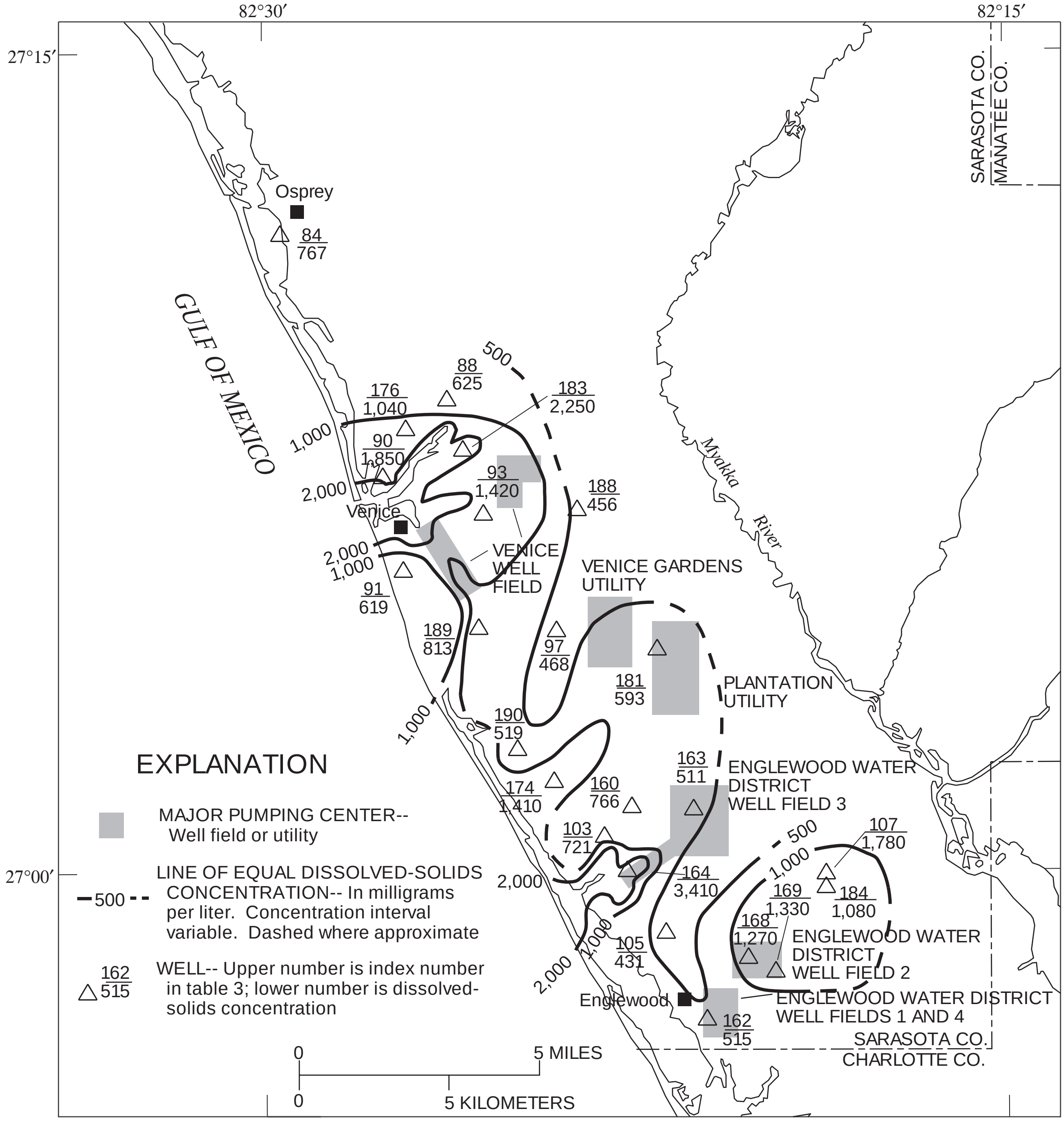
Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 29. Chloride concentration in water from wells open to the intermediate aquifer system, permeable zone 1, in southwest Sarasota County.



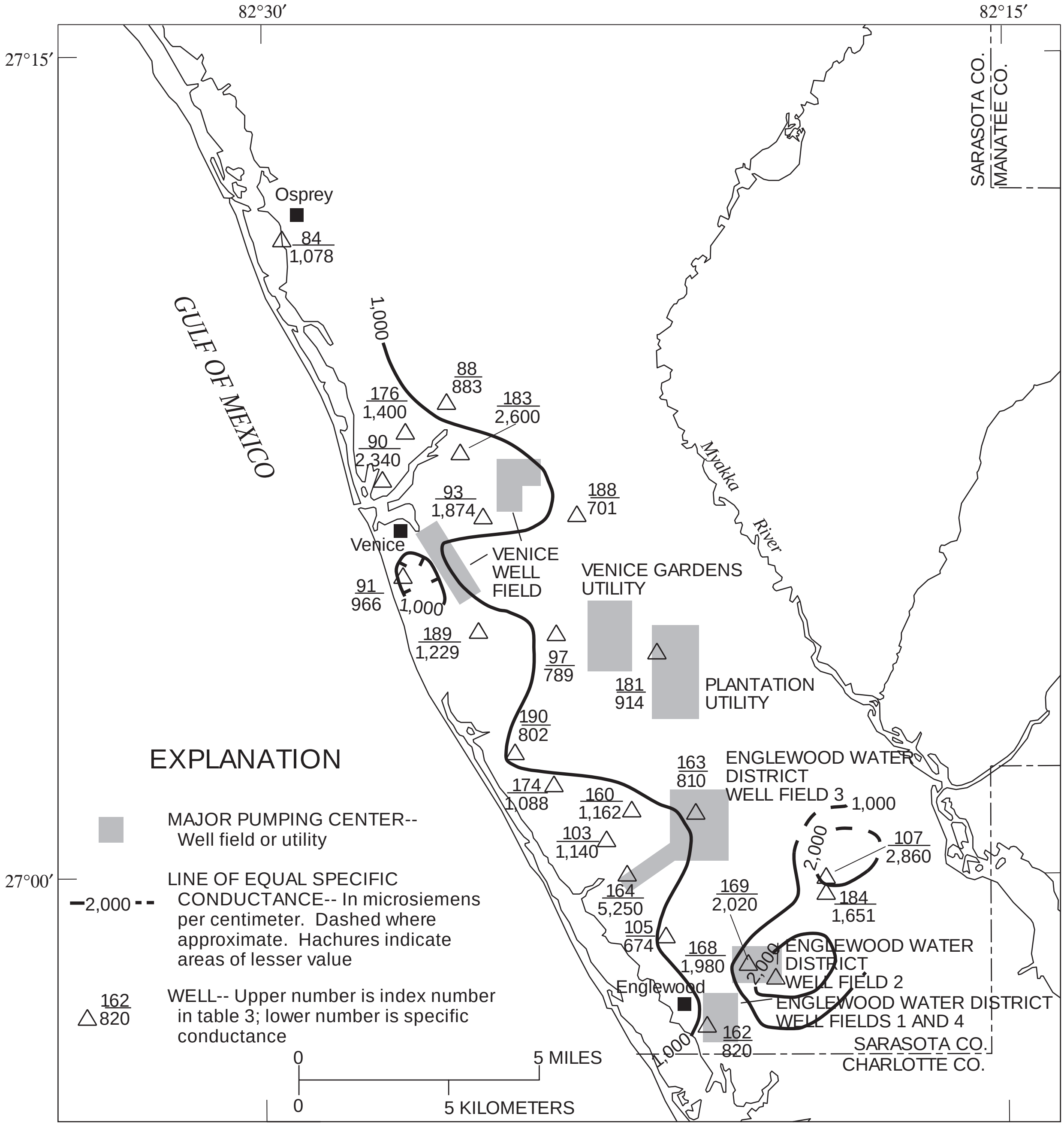
Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 30. Sulfate concentration in water from wells open to the intermediate aquifer system, permeable zone 1, in southwest Sarasota County.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 31. Dissolved-solids concentration in water from wells open to the intermediate aquifer system, permeable zone 1, in southwest Sarasota County.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 32. Specific conductance of water from wells open to the intermediate aquifer system, permeable zone 1, in southwest Sarasota County.

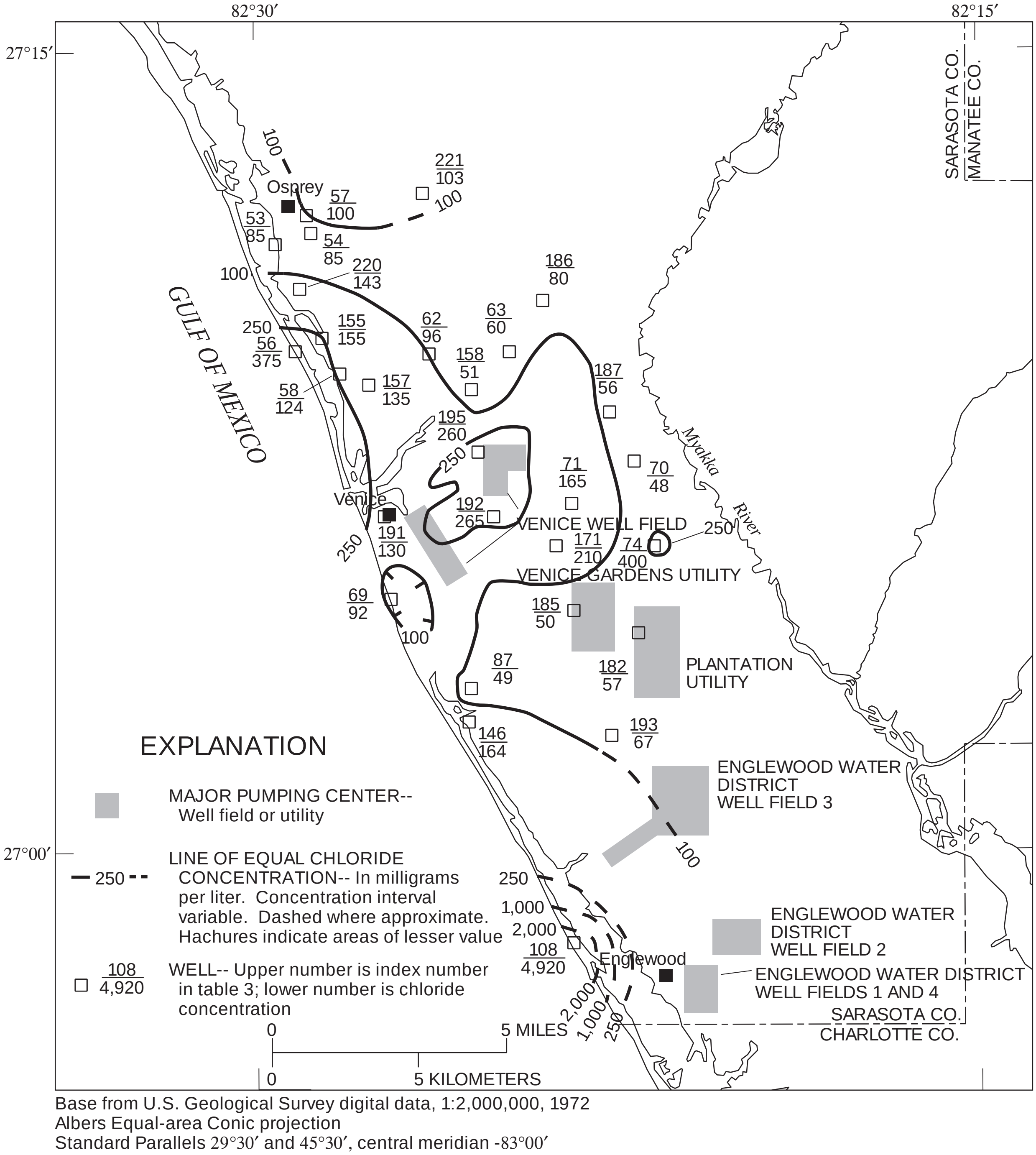
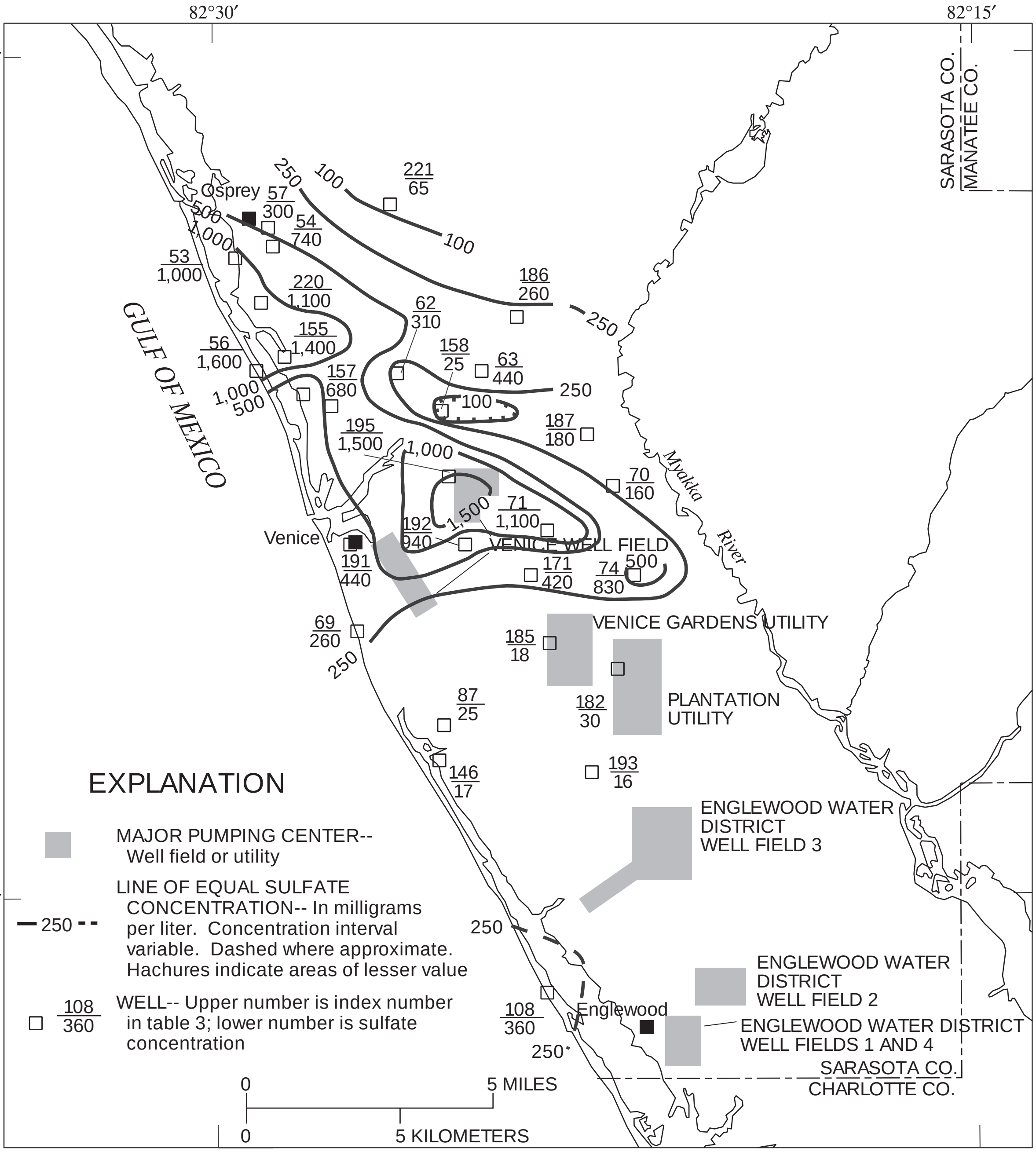
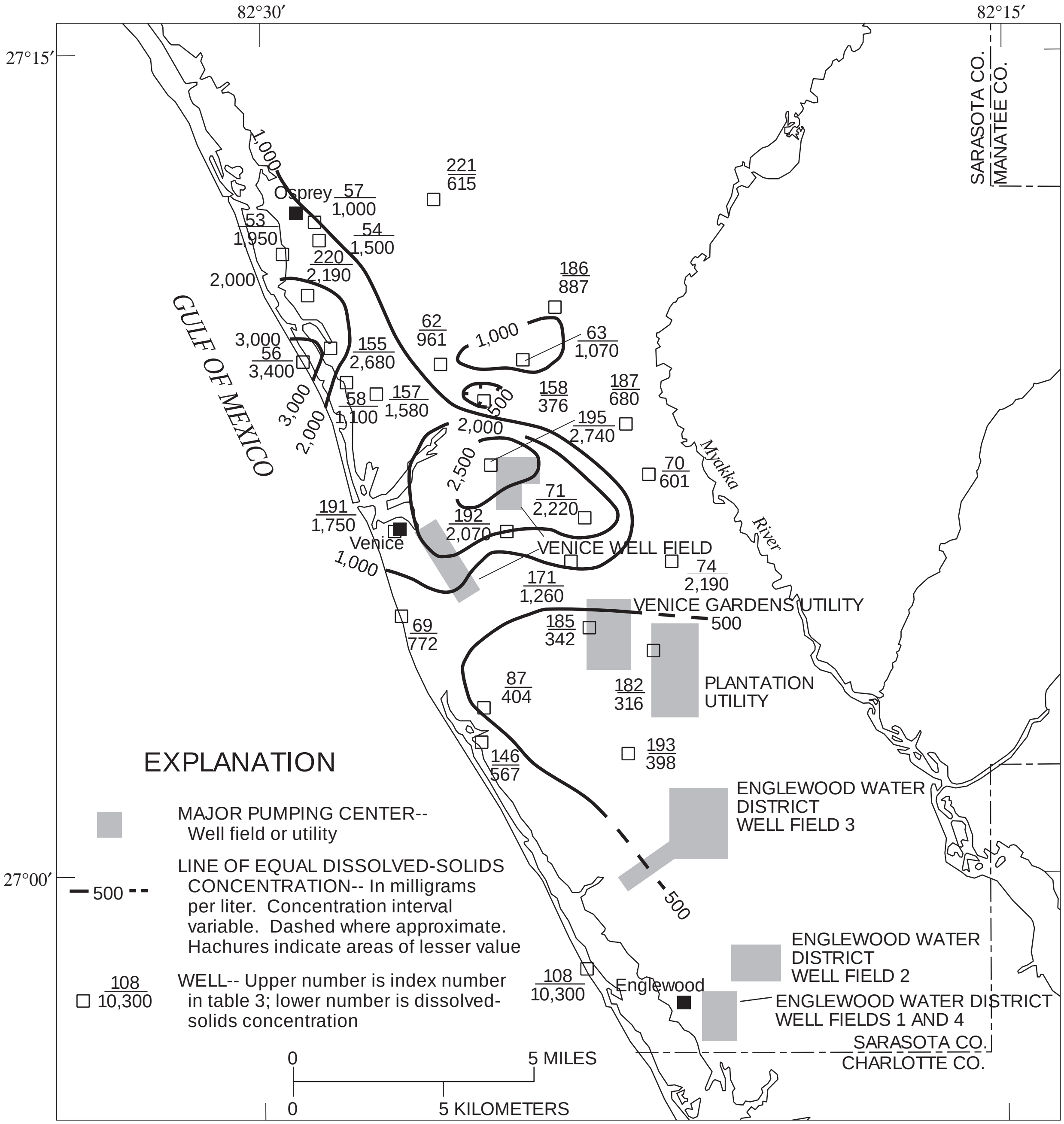


Figure 33. Chloride concentration in water from wells open to the intermediate aquifer system, permeable zone 2, in southwest Sarasota County.



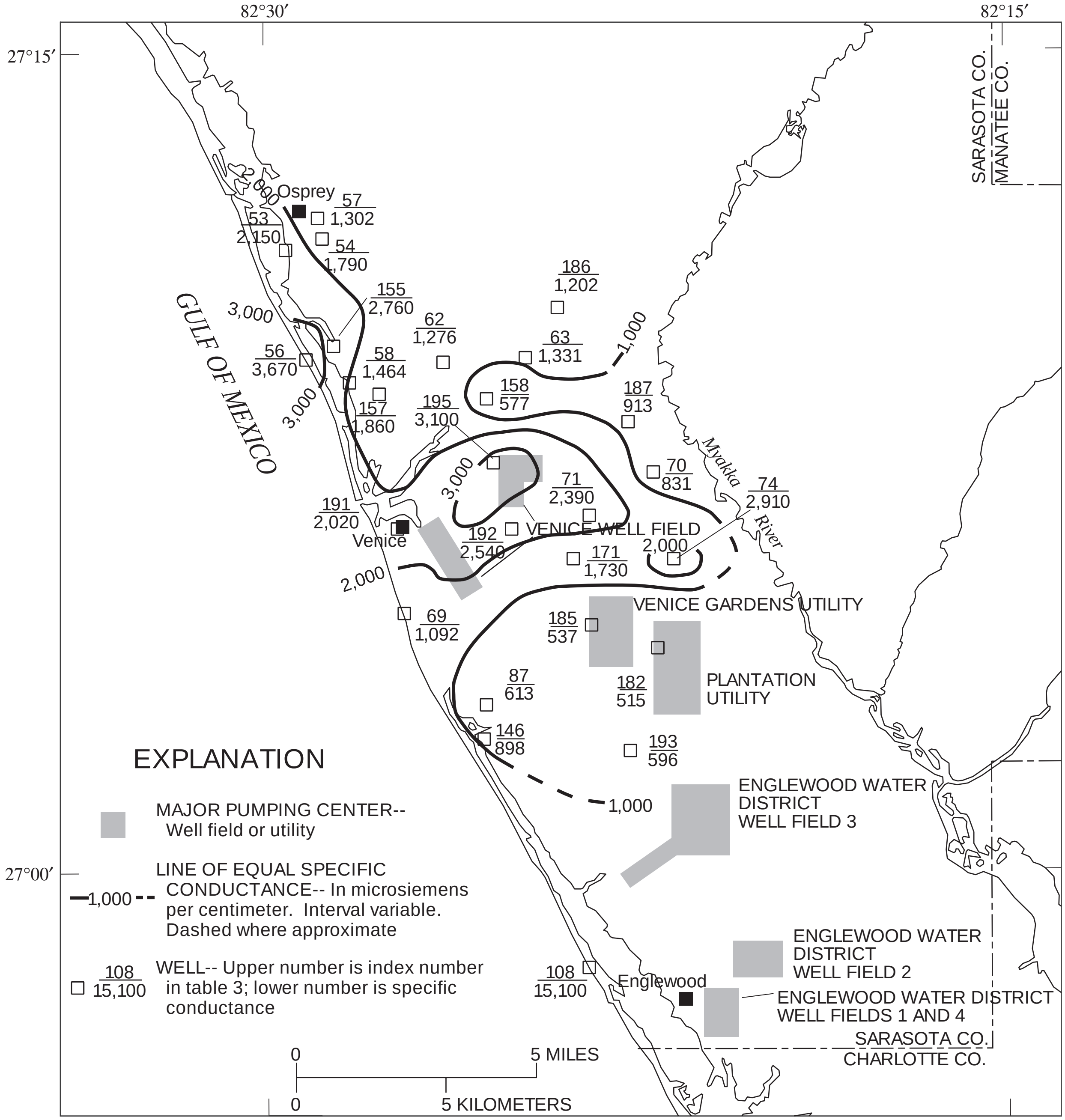
Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 34. Sulfate concentration in water from wells open to the intermediate aquifer system, permeable zone 2, in southwest Sarasota County.



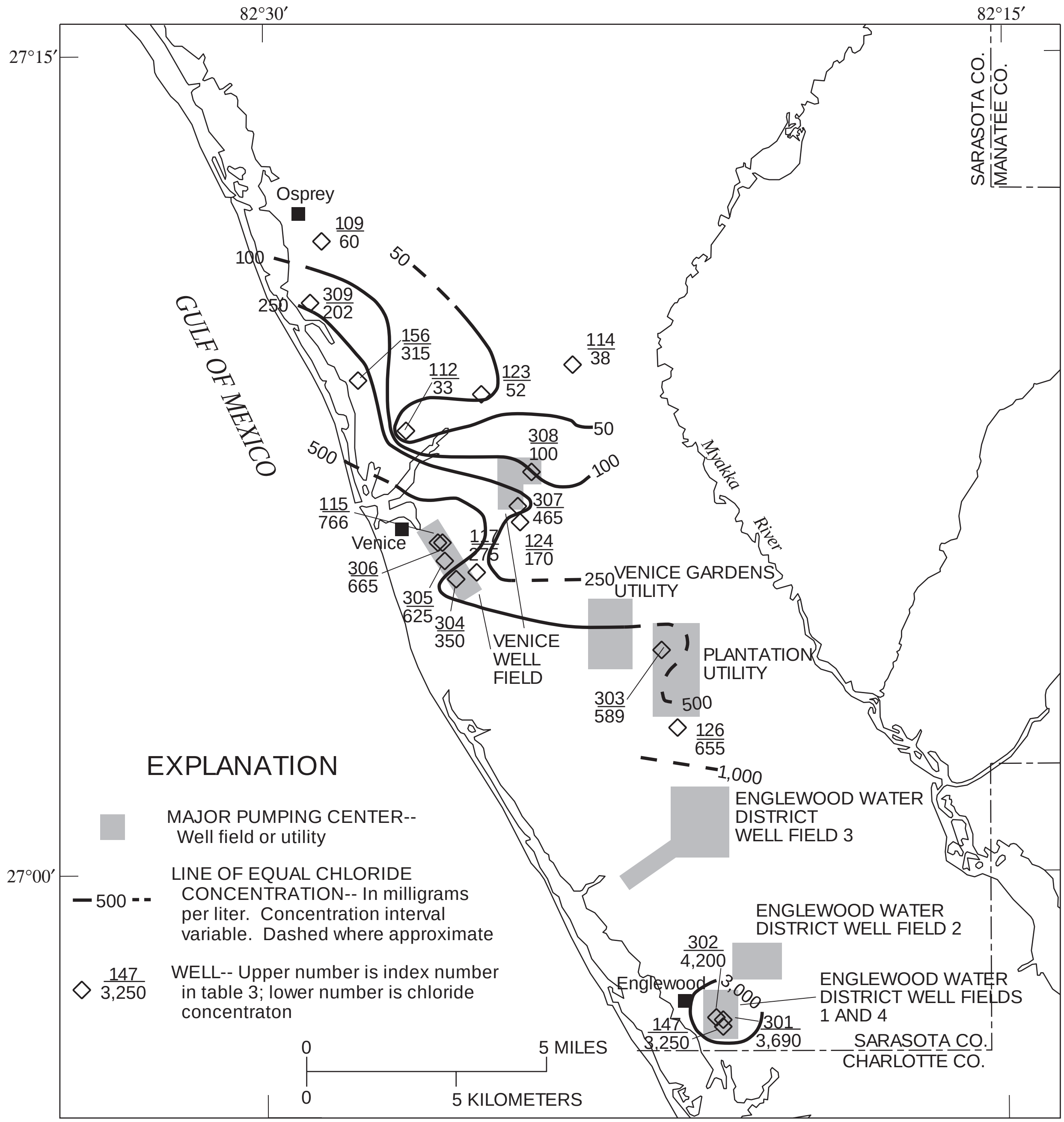
Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 35. Dissolved-solids concentration in water from wells open to the intermediate aquifer system, permeable zone 2, in southwest Sarasota County.



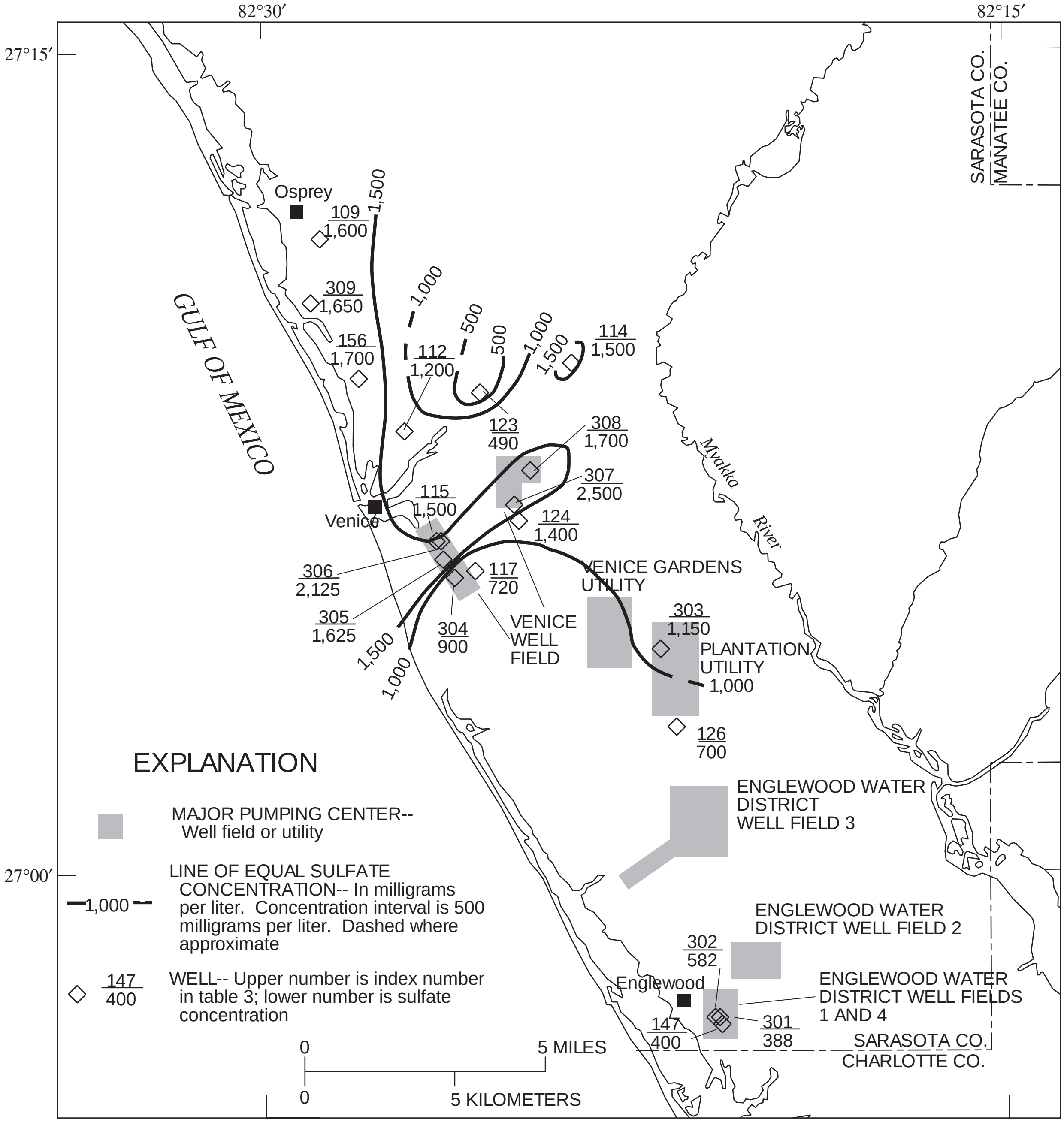
Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 36. Specific conductance of water from wells open to the intermediate aquifer system, permeable zone 2, in southwest Sarasota County.



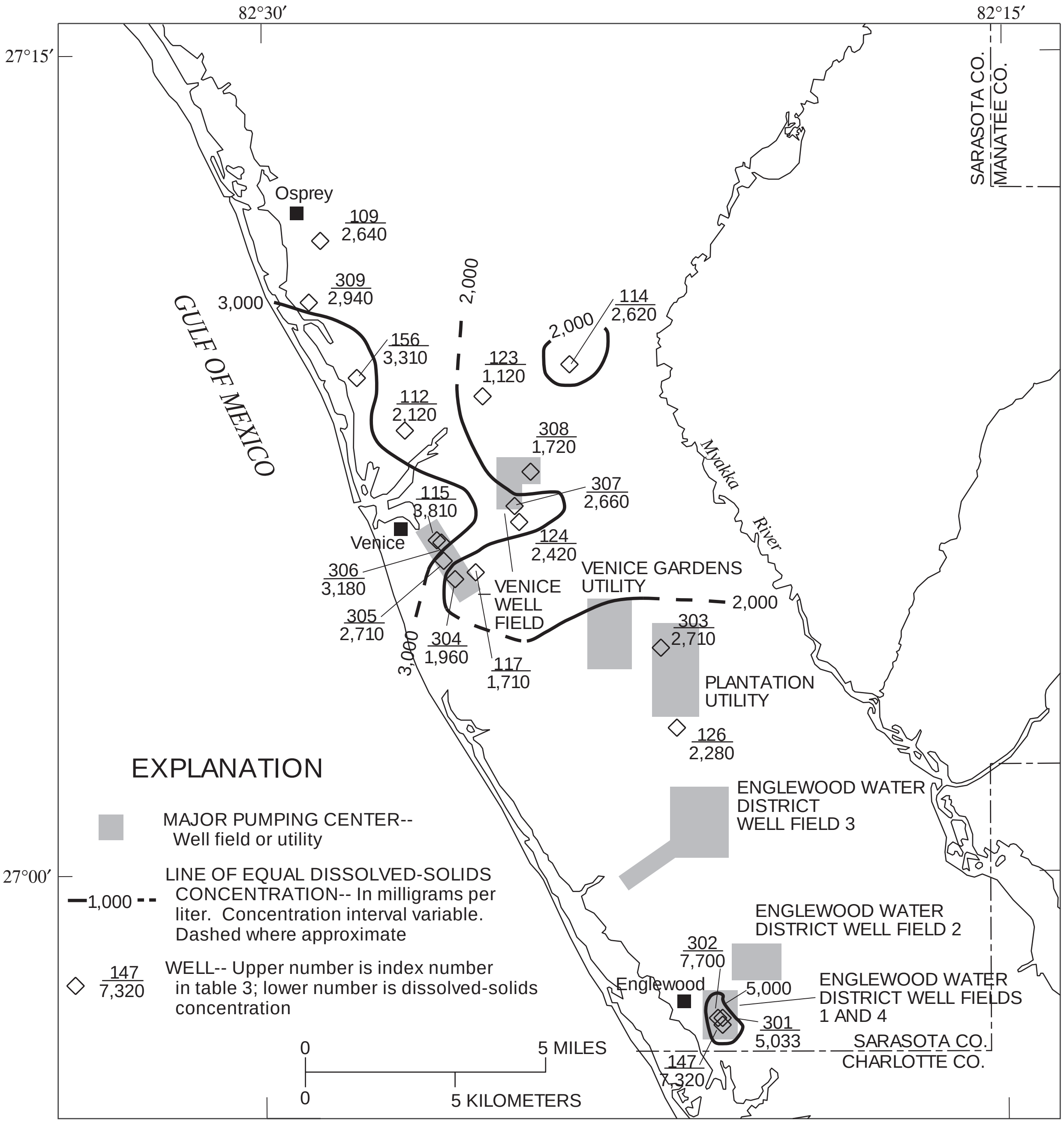
Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 37. Chloride concentration in water from wells open to the intermediate aquifer system, permeable zone 3, in southwest Sarasota County.



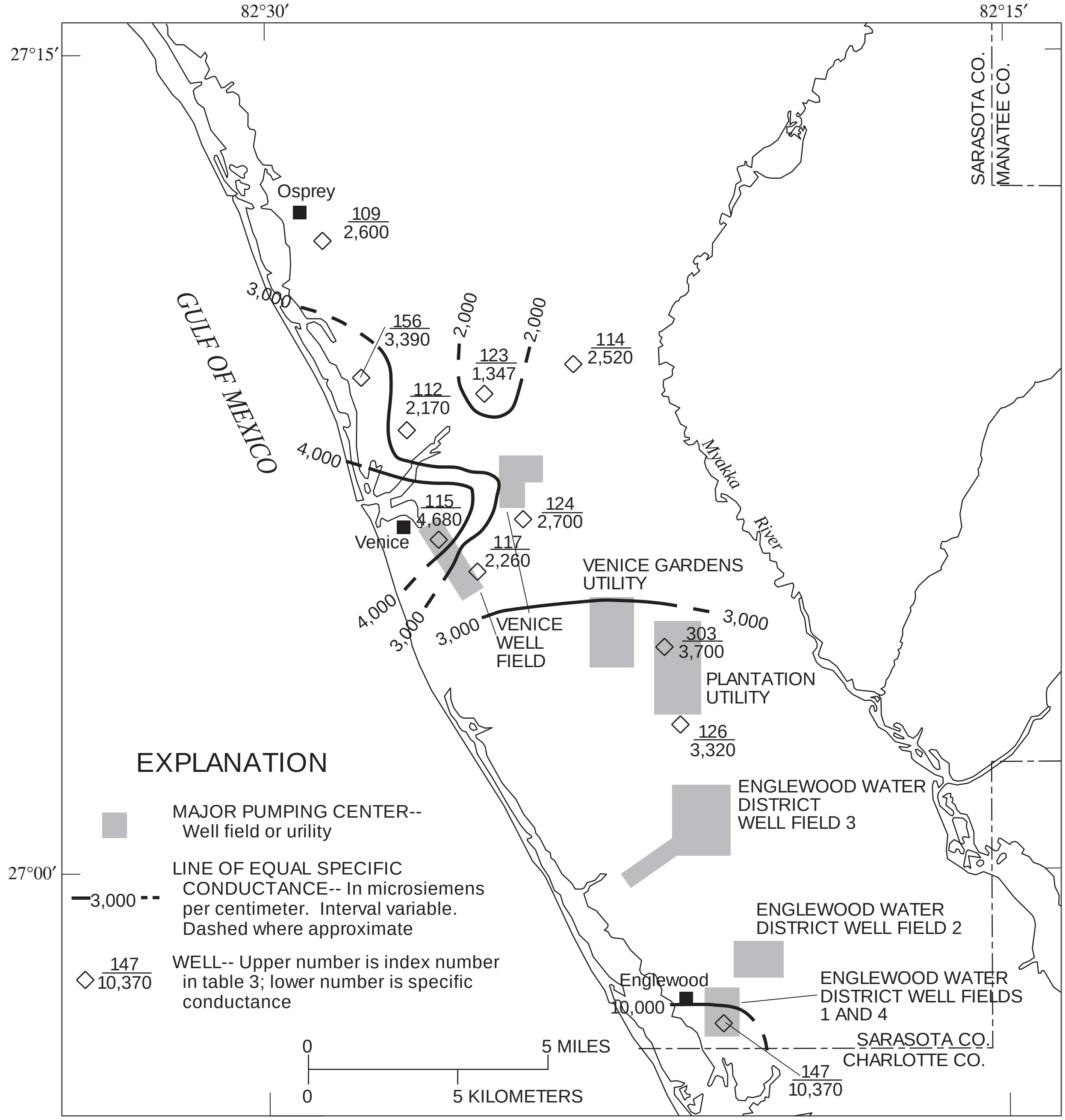
Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 38. Sulfate concentration in water from wells open to the intermediate aquifer system, permeable zone 3, in southwest Sarasota County.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 39. Disolved-solids concentration in water from wells open to the intermediate aquifer system, permeable zone 3, in southwest Sarasota County.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 40. Specific conductance of water from wells open to the intermediate aquifer system, permeable zone 3, in southwest Sarasota County.

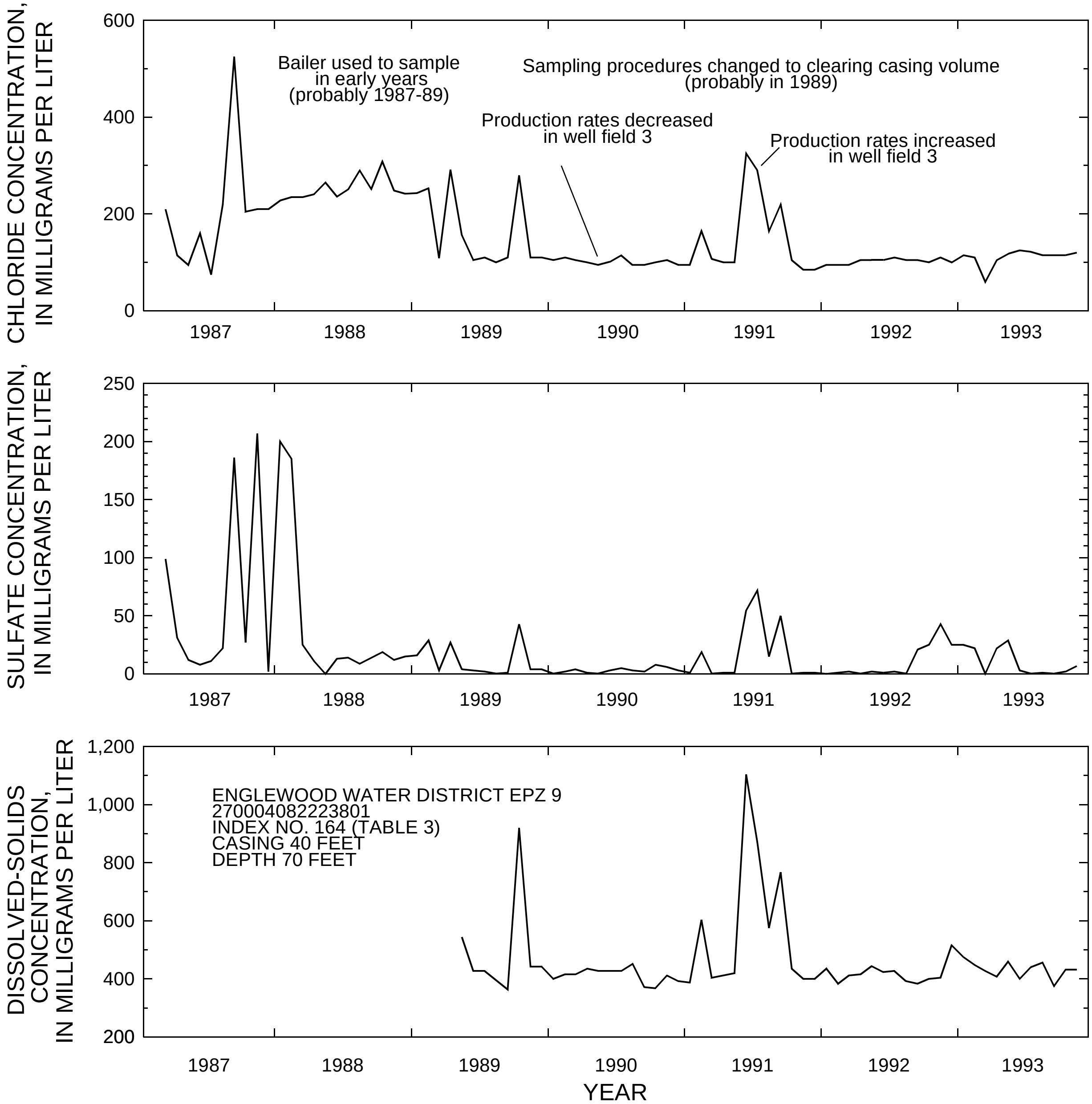


Figure 41. Chloride, sulfate, and dissolved-solids concentrations in water from intermediate aquifer system, permeable zone 1, at the Englewood Water District well EPZ 9, 1987-93. (Data collected by Englewood Water District personnel.)

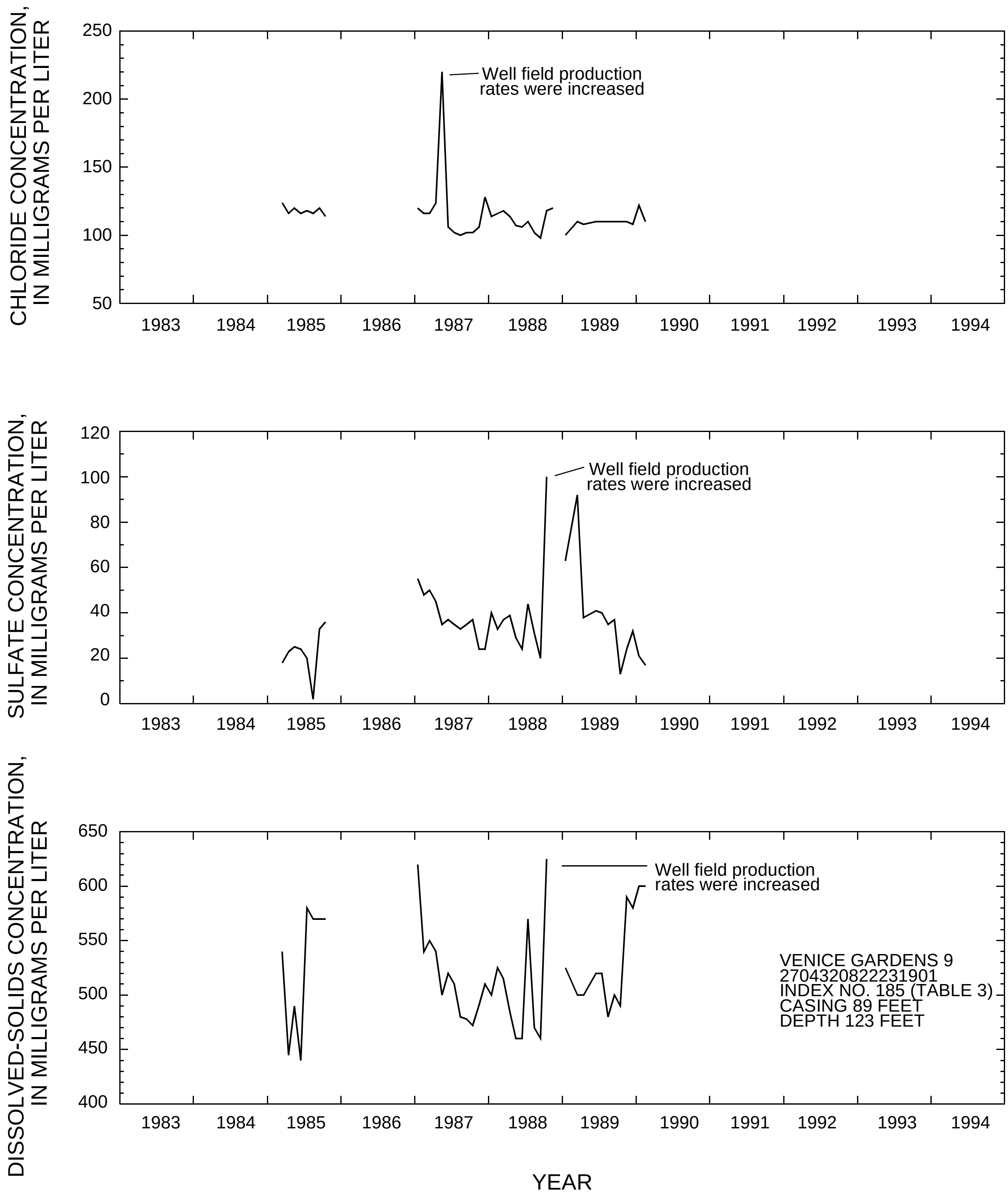


Figure 42. Chloride, sulfate, and dissolved-solids concentrations in water from intermediate aquifer system, permeable zone 2, at the Venice Gardens well field monitor well 9, 1985-90. (Data collected by Venice Gardens personnel.)

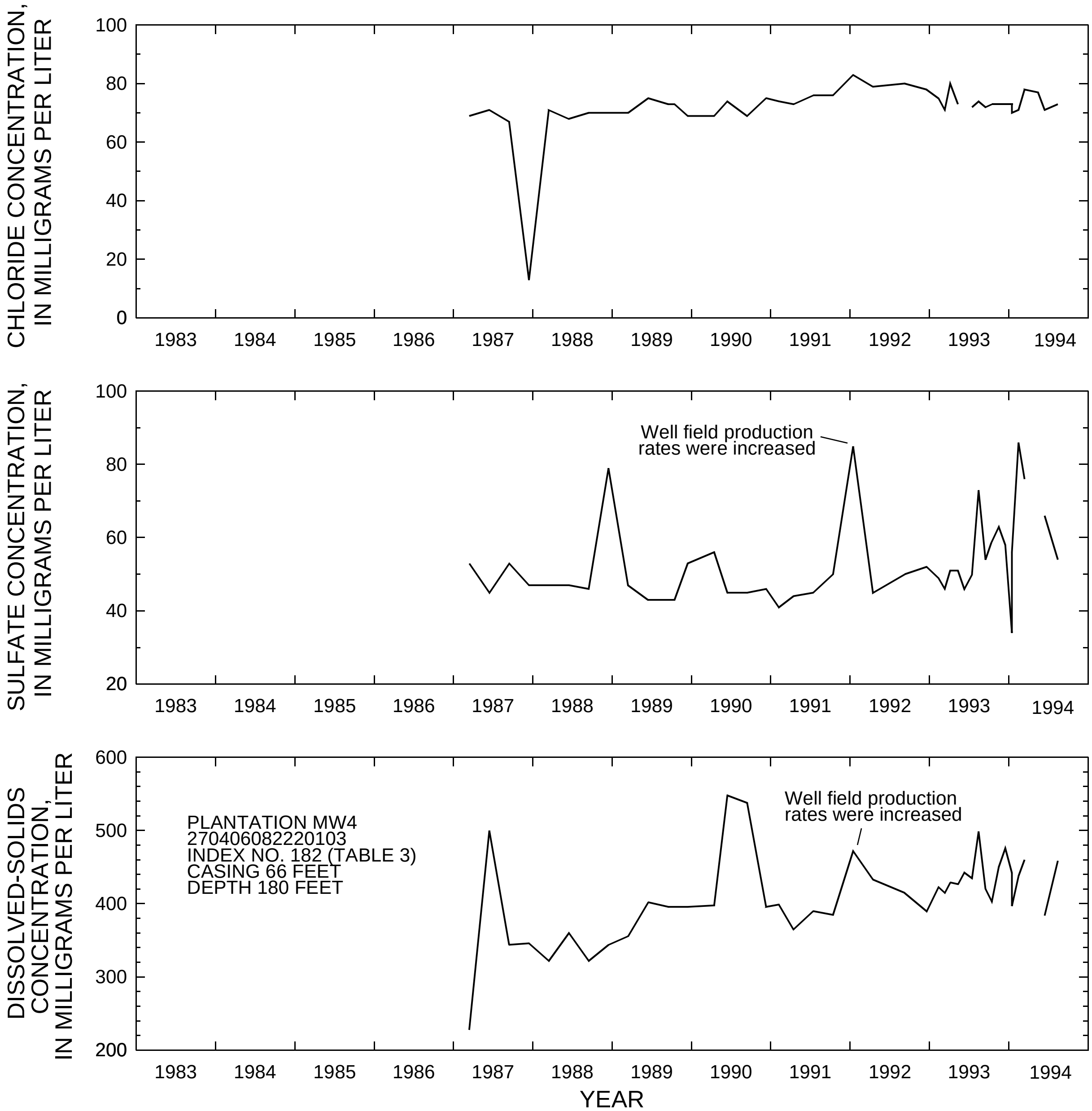


Figure 43. Chloride, sulfate, and dissolved-solids concentrations in water from intermediate aquifer system, permeable zone 2, at the Plantation monitor well MW4, 1987-94. (Data collected by Plantation personnel.)

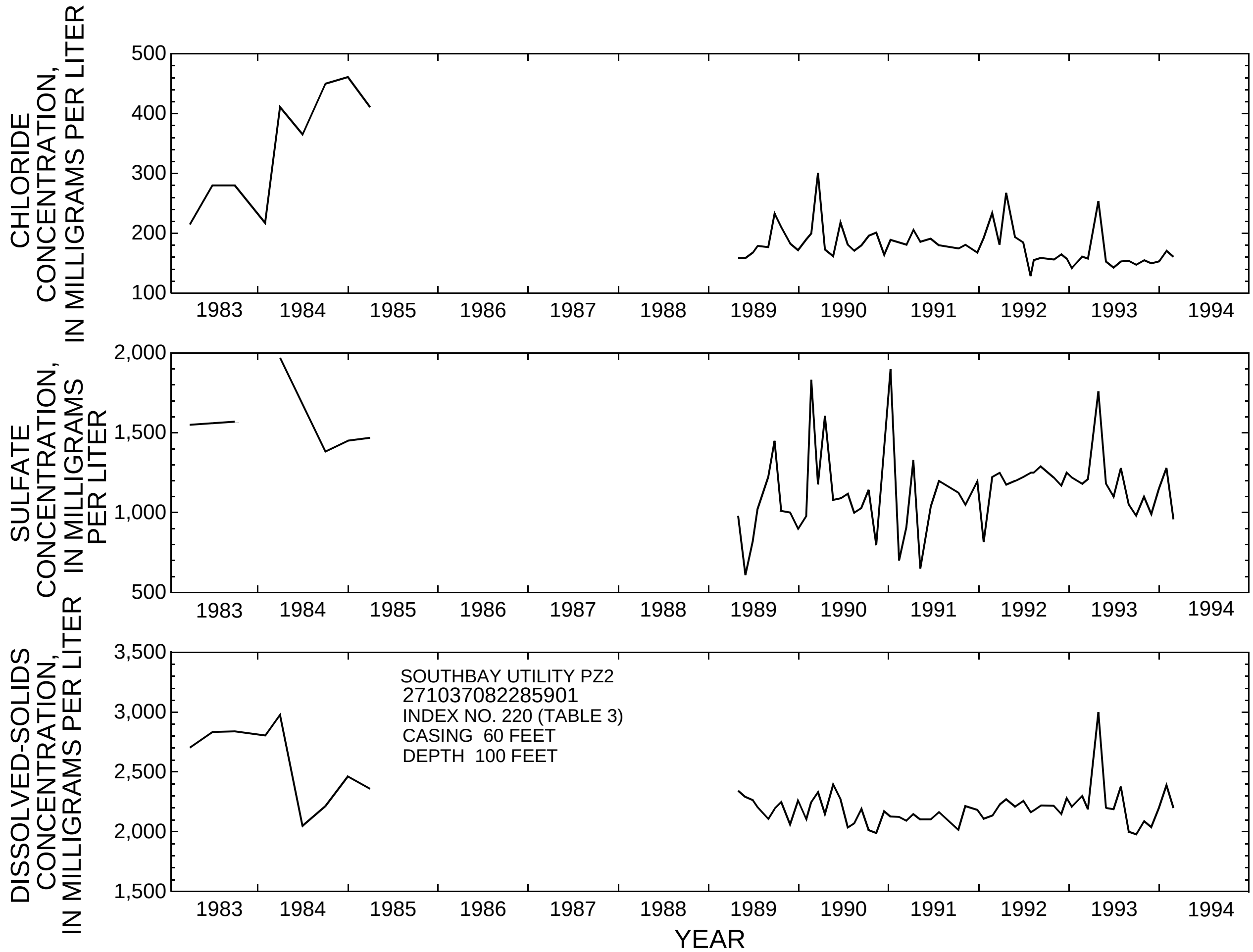


Figure 44. Chloride, sulfate, and dissolved-solids concentrations in water from intermediate aquifer system, permeable zone 2, at the Southbay Utility well PZ2, 1983-94. (Data collected by Southbay Utility personnel.)

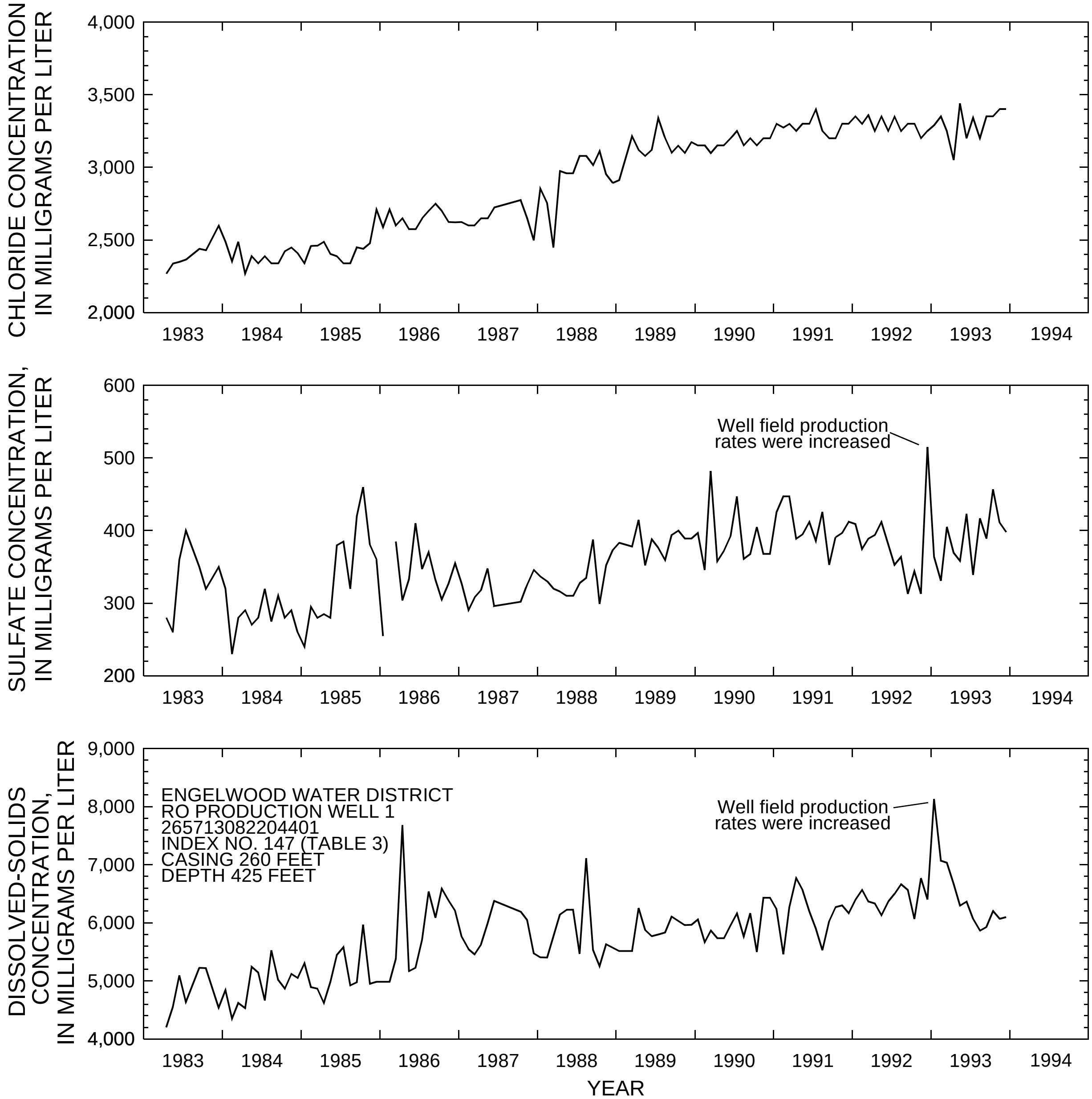


Figure 45. Chloride, sulfate, and dissolved-solids concentrations in water from intermediate aquifer system, permeable zone 3, at the EWD RO Production well 1, 1983-93. (Data collected by Englewood Water District personnel.)

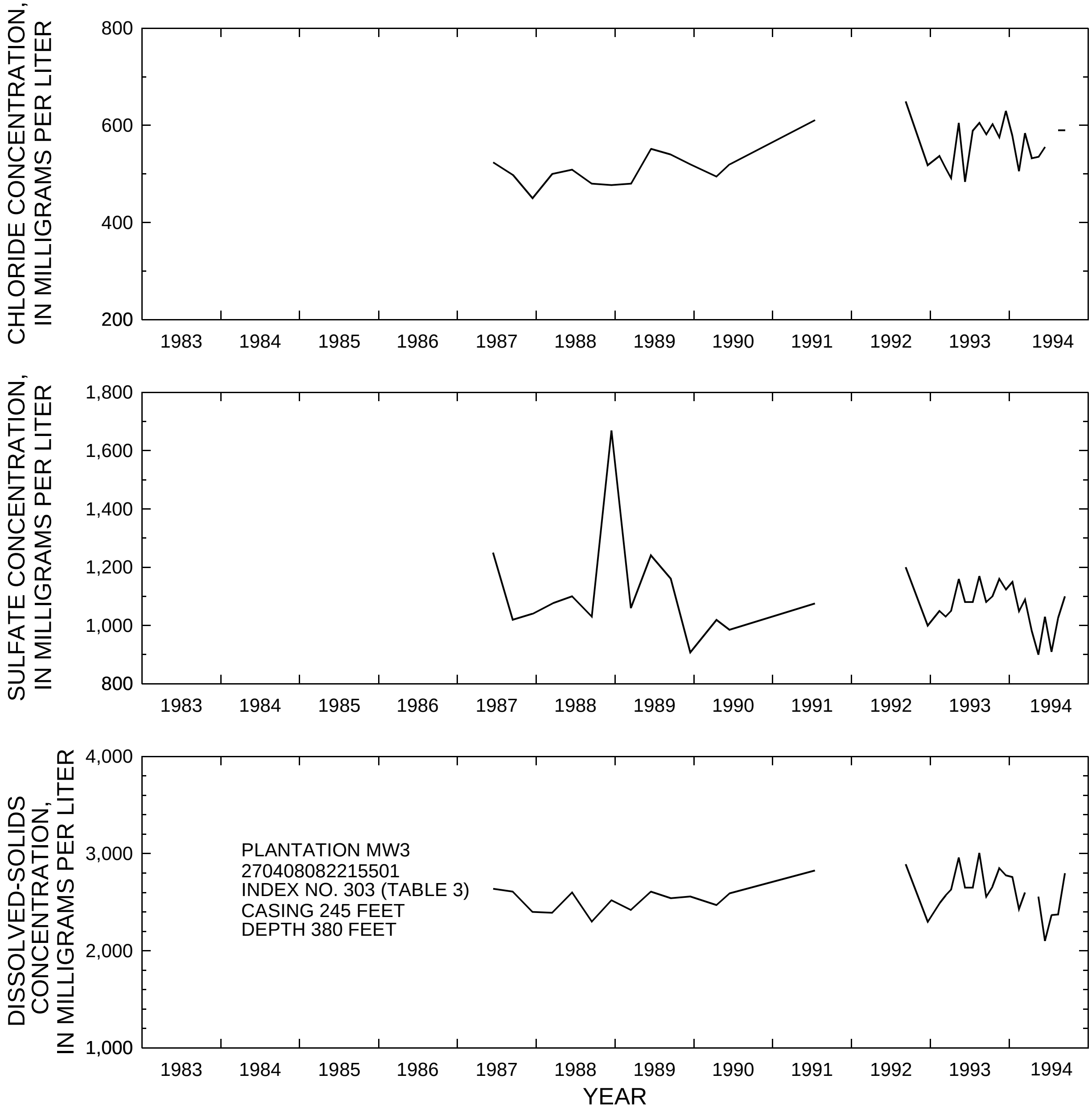


Figure 46. Chloride, sulfate, and dissolved-solids concentrations in water from intermediate aquifer system, permeable zone 3, at the Plantation monitor well MW3, 1987-94. (Data collected by Plantation personnel.)

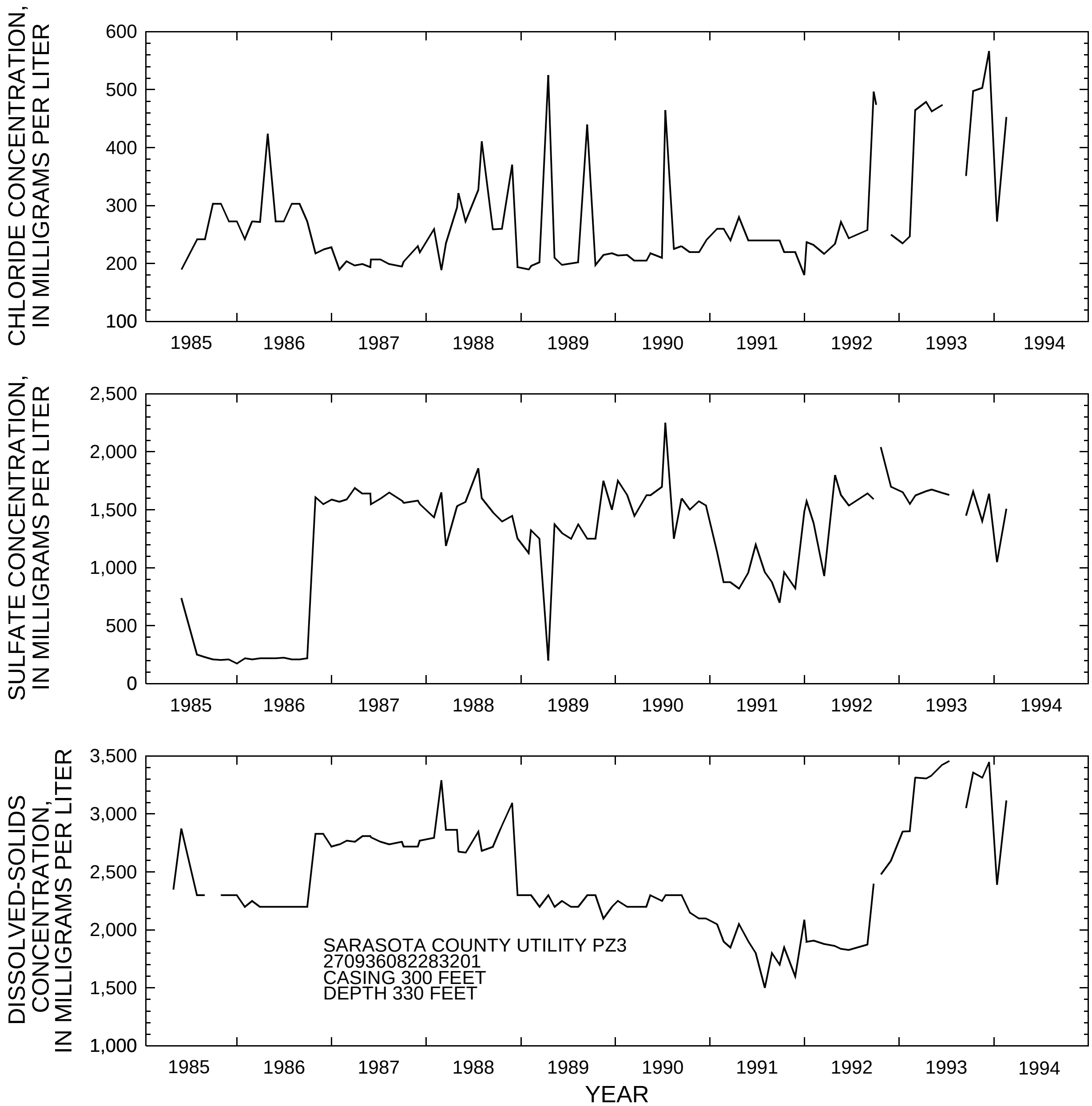


Figure 47. Chloride, sulfate, and dissolved-solids concentrations in water from intermediate aquifer system, permeable zone 3, at the Sarasota County Utility well PZ3, 1985-94. (Data collected by Sarasota County personnel.)

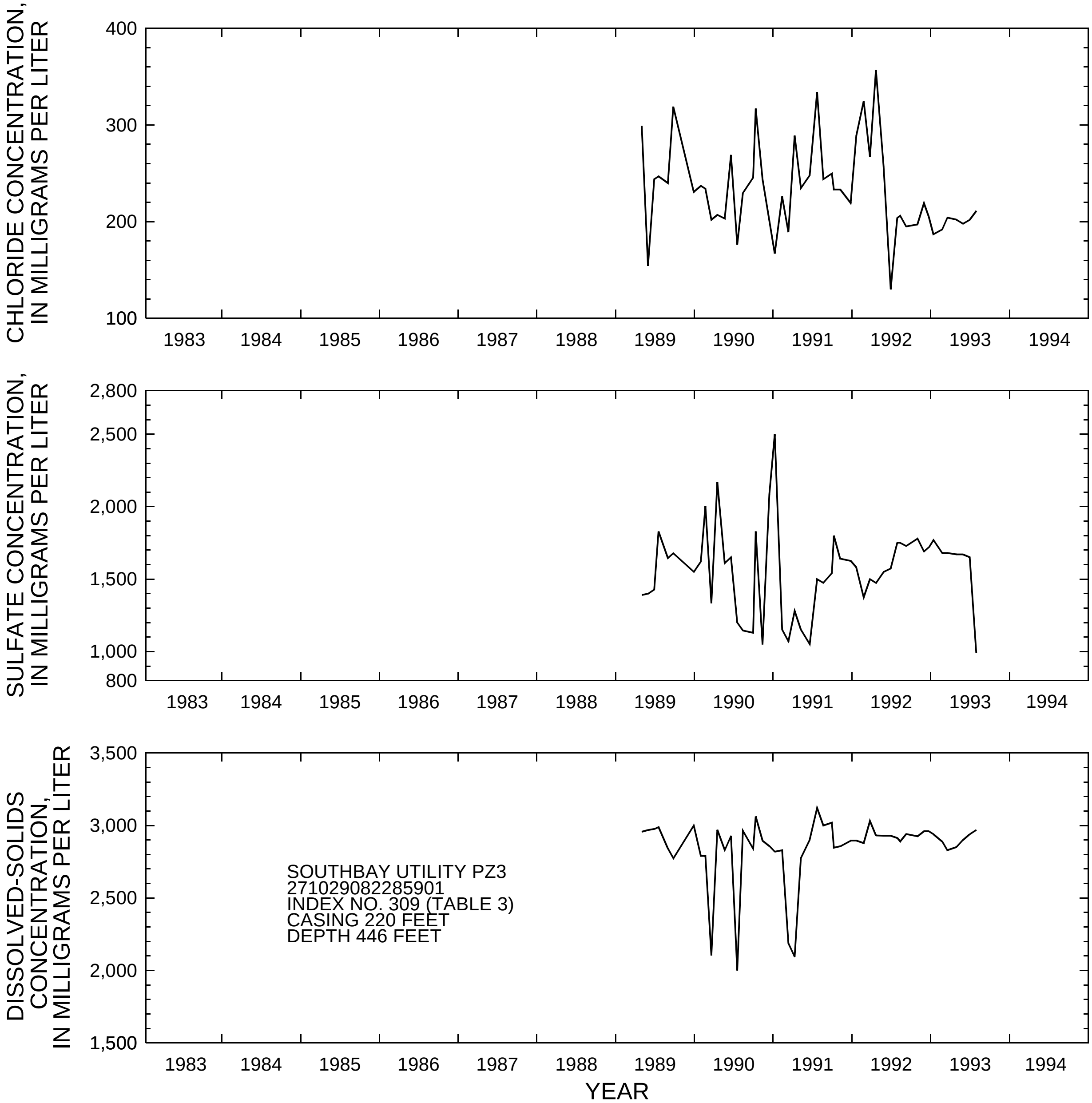


Figure 48. Chloride, sulfate, and dissolved-solids concentrations in water from intermediate aquifer system, permeable zone 3, at the Southbay Utility well PZ3, 1989-93. (Data collected by Southbay Utility personnel.)

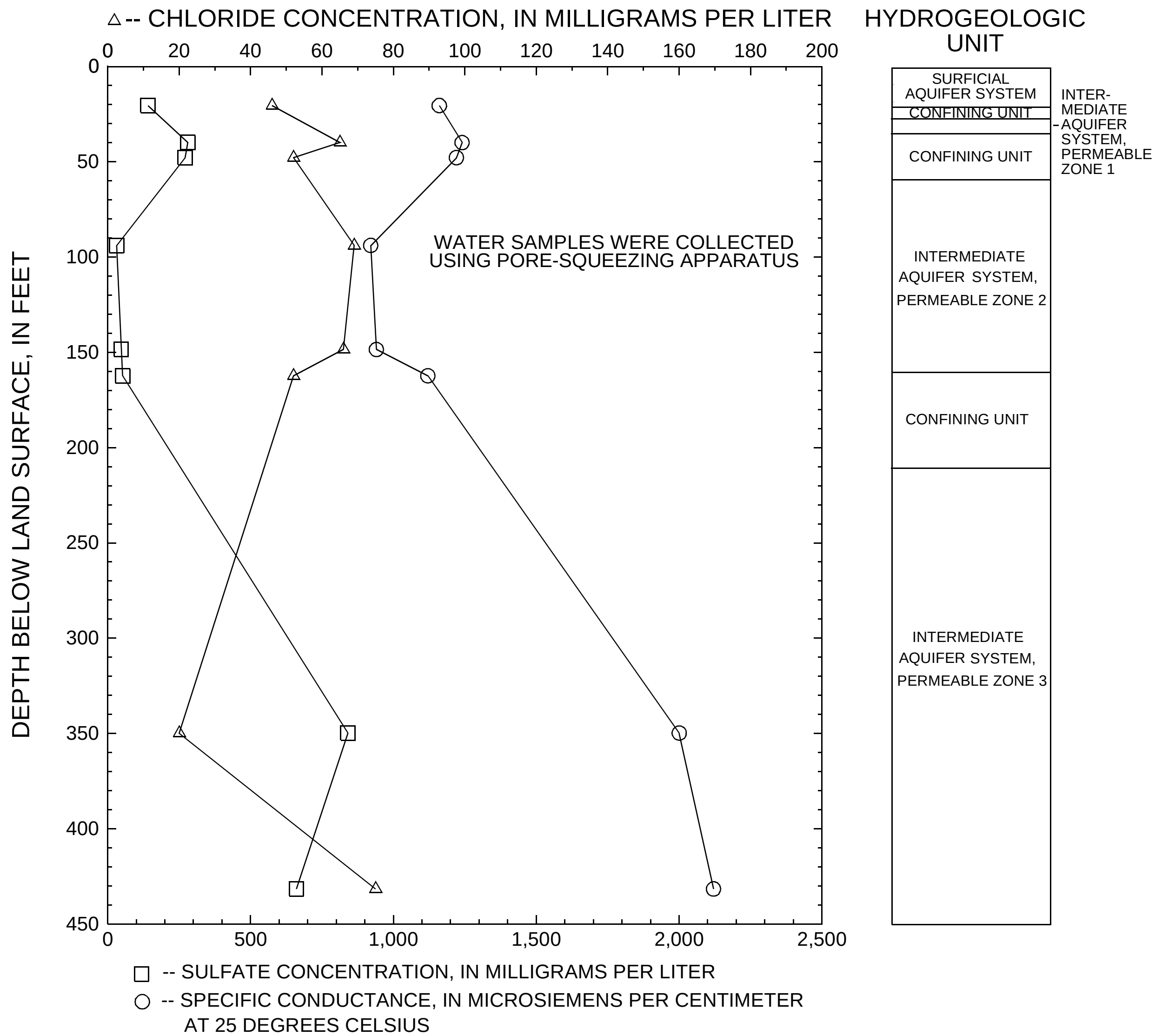


Figure 49. Chloride, sulfate, and specific-conductance values at selected depth intervals below land surface at the Carlton Reserve test well.

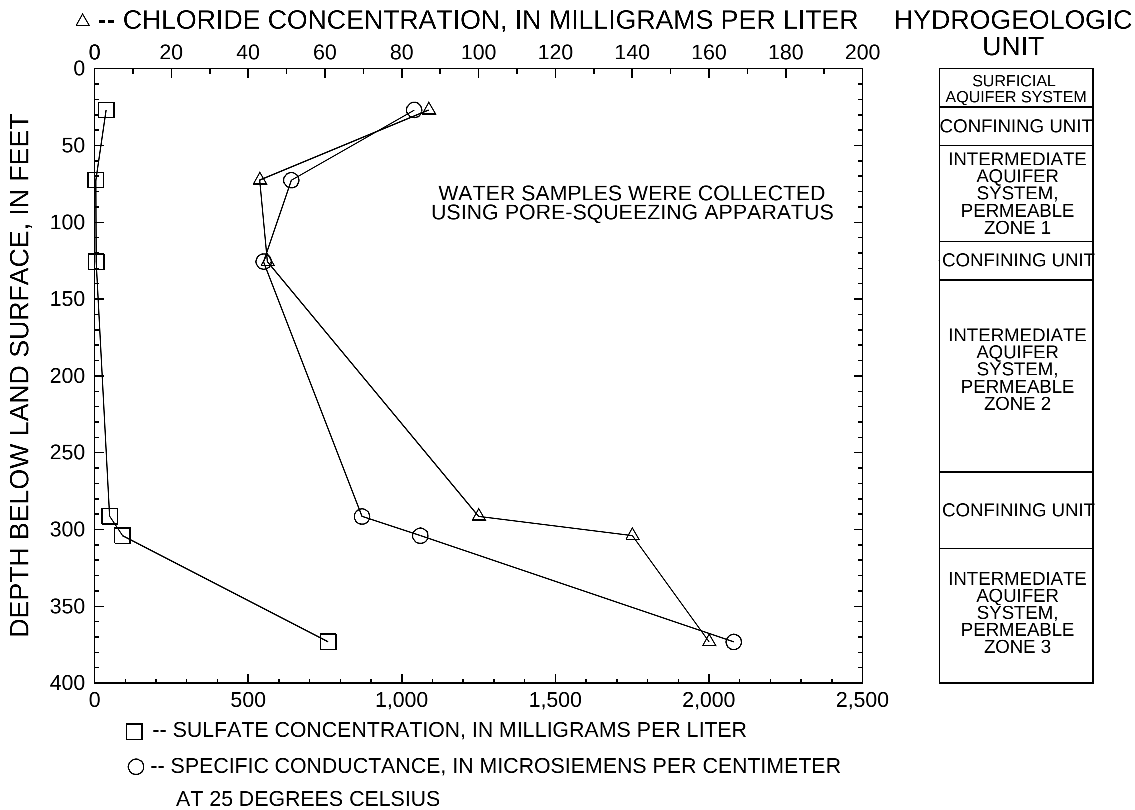


Figure 50. Chloride, sulfate, and specific-conductance values at selected depth intervals below land surface at the South Venice test well.

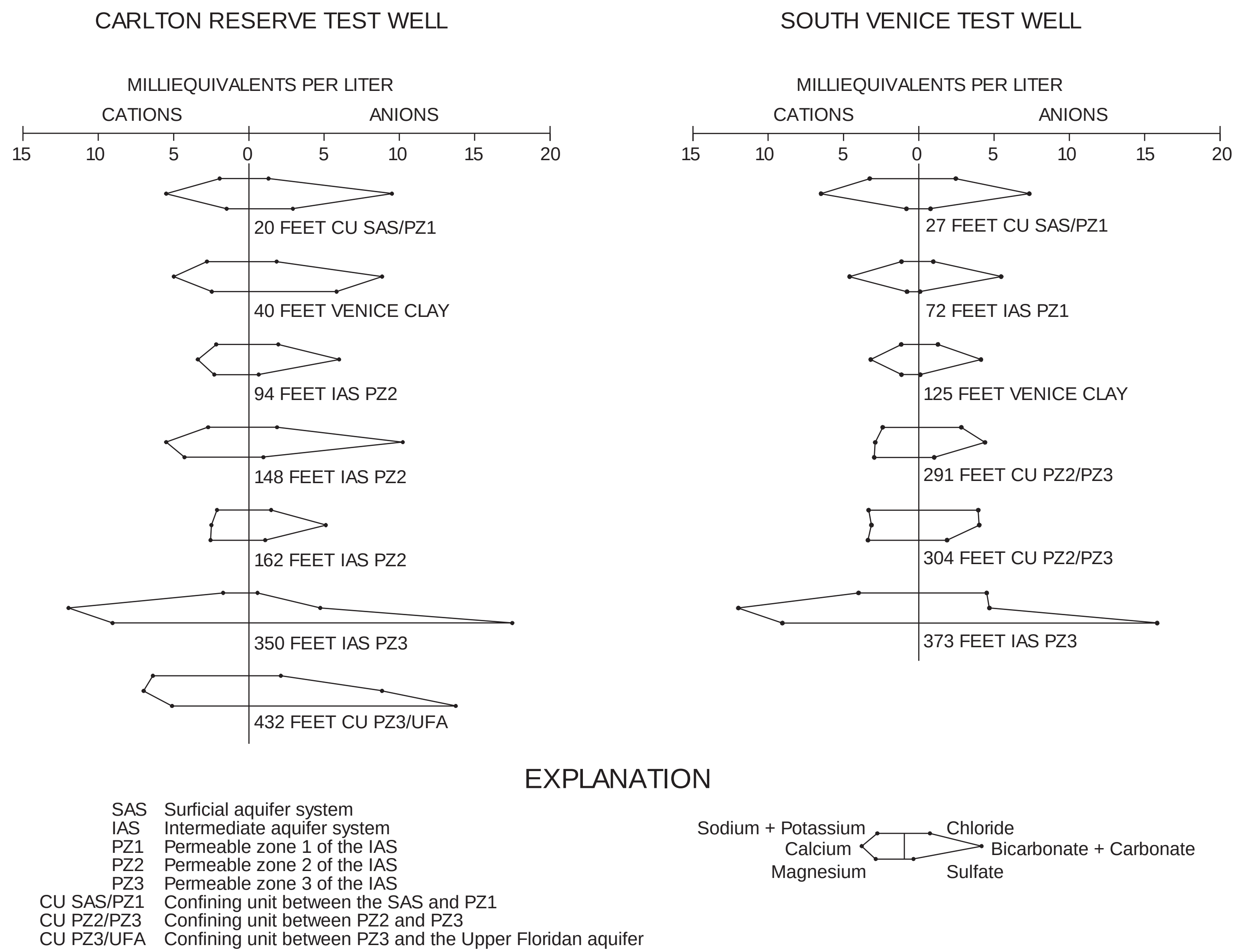
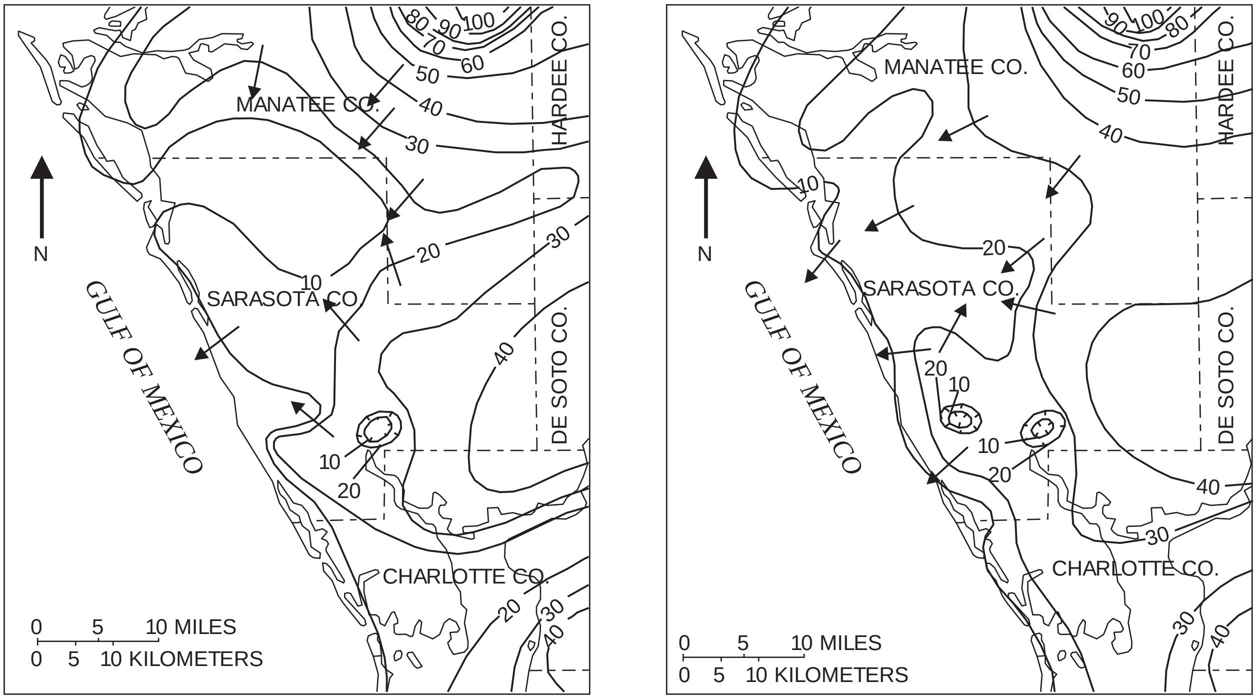


Figure 51. Major-ion concentrations of water from the intermediate aquifer system at selected intervals below land surface at the Carlton Reserve and South Venice test wells.



Bases from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-area Conic projection
Standard Parallels 29°30′ and 45°30′, central meridian -83°00′

Hydrology from Mularoni (1994a);
Modified by Barr, 1996

Hydrology from Mularoni (1994b);
Modified by Barr, 1996

MAY 1993

SEPTEMBER 1993

EXPLANATION

—20— POTENTIOMETRIC SURFACE CONTOUR -- Shows altitude of potentiometric surface. Contour interval is 10 feet. Hachures indicate depressions. Datum is sea level

← Direction of ground-water flow

Figure 52. Composite potentiometric surface of the intermediate aquifer system, May and September 1993.

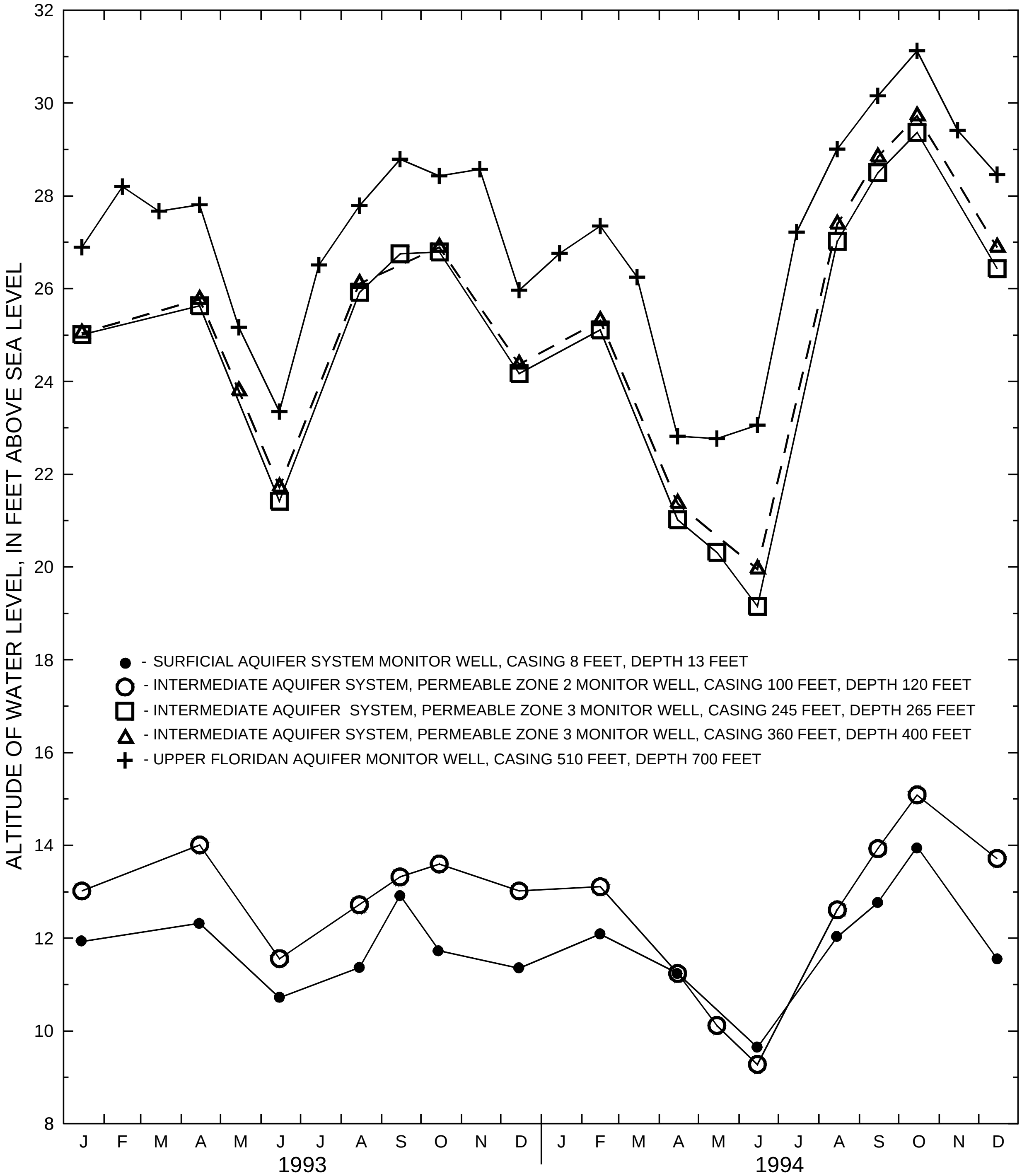


Figure 54. Water levels in the surficial, intermediate, and Upper Floridan aquifer monitor wells at ROMP TR 5-2, January 1993 to December 1994.

Table 1. Summary of well records and hydraulic properties of the surficial and intermediate aquifer systems at selected sites and areas in southwest Florida

[EWD, Englewood Water District; FGS, Florida Geological Survey; SWFWMD, Southwest Florida Water Management District; ROMP, Regional Observation Monitor Program; USGS, U.S. Geological Survey; ft, feet; ft^2/d, feet squared per day; (ft/d)/ft, feet per day per foot; ft/d, feet per day; <, less than; >, greater than; --, no data]

Site name/well number	Site identification	Hydrogeologic unit[1]	Casing/depth or interval below land surface (ft)	Transmissivity (ft^2/d)	Leakance coefficient [(ft/d)/ft]	Storage coefficient	Hydraulic conductivity (ft/d)	Reference
Carlton Reserve test well	270803082210301	SAS	[2] 6	--	--	--	[7] 0.0511	Campbell and others, (1993)
		SAS	[2] 15	--	--	--	[7] .00233	Do.
		SAS	[2] 19	--	--	--	[7] .673	Do.
		CU PZ1/PZ2 (Venice Clay)	[2] 39	--	--	--	[7] .001	Do.
		IAS PZ2 (confining material)	[3] 101	--	--	--	[7] .00394	Do.
		IAS PZ2 (confining material)	[3] 122	--	--	--	[4] .0024	Do.
		CU PZ2/PZ3	[3] 165	--	--	--	[7] .000196	Do.
		CU PZ2/PZ3	[3] 179	--	--	--	[7] .000155	Do.
		CU PZ2/PZ3	[3] 206	--	--	--	[8] <.00000000036	Do.
		IAS PZ3 (confining material)	[3] 402	--	--	--	[8] <.00000000036	Do.
		IAS PZ3 (confining material)	[3] 413	--	--	--	[8] <.00000000036	Do.
		CU PZ3/UFA	[3] 426	--	--	--	[7] .0000155	Do.
		CU PZ3/UFA	[3] 441	--	--	--	[8] <.00000000036	Do.
		CU PZ3/UFA	[3] 460	--	--	--	[8] <.00000000036	Do.
South Venice test well	2703400822554	CU SAS/PZ1	[2] 31	--	--	--	[7] .00282	Do.
		CU SAS/PZ1	[2] 38	--	--	--	[7] .00385	Do.
		CU SAS/PZ1	[2] 59	--	--	--	[7] .00502	Do.
		CU SAS/PZ1	[2] 76	--	--	--	[7] .00592	Do.
		IAS PZ1 (confining material)	[2] 111	--	--	--	[7] .00828	Do.
		CU PZ1/PZ2 (Venice Clay)	[2] 126	--	--	--	[7,9] .000265	Do.
		IAS PZ2 (confining material)	[3] 246	--	--	--	[7] .0000002	Do.
		IAS PZ3 (confining material)	[3] 416	--	--	--	.00523	Do.
		IAS PZ3 (confining material)	[3] 543	--	--	--	[7] .000332	Do.

Table 1. Summary of well records and hydraulic properties of the surficial and intermediate aquifer systems at selected sites and areas in southwest Florida --Continued

[EWD, Englewood Water District; FGS, Florida Geological Survey; SWFWMD, Southwest Florida Water Management District; ROMP, Regional Observation Monitor Program; USGS, U.S. Geological Survey; ft, feet; ft^2/d, feet squared per day; (ft/d)/ft, feet per day per foot; ft/d, feet per day; <, less than; >, greater than; --, no data]

Site name/well number	Site identification	Hydrogeologic unit[1]	Casing/depth or interval below land surface (ft)	Transmis-sivity (ft^2/d)	Leakance coefficient [(ft/d)/ft]	Storage coefficient	Hydraulic conductivity (ft/d)	Reference
Walton test well	2711430822403	CU SAS/PZ1	[2] 25	--	--	--	0.000229	FGS, written comm. (1991)
		IAS PZ2 (confining material)	[3] 80	--	--	--	[8].00000752	Do.
		IAS PZ2 (confining material)	[3] 114	--	--	--	.0000454	Do.
		CU PZ2/PZ3	[3] 182	--	--	--	[8].000000752	Do.
		CU PZ2/PZ3	[3] 200	--	--	--	.0000324	Do.
		IAS PZ3 (confining material)	[3] 249	--	--	--	[7] .00342	Do.
		CU PZ3/UFA	[3] 285	--	--	--	[7] .00139	Do.
Gasparilla Island well field (west Charlotte Co.)	--	SAS	--	[12]1,340-1,870	--	--	47-60	Sutcliffe (1975)
Gasparilla Island well field (north-west Charlotte Co.)	--	SAS	--	[12]2,140->3,340	--	--	53	Do.
Carlton Reserve (central Sarasota Co.)	--	SAS	--	1,800	--	[4] 0.19	[5] 56	Geraghty and Miller, Inc. (1981)
Carlton Reserve (central Sarasota Co.)	--	SAS	--	1,100	--	[4] 0.15	[55]17	Do.
Sarasota Central Landfill Complex (12 wells, central Sarasota Co.)	--	SAS	5-10/10-16	--	--	--	[5] 2.5-159	Ardaman and Assoc., Inc. (1992)
Verna well-field (northeast Sarasota Co.):								
14E4	272247082175301	SAS	41/67	430	--	--	--	Geraghty and Miller, Inc. (1975)
2E7	272248082190302	SAS	21/85	250	--	[4,11] 0.1	[5,11] 13.4	Do.
12E8	272255082180201	SAS	10/30	470	--	--	--	Geraghty and Miller, Inc. (1981)

Table 1. Summary of well records and hydraulic properties of the surficial and intermediate aquifer systems at selected sites and areas in southwest Florida --Continued

[EWD, Englewood Water District; FGS, Florida Geological Survey; SWFWMD, Southwest Florida Water Management District; ROMP, Regional Observation Monitor Program; USGS, U.S. Geological Survey; ft, feet; ft^2/d, feet squared per day; (ft/d)/ft, feet per day per foot; ft/d, feet per day; <, less than; >, greater than; --, no data]

Site name/well number	Site identification	Hydrogeologic unit[1]	Casing/depth or interval below land surface (ft)	Transmis-sivity (ft^2/d)	Leakance coefficient [(ft/d)/ft]	Storage coefficient	Hydraulic conductivity (ft/d)	Reference
12obs	272255082180202	SAS	--	530	--	--	--	Geraghty and Miller, Inc. (1981)
6E2	272256082183701	SAS	21/42	160	--	--	--	Do.
9E3A	272257082181702	SAS	20/40	150	--	--	--	Do.
Englewood Water District (southwest Sarasota Co.):								
EWD Production 27	265722082210301	IAS PZ1	25/40	7,800	--	0.00005	--	Wolansky and Corral (1985)
EWD Production 9	265735082205701	IAS PZ1	49/55	5,500	0.0007	.00011	--	Do.
EWD Production test 2	270015082211301	IAS PZ1	31/75	1,260	.12	.00087	--	CH2M Hill, Inc. (1978)
EWD R5	270019082213701	IAS PZ1	34/92	8,000	.0005	.0004	--	Do.
EWD R3	270021082221301	IAS PZ1	42/43	6,250	.0004	.0003	--	Do.
EWD Production test 4	270033082214201	IAS PZ1	35/70	3,320	.000036	.000016	--	Do.
EWD C-10	270036082214101	IAS PZ1	42/70	3,800	.00024	.00017	--	Wolansky and Corral (1985)
EWD Production test 5	270038082211301	IAS PZ1	35/70	1,525	.005	.000058	--	CH2M Hill, Inc. (1978)
EWD Production test 3	270104082214101	IAS PZ1	42/70	1,608	--	--	--	Do.
EWD Production test 1	270107082211201	IAS PZ1	43/70	2,970	.013	.00065	--	Do.
Venice well field 32	270536082253901	IAS PZ1	42/59	1,100	.0009	--	--	Clark (1964)
Carlton Reserve (central Sarasota Co.)	--	IAS PZ2	81/205	2,670	.00013	.0001	--	Geraghty and Miller, Inc. (1981)
Manatee Jr. College, south well	270219082185801	IAS PZ2	110/270	200	--	.00002	--	USGS test (1984)
Plantation Utility 3A	270403082220501	IAS PZ2	70/180	[12]200-400	[12].0000196-.000038	--	--	Post, Buckley, Schuh, and Jernigan, Inc. (1981)

Table 1. Summary of well records and hydraulic properties of the surficial and intermediate aquifer systems at selected sites and areas in southwest Florida --Continued

[EWD, Englewood Water District; FGS, Florida Geological Survey; SWFWMD, Southwest Florida Water Management District; ROMP, Regional Observation Monitor Program; USGS, U.S. Geological Survey; ft, feet; ft^2/d, feet squared per day; (ft/d)/ft, feet per day per foot; ft/d, feet per day; <, less than; >, greater than; --, no data]

Site name/well number	Site identification	Hydrogeologic unit[1]	Casing/depth or interval below land surface (ft)	Transmissivity (ft^2/d)	Leakance coefficient [(ft/d)/ft]	Storage coefficient	Hydraulic conductivity (ft/d)	Reference
Plantation Utility 4	270405082215601	IAS PZ2	66/180	[12]250-300	[12]0.000045-.00001	--	--	Post, Buckley, Schuh, and Jernigan, Inc. (1981)
Plantation Utility 5	270406082215602	IAS PZ2	68/180	300	--	--	--	Do.
ROMP TR 5-2	270919082234200	IAS PZ2	60/100	5,000	--	--	--	USGS test (1986)
ROMP 18-1	271137082074801	IAS PZ2	57/223	[10]3,600	--	--	--	Geraghty and Miller (1980)
ROMP 18-2	271137082074802	IAS PZ2	57/223	[10]3,700	--	--	--	Do.
ROMP 20	271137082284501	IAS PZ2	75/125	1,800	--	0.00006	--	SWFWMD data files
Venice well-field 2	270536082253901	IAS PZ2	77/140	550	.0005	.000042	--	Post, Buckley, Schuh, and Jernigan, Inc. (1982b)
Venice Gardens well-fieldTPVG-1	270322082234701	IAS PZ2	60/160	[12]600-650	--	--	--	Geraghty and Miller (1980)
Venice Gardens well-field MWVG-1	270322082234702	IAS PZ2	61/160	[12]450-550	[12].00021-.0011	.00017-.00062	--	Do.
Venice Gardens well-fieldTP-49	270430082221501	IAS PZ2	61/160	400	--	--	--	Do.
Venice Gardens well-field MW-49	270430082221502	IAS PZ2	60/160	400	--	.000006	--	Geraghty and Miller (1980)
Venice Gardens well-field TPN-1	270508082223301	IAS PZ2	60/160	650	--	--	--	Do.
Venice Gardens well-field MWN-1	270508082223302	IAS PZ2	61/160	600	.00043	--	--	Do.
Venice Gardens well-field 1A	--	IAS PZ2	87/90	1,120	--	.000248	--	Geraghty and Miller, Inc. (1974)
Venice Gardens well-field 2A	--	IAS PZ2	97/150	610	--	--	--	Do.
Venice Gardens well-field 3A	--	IAS PZ2	100/106	720	--	--	--	Do.
Venice Gardens well-field 5A	--	IAS PZ2	85/130	790	--	.000175	--	Do.

Table 1. Summary of well records and hydraulic properties of the surficial and intermediate aquifer systems at selected sites and areas in southwest Florida --Continued

[EWD, Englewood Water District; FGS, Florida Geological Survey; SWFWMD, Southwest Florida Water Management District; ROMP, Regional Observation Monitor Program; USGS, U.S. Geological Survey; ft, feet; ft^2/d, feet squared per day; (ft/d)/ft, feet per day per foot; ft/d, feet per day; <, less than; >, greater than; --, no data]

Site name/well number	Site identification	Hydrogeologic unit[1]	Casing/depth or interval below land surface (ft)	Transmissivity (ft^2/d)	Leakance coefficient [(ft/d)/ft]	Storage coefficient	Hydraulic conductivity (ft/d)	Reference
Plantation Utility RO-2	270407082215801	IAS PZ3	228/366	5,600	0.000035	0.00033	--	Post, Buckley, Schuh, and Jernigan, Inc. (1982b)
EWD Production RO-2	265714082203801	IAS PZ3	260/425	8,200	--	.000085	--	CH2M Hill, Inc. (1980)
ROMP TR 5-2	270919082234200	IAS PZ3	240/410	10,000	--	--	--	USGS test (1986)
ROMP 20	271137082284501	IAS PZ3	250/370	1,700	--	.00013	--	SWFWMD data files
Venice well field RO-6	2705340822609	IAS PZ3	206/441	15,400	--	.00064	--	Post, Buckley, Schuh, and Jernigan, Inc. (1982a)
(Sarasota Co., digital flow model)	--	CU SAS/PZ1	--	--	.00002 .0004	--	--	Ryder (1982)
ROMP TR 5-2	270919082234200	CU PZ2/PZ3	100/230	--	--	--	[6] 0.1	Hutchinson and Trommer (1992)
(Sarasota Co., digital flow model)	--	CU PZ3/UFA	--	--	.000027- .0000067	--	--	Ryder (1982)
ROMP TR 5-2	270919082234200	CU PZ3/UFA	410/500	--	--	--	[6] 10	Hutchinson and Trommer (1992)

[1]Explanation: SAS, surficial aquifer system; IAS PZ1, intermediate aquifer system, permeable zone 1; IAS PZ2, intermediate aquifer system, permeable zone 2; IAS PZ3, intermediate aquifer system, permeable zone 3; CU SAS/PZ1, confining unit between SAS and IAS PZ1; CU PZ1/PZ2, confining unit between IAS PZ1 and IAS PZ2; CU PZ2/PZ3, confining unit between IAS PZ2 and IAS PZ3; CU PZ3/UFA, confining unit between IAS PZ3 and UFA; and, UFA, Upper Floridan aquifer.

[2]Split-spoon sample, in feet below land surface

[3]Core sample, in feet below land surface

[4]Specific yield

[5]Horizontal hydraulic conductivity

[6]Vertical hydraulic conductivity from model simulations

[7]Average of 3 permeameter tests

[8]Sample did not saturate after 31 days or more

[9]Sample may have been disturbed in permeameter

[10]Average of several analytical methods for one test

[11]Average from 5 aquifer tests

[12]Average from multiple aquifer tests

Table 3. Well records for ground-water sampling network and ground-water quality data in southwest Sarasota County, 1993

[°C, degrees Celsius; EWD, Englewood Water District; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; <, less than; --, no data; ROMP, Regional Observation Monitor Program; SAS, surficial aquifer system; IAS PZ1, intermediate aquifer system permeable zone 1; IAS PZ2, intermediate aquifer system permeable zone 2; IAS PZ3, intermediate aquifer system permeable zone 3; index numbers refer to fig. 24]

Index no.	Site identification	Site name	Casing/ depth (feet)	Hydro- geologic unit	Sample collection date	Temp- erature (°C)	Specific conductance (µS/cm)	pH (units)	Chloride (mg/L)	Sulfate (mg/L)	Dissolved solids (mg/L)	NO^2+NO^3 (mg/L as N)
10	270325082262501	Casperson Beach	7/9	SAS	11-4-93	28.2	786	6.7	32	18	505	0.16
11	270401082191201	Rambler's Rest	5/7	SAS	11-4-93	--	1,090	7.4	68	2	874	<0.02
12	270542082261804	Venice Test 38	25/26	SAS	8-26-93	27.0	610	7.4	58	5	331	0.18
13	270722082281001	Nokomis Beach	10/12	SAS	11-4-93	26.6	22,000	7.3	7,000	1,000	14,800	0.85
14	271052082294401	Blackburn Point	10/12	SAS	11-4-93	28.7	630	7.9	19	72	441	--
15	271152082264601	Palmer Ranch	7/9	SAS	11-4-93	27.6	1,460	6.5	192	10	920	<0.02
40	265714082212301	Comm. Presby. Church	--/42	SAS	7-29-93	26.2	606	6.9	33	6	393	0.02
130	271137082284505	ROMP TR 20 SAS	12/32	SAS	6-23-93	23.9	1,867	6.7	265	100	1,240	<0.02
131	270511082271701	Beach Comber Apts	40/46	SAS	8-11-93	26.5	1,444	6.9	224	88	988	<0.02
139	265839082211301	Ethier	--/25	SAS	8-02-93	32.4	516	8.9	118	32	319	0.09
142	265950082183401	Myakka Pines Golf Club	42/50	SAS	7-29-93	28.6	1,200	6.7	124	28	863	<0.02
145	270919082234201	ROMP TR 5-2 SAS	8/13	SAS	6-23-93	26.5	652	6.3	13	73	467	<0.02
159	270113082223303	EWD EWT-5	10/15	SAS	6-24-93	23.6	681	7.1	43	<0.2	452	<0.02
170	265834082202402	EWD TH-14A	10/20	SAS	6-24-93	24.3	102	6.4	7	10	60	0.02
180	265712082205702	EWD SA-1	16/26	SAS	6-24-93	25.8	525	6.8	33	15	300	0.02
196	270732082252101	Faith Baptist Church	--/10	SAS	8-19-93	29.7	1,862	5.5	140	840	1,530	<0.02
198	270642082264201	Venetia Bay Plaza	--/10	SAS	8-26-93	31.1	13,600	7.8	4,250	750	8,760	<0.02
199	265910082220101	Cannon	--/20	SAS	9-21-93	26.7	1,260	6.7	132	60	855	<0.02
200	270416082250501	Gasporvich	--/25	SAS	9-22-93	25.6	648	7.1	79	21	397	<0.02
201	265925082240501	Matisen	--/10	SAS	9-22-93	27.3	13,000	7.0	3,900	490	8,260	<0.02
202	270017082231001	Nea Yung	--/30	SAS	9-22-93	27.7	613	4.9	156	22	413	<0.02
203	270116082243601	Samarrco	--/14	SAS	9-22-93	25.2	772	6.6	54	20	452	<0.02
204	270334082253501	Schrage	--/19	SAS	9-22-93	26.7	745	4.8	186	34	471	<0.02
205	270300082212801	Plantation	--/14	SAS	9-23-93	27.3	1,250	6.4	68	160	989	<0.02
206	270920082283101	Casas Bonitas	--/20	SAS	9-27-93	26.4	2,860	6.3	145	860	2,760	<0.02
207	270720082215801	Besosa	--/20	SAS	9-28-93	26.1	777	7.0	38	1	514	<0.02
84	271141082293401	Cobb	30/55	IAS PZ1	7-07-93	25.1	1,078	7.3	64	250	767	--
88	270841082261301	Pixley	45/68	IAS PZ1	7-09-93	24.7	883	7.8	48	200	625	--
90	270716082273101	Balls	42/75	IAS PZ1	7-02-93	25.1	2,340	7.0	210	810	1,850	--

Table 3. Well records for ground-water sampling network and ground-water quality data in southwest Sarasota County, 1993 --Continued

[°C, degrees Celsius; EWD, Englewood Water District; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; <, less than; --, no data; ROMP, Regional Observation Monitor Program; SAS, surficial aquifer system; IAS PZ1, intermediate aquifer system permeable zone 1; IAS PZ2, intermediate aquifer system permeable zone 2; IAS PZ3, intermediate aquifer system permeable zone 3; index numbers refer to fig. 24]

Index no.	Site identification	Site name	Casing/ depth (feet)	Hydro- geologic unit	Sample collection date	Temp- erature (°C)	Specific conductance (µS/cm)	pH (units)	Chloride (mg/L)	Sulfate (mg/L)	Dissolved solids (mg/L)	NO^2+NO^3 (mg/L as N)
91	270532082270801	Minnerly	60/65	IAS PZ1	7-07-93	25.8	966	7.4	62	46	619	--
93	270635082253101	Shannon	42/65	IAS PZ1	7-07-93	24.8	1,874	7.2	170	600	1,420	--
97	270427082240201	Reinhart	44/80	IAS PZ1	7-07-93	24.6	789	7.2	45	0.3	468	--
103	270041082230401	Englewood Tennis Club	99/130	IAS PZ1	7-02-93	25.6	1,140	7.8	252	15	721	--
105	265856082215001	Cascaddan	63/70	IAS PZ1	8-06-93	24.6	674	7.4	57	2	431	--
107	265959082183701	Myakka Pines Golf Club	42/100	IAS PZ1	8-19-93	25.0	2,860	7.1	710	110	1,780	--
160	270113082223302	EWD EPZ-5	40/70	IAS PZ1	6-24-93	23.6	1,162	7.2	176	24	766	--
162	265717082210301	EWD Prod 14	56/82	IAS PZ1	6-28-93	25.7	820	7.5	76	130	515	--
163	270111082211602	EWD EPZ-1	102/130	IAS PZ1	7-02-93	28.1	810	7.2	54	14	511	--
164	270004082223801	EWD EPZ-9	40/70	IAS PZ1	6-28-93	26.1	5,250	7.4	1,520	260	3,410	--
168	265826082201301	EWD TH-13	49/90	IAS PZ1	6-28-93	24.1	1,980	7.6	510	33	1,270	--
169	265809082194001	EWD TH-6	45/65	IAS PZ1	6-24-93	23.9	2,020	6.6	480	40	1,330	--
174	270140082240701	Japanese Gardens 7	60/104	IAS PZ1	7-29-93	25.0	1,088	7.7	144	7	1,410	--
176	270808082270504	ROMP TR 5-1 UH	40/59	IAS PZ1	6-22-93	26.8	1,400	7.,1	160	280	1,040	--
181	270406082220104	Plantation MW2-PZ1	52/65	IAS PZ1	7-06-93	28.0	914	7.6	104	160	593	--
183	270745082255601	Revels	42/60	IAS PZ1	7-16-93	24.4	2,600	7.2	185	1,200	2,250	--
184	265943082183901	Myakka Pines Golf Club	40/45	IAS PZ1	7-30-93	26.0	1,651	6.7	230	55	1,080	--
188	270637082233701	Marston	33/50	IAS PZ1	8-10-93	24.4	701	7.2	48	20	456	--
189	270429082253701	Shinsky	45/55	IAS PZ1	8-06-93	26.9	1,229	7.2	144	8	813	--
190	270216082245201	Borkovich	55/80	IAS PZ1	8-10-93	25.2	802	7.2	54	<0.2	519	--
53	271125082292901	Dean	68/95	IAS PZ2	6-28-93	25.8	2,150	7.4	85	1,000	1,950	--
54	271137082284504	ROMP 20 UH	75/125	IAS PZ2	7-30-93	24.8	1,790	7.4	85	740	1,500	--
56	270926082290501	Lippincott	68/194	IAS PZ2	6-28-93	25.5	3,670	7.0	375	1,600	3,400	--
57	271159082284901	Hansen	42/108	IAS PZ2	8-04-93	24.7	1,302	7.2	100	300	1,000	--
58	270901082281101	Corgan	80/110	IAS PZ2	6-28-93	25.8	1,464	7.2	124	320	1,100	--
62	270922082261801	Verdral	56/116	IAS PZ2	6-28-93	25.6	1,276	6.7	96	310	961	--
63	270925082243901	Brock	38/90	IAS PZ2	7-02-93	24.4	1,331	6.7	60	440	1,070	--
69	270447082270801	Love	80/150	IAS PZ2	7-02-93	25.9	1,092	7.2	92	260	772	--

Table 3. Well records for ground-water sampling network and ground-water quality data in southwest Sarasota County, 1993 --Continued

[°C, degrees Celsius; EWD, Englewood Water District; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; <, less than; --, no data; ROMP, Regional Observation Monitor Program; SAS, surficial aquifer system; IAS PZ1, intermediate aquifer system permeable zone 1; IAS PZ2, intermediate aquifer system permeable zone 2; IAS PZ3, intermediate aquifer system permeable zone 3; index numbers refer to fig. 24]

Index no.	Site identification	Site name	Casing/ depth (feet)	Hydro- geologic unit	Sample collection date	Temp- erature (°C)	Specific conductance (µS/cm)	pH (units)	Chloride (mg/L)	Sulfate (mg/L)	Dissolved solids (mg/L)	NO^2+NO^3 (mg/L as N)
70	270720082220501	Holland Landscaping	42/83	IAS PZ2	6-29-93	24.8	831	7.2	48	160	601	--
71	270633082232301	Burks	53/108	IAS PZ2	6-29-93	24.9	2,390	7.0	165	1,100	2,220	--
74	270544082214001	Industrial Space, Inc.	70/160	IAS PZ2	7-16-93	25.2	2,910	7.2	400	830	2,190	--
87	270305082252801	Knocke	67/85	IAS PZ2	7-07-93	25.4	613	7.6	49	25	404	--
108	265817082232501	Couchot	150/166	IAS PZ2	8-06-93	25.6	15,100	7.4	4,920	360	10,300	--
146	270227082253201	Rinehart	136/159	IAS PZ2	7-02-93	25.1	898	7.6	164	17	567	--
155	270940082283201	Sorrento Shores 2	63/87	IAS PZ2	6-22-93	25.1	2,760	7.1	155	1,400	2,680	--
157	270848082273501	Lake Village, Inc.	60/94	IAS PZ2	6-22-93	25.6	1,860	7.1	135	680	1,580	--
158	270842082252701	King’s Gate, Inc. 3	63/140	IAS PZ2	6-23-93	25.2	577	6.5	51	25	376	--
171	270545082234201	Venice Ranch, Inc.	60/95	IAS PZ2	8-20-93	26.3	1,730	7.4	210	420	1,260	--
182	270406082220103	Plantation MW4-PZ2	66/180	IAS PZ2	7-06-93	25.7	515	7.7	57	30	316	--
185	270432082231901	Venice Gardens 9	89/123	IAS PZ2	8-02-93	25.2	537	7.4	50	18	342	--
186	271022082235701	Austin	63/81	IAS PZ2	8-05-93	25.2	1,202	7.2	80	260	887	--
187	270816082223301	Grant	42/80	IAS PZ2	8-04-93	25.3	913	7.3	56	180	680	--
191	270619082271601	Hunter	70/120	IAS PZ2	8-06-93	25.0	2,020	7.5	130	440	1,750	--
192	270618082245801	Venice Ball Park 51	70/97	IAS PZ2	8-06-93	25.3	2,540	7.5	265	940	2,070	--
193	270213082223301	Circlewood	40/85	IAS PZ2	8-10-93	24.9	596	7.6	67	16	398	--
195	270731082251901	Faith Baptist Ch. Deep	62/96	IAS PZ2	8-19-93	27.5	3,100	7.6	260	1,500	2,740	--
220	271037082285901	Southbay Utility PZ2	60/100	IAS PZ2	[1]6-30-93	--	--	--	143	1,100	2,190	--
221	271223082262601	Central Co. Utility PZ2	63/200	IAS PZ2	[1]6-01-93	--	--	--	103	65	615	--
109	271137082284503	ROMP 20 LH	250/370	IAS PZ3	6-23-93	25.6	2,600	6.4	60	1,600	2,640	--
112	270808082270503	ROMP TR 5-1 LH	275/289	IAS PZ3	6-22-93	27.2	2,170	7.1	33	1,200	2,120	--
114	270919082234204	ROMP TR 5-2 TPA	360/400	IAS PZ3	6-23-93	28.4	2,520	6.9	38	1,500	2,620	--
115	270607082262701	Venice RO 2	250/450	IAS PZ3	8-06-93	26.2	4,680	7.1	766	1,500	3,810	--
117	270532082254001	Venice By-Pass Park	300/479	IAS PZ3	7-09-93	26.2	2,260	7.2	275	720	1,710	--
123	270847082253101	Alakna	300/555	IAS PZ3	8-04-93	26.0	1,347	7.5	52	490	1,120	--
124	270628082244601	Capri Isles Golf Club	300/600	IAS PZ3	8-19-93	25.6	2,700	7.0	170	1,400	2,420	--
126	270241082213601	Taylor Ranch Elem. Sch.	300/590	IAS PZ3	7-09-93	25.8	3,320	7.5	655	700	2,280	--

Table 3. Well records for ground-water sampling network and ground-water quality data in southwest Sarasota County, 1993 --Continued

[°C, degrees Celsius; EWD, Englewood Water District; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; <, less than; --, no data; ROMP, Regional Observation Monitor Program; SAS, surficial aquifer system; IAS PZ1, intermediate aquifer system permeable zone 1; IAS PZ2, intermediate aquifer system permeable zone 2; IAS PZ3, intermediate aquifer system permeable zone 3; index numbers refer to fig. 24]

Index no.	Site identification	Site name	Casing/ depth (feet)	Hydro- geologic unit	Sample collection date	Temp- erature (°C)	Specific conductance (µS/cm)	pH (units)	Chloride (mg/L)	Sulfate (mg/L)	Dissolved solids (mg/L)	NO^2+NO^3 (mg/L as N)
147	265713082204401	EWD RO Prod 1	260/425	IAS PZ3	6-28-93	26.5	10,370	7.5	3,250	400	7,320	--
156	270905082280201	Sorrento Shores 10	302/320	IAS PZ3	6-21-93	25.7	3,390	6.9	315	1,700	3,310	--
301	265721082204501	EWD RO Prod 9	--/372	IAS PZ3	[2]6-22-93	--	--	--	3,690	388	5,033	--
302	265722082205101	EWD RO Prod 4	--/375	IAS PZ3	26-22-93	--	--	--	4,200	582	7,700	--
303	270408082215501	Plantation MW3	245/380	IAS PZ3	[1]7-06-93	26.0	3,700	7.4	589	1,150	2,710	--
304	270526082260401	Venice RO 7	230/439	IAS PZ3	[3]8-26-93	--	--	7.2	350	900	1,960	--
305	270546082261701	Venice RO 4	230/450	IAS PZ3	[3]8-10-93	--	--	7.3	625	1,625	2,710	--
306	270605082262101	Venice RO 2A	230/450	IAS PZ3	[3]8-10-93	--	--	7.3	665	2,125	3,180	--
307	270646082245101	Venice 1E	269/405	IAS PZ3	[3]8-10-93	--	--	7.3	465	2,500	2,660	--
308	270723082243201	Venice 3E	197/360	IAS PZ3	[3]8-20-93	--	--	7.3	100	1,700	1,720	--
309	271029082285901	Southbay Utility PZ3	220/446	IAS PZ3	[1]6-30-93	--	--	--	202	1,650	2,940	--

[1]Sample collected by utility personnel and analyzed by private laboratories
[2]Sample collected and analyzed by Englewood Water District well-field personnel
[3]Sample collected and analyzed by City of Venice well-field personnel

Table 4. Ground water-quality data collected with a pore squeezer at the Carlton Reserve and South Venice test wells, Sarasota County, Florida, 1992

[Unconsolidated clay material is the source of all water samples. Alkalinity concentrations from the South Venice test well are not laboratory data, but were approximated. SAS, surficial aquifer system; IAS, intermediate aquifer system; V.C., Venice Clay; PZ1, permeable zone 1; PZ2, permeable zone 2; PZ3, permeable zone 3; CU SAS/PZ1, confining unit between SAS and IAS PZ1; CU PZ1/PZ2, confining unit between IAS PZ1 and IAS PZ2; CU PZ2/PZ3, confining unit between IAS PZ2 and IAS PZ3; CU PZ3/UFA, confining unit between IAS PZ3 and upper Floridan aquifer; ft, feet; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; mg/L, micrograms per liter; <, less than; --, no data]

Site Name	Site identification	Sample depth (ft)	Hydrogeologic unit	Sample collection date	Specific conductance (µS/csm)	pH (units)	Alkalinity (mg/L)	Hardness, total (mg/L)
Carlton Reserve	270803082210301	20	CU SAS/PZ1	4-28-92	1,160	6.6	476	350
		40	CU PZ1/PZ2 (V.C.)	4-28-92	1,240	6.5	443	375
		48	Do.	4-29-92	1,220	6.8	249	168
		94	PZ2	4-30-92	920	7.2	300	287
		148	Do.	5-02-92	940	7.9	512	294
		162	Do.	5-02-92	1,120	7.0	256	256
		350	PZ3	5-27-92	2,000	7.1	238	1,068
		432	CU PZ3/UFA	5-28-92	2,120	6.3	443	615
South Venice	270340082255401	27	CU SAS/PZ1	7-26-92	1,040	--	448	367
		72	PZ1	8-04-92	640	--	334	270
		125	CU PZ1/PZ2 (V.C.)	8-08-92	550	--	252	218
		291	CU PZ2/PZ3	8-19-92	870	--	268	297
		304	Do.	8-20-92	1,060	--	245	331
		373	PZ3	8-21-92	2,080	--	286	1,067

Table 4. Ground-water quality data collected with a pore squeezer at the Carlton Reserve and South Venice test wells, Sarasota County, Florida, 1992-Continued

[Unconsolidated clay material is the source of all water samples. Alkalinity concentrations from the South Venice test well are not laboratory data, but were approximated. SAS, surficial aquifer system; IAS, intermediate aquifer system; V.C., Venice clay; PZ1, permeable zone 1; PZ2, permeable zone 2; PZ3, permeable zone 3; CU SAS/PZ1, confining unit between SAS and IAS PZ1; CU PZ1/PZ2, confining unit between IAS PZ1 and IAS PZ2; CU PZ2/PZ3, confining unit between IAS PZ2 and IAS PZ3; CU PZ3/UFA, confining unit between IAS PZ3 and upper Floridan aquifer; ft, feet; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than;--, no data]

Site Name	Sample depth (ft)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Sulfate, dissolved (mg/L)	Iron, dissolved (µg/L)	Strontium, dissolved (µg/L)	Nitrogen, NO_2+NO_3, dissolved (mg/L)
Carlton Reserve	20	110	18	42	4.6	46	140	300	1,200	0.70
	40	100	30	61	5.4	65	280	6	1,800	0.80
	48	110	34	48	--	52	270	80	1,900	0.52
	94	68	28	46	6.8	69	31	40	2,000	0.28
	148	110	52	54	14	66	46	1,100	3,000	0.14
	162	50	31	44	8.2	52	52	20	--	2.80
	350	240	110	38	2.4	20	840	<5	14,000	0.38
	432	140	62	140	11	75	660	400	8,800	2.50
South Venice	27	130	10	70	8.3	87	37	140	870	<0.02
	72	92	9.5	24	4.2	34	4.0	<5	720	<0.02
	125	64	14	24	4.8	45	4.8	130	620	0.30
	291	58	36	50	8.7	100	49	<5	3,900	0.42
	304	63	41	69	13	140	90	80	4,700	0.35
	373	240	110	86	10	160	760	30	13,000	0.22