Transmissivity and Water Quality of Water-Producing Zones in the Intermediate Aquifer System, Sarasota County, Florida

By Lari A. Knochenmus and Geronia (Moe) Bowman

U.S. Geological Survey

Water-Resources Investigations Report 98-4091

Prepared in cooperation with

SARASOTA COUNTY

Tallahassee, Florida
1998

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

U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, Acting Director

Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

For additional information write to:

District Chief
U.S. Geological Survey
Suite 3015
227 N. Bronough Street
Tallahassee, FL 32301

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225
800-USA-MAPS

CONTENTS

Figures

Tables

VERTICAL DATUM, ACRONYMNS, AND ABBREVIATIONS

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

mi^2	square mile
ft	foot
ft^2/d	foot squared per day
(gal/min)/ft	gallons per minute per foot
Mgal/d	million gallons per day
Bgal/yr	billion gallons per year
μS/cm	microsiemens per centimeter at 25 degrees Celsius
PZ1	producing zone 1
PZ2	producing zone 2
PZ3	producing zone 3
ROMP	Regional Observation and Monitoring Well Program
SWFWMD	Southwest Florida Water Management District
USGS	U.S. Geological Survey

Transmissivity and Water Quality of Water-Producing Zones in the Intermediate Aquifer System, Sarasota County, Florida

By Lari A. Knochenmus *and* Geronia (Moe) Bowman

Abstract

The intermediate aquifer system is an important water source in Sarasota County, Florida, because the quality of water in it is usually better than that in the underlying Upper Floridan aquifer. The intermediate aquifer system consists of a group of up to three water-producing zones separated by less-permeable units that restrict the vertical movement of ground water between zones. The diverse lithology, that makes up the intermediate aquifer system, reflects the variety of depositional environments that occurred during the late Oligocene and Miocene epochs. Slight changes in the depositional environment resulted in aquifer heterogeneity, creating both localized connection between water-producing zones and abrupt culmination of water-producing zones that are not well documented. Aquifer heterogeneity results in vertical and areal variability in hydraulic and water-quality properties.

The uppermost water-producing zone is designated producing zone 1 but is not extensively used because of its limited production capability and limited areal extent. The second water-producing zone is designated producing zone 2, and most of the domestic- and irrigation-supply wells in the area are open to this zone. Additionally, producing zone 2 is utilized for public supply in southern coastal areas of Sarasota County. Producing zone 3 is the lowermost and most productive water-producing zone in the intermediate aquifer system. Public-supply well fields serving the cities of Sarasota and Venice, as well as the Plantation and Mabry Carlton Reserve well fields, utilize producing zone 3.

Heads within the intermediate aquifer system generally increase with aquifer depth. However, localized head-gradient reversals occur in the study area, coinciding with sites of intense ground-water withdrawals. Heads in producing zones 1, 2, and 3 range from 1 to 23, 0.2 to 34, and 7 to 42 feet above sea level, respectively. Generally, an upward head gradient exists between producing zones 3 and 2. However, an upward head gradient between producing zones 2 and 1 does not consistently occur throughout Sarasota County, probably the result of greater ground-water withdrawals from producing zone 2 than from producing zone 1.

The transmissivity of the intermediate aquifer system is spatially variable. Specific-capacity data from selected wells penetrating producing zones 2 and 3, were used to estimate transmissivity. Estimated transmissivity values for producing zones 2 and 3 range from about 100 to 26,000 feet squared per day and from about 1,300 to 6,200 feet squared per day, respectively. Because the capacity of specific water-producing zones is highly variable from site to site, estimating the performance of a specific water-producing zone as a water resource is difficult.

Water samples collected during the study were analyzed for major-ion concentrations. Generally, bicarbonate type water from rock interaction occurs in northern Sarasota County; enriched calcium-magnesium-sulfate type water from deeper aquifers occurs in central Sarasota County; and sodium-chloride type water from saltwater mixing occurs in southern Sarasota County. In some areas of northern Sarasota County, the major-ion concentrations in water are lower in producing zone 2 than in producing zone 1. Major-ion concentrations in water are higher in producing zone 3 throughout the study area.

A major objective of the study was to evaluate hydraulic and water-quality data to determine distinctions that could be used to characterize a particular producing zone. However, data indicate that both hydraulic and water-quality properties are highly variable within and between zones, and are more related to the degree of connection between and areal extent of water-producing zones than to aquifer depth and distance from the coast.

INTRODUCTION

Demand for potable water continues to increase in Sarasota County. Total withdrawals for public supply are projected to increase from about 29 Mgal/d in 1990 to about 63 Mgal/d by 2020 (Southwest Florida Water Management District, 1992). The area depends primarily on ground water pumped from three aquifer systems. The surficial aquifer system and intermediate aquifer system overlie the Floridan aquifer system and are the principal sources of potable ground water in much of Sarasota County. The Floridan aquifer system is used less because it contains water too mineralized for most uses. As the demand for water in Sarasota County increases, more information is needed to efficiently develop and manage the intermediate aquifer system as a water-supply source. A better understanding of the vertical and areal variability in hydraulic and water-quality properties of the intermediate aquifer system is essential, particularly because heavy pumping could induce mixing of ground water with differing water quality.

In 1995, the U.S. Geological Survey (USGS), in cooperation with Sarasota County, began a study to describe the hydraulic and water-quality properties and variations among the different water-producing zones of the intermediate aquifer system underlying Sarasota County (fig. 1). The study area encompasses 572 mi^2 and includes all of Sarasota County and four well sites just outside of the county boundary. For the purposes of this report, the designation "Sarasota County" includes the four additional well sites just outside of the Sarasota County boundary in Charlotte and Manatee Counties.

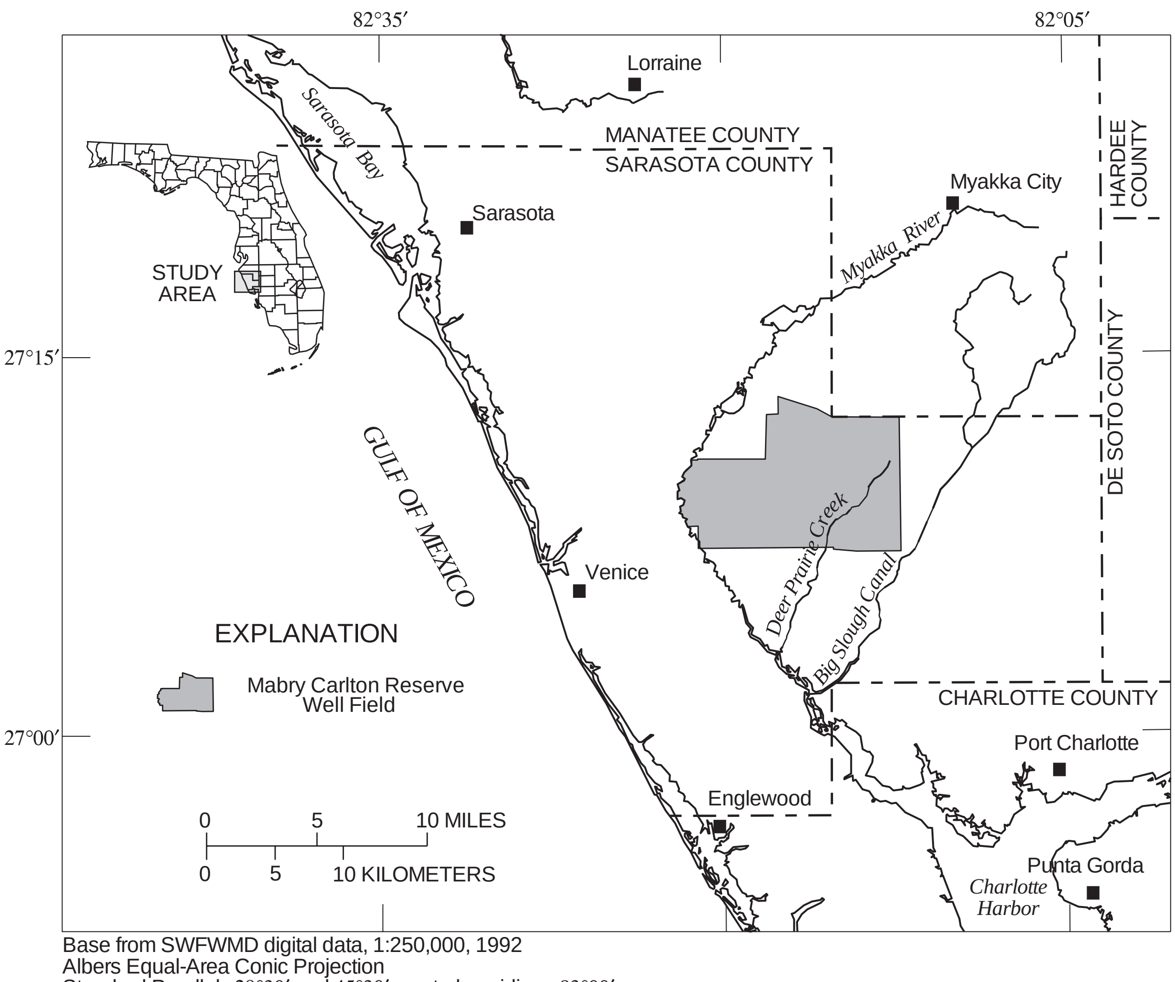


Figure 1. Study area, including the Mabry Carlton Reserve well field in central Sarasota County.

Purpose and Scope

This report describes the hydrogeologic framework and hydrologic (hydraulic and chemical) properties of the water-producing zones in the intermediate aquifer system underlying Sarasota County. The hydrologic properties of individual water-producing zones within the intermediate aquifer system were assessed using water-level, specific-capacity, and water-quality data collected from wells open to a single water-producing zone. Specific objectives of this report are:

1. Describe the hydrogeologic framework and hydraulic properties of the intermediate aquifer system.
2. Describe the areal and vertical distribution of water quality.
3. Evaluate hydraulic and water-quality data for distinctions that could be used to characterize a particular water-producing zone.

Information presented in this report was obtained from data collected by the USGS during this investigation and from published USGS and Southwest Florida Water Management District (SWFWMD) reports. Data include lithologic and geophysical logs, water samples, and specific-capacity data from 31 existing and 26 new supply wells.

Description of the Study Area

The study area includes all of Sarasota County, one well site in Charlotte County, and three well sites in Manatee County. Coastal areas are characterized by high-density residential, recreational, and commercial development, whereas inland areas are characterized by mostly agricultural land use. The study area lies in the Florida central or midpeninsular physiographic zone described by White (1970). Subdivisions of this zone include the Gulf Coastal Lowlands, the Gulf Coastal Lagoons and Barrier Chain, and the Desoto Plain (White, 1970). Land-surface altitudes range from sea level along the coast to over 100 ft in northeastern Sarasota County. The topography of the study area is characterized by broad flatlands with many sloughs and swamps in lowland areas (Wolansky, 1983), gradually sloping scarps and terraces created by various Pleistocene sea-level stands in coastal areas (Broska and Knochenmus, 1996), and dry upland areas made up of palustrine forest, scrub-shrub, or palustrine emergent wetlands in inland areas (U.S. Fish and Wildlife Service, 1985).

Methods Used to Obtain Hydraulic and Water-Quality Data

Hydraulic data were collected following the guidelines presented in Bentall (1963). Data were collected from 57 wells (31 existing and 26 new). Existing monitor wells were used for analysis if they were open to discrete water-producing zones. New supply wells were constructed by others during the study. The new wells were sampled during drilling (test wells) and after completion (supply wells). In this report, the following terminology is used to differentiate wells: *test well*—uncompleted private supply well drilled during the study; *supply well*—completed private supply well drilled during the study; *existing well*—monitor well drilled prior to the study.

The types of data collected include geophysical logs, water levels, and water quality. Geophysical logs including, but not limited to, caliper, electric, and natural-gamma ray logs were collected using the Tampa USGS analog borehole-geophysical logger. Standard USGS protocols were used for water-quality sampling (Wood, 1976). Temperature and specific conductance were measured and water samples were collected after field parameters stabilized and a sufficient volume was evacuated from the well. Wells were evacuated and sampled using a submersible pump or were allowed to flow naturally. Water levels were measured using a calibrated steel tape or pressure gage.

Twenty-six supply wells were drilled by others during the study using a cable-tool rig. Water levels and water samples were collected during the drilling process whenever a water-producing zone was intercepted by the test well. After data and sample collection, the test well was deepened into the underlying less-permeable unit and the casing was pounded into this lithologic sequence. Placement of the casing effectively sealed off the overlying water-producing zone. Drilling then continued until the next water-producing zone was intercepted. After reaching the targeted water-producing zone, the casing was grouted. Geophysical logs, water levels, and water samples were collected from the supply well as described above. Specific-capacity tests were conducted during well development and the data were used to estimate aquifer transmissivity.

The well sites used for data collection are shown in figure 2 and well information is listed in table 1. The table includes well names, land-surface elevations, and completion information. The well location number is a 15-digit number that reflects the location of the well based on latitude (6 digits), longitude (7 digits), and a sequential number (2 digits). Well clusters (wells with the same latitude and longitude) and test wells (well construction prior to well completion) are identified by a single well location number in the figures and tables.

HYDROGEOLOGIC FRAMEWORK AND HYDRAULIC PROPERTIES

The hydrogeologic framework of the study area is composed of Tertiary- and Quaternary-aged sediments and sedimentary rocks that make up the surficial aquifer system, intermediate aquifer system, and Floridan aquifer system. Each of these aquifer systems contains one or more water-producing zones separated by less-permeable units. The intermediate aquifer system includes all rock units that lie between the overlying surficial aquifer system and the underlying Upper Floridan aquifer of the Floridan aquifer system and generally corresponds to the lithostratigraphic unit designated as the Hawthorn Group (fig. 3). The Hawthorn Group is a 400-ft thick (average) sequence of sedimentary units including sand, shell, clay, and carbonate. The diverse lithology (aquifer heterogeneity) reflects the variety of depositional environments that occurred during the late Oligocene and Miocene epochs. The heterogeneous nature of the lithostratigraphic units that make up the intermediate aquifer system results in localized, highly variable hydrogeologic characteristics common to karstic aquifers.

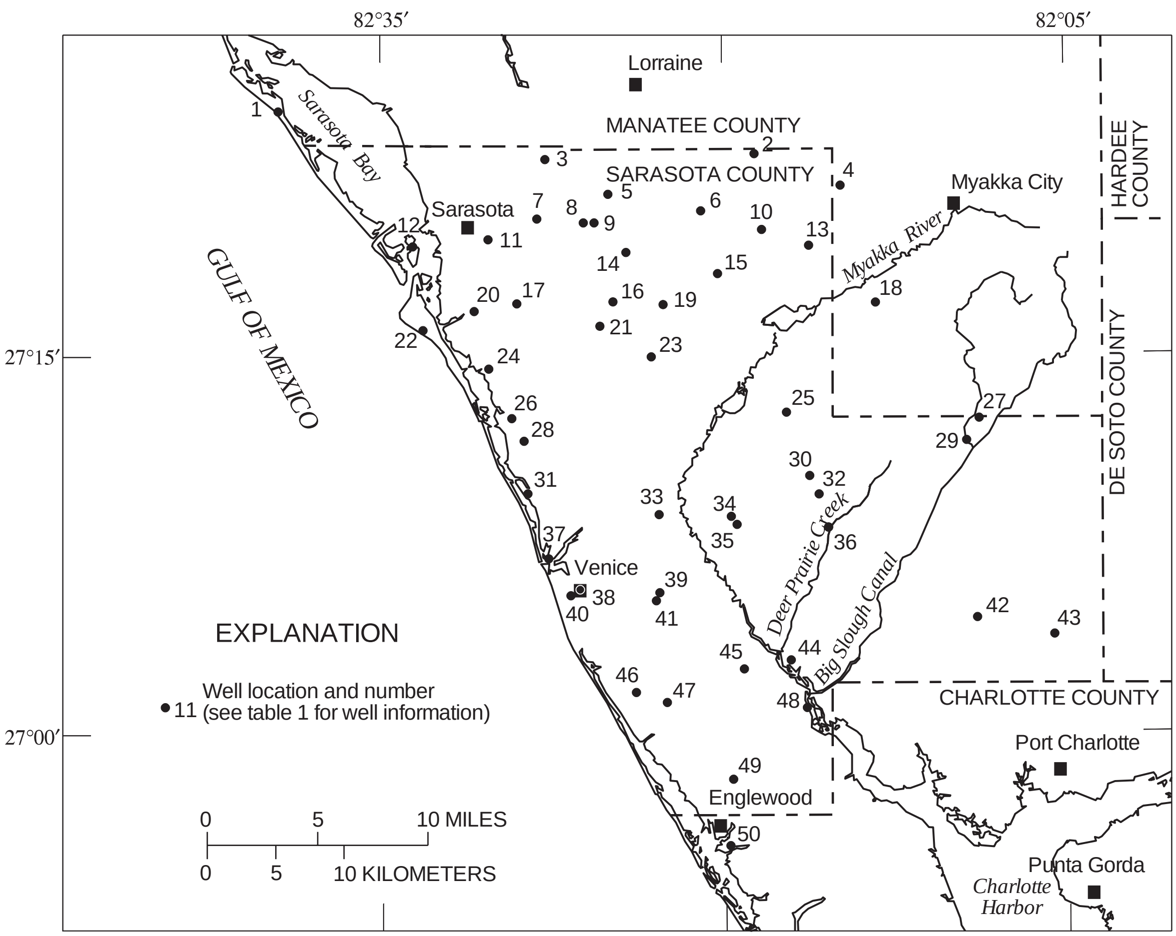


Figure 2. Locations of wells used for data collection during this study.

Table 1. Well information

[Number corresponds to number shown in figure 2; Well location number, location based on latitude and longitude; Land surface datum, in feet above sea level; Depth, in feet below land surface; Casing, in feet below land surface; Logs, geophysical logs; C, caliper; G, gamma; T, temperature; FR, fluid resistivity; E, electric; SP, self-potential; FC, fluid conductivity; Q, flowmeter]

Number	Well location number	Well name	Land surface	Depth	Casing	Producing zone	Logs
1	272443082392901	Longboat Key Fire Station	5	475	346	3	C,G,T,FR
2	272257082183501	Verna Test 6-A	75	99	89	2	C,G,E
3	272247082274601	Tim Thrower	20	280	228	2	---
4	272141082144901	Rick Lewis	90	140	120	2	---
4	272141082144901	Rick Lewis	90	380	140	3	
5	272123082250101	Racimo Ranch	35	205	104	2	C,SP,E,FR,G
6	272042082205601	Tom Justice	40	61	41	1	C,G,E,FR
6	272042082205601	Tom Justice	40	153	64	2	
7	272025082280801	Mike Swartz	25	50	41	1	SP,FR,G,C
7	272025082280801	Mike Swartz	25	143	72	1,2	
8	272016082260601	Fancee Farms	20	235	64	1,2	C,E,SP,G
9	272015082253801	Kim Elmenuani	25	58	57	1	---
9	272015082253801	Kim Elmenuani	25	105	57	2	
10	271957082181701	Tracy Fultz	50	65	45	1	C,E,G
10	271957082181701	Tracy Fultz	50	185	70	2	
11	271937082301701	Lord	10	52	41	1	E,G,FR,C,
11	271937082301701	Lord	10	197	74	2	
12	271920082333501	Guy Boyler	5	45	26	1	G,E,C
12	271920082333501	Guy Boyler	5	276	38	2	
13	271919082161301	Jerry Cantwell	50	180	80	2	---
14	271905082241401	Kallio	30	175	72	2	G,C
15	271813082201304	ROMP 22 (U IAS)	35	125	90	1	---
15	271813082201303	ROMP 22 (L IAS)	35	260	230	2	
16	271707082244901	Kazmark	35	42	30	1	G,C,E,FR
16	271707082244901	Kazmark	35	65	56	1	
16	271707082244901	Kazmark	35	130	56	2	
17	271704082290201	Francis Crum	35	50	49	1	C,G,E
17	271704082290201	Francis Crum	35	110	50	2	
18	271703082131801	Chris Houser	30	162	94	2	FR,G,C,E
19	271700082223701	Pete Bosarino	30	41	40	1	---
20	271646082305401	Ray Newton	20	110	63	1	E,C,G
20	271646082305401	Ray Newton	20	223	155	2	
21	271609082252401	Thompson Foxfire	35	147	39	2	C,E,G,FR
22	271601082330501	ROMP TR6-1	6	315	300	3	---
23	271456082230901	USGS TH10	20	45	38	1	---
24	271429082301701	Spano	15	25	20	1	G,C,E
24	271429082301701	Spano	15	120	54	2	
25	271242082171501	MCR 10 series	27	312	269	3	---
26	271231082291701	Larry Jayne	10	22	18	1	---
26	271231082291701	Larry Jayne	10	85	52		
27	271227082084801	Mabry Carlton 6	40	369	311	3	FR,E,G,C
28	271137082284502	ROMP 20 (HTRN)	15	370	250	3	---
28	271137082284503	ROMP 20 (TUH)	15	125	75	2	
29	271134082092201	Big Slough Deep	33	100	78	2	---
30	271011082161501	MCR 13 series	30	327	274	3	C
31	270931082283501	Ron Stogner	12	42	41	1	---
31	270931082283501	Ron Stogner	12	95	62	1,2	
32	270926082155104	MCR 14DN	31	96	70	2	---
33	270840082225101	Henry Ranch 3	12	78	22	1	C,G,E
34	270835082194101	MCR STM24A	21	379	279	3	---
35	270816082192604	MCR (3H)	21	304	264	3	---
35	270816082192602	MCR (3E)	21	230	65	2	
36	270808082152602	MCR 14GS	25	300	275	3	---
37	270656082274201	Little Bear Inc.	5	120	64	2	E,C
38	270542082261801	Venice 35	13	163	86	2	E,C
38	270542082261802	Venice 36	13	70	59	1	
39	270534082225001	Peter DeCarlo	13	43	41	1	---
39	270534082225001	Peter DeCarlo	13	120	41	2	
40	270528082264401	Venice Hospital	18	80	63	1	C,G
40	270528082264401	Venice Hospital	18	202	83	2	
40	270528082264401	Venice Hospital	18	437	280	3	
41	270515082225901	Parrish Sugarwood	13	111	42	2	---
42	270432082085703	ROMP 9 (LH)	25	280	190	3	---
42	270432082085704	ROMP 9 (UH)	25	164	122	2	
43	270351082053501	Vernon Veach	25	180	73	2	---
44	270252082170701	Lazy River Estates	5	105	65	2	---
45	270231082191001	Manatee Jr. College	10	42	27	1	---
46	270137082235301	Manasota 14 deep	16	305	263	3	---
47	270113082223302	Englewood Prod 5	15	70	40	1	---
47	270113082223301	Deep Zone 5	12	149	132	2	C,G,E
48	270059082162501	George Campbell	5	50	30	1	---
49	265809082194001	Englewood Test 6	11	65	45	2	G
50	265531082194804	ROMP TR3-3 (LH)	6	410	370	2	C,G,E,T
50	265531082194805	ROMP TR3-3 (UH)	6	175	155	3	FC,Q

Aquifer System	Stratigraphic Unit	Sutcliffe, 1975; Joyner and Sutcliffe, 1976	Barr, 1996	Wolansky, 1983; Duerr and Wolansky, 1986	Broska and Knochenmus, 1996	This report
Surficial Aquifer System	Undifferentiated clastics	water-table aquifer	surficial aquifer	surficial aquifer	surficial aquifer	surficial aquifer
	Undifferentiated Tamiami Formation	confining bed	confining unit	confining bed	confining unit	confining unit
		artesian zone 1	permeable zone 1	Tamiami-Upper Hawthorn aquifer		producing zone 1
Intermediate Aquifer System		"Venice Clay" confining bed	"Venice Clay" confining unit			confining unit
	Hawthorn Group, Arcadia Formation	artesian zone 2	permeable zone 2		Upper Hawthorn permeable zone	producing zone 2
		confining bed	confining unit	confining bed	confining unit	confining unit
		artesian zone 3	permeable zone 3	Lower Hawthorn-Upper Tampa aquifer	Tampa permeable zone	producing zone 3
	Tampa Member	confining bed	confining unit	confining bed	confining unit	confining unit

Figure 3. Hydrogeologic designations used in this report. (Modified from Sutcliffe, 1975; Sutcliffe and Joyner, 1976; Wolansky, 1983; Duerr and Wolansky, 1986; Barr, 1996; and Broska and Knochenmus, 1996.)

Water-Producing Zones

The intermediate aquifer system consists of (1) a sandy clay to clayey sand confining unit directly overlying the Upper Floridan aquifer; (2) a group of up to three water-producing zones composed primarily of sand and carbonate rocks; and (3) a sandy clay, clay, and marl confining unit that separates the water-producing zones from the overlying surficial aquifer system. The three water-producing zones are separated by less-permeable units that restrict the vertical movement of ground water between zones. Identification of the water-producing zones is based on their stratigraphic position and lithology, and on an increase in productivity, change in water levels, and change in chemical quality of the water produced from them. Figure 3 shows a correlation between the hydrogeologic-unit names used in this report and those used in previous reports.

The uppermost water-producing zone (PZ1) coincides with the undifferentiated clastics and limestones that make up the upper part of the Tamiami Formation in Sarasota County, and designated by Sutcliffe (1975) and Joyner and Sutcliffe (1976) as artesian zone 1. PZ1 is less than 80 ft thick and is not continuous throughout the study area. Barr (1996) mapped the extent of this zone based on lithologic descriptions of the Venice Clay. The Venice Clay underlies PZ1 (where it exists) in Sarasota County. PZ1 was not treated as a distinct water-producing zone in reports by Wolansky (1983), Duerr and Wolansky (1986), and Broska and Knochenmus (1996) because of its limited production capability and areal extent. Twenty-one wells (6 existing and 15 test wells) open to PZ1 were sampled during the study. The existing wells are located in southern and southwestern Sarasota County where PZ1 is thickest (Barr, 1996, p. 36). The test wells are areally distributed from north to south, but all of the wells are located west of the Myakka River. Well depths range from 42 to 78 ft. Well locations and numbers are shown in figure 4. After the hydrologic data were collected from PZ1, all of the test wells were deepened and converted to supply wells. None of the new supply wells are currently (1997) open to PZ1.

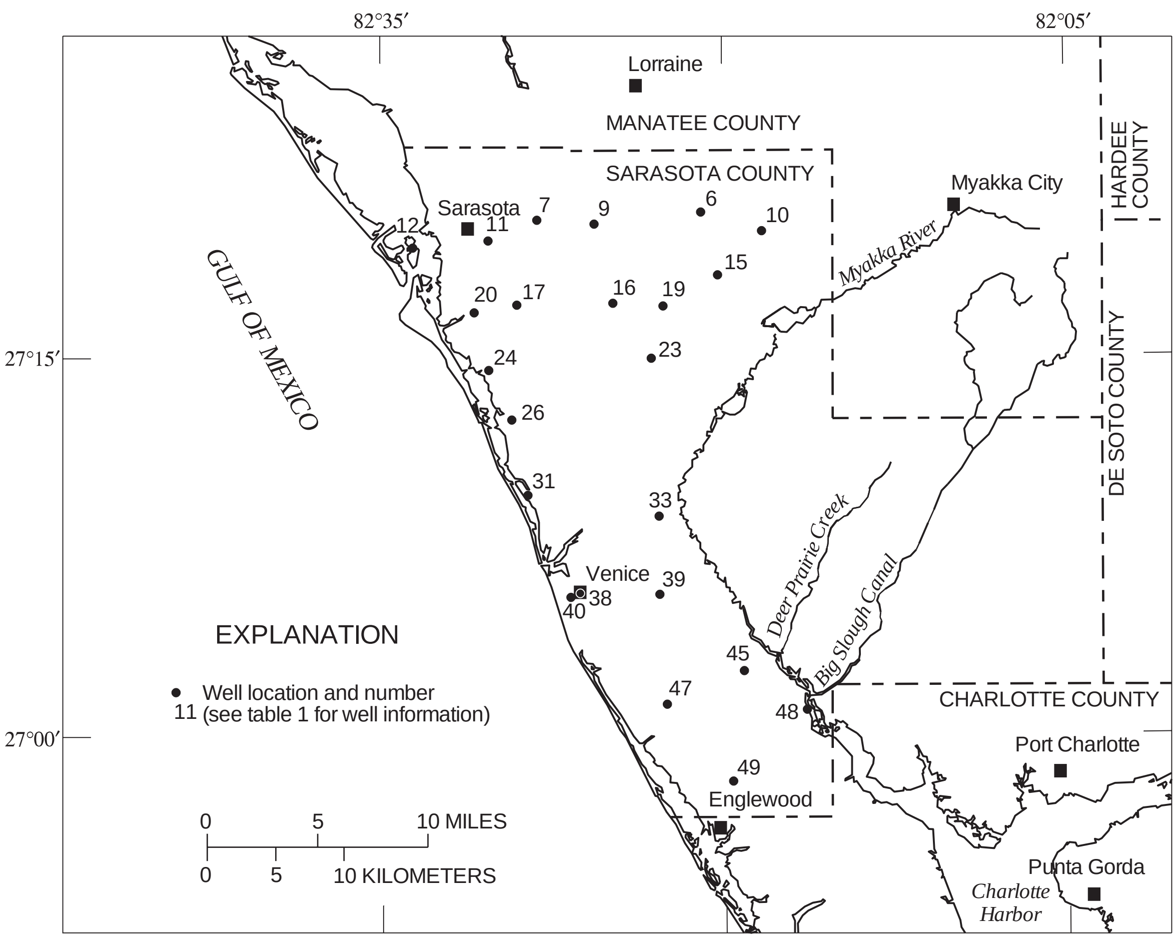


Figure 4. Wells open to producing zone 1.

The second water-producing zone (PZ2) coincides with the carbonate rocks that make up the Tamiami-Upper Hawthorn aquifer (Wolansky, 1983; Duerr and Wolansky, 1986), the Upper Hawthorn permeable zone (Broska and Knochenmus 1996), and artesian zone 2 (Sutcliffe, 1975; Joyner and Sutcliffe, 1976). This zone is about 200 ft thick and is continuous throughout the study area. Well depths range from 90 to 280 ft. PZ2 is utilized for public supply in the southern coastal area of Sarasota County. Additionally, PZ2 supplies most of the ground water used for domestic and irrigation purposes in Sarasota County. Wells open to PZ2, that were sampled during this study, are shown in figure 5.

The third and lowermost water-producing zone (PZ3) coincides with the carbonate rocks that make up the Lower Hawthorn-Upper Tampa aquifer (Duerr and Wolansky, 1986), the Tampa permeable zone (Broska and Knochenmus, 1996), and artesian zone 3 (Sutcliffe, 1975; Joyner and Sutcliffe, 1976). PZ3 is a 150-ft thick water-producing zone with well depths ranging from 280 to 437 ft. Typically, PZ3 is the most productive zone in the intermediate aquifer system. Public-supply well fields serving the cities of Sarasota and Venice, as well as the Plantation and Mabry Carlton Reserve well fields, utilize PZ3. Wells open to PZ3, that were sampled during this study, are shown in figure 6.

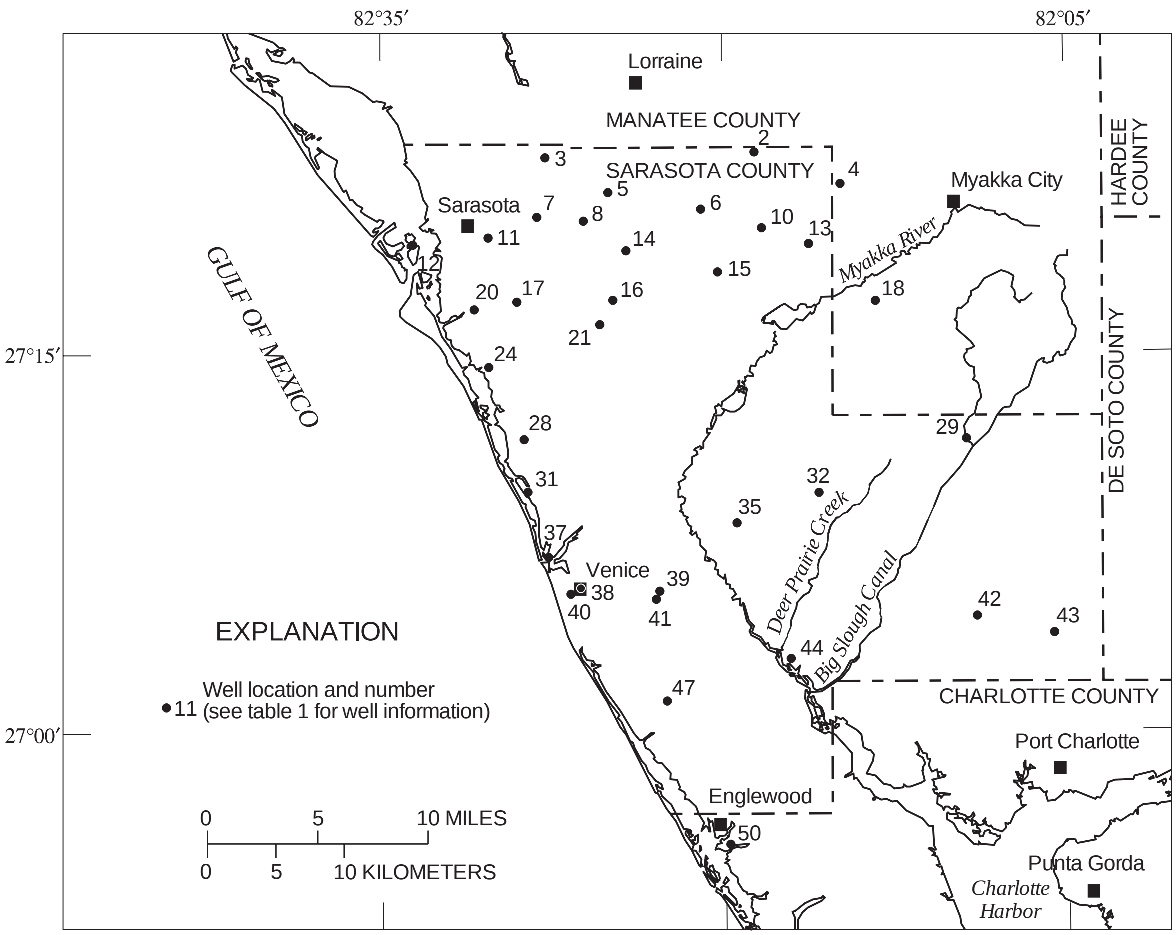


Figure 5. Wells open to producing zone 2.

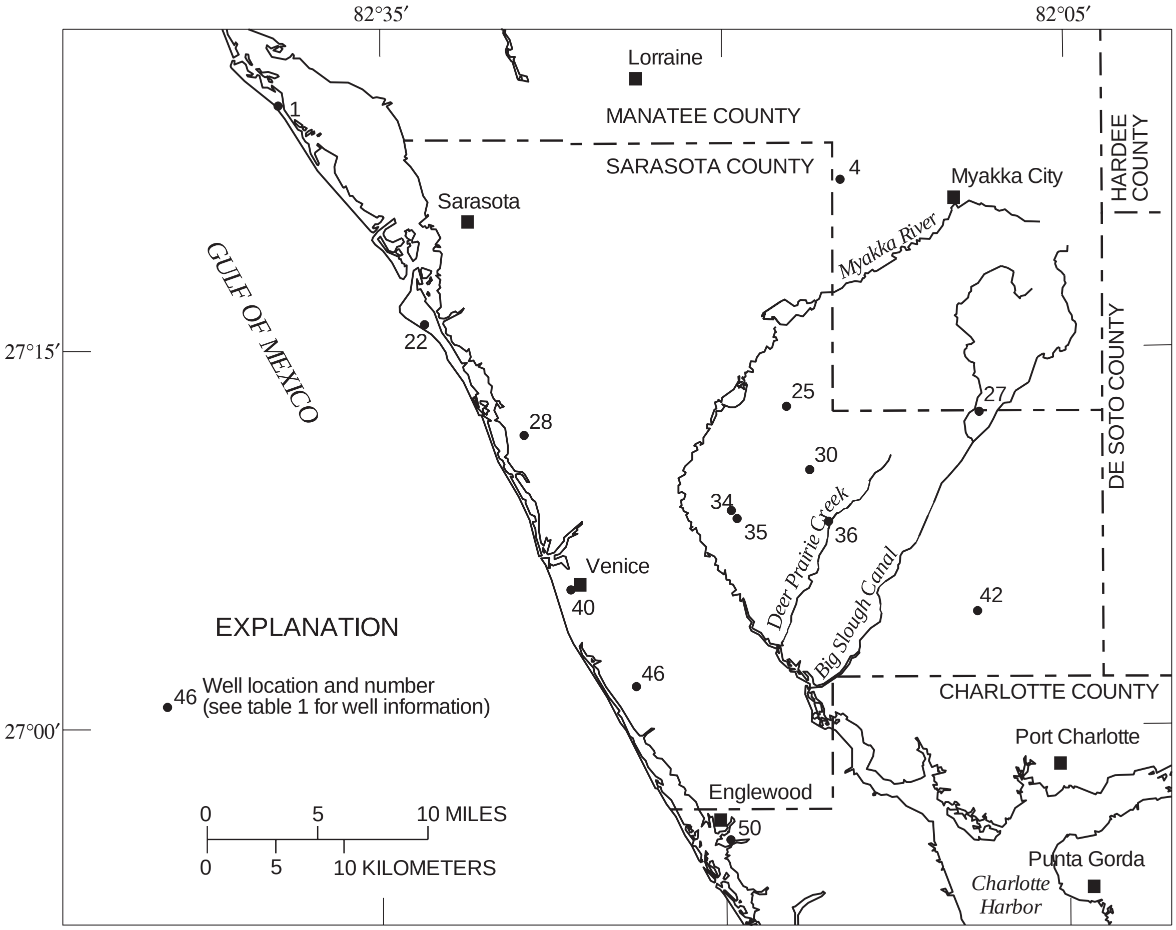


Figure 6. Wells open to producing zone 3.

Ground-Water Flow

Regional ground-water flow in the intermediate aquifer system is generally west or southwest toward the Gulf of Mexico (fig. 7). Ground-water inflow to the intermediate aquifer system occurs as upward leakage from the underlying Upper Floridan aquifer and as lateral flow from adjacent inland areas (Broska and Knochenmus, 1996, p. 49; Metz and Brendle, 1996, p. 9). Little, if any, ground water enters the intermediate aquifer system from the surficial aquifer system. Upward flow within and between aquifers may be enhanced by preferential flow through deep fractures or faults.

An upward head gradient exists between the Upper Floridan aquifer and the intermediate aquifer system throughout most of Sarasota County (Metz and Brendle, 1996, p. 9 and 11). Lateral facies changes within the intermediate aquifer system result in localized good hydraulic connections between the intermediate aquifer system and the Upper Floridan aquifer. Water-level data for wells finished at discrete depths are presented for two sites in the Mabry Carlton Reserve well field (fig. 8). At these sites (CW-6 and CW-7), an upward head gradient occurs between the Upper Floridan aquifer and the intermediate aquifer system, and between the intermediate aquifer system and the surficial aquifer system. One notable

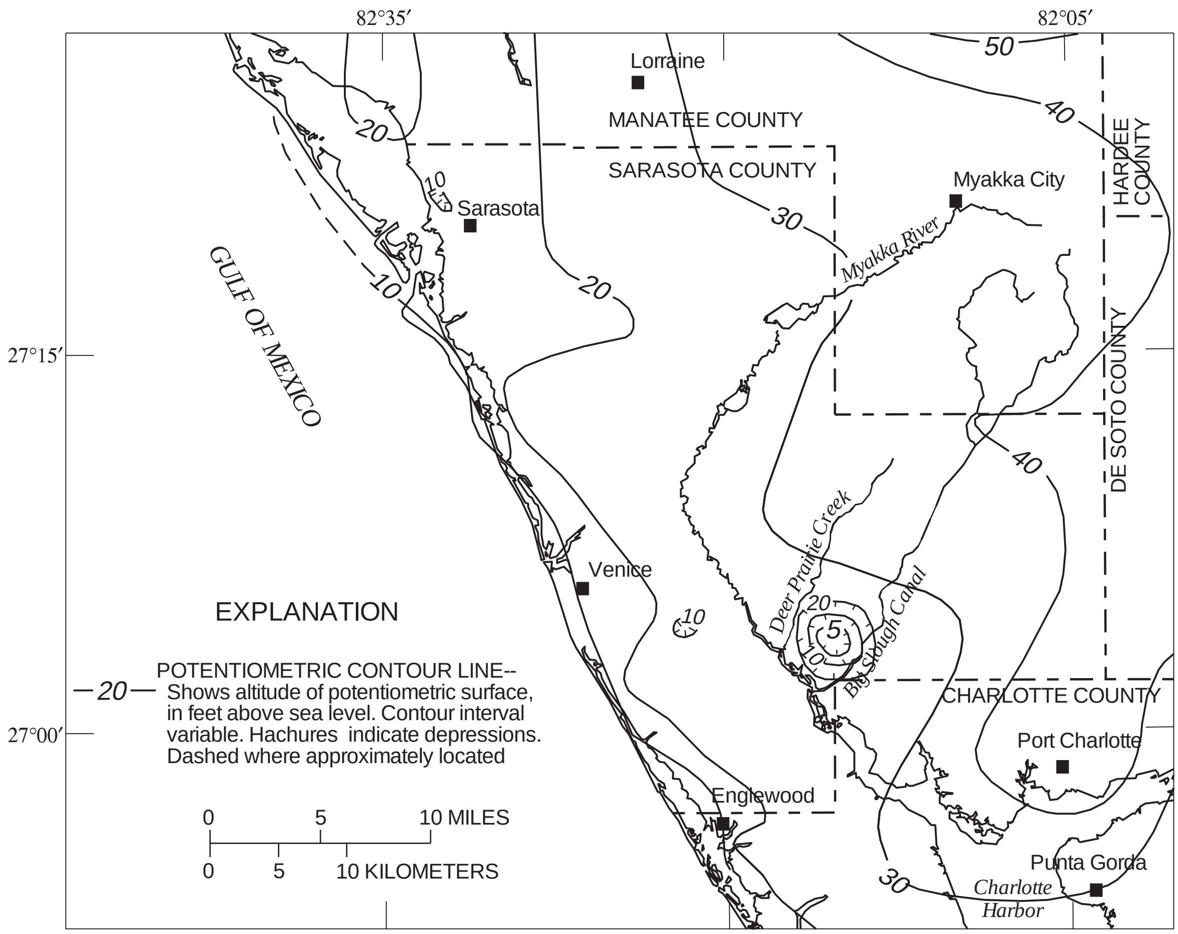
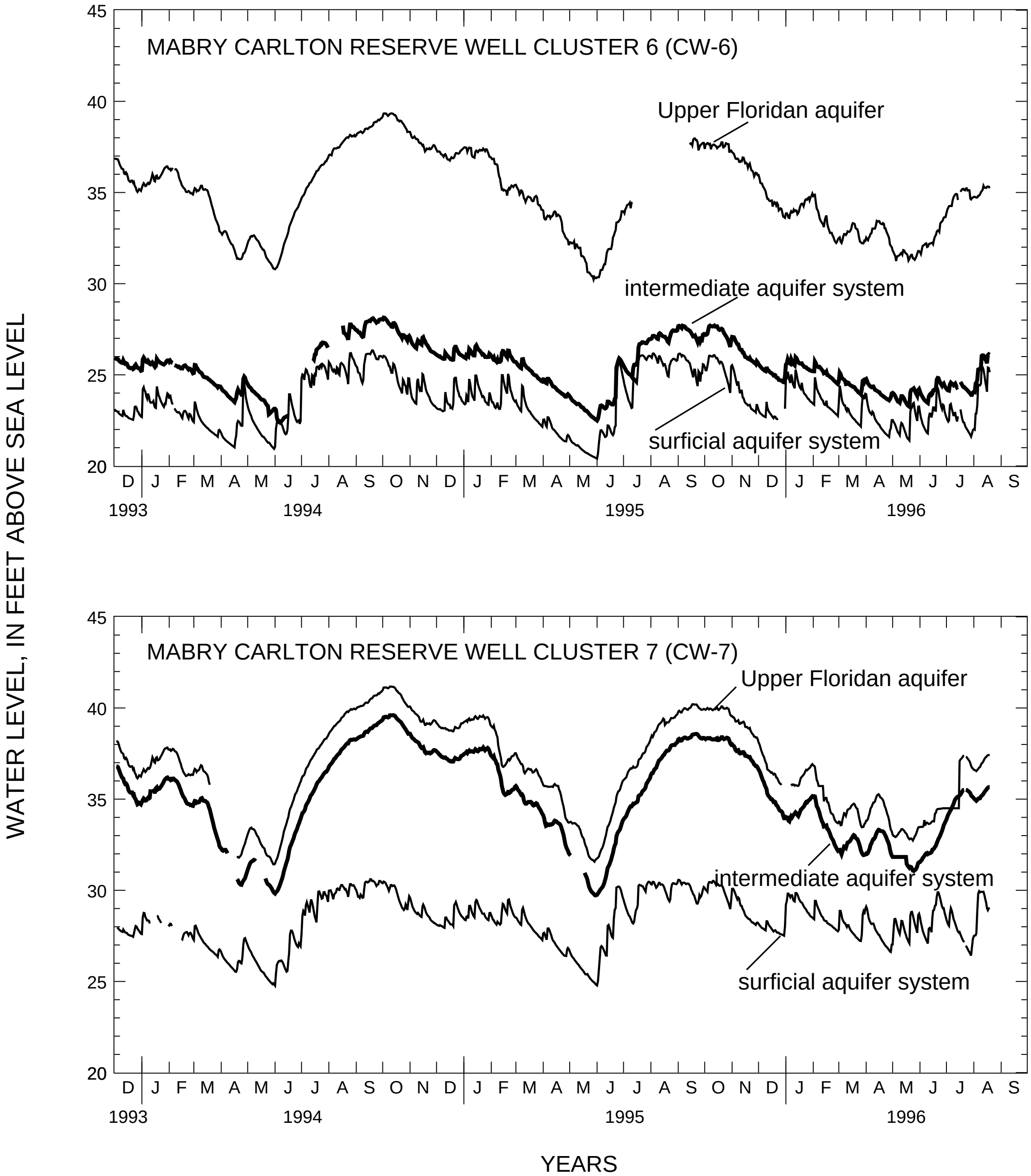


Figure 7. Composite potentiometric surface of the intermediate aquifer system, September, 1995. (Modified from Metz and others, 1996.)

difference between the hydrographs for the two sites is that inferred heads in the intermediate aquifer system are closer to the Upper Floridan aquifer heads at CW-7, and closer to the surficial aquifer heads at CW-6. Intermediate aquifer head values are controlled by the open-hole intervals of the wells penetrating the intermediate aquifer system. The well penetrating the intermediate aquifer system at CW-7 is open from 100 to 250 ft, and at CW-6 the well is open from 41 to 210 ft.

The altitude of the composite potentiometric surface of the intermediate aquifer system in the study area ranges from about 5 ft to more than 40 ft above sea level (Metz and others, 1996). Heads generally increase with aquifer depth; however, localized head-gradient reversals occur in the study area, coinciding with sites of intense ground-water withdrawals. Relatively large water-level differences (ranging from 5-10 ft) between water-producing zones indicate hydraulic separation of the zones; however, water-level trends are similar between the producing zones, indicating that the aquifers are interconnected or affected by the same stresses (Hutchinson, 1992).

Water-level data from wells penetrating the three water-producing zones in the intermediate aquifer system are shown in figures 9-11. Generally, water levels increase inland. Water levels in wells open to PZ1, PZ2, and PZ3 range from 1 to 23 ft, from 0.2 to 34 ft, and from 7 to 42 ft above sea level, respectively. These water levels were not contoured because the data were not collected synoptically.



Note: Breaks in hydrograph line indicate missing data. Well information and locations are in the U.S. Geological Survey Water-Data Report FL-96-3B (1997).

Figure 8. Water-level hydrographs for two well clusters in the Mabry Carlton Reserve well field.

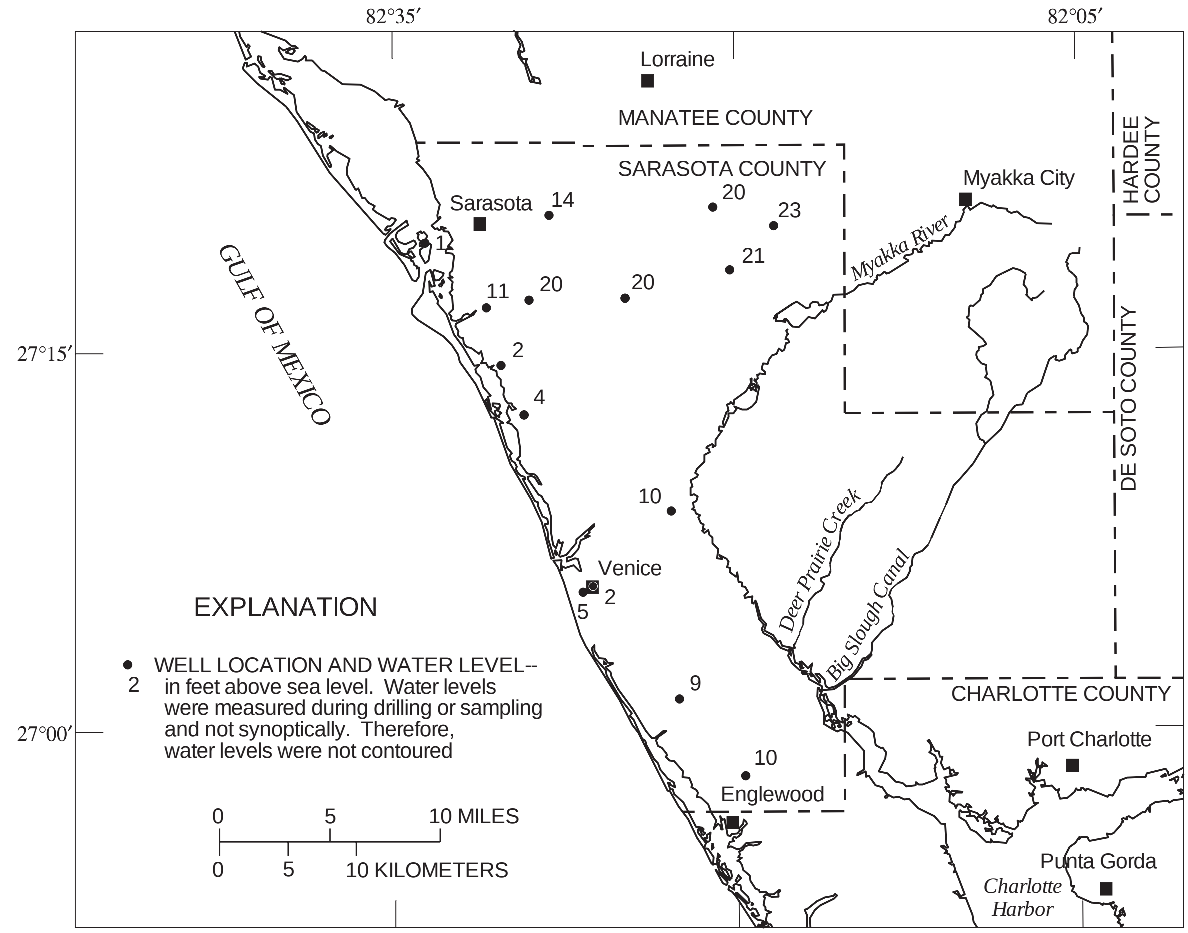


Figure 9. Water levels in wells open to producing zone 1.

An upward head gradient exists between the Upper Floridan aquifer and the intermediate aquifer system and between the intermediate aquifer system and the surficial aquifer system. Within the intermediate aquifer system, an upward head gradient exists between PZ3 and PZ2; however, an upward head gradient between PZ2 and PZ1 does not occur consistently throughout Sarasota County (fig. 12). A downward head gradient exists between PZ1 and PZ2 in the vicinity of the City of Sarasota downtown and the Englewood well fields. These gradients are probably due to ground-water withdrawals from PZ2, resulting in the lowering of water levels in PZ2. The direction and magnitude of the head gradients among the water-producing zones within the intermediate aquifer system are shown in figure 13.

Hydrographs of USGS ground-water data-network sites that are open to a discrete water-producing zone in the intermediate aquifer system are indicative of spatially varying temporal changes (or lack thereof) within the intermediate aquifer system (fig. 14). Water-level hydrographs from the three coastal wells show long-term head declines. The ROMP TR6-1 and Manasota 14 wells are open to PZ3 and the Osprey 9 well is open to PZ2, indicating that in coastal areas both PZ2 and PZ3 may be experiencing head declines. The declines are likely the result of increased ground-water pumpage due to population growth and urban development along the coast. Water-level hydrographs

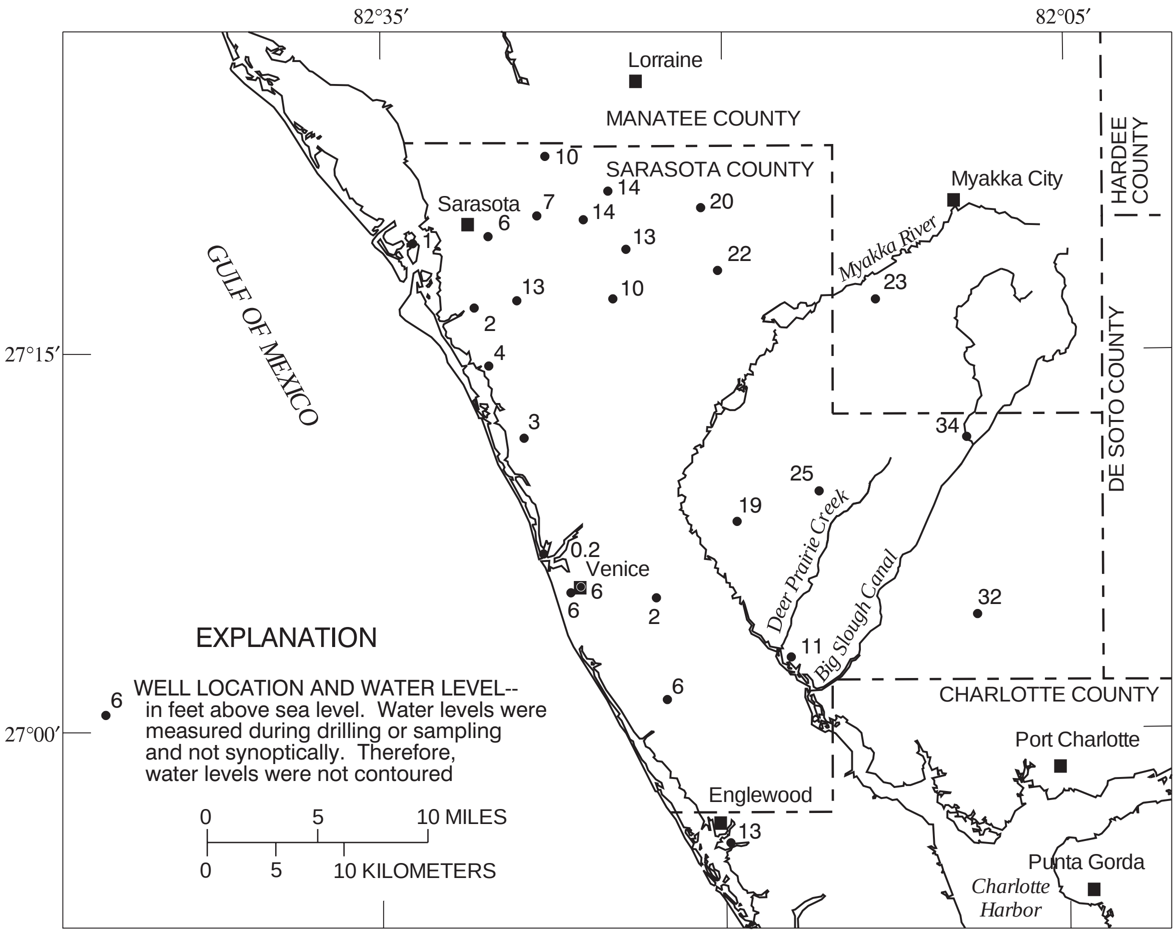


Figure 10. Water levels in wells open to producing zone 2.

from Mabry Carlton 6 (PZ3 monitor) and Big Slough (PZ2 monitor) wells do not indicate declines. The water-level hydrograph from the KME 14A well (PZ2 monitor) indicates an increase in head. The water-level rise at the KME 14A well (located at the Verna well field water plant) is probably the result of reduced pumping (3 Bgal/yr in 1980 compared to 1.5 Bgal/yr in 1994) from the Verna well field.

Estimates of Transmissivity

The transmissivity values for the intermediate aquifer system vary spatially in the study area. This variability is the result of lithologic heterogeneity and solution conduit development within carbonate units rather than the result of aquifer thickness. Transmissivity values for the intermediate aquifer system, reported from aquifer tests, range from less than 100 to 13,000 ft^2/d (Ryder, 1982). Transmissivities determined from aquifer tests for the intermediate aquifer system vary widely because: (1) some wells intersect locally occurring solution conduits whereas others do not, (2) older wells may have corroded casings or collapses within the open borehole affecting the well efficiency, and (3) the hydrogeologic framework (the presence of karst features) makes the application of standard methods of aquifer-test analysis uncertain. Results of aquifer tests for specific water-producing zones are:

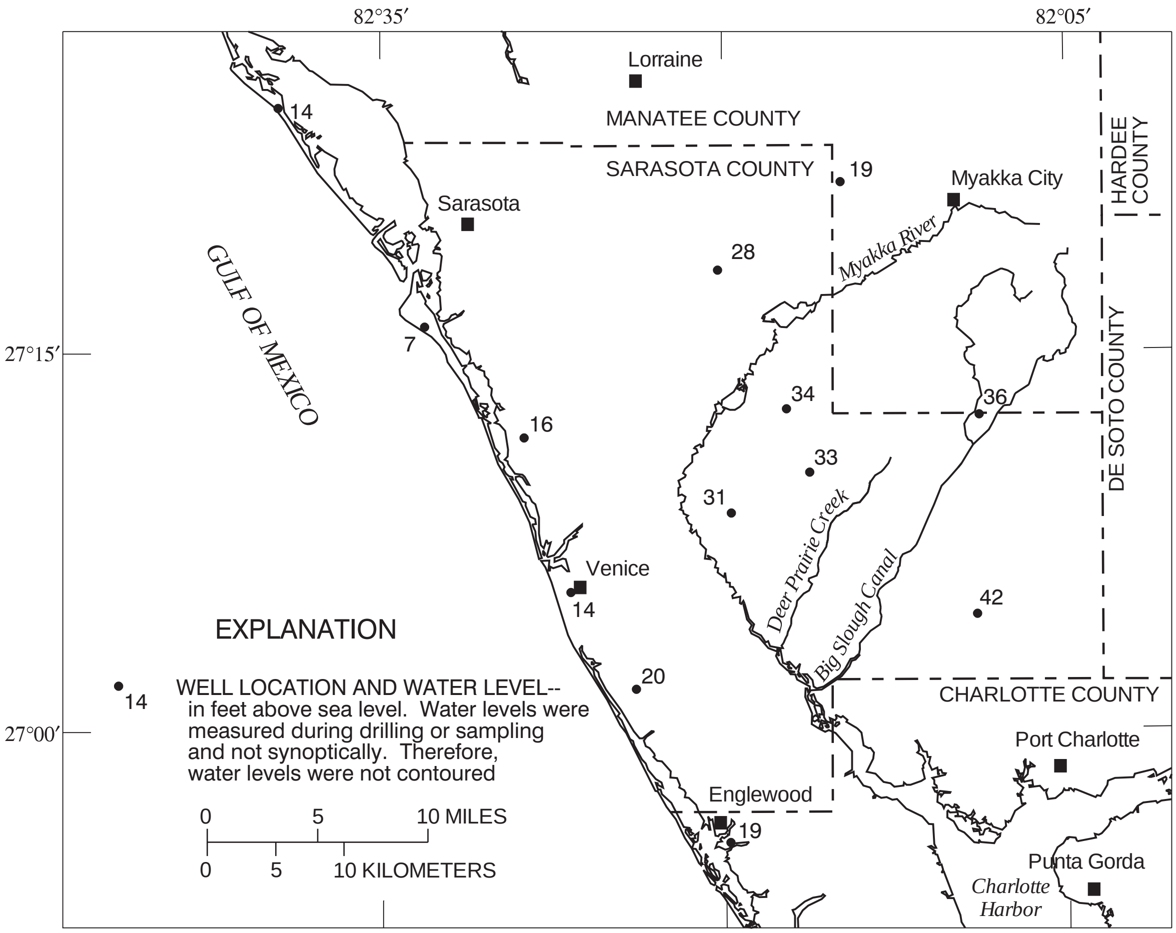


Figure 11. Water levels in wells open to producing zone 3.

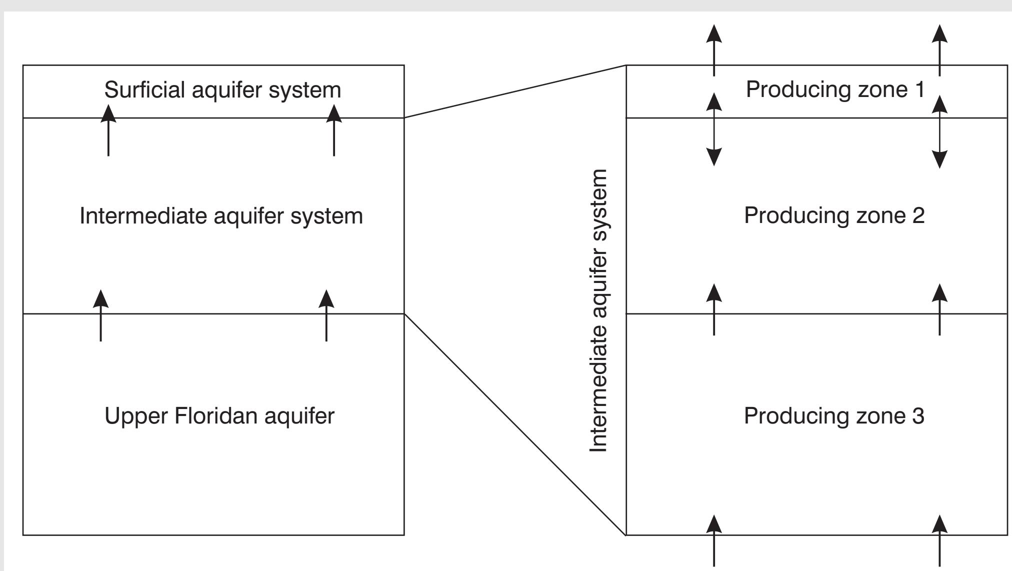
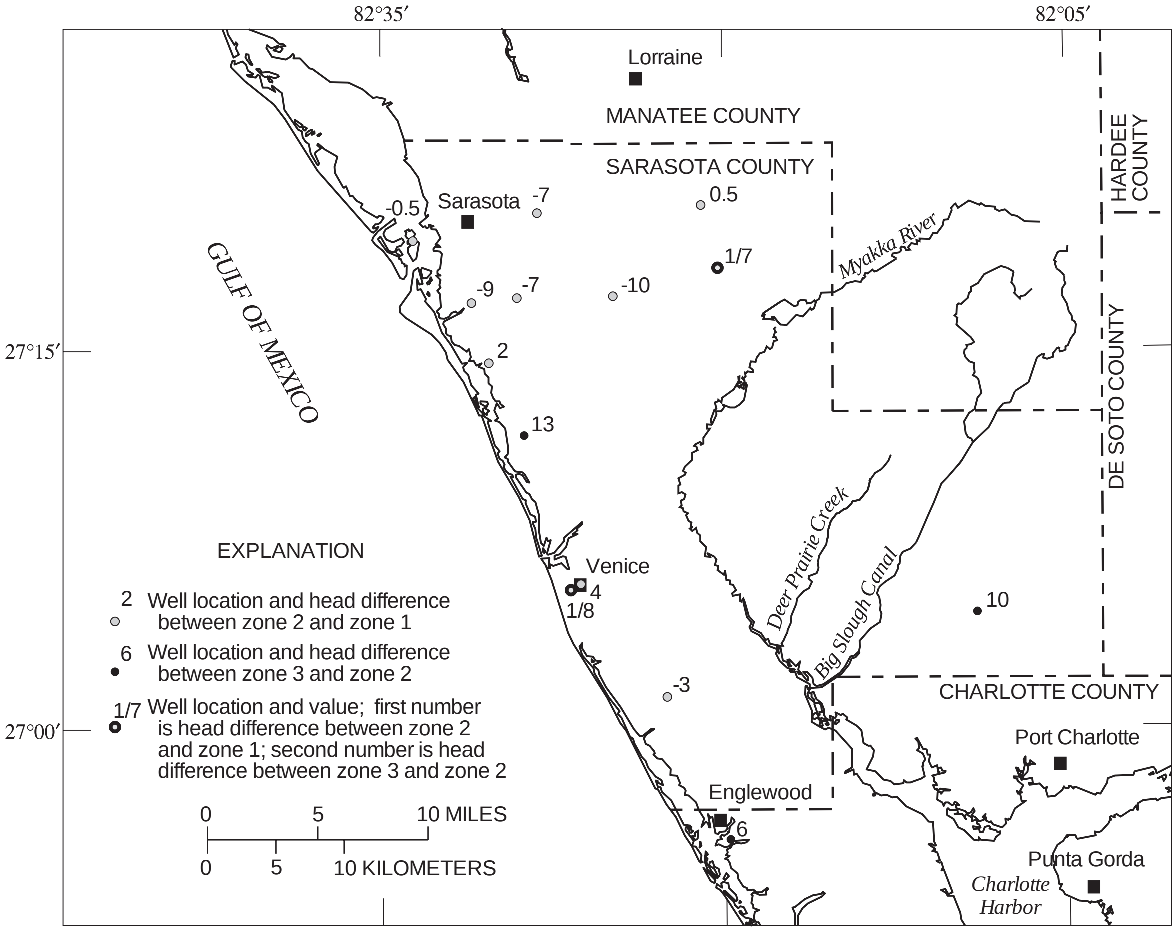


Figure 12. Head gradients among the aquifer systems and within the intermediate aquifer system.



Note: Negative numbers indicate a downward head gradient and positive numbers indicate an upward head gradient.

Figure 13. Head differences among the producing zones.

Zone 1—
T = 1,100 to 8,000 ft^2/d (Barr, 1996, p. 12)
8,000 ft^2/d (Duerr and others, 1988, p. 21)

Zone 2—
T = 200 to 5,000 ft^2/d (Barr, 1996, p. 12)
740 and 2,400 ft^2/d (Duerr and others, 1988, p. 21)
500 to 3,500 ft^2/d (Wolansky, 1983)

Zone 3—
T = 5,600 to 15,400 ft^2/d (Barr, 1996, p. 12)
500 to 10,000 ft^2/d (Wolansky, 1983)

Table 2 lists reported transmissivity values compiled by SWFWMD (1994) from aquifer tests.

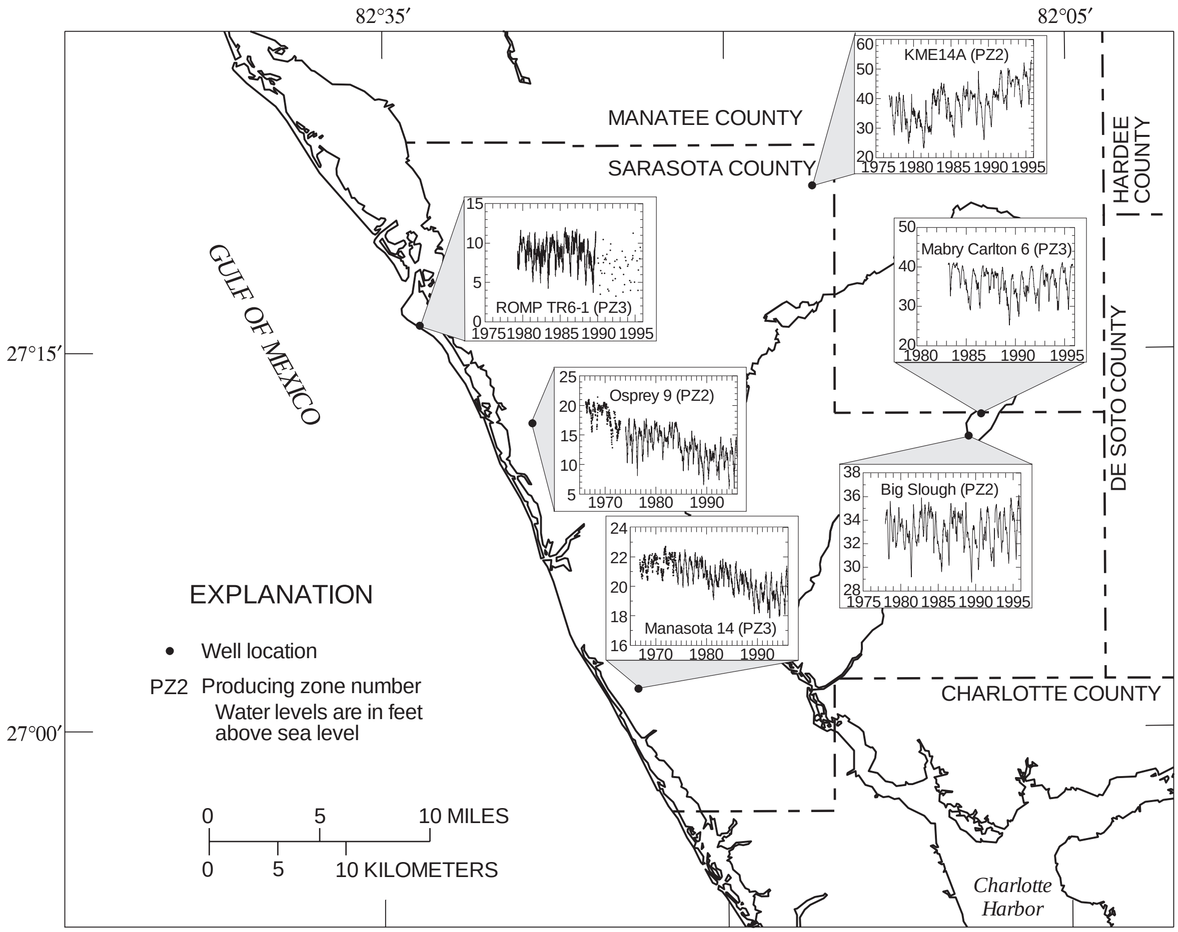
As part of this study, specific-capacity tests were conducted whenever possible. Transmissivity values in gallons per day per foot were estimated using the equation (Driscoll, 1986, p. 1021):

$$T = Q/s \times (2{,}000) \qquad (1)$$

where,

T is transmissivity, in gallons per day per foot;
Q/s is specific capacity, in gallons per minute per foot; and
2,000 is a constant for unit conversion.

The transmissivity values computed from Driscoll's equation were converted to consistent units of feet squared per day.



Note: Well information and locations are in the U.S. Geological Survey Water-Data Report FL-96-3B (1997).

Figure 14. Long-term water-level hydrographs for selected network wells.

Estimated values of transmissivity from 18 specific-capacity tests range from about 100 to 26,000 ft^2/d for PZ2. The lowest and highest values are from wells in close proximity (fig. 15). Estimated values of transmissivity from four specific-capacity tests range from about 1,300 to 6,200 ft^2/d for PZ3 (fig. 15). Results indicate that productivity of specific water-producing zones within the intermediate aquifer system is highly variable from site to site. The estimated transmissivity range from data collected during this study is an order of magnitude less than published values from previous studies. This variability could be a result of well losses, aquifer heterogeneity, and well penetration depths. Locations of fractures and solution-enhanced conduits create contrasts in hydraulic properties arising from the differences between wells penetrating zones of numerous, open, well-connected fractures and wells penetrating zones of sparse, tight, poorly connected fractures.

Table 2. Reported transmissivity values for the intermediate aquifer system

[From the Southwest Florida Water Management District, 1994]

Name	Index number*	Transmissivity (feet squared per day)	Depth/casing (feet below land surface)
Verna well 3A	28	740	106/100
Verna	29	2,000	440/91
No name**	30	1,870	-----
ROMP 20 TUH	32	1,740	125/75
ROMP 20 HTRN	32	17,400	370/250
Southbay Utilities	33	5,000	100/60
Southbay Utilities	33	13,000	450/223
Palmer Ranch Wellfield	34	1,200	200/63
ROMP TR5-2 TUH	35	5,000	100/60
ROMP TR5-2 HTRN	35	10,000	410/240
ROMP TR5-2 Tampa	35	17,000	480/60
Waterford Development	36	8,000	320/197
MacTract West (now MCR)	37	2,700	205/81
ROMP 18	38	2,100	-----
City of Venice	40	13,000	400/265
Venice well 31 (PZ2)	41	800	110/29
Venice well 31 (PZ1)	41	1,100	59/42
Venice well 31 (PZ3)	41	15,000	456/221
City of Venice	42	500	155/92
Venice Gardens TPVG-1	43	700	160/60
Venice well 9S (pumped well)	44	1,100	59/42
Venice well 9S (observation)	44	800	110/29
Venice well 2	44	500	140/77
No name**	45	1,800	-----
Venice RO-6	45	15,000	441/206
Venice Gardens TP-49	46	400	160/61
Plantation well	47	300	200/60
Plantation RO test well 2	47	5,600	366/228
The Plantation	47	5,600	380/242
Plantation	47	300	180/68
Venice Gardens MWVG-1	48	655	160/61
Manatee Jr. College south	49	200	270/110
Englewood Prod. 1	51	3,000	70/43
Englewood Prod. 4	51	3,300	70/35
Englewood Test C-10	51	3,800	70/42
Englewood Prod. 5	51	1,500	70/35
Englewood Prod. 3	51	1,600	70/42
Englewood	52	2,700	-----
Englewood Prod. 2	52	1,300	75/31
Englewood Prod. 9	53	5,500	55/49
Englewood well 27	55	7,800	40/25
Englewood well 9	55	5,500	55/49
Englewood RO-1	55	8,200	425/260
Gasparilla Pines (Fiveland)	60	1,000	250/200

* From SWFWMD report.
** No name listed in SWFWMD report.

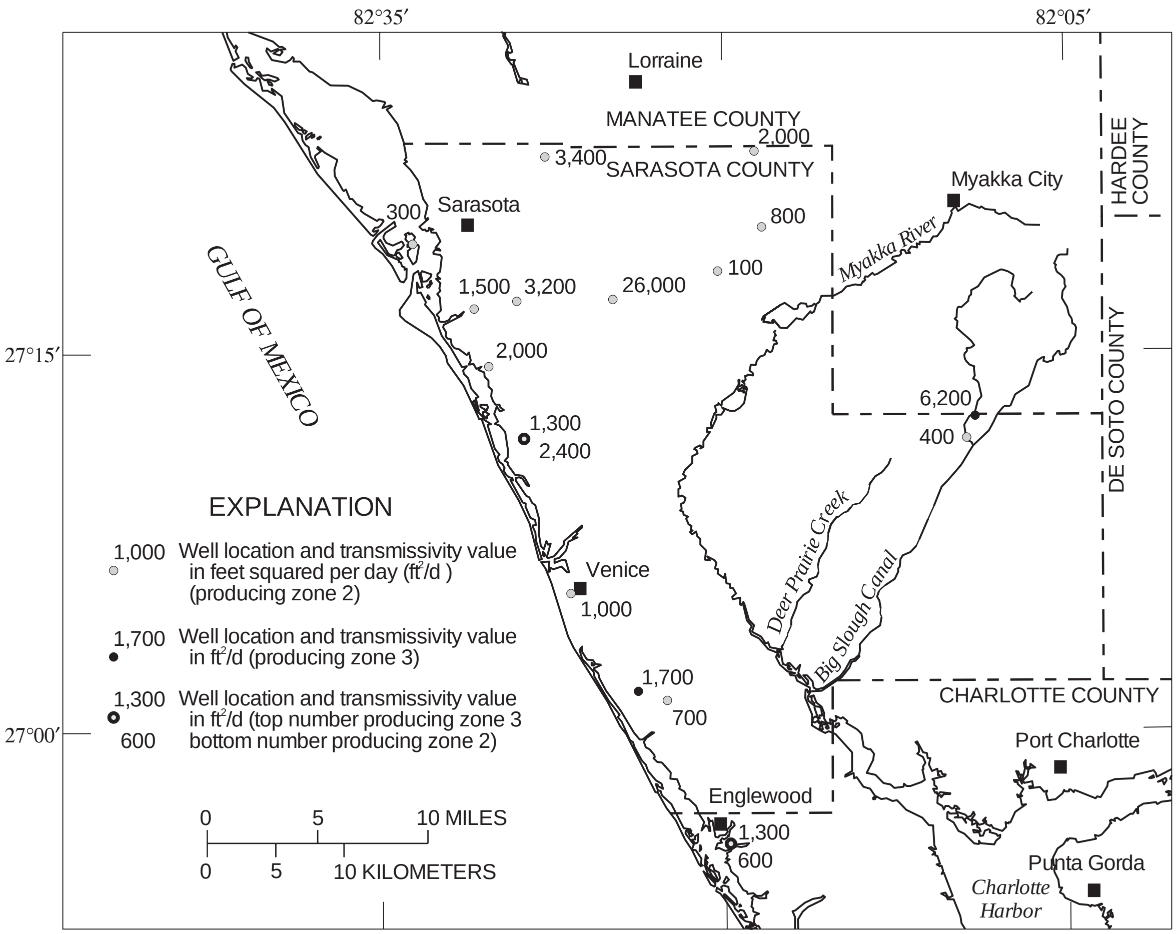


Figure 15. Distribution of transmissivity values estimated from specific-capacity data from producing zones 2 and 3 of the intermediate aquifer system.

WATER QUALITY

The intermediate aquifer system is an important water source in the study area, because the water is less mineralized than that in the underlying Upper Floridan aquifer. Thus, many private and public-supply wells are completed in the intermediate aquifer system. Irrigation and public-supply wells are commonly open to both the intermediate aquifer system and the Upper Floridan aquifer, to optimize well yields (Broska and Knochenmus, 1996). However, this practice is not encouraged, because more mineralized water from the Upper Floridan aquifer can move up the borehole, thereby degrading the water quality of the intermediate aquifer system (Metz and Brendle, 1996). Near the coast, the intermediate aquifer system has been developed as a public supply for coastal communities such as Sarasota, Venice, and Englewood. Mineralized water pumped from deeper water-producing zones in the intermediate aquifer system is treated by reverse-osmosis (Wolansky, 1983; Broska and Knochenmus, 1996).

The chemical composition of water in the intermediate aquifer system is controlled by differences in the composition and solubility of aquifer material and by the quality of water entering the intermediate aquifer system from other aquifers. Three types of ground water occur in the study area (Sacks and Tihansky, 1996). The first type generally occurs in inland areas and ranges in composition from bicarbonate to mixed-ion type water. Bicarbonate water is the typical composition of ground water in the intermediate aquifer system and the Upper Floridan aquifer. Mixed-ion type water contains elevated sodium and chloride concentrations and could be the result of evaporative concentration prior to recharge. Much of the land surface in areas where chloride concentrations are elevated, such as in southeastern Sarasota County, has standing water during the rainy season because of poorly drained soils and low topographic relief (Sacks and Tihansky, 1996, p. 33). This water evaporates during drier periods, increasing the ion content of the water. The second ground-water type is enriched in calcium, magnesium, and sulfate and is very similar in composition to the dedolomitization waters from the Upper Floridan aquifer. Generally, these waters are in coastal Sarasota County where water discharges from the Upper Floridan aquifer, but also may occur in isolated inland locations. The third ground-water type, dominated by sodium and chloride, occurs in southwestern Sarasota and northwestern Charlotte Counties. Here, elevated chloride concentrations are probably the result of mixing with unflushed relict water from previous seawater inundations (Sacks and Tihansky, 1996, p. 34).

Table 3. Specific-conductance data from the intermediate aquifer system water-producing zones

[Number corresponds to number shown in fig. 2; Specific conductance in microsiemens per centimeter at 25 degrees Celsius]

Producing Zone 1		Producing Zone 2		Producing Zone 3	
Number	Specific conductance	Number	Specific conductance	Number	Specific conductance
6	1,310	2	516	1	2,490
7	1,040	3	400	4	445
9	512	4	530	22	3,380
10	545	5	788	25	-----
11	673	6	715	27	923
12	2,880	7	1,000	28	2,640
15	655	8	700	30	1,440
16	976	10	552	34	-----
17	738	11	904	35	1,332
19	800	12	790	36	1,710
20	1,500	13	617	40	2,920
23	-----	14	1,383	42	2,310
24	869	15	1,074	46	594
26	820	16	1,056	50	8,940
31	2,730	17	959		
33	2,150	18	570		
38	396	20	892		
39	2,420	21	838		
40	1,440	24	1,065		
45	925	28	1,740		
47	1,165	29	950		
48	2,610	31	2,790		
49	1,720	32	715		
		35	782		
		37	3,720		
		38	1,510		
		39	2,420		
		40	1,300		
		41	3,500		
		42	1,980		
		43	919		
		44	4,720		
		47	2,910		
		50	3,360		

Water samples were collected from existing wells and wells drilled during this study. Field specific-conductance values are listed in table 3. Major-ion concentrations are listed in the appendix. The samples were analyzed for major-ion concentrations and the concentrations, converted to milliequivalents per liter, were plotted as Stiff diagrams. Stiff diagrams have three parallel horizontal axes extending on each side of a vertical zero axis (fig. 16). The concentrations of three cations (sodium and potassium, Na+K; calcium, Ca; and magnesium, Mg) are plotted one on each axis to the left of zero. The concentrations of three anions (chloride, Cl; bicarbonate, HCO_3; and sulfate, SO_4) are plotted one on each axis to the right of zero. The resulting six points are connected to give

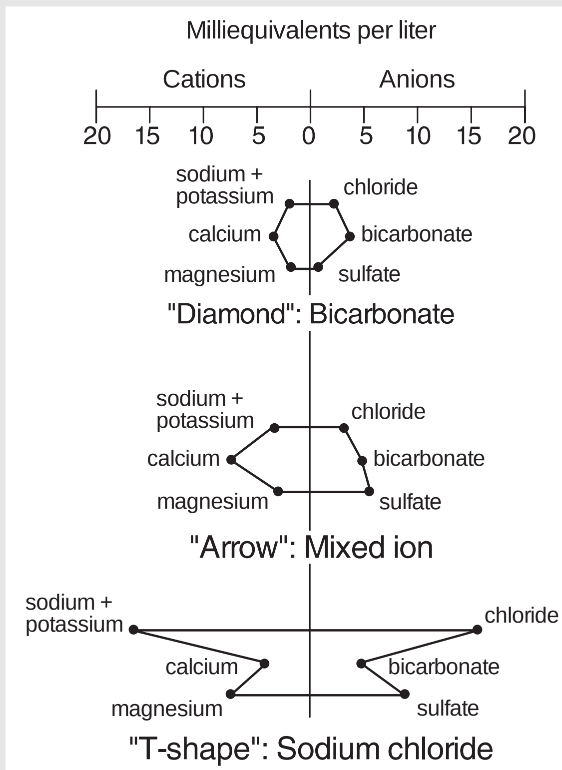


Figure 16. Stiff diagrams for three water types typically occurring in the intermediate aquifer system.

a polygon shape. Comparing shapes of the Stiff diagrams can be used to show water-composition differences. For example, a "diamond" shape indicates calcium bicarbonate type water; an "arrow" or "bowtie" shape indicates mixed-ion type water; and a "T" shape indicates sodium-chloride type water (fig. 16). The width or size of the diagram is an approximate indication of total ionic content (Hem, 1985, p. 175). Stiff diagrams can be used to indicate the areal distribution of water types and relative concentrations of ions in the ground water throughout the study area.

Multiple water types occur in PZ1 (fig. 17). Bicarbonate and mixed-ion type water occurs in inland areas of northern Sarasota County, (wells, 6, 7, 9, 10, 15, 16, 17, 19, and 23) and in wells 45 and 47 in southern Sarasota County. Along the Gulf Coast, the water types range from low ionic-strength bicarbonate (wells, 24, 26, and 38) to an enriched calcium-magnesium-sulfate type water caused by upwelling from deeper water-producing zones (wells 31 and 33) to a sodium-chloride type water characteristic of saltwater mixing (wells 12, 20, 48, and 49). The specific conductance ranged from 396 to 2,880 µS/cm.

Multiple water types also occur in PZ2 (fig. 18). Bicarbonate and mixed-ion type water occurs in PZ2 in most of northern Sarasota County, including the coastal area (wells 2-8, 10-13, 15-18, 20, 21, and 24), and in wells 32 and 35 in central Sarasota County. Enriched calcium-magnesium-sulfate type water occurs in central Sarasota County (wells 28, 31, and 37-41). Sodium-chloride type water occurs in PZ2 throughout the southern and southeastern parts of Sarasota County (wells 42-44, 47, and 50).

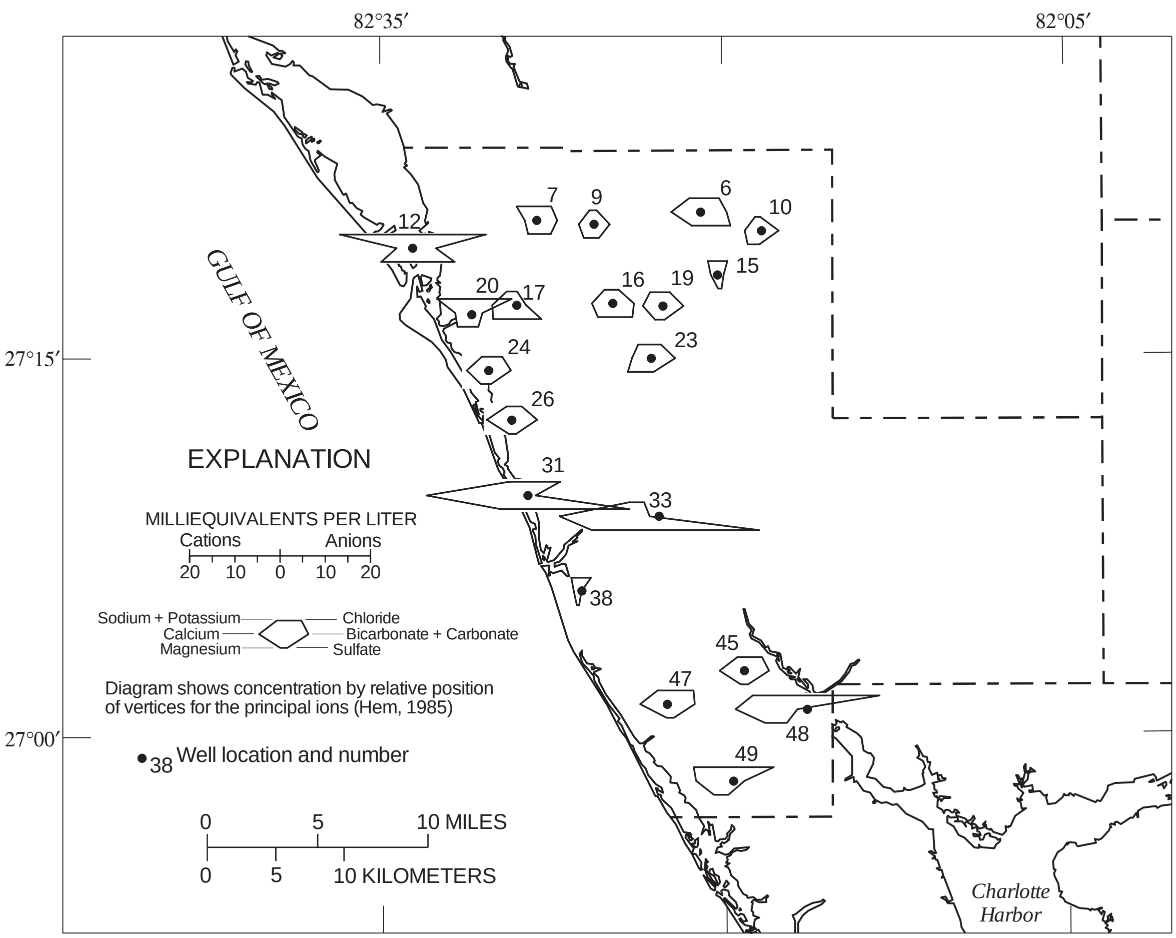


Figure 17. Major-ion concentrations in water from wells open to producing zone 1.

Generally, major-ion concentrations in water from wells open to PZ2 in central and southern Sarasota County are greater than water from wells penetrating PZ1; however, Stiff diagram sizes indicate that water is less mineralized in PZ2 than in PZ1 in the northern coastal wells 12 and 20 and north-central wells 6, 10, and 17. Specific conductance ranged from 400 to 4,720 μS/cm.

Although fewer wells are completed in PZ3, multiple water types also occur in PZ3 (fig. 19). Data from wells completed only in PZ3 are more sparse, because wells typically are completed in both PZ3 and the Upper Floridan aquifer. Only one well sampled during this study contained bicarbonate type water (well 4). Enriched calcium-magnesium-sulfate type water occurs in central Sarasota County (wells 28, 30, 35, and 36). Sodium-chloride type water in PZ3 occurs in southeastern Sarasota County and northwestern Charlotte County (wells 42 and 50). Generally, water samples from wells open to PZ3 contained more mineralized water than samples from PZ2 and PZ1. Specific conductance ranged from 445 to 8,940 μS/cm.

There is considerable variability in the major-ion composition of ground water from the water-producing zones within the intermediate aquifer system. A distinct geochemical signature for characterizing individual water-producing zones is not apparent. This is probably related to the heterogeneous lithology of the Hawthorn Group whose beds make up the intermediate aquifer system, the lack of continuity of the water-producing zones, and the water quality of the overlying surficial aquifer system and underlying Upper Floridan aquifer.

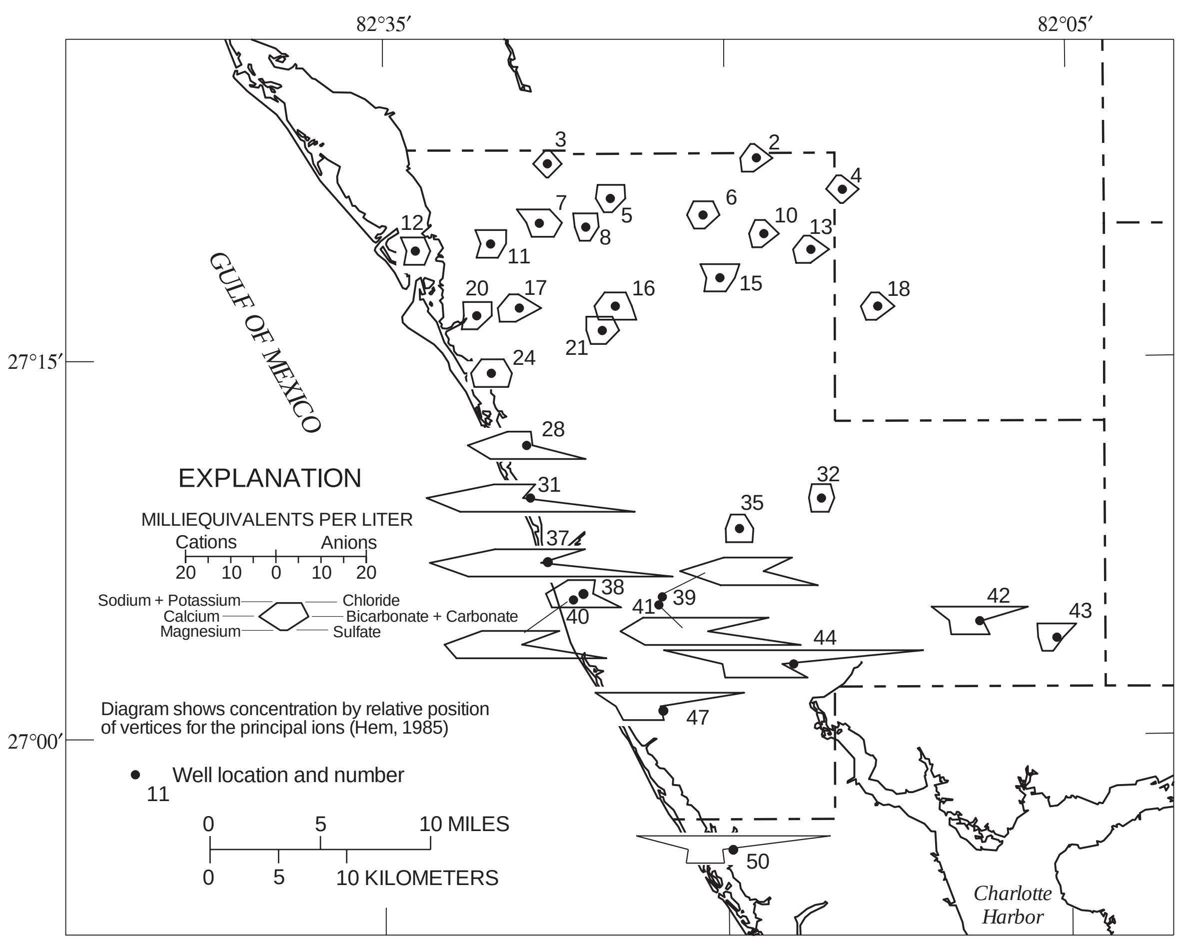


Figure 18. Major-ion concentrations in water from wells open to producing zone 2.

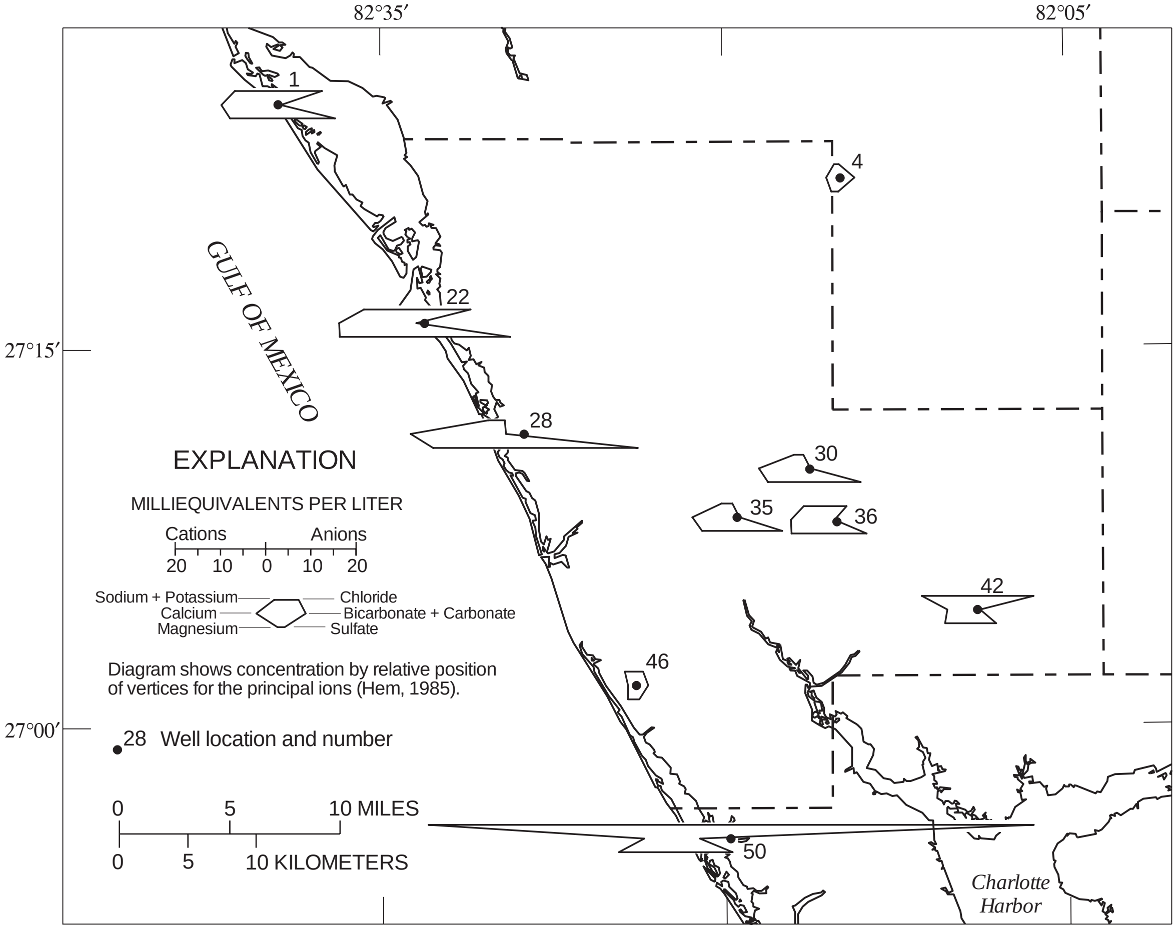


Figure 19. Major-ion concentrations in water from wells open to producing zone 3.

SUMMARY

The intermediate aquifer system, underlying Sarasota County, consists of a group of up to three water-producing zones. These zones are separated by less-permeable units that restrict the vertical movement of ground water between zones. However, discontinuities in the less-permeable units result in localized connection between water-producing zones. This report describes the variability in transmissivity and water quality among these three water-producing zones. The properties were assessed using water-level, specific-capacity, and water-quality data from 31 existing wells and 26 new supply wells. Data were evaluated for distinctions that could be used to characterize a particular producing zone.

The intermediate aquifer system is an important water source in the study area, because the water quality is usually better than that in the underlying Upper Floridan aquifer. Thus, many private and public-supply wells are completed in the intermediate aquifer system. The uppermost water-producing zone is designated PZ1, although it is not continuous throughout the study area. This discontinuous water-producing zone is less than 80 ft thick, and is not extensively used because of its limited production capability. The underlying water-producing zone is designated PZ2 and is continuous throughout the study area. Most of the domestic-supply wells are open to this zone. Additionally, it is utilized for public supply in southern coastal areas of Sarasota County. The third and lowermost water-producing zone is designated PZ3.

This water-producing zone is the most productive in the intermediate aquifer system. Public-supply well fields serving the cities of Sarasota and Venice, as well as the Plantation and Mabry Carlton Reserve well fields, utilize PZ3.

Throughout most of Sarasota County, an upward head gradient exists between the Upper Floridan aquifer and intermediate aquifer system. The water-level differences between these aquifers indicate that the intermediate aquifer system is recharged by upward leakage from the underlying Upper Floridan aquifer. Heads within the intermediate aquifer system generally increase with aquifer depth. However, localized head-gradient reversals occur in the study area coincident with localized, intense ground-water withdrawals. Water levels in PZ1 range from 1 to 23 ft, in PZ2 from 0.2 to 34 ft, and in PZ3 from 7 to 42 ft above sea level, respectively. Generally, an upward head gradient exists between PZ3 and PZ2. However, an upward head gradient between PZ2 and PZ1 does not consistently occur throughout Sarasota County. This is probably the result of high water pumpage from PZ2, resulting in the lowering of water levels in PZ2.

Water-level hydrographs from wells indicate that long-term water levels in wells along coastal Sarasota County have declined, in central Sarasota County they have not changed, and in the vicinity of Verna well field they have risen. The water-level declines are probably the result of increased pumpage due to population growth and urban development along the coast. The water-level rises are probably the result of reduced pumpage from the Verna well field.

The transmissivity of the intermediate aquifer system is spatially variable. This variability is probably due to lithologic heterogeneity and solution development within the aquifer. Specific-capacity data from PZ2 and PZ3 were used to estimate transmissivity. The estimated transmissivity values for PZ2 and PZ3 ranged from 100 to 26,000 ft^2/d and from 1,300 to 6,200 ft^2/d, respectively. Results indicate that productivity of specific water-producing zones within the intermediate aquifer system is highly variable from site to site. Additionally, the transmissivity range estimated from data collected during this study is an order of magnitude less than published values from previous studies. Therefore, it appears that productivity is not readily predictable for individual wells in the study area. Well productivity is related to the uneven distribution of fractures and solution-enhanced conduits; locations of fractures and solution-enhanced conduits create contrasts in transmissivity arising from the differences between wells penetrating zones of numerous, open, well-connected fractures and wells penetrating zones of sparse, tight, poorly connected fractures.

The chemical composition of water in the intermediate aquifer system is controlled by differences in the composition and solubility of aquifer material and by the quality of water entering the intermediate aquifer system from other aquifers. The water samples were analyzed for major-ion concentrations and the data were used to construct Stiff diagrams. Multiple water types occur in each of the water-producing zones. Bicarbonate type water from rock interaction occurs in northern Sarasota County; enriched calcium-magnesium-sulfate type water from deeper aquifers occurs in central Sarasota County; and sodium-chloride type water from saltwater mixing occurs in southern Sarasota County. In some areas of northern Sarasota County the water is less mineralized in PZ2 than in PZ1. Water is more mineralized in PZ3 than in the other two zones throughout the study area. A distinct geochemical signature for characterizing individual water-producing zones is not apparent. Evaluation of data indicates that both transmissivity and water-quality properties of individual zones are related more to the degree of interconnection between, and the areal extent of, water-producing zones than to aquifer depth and distance from the coast.

SELECTED REFERENCES

Barr, G.L., 1996, Hydrogeology of the surficial and intermediate aquifer systems in Sarasota and adjacent counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4063, 81 p.

Bentall, Ray, ed., 1963, Permeability, transmissibility, and drawdown: U.S. Geological Survey Water-Supply Paper 1536-I, 98 p.

Broska, J.C., and Knochenmus, L.A., 1996, Assessment of the hydrogeology and water quality in a near-shore well field, Sarasota, Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4036, 64 p.

Driscoll, F.G., 1986, Groundwater and wells: St. Paul, Minn., Johnson Filtration Systems, Inc., 1089 p.

Duerr, A.D., Hunn, J.D., Lewelling, B.R., and Trommer, J.T., 1988, Geohydrology and 1985 water withdrawals of the aquifer systems in southwest Florida, with emphasis on the intermediate aquifer system: U.S. Geological Survey Water-Resources Investigations Report 87-4259, 115 p.

Duerr, A.D., and Wolansky, R.M., 1986, Hydrogeology of the surficial and intermediate aquifers of central Sarasota County, Florida: U.S. Geological Survey Water-Resources Investigations Report 86-4068, 48 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hutchinson, C.B., 1992, Assessment of hydrogeologic conditions with emphasis on water quality and wastewater injection, southwest Sarasota and west Charlotte Counties, Florida: U.S. Geological Survey Water-Supply Paper 2371, 74 p.

Joyner, B.F., and Sutcliffe, Horace, Jr., 1976, Water resources of Myakka River basin area, southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 76-58, 87 p.

Metz, P.A., and Brendle, D.L., 1996, Potential for water-quality degradation of interconnected aquifers in west-central Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4030, 54 p.

Metz, P.A., Swenson, E.S., and Stelman, K.A., 1996, Potentiometric surfaces of the intermediate aquifer system, west-central Florida, September, 1995: U.S. Geological Survey Open-File Report 96-136, 1 sheet.

Ryder, P.D., 1982, Digital model of predevelopment flow in the Tertiary limestone (Floridan) aquifer system in west-central Florida: U.S. Geological Survey Water-Resources Investigations Report 81-54, 61 p.

------ 1985, Hydrology of the Floridan aquifer system in west-central Florida: U.S. Geological Survey Professional Paper 1403-F, 63 p.

Sacks, L.A., and Tihansky, A.B., 1996, Geochemical and isotopic composition of ground water, with emphasis on sources of sulfate, in the Upper Floridan aquifer and intermediate aquifer system in southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4146, 67 p.

Southwest Florida Water Management District, 1992, Water supply needs and sources 1990-2020: Brooksville, Fla., 322 p.

----- 1994, Aquifer characteristics within the Southwest Florida Water Management District: Brooksville, Fla., 30 p.

Sutcliffe, Horace, Jr., 1975, Appraisal of the water resources of Charlotte County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 78, 53 p.

Sutcliffe, Horace, Jr., and Joyner, B.F., 1968, Test well exploration in the Myakka River basin area, Florida: Tallahassee, Florida Geological Survey Information Circular 56, 61 p.

Sutcliffe, Horace, Jr., and Thompson, T.H., 1983, Occurrence and use of ground water in the Venice-Englewood area, Sarasota and Charlotte Counties, Florida: U.S. Geological Survey Open-File Report 82-700, 59 p.

U.S. Fish and Wildlife Service, 1985, Wetlands and deepwater habitats of Florida: U.S. Fish and Wildlife Service National Wetlands Inventory, 1 sheet.

U.S. Geological Survey, 1997, Water resources data Florida, water year 1996: U.S. Geological Survey Water-Data Report FL-96-3A, 183 p.

White, W.A., 1970, The geomorphology of the Florida Peninsula: Tallahassee, Florida Bureau of Geology Bulletin 51, 164 p.

Wolansky, R.M., 1983, Hydrogeology of the Sarasota-Port Charlotte area, Florida: U.S. Geological Survey Water-Resources Investigations Report 82-4089, 48 p.

Wood, W.W., 1976, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations, book 1, chap. D2, 24 p.

Appendix

Major-ion concentrations in water from selected wells

Appendix. Major-ion concentrations in water from selected wells

[No., number corresponds to number shown in figure 2; SD, sampling depth; DS, dissolved solids in milligrams per liter; SCond, specific conductance in microsiemens per centimeter; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Cl, chloride; SO_4, sulfate; F, fluoride; Si, silica; Sr, strontium; Alk, alkalinity; all ion concentrations except Sr in milligramsper liter; Sr concentrations micrograms per liter]

No.	Well Location No.	Well Name	Date	Time	SD	DS	SCond	Ca	Mg	Na	K	Cl	SO_4	F	Si	Sr	Alk
1	272443082392901	Longboat Key F.S.	5/26/95	0925	475	1,800	2,500	220	110	180	7.7	400	680	1.7	21	21,000	131
2	272257082183501	Verna Test 6-A	11/30/95	1215	99	306	513	57	30	13	1.2	11	5.6	0.3	27	260	263
3	272247082274601	Tim Thrower	4/4/95	0930	280	230	396	65	4.3	11	1.0	14	4.5	0.4	16	220	187
4	272141082144901	Rick Lewis	8/15/95	1200	140	322	523	63	22	19	1.9	7.1	29	0.6	21	740	249
4	272141082144901	Rick Lewis	8/17/95	1700	380	268	444	52	18	19	1.8	6.9	3.9	1.0	32	540	223
5	272123082250101	Racimo Ranch	7/12/95	1700	205	474	755	65	18	63	3.5	110	18	1.9	43	2,100	199
6	272042082205601	Tom Justice	8/22/95	1500	61	920	1,340	150	36	80	2.4	110	270	0.6	48	1,800	290
6	272042082205601	Tom Justice	8/24/95	1000	153	460	715	70	23	46	1.8	82	22	1.0	44	530	228
7	272025082280801	Mike Swartz	5/10/95	0800	50	632	1,040	61	28	110	3.2	100	130	0.4	17	240	254
7	272025082280801	Mike Swartz	5/10/95	1600	143	636	1,000	64	25	120	3.8	68	140	0.8	32	560	284
8	272016082260601	Fancee Farms	6/1/95	1300	235	420	703	50	17	64	3.0	90	44	2.0	34	1,400	174
9	272015082253801	Kim Elmenuani	2/8/96	1100	57	364	591	64	25	18	1.9	27	61	0.4	16	480	223
10	271957082181701	Tracy Fultz	1/18/96	1700	40	348	545	61	29	17	1.3	14	9.8	0.5	23	290	273
10	271957082181701	Tracy Fultz	1/23/96	1225	70	358	552	54	24	30	2.1	30	5.9	1.3	40	740	240
11	271937082301701	Lord	7/14/95	1600	190	568	904	46	39	75	8.3	120	74	3.6	50	2,800	205
12	271920082333501	Guy Boyler	9/29/95	1400	38	1,760	2,880	79	89	350	48.0	560	430	1.4	27	4,800	293
12	271920082333501	Guy Boyler	10/5/95	1640	275	490	790	40	31	70	9.7	68	96	3.2	46	4,400	199
13	271919082161301	Jerry Cantwell	11/30/95	1430	80	372	617	67	32	21	1.3	16	27	0.6	24	480	284
15	271813082201303	ROMP 22 (L IAS)	6/12/96	1430	230	620	1,060	56	40	92	5.2	160	72	3.7	44	8,600	214
15	271813082201304	ROMP 22 (U IAS)	6/12/96	1335	90	254	589	34	0.9	47	10.0	70	34	0.7	0.3	1,300	70
16	271707082244901	Kazmark	3/30/95	1200	65	654	968	96	42	45	2.4	40	200	0.6	24	620	275
16	271707082244901	Kazmark	3/31/95	1045	130	710	1,050	94	46	54	2.5	80	220	1.0	29	2,600	218
17	271704082290201	Francis Crum	1/25/96	0800	41	464	738	75	40	27	1.1	30	11	0.4	20	280	358
17	271704082290201	Francis Crum	1/26/96	1015	50	768	959	93	54	31	3.5	30	300	0.9	33	7,000	172
18	271703082131801	Chris Houser	7/7/95	1340	162	354	555	66	26	22	1.9	26	5.9	1.0	43	810	255
19	271700082223701	Pete Bosarino	2/13/96	1600	40	472	782	83	18	58	1.7	62	32	0.8	23	670	294
20	271646082305401	Ray Newton	10/17/95	0727	110	912	1,500	69	36	170	1.7	320	80	0.4	15	100	156
20	271646082305401	Ray Newton	10/23/95	1130	223	502	892	50	38	58	5.2	130	24	2.3	47	2,500	225
21	271609082252401	Thompson Foxfire	6/7/95	1245	147	502	838	64	27	73	1.2	90	54	0.3	20	170	247
22	271601082330501	ROMP TR 6-1	6/22/95	1420	300	2,680	3,380	300	180	210	14.0	500	1,100	1.7	23	25,000	129
24	271429082301701	Spano	4/4/95	1500	25	572	867	100	23	43	1.8	100	17	0.6	22	500	288

Appendix. Major-ion concentrations in water from selected wells (Continued)

[No., number corresponds to number shown in figure 2; SD, sampling depth; DS, dissolved solids in milligrams per liter; SCond, specific conductance in microsiemens per centimeter; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Cl, chloride; SO_4, sulfate; F, fluoride; Si, silica; Sr, strontium; Alk, alkalinity; all ion concentrations except Sr in milligramsper liter; Sr concentrations micrograms per liter]

No.	Well Location No.	Well Name	Date	Time	SD	DS	SCond	Ca	Mg	Na	K	Cl	SO_4	F	Si	Sr	Alk
24	271429082301701	Spano	4/5/95	1530	120	706	1,050	94	48	57	4.7	90	170	1.4	43	1,300	266
26	271231082291701	Larry Jayne	1/15/96	1200	22	524	806	120	14	36	2.0	62	24	0.4	15	520	313
26	271231082291701	Larry Jayne	1/17/96	1505	52	640	953	92	34	60	4.1	98	100	0.9	36	720	244
27	271227082084801	Mabry Carlton 6	1/29/96	1145	311	644	920	90	47	31	3.2	48	230	1.8	26	12000	190
28	271137082284502	ROMP 20 (HTRN)	11/20/95	1050	250	2,510	2,640	380	170	38	5.0	65	1,500	1.5	23	16,000	128
28	271137082284503	ROMP 20 (TUH)	11/9/95	1025	125	1,380	1,740	230	79	58	5.8	88	700	0.6	31	4,900	173
29	271134082092201	Big Slough Deep	1/30/96	1240	78	608	948	70	25	92	1.5	100	72	1.3	40	1,200	257
30	271011082161501	MCR 13 Series	6/22/95	1022	327	1,190	1,440	180	85	26	3.5	30	650	1.3	25	15,000	146
31	270931082283501	Ron Stogner	2/7/96	1200	41	2,180	2,650	440	68	82	4.7	270	1,100	0.3	16	1,900	131
31	270931082283501	Ron Stogner	2/7/96	1600	62	2,430	2,760	380	140	89	7.7	180	1,300	0.6	26	13,000	146
32	270926082155104	MCR (14DN)	6/12/96	1122	70	434	707	56	27	47	3.2	71	76	2.6	30	4,100	174
35	270816082192602	MCR (3E)	6/11/96	1307	65	510	771	60	35	39	6.0	44	140	2.9	45	4,700	191
35	270816082192604	MCR (3H)	6/11/96	1330	264	1,050	1330	160	71	33	4.0	30	570	1.9	25	9,500	146
36	270808082152602	MCR 14GS	6/12/96	1055	275	1,170	1,710	140	83	92	4.8	190	470	1.7	24	10,000	163
37	270656082274201	Little Bear	12/7/95	1600	64	3,120	3,720	450	170	180	7.6	420	1,500	0.8	26	14,000	132
38	270542082261801	Venice 35	10/13/95	1030	163	1,120	1,510	150	75	56	6.7	120	440	0.7	33	3,600	179
38	270542082261802	Venice 36	10/13/95	1230	70	244	396	23	6	38	1.9	94	0.9	0.1	0.8	410	33
39	270515082225901	Parrish Sugarwood	8/2/95	1000	111	2,670	3,590	340	140	270	9.1	560	1,100	0.2	19	13,000	145
39	270534082225001	Peter DeCarlo	7/31/95	1400	43	1,780	2,440	310	79	130	5.2	330	720	0.4	19	7,600	183
42	270432082085703	ROMP 9 (LH)	9/26/95	0920	190	1,380	2,310	100	67	240	8.7	500	280	1.4	19	21,000	138
42	270432082085704	ROMP 9 (UH)	9/26/95	0915	122	1,150	1,980	100	55	200	7.4	440	190	1.3	17	13,000	148
43	270351082053501	Vernon Veach	9/26/95	1130	180	540	919	61	26	73	3.5	190	12	1.4	16	5,200	154
44	270252082170701	Lazy River Estates	9/26/95	1245	130	968	4,680	210	120	530	14.0	1,200	400	0.5	18	19,000	165
45	270231082191001	Manatee Jr. College	9/27/95	1000	45	584	927	120	16	46	1.8	120	13	0.5	21	1,700	301
46	270137082235301	Manasota 14 deep	11/8/95	1110	305	334	594	34	21	51	6.9	58	39	3.6	19	4,000	169
47	270113082223301	Deep Zone 5	10/19/95	1200	132	1,690	2,950	150	71	270	11.0	740	150	0.6	41	12,000	145
47	270113082223302	Englewood Prod 5	11/6/95	1200	70	718	1,170	140	14	71	1.5	170	22	0.2	20	780	310
48	270059082162501	George Campbell	9/27/95	1115	50	1,830	2,610	220	54	160	8.4	740	19	0.6	28	9,900	165
49	265809082194001	Englewood Test 6	9/27/95	1230	65	1,040	1,720	130	31	160	1.7	380	31	0.1	16	1,400	260
50	265531082194804	ROMP TR3-3 (LH)	11/2/95	1300	410	5,270	8,940	200	190	1,300	46.0	2,700	460	1.2	14	26,000	140
50	265531082194805	ROMP TR3-3 (UH)	11/2/95	1145	175	2,040	3,360	110	72	380	18.0	920	120	0.8	16	11,000	128