EVALUATION OF METHODOLOGY FOR DELINEATION OF PROTECTION ZONES AROUND PUBLIC-SUPPLY WELLS IN WEST-CENTRAL FLORIDA

By John Vecchioli, James D. Hunn, and Walter R. Aucott

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ABBREVIATIONS AND CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, conversion factors for terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
square foot (ft^2)	0.09290	square meter (m^2)
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

* * *

1 cubic foot per day = 7.48 gallons per day

* * *

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 "Mean Sea Level of 1929."

* * *

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ABSTRACT

Public-supply wells in the west-central Florida area of Citrus, Hernando, Pasco, Hillsborough, and Pinellas Counties derive their supply solely from the Floridan aquifer system. Over most of that area, the Floridan is at or near land surface and vulnerable to contamination from surface sources. Recognizing the potential threat to this and other aquifers in the State, the Florida Department of Environmental Regulation recently promulgated regulations that provide for the designation and delineation of protection zones around public-supply wells that tap vulnerable aquifers, such as the Floridan in west-central Florida. This report evaluates the methodology used to define the protection zones for public-supply wells in west-central Florida in accordance with the methods detailed by the Florida Department of Environmental Regulation.

Protection zones were delineated for a total of 336 wells and 8 well fields that are permitted an average daily withdrawal of 100,000 gallons or more and that tap the Floridan aquifer system where it is unconfined or leaky confined. As specified in the regulations of the Florida Department of Regulation, leaky confined pertains to conditions such that the time for a particle of water to travel vertically from the water table to the top of the Floridan is 5 years or less. Protection zones were delineated by using a radial volumetric displacement model based on 5 years of permitted-rate withdrawal. Where zones of individual wells did not overlap, the radius of the circle encompassing the zone was tabulated. Where zones overlapped, such as for well fields, composite protection zones in shapes that varied according to the configuration of well arrays were delineated on maps, samples of which are included herein.

INTRODUCTION

Ground water is the source of drinking water for about 90 percent of Florida's residents. However, throughout much of Florida, aquifers that are tapped for public supply are vulnerable to contamination because they occur at relatively shallow depths and are overlain by materials that do not greatly impede downward movement of water. Recognizing this potential threat to the State's principal potable-water source, the Florida Department of Environmental Regulation (FDER) has developed a "unique aquifer" category within the State's ground water classification scheme and has promulgated regulations that include provisions for defining and delineating "protection zones" around public-supply wells and well fields tapping unconfined or leaky confined aquifers (Florida Department of Environmental Regulation, 1987). These regulations prohibit or restrict certain activities having potential for contaminating the underlying ground water within a protection zone.

The FDER ground-water regulations (G–1 Rule) require that the State map protection zones around existing public-supply wells and well fields. This mapping activity was undertaken in 1987 as part of a cooperative study between the U.S. Geological Survey and the FDER in the west-central Florida area consisting of Citrus, Hernando, Pasco, Hillsborough, and Pinellas Counties. Similar mapping in other areas of Florida is planned by FDER.

Purpose and Scope

This report evaluates the methodology used to define protection zones for public supply wells in west-central Florida in accordance with the methods given in the FDER regulations (1987). Hydrogeologic conditions at public-supply wells in west-central Florida are evaluated and calculations of the size of individual protection zones around each well or well field tapping unconfined or leaky confined parts of the Floridan aquifer system are presented. Public-supply wells in the west-central Florida area that are permitted an average daily withdrawal of 100,000 gallons or more are considered in this report.

Contained in the report is a map depicting the areas in which the Floridan aquifer system is under unconfined, leaky confined, or confined conditions. Other maps display the composite protection zone for selected well fields that contain wells having overlapping individual protection zones. Although composite protection zones were mapped for every instance of overlap, only selected samples are reproduced herein because of the perceived limited interest in each of the composite protection zone maps. Those not included are on file with FDER. Radii of circles encompassing the protection zone around individual wells with no overlapping protection zones are presented in tabular form along with pertinent location, construction, and withdrawal data for the wells.

The methodology used in delineating the protection zones is explained. Sources of hydrogeologic information used for making the needed calculations are described.

Study Area

The study area consists of five counties in west-central Florida: Citrus, Hernando, Pasco, Hillsborough, and Pinellas (fig. 1). These counties range from sparsely populated, predominantly rural counties, such as Citrus in the north, to densely populated urban areas such as Pinellas County in the south.

Acknowledgments

The authors gratefully acknowledge the assistance provided by the Southwest Florida Water Management District (SWFWMD), and particularly David Moore, for providing the well data from well permit files. The City of St. Petersburg, the City of Tampa, the Pinellas County Water System, and the West Coast Regional Water Supply Authority also assisted in this investigation by providing maps of well fields.

GENERAL HYDROGEOLOGY

The five-county study area in west-central Florida is underlain by Eocene and younger sediments that, in parts of the area, comprise three principal hydrogeologic units: a surficial aquifer, the Floridan aquifer system, and an intermediate confining unit (table 1).

Table 1.—*Hydrogeologic units in west-central Florida*

[Modified from Ryder (1985), table 1]

System	Series	Stratigraphic unit	General lithology	Hydrogeologic unit	
Quaternary	Holocene and Pleistocene	Surficial sand, terrace sand, phosphorite	Predominantly fine sand; interbedded clay, marl, shell, limestone, phosphorite	Surficial aquifer	
Tertiary	Miocene	Hawthorn Formation	Clayey sand and limestone; silty, phosphatic	Intermediate confining unit	
		Tampa Limestone	Limestone, sandy, fossiliferous; sand and clay in lower part in some areas	Floridan aquifer system	Upper Floridan aquifer
	Oligocene	Suwannee Limestone	Limestone, sandy limestone, fossiliferous		
	Eocene	Ocala Limestone	Limestone, chalky, foraminiferal, dolomitic near bottom		
		Avon Park Formation	Limestone and hard brown dolomite; intergranular evaporite in lower part in some areas		
		Oldsmar Formation	Dolomite and limestone with intergranular gypsum in most areas		Middle confining unit and Lower Floridan aquifer undifferentiated
	Paleocene	Cedar Keys Formation	Dolomite and limestone with intergranular gypsum and bedded anhydrite	Sub-Floridan confining unit	

Figure 1.—Location of the study area.

The surficial aquifer is present in all but the northern part of the study area. The surficial deposits that make up the surficial aquifer generally consist of sand, clayey sand, shell, and shelly marl. The combined thickness of these deposits ranges from nearly zero in the north, where surficial deposits are thin and discontinuous over large areas, to greater than 50 feet in southern parts of the study area (Wolansky and others, 1979). Transmissivity of the surficial aquifer ranges from 205 to 1,800 ft^2/d and is much less than that of the Floridan aquifer system (Ryder, 1985; Wolansky and Corral, 1985).

The intermediate confining unit consists of clayey sand and clay of the Hawthorn Formation. Its thickness and composition is highly variable in the study area. In the northern part, it is generally not present, whereas in the southern part, it occurs throughout most of the area and becomes progressively thicker and less permeable to the south. In the extreme southern part of the study area (southern Hillsborough County), the intermediate confining unit thickens and sand and limestone beds within it constitute aquifers. Where the unit is an important source of water, such as south of the study area in Manatee and Sarasota Counties, it is known as the intermediate aquifer system. Within the study area, these aquifers are very limited in extent and no public-supply wells tap them there; therefore, they are not considered in this report.

The principal water-producing unit in the study area is the Floridan aquifer system. All large-capacity municipal wells in the study area are open to the Floridan. The Floridan aquifer system is a vertically continuous sequence of Tertiary age carbonate rocks of high permeability (table 1) that are hydraulically connected in varying degrees, and whose permeability is several orders of magnitude greater than that of rocks that bound the system above and below. The Floridan aquifer system includes units of late Paleocene to early Miocene age, but within the study area, the formations of interest include the Avon Park Formation, Ocala Limestone, Suwannee Limestone, and the Tampa Limestone of Eocene to early Miocene age. Definition of the Floridan aquifer system and its relation to Florida's other regional hydrogeologic units is given by Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition (1986). Miller (1986) presents a detailed geologic description of the Floridan, its component aquifers and confining units, and their relation to stratigraphic units throughout its geographic extent. The Floridan is referred to as an aquifer system because regionally it contains more than one distinct, highly permeable zone separated by a confining unit. In the study area, however, all municipal wells are open only to the upper part of the Floridan aquifer system referred to hereinafter as the Upper Floridan aquifer or the Floridan.

Transmissivities of the Upper Floridan aquifer in the study area range from 26,000 to more than 1 million ft^2/d from reported aquifer tests and model analysis (Hutchinson, 1984; Ryder, 1985; Wolansky and Corral, 1985).

The flow system of the Upper Floridan aquifer is deducible from the potentiometric surface map in figure 2. Water flows from areas of high potential in central Florida (Polk and Lake Counties), and local potentiometric-surface highs, such as the one in Pasco County, westward toward the coast. Natural discharge is to rivers and streams, such as the Hillsborough and Withlacoochee Rivers, to springs which are prevalent in the coastal areas of Citrus and Hernando Counties, to the overlying surficial aquifer, and to the Gulf of Mexico and Tampa Bay. Hydraulic gradients average about 3 ft/mi or 0.0006 ft/ft. In the northern half of the study area, the potentiometric surface of the Floridan aquifer system is little changed from predevelopment times (fig. 3) despite the large ground-water withdrawals from the area. In the southern half where the Floridan is confined, the potentiometric surface has declined over most of the area because of large ground-water withdrawals, mainly for agriculture and phosphate mining.

METHODOLOGY FOR DELINEATING PROTECTION ZONES

Protection zones were delineated according to criteria and methods in the FDER regulations (G–1 Rule), insofar as they were prescribed. The delineation of protection zones is a multistep process (fig. 4). The first step consists of determining whether the aquifer under consideration is unconfined, confined, or leaky confined. If unconfined, protection zones are required and the zone's size is calculated according to the method described later. If confined, protection zones beyond the inner zone of 200 feet radius that applies to all public-supply wells are not required and no further work is done. If leaky confined conditions are thought to occur, a calculation is made to determine average travel time for water to move vertically from the water table downward to the top of the aquifer. If the travel time is computed as 5 years or less, the aquifer is judged to be leaky confined (per FDER regulations) and a protection zone is required; its size is calculated similarly to that for the unconfined condition. If the travel time is greater than 5 years, the aquifer is considered confined and no protection-zone calculation is made.

The calculation of the size of protection zone required is performed first on an individual well basis and the area determined is simply circumscribed uniformly around the well. If the individual circumscribed zones overlap, the area of overlap is determined and distributed around the nonoverlapping parts of the individual zones. Where a number of wells are involved, such as in some of the large well fields, a composite protection zone is determined and distributed around the wells in the well field as described later.

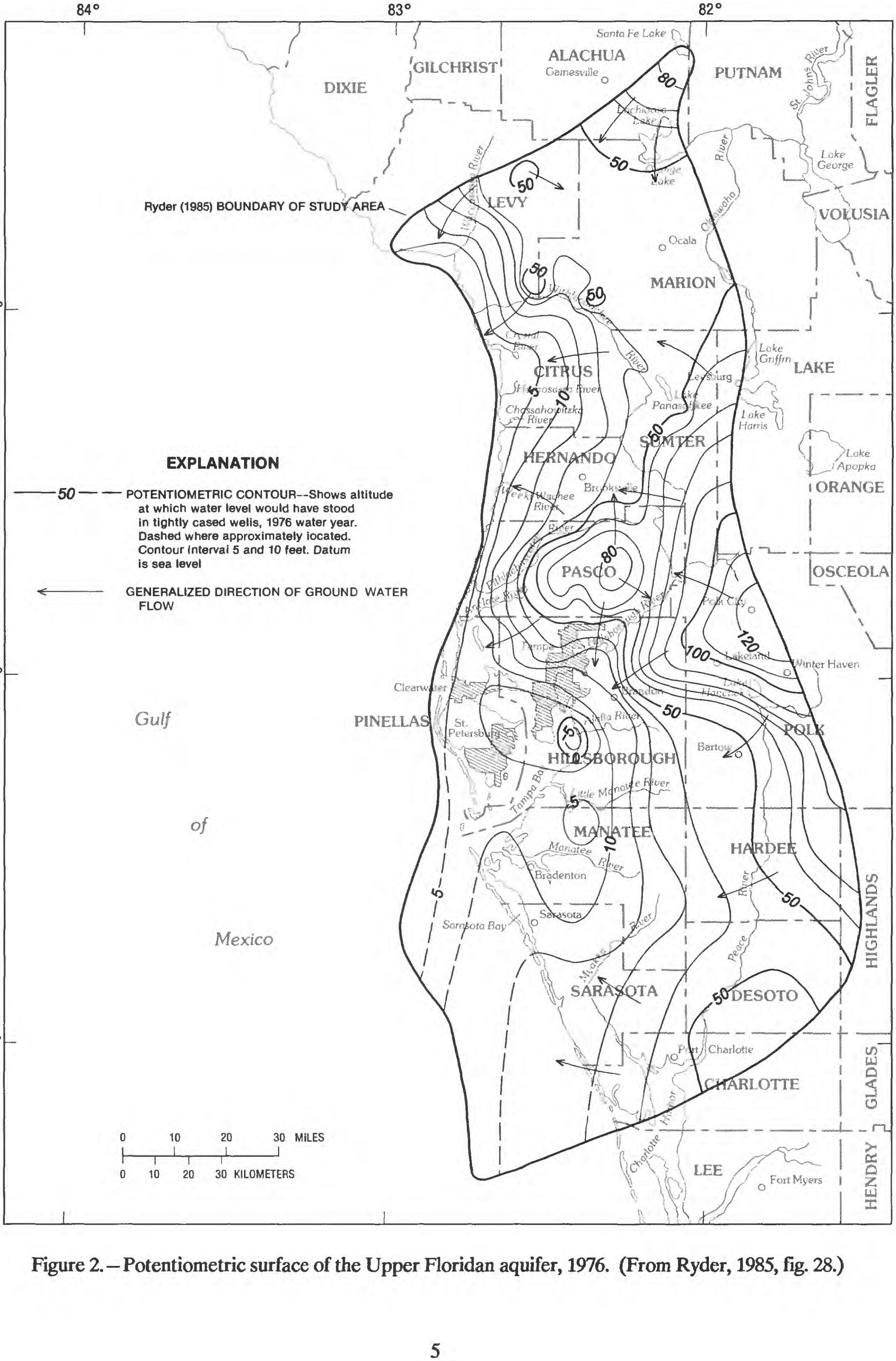


Figure 2.—Potentiometric surface of the Upper Floridan aquifer, 1976. (From Ryder, 1985, fig. 28.)

Determination of Unconfined, Leaky Confined, and Confined Areas

A number of sources of information were used to determine where the Upper Floridan aquifer is unconfined, leaky confined, or confined (Buono and Rutledge, 1979; Buono and others, 1979; Ryder, 1985; Miller, 1986; and an unpublished map dated March 1985 prepared by the Southwest Florida Water Management District). Extent of the areas where these conditions occur in the west-central Florida study area is shown in figure 5. The unconfined/leaky confined boundary was determined using a combination of the references noted above. The leaky confined/confined boundary was generalized from the line where leakance of the confining unit overlying the Upper Floridan was less than $1x10^{-4}$ ft/d/ft, as shown by Ryder (1985, p. 16). Leakance is the vertical hydraulic conductivity of the confining bed divided by its thickness and can be expressed as K_z/ℓ. A leakance value of $1x10^{-4}$ ft/d/ft, coupled with typical vertical head gradients prevalent in the confined area, results in vertical travel time calculations of much greater than 5 years. Therefore, it was considered a reasonable threshold value for bounding the area where the degree of confinement was such as to preclude the need to make site by site calculations of vertical travel time.

Calculation of Vertical Travel Time

The average vertical travel time for a particle of water to travel from the water table to the top of the Upper Floridan aquifer was computed for all wells or well fields in the area mapped as leaky confined. If the travel time at a particular well, or anywhere within a designated well field, was less than or equal to 5 years, the confining unit was considered to be sufficiently leaky to require that a protection zone be calculated. If the travel time was greater than 5 years throughout the well field, the confining unit was not considered to be leaky, as defined in the FDER regulation, and no protection zone was calculated.

Vertical travel time was calculated using the formulae specified in the FDER regulation (Florida Department of Environmental Regulation, 1987) which when combined yield:

$$t_v = \frac{n\ell^2}{K_z \Delta h}, \qquad (1)$$

derived from Darcy's law, where

t_v = vertical travel time between water table and top of Upper Floridan aquifer;

n = equivalent effective porosity of deposits between water table and top of Upper Floridan aquifer = 0.2, an assumed value believed to be representative of the vertical section overlying the Upper Floridan aquifer;

ℓ = distance between water table and top of Upper Floridan aquifer;

K_z = equivalent hydraulic conductivity of material between the water table and the top of the Upper Floridan aquifer; and

Δh = head difference between the potentiometric surface of the Upper Floridan aquifer and the water table.

Data used for the vertical travel-time calculations were derived from a number of sources. Data on the top of the Floridan were derived using Stewart (1968), Buono and Rutledge (1979), and well logs. The equivalent vertical hydraulic conductivity, K_z, is calculated by taking into account the individual vertical hydraulic conductivity and thickness of each layer of material between the water table and the top of the Upper Floridan aquifer. Mathematically, this can be expressed as (Freeze and Cherry, 1979, p. 34):

$$K_z = \frac{d}{\sum_{i=1}^{n} d_i/K_i}, \qquad (2)$$

where

d_i and K_i = the respective thickness and vertical hydraulic conductivity of individual layers, and

d = the total thickness.

However, it can be shown that in the case of two layers—surficial aquifer underlain by a confining unit—the leakance of the two layers, which equals the equivalent vertical hydraulic conductivity divided by the surficial aquifer-confining unit thickness, approximates the leakance of the confining unit, which equals the vertical hydraulic conductivity of the confining unit divided by its thickness, where the confining unit conductivity is much smaller than the vertical hydraulic conductivity of the surficial aquifer, and the thickness of the surficial aquifer is not significantly greater than that of the confining unit. Therefore, for the surficial aquifer and confining unit materials extant in the study area, primarily sand and clay, respectively, it is reasonable to estimate their equivalent vertical hydraulic conductivity and thickness by considering only the hydraulic conductivity and thickness of the confining unit.

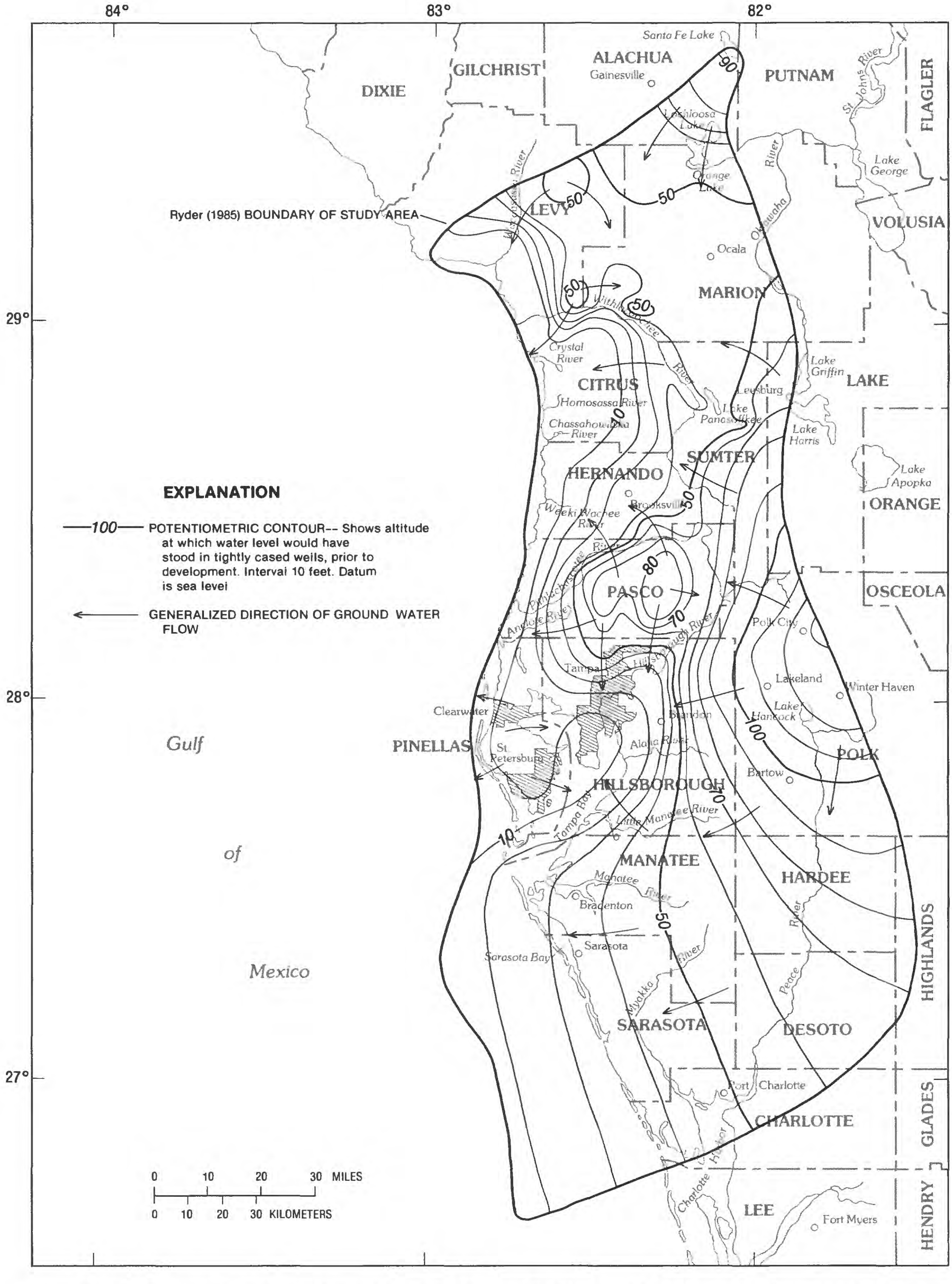


Figure 3.—Estimated potentiometric surface of the Upper Floridan aquifer prior to development (modified from Johnston and others, 1980). (From Ryder, 1985, fig. 17.)

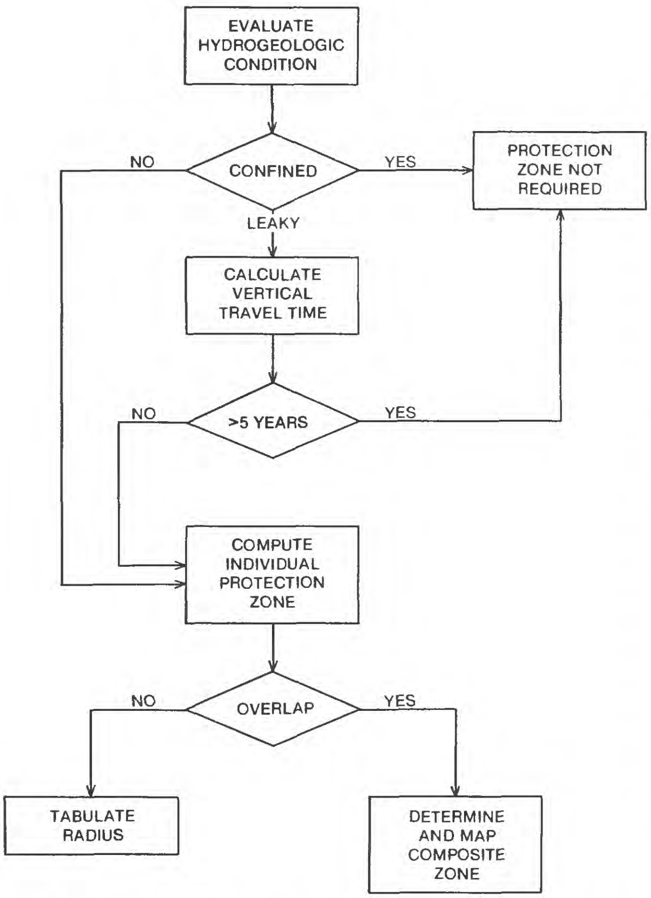


Figure 4.—Procedure used in delineating protection zones.

Data utilized for computing vertical travel times for the well fields were derived from a number of sources. Floridan heads and water-table altitudes were derived from Ryder and Mills (1977), Yobbi and others (1980), Yobbi and Woodham (1981), and Barr (1982), for times when the well fields were pumping near their average permitted withdrawal rates. No water-level maps were available for the Cross Bar Ranch and Starkey well fields for a period when they were pumping near their average permitted withdrawal rates. A model-simulated head difference from Hutchinson (1985) was used at the Cross Bar Ranch well field. Head difference was calculated for Starkey using analytical methods (Jacob, 1945; Lohman, 1972) combined with May 1982 water levels. The equivalent hydraulic conductivity was determined from model analyses of Hutchinson (1984) and Ryder (1985) and from aquifer tests for which confining bed characteristics were calculated (Wolansky and Corral, 1985). Data from wells in the leakiest part of the well field were used for the vertical calculation for each well field. The rationale was that if any well in a dense grouping of wells, such as in a well field, needed a protection zone, then all wells in that well field should be protected.

The location of the major well fields in the study area is shown in figure 6. The data utilized and the results of the vertical travel-time calculations for the 11 well fields located in the leaky confined part of the study area are listed in table 2. Eight of the eleven well

Table 2.—*Vertical travel-time calculations for well fields*

[gal/d = gallons per day, ft/d/ft = feet per day per foot]

Well field name	Consumptive use permit number	Permitted average pumping rate (gal/d)	Time of calculation		Altitude		Vertical head difference (feet)	Altitude top of Floridan aquifer system (feet)	Vertical distance (feet)[1]	Leakance (ft/d/ft)	Vertical travel time (days)
			Date	Pumping rate (gal/d)	Water table (feet)	Potentiometric surface (feet)					
South Pasco	0364701	16,900,000	May 1981	17,300,000	55	37	18	5	50	0.00036	1,543
Cypress Creek	0365002	30,000,000	May 1982	30,000,000	63	49	14	40	23	.0003	1,095
Cross Bar	0429001	30,000,000	Simulated	30,000,000	50	45	5	30	20	.0009	889
Starkey	0444602	8,000,000	Calculated	(2)	20	14	6	-10	32	.0006	1,778
Eldridge-Wilde	0267301	35,244,000	May 1980	27,400,000	22	13	9	-10	32	.00054	1,317
East Lake Road	0439101	3,000,000	May 1977	4,300,000	10	3	7	-25	35	.00054	1,852
Section 21	0000301	13,000,000	May 1982	11,100,000	48	34	14	15	33	.0003	1,571
Cosme-Odessa	0000401	13,000,000	May 1981	10,400,000	42	14	28	-10	52	.0003	1,238
Morris Bridge	0418000	15,500,000	May 1981	15,000,000	32	28	4	20	12	.0008	750
Sun City	0435201	3,600,000	May 1982	2,300,000	53	-5	58	-90	143	.0000098	50,000
Riverview	0435201	2,100,000	May 1980	1,900,000	56	2	54	-50	106	.0000098	40,000

[1]Water table to top of Floridan.
[2]Calculated based on individual well permit rates.

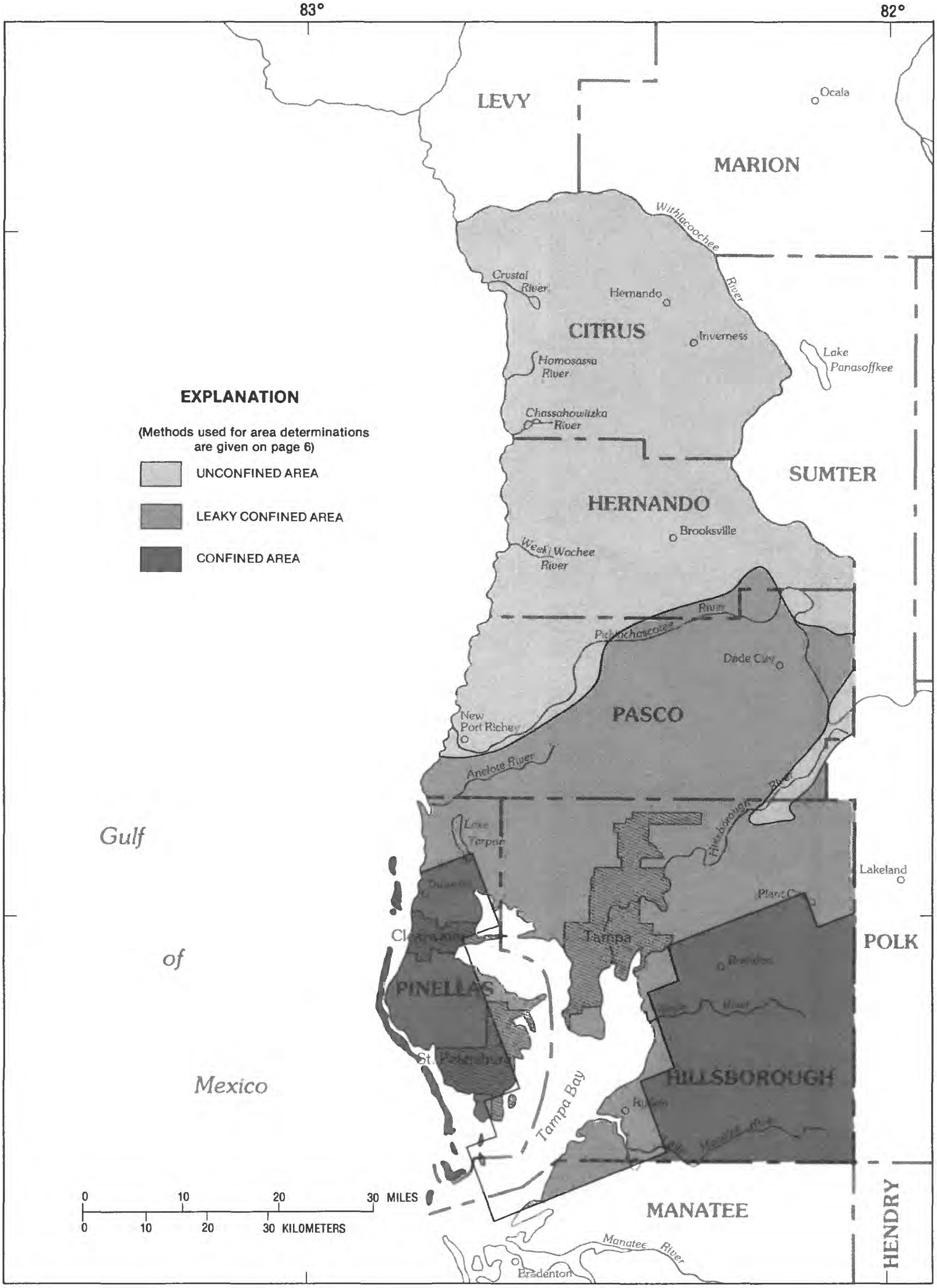


Figure 5.—Confined, leaky confined, and unconfined areas in the Floridan aquifer system in west-central Florida.

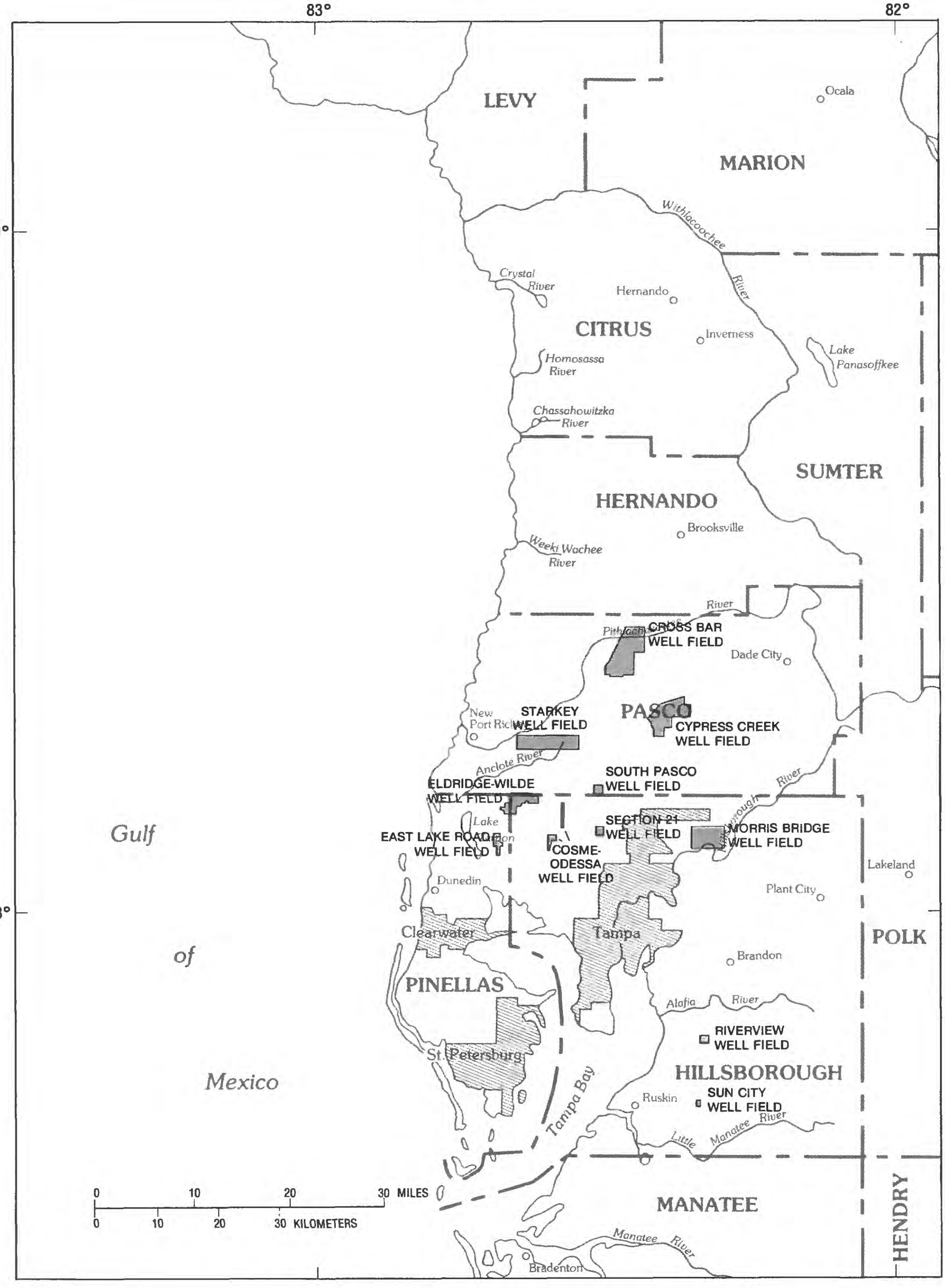


Figure 6.—Major public supply well fields in the five county area, west-central Florida.

fields have computed vertical travel times of less than 5 years (1,825 days) and thus require protection zones. These include the Cross Bar Ranch, Cypress Creek, South Pasco, Eldridge-Wilde, Cosme-Odessa, Section 21, Morris Bridge, and Starkey well fields. These well fields are predominantly located in the northern part of the leaky confined area where the confining unit overlying the Floridan is the leakiest. Three of the eleven well fields, East Lake Road, Sun City, and Riverview, have computed vertical travel times of greater than 5 years and thus do not require protection zones.

The data utilized and the results of the vertical travel-time calculations for individual wells are listed in table 3. Floridan heads were derived from Barr (1982) and Barr and Schiner (1982). Water-table altitudes were derived from Barr (1982) and estimated from topographic maps outside the area Barr mapped. Because of the wide contour spacing and topographic relief in some areas of Barr's map, all interpolated water levels were checked against land surface and water features on U.S. Geological Survey 7-1/2-minute topographic maps and adjusted where necessary. The leakance of the confining unit overlying the Floridan, derived from Hutchinson (1984) and Ryder (1985), was substituted for K_z/ℓ in equation (1), as explained previously.

Table 3.—*Computation of vertical travel time and radius of well protection zones for wells in the leaky confined area*

Sources and explanation of data for calculations:

Well - Well number from Southwest Florida Water Management District (SWFWMD) files. Blank where not available.
Owner - From SWFWMD permitting files, February 2, 1987.
Cons. use permit - Consumptive use permit number. From SWFWMD permitting files, February 2, 1987.
Well name - From SWFWMD files.
County - From SWFWMD permitting files, February 2, 1987.
Lat, Long, Sec, Twn, and Rng - Latitude, longitude, section, township, and range. From SWFWMD permitting files, February 2, 1987.
Av.Q - Permitted average pumping rate, in gallons per day, for public-supply use. From SWFWMD permitting files, February 2, 1987.
Well depth, in feet - From SWFWMD files. Blank where not available.
Dia - Well diameter, in inches. From SWFWMD permitting files, February 2, 1987.
Lsd - Altitude of land surface, in feet, from U.S. Geological Survey 7½-minute topographic maps at latitude and longitude given.
Fl - Altitude of top of Upper Floridan aquifer, in feet (Buono and Rutledge, 1979).
m - Thickness of Upper Floridan aquifer at well site (Miller, 1982).
T - Transmissivity, in feet squared per day, of Upper Floridan aquifer at well site (Hutchinson, 1984). Values of transmissivity outside Hutchinson's model area are from Ryder (1985).
h - Thickness of Upper Floridan aquifer, in feet, penetrated by the well (well depth-[Lsd-Fl]).
WT - Altitude of the water table, in feet above sea level, at the well site, May 1982 (Barr, 1982). Because of the topographic relief and wide spacing of contours in some areas, interpolated water-table altitudes were checked against topographic maps and adjusted where necessary. Water-table altitudes outside the map area were estimated from USGS 7½-minute topographic maps.
Pot - Altitude of the potentiometric surface of the Upper Floridan aquifer, in feet above sea level, at the well site, May 1982 (Barr, 1982; Barr and Schiner, 1982).
s - Drawdown of the potentiometric surface, in feet, after one day pumping at the rate shown under "Av.Q", in gallons per day, calculated by the modified nonequillibrium formula (Cooper and Jacob, 1946, cited in Lohman, 1972, p. 19):

$$s = \frac{(2.30)(Av.Q)}{(7.48)(4)(\pi)T} \log_{10} \frac{(2.25)(T)(1)}{\left(Dia/_{24}\right)^2 (0.001)}$$

s(K) - Drawdown, as above, corrected for partial penetration (h/m) by the Kozeny (1933) formula, modified from Jacob (1945):

$$s(K) = s / \left[h/m \left(1+7 \left[\frac{Dia/24}{2h}\right]^{1/2} \cos \frac{\pi \, h/m}{2} \right)\right].$$

The argument for cosine is in radians. Tabulated values of s(K) are truncated to integers.
Δh - Difference in water-level altitude between the water table (WT) and the potentiometric surface (pot) minus drawdown (s(K)). Δh = WT - [Pot-s(K)], in feet.
ℓ - Vertical distance, water table to top of Upper Floridan aquifer (WT-Fl).
Leak - Leakance of the confining unit overlying the Upper Floridan aquifer, (Hutchinson, 1984), in feet per day per foot (ft/d/ft), or, in the case of two confining units, the equivalent leakance of both units. Values of leakance outside Hutchinson's model area are from Ryder (1985). Leakance equals vertical hydraulic conductivity divided by thickness.

t_v - Calculated vertical travel time, in days, $= \frac{0.2\ (\ell)}{(leak)(\Delta h+5)}$. The value of Δh was increased by 5 feet, as explained on page 16, because of the approximate nature of the water table and potentiometric surface maps. ">1,825 days" means that calculated vertical travel time at the well site is greater than 5 years, even if a corrected drawdown is applied for only 5 percent penetration of the Floridan.

r - Radius of protection zone of the well $= \left[\frac{1825\ Q}{7.48\ \pi\ hn}\right]^{1/2}$, rounded to the nearest 10 feet n = 0.05 for the Upper Floridan aquifer. No entry indicates a vertical travel time greater than 5 years, hence no protection zone is calculated. "**" means that a protection zone is needed even if the well is fully penetrating, but the radius cannot be calculated because of missing well depth data. "*" means that the presence or absence of a protection zone depends on the partial penetration correction, which cannot be calculated because of missing well depth data.

Table 3.—*Computation of vertical travel time and radius of well protection zones for wells in the leaky confined area*—Continued

Well	Owner	Cons. use permit	Well name	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Av.Q (gal/d)	Well depth (ft)	Dia (in)
			Pasco County								
00032	WATER & SEWER DISTRICT A	0002502	C	281148	822629	30	26	19	112,000	665	12
00033	WATER & SEWER DISTRICT A	0002502	D	281143	822629	30	26	19	112,000	620	8
00115	LYKES PASCO PACKING CO	0045101	MP2	282230	821124	27	24	21	2,000,000	461	10
00120	HOLIDAY GARDENS UTILITIES INC.	0054002	1	281129	824340	29	26	16	128,000	85	8
00122	CRESTRIDGE GARDENS UTIL CORP	0054302	1	281034	824405	31	26	16	110,000	100	8
00125	CRESTRIDGE GARDENS UTIL CORP	0054302	4	281045	824358	31	26	16	130,000	170	12
00126	CRESTRIDGE GARDENS UTIL CORP	0054302	5	281052	824357	31	26	16	110,000	160	12
00127	CRITERION CORPORATION	0059001	1	281026	822505	33	26	19	131,000	575	12
00128	CRITERION CORPORATION	0059001	2	281110	822537	29	26	19	131,000	560	12
00221	DADE CITY FLORIDA, CITY OF	0163101	1	282148	821130	27	24	21	500,000	400	8
00222	DADE CITY FLORIDA, CITY OF	0163101	2	282148	821130	27	24	21	500,000	400	8
00223	DADE CITY FLORIDA, CITY OF	0163101	3	282148	821130	27	24	21	500,000	400	8
00224	DADE CITY FLORIDA, CITY OF	0163101	4	282139	821152	34	24	21	1,400,000	492	8
00256	BETMAR UTILITIES	0203001	2	281356	821204	10	26	21	195,000	400	6
00257	BETMAR UTILITIES	0203001	3	281357	821215	10	26	21	195,000	200	4
00258	BETMAR UTILITIES	0203001	4	281350	821230	9	26	21	260,000	200	4
00259	BETMAR UTILITIES	0203001	5	281405	821236	9	26	21	260,000	450	10
	ZARING CORPORATION	0285602		281041	822415	33	26	19	165,000		12
	ZARING CORPORATION	0285602		281054	822415	33	26	19	165,000		12
00441	LINDRICK SERVICE CORPORATION	0297801	2	281331	824352	17	26	16	225,000	90	10
00517	ALOHA UTILITIES INC.	0318201	3	281222	824024	23	26	16	110,000	350	6
00518	ALOHA UTILITIES INC.	0318201	4	281222	824015	23	26	16	110,000	350	6
00519	ALOHA UTILITIES INC.	0318201	1	281145	823814	30	26	17	330,000	280	10
00520	ALOHA UTILITIES INC.	0318201	2	281135	823705	29	26	17	330,000	500	8
00521	ALOHA UTILITIES INC.	0318201	6	281332	823930	13	26	16	110,000	305	8
00522	ALOHA UTILITIES INC.	0318201	7	281326	823921	13	26	16	110,000	302	8
00561	BARTELT SUNSHINE CORP	0359001	3	281122	824429	30	26	16	130,000	105	8
00683	PASCO COUNTY	0426901	7	281247	824311	20	26	16	230,000	186	12
00684	PASCO COUNTY	0426901	8	281247	824307	20	26	16	230,000	137	8
00685	PASCO COUNTY	0426901	9	281247	824306	20	26	16	230,000	180	8
00688	PASCO COUNTY	0428901	2	281252	824346	20	26	16	100,000	137	8
	SAN ANTONIO, CITY OF	0455002		282013	821624	2	25	20	231,000		8
	SAN ANTONIO, CITY OF	0455002		282007	821632	2	25	20	231,000		10
00962	UTILITIES INC. OF FLORIDA	0466801	1	281141	824404	30	26	16	120,000	160	12
00963	UTILITIES INC. OF FLORIDA	0466801	2	281143	824412	30	26	16	105,000	117	12
01299	PASCO COUNTY	0601102	3	282534	821128	3	24	21	125,000		16
01307	ZEPHYRHILLS, CITY OF	0604002	3	281353	821007	12	26	21	121,000	840	16
01308	ZEPHYRHILLS, CITY OF	0604002	4	281432	821130	10	26	21	154,000	460	16
01309	ZEPHYRHILLS, CITY OF	0604002	5	281450	821112	2	26	21	1,006,000	885	16
01320	PASCO COUNTY	0612500	1	281023	823533	34	26	17	220,000	200	12
01406	QUAIL HOLLOW UTILITY CO	0646000	2	281325	822248	14	26	19	250,000	900	10
01468	INTERNATIONAL COMMUNITY CORP	0653900	2	281053	822025	31	26	20	1,000,000	605	16
01546	PASCO COUNTY	0668801	3	281352	822003	8	26	20	150,000	425	10
01547	PASCO COUNTY	0668801	1	281040	821827	33	26	20	150,000	300	12
01566	SCARECROW UTILITY INC.	0681102	P1	281039	822741	36	26	18	131,000	350	8
	SCARECROW UTILITY INC.	0681102		281041	822741	36	26	18	141,000		10
01574	VILLAGE-TAMPA INC., THE	0686700	1	281504	820808	5	26	22	120,000	345	6
01575	VILLAGE-TAMPA INC., THE	0686700	2	281504	820808	5	26	22	120,000	345	6
01700	MERTZ, ESTATE OF HAROLD E.	0742300	1	281402	822549	8	26	19	450,000		12
01701	MERTZ, ESTATE OF HAROLD E.	0742300	2	281433	822608	8	26	19	450,000		12
01702	MERTZ, ESTATE OF HAROLD E.	0742300	3	281430	822526	8	26	19	450,000		12
01703	MERTZ, ESTATE OF HAROLD E.	0742300	4	281527	822552	5	26	19	450,000		12
01704	MERTZ, ESTATE OF HAROLD E.	0742300	5	281525	822642	6	26	19	450,000		12
01705	MERTZ, ESTATE OF HAROLD E.	0742300	6	281605	822607	32	25	19	450,000		12
01706	MERTZ, ESTATE OF HAROLD E.	0742300	7	281613	822655	31	25	19	450,000		12
01743	PASCO COUNTY	0759300	1	281402	821302	9	26	21	200,000		8
01745	PASCO COUNTY	0759500	1	281421	821408	8	26	21	200,000	200	8
	FIRST PASCO SERVICE CORPORATION	0811200		281949	821847	9	25	20	138,000		12
	FIRST PASCO SERVICE CORPORATION	0811200		281949	821847	9	25	20	137,000		12
	BETMAR UTILITIES	0837700		281420	821250	9	26	21	100,000		6
	HILLVEST, INC	0849100		281320	821210	15	26	21	248,000		10

Table 3.—*Computation of vertical travel time and radius of well protection zones for wells in the leaky confined area*—Continued

Well	Lsd (sea lev.)	Fl (sea lev.)	m (ft)	T (ft^2/d)	h (ft)	WT (sea lev.)	Pot (sea lev.)	s (ft)	s(K) (ft)	Δh (ft)	ℓ (ft)	Leak (ft/d/ft)	t_v (days)	r (ft)
							Pasco County							
00032	87	10	960	42,000	588	72	61	0.56	1	12	62	0.000760	960	540
00033	87	10	960	42,000	543	72	60	0.58	1	13	62	0.000760	906	570
00115	97	60	890	500,000	424	75	65	0.96	2	12	15	0.000270	654	2,710
00120	13	-10	960	57,000	62	6	4	0.50	6	8	16	0.000300	821	1,790
00122	15	-10	970	57,000	75	5	5	0.43	4	4	15	0.000300	1,111	1,510
00125	20	-10	970	57,000	140	5	5	0.49	3	3	15	0.000300	1,250	1,200
00126	25	-10	970	57,000	125	5	5	0.41	2	2	15	0.000300	1,429	1,170
00127	65	-10	970	42,000	500	62	53	0.66	1	10	72	0.000760	1,263	640
00128	76	-10	970	42,000	474	71	57	0.66	1	15	81	0.000760	1,066	660
00221	116	60	890	500,000	344	80	65	0.25	1	16	20	0.000270	705	1,500
00222	116	60	890	500,000	344	80	65	0.25	1	16	20	0.000270	705	1,500
00223	116	60	890	500,000	344	80	65	0.25	1	16	20	0.000270	705	1,500
00224	145	60	890	500,000	407	80	65	0.69	1	16	20	0.000270	705	2,310
00256	87	50	940	100,000	363	80	75	0.46	1	6	30	0.000130	4,196	
00257	87	50	940	100,000	163	80	75	0.47	2	7	30	0.000130	3,846	
00258	87	50	940	100,000	163	80	75	0.63	3	8	30	0.000130	3,550	
00259	86	50	940	100,000	414	80	76	0.58	1	5	30	0.000130	4,615	
	68	20	970	42,000		49	52	0.83			29	0.000760		*
	68	20	970	42,000		49	53	0.83			29	0.000360		*
00441	25	-10	950	57,000	55	3	3	0.86	10	10	13	0.000360	481	2,520
00517	26	-10	960	57,000	314	12	16	0.44	1	-3	22	0.000300	7,333	
00518	26	-10	960	57,000	314	12	16	0.44	1	-3	22	0.000300	7,333	
00519	39	0	970	57,000	241	28	24	1.26	4	8	28	0.000300	1,436	1,460
00520	43	0	970	57,000	457	37	29	1.29	2	10	37	0.000300	1,644	1,060
00521	26	-10	950	57,000	269	21	21	0.43	1	1	31	0.000300	3,444	
00522	26	-10	950	57,000	266	21	21	0.43	1	1	31	0.000300	3,444	
00561	17	-10	970	57,000	78	5	4	0.51	5	6	15	0.000300	909	1,610
00683	35	-10	950	57,000	141	6	4	0.86	5	7	16	0.000300	889	1,590
00684	46	-10	950	57,000	81	6	4	0.90	8	10	16	0.000300	711	2,100
00685	48	-10	950	57,000	122	6	4	0.90	6	8	16	0.000300	821	1,710
00688	35	-10	950	57,000	92	4	3	0.39	3	4	14	0.000360	864	1,300
	150	100	890	40,000		120	80	1.26			20	0.000130		**
	158	90	1,201	40,000		115	80	1.23			25	0.000130		**
00962	16	-10	960	57,000	134	5	3	0.45	2	4	15	0.000300	1,111	1,180
00963	15	-10	960	57,000	92	5	3	0.39	3	5	15	0.000300	1,000	1,330
01299	86	50	880	500,000		70	62	0.06			20	0.000130	>1,825	
01307	105	50	950	100,000	785	80	66	0.26	0	14	30	0.000130	2,429	
01308	94	50	940	100,000	416	87	66	0.33	1	22	37	0.000130	2,108	
01309	98	50	940	100,000	837	90	65	2.15	2	27	40	0.000130	1,923	
01320	49	5	980	57,000	156	45	33	0.82	4	16	40	0.000300	1,270	1,480
01406	65	30	950	42,000	865	56	60	1.27	1	-3	26	0.000300	8,667	
01468	55	30	970	42,000	580	53	56	4.86	7	4	23	0.000300	1,704	1,640
01546	77	50	940	42,000	398	75	71	0.76	2	6	25	0.000150	3,030	
01547	73	40	970	42,000	267	61	61	0.75	2	2	21	0.000150	4,000	
01566	69	10	980	26,000	291	68	60	1.08	3	11	58	0.000760	954	840
	69	10	980	26,000		68	60	1.13			58	0.000760		*
01574	82	60	940	100,000	323	80	70	0.28	1	11	20	0.000270	926	760
01575	82	60	940	100,000	323	80	70	0.28	1	11	20	0.000270	926	760
01700	71	30	940	26,000		66	59	3.55			36	0.000760		**
01701	76	30	940	26,000		68	62	3.55			38	0.000760		**
01702	58	30	940	42,000		58	58	2.25			28	0.000760		*
01703	67	30	930	42,000		58	60	2.25			28	0.000760		*
01704	74	30	930	26,000		72	70	3.55			42	0.000760		*
01705	75	30	920	26,000		70	66	3.55			40	0.000760		*
01706	76	20	920	26,000		73	70	3.55			53	0.000760		*
01743	87	50	940	100,000		80	77	0.46			30	0.000130	>1,825	
01745	103	50	940	50,000	147	85	81	0.88	5	9	35	0.000130	3,846	
	95	60	890	86,000		85	78	0.35			25	0.000061	>1,825	
	95	60	890	86,000		85	78	0.35			25	0.000061	>1,825	
	93	50	940	100,000		80	77	0.23			30	0.000130	>1,825	
	88	50	950	100,000		78	74	0.55			28	0.000130	>1,825	

Table 3.—*Computation of vertical travel time and radius of well protection zones for wells in the leaky confined area*—Continued

Well	Owner	Cons. use permit	Well name	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Av.Q (gal/d)	Well depth (ft)	Dia (in)
					Pinellas County						
00171	TARPON SPRINGS, CITY OF	0074202	1	280843	824513	12	27	15	100,000	110	10
00172	TARPON SPRINGS, CITY OF	0074202	2	280846	824407	7	27	16	550,000	110	10
00173	TARPON SPRINGS, CITY OF	0074202	3	280822	824402	18	27	16	100,000	110	10
00481	CLEARWATER, CITY OF	0298101	45	275752	824345	17	29	16	472,500	290	10
00482	CLEARWATER, CITY OF	0298101	46	275751	824332	17	29	16	306,500	290	10
00484	CLEARWATER, CITY OF	0298101	51	275751	824400	18	29	16	423,200	200	12
00485	CLEARWATER, CITY OF	0298101	52	275747	824400	18	29	16	380,666	200	12
00486	CLEARWATER, CITY OF	0298101	53	275741	824401	18	29	16	269,000	240	12
					Hillsborough County						
00112	SOUTHERN UTILITIES INC.	0043501	1	280404	822310	10	28	19	100,000	200	6
	TEMPLE TERRACE, CITY OF	0045003	1	280211	822308	22	28	19	400,000		8
	TEMPLE TERRACE, CITY OF	0045003	2	280212	822307	23	28	19	200,000		10
	TEMPLE TERRACE, CITY OF	0045003	3	280241	822319	15	28	19	260,000		12
	TEMPLE TERRACE, CITY OF	0045003	4	280241	822318	15	28	19	640,000		12
	TEMPLE TERRACE, CITY OF	0045003	5	280203	822303	23	28	19	650,000		8
	TEMPLE TERRACE, CITY OF	0045003	6	280251	822330	15	28	19	400,000		10
	TEMPLE TERRACE, CITY OF	0045003	7	280251	822330	15	28	19	400,000		10
	TEMPLE TERRACE, CITY OF	0045003	8	280251	822330	15	28	19	300,000		10
	TEMPLE TERRACE, CITY OF	0045003	11	280249	822324	15	28	19	640,000		10
	TEMPLE TERRACE, CITY OF	0045003	14	280140	822221	24	28	19	160,000		6
00231	PLANT CITY, CITY OF	0177601	1	280109	820720	29	28	22	800,000	676	12
00232	PLANT CITY, CITY OF	0177601	2	280109	820719	29	28	22	800,000	367	12
00233	PLANT CITY, CITY OF	0177601	3	280108	820720	29	28	22	800,000	760	10
00234	PLANT CITY, CITY OF	0177601	4	280042	820725	29	28	22	900,000	650	12
00236	PLANT CITY, CITY OF	0177601	6	280134	820551	22	28	22	2,900,000	1,200	18
00241	SCARECROW UTILITY INC.	0178701	2	280751	822625	18	27	19	400,000	585	8
00242	SCARECROW UTILITY INC.	0178701	3	280743	822633	18	27	19	400,000	585	8
00247	UNIVERSITY OF SOUTH FLORIDA	0196002	2	280358	822451	9	28	19	170,000	350	12
00249	UNIVERSITY OF SOUTH FLORIDA	0196002	5	280359	822451	9	28	19	230,000	300	12
00250	UNIVERSITY OF SOUTH FLORIDA	0196002	6	280355	822452	9	28	19	150,000	350	12
00251	UNIVERSITY OF SOUTH FLORIDA	0196002	7	280357	822452	9	28	19	160,000	340	12
00378	EAST SIDE WATER CO INC.	0270701	1	275944	822251	2	29	19	427,000	338	6
00379	EAST SIDE WATER CO INC.	0270701	2	275944	822252	2	29	19	427,000	537	10
00405	SEABOARD UTILITIES CORP	0284002	11	275610	822146	25	29	19	160,000		8
00406	SEABOARD UTILITIES CORP	0284002	12	275613	822133	25	29	19	160,000	315	8
00512	PEBBLE CREEK SERVICE CORP	0313203	4	280906	822105	7	27	20	151,000	560	12
	PEBBLE CREEK SERVICE CORP	0313203	6	280856	822015	7	27	20	308,700		12
	PEBBLE CREEK SERVICE CORP	0313203	7	280916	822015	7	27	20	308,700		12
00774	WEST COAST REGIONAL WAT SUP AU	0435201	RUS9	274252	822317	10	32	19	350,000	800	10
00775	WEST COAST REGIONAL WAT SUP AU	0435201	RS10	274252	822324	10	32	19	350,000	700	10
00814	WEST COAST REGIONAL WAT SUP AU	0435201	TRAL	275953	821833	33	28	20	500,000	215	8
00815	WEST COAST REGIONAL WAT SUP AU	0435201	POL2	280009	821651	35	28	20	250,000		8
00817	WEST COAST REGIONAL WAT SUP AU	0435201	POL1	280017	821636	35	28	20	400,000	535	12
00820	WEST COAST REGIONAL WAT SUP AU	0435201	PRMN	275908	821826	4	29	20	450,000	470	10
00824	WEST COAST REGIONAL WAT SUP AU	0435201	AB4	274604	822337	22	31	19	108,000	600	8
00825	WEST COAST REGIONAL WAT SUP AU	0435201	AB5	274616	822332	22	31	19	108,000	400	6
00826	WEST COAST REGIONAL WAT SUP AU	0435201	AB6	274624	822329	22	31	19	108,000	400	6
00827	WEST COAST REGIONAL WAT SUP AU	0435201	AB7	274553	822337	22	31	19	123,000	280	8
00828	WEST COAST REGIONAL WAT SUP AU	0435201	AB8	274610	822338	22	31	19	123,000	315	8
00829	WEST COAST REGIONAL WAT SUP AU	0435201	AB12	274554	822333	22	31	19	123,000	340	8
00830	WEST COAST REGIONAL WAT SUP AU	0435201	AB17	274601	822341	22	31	19	123,000	300	6
00835	WEST COAST REGIONAL WAT SUP AU	0435201	H.OK	280015	821617	35	28	20	770,000	600	16
	CYPRESS BEND DEVELOPMENT CORP	0530000	1	280823	823309	13	27	17	182,500		12
	CYPRESS BEND DEVELOPMENT CORP	0530000	2	280816	823319	13	27	17	182,500		12
	FLORIDA CITIES WATER COMPANY	0588601	1	280307	822935	15	28	18	400,000		8
	FLORIDA CITIES WATER COMPANY	0588601	2	280310	822944	15	28	18	400,000		12
	FLORIDA CITIES WATER COMPANY	0588601	3	280233	822958	15	28	18	420,000		12
01355	C W D INC.	0631200	1	280633	823815	30	27	17	116,000	401	12
01499	WEST COAST REGIONAL WAT SUP AU	0667600	CC-1	280441	822935	3	28	18	157,000	352	6

Table 3.—*Computation of vertical travel time and radius of well protection zones for wells in the leaky confined area*—Continued

Well	Lsd (sea lev.)	Fl (sea lev.)	m (ft)	T (ft^2/d)	h (ft)	WT (sea lev.)	Pot (sea lev.)	s (ft)	s(K) (ft)	Δh (ft)	ℓ (ft)	Leak (ft/d/ft)	t_v (days)	r (ft)
							Pinellas County							
00171	20	0	990	57,000	90	5	3	0.38	3	5	5	0.000300	333	1,310
00172	25	0	990	57,000	85	5	5	2.10	18	18	5	0.000300	145	3,170
00173	24	0	1,000	57,000	86	4	5	0.38	3	2	4	0.000300	381	1,340
00481	48	-20	1,120	70,000	222	35	5	1.48	6	36	55	0.000013	20,638	
00482	47	-20	1,120	70,000	223	32	4	0.96	4	32	52	0.000013	21,622	
00484	55	-20	1,120	70,000	125	37	5	1.30	9	41	57	0.000013	19,064	
00485	58	-20	1,120	70,000	122	37	5	1.17	8	40	57	0.000013	19,487	
00486	60	-20	1,120	70,000	160	37	5	0.83	5	37	57	0.000013	20,879	
							Hillsborough County							
00112	37	-10	1,080	240,000	153	25	25	0.10	1	1	35	0.000610	1,913	
	65	0	1,110	240,000		29	20	0.40			29	0.000300		*
	67	0	1,110	240,000		29	20	0.19			29	0.000300		*
	80	0	1,110	240,000		40	20	0.25			40	0.000300		**
	75	0	1,100	240,000		40	20	0.61			40	0.000300		**
	60	0	1,120	240,000		28	20	0.64			28	0.000300		*
	65	0	1,100	240,000		48	21	0.39			48	0.000300		**
	65	0	1,100	240,000		48	21	0.39			48	0.000300		**
	65	0	1,100	240,000		48	21	0.29			48	0.000300		**
	78	0	1,100	240,000		43	20	0.62			43	0.000300		**
	33	0	1,120	240,000		22	21	0.16			22	0.000300		*
00231	130	20	1,100	130,000	566	120	72	1.37	2	50	100	0.000067	5,427	
00232	128	20	1,100	130,000	259	120	72	1.37	5	53	100	0.000067	5,147	
00233	130	20	1,100	130,000	650	120	72	1.39	2	50	100	0.000067	5,427	
00234	124	20	1,100	130,000	546	120	70	1.54	3	53	100	0.000067	5,147	
00236	146	30	1,090	130,000	1,084	120	78	4.76	5	47	90	0.000067	5,166	
00241	64	0	1,000	26,000	521	53	52	3.29	6	7	53	0.000760	1,162	1,090
00242	64	0	1,010	26,000	521	53	52	3.29	6	7	53	0.000760	1,162	1,090
00247	52	0	1,080	100,000	298	26	24	0.37	1	3	26	0.000300	2,167	
00249	54	0	1,080	100,000	246	26	24	0.50	2	4	26	0.000300	1,926	
00250	48	0	1,090	100,000	302	26	24	0.33	1	3	26	0.000300	2,167	
00251	50	0	1,080	100,000	290	26	24	0.35	1	3	26	0.000300	2,167	
00378	34	0	1,160	200,000	304	22	14	0.52	2	10	22	0.000067	4,378	
00379	34	0	1,160	200,000	503	22	14	0.49	1	9	22	0.000067	4,691	
00405	26	-10	1,200	200,000		20	9	0.19			30	0.000007	>1,825	
00406	27	-10	1,200	200,000	278	20	10	0.19	1	11	30	0.000007	53,571	
00512	48	20	980	42,000	532	44	42	0.76	1	3	24	0.000300	2,000	
	56	20	980	42,000		48	42	1.54			28	0.000300		*
	55	20	980	42,000		50	44	1.54			30	0.000300		*
00774	42	-120	1,170	130,000	638	37	-4	0.61	1	42	157	0.000013	51,391	
00775	42	-120	1,170	130,000	538	36	-4	0.61	1	41	156	0.000013	52,174	
00814	31	0	1 130	200,000	184	25	17	0.59	3	11	25	0.000067	4,664	
00815	85	10	1,120	200,000		56	19	0.29			46	0.000067	>1,825	
00817	82	10	1,100	200,000	463	51	19	0.45	1	33	41	0.000067	3,221	
00820	77	0	1,140	200,000	393	33	17	0.52	1	17	33	0.000067	4,478	
00824	12	-80	1,170	130,000	508	8	1	0.19	0	7	88	0.000010	146,667	
00825	11	-75	1,180	130,000	314	8	1	0.20	1	8	83	0.000010	127,692	
00826	12	-75	1,180	130,000	313	7	1	0.20	1	7	82	0.000010	136,667	
00827	12	-80	1,170	130,000	188	8	1	0.22	1	8	88	0.000010	135,385	
00828	10	-80	1,180	130,000	225	7	1	0.22	1	7	87	0.000010	145,000	
00829	11	-80	1,170	130,000	249	8	1	0.22	1	8	88	0.000010	135,385	
00830	11	-80	1,170	130,000	209	7	1	0.22	1	7	87	0.000010	145,000	
00835	47	10	1,170	200,000	563	42	20	0.85	2	24	32	0.000067	3,294	
	56	0	1,000	57,000		50	34	0.68			50	0.000300		**
	56	0	1,010	57,000		49	33	0.68			49	0.000300		*
	47	0	1,110	57,000		36	25	1.56			36	0.000300		**
	43	0	1,110	26,000		36	25	3.15			36	0.000300		**
	43	0	1,130	57,000		34	20	1.57			34	0.000300		**
01355	32	-10	1,030	57,000	359	25	18	0.43	1	8	35	0.000540	997	710
01499	53	0	1,080	26,000	299	45	35	1.33	4	14	45	0.000360	1,316	900

Table 3. – *Computation of vertical travel time and radius of well protection zones for wells in the leaky confined area* – Continued

Well	Owner	Cons. use permit	Well name	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Av.Q (gal/d)	Well depth (ft)	Dia (in)
				Hillsborough County--Continued							
01500	WEST COAST REGIONAL WAT SUP AU	0667600	CC-2	280426	822945	3	28	18	157,000		6
01510	WEST COAST REGIONAL WAT SUP AU	0667600	PL-1	280245	823139	17	28	18	168,000	539	12
01511	WEST COAST REGIONAL WAT SUP AU	0667600	PL-2	280246	823128	17	28	18	280,000	512	12
01512	WEST COAST REGIONAL WAT SUP AU	0667600	PL-3	280248	823139	17	28	18	168,000	490	8
01513	WEST COAST REGIONAL WAT SUP AU	0667600	PL-4	280242	823120	17	28	18	280,000	552	10
01515	WEST COAST REGIONAL WAT SUP AU	0667600	RO-1	280133	823428	23	28	17	150,000	94	8
01516	WEST COAST REGIONAL WAT SUP AU	0667600	RO-2	280131	823420	26	28	17	220,000	174	8
01517	WEST COAST REGIONAL WAT SUP AU	0667600	RO-3	280131	823359	25	28	17	300,000	180	8
01519	WEST COAST REGIONAL WAT SUP AU	0667600	RO-5	280139	823332	24	28	17	360,000	300	16
01521	WEST COAST REGIONAL WAT SUP AU	0667600	CM-1	280447	823307	1	28	17	400,000	450	10
01522	WEST COAST REGIONAL WAT SUP AU	0667600	CM-2	280447	823303	1	28	17	400,000	400	10
01523	WEST COAST REGIONAL WAT SUP AU	0667600	CM-3	280445	823306	1	28	17	400,000	525	10
01524	WEST COAST REGIONAL WAT SUP AU	0667600	ND-1	280538	823024	33	27	18	317,000	530	10
01525	WEST COAST REGIONAL WAT SUP AU	0667600	ND-2	280612	823153	29	27	18	317,000	400	10
01526	WEST COAST REGIONAL WAT SUP AU	0667600	ND-3	280619	823157	29	27	18	317,000	500	10
01527	WEST COAST REGIONAL WAT SUP AU	0667600	DM-1	280412	823111	5	28	18	671,000	504	16
01528	WEST COAST REGIONAL WAT SUP AU	0667600	DM-2	280349	823033	9	28	18	671,000	507	16
01529	WEST COAST REGIONAL WAT SUP AU	0667600	CP-1	280545	823217	31	27	18	595,000	1,000	12
01530	WEST COAST REGIONAL WAT SUP AU	0667600	CP-2	280552	823158	32	27	18	595,000	550	12
01531	WEST COAST REGIONAL WAT SUP AU	0667600	CP-3	280550	823157	32	27	18	595,000	570	10
01532	WEST COAST REGIONAL WAT SUP AU	0667600	NL-2	280614	822942	27	27	18	540,000	574	10
01533	WEST COAST REGIONAL WAT SUP AU	0667600	NL-3	280615	822925	27	27	18	540,000	550	10
01534	WEST COAST REGIONAL WAT SUP AU	0667600	SR-1	280338	823510	10	28	17	2,000,000	300	16
01536	WEST COAST REGIONAL WAT SUP AU	0667600	NW-1	280355	823435	11	28	17	2,000,000	650	24
01537	WEST COAST REGIONAL WAT SUP AU	0667600	NW-2	280349	823317	12	28	17	2,000,000	650	24
01538	WEST COAST REGIONAL WAT SUP AU	0667600	NW-3	280340	823233	7	28	18	2,000,000	650	24
01539	WEST COAST REGIONAL WAT SUP AU	0667600	NW-4	280332	823240	7	28	18	2,000,000	650	24
01540	WEST COAST REGIONAL WAT SUP AU	0667600	NW-5	280321	823154	8	28	18	2,000,000	650	24
01541	WEST COAST REGIONAL WAT SUP AU	0667600	NW-6	280741	823207	18	27	18	2 000,000	650	24
01609	JACOBSEN, WILLIAM L.	0696000	2	280558	823844	30	27	17	105,000	180	4
01681	STRAWBERRY GROVES LTD	0731100	1	280829	822758	13	27	18	106,000	275	8
01682	STRAWBERRY GROVES LTD	0731100	2	280829	822751	13	27	18	106,000	275	8
01754	LAKE HIGHLANDS UTILITIES INC.	0763700	1	274101	822706	19	32	19	140,000	403	8
01793	PARK INVESTMENT II	0779000	1	275920	822029	6	29	20	150,000	277	6
01794	PARK INVESTMENT II	0779000	2	275919	822029	6	29	20	150,000	250	6
01795	PARK INVESTMENT II	0779000	3	275919	822030	6	29	20	150,000	275	6
01826	FLORIDA DEPT-NATURAL RESOURCES	0792000	1	274014	822252	26	32	19	100,000	400	8

Except in large well fields, the scale of the available potentiometric-surface maps was insufficient to give accurate pumping water levels in the vicinity of municipal supply wells. For wells where pumping water levels were not available, a 1-day drawdown was calculated using the average permitted pumping rate, transmissivity at the well site, and a storage coefficient of 0.001. Drawdowns for fully penetrating wells were calculated for one day of pumping using the modified nonequilibrium formula developed by Cooper and Jacob in 1946 (cited in Lohman, 1972, p. 19). For partially penetrating wells, a correction was made using the Kozeny formula (1933) as given by Jacob (1945), modified to show drawdown in the partially penetrating well:

$$s(K) = \frac{s}{p\left[1+7\sqrt{\frac{r_w}{2pm}}\cos\frac{p\pi}{2}\right]}, \quad (3)$$

where

s = drawdown in a hypothetical fully penetrating well, in feet;

$s(K)$ = drawdown in the partially penetrating well, in feet;

p = fraction of the aquifer penetrated, expressed as a decimal;

r_w = radius of the well, in feet;

m = aquifer thickness, in feet; and

the argument for cosine is in radians.

The corrected drawdown was subtracted from the altitude of the Floridan potentiometric surface, which was determined from potentiometric-surface maps, and the resulting value was subtracted from the altitude of the water table to obtain the estimated head difference (Δh) under pumping conditions, as shown in table 3. The value of Δh was increased by 5 feet, or half of a contour interval on the potentiometric surface

Table 3.—*Computation of vertical travel time and radius of well protection zones for wells in the leaky confined area*—Continued

Well	Lsd (sea lev.)	Fl (sea lev.)	m (ft)	T (ft^2/d)	h (ft)	WT (sea lev.)	Pot (sea lev.)	s (ft)	s(K) (ft)	Δh (ft)	ℓ (ft)	Leak (ft/d/ft)	t_v (days)	r (ft)
						Hillsborough County--Continued								
01500	53	0	1,080	26,000	ERR	43	34	1.33			43	0.000360		
01510	37	0	1,120	52,000	502	30	20	0.69	1	11	30	0.000300	1,250	720
01511	43	0	1,120	52,000	469	30	20	1.14	2	12	30	0.000300	1,176	960
01512	37	0	1,110	52,000	453	30	20	0.71	2	12	30	0.000300	1,176	760
01513	43	0	1,120	52,000	509	30	20	1.16	2	12	30	0.000300	1,176	920
01515	15	-10	1,130	57,000	69	7	11	0.58	7	3	17	0.000300	1,417	1,840
01516	16	-10	1,130	57,000	148	9	11	0.86	5	3	19	0.000300	1,583	1,520
01517	19	-10	1,130	57,000	151	12	12	1.17	7	7	22	0.000300	1,222	1,760
01519	23	-10	1,130	57,000	267	15	13	1.31	5	7	25	0.000300	1,389	1,450
01521	45	0	1,080	57,000	405	40	25	1.52	4	19	40	0.000300	1,111	1,240
01522	47	0	1,080	57,000	353	40	25	1.52	4	19	40	0.000300	1,111	1,330
01523	43	0	1,080	57,000	482	40	25	1.52	3	18	40	0.000300	1,159	1,140
01524	60	0	1,060	52,000	470	49	32	1.32	3	20	49	0.000360	1,089	1,020
01525	53	0	1,040	57,000	347	48	31	1.21	3	20	48	0.000300	1,280	1,190
01526	53	0	1,040	57,000	447	48	31	1.21	3	20	48	0.000300	1,280	1,050
01527	44	0	1,090	39,000	460	41	28	3.50	7	20	41	0.000300	1,093	1,510
01528	51	0	1,100	39,000	456	40	29	3.50	7	18	40	0.000300	1,159	1,510
01529	52	0	1,050	52,000	948	46	29	2.43	3	20	46	0.000300	1,227	990
01530	51	0	1,050	52,000	499	46	29	2.43	5	22	46	0.000300	1,136	1,360
01531	51	0	1,050	52,000	519	46	29	2.47	5	22	46	0.000300	1,136	1,330
01532	55	0	1,040	52,000	519	50	41	2.25	4	13	50	0.000360	1,543	1,270
01533	54	0	1,040	39,000	496	50	43	2.95	6	13	50	0.000760	731	1,300
01534	24	0	1,090	57,000	276	20	19	7.27	23	24	20	0.000300	460	3,350
01536	43	0	1,080	57,000	607	27	21	6.97	11	17	27	0.000300	818	2,260
01537	30	0	1,090	57,000	620	25	23	6.97	11	13	25	0.000300	926	2,240
01538	37	0	1,100	52,000	613	28	23	7.60	12	17	28	0.000300	848	2,250
01539	35	0	1,100	57,000	615	28	22	6.97	11	17	28	0.000300	848	2,250
01540	40	0	1,100	52,000	610	32	22	7.60	12	22	32	0.000300	790	2,260
01541	57	0	1,020	57,000	593	51	36	6.97	11	26	51	0.000360	914	2,290
01609	24	-10	1,040	57,000	146	20	17	0.44	3	6	30	0.000300	1,818	1,060
01681	67	0	1,000	26,000	208	61	53	0.87	4	12	61	0.000760	944	890
01682	65	0	1,000	26,000	210	61	53	0.87	3	11	61	0.000760	1,003	890
01754	22	-180	1,190	130,000	201	5	3	0.25	1	3	185	0.000089	51,966	
01793	64	0	1,150	200,000	213	28	15	0.18	1	14	28	0.000067	4,399	
01794	63	0	1,150	200,000	187	28	15	0.18	1	14	28	0.000067	4,399	
01795	65	0	1,150	200,000	210	28	15	0.18	1	14	28	0.000067	4,399	
01826	21	-190	1,190	130,000	189	5	-1	0.18	1	7	195	0.000013	250,000	

and water-table maps, in order to compensate for the approximate nature of the maps.

The head difference, Δh, and other hydraulic parameters previously determined were then used to determine vertical travel times using equation 1. For each well having a vertical travel time of 5 years or less, the radius of the required protection zone was calculated. Radii of the protection zones for these wells are listed in table 3.

Calculation of Protection Zones for Individual Wells

The protection zone around an individual well is a circle with the center of the circle at the well. The radius of the protection zone for each individual public-supply well with an average permitted withdrawal rate of 100,000 gallons or greater per day, or a well that is part of a well field with an average permitted withdrawal rate of 100,000 gallons or greater per day, was computed using the FDER formula (Florida Department of Environmental Regulation, 1987):

$$r = \left(\frac{Qt_h}{\pi hn} \right)^{1/2} , \qquad (4)$$

where

r = radius of individual zone of protection;

t_h = horizontal travel time to well—5 years (1,825 days);

n = effective porosity of the Upper Floridan aquifer = 0.05, as specified in the FDER regulation;

π = 3.14;

Q = average permitted withdrawal rate for the well, in cubic feet per day; and

h = average thickness of the Upper Floridan aquifer penetrated by the well, in feet.

The thickness of the Upper Floridan aquifer interval penetrated was determined for unconfined areas by subtracting the depth to water in the Upper Floridan aquifer from the depth of the well. The depth of the well was obtained from SWFWMD files. The depth to water was determined using a multicounty water-level altitude map with a contour interval of 10 feet (Barr, 1985a) and land-surface altitudes from topographic maps having 5- to 10-foot contour intervals. In areas where the Floridan aquifer is leaky confined, the thickness was determined by subtracting the depth to the top of the Floridan from the well depth. The depth to the top of the Floridan was determined either by using maps of the top of the aquifer (Stewart, 1968; Buono and Rutledge, 1979) or from well-field reports (Ryder, 1978; Ryder and others, 1980; Hutchinson, 1985) and land surface from topographic maps. The permitted withdrawal rates were obtained from SWFWMD permit files dated February 2, 1987. In all cases, map data were derived from the locations determined from SWFWMD latitude-longitude coordinates for each public-supply well.

The result of this calculation is the radius of a circle around each permitted well that describes the zone of protection for that well. The computed protection zone radii and the data used in the calculations for the unconfined areas of Citrus, Hernando, and Pasco Counties are shown in table 4. Similar information for individual wells included in the major well fields in leaky confined areas with vertical travel times of less than 5 years is shown in table 5. The tabulated radius and location may be used to delineate the protection zone on a map of any scale.

Calculation of Protection Zones for Well Fields

The circles delineating individual protection zones overlap in some cases. Because the formula is based on a volumetric displacement concept, overlapping protection zones underestimate the amount of protection required by an amount equal to the area of the overlap.

The procedure used to determine zones of protection around individual wells with overlapping zones was to add the areas of the overlapping zones together to determine a composite protection-zone area. In some cases, groups of wells were permitted together at a withdrawal rate less than the sum of the permitted rates of the individual wells. Such groups of wells with overlapping zones were treated the same as well fields. For well fields, a composite area for the protection zone was determined using a formula analogous to that used to calculate the radius of protection:

$$A = \frac{Qt_h}{hn} , \qquad (5)$$

where

A = area of well field zone of protection, in square feet;

t_h = horizontal travel time to well – 5 years (1,825 days);

n = effective porosity of the Upper Floridan aquifer = 0.05, as specified in the FDER regulation;

Q = average permitted withdrawal rate for the well field, in cubic feet per day; and

h = average thickness of the Upper Floridan aquifer penetrated in the well field, in feet.

These areas were delineated on a map of each well field, or on a quadrangle sheet for individual wells with overlapping zones, in a shape that approximated the configuration of wells in the field. This was done by successive approximation until the designated area was within 5 percent of the calculated area. In all cases, the boundary of the composite protection zone was equal to or outside the boundary of the protection zone for each individual well. If a composite protection zone overlapped protection zones of additional wells, those areas were added to the total and the zone was recomputed.

Well fields with composite protection zones are designated in table 6. Selected well field zones are individually mapped in plates 1–3. Individual wells with overlapping zones, thus requiring composite zones, are noted in table 7 and selected ones are mapped in figures 7–9. Maps showing composite protection zones for other wells or well fields are on file with FDER.

This method of delineating composite protection zones, as with any procedure, creates some anomalous situations. A good example is the Morris Bridge well field (pl. 3). The permitted well field pumping rate for Morris Bridge of 15.5 Mgal/d is not only considerably less than the sum of the permitted rates for the individual wells in the field (21.9 Mgal/d), but yields an area less than the area formed by the outside boundary of the intersecting circles which is by rule the boundary of the protection zone (pl. 3). This zone of protection, however, does not include some area in the center of the well field which would seem to be logically included because water cannot flow there except through the zone of protection. An alternative composite zone of protection was delineated for illustrative purposes by assigning the calculated area outside of a perimeter formed by connecting all of the outermost wells in the field. This zone is more conservative and includes all of the interior areas excluded by the rule method.

Table 4.—*Computation of well protection zones in the unconfined area*

Sources and explanation of data for calculations:

Well - Well number from Southwest Florida Water Management District (SWFWMD) files. Blank where unavailable.
Lat, Long, Sec, Twn, and Rng - Latitude, longitude, section, township, and range. From SWFWMD permitting files, February 2, 1987.
Cons. use permit - Consumptive use permit number. From SWFWMD permitting files, February 2, 1987.
Av.Q - Permitted average pumping rate, in gallons per day, for public-supply use. From SWFWMD permitting files, February 2, 1987.
Well depth, in feet - From SWFWMD files, with some additions from U.S. Geological Survey data files. Blank where unavailable.
Well name - From SWFWMD files. Blank where unavailable.
Owner - From SWFWMD permitting files, February 2, 1987.
County - From SWFWMD permitting files, February 2, 1987.
Lsd - Altitude of land surface, in feet above sea level, from U.S. Geological Survey 7½-minute topographic maps at latitude and longitude given.
Fl - Top of saturated zone in Upper Floridan aquifer, May 1985 (Barr, 1985a), in feet above sea level.
h - Saturated thickness of Upper Floridan aquifer penetrated by the well, in feet. (Well depth - [Lsd-Fl]).
r - Radius of protection zone of the well, rounded to the nearest 10 feet. $r = \left[\frac{1825\ Q}{7.48\ \pi\ hn}\right]^{1/2}$; n = 0.05 for the Upper Floridan aquifer. Radius not computed where well depth unavailable.

Well	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Cons. use permit	Av.Q (gal/d)	Well depth (ft)	Well name	Owner	Lsd (sea lev.)	Fl (sea lev.)	h (ft)	r (ft)
							Citrus County							
00050	285356	823530	21	18	17	0020702	250,000	157	1	CRYSTAL RIVER, CITY OF	5	1	153	1,590
00051	285406	823438	22	18	17	0020702	600,000	250	P-1	CRYSTAL RIVER, CITY OF	7	2	245	1,950
00052	285404	823438	22	18	17	0020702	250,000	175	P-2	CRYSTAL RIVER, CITY OF	7	2	170	1,510
00102	285022	822006	17	19	20	0041902	600,000	400	1	INVERNESS, CITY OF	58	30	372	1,580
00103	285022	822006	17	19	20	0041902	600,000	250	2	INVERNESS, CITY OF	58	30	222	2,050
00104	284925	822046	19	19	20	0041902	1,000,000	250	3	INVERNESS, CITY OF	70	20	200	2,790
00194	284437	821754	15	20	20	0111801	194,000	193	2	FLORAL CITY WATER ASSOC INC.	82	30	141	1,460
00195	284650	821747	3	20	20	0111801	194,000	195	3P	FLORAL CITY WATER ASSOC INC.	49	30	176	1,310
00411	290033	822730	11	17	18	0284202	252,000	184	CS7	CITRUS SPRINGS UTILITIES	105	10	89	2,100
00416	285754	822849	27	17	18	0284202	170,000		13	CITRUS SPRINGS UTILITIES	84	5		
00599	284429	823101	16	20	18	0367302	432,000	250	5	PUNTA GORDA DEVELOPERS	91	6	165	2,020
00598	284421	823101	16	20	18	0367302	432,000	312	6	PUNTA GORDA DEVELOPERS	88	6	230	1,710
	284223	823125	32	20	18	0367302	432,000	325	8	PUNTA GORDA DEVELOPERS	60	7	272	1,570
	284212	823115	32	20	18	0367302	432,000	325	9	PUNTA GORDA DEVELOPERS	72	7	260	1,610
	284450	823058	16	20	18	0367302	432,000	325	10	PUNTA GORDA DEVELOPERS	100	6	231	1,700
	284412	823055	21	20	18	0367302	432,000	325	11	PUNTA GORDA DEVELOPERS	88	7	244	1,660
	284407	823057	21	20	18	0367302	432,000	300	12	PUNTA GORDA DEVELOPERS	70	7	237	1,680
	284453	823058	16	20	18	0367302	432,000	300	13	PUNTA GORDA DEVELOPERS	110	6	196	1,850
	284230	823134	32	20	18	0367302	432,000	300	14	PUNTA GORDA DEVELOPERS	61	7	246	1,650
	284234	823144	29	20	18	0367302	432,000	300	15	PUNTA GORDA DEVELOPERS	60	7	247	1,650
00648	285532	822709	11	18	18	0415302	215,000	320	1	ROLLING OAKS UTILITIES INC.	132	4	192	1,320
00649	285532	822709	11	18	18	0415302	175,000	350	2	ROLLING OAKS UTILITIES INC.	132	4	222	1,110
00650	285503	822700	13	18	18	0415302	130,000	280	4	ROLLING OAKS UTILITIES INC.	70	5	215	970
00651	285446	822718	14	18	18	0415302	215,000	280	5	ROLLING OAKS UTILITIES INC.	79	4	205	1,280
00652	285513	822758	14	18	18	0415302	215,000	340	6	ROLLING OAKS UTILITIES INC.	96	4	248	1,160
00653	285447	822803	14	18	18	0415302	259,000	300	7	ROLLING OAKS UTILITIES INC.	104	4	200	1,420
00654	285458	822813	15	18	18	0415302	345,000	405	8	ROLLING OAKS UTILITIES INC.	106	4	303	1,330
00655	285432	822737	14	18	18	0415302	518,000	355	9	ROLLING OAKS UTILITIES INC.	126	4	233	1,860
	285458	822616	13	18	18	0415302	518,000		10	ROLLING OAKS UTILITIES INC.	96	5		
00872	284720	823455	27	19	17	0440603	138,000	110	1	HOMOSASSA SPECIAL WATER DISTRI	7	2	105	1,430
00873	284736	823429	27	19	17	0440603	138,000	195	3BRA	HOMOSASSA SPECIAL WATER DISTRI	9	2	188	1,070
00874	284820	823215	24	19	17	0440603	264,000	190	4NOR	HOMOSASSA SPECIAL WATER DISTRI	15	3	178	1,520
00875	284720	823453	27	19	17	0440603	100,000	110	2	HOMOSASSA SPECIAL WATER DISTRI	7	2	105	1,220
00876	284809	823055	29	19	18	0440603	396,000	333	5	HOMOSASSA SPECIAL WATER DISTRI	132	4	205	1,730
00961	285200	823425	34	18	17	0465901	400,000	90	3	OZELLO WATER ASSOCIATION INC.	10	2	82	2,750
01641	285323	823158	30	18	18	0712100	167,000		1	MEADOWCREST UTILITIES INC.	70	3		
01642	285320	823158	30	18	18	0712100	167,000		2	MEADOWCREST UTILITIES INC.	70	3		
01692	285330	822640	25	18	18	0735800	393,000	350	1	CITRUS COUNTY	209	5	146	2,040
01693	285330	822638	25	18	18	0735800	393,000	350	2	CITRUS COUNTY	208	5	147	2,040
01821	284103	821841	4	21	20	0787900	112,000	210	1	SOUTHERN STATES UTILITIES INC.	89	29	150	1,080
01822	284103	821840	4	21	20	0787900	112,000	210	2	SOUTHERN STATES UTILITIES INC.	89	29	150	1,080
	290013	824005	11	17	16	0862300	120,000	100		CITRUS CONDOS, INC.	17	5	88	1,460
	290013	824005	11	17	16	0862300	120,000	100		CITRUS CONDOS, INC.	17	5	88	1,460
							Hernando County							
00095	283227	823400	26	22	17	0036801	290,000	245	1	ROYAL PALM BEACH COLONY INC.	21	11	235	1,380
00227	283130	821348	32	22	21	0165101	300,000	600	1	HERNANDO COUNTY	71	45	574	900
00228	283130	821400	32	22	21	0165101	150,000	275	2	HERNANDO COUNTY	90	45	230	1,010
00505	283241	823121	29	22	18	0298302	300,000	500	3	HERNANDO COUNTY	65	17	452	1,020
00989	283222	823235	30	22	18	0298302	335,000	320	WH-1	HERNANDO COUNTY	35	15	300	1,320

Table 4.—*Computation of well protection zones in the unconfined area*—Continued

Well	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Cons. use permit	Av.Q (gal/d)	Well depth (ft)	Well name	Owner	Lsd (sea lev.)	Fl (sea lev.)	h (ft)	r (ft)
							Hernando County--Continued							
00990	283235	823233	30	22	18	0298302	335,000	218	WH-2	HERNANDO COUNTY	52	15	181	1,700
00991	283245	823230	30	22	18	0298302	335,000	275	WH-3	HERNANDO COUNTY	25	15	265	1,400
00992	283302	823225	19	22	18	0298302	335,000	275	WH-4	HERNANDO COUNTY	31	15	259	1,420
01586	283244	822933	27	22	18	0298302	275,000	700		HERNANDO COUNTY	94	23	629	820
01587	283305	822930	22	22	18	0298302	175,000	325		HERNANDO COUNTY	74	22	273	1,000
00536	283126	821736	34	22	20	0340802	121,000	110	1	HERNANDO COUNTY	100	42	52	1,900
00537	283133	821736	34	22	20	0340802	121,000	400	2	HERNANDO COUNTY	100	42	342	740
01085	282724	823633	28	23	17	0484204	227,000	373	2	SPRING HILL UTILITIES	34	15	354	1,000
01086	282652	823637	33	23	17	0484204	227,000	286	6	SPRING HILL UTILITIES	31	16	271	1,140
01087	282751	823039	21	23	18	0484204	566,000	320	7	SPRING HILL UTILITIES	60	25	285	1,760
01088	282937	823317	12	23	17	0484204	397,000	418	10	SPRING HILL UTILITIES	35	16	399	1,240
01089	282726	823638	28	23	17	0484204	397,000	350	11	SPRING HILL UTILITIES	34	15	331	1,360
01090	282708	823351	25	23	17	0484204	227,000	395	12	SPRING HILL UTILITIES	35	20	380	960
01091	282934	823318	12	23	17	0484204	227,000	484	13	SPRING HILL UTILITIES	35	16	465	870
01092	283042	823104	4	23	18	0484204	453,000	400	17	SPRING HILL UTILITIES	82	22	340	1,440
01093	282817	823306	19	23	18	0484204	325,000	290	18	SPRING HILL UTILITIES	39	21	272	1,360
01094	283044	823106	4	23	18	0484204	325,000	400	19P	SPRING HILL UTILITIES	82	22	340	1,220
01095	282754	823036	21	23	18	0484204	325,000	300	20P	SPRING HILL UTILITIES	60	25	265	1,380
01096	282710	823352	25	23	17	0484204	227,000	300	21P	SPRING HILL UTILITIES	35	20	285	1,110
01178	282849	822735	13	23	18	0518602	112,000	500	9P	HERNANDO COUNTY	69	32	463	610
	282937	822832	11	23	18	0575501	150,000	200		HERNANDO COUNTY	70	29	159	1,210
	283000	821038	11	23	21	0578901	184,000	360	1	HERNANDO COUNTY	77	48	331	930
	283030	821141	3	23	21	0578901	184,000	144	4	HERNANDO COUNTY	72	46	118	1,560
01303	282833	823606	21	23	17	0603901	450,000	200	2	U S HOME CORP	36	14	178	1,980
01304	282833	823606	21	23	17	0603901	450,000	200	3	U S HOME CORP	36	14	178	1,980
01585	283238	823401	26	22	17	0689500	200,000	245	1	HERNANDO COUNTY	22	11	234	1,150
01748	283304	822323	22	22	19	0762700	200,000	593	1	BROOKSVILLE, CITY OF	138	35	490	800
01749	283304	822321	22	22	19	0762700	200,000	750	2	BROOKSVILLE, CITY OF	138	35	647	690
01750	283411	822334	15	22	19	0762700	400,000	740	3	BROOKSVILLE, CITY OF	175	35	600	1,020
01751	283127	822355	34	22	19	0762700	250,000	750	4	BROOKSVILLE, CITY OF	186	37	601	800
01752	283129	822351	34	22	19	0762700	550,000	600	5	BROOKSVILLE, CITY OF	202	37	435	1,400
01753	283443	822239	11	22	19	0762700	200,000	450	6	BROOKSVILLE, CITY OF	92	35	393	890
								Pasco County						
00080	281818	824121	15	25	16	0027902	100,000	60	SEWG	JASMINE LAKES SERVICES INC.	11	3	52	1,730
00217	282329	823756	17	24	17	0159602	103,000	410	2	MYRICK, GEORGE	25	18	403	630
00260	281503	824103	3	26	16	0204303	150,000	385	1	ORANGEWOOD LAKES MOBILE HOME	20	5	370	790
00434	281643	824149	27	25	16	0297601	150,000	281	1	PASCO COUNTY	35	4	250	970
00435	281631	824151	27	25	16	0297601	150,000	267	2	PASCO COUNTY	19	4	252	960
00436	281629	824153	27	25	16	0297601	150,000	209	5	PASCO COUNTY	33	4	180	1,140
00437	281627	824129	27	25	16	0297601	200,000	200	7	PASCO COUNTY	25	4	179	1,320
00608	281651	824234	28	25	16	0369203	112,000	230	1	PORT RICHEY, CITY OF	22	1	209	910
00609	281652	824235	28	25	16	0369203	237,000	150	2	PORT RICHEY, CITY OF	20	1	131	1,680
00622	281852	824054	15	25	16	0375901	102,000	110	1	SMITH UTILITIES INC., C. L.	21	2	91	1,320
00623	282042	823657	4	25	17	0376101	435,000	350	101	PASCO COUNTY	34	25	341	1,410
00624	282032	823656	4	25	17	0376101	115,000	350	102	PASCO COUNTY	36	25	339	730
00646	282015	824023	2	25	16	0405701	125,000		10	PASCO COUNTY	25	4		
00647	282012	824020	2	25	16	0405701	100,000		12	PASCO COUNTY	30	4		
00966	282228	824023	26	24	16	0466902	100,000	100	1	HUDSON WATER WORKS INC.	21	4	83	1,370
00967	282222	824023	26	24	16	0466902	100,000	100	3	HUDSON WATER WORKS INC.	20	4	84	1,360
00968	282218	824023	26	24	16	0466902	100,000	100	4	HUDSON WATER WORKS INC.	21	4	83	1,370
00969	282226	824015	26	24	16	0466902	100,000	50	5	HUDSON WATER WORKS INC.	20	4	34	2,140
00970	282222	824015	26	24	16	0466902	100,000	100	7	HUDSON WATER WORKS INC.	25	4	79	1,400
00971	282226	824013	26	24	16	0466902	100,000	90	11	HUDSON WATER WORKS INC.	20	4	74	1,450
00972	282223	824013	26	24	16	0466902	100,000	105	13	HUDSON WATER WORKS INC.	30	4	79	1,400
00973	282210	824017	26	24	16	0466902	100,000	95	14	HUDSON WATER WORKS INC.	22	4	77	1,420
00974	282207	824020	26	24	16	0466902	100,000	93	15	HUDSON WATER WORKS INC.	20	4	77	1,420
00975	282253	823919	24	24	16	0466902	100,000	100	16	HUDSON WATER WORKS INC.	40	8	68	1,510
00976	282253	823923	24	24	16	0466902	100,000	100	17	HUDSON WATER WORKS INC.	42	8	66	1,530
00977	282249	823919	24	24	16	0466902	100,000	100	18	HUDSON WATER WORKS INC.	30	8	78	1,410
00978	282249	823923	24	24	16	0466902	100,000	100	19	HUDSON WATER WORKS INC.	40	8	68	1,510
00979	282246	823919	24	24	16	0466902	100,000	100	20	HUDSON WATER WORKS INC.	30	8	78	1,410
00980	282246	823923	24	24	16	0466902	100,000	100	21	HUDSON WATER WORKS INC.	25	8	83	1,370
00981	282243	823919	24	24	16	0466902	100,000	100	22	HUDSON WATER WORKS INC.	36	8	72	1,470
00982	282243	823923	24	24	16	0466902	100,000	100	23	HUDSON WATER WORKS INC.	35	8	73	1,460
01001	281529	823910	1	26	16	0473401	440,000	300	W-5	NEW PORT RICHEY, CITY OF	25	15	290	1,540
01670	282055	823911	36	24	16	0728200	200,000	121	PW-1	PASCO COUNTY	19	10	112	1,670
01672	282149	823856	30	24	17	0728200	375,000	133	PW-3	PASCO COUNTY	21	16	128	2,130
01673	282150	823856	30	24	17	0728200	375,000	133	PW-4	PASCO COUNTY	22	16	127	2,140

Table 5.—*Computation of well protection zones for well fields*

Sources and explanation of data for calculations:

Well name - From water companies, West Coast Regional Water Supply Authority, and Southwest Florida Water Management District (SWFWMD) files.
Cons. use permit - Consumptive use permit number. From SWFWMD permitting files, February 2, 1987.
Lat, Long, Sec, Twn, and Rng - Latitude, longitude, section, township, and range. From SWFWMD permitting files, February 2, 1987.
Av.Q - Permitted average pumping rate, in gallons per day, for public-supply use. From SWFWMD permitting files, February 2, 1987.
Well depth, in feet - From SWFWMD and U.S. Geological Survey files (Eldridge-Wilde), and Hutchinson (1985)-Cross Bar Ranch.
Fl - Altitude of top of Upper Floridan aquifer, in feet above sea level. From Buono and Rutledge (1978) and Stewart (1968)-Eldridge-Wilde, East Lake Road, south Pasco, Section 21, and Cosme-Odessa.
Lsd - Altitude of land surface, in feet above sea level, from USGS 7½-minute topographic maps at latitude and longitude given.
h - Thickness of Upper Floridan aquifer penetrated, in feet. h = Well depth - (Lsd-Fl).
r - Radius of protection zone of the well, rounded to the nearest 10 feet. $r = \left[\frac{1825(Av.Q)}{7.48\ \pi\ hn}\right]^{½}$; n = 0.05 for the Upper Floridan aquifer.
Area - Area of protection zone of the well, rounded to the nearest 10,000 square feet. $Area = \frac{1825\ (Av.Q)}{7.48\ hn}$.

[Radius and area not computed where vertical travel time exceeds 5 years]

Well name	Cons. use permit	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Av.Q (gal/d)	Well depth (ft)	Fl (sea lev.)	lsd (sea lev.)	h (ft)	r (ft)	Area (ft²)
						South Pasco							
41	0364701	281024	823059	33	26	18	3,000,000	707	5	59	653	2,670	22,420,000
43	0364701	281041	823046	33	26	18	3,000,000	704	5	60	649	2,680	22,560,000
44	0364701	281045	823028	33	26	18	3,000,000	708	5	61	652	2,670	22,450,000
46	0364701	281050	823101	33	26	18	3,000,000	653	5	58	600	2,790	24,400,000
47	0364701	281105	823108	33	26	18	3,000,000	704	5	59	650	2,680	22,520,000
48	0364701	281106	823121	32	26	18	3,000,000	506	5	61	450	3,220	32,530,000
49	0364701	281125	823058	28	26	18	3,000,000	706	5	60	651	2,680	22,490,000
50	0364701	281126	823038	28	26	18	3,000,000	612	5	59	558	2,890	26,230,000
						Cypress Creek							
C-1	0365002	281828	822236	14	25	19	3,000,000	700	40	78	662	2,650	22,110,000
C-2	0365002	281809	822245	14	25	19	3,000,000	700	40	79	661	2,660	22,150,000
C-3	0365002	281800	822250	23	25	19	3,000,000	700	40	72	668	2,640	21,910,000
C-4	0365002	281752	822258	23	25	19	3,000,000	700	40	72	668	2,640	21,910,000
C-5	0365002	281742	822307	23	25	19	3,000,000	700	40	72	668	2,640	21,910,000
C-6	0365002	281741	822329	22	25	19	3,000,000	700	40	71	669	2,640	21,880,000
C-7	0365002	281728	822338	22	25	19	3,000,000	700	40	67	673	2,630	21,750,000
C-8	0365002	281713	822340	27	25	19	3,000,000	700	40	66	674	2,630	21,720,000
C-9	0365002	281650	822340	27	25	19	3,000,000	700	40	65	675	2,630	21,690,000
C-10	0365002	281641	822404	27	25	19	3,000,000	700	40	64	676	2,630	21,660,000
C-11	0365002	281804	822235	23	25	19	3,000,000	700	40	72	668	2,640	21,910,000
C-12	0365002	281743	822220	23	25	19	3,000,000	700	40	71	669	2,640	21,880,000
C-13	0365002	281738	822208	24	25	19	3,000,000	700	40	71	669	2,640	21,880,000
						Cross Bar Ranch							
CB-1	0429001	282110	822736	36	24	18	3,000,000	710	20	76	654	2,670	22,380,000
CB-2	0429001	282135	822757	36	24	18	3,000,000	702	20	78	644	2,690	22,730,000
CB-3	0429001	282149	822837	26	24	18	3,000,000	700	20	75	645	2,690	22,700,000
CB-4	0429001	282154	822806	25	24	18	3,000,000	705	20	76	649	2,680	22,560,000
CB-5	0429001	282220	822806	25	24	18	3,000,000	705	30	71	664	2,650	22,050,000
CB-6	0429001	282235	822843	23	24	18	3,000,000	705	30	71	664	2,650	22,050,000
CB-7	0429001	282243	822813	23	24	18	3,000,000	485	30	73	442	3,250	33,120,000
CB-8	0429001	282309	822809	24	24	18	3,000,000	710	30	71	669	2,640	21,880,000
CB-9	0429001	282326	822821	14	24	18	3,000,000	703	30	70	663	2,650	22,080,000
CB-10	0429001	282340	822752	13	24	18	3,000,000	710	30	70	670	2,640	21,850,000
CB-11	0429001	282347	822715	13	24	18	3,000,000	702	30	72	660	2,660	22,180,000
CB-12	0429001	282347	822645	18	24	19	3,000,000	710	30	72	668	2,640	21,910,000
CB-13	0429001	282413	822714	13	24	18	3,000,000	700	30	72	658	2,660	22,250,000
CB-14	0429001	282412	822643	18	24	19	3,000,000	710	30	72	668	2,640	21,910,000
CB-15	0429001	282412	822751	13	24	18	3,000,000	710	30	68	672	2,630	21,780,000
CB-16A	0429001	282439	822743	12	24	18	3,000,000	630	30	60	600	2,790	24,400,000
CB-17	0429001	282445	822639	7	24	19	3,000,000	710	30	75	665	2,650	22,010,000

Table 5. – *Computation of well protection zones for well fields* – Continued

Well name	Cons. use permit	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Av.Q (gal/d)	Well depth (ft)	Fl (sea lev.)	lsd (sea lev.)	h (ft)	r (ft)	Area (ft^2)
							Starkey						
W-1	0444602	281530	823839	6	26	17	350,000	300	17	22	268	1,420	5,790,000
W-2	0444602	281513	823849	6	26	17	100,000	550	18	22	518	550	890,000
W-3	0444602	281500	823847	6	26	17	350,000	345	20	36	299	1,350	5,190,000
W-4	0444602	281526	823812	6	26	17	200,000	300	20	31	259	1,100	3,380,000
W-6	0444602	281500	823624	4	26	17	740,000	750	0	28	712	1,270	5,000,000
W-7	0444602	281449	823622	4	26	17	740,000	750	0	39	711	1,270	5,080,000
W-8	0444602	281500	823541	3	26	17	740,000	750	0	41	709	1,270	5,090,000
W-9	0444602	281449	823542	3	26	17	740,000	750	0	47	703	1,280	5,140,000
W-10	0444602	281500	823511	3	26	17	740,000	750	0	44	706	1,280	5,110,000
W-11	0444602	281437	823511	10	26	17	740,000	750	0	43	707	1,280	5,110,000
W-12	0444602	281500	823426	2	26	17	740,000	750	0	43	707	1,280	5,110,000
W-13	0444602	281437	823427	11	26	17	740,000	750	0	45	705	1,280	5,120,000
W-14	0444602	281500	823343	1	26	17	740,000	750	0	48	702	1,280	5,140,000
W-15	0444602	281450	823358	1	26	17	740,000	750	0	48	702	1,280	5,140,000
							Eldridge-Wilde						
5B	0267301	280902	823945	12	27	16	948,276	300	-25	28	247	2,440	18,730,000
5S	0267301	280852	823942	12	27	16	948,276	175	-25	26	124	3,450	37,320,000
5N	0267301	280922	823950	12	27	16	948,276	340	-25	30	285	2,270	16,240,000
6S	0267301	280844	823931	12	27	16	948,276	140	-25	28	87	4,110	53,190,000
7S	0267301	280856	823935	12	27	16	948,276	290	-25	28	237	2,490	19,520,000
6N	0267301	280922	823944	12	27	16	948,276	346	-25	31	290	2,250	15,960,000
8S	0267301	280851	823924	12	27	16	948,276	245	-25	31	189	2,790	24,480,000
101	0267301	281021	823934	1	27	16	948,276	311	-15	30	266	2,350	17,400,000
102	0267301	281013	823935	1	27	16	948,276	316	-20	29	267	2,350	17,330,000
103	0267301	281021	823926	1	27	16	948,276	310	-15	31	264	2,360	17,530,000
104	0267301	281011	823925	1	27	16	948,276	402	-15	32	355	2,040	13,030,000
105	0267301	281017	823919	1	27	16	948,276	250	-10	33	207	2,670	22,350,000
106	0267301	281021	823907	1	27	16	948,276	345	-10	34	301	2,210	15,370,000
107	0267301	281013	823907	1	27	16	948,276	308	-10	37	261	2,380	17,730,000
109	0267301	281000	823916	1	27	16	948,276	384	-15	33	336	2,090	13,770,000
110	0267301	280952	823916	1	27	16	948,276	333	-20	31	282	2,290	16,410,000
111	0267301	281008	823916	1	27	16	948,276	399	-15	33	351	2,050	13,180,000
112	0267301	280958	823905	1	27	16	948,276	314	-15	35	264	2,360	17,530,000
113	0267301	280942	823906	1	27	16	948,276	503	-20	35	448	1,810	10,330,000
114	0267301	280932	823916	1	27	16	948,276	407	-20	30	357	2,030	12,960,000
115	0267301	280944	823927	1	27	16	948,276	321	-20	32	269	2,340	17,200,000
116	0267301	280938	823923	1	27	16	948,276	400	-20	34	346	2,060	13,370,000
117	0267301	280927	823948	12	27	16	948,276	302	-20	29	253	2,410	18,290,000
118	0267301	280927	823927	12	27	16	948,276	407	-20	31	356	2,030	13,000,000
119	0267301	280923	823927	12	27	16	948,276	407	-20	30	357	2,030	12,960,000
120	0267301	280915	823904	12	27	16	948,276	809	-20	26	763	1,390	6,060,000
121	0267301	280926	823906	12	27	16	948,276	770	-20	40	710	1,440	6,520,000
122	0267301	280931	823904	1	27	16	948,276	291	-20	37	234	2,510	19,770,000
131	0267301	281020	823858	6	27	17	948,276	460	-10	37	413	1,890	11,200,000
134	0267301	281020	823844	6	27	17	948,276	275	-10	37	228	2,540	20,300,000
135	0267301	281013	823846	6	27	17	948,276	286	-10	38	238	2,490	19,440,000
136	0267301	281020	823831	6	27	17	948,276	440	-10	36	394	1,930	11,740,000
137	0267301	281013	823826	6	27	17	948,276	330	-10	37	283	2,280	16,350,000
138	0267301	280958	823811	6	27	17	948,276	400	-10	40	350	2,050	13,220,000
139	0267301	280916	823812	6	27	17	948,276	560	-10	42	508	1,700	9,110,000
140	0267301	281020	823815	6	27	17	948,276	440	-10	37	393	1,940	11,770,000
141	0267301	281009	823810	6	27	17	948,276	510	-10	39	461	1,790	10,040,000
142	0267301	281014	823809	6	27	17	948,276	400	-10	38	352	2,050	13,150,000
1	0267301	280906	824028	11	27	16	948,276	300	-30	24	246	2,450	18,810,000
2	0267301	280904	824023	11	27	16	948,276	297	-30	24	243	2,460	19,040,000
4	0267301	280904	823958	12	27	16	948,276	300	-30	28	242	2,470	19,120,000
5	0267301	280903	823953	12	27	16	948,276	300	-25	28	247	2,440	18,730,000
6	0267301	280903	823933	12	27	16	948,276	300	-25	30	245	2,450	18,890,000
7	0267301	280908	823925	12	27	16	948,276	285	-25	34	226	2,550	20,470,000
8	0267301	280903	823920	12	27	16	948,276	300	-25	34	241	2,470	19,200,000
9	0267301	280911	823912	12	27	16	948,276	302	-20	32	250	2,430	18,510,000
10A	0267301	280918	823912	12	27	16	948,276	550	-20	32	498	1,720	9,290,000
11A	0267301	280902	823912	12	27	16	948,276	300	-20	29	251	2,420	18,440,000

Table 5.—*Computation of well protection zones for well fields*—Continued

Well name	Cons. use permit	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Av.Q (gal/d)	Well depth (ft)	Fl (sea lev.)	lsd (sea lev.)	h (ft)	r (ft)	Area (ft^2)
Eldridge-Wilde--Continued													
12	0267301	280853	823904	12	27	16	948,276	300	-20	29	251	2,420	18,440,000
13	0267301	280845	823905	12	27	16	948,276	320	-25	29	266	2,350	17,400,000
1S	0267301	280852	824005	11	27	16	948,276	300	-30	29	241	2,470	19,200,000
2A	0267301	280856	824015	11	27	16	948,276	450	-30	25	395	1,930	11,710,000
3S	0267301	280900	824024	11	27	16	948,276	309	-30	23	256	2,400	18,080,000
3B	0267301	280902	824006	11	27	16	948,276	410	-30	26	354	2,040	13,070,000
4N	0267301	280917	823958	12	27	16	948,276	300	-25	27	248	2,440	18,660,000
4S	0267301	280851	823955	12	27	16	948,276	285	-30	26	229	2,540	20,210,000
4A	0267301	280902	823957	12	27	16	948,276	210	-25	27	158	3,050	29,290,000
5A	0267301	280917	823946	12	27	16	948,276	295	-25	30	240	2,480	19,280,000
East Lake Road													
EL-1	0439101	280631	824117	27	27	16	625,000	200	-25	16	159		
EL-2	0439101	280614	824117	27	27	16	625,000	125	-25	17	83		
EL-3	0439101	280603	824109	27	27	16	625,000	169	-25	14	130		
EL-4	0439101	280556	824056	35	27	16	625,000	235	-25	15	195		
EL-5	0439101	280617	824056	26	27	16	625,000	220	-25	14	181		
EL-6	0439101	280639	824055	26	27	16	625,000	200	-25	16	159		
EL-7	0439101	280532	824057	34	27	16	625,000	220	-25	14	181		
EL-8	0439101	280511	824056	34	27	16	625,000	200	-25	14	161		
Section 21													
21-2	0000301	280709	823059	21	27	18	3,000,000	412	10	55	367	3,560	39,890,000
2110	0000301	280652	823011	21	27	18	3,000,000	411	15	54	372	3,540	39,350,000
21-9	0000301	280708	823011	21	27	18	3,000,000	601	15	58	558	2,890	26,230,000
21-8	0000301	280721	823011	21	27	18	3,000,000	551	15	56	510	3,020	28,700,000
21-5	0000301	280738	823034	21	27	18	3,000,000	602	10	57	555	2,900	26,380,000
21-6	0000301	280738	823020	21	27	18	3,000,000	412	10	59	363	3,580	40,330,000
21-1	0000301	280724	823057	21	27	18	3,000,000	571	10	55	526	2,980	27,830,000
21-3	0000301	280655	823058	21	27	18	3,000,000	412	10	55	367	3,560	39,890,000
Cosme-Odessa													
1C	0000401	280550	823549	34	27	17	945,000	345	-20	43	282	2,280	16,350,000
2	0000401	280550	823543	34	27	17	565,000	305	-15	44	246	1,890	11,210,000
3A	0000401	280606	823529	27	27	17	445,000	335	-15	45	275	1,590	7,900,000
4	0000401	280611	823516	27	27	17	1,000,000	345	-15	49	281	2,350	17,370,000
5	0000401	280622	823514	27	27	17	1,000,000	350	-10	49	291	2,310	16,770,000
6A	0000401	280601	823508	27	27	17	965,000	333	-10	47	276	2,330	17,060,000
7A	0000401	280643	823426	26	27	17	945,000	324	-10	54	260	2,380	17,740,000
8	0000401	280649	823420	26	27	17	1,000,000	345	-5	54	286	2,330	17,060,000
9A	0000401	280635	823504	27	27	17	980,000	318	-10	52	256	2,440	18,680,000
10	0000401	280652	823417	23	27	17	995,000	300	-5	53	242	2,530	20,060,000
12A	0000401	280713	823413	23	27	17	995,000	300	0	56	244	2,520	19,900,000
16	0000401	280600	823503	27	27	17	875,000	300	-10	50	240	2,380	17,790,000
18	0000401	280601	823518	27	27	17	545,000	320	-15	44	261	1,800	10,190,000
19	0000401	280608	823503	27	27	17	985,000	312	-10	48	254	2,450	18,920,000
20	0000401	280614	823530	27	27	17	965,000	310	-15	48	247	2,460	19,060,000
21	0000401	280622	823533	27	27	17	1,000,000	320	-15	49	256	2,460	19,060,000
23	0000401	280714	823420	23	27	17	570,000	354	0	50	304	1,710	9,150,000
24	0000401	280721	823421	23	27	17	725,000	357	0	58	299	1,940	11,830,000
25	0000401	280733	823421	23	27	17	785,000	350	0	56	294	2,040	13,030,000
30	0000401	280744	823429	14	27	17	545,000	384	0	61	323	1,620	8,230,000
31	0000401	280752	823430	14	27	17	645,000	374	0	64	310	1,800	10,150,000
32	0000401	280758	823433	14	27	17	785,000	334	0	62	272	2,120	14,080,000
34	0000401	280812	823440	11	27	17	790,000	407	0	62	345	1,890	11,170,000
Morris Bridge													
150	0418000	280718	822107	19	27	20	1,200,000	628	0	42	586	1,780	9,990,000
151	0418000	280733	822103	19	27	20	1,000,000	610	0	46	564	1,660	8,650,000
152	0418000	280705	822023	19	27	20	1,100,000	572	0	43	529	1,800	10,150,000
153	0418000	280728	822108	19	27	20	1,000,000	565	0	40	525	1,720	9,290,000
154	0418000	280717	822004	20	27	20	1,100,000	550	0	42	508	1,830	10,570,000
155	0418000	280732	821944	20	27	20	1,100,000	567	20	44	543	1,770	9,890,000
156	0418000	280721	821924	20	27	20	1,100,000	574	20	43	551	1,760	9,740,000
157	0418000	280736	821909	20	27	20	1,000,000	614	20	45	589	1,620	8,280,000

Table 5. — *Computation of well protection zones for well fields* — Continued

Well name	Cons. use permit	Lat.	Long.	Sec.	Twn. (S.)	Rng. (E.)	Av.Q (gal/d)	Well depth (ft)	Fl (sea lev.)	lsd (sea lev.)	h (ft)	r (ft)	Area (ft^2)
							Morris Bridge--Continued						
158	0418000	280727	821846	21	27	20	1,100,000	603	20	42	581	1,710	9,240,000
159	0418000	280659	822051	19	27	20	1,100,000	553	0	39	514	1,820	10,440,000
160	0418000	280628	822059	30	27	20	1,100,000	614	0	35	579	1,720	9,270,000
161	0418000	280610	822107	30	27	20	1,100,000	542	0	34	508	1,830	10,570,000
162	0418000	280626	822008	29	27	20	1,100,000	608	0	36	572	1,730	9,380,000
163	0418000	280615	821952	29	27	20	1,100,000	616	0	34	582	1,710	9,220,000
164	0418000	280629	821931	29	27	20	1,100,000	617	0	34	583	1,710	9,210,000
165	0418000	280643	821924	29	27	20	1,100,000	620	10	32	598	1,690	8,980,000
166	0418000	280652	821859	21	27	20	1,200,000	599	0	35	564	1,820	10,380,000
167	0418000	280647	821817	21	27	20	1,100,000	590	10	35	565	1,740	9,500,000
168	0418000	280655	821835	21	27	20	1,100,000	617	10	38	589	1,700	9,110,000
169	0418000	280711	821819	21	27	20	1,100,000	607	10	35	582	1,710	9,220,000
							Sun City						
SUN1	0435201	274318	822028	6	32	20	500,000	829	-90	58	681		
SUN2	0435201	274318	822030	6	32	20	500,000	637	-90	58	489		
SUN3	0435201	274309	822033	7	32	20	600,000	704	-90	58	556		
SUN4	0435201	274301	822035	7	32	20	700,000	705	-90	58	557		
SUN5	0435201	274322	822026	6	32	20	700,000	900	-90	58	752		
SUN6	0435201	274315	822017	6	32	20	500,000	690	-90	65	535		
SUN8	0435201	274403	822009	31	31	20	250,000	500	-80	65	355		
SUN9	0435201	274443	822009	31	31	20	350,000	500	-80	60	360		
							Riverview						
RVW1	0435201	274907	821953	5	31	20	350,000	600	-50	57	493		
RVW2	0435201	274903	821953	5	31	20	300,000	700	-50	58	592		
RVW3	0435201	274857	821953	5	31	20	250,000	600	-50	58	492		
RVW4	0435201	274857	821947	5	31	20	250,000	725	-50	62	613		
RVW5	0435201	274901	821941	5	31	20	300,000	600	-50	62	488		
RVW6	0435201	274904	821947	5	31	20	200,000	750	-50	60	640		
RVW7	0435201	274909	821947	5	31	20	200,000	600	-50	59	491		
RVW8	0435201	274914	821947	5	31	20	250,000	688	-50	58	580		

Table 6. — *Composite protection zones for well fields*

Well-field name	Permitted average daily withdrawal (gallons)	Average thickness of penetration of Upper Floridan aquifer (feet)	Area of protection (square miles)
	Pasco County		
South Pasco	16,900,000	608	4.87
Cypress Creek	30,000,000	669	7.85
Cross Bar Ranch	30,000,000	644	8.15
Starkey	8,000,000	601	2.33
	Pinellas/Hillsborough Counties		
Eldridge-Wilde	35,244,000	304	20.3
	Hillsborough County		
Section 21	13,000,000	452	5.03
Cosme-Odessa	13,000,000	276	8.24
Morris Bridge	15,500,000	561	4.84

Table 7.—*Composite protection zones for individual wells with overlapping zones of protection*

Sources and explanation of data for calculations:

Well - Well number from Southwest Florida Water Management District (SWFWMD) files. Blank where unavailable.
Cons. use permit - Consumptive use permit number from SWFWMD permitting files, February 2, 1987.
Av.Q - Permitted average pumping rate, in gallons per day, (for public-supply use) for each well. From SWFWMD permitting files, February 2, 1987.
Well depth, in feet - From SWFWMD files.
Well name - From SWFWMD files.
Owner - From SWFWMD permitting files, February 2, 1987.
County - From SWFWMD permitting files, February 2, 1987.
r - Radius of protection zone of the well, rounded to the nearest 10 feet. $r = \left[\frac{1825(Av.Q)}{7.48\ \pi\ hn}\right]^{\frac{1}{2}}$; n = 0.05 for the Upper Floridan aquifer. (From tables 4 and 5.)
Area - Area of protection zone of the well, rounded to the nearest 10,000 square feet. $Area = \frac{1825\ (Av.Q)}{7.48\ hn}$. (From data in tables 4 and 5.)
Tot.Q - Permitted average pumping rate, in gallons per day, for public-supply use for the group of wells equal to or less than the sum or Av.Q of the individual wells.
Avg. h - Average penetration, in feet, of saturated Upper Floridan aquifer. Given only for groups of wells whose Tot.Q is less than the sum of Av.Q of the individual wells. (From data in tables 4 and 5.)
Total area - For those groups whose Tot.Q = sum, Av.Q, total area = sum, area of each individual well. For those groups whose Tot.Q is less than the sum of Av.Q's, total area = $\frac{(1825)(Tot.Q)}{(7.48)(Av.h)n}$. n = 0.05 for the Upper Floridan aquifer. * - calculated area is less than the individual well areas shown on the indicated figure. ** - included with Starkey well field (fig. 9).
Quad - Name of U.S. Geological Survey 7½-minute topographic map on which the wells are located.

Well	Cons. use permit	Av.Q (gal/d)	Well depth (ft)	Well name	Owner	r (ft)	Area (ft²)	Tot.Q (gal/d)	Avg. h (ft)	Total area (ft²)	Quad.
					Unconfined area						
					Citrus County						
[1]00051	0020702	600,000	250	P-1	CRYSTAL RIVER, CITY OF	1,950	11,950,000				Crystal
[1]00052	0020702	250,000	175	P-2	CRYSTAL RIVER, CITY OF	1,510	7,180,000	850,000		19,130,000	River
00102	0041902	600,000	400	1	INVERNESS, CITY OF	1,580	7,870,000				Inver-
00103	0041902	600,000	250	2	INVERNESS, CITY OF	2,050	13,190,000	1,000,000	277	17,620,000	ness
	0367302	432,000	325	8	PUNTA GORDA DEVELOPERS	1,570	7,750,000				
	0367302	432,000	325	9	PUNTA GORDA DEVELOPERS	1,610	8,110,000				
	0367302	432,000	300	14	PUNTA GORDA DEVELOPERS	1,650	8,570,000				Chassa-
	0367302	432,000	300	15	PUNTA GORDA DEVELOPERS	1,650	8,530,000	1,728,000		32,960,000	howitzka
00599	0367302	432,000	250	5	PUNTA GORDA DEVELOPERS	2,020	12,780,000				
00598	0367302	432,000	312	6	PUNTA GORDA DEVELOPERS	1,710	9,170,000				
	0367302	432,000	325	10	PUNTA GORDA DEVELOPERS	1,700	9,130,000				
	0367302	432,000	325	11	PUNTA GORDA DEVELOPERS	1,660	8,640,000				
	0367302	432,000	300	12	PUNTA GORDA DEVELOPERS	1,680	8,890,000				Chassa-
	0367302	432,000	300	13	PUNTA GORDA DEVELOPERS	1,850	10,760,000	2,592,000		59,370,000	howitzka
00648	0415302	215,000	320	1	ROLLING OAKS UTILITIES INC.	1,320	5,460,000				
00649	0415302	175,000	350	2	ROLLING OAKS UTILITIES INC.	1,110	3,850,000				
00650	0415302	130,000	280	4	ROLLING OAKS UTILITIES INC.	970	2,950,000				
00651	0415302	215,000	280	5	ROLLING OAKS UTILITIES INC.	1,280	5,120,000				
00652	0415302	215,000	340	6	ROLLING OAKS UTILITIES INC.	1,160	4,230,000				
00653	0415302	259,000	300	7	ROLLING OAKS UTILITIES INC.	1,420	6,320,000				
00654	0415302	345,000	405	8	ROLLING OAKS UTILITIES INC.	1,330	5,560,000				
00655	0415302	518,000	355	9	ROLLING OAKS UTILITIES INC.	1,860	10,850,000	2,072,000		44,340,000	Holder
00872	0440603	138,000	110	1	HOMOSASSA SPL. WATER DISTRICT	1,430	6,410,000				
00873	0440603	138,000	195	3BRA	HOMOSASSA SPL. WATER DISTRICT	1,070	3,580,000				
00875	0440603	100,000	110	2	HOMOSASSA SPL. WATER DISTRICT	1,220	4,650,000	376,000		14,640,000	Homosassa
01692	0735800	393,000	350	1	CITRUS COUNTY	2,040	13,140,000				
01693	0735800	393,000	350	2	CITRUS COUNTY	2,040	13,050,000	786,000		26,190,000	Holder
01821	0787900	112,000	210	1	SOUTHERN STATES UTILITIES INC.	1,080	3,640,000				
01822	0787900	112,000	210	2	SOUTHERN STATES UTILITIES INC.	1,080	3,640,000	120,000	201	*	Nobleton
	0862300	120,000	100		CITRUS CONDOS, INC.	1,460	6,650,000				Yankee-
	0862300	120,000	100		CITRUS CONDOS, INC.	1,460	6,650,000	160,000	88	8,870,000	town
					Hernando County						
[2]00095	0036801	290,000	245	1	ROYAL PALM BEACH COLONY INC.	1,380	6,020,000				Weeki-
[2]01585	0689500	200,000	245	1	HERNANDO COUNTY	1,150	4,170,000	490,000		10,190,000	wachee
00227	0165101	300,000	600	1	HERNANDO COUNTY	900	2,550,000				St.
00228	0165101	150,000	275	2	HERNANDO COUNTY	1,010	3,180,000	300,000	341	*	Catherine

[1]This composite protection zone is shown in figure 7.
[2]This composite protection zone is shown in figure 8.

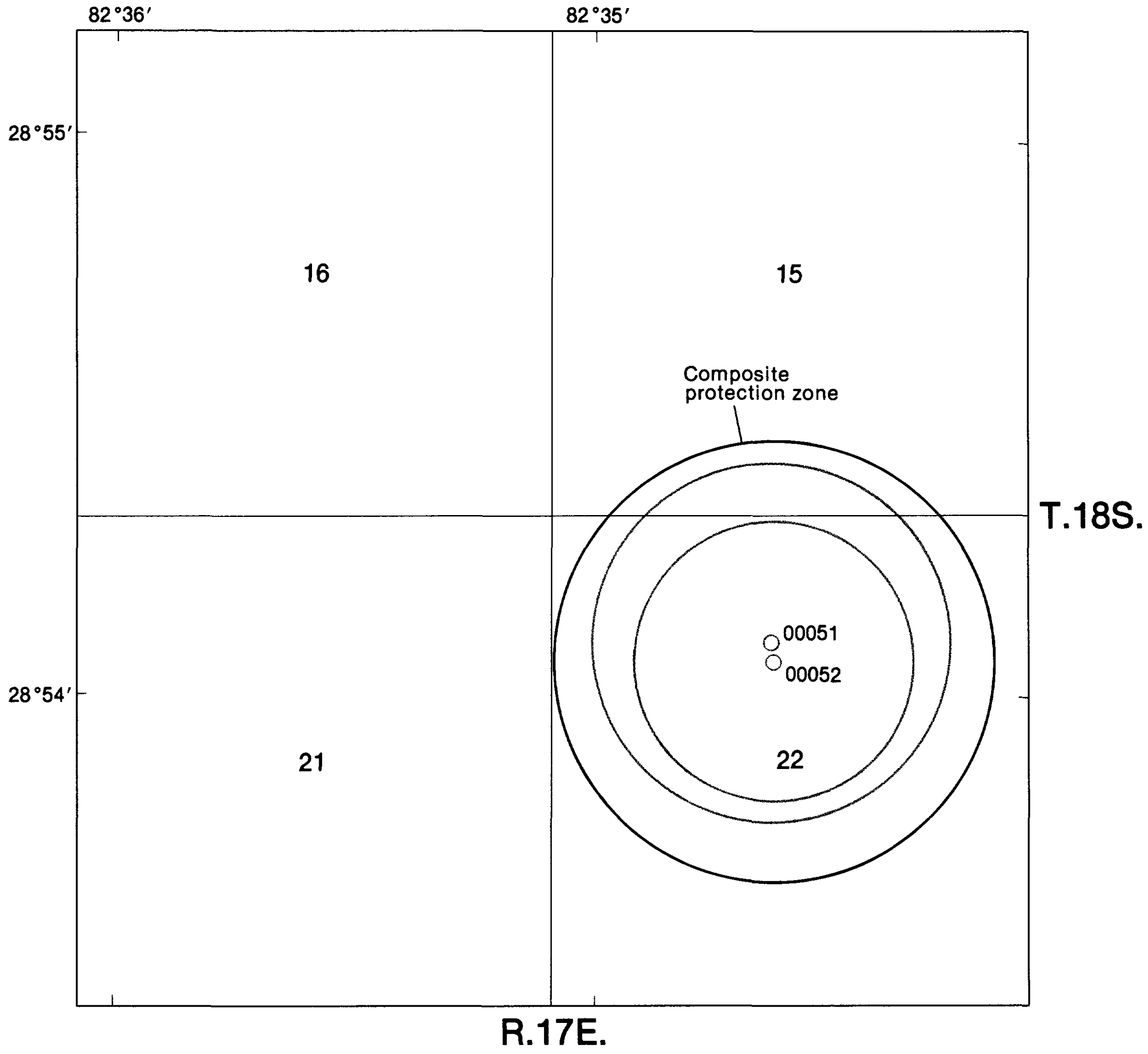
Table 7.—*Composite protection zones for individual wells with overlapping zones of protection*—Continued

Well	Cons. use permit	Av.Q (gal/d)	Well depth (ft)	Well name	Owner	r (ft)	Area (ft^2)	Tot.Q (gal/d)	Avg. h (ft)	Total area (ft^2)	Quad.
					Hernando County--Continued						
00989	0298302	335,000	320	WH-1	HERNANDO COUNTY	1,320	5,450,000				
00990	0298302	335,000	218	WH-2	HERNANDO COUNTY	1,700	9,030,000				
00991	0298302	335,000	275	WH-3	HERNANDO COUNTY	1,400	6,170,000				Weeki-
00992	0298302	335,000	275	WH-4	HERNANDO COUNTY	1,420	6,310,000	1,340,000		26,960,000	wachee
00536	0340802	121,000	110	1	HERNANDO COUNTY	1,900	11,350,000				Brooks-
00537	0340802	121,000	400	2	HERNANDO COUNTY	740	1,730,000	121,000	230	*	ville SE
01085	0484204	227,000	373	2	SPRING HILL UTILITIES	1,000	3,130,000				Port
01089	0484204	397,000	350	11	SPRING HILL UTILITIES	1,360	5,850,000	624,000		8,980,000	Richey N
01087	0484204	566,000	320	7	SPRING HILL UTILITIES	1,760	9,690,000				Port
01095	0484204	325,000	300	20P	SPRING HILL UTILITIES	1,380	5,980,000	891,000		15,670,000	Richey N
01088	0484204	397,000	418	10	SPRING HILL UTILITIES	1,240	4,860,000				Port
01091	0484204	227,000	484	13	SPRING HILL UTILITIES	870	2,360,000	624,000		7,240,000	Richey N
01090	0484204	227,000	395	12	SPRING HILL UTILITIES	960	2,910,000				Port
01096	0484204	227,000	300	21P	SPRING HILL UTILITIES	1,110	3,890,000	454,000		6,800,000	Richey N
01092	0484204	453,000	400	17	SPRING HILL UTILITIES	1,440	6,500,000				Weeki-
01094	0484204	325,000	400	19P	SPRING HILL UTILITIES	1,220	4,660,000	778,000		11,160,000	wachee
01303	0603901	450,000	200	2	U S HOME CORP	1,980	12,340,000				Port
01304	0603901	450,000	200	3	U S HOME CORP	1,960	12,340,000	900,000		24,680,000	Richey N
01748	0762700	200,000	593	1	BROOKSVILLE, CITY OF	800	1,990,000				Brooks-
01749	0762700	200,000	750	2	BROOKSVILLE, CITY OF	690	1,510,000	400,000		3,500,000	ville
01751	0762700	250,000	750	4	BROOKSVILLE, CITY OF	800	2,030,000				Brooks-
01752	0762700	550,000	600	5	BROOKSVILLE, CITY OF	1,400	6,170,000	800,000		8,200,000	ville
					Pasco County						
00434	0297601	150,000	281	1	PASCO COUNTY	970	2,930,000				
00435	0297601	150,000	267	2	PASCO COUNTY	960	2,900,000				
00436	0297601	150,000	209	5	PASCO COUNTY	1,140	4,070,000				Port
00437	0297601	200,000	200	7	PASCO COUNTY	1,320	5,450,000	650,000		15,410,000	Richey
00608	0369203	112,000	230	1	PORT RICHEY, CITY OF	910	2,610,000				Port
00609	0369203	237,000	150	2	PORT RICHEY, CITY OF	1,680	8,830,000	349,000		11,440,000	Richey
00623	0376101	435,000	350	101	PASCO COUNTY	1,410	6,220,000				
00624	0376101	115,000	350	102	PASCO COUNTY	730	1,660,000	550,000		7,880,000	Fivay
00966	0466902	100,000	100	1	HUDSON WATER WORKS INC.	1,370	5,880,000				
00967	0466902	100,000	100	3	HUDSON WATER WORKS INC.	1,360	5,610,000				
00968	0466902	100,000	100	4	HUDSON WATER WORKS INC.	1,370	5,880,000				
00969	0466902	100,000	50	5	HUDSON WATER WORKS INC.	2,140	14,350,000				
00970	0466902	100,000	100	7	HUDSON WATER WORKS INC.	1,400	6,180,000				
00971	0466902	100,000	90	11	HUDSON WATER WORKS INC.	1,450	6,590,000				
00972	0466902	100,000	105	13	HUDSON WATER WORKS INC.	1,400	6,180,000				
00973	0466902	100,000	95	14	HUDSON WATER WORKS INC.	1,420	6,340,000				Port
00974	0466902	100,000	93	15	HUDSON WATER WORKS INC.	1,420	6,340,000	582,353	82	34,650,000	Richey
00975	0466902	100,000	100	16	HUDSON WATER WORKS INC.	1,510	7,180,000				
00976	0466902	100,000	100	17	HUDSON WATER WORKS INC.	1,530	7,390,000				
00977	0466902	100,000	100	18	HUDSON WATER WORKS INC.	1,410	6,260,000				
00978	0466902	100,000	100	19	HUDSON WATER WORKS INC.	1,510	7,180,000				
00979	0466902	100,000	100	20	HUDSON WATER WORKS INC.	1,410	6,260,000				
00980	0466902	100,000	100	21	HUDSON WATER WORKS INC.	1,370	5,880,000				
00981	0466902	100,000	100	22	HUDSON WATER WORKS INC.	1,470	6,780,000				
00982	0466902	100,000	100	23	HUDSON WATER WORKS INC.	1,460	6,680,000	517,647	65	38,660,000	Aripeka
01672	0728200	375,000	133	PW-3	PASCO COUNTY	2,130	14,300,000				Port
01673	0728200	375,000	133	PW-4	PASCO COUNTY	2,140	14,410,000	950,000		28,640,000	Richey
					HUDSON + PASCO COUNTY			2,100,000		102,150,000	
01001	0473401	440,000	300	W-5	NEW PORT RICHEY, CITY OF	1,540	7,400,000	440,000		**	

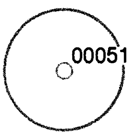
Table 7.—*Composite protection zones for individual wells with overlapping zones of protection*—Continued

Well	Cons. use permit	Av.Q (gal/d)	Well depth (ft)	Well name	Owner	r (ft)	Area (ft^2)	Tot.Q (gal/d)	Avg. h (ft)	Total area (ft^2)	Quad.
					Leaky confined area						
					Pasco County						
00032	0002502	112,000	665	C	WATER & SEWER DISTRICT A	540	930,000				
00033	0002502	112,000	620	D	WATER & SEWER DISTRICT A	570	1,010,000	224,000		1,940,000	Lutz
00122	0054302	110,000	100	1	CRESTRIDGE GARDENS UTIL CORP	1,510	7,160,000				
00125	0054302	130,000	170	4	CRESTRIDGE GARDENS UTIL CORP	1,200	4,530,000				
00126	0054302	110,000	160	5	CRESTRIDGE GARDENS UTIL CORP	1,170	4,290,000	153,000	113	*	Elfers
00115	0045101	2,000,000	461	MP2	LYKES PASCO PACKING CO	2,710	23,020,000				
00221	0163101	500,000	400	1	DADE CITY FLORIDA, CITY OF	1,500	7,090,000				
00222	0163101	500,000	400	2	DADE CITY FLORIDA, CITY OF	1,500	7,090,000				
00223	0163101	500,000	400	3	DADE CITY FLORIDA, CITY OF	1,500	7,090,000				
00224	0163101	1,400,000	492	4	DADE CITY FLORIDA, CITY OF	2,310	16,790,000	4,900,000		61,080,000	Dade City
00441	0297801	225,000	90	2	LINDRICK SERVICE CORPORATION	2,520	19,960,000				
00683	0426901	230,000	186	7	PASCO COUNTY	1,590	7,960,000				
00684	0426901	230,000	137	8	PASCO COUNTY	2,100	13,860,000				
00685	0426901	230,000	180	9	PASCO COUNTY	1,710	9,200,000				
00688	0426901	100,000	137	2	PASCO COUNTY	1,300	5,300,000	1,015,000		56,280,000	Elfers
00120	0054002	128,000	85	1	HOLIDAY GARDENS UTILITIES INC.	1,790	10,070,000				
00561	0359001	130,000	105	3	BARTELT SUNSHINE CORP	1,610	8,130,000				
00962	0466801	120,000	160	1	UTILITIES INC. OF FLORIDA	1,180	4,370,000				
00963	0466801	105,000	117	2	UTILITIES INC. OF FLORIDA	1,330	5,570,000	483,000		28,140,000	Elfers
01574	0686700	120,000	345	1	VILLAGE-TAMPA INC., THE	750	1,770,000				
01575	0686700	120,000	345	2	VILLAGE-TAMPA INC., THE	750	1,770,000	120,000	323	*	Dade City
					Pinellas County						
00172	0074202	550,000	110	2	TARPON SPRINGS, CITY OF	3,170	31,570,000				
00173	0074202	100,000	110	3	TARPON SPRINGS, CITY OF	1,340	5,670,000	650,000		37,240,000	Elfers
					Hillsborough County						
00241	0178701	400,000	585	2	SCARECROW UTILITY INC	1,090	3,750,000				Lutz
00242	0178701	400,000	585	3	SCARECROW UTILITY INC	1,090	3,750,000	400,000	521	*	Lutz
01510	0667600	168,000	539	PL-1	WEST COAST REGIONAL WAT SUP AU	720	1,630,000				
01511	0667600	280,000	512	PL-2	WEST COAST REGIONAL WAT SUP AU	960	2,910,000				
01512	0667600	168,000	490	PL-3	WEST COAST REGIONAL WAT SUP AU	760	1,810,000				Citrus
01513	0667600	280,000	552	PL-4	WEST COAST REGIONAL WAT SUP AU	920	2,680,000	896,000		9,030,000	Park
01515	0667600	150,000	94	RO-1	WEST COAST REGIONAL WAT SUP AU	1,840	10,610,000				
01516	0667600	220,000	174	RO-2	WEST COAST REGIONAL WAT SUP AU	1,520	7,250,000				
01517	0667600	300,000	180	RO-3	WEST COAST REGIONAL WAT SUP AU	1,760	9,690,000				Citrus
01519	0667600	360,000	300	RO-5	WEST COAST REGIONAL WAT SUP AU	1,450	6,580,000	670,000		34,130,000	Park
01521	0667600	400,000	450	CM-1	WEST COAST REGIONAL WAT SUP AU	1,240	4,820,000				
01522	0667600	400,000	400	CM-2	WEST COAST REGIONAL WAT SUP AU	1,330	5,530,000				Citrus
01523	0667600	400,000	525	CM-3	WEST COAST REGIONAL WAT SUP AU	1,140	4,050,000	1,200,000		14,400,000	Park
[3]01525	0667600	317,000	400	ND-2	WEST COAST REGIONAL WAT SUP AU	1,190	4,460,000				
[3]01526	0667600	317,000	500	ND-3	WEST COAST REGIONAL WAT SUP AU	1,050	3,460,000				
[3]01529	0667600	595,000	1,000	CP-1	WEST COAST REGIONAL WAT SUP AU	,990	3,060,000				
[3]01530	0667600	595,000	550	CP-2	WEST COAST REGIONAL WAT SUP AU	1,360	5,820,000				Citrus
[3]01531	0667600	595,000	570	CP-3	WEST COAST REGIONAL WAT SUP AU	1,330	5,590,000	2,419,000		22,390,000	Park
01532	0667600	540,000	574	NL-2	WEST COAST REGIONAL WAT SUP AU	1,270	5,080,000				Sulphur
01533	0667600	540,000	550	NL-3	WEST COAST REGIONAL WAT SUP AU	1,300	5,310,000	1,080,000		10,390,000	Springs
01534	0667600	2,000,000	300	SR-1	WEST COAST REGIONAL WAT SUP AU	3,350	35,360,000				Citrus
01536	0667600	2,000,000	650	NW-1	WEST COAST REGIONAL WAT SUP AU	2,260	16,080,000	4,000,000		51,440,000	Park
01537	0667600	2,000,000	650	NW-2	WEST COAST REGIONAL WAT SUP AU	2,240	15,740,000				
01538	0667600	2,000,000	650	NW-3	WEST COAST REGIONAL WAT SUP AU	2,250	15,920,000				
01539	0667600	2,000,000	650	NW-4	WEST COAST REGIONAL WAT SUP AU	2,250	15,870,000				Citrus
01540	0667600	2,000,000	650	NW-5	WEST COAST REGIONAL WAT SUP AU	2,260	16,000,000	8,000,000		63,530,000	Park
01681	0731100	106,000	275	1	STRAWBERRY GROVES LTD	890	2,490,000				
01682	0731100	106,000	275	2	STRAWBERRY GROVES LTD	890	2,460,000	106,000	209	*	Lutz

[3]This composite protection zone is shown in figure 9.



EXPLANATION



OUTER CIRCLE IS PROTECTION ZONE FOR PUBLIC SUPPLY WELL LOCATED IN CENTER OF CIRCLE. NUMBER IS WELL NUMBER IN TABLES.

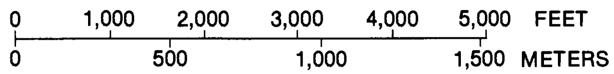


Figure 7.—Composite protection zones for wells of the city of Crystal River, Citrus County.

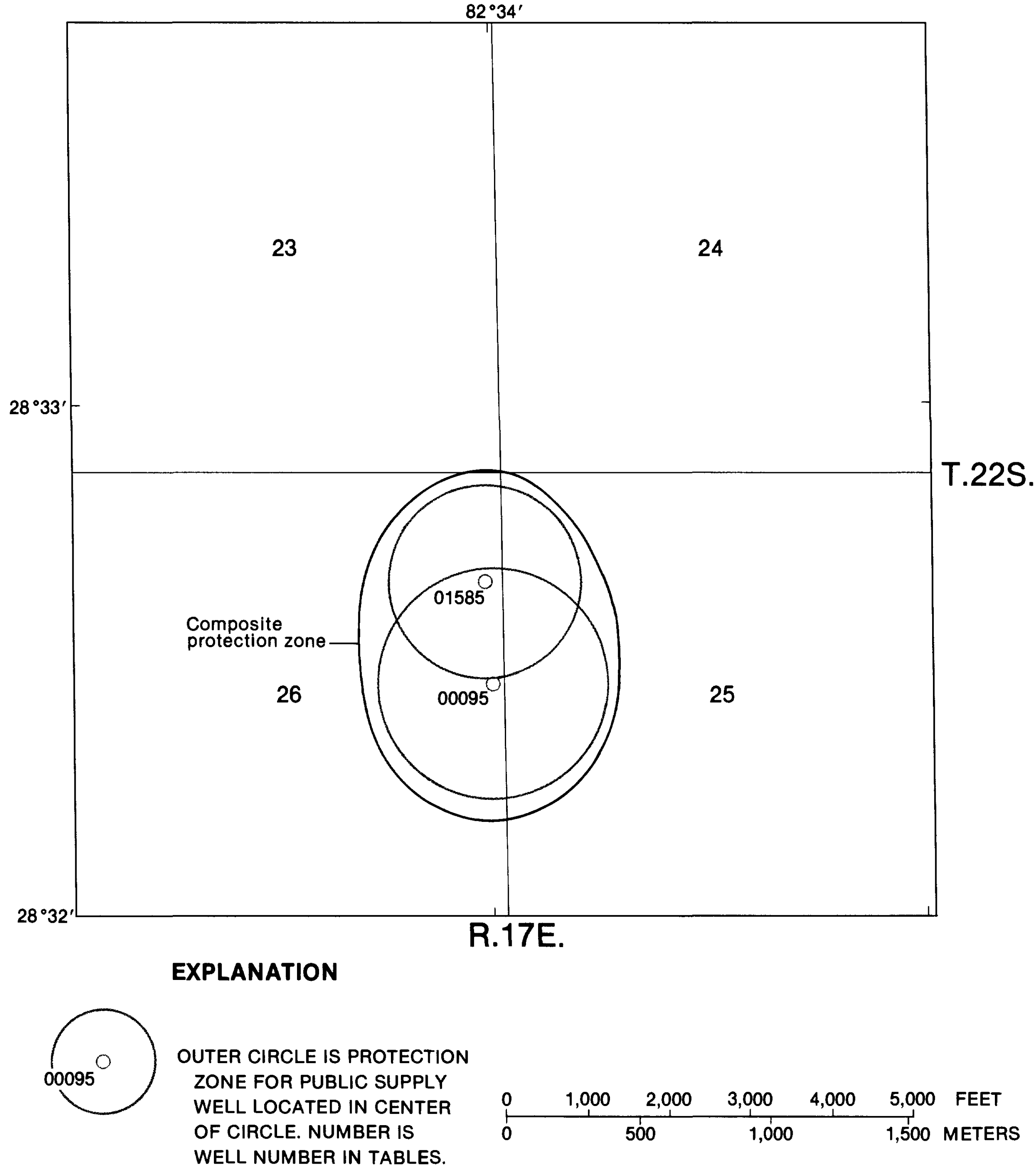


Figure 8.—Composite protection zones for wells of the Royal Palm Beach Colony, Inc., Hernando County.

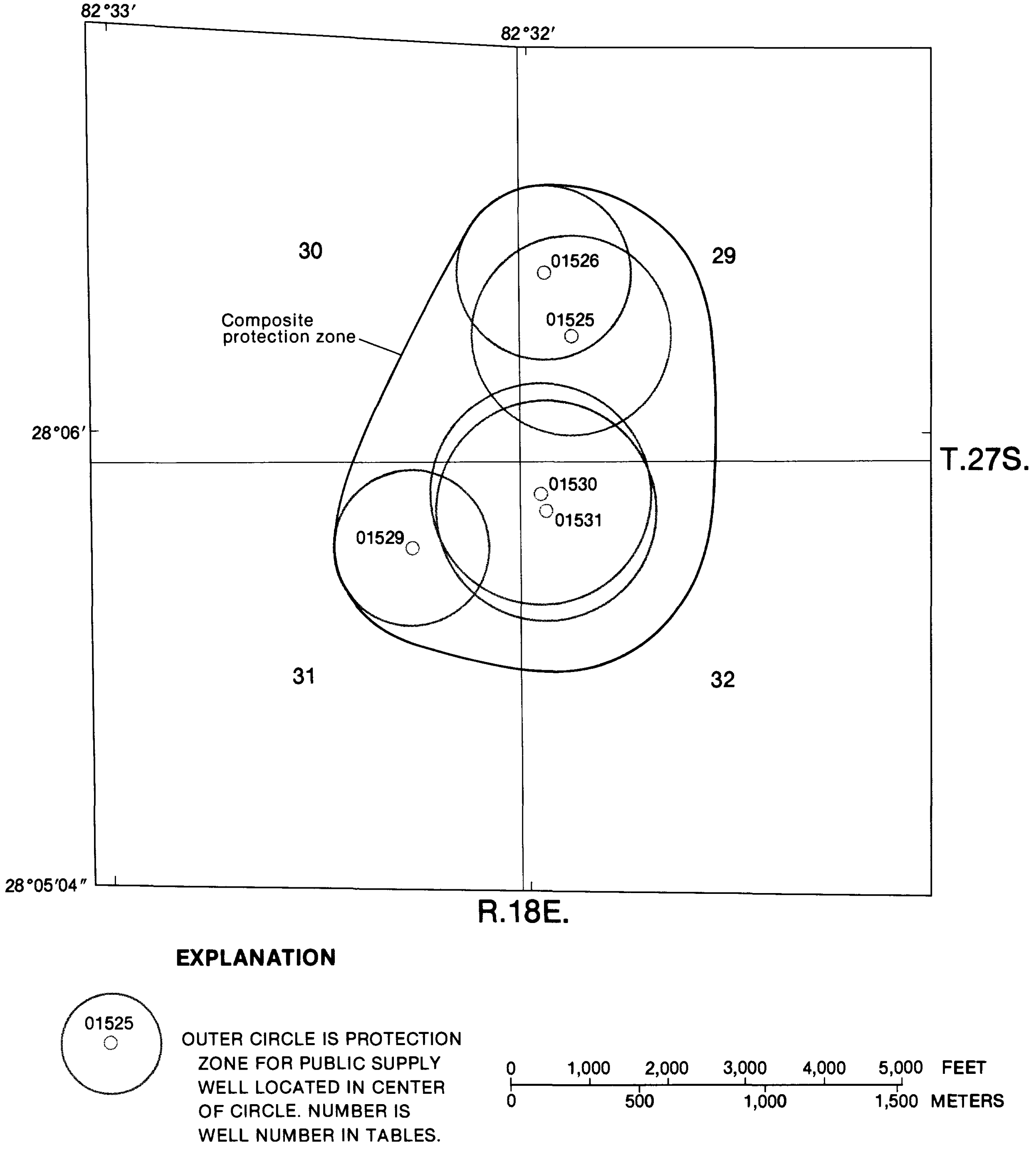


Figure 9.—Composite protection zones for some wells of the West Coast Regional Water Supply Authority, Hillsborough County.

EVALUATION OF METHODOLOGY FOR DELINEATING PROTECTION ZONES

Basis of the Volumetric Equation

The volumetric equation used in delineating the protection zones is based on a simplification of the ground-water flowfield around a pumping well. The flowfield is conceptualized as one of uniform radial flow toward the pumping well emanating from distances far beyond the anticipated "protection-zone boundary." Only lateral flow is presumed and there are no incremental gains from storage, recharge, or leakage as the pumping well is approached. Accordingly, invoking the law of conservation of mass requires that the volume of water pumped from the well in a specified time be replaced by an equal volume flowing through a cylindrical face of the aquifer at a distance "r" from the well such that the volume of aquifer circumscribed by the cylinder contains the volume of water pumped. The model further presumes that a potential contaminant passing through the cylindrical face would be transported toward the well under advective "plug-flow" conditions only. Thus, the time required for a potential contaminant to enter the well from some distance "r" in the aquifer is simply a function of the amount of water in the cylinder of aquifer around the well that must be displaced.

Although appearing to be devoid of variables such as hydraulic conductivity or velocity and hydraulic gradient, the volumetric equation is derivable, as suggested by Mark T. Stewart (University of South Florida, written commun., December 16, 1986), from the radial form of Darcy's law:

$$Q = K2\pi rhi \qquad (6)$$

where

Q = rate of discharge,
K = hydraulic conductivity,
r = radial distance,
h = aquifer thickness, and
i = hydraulic gradient.

Recognizing that average particle velocity, $\bar{v}$, times porosity, n, is equal to Ki, then through substitution and rearrangement,

$$\bar{v} = \frac{Q}{2\pi rhn},$$

and substitution of r/t, where t = time, for $\bar{v}$, differentiation of r with respect to t, and rearrangement yields

$$rdr = \frac{Q}{2\pi hn} dt$$

and integrating from t_1 *to* t_2;

$$\int_{r_1}^{r_2} rdr = \frac{Q}{2\pi hn} \int_{t_1}^{t_2} dt$$

results in $\frac{r_2{}^2}{2} - \frac{r_1{}^2}{2} = \frac{Q}{2\pi hn}(t_2 - t_1)$,

and when $t_1 = 0$, $r_1 = 0$,

gives $\frac{r^2}{2} = \frac{Qt}{2\pi hn}$

or $r = \left[\frac{Qt}{\pi hn}\right]^{1/2}$

Hydrologic Factors Influencing Applicability

Potentiometric-Surface Slope

Superposition of the drawdown from a pumping well producing from an aquifer that has a sloping potentiometric surface results in a nonradially symmetric flowfield around the well. As described by Todd (1980, p. 122), the boundary of the contributing area extends downgradient to a stagnation point beyond which water is not drawn toward the pumping well. However, in the upgradient direction, the contributing area extends to a greater distance. The greater the slope of the potentiometric surface, the closer is the stagnation point in the downgradient direction and the greater the flowfield departs from being radially symmetrical.

As a result of the distortion from a radially symmetrical flowfield, application of the volumetric equation to a well pumping from an aquifer with a sloping potentiometric surface delineates a protection zone that may be overprotective in the downgradient direction and underprotective in the upgradient direction. The degree to which inappropriate areas are included within the delineated protection zones can be assessed by considering a range of gradients typical of the slope of the potentiometric surface in west-central Florida. From potentiometric-surface maps of the Upper Floridan aquifer (Barr, 1985b; Barr and Lewelling, 1986), it is seen that the hydraulic gradient varies from near zero to a maximum of about 0.001. Table 8 compares the downgradient distance to the stagnation point with the radial distance calculated from the volumetric equation for typical pumping rates, aquifer characteristics, and gradient extremes. For example, the stagnation point where the transmissivity is 25,000 ft^2/d and the horizontal gradient is 0.0001 is 8,500 feet

Table 8.—*Comparison of downgradient distance to stagnation point with radial distance calculated from volumetric equation*

[ft^2/d = foot squared per day; Mgal/d = million gallons per day]

		Transmissivity = 25,000 ft^2/d			Transmissivity = 100,000 ft^2/d		
Pumping rate, Mgal/d		0.1	1	3	0.1	1	3
Stagnation point distance, feet, for i =							
	0.001	85	850	2,600	21	210	630
	0.0001	850	8,500	26,000	210	2,100	6,300
Volumetric radial distance, feet		620	2,000	3,400	620	2,000	3,400

Note: Stagnation point distance computed from $\chi_L = -\frac{Q}{2\pi Kmi}$ (Todd, 1980, p. 123)

where

χ_L = downgradient stagnation point distance from well,
Q = pumping rate,
K = aquifer hydraulic conductivity,
m = aquifer thickness, and
i = hydraulic gradient.

Volumetric radial distance computed from equation 4 with h = 400 feet and n = 0.05.

downgradient of a well pumping 1 Mgal/d. Because the stagnation point is farther from the well than is the radial distance (2,000 feet) calculated from the volumetric equation for typical conditions in the area, the calculated protection zone lies fully within the contributing area. In this case, the calculated zone is only slightly overprotective on the downgradient side. This results because the head gradient at any given radius from the well will be less on the downgradient side than on the upgradient side when the sloping potentiometric surface is considered. In cases where the stagnation point is closer to the well than the radial distance from the volumetric equation, the computed protection zone is more significantly overprotecting the area downgradient of the well, because water on the downgradient side of the stagnation point cannot flow to the well.

Boundaries

The conceptual model used as the basis for the volumetric equation assumes that the aquifer extends from the well to be protected in all directions to distances far beyond the boundaries of the protection zone and is not intersected by hydraulic boundaries. For leaky confined aquifers, that assumption is valid because the aquifer is isolated hydraulically to some degree from surface streams and lakes that would function as recharge boundaries. For unconfined aquifers, the presence of streams, lakes, or canals in the vicinity of a public-supply well would distort the flowfield around the well. If the surface-water source were in good hydraulic communication with the unconfined aquifer, it could function as a fully effective boundary that prevents the flowfield produced by the pumping well from spreading beyond the boundary. Therefore, if the protection zone calculated with the volumetric formula extends beyond the surface-water body, that part of the zone that falls beyond may be regarded as unnecessary protection. On the other hand, that part of the zone that falls beyond, if not regulated, could contribute contaminants to the surface-water body and thence indirectly to the public-supply well through induced infiltration.

Porosity Variation

Effective porosity is assumed to be uniform around the pumping well and not to vary from site to site. The radius calculated from the volumetric equation varies inversely with the square root of effective porosity. Accordingly, a 100 percent increase in the assigned effective porosity—say from 0.05 to 0.10—results in a calculated radius that is 71 percent of the radius using 0.05. A 200 percent increase in effective porosity would result in a 42 percent decrease in radius.

Effective porosity refers to the amount of interconnected pore space available for fluid transmission (Lohman and others, 1972, p. 10). Some aquifers are characterized by diffuse flow in which water moves more or less uniformly throughout the interconnected pores distributed throughout the mass of the rock. Unconsolidated sand and sand and gravel aquifers fall into this category as does the Biscayne aquifer in general. Some consolidated rock aquifers, such as the Floridan, are characterized by conduit flow along irregularly distributed solution enlarged fractures in combination with diffuse flow through the much more uniformly distributed interconnected pores. In these aquifers, water tends to travel fastest through the fracture openings and thus contaminant movement is dominated by the porosity associated with the fracture openings, as shown schematically by Freeze and Cherry (1979, p. 411) and described by Gilham and others (1983, p. 23). In contrast, the amount of porosity associated with fracture openings is much less than that of the pores; thus the effective porosity value of 0.05 assigned to the Floridan in the FDER regulation is much less than that assigned to the other aquifers that possess diffuse-flow characteristics. However, the assigned porosity value is simply a judgment and is not based on specific measurements of fracture porosity, because fracture porosity is variable and extremely difficult to measure.

Thickness Determination

The thickness-of-aquifer value used in the volumetric equation is prescribed as the distance between the top of the aquifer and the bottom of the well. As with porosity, the calculated radius of the protection zone varies inversely with the square root of the aquifer thickness. For example, if a well penetrated the Floridan aquifer system in the west-central Florida area to a depth of 400 feet, a not uncommon depth, but the overall thickness of the aquifer were 25 to 50 percent greater, then the calculated radius would be 12 to 25 percent greater from what it would be if the full aquifer thickness were used in the calculation.

SUMMARY

Numerous public-supply wells in west-central Florida tap the Floridan aquifer system. Because the Floridan is at or near land surface and unconfined to poorly confined over most of the area of northern Hillsborough and Pinellas Counties and Pasco, Hernando, and Citrus Counties, it is vulnerable to contamination from surface sources. A recent regulation of the Florida Department of Environmental Regulation (1987) calls for the delineation of protection zones around public-supply wells that tap such vulnerable aquifers. This report evaluates the conditions of confinement of the Upper Floridan aquifer at each of the public-supply well sites and it defines protection zones where required in accordance with the FDER regulation.

Vulnerability was assessed by delineating areas where the Floridan aquifer system is unconfined, leaky confined, or confined. Leaky confined areas were evaluated to determine vertical travel time through overlying material to the Floridan. Protection zones were calculated for wells and well fields of greater than 100,000 gallons per day permitted use in unconfined areas and in leaky confined areas with less than 5-year vertical travel time from the water table to the top of the Floridan. Protection zones were delineated using a volumetric displacement model derivable from Darcy's Law. Where zones of individual wells did not overlap, radii of circles of appropriate area around individual wells were tabulated. Where zones overlapped, composite areas were determined and composite protection zones were delineated in shapes that were appropriate for each configuration of wells with overlapping zones.

The report evaluates the effects of various hydrogeologic factors on the size and/or shape of the protection zones delineated in accordance with the FDER regulations. The natural slope of the potentiometric surface, hydrologic boundaries, porosity variations, and differences in total aquifer thickness from that penetrated by the public-supply well all cause the delineated protection zone to depart, in varying degree, from the actual 5-year travel-time threshold boundary.

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Barr, G.L., 1982, Water levels in selected well fields and in west-central Florida, May 1982: U.S. Geological Survey Open-File Report 82–867, 2 sheets.

– – – 1985a, Potentiometric surface of the Upper Floridan aquifer, west-central Florida, May 1985: U.S. Geological Survey Open-File Report 85–482, 1 sheet.

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