HYDROGEOLOGY OF THE CROSS BAR RANCH WELL-FIELD AREA AND PROJECTED IMPACT OF PUMPING, PASCO COUNTY, FLORIDA

By C. B. Hutchinson

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4001

Prepared in cooperation with the

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Tallahassee, Florida

1985

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

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

Copies of this report can be
purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225
(Telephone: (303) 236-7476)

CONTENTS

ILLUSTRATIONS

TABLES

ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System of Units (SI) and abbreviation of units

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
gallon per minute (gal/min)	0.00006309	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
square feet per day (ft^2/d)	0.09290	square meters per day (m^2/d)
feet per day per foot [(ft/d)/ft]	1.0	meters per day per meter [(m/d)/m]
inches per year (in/yr)	25.4	millimeters per year (mm/yr)

HYDROGEOLOGY OF THE CROSS BAR RANCH WELL-FIELD AREA AND PROJECTED IMPACT OF PUMPING, PASCO COUNTY, FLORIDA

By C. B. Hutchinson

ABSTRACT

The Cross Bar Ranch well field, occupying 13 square miles in central Pasco County, contains 17 wells that tap the upper 600 feet of the Upper Floridan aquifer. The well field is permitted for an average annual withdrawal of 30 million gallons per day and a maximum daily withdrawal of 45 million gallons. Digital models of steady-state ground-water flow were used to assess the environmental impact of pumping such large quantities of water from an area where aquifers were not previously developed. Aquifers of interest include the surficial aquifer, consisting of a thin bed of fine sand, and the Upper Floridan aquifer, which comprises a 900-foot thick sequence of highly transmissive carbonate rocks.

Regional pumping near the Cross Bar Ranch well field causes drawdowns to be greatest in the southern part of the well field. At the southern boundary of the well field, the model-simulated water-table declines in the surficial aquifer and potentiometric surface of the Upper Floridan aquifer are 0.6 foot and 1 foot, respectively. These drawdowns primarily result from pumping 30 million gallons per day from the Cypress Creek well field, about 5 miles southeast of Cross Bar Ranch.

Pumping from the Cross Bar Ranch well field was simulated to assess the extent and depth of cones of depression around the well field. At the average annual permitted rate of 30 million gallons per day, a cone 5 to 17 feet deep in the water table spread over an 8-square-mile area and a cone 5 to 21 feet deep in the potentiometric surface spread over a 15-square-mile area. Under the 45-million-gallon-per-day maximum permitted rate, simulated drawdown was 5 to 26 feet in the water table of the surficial aquifer and 5 to 35 feet in the potentiometric surface of the Upper Floridan aquifer over areas of 16 and 28 square miles, respectively. The surficial aquifer could possibly be completely dewatered in small areas in the northern part of the well field when the Upper Floridan aquifer is pumped at the maximum rate. Pumping increases downward leakage from tne surficial aquifer to the Upper Floridan aquifer and, ultimately, results in reduced evapotranspiration and surface runoff.

INTRODUCTION

The Cross Bar Ranch well field occupies 13 mi^2 in north-central Pasco County (fig. 1). Seventeen wells that average 688 feet in depth have been permitted for an average annual withdrawal of 30 Mgal/d and a maximum daily withdrawal of 45 Mgal. In addition to this pumpage, water levels in the well-field area are affected by pumping elsewhere in the region for irrigation and public supplies.

The well field supplies water to Pinellas and western Pasco Counties. Production started in April 1980 and averaged about 12 Mgal/d through 1982. The potential impact on the hydrologic system of pumping large quantities of water from an area where aquifers were not previously developed is of concern to water managers and nearby landowners. Even at reduced levels of pumping, concern has been raised over the declining level of Pasco Lake and interfering cones of depression around the Cross Bar Ranch and Cypress Creek well fields.

Purpose and Scope

The purpose of this study is to evaluate the long-term availability of the ground-water supply in the Cross Bar Ranch area by focusing on the following:

1. Describe the hydrogeologic framework;
2. Provide a quantitative description of the ground-water flow system; and
3. Project the impact of pumping.

The investigation includes compilation of data from about 50 monitor wells, test wells, and production wells within a 121-mi^2 study area, including the 13-mi^2 well field. Hydrologic and geologic records examined and analyzed include rainfall, streamflow, lake levels, ground-water levels, aquifer-test data, and geologic data, including geophysical logs and drillers' logs. Two aquifers were delineated and maps were prepared that show general hydrologic conditions within each aquifer. The data were used to develop a digital model of the ground-water system.

This report is organized to focus on the project objectives listed above. The policy for most U.S. Geological Survey reports that deal with model development is to discuss modeling procedures in detail. Generally, this entails describing the grid system, boundary conditions, input data, calibration and validation procedures, and model sensitivity. Some reports even provide listings of the model-input data and FORTRAN coding changes that were made to modify a standard model. This information can be used by hydrologists and engineers to evaluate the technical quality of a study, but it is generally overlooked by water managers and public officials. To broaden audience appeal and focus on project objectives, a discussion of modeling procedures is given in a Supplemental Data section at the end of the report.

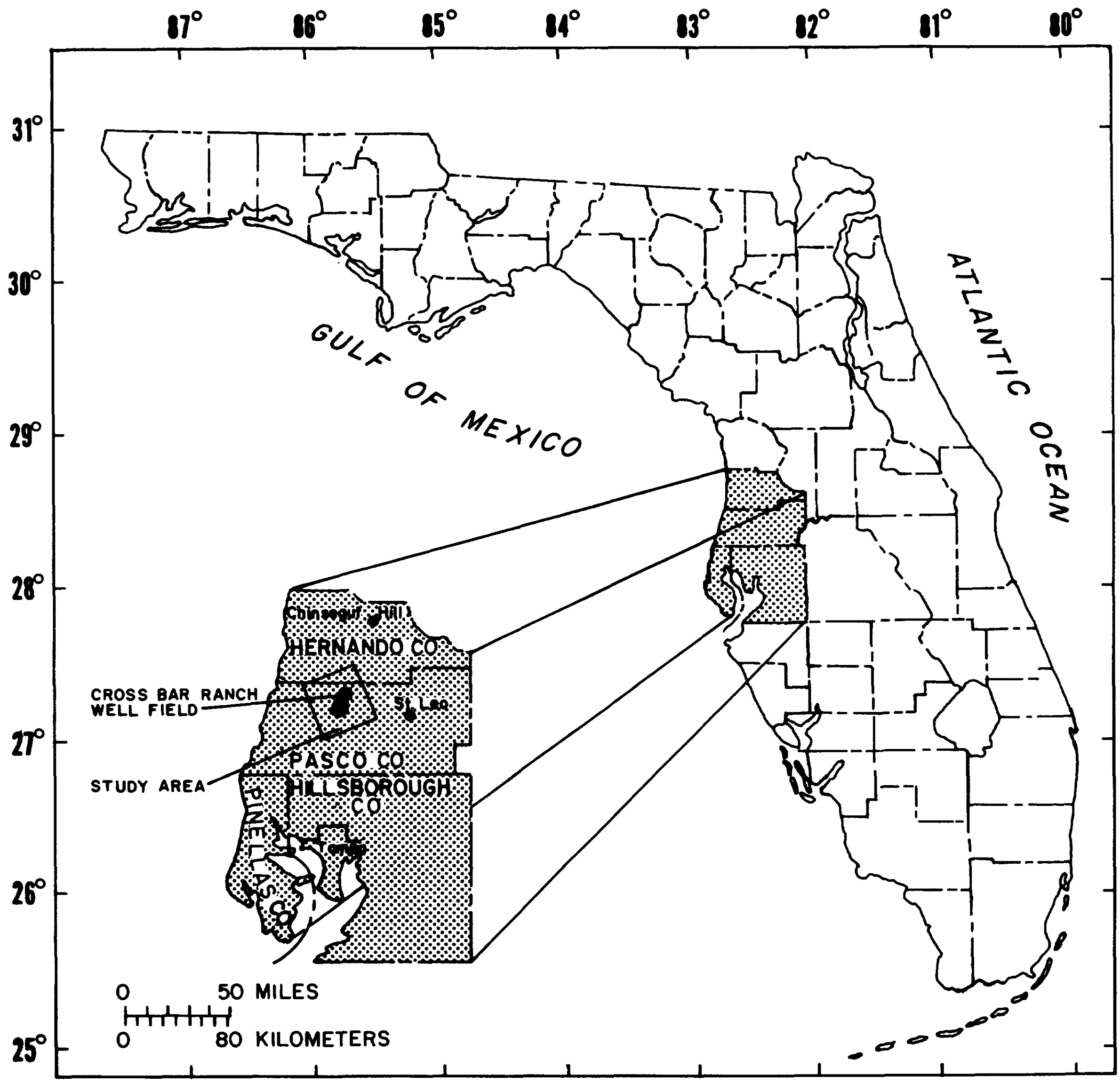

Figure 1.--Location of the Cross Bar Ranch well field and study area.

Approach

The hydrogeologic framework is defined through analysis of well logs, aquifer tests, water-level measurements, and water-quality data. Quantitative estimates of flow to and from the ground-water system are made by developing a conceptual model that couples the hydrogeologic framework with the hydrologic cycle. The flow estimates are verified and refined using a digital model that simulates ground-water levels and flow in two layers. Modeling results serve as a basis for evaluating the impact of well-field development.

Previous Investigations

The geology and hydrology of the general area of the Cross Bar Ranch well field are described by Wetterhall (1964) and Cherry and others (1970). Reports that describe drilling and testing within the well field were prepared by Leggette, Brashears, and Graham, Inc. (1976; 1977; 1978; 1979a; 1979b; 1979c; 1979d; 1979e; 1980a; 1980b; 1980c; 1980d; 1981). Miller (1977) recommended that the Cross Bar Ranch production wells be drilled along linear features observed on aerial photographs. Gilboy and Moore (1982) studied a hydrologic anomaly that occurs in the northern part of the well field based on surface geophysics and lithologic logs.

Digital models of ground-water systems that encompass the well field include single-layer models of the Upper Floridan aquifer by Hutchinson and others (1981) and Ryder (1982). Two-layer models of flow in the surficial and Upper Floridan aquifers were developed by Leggette, Brashears, and Graham, Inc. (1978), and Hutchinson (1984a). The model developed by Leggette, Brashears, and Graham, Inc., focused on the Cross Bar Ranch area and is being used to manage the distribution and rates of pumping at the well field (Heath, 1983). The other three models are regional wherein the Cross Bar Ranch is a small part of the modeled area.

Acknowledgments

Numerous contacts were made with personnel of the West Coast Regional Water Supply Authority and the consulting firm of Leggette, Brashears, and Graham, Inc. The assistance of Loretta Hennessey, West Coast Regional Water Supply Authority, and Harry Oleson, Leggette, Brashears, and Graham, Inc., are especially appreciated.

This study was undertaken as part of a cooperative program between the U.S. Geological Survey and the Southwest Florida Water Management District to evaluate the hydrogeology of the aquifer system underlying the Cross Bar Ranch well field. Knowledge gained through this assessment will help evaluate the environmental impact caused by pumping from the Cross Bar Ranch well field.

HYDROGEOLOGIC FRAMEWORK

Physical Setting

The study area occupies 121 mi^2 (fig. 2). Four physiographic units in or near the well field have been identified from areal photography and topographic maps (Gilboy and Moore, 1982; Hutchinson, 1984a). The Lakes Terrace physiographic unit that occupies the southern half of the well field is a wetlands area characterized by numerous lakes and sinkholes. The Central Swamp physiographic unit, about 5 miles southeast of the well field, is characterized by marshy areas that are maintained by upwelling of artesian water from underlying aquifers. The Lowlands Plain physiographic unit occupies the northern half of the well field. The unit is a moderately drained area that is characterized by lack of wetlands and the presence of large oak trees and improved pastureland. The Brooksville Ridge physiographic unit is about 3 miles east of the well field and is characterized by thick deposits of white sand that seem to be old, stabilized dunes (White, 1970). The Brooksville Ridge forms the eastern limit of the study area.

The landscape is dotted by sinkhole depressions that are typical of Florida's karst environment. The ground-water system consists of an unconfined surficial aquifer underlain by a leaky confining unit and deeper carbonates of the Floridan aquifer system. Solution cavities in the carbonates have caused sudden collapse or slow subsidence of the overburden deposits to form the karst topography. Water levels are near land surface and the general direction of ground-water movement is northwest toward the Gulf of Mexico. Ground-water levels have been lowered by pumping from the well field.

Aquifers and Confining Units

Sedimentary deposits several hundred feet in thickness comprise the aquifer and confining units in north-central Pasco County. The water-bearing unit developed at the Cross Bar Ranch well field is the Floridan aquifer system. The Floridan aquifer system is a thick sequence of carbonate rocks that have been generally referred to in the past as the Floridan aquifer. As originally defined by Parker and others (1955), the Floridan aquifer included, in ascending order, highly permeable rocks of all or parts of the Lake City, Avon Park, Ocala, and Tampa Limestones and highly permeable parts of the Hawthorn Formation that are in hydrologic contact with the rest of the aquifer. Miller (in press) in his redefinition of the aquifer indicated that subsurface information and hydraulic testing have shown that:

1. Except very locally, there are no high-permeability carbonate rocks in the lower part of the Hawthorn Formation that are in direct hydraulic contact with the main part of the Floridan aquifer system.
2. The Lake City Limestone cannot be distinguished lithologically or faunally from the overlying Avon Park Limestone and should be part of the Avon Park.
3. The Avon Park is more properly called a "formation" rather than a "limestone" because the unit contains rock types other than limestone.
4. Regionally, permeable carbonate rocks extend to deeper stratigraphic horizons than those included in the Floridan aquifer as it was originally described by Parker and others.

Miller's work represents one phase of a U.S. Geological Survey program, termed Regional Aquifer Systems Analysis (RASA), to study Tertiary limestone aquifers in Florida and parts of Georgia, Alabama, and South Carolina. Subsequent phases of the RASA study have been based on the hydrogeologic framework described by Miller. The Floridan aquifer system as defined by Miller (in press) comprises:

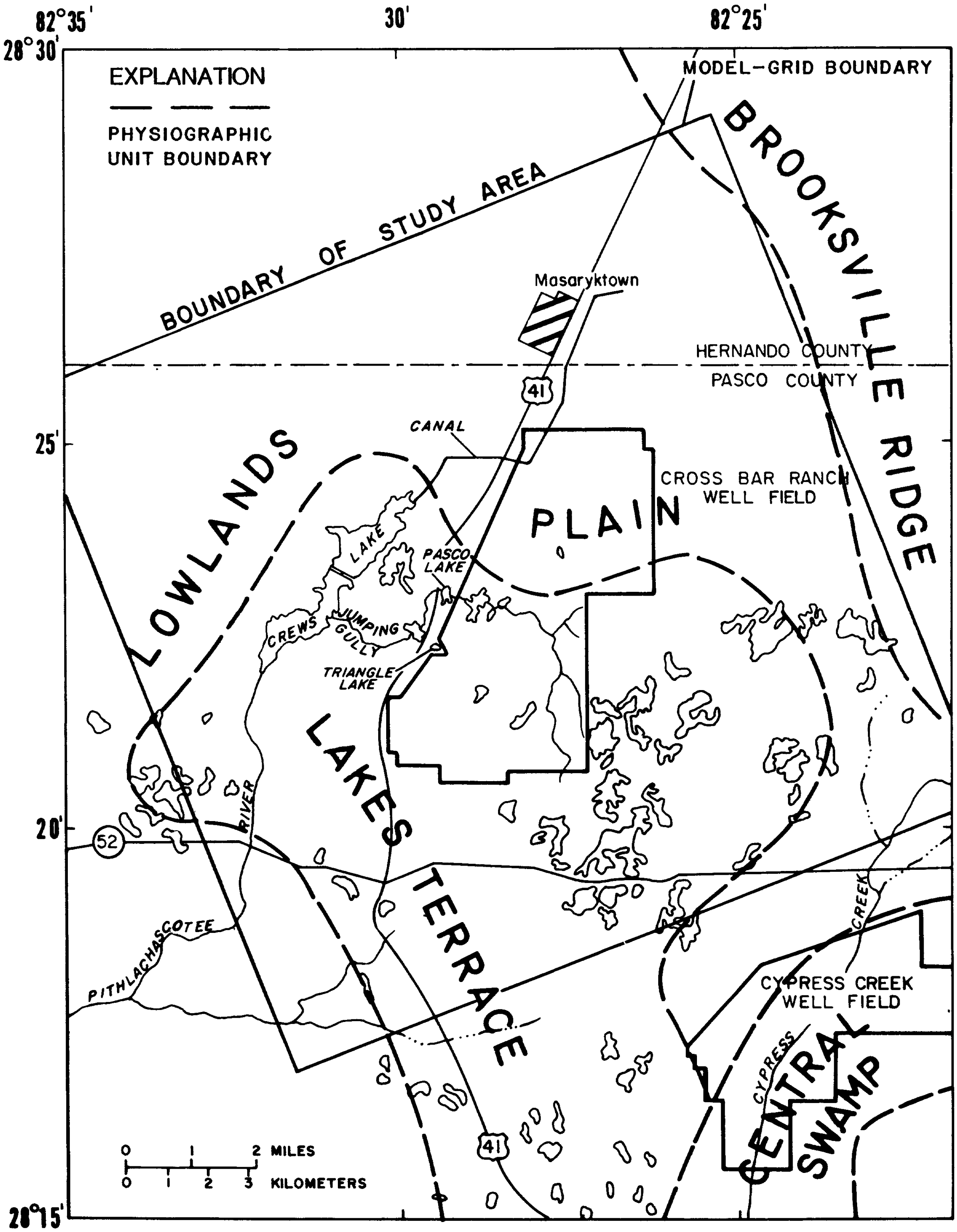

Figure 2.--Physiography of the well-field area.

"a vertically continuous sequence of carbonate rocks of generally high permeability that are mostly of middle and late Tertiary age, that are hydraulically connected in varying degrees, and whose permeability is, in general, an order to several orders of magnitude greater than that of those rocks that bound the system above and below."

"... (in west-central Florida), less-permeable carbonate units of subregional extent separate the system into two aquifers, herein called the Upper and Lower Floridan aquifers."

In Pasco County, the freshwater-bearing part of the Floridan aquifer system is the Upper Floridan aquifer.

Hydrogeologic units in the Cross Bar Ranch well-field area are listed in table 1. The surficial aquifer generally is about 35 feet thick and is composed of fine-grained sand. It grades downward to a discontinuous bed of sandy clay that is about 10 to 20 feet thick and forms the upper confining unit of the Upper Floridan aquifer. The Upper Floridan aquifer is a 900-foot-thick sequence of limestone and dolomite. The underlying middle confining unit, within the Avon Park Formation, consists of low-permeability gypsiferous dolomite and dolomitic limestone. The top of the middle confining unit lies between 890 and 910 feet below sea level at observation well B-1 (Leggette, Brashears, and Graham, Inc., 1979e). Table 2 lists well-construction information for wells pertinent to the study. Figure 3 shows the locations of all production wells and key test wells in and around the well field. Figure 4 is a generalized north-south hydrogeologic section that shows aquifer relations and zones that are tapped by production wells.

Hydraulic Characteristics

Hydraulic characteristics of the aquifers and confining units were determined from laboratory tests and aquifer tests. The hydraulic conductivity of the surficial aquifer is estimated to be 10 ft/d based on laboratory measurements of core samples in nearby Hillsborough County (Sinclair, 1974). Based on this estimate, the 35-foot thick, fully saturated areas of the surficial aquifer would have a transmissivity of 350 ft^2/d. The aquifer is pumped only through shallow domestic and stock-watering wells that generally yield less than 20 gal/min.

Leakance of the upper confining unit and transmissivity of the Upper Floridan aquifer were determined by Leggette, Brashears, and Graham, Inc. (1978), from aquifer tests in the northern, central, and southern parts of the well field (fig. 5). Leakance ranges from about 0.0005 to 0.003 (ft/d)/ft and is ascribed primarily to the upper confining unit. The transmissivity at test site C is about 115,000 ft^2/d, or more than double that of the other two sites.

A comparison of specific capacities in similarly constructed and developed wells can give some indication of the variation in aquifer characteristics. Specific capacity tests indicate that the transmissivity of the Upper Floridan aquifer and the degree of well development vary widely within the well field

Table 1.--Hydrogeologic framework

Series	Stratigraphic unit	Hydrogeologic unit[1/]	Approximate thickness (feet)	Hydrogeologic characteristics
Holocene Pleistocene Pliocene	Surficial sand and clay	Surficial aquifer	35	Marine and nonmarine unconsolidated quartz sand, clay, and shells. Wells yield less than 20 gal/min. Excellent water quality. Unit is cased off in production wells.
Miocene	Hawthorn Formation Tampa Limestone	Upper confining unit	10-20	Clay with traces of sand and silt. Retards downward movement of water from the surficial to Upper Floridan aquifer.
Oligocene	Suwannee Limestone	Upper Floridan aquifer	900	Limestone and dolomite. Production wells yield up to 3,000 gal/min. Water quality is good. Upper 600 feet is tapped by production wells. Water levels are affected by regional pumping for irrigation and municipal supply.
Eocene	Ocala Limestone Avon Park Formation[1/]			
		Middle confining unit	300	Limestone and dolomite with intergranular gypsum and anhydrite. Extremely low permeability. Water quality is poor.

[1/] Based on nomenclature defined by Miller (in press).

(fig. 6). The specific capacities of 15 production wells and 1 test well (B-1), all 15 to 17.5 inches in diameter and approximately 700 feet deep, ranged from 110 to 800 gal/min per foot of drawdown. Production wells CB-7 and CB-16 are less than 700 feet deep (table 2), but their specific capacities also are within this range. Ignoring well losses, transmissivity is estimated to be directly proportional to specific capacity. Specific capacity, and hence aquifer transmissivity, is generally highest in the center of the northeast part of the well field and lowest in the northwest part.

Table 2.--Well construction characteristics

Production wells[1/]

Location	Well	Depth (feet)	Diameter (inches) Casing	Diameter (inches) Open hole	Casing depth (feet)
282123082274401	CB-1	710	24	17.5	150
282133082275301	CB-2	702	24	15	158
282142082283701	CB-3	700	24	15	152
282154082280101	CB-4	705	24	17.5	155
282222082280701	CB-5	705	24	15	152
282233082283801	CB-6	705	24	17.5	155
282246082281601	CB-7	485	24	15	154
282310082281901	CB-8	710	24	17.5	151
282324082281901	CB-9	703	24	15	154
282342082274801	CB-10	710	24	17.5	152
282346082271201	CB-11	702	24	15	155
282352082263901	CB-12	710	24	17.5	120
282410082271301	CB-13	700	24	15	152
282422082263901	CB-14	710	24	17.5	120
282422082275101	CB-15	710	24	17.5	160
282442082273201	CB-16A	630	24	17.5	118
282443082263901	CB-17	710	24	17.5	117

Observation wells

Location	Well		Depth (feet)	Diameter (inches)	Casing depth (feet)	Aquifer[2/]
282851082271601	W-708		340	8	80	UF
282540082275702	Masaryktown	S	19	1.25	9	SA
282540082275701		D	82	6	29	UF
282505082271102	NRW	S	21	6	17	SA
282505082271101		D	706	6	155	UF
282326082285202	WRW	S	21	6	19	SA
282326082285201		D	642	6	153	UF
282411082261402	NERW	S	27	6	23	SA
282411082261402		D	700	6	146	UF
282259082282802	B-1	S	23	6	19	SA
282259082282801		D	701	12	143	UF
282259082282803		4-inch	1,260	4	1,235	MCU
282207082271102	SERW	S	21	6	18	SA
282207082271101		D	700	6	155	UF
281931082284102	SRW	S	13	6	9	SA
281931082284101		D	700	6	146	UF
281918082264602	Gowers	S	7	1.25	6	SA
	Corner	D	73	6	38	UF
25,T25S,R18E[3/]	W-12346		250			UF

[1/] All production wells tap the Upper Floridan aquifer.

[2/] SA = surficial aquifer; UF = Upper Floridan aquifer; MCU = middle confining unit.

[3/] Section, township, range given on Florida Bureau of Geology computer printout of lithologic log.

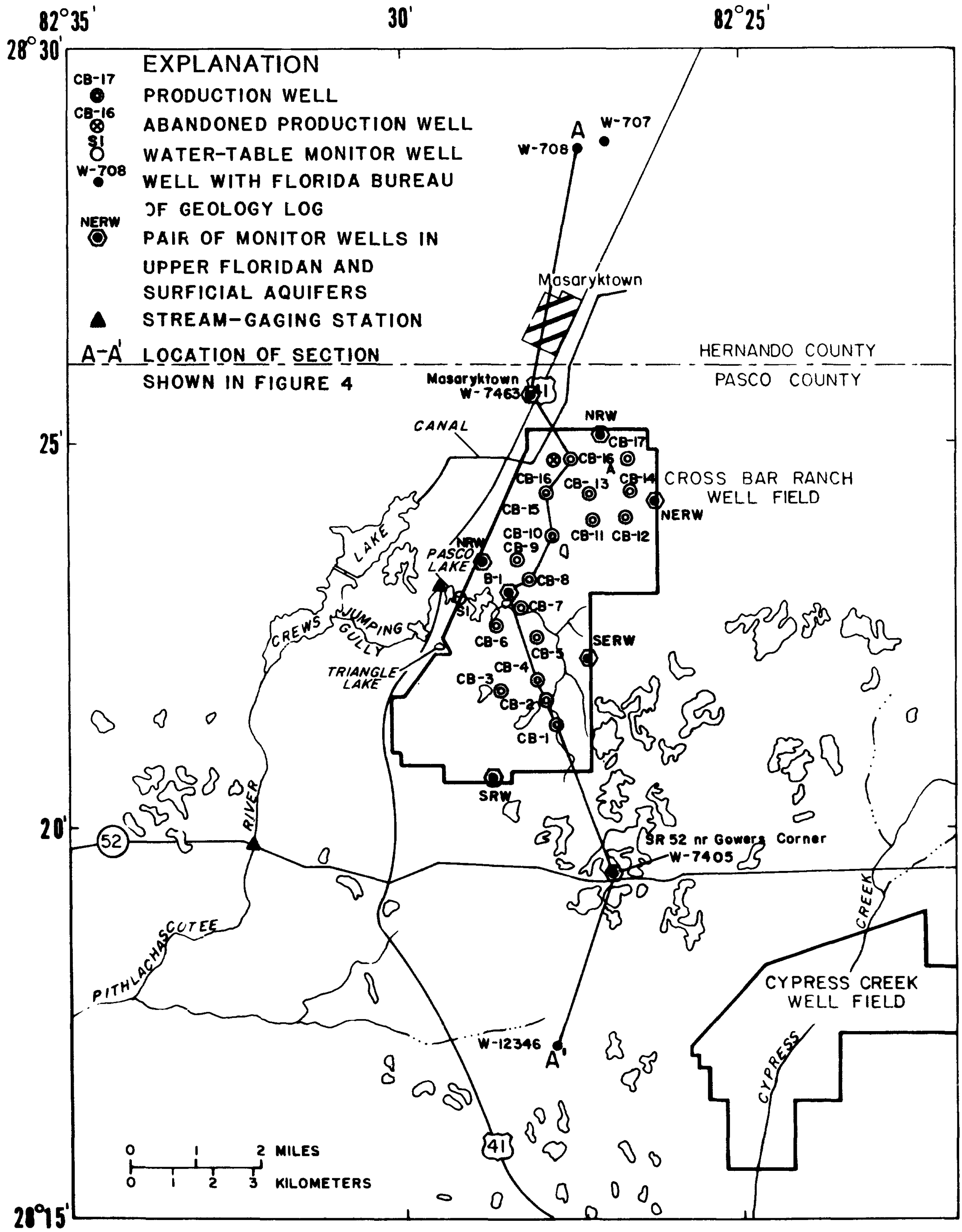

Figure 3.--Locations of data-collection sites.

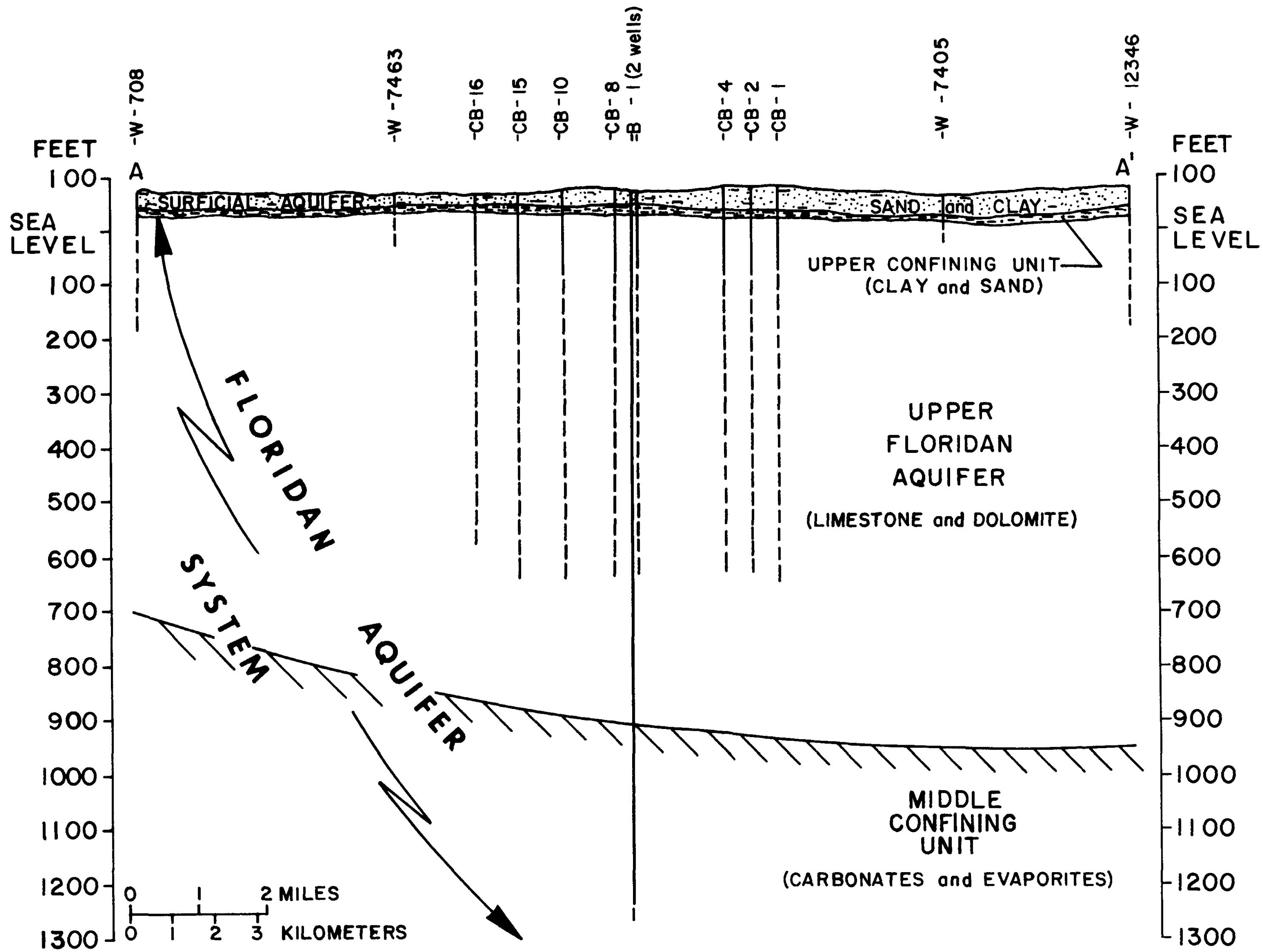

Figure 4.--Hydrogeologic section. (Location of section is shown in figure 3.)

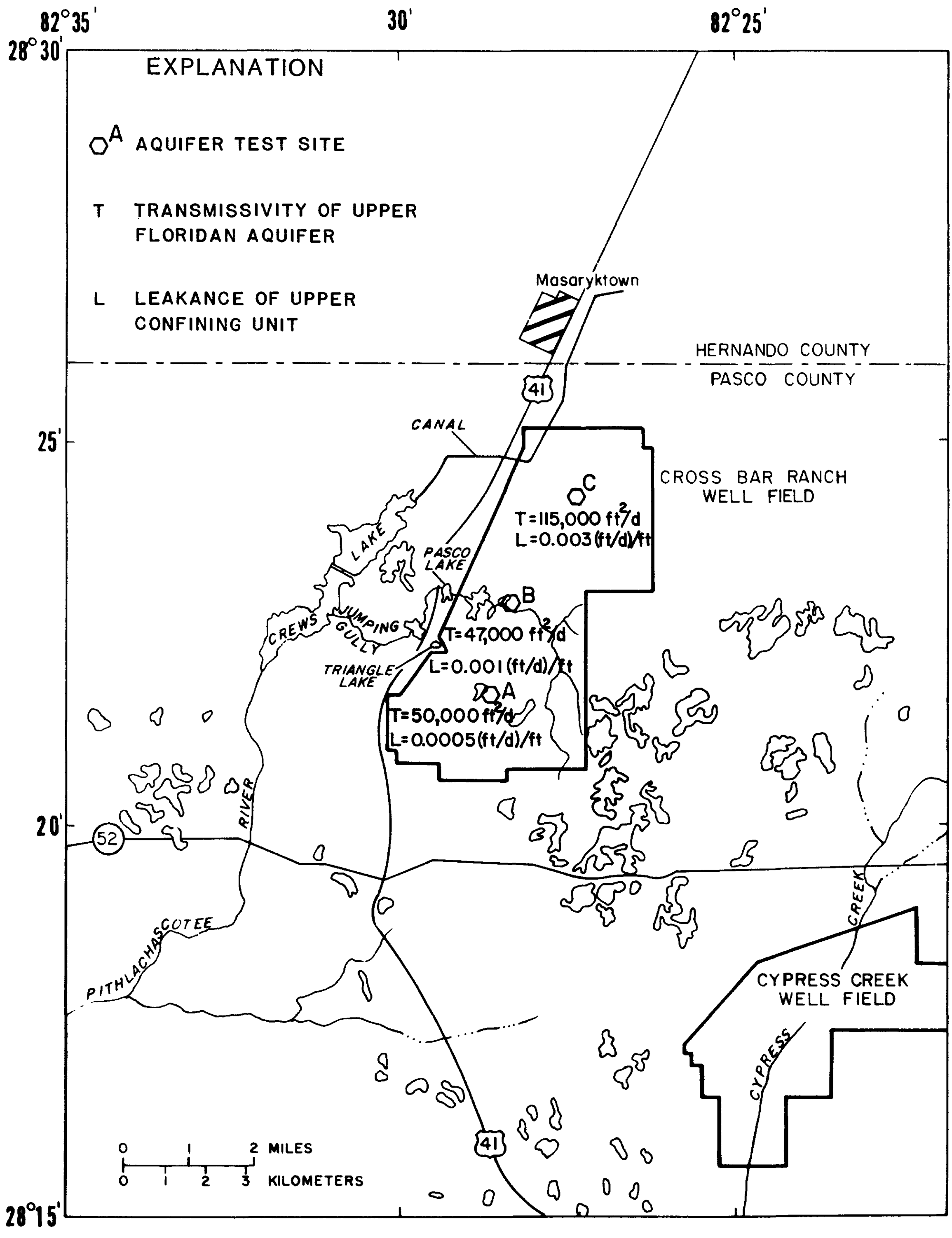

Figure 5.--Pumping test sites and values of transmissivity and leakance. (Based on tests described in Leggette, Brashears, and Graham, Inc., 1978.)

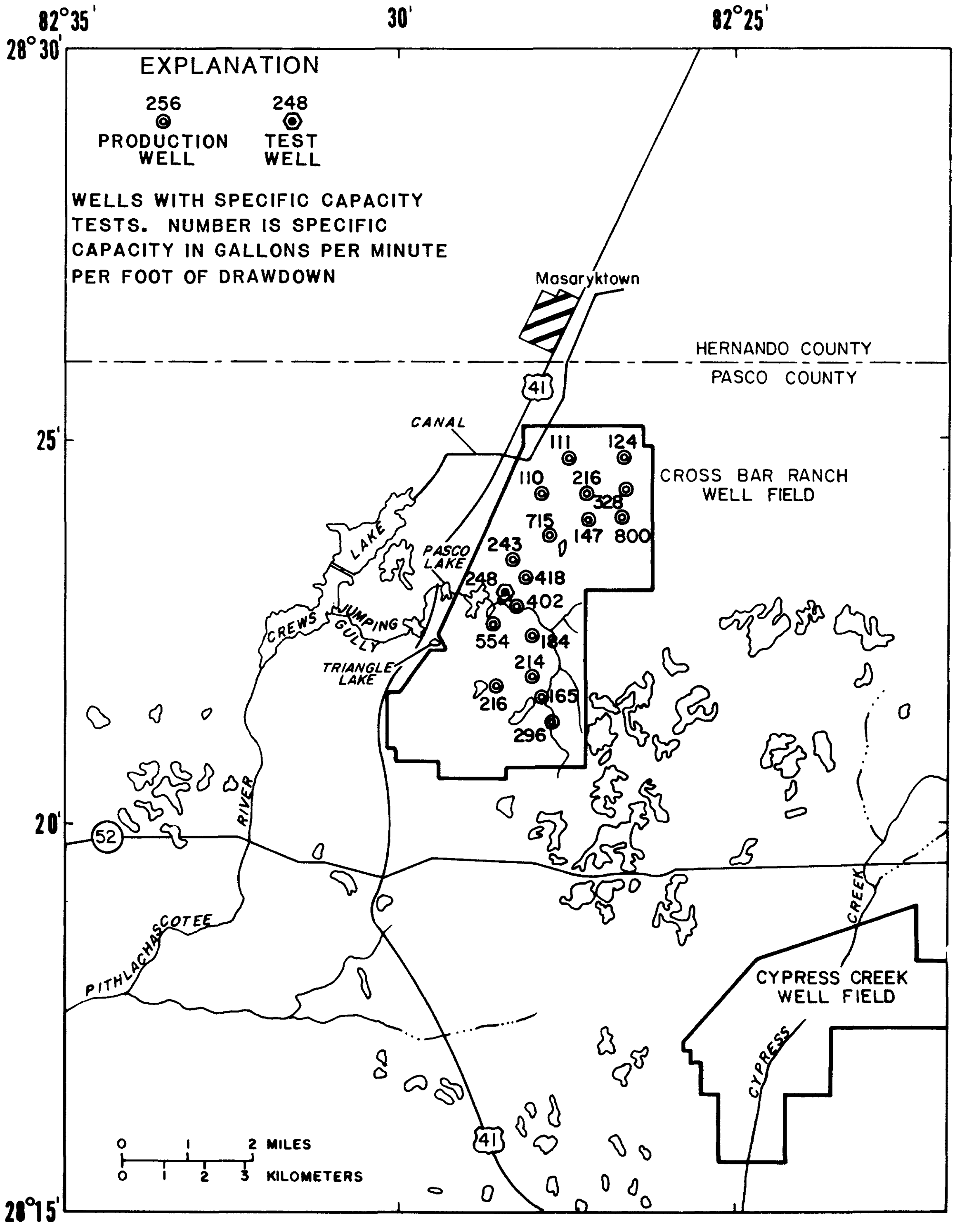

Figure 6.--Specific capacities of wells tapping the Upper Floridan aquifer producing zone.

Production wells that had low specific capacities were injected with a solution that contained 15 percent hydrochloric acid to clean fine materials from fractures in the dolomitic limestone and increase well efficiencies. Results of the acidization conducted by Leggette, Brashears and Graham, Inc. (1980a; 1981), are shown in table 3. Because acidization did not adequately increase the specific capacity of production well CB-16, the well was abandoned and replaced with well CB-16A about 1,000 feet to the east. In the other wells, acidization was also not very effective. By contrast, specific capacities had increased by more than 100 percent in previous acidization tests of two wells (C-7 and C-8) at the Cypress Creek well field. The less successful results in the Cross Bar Ranch area may be attributed to a lower number of fractures in the rock.

Table 3.--Effects of acidization on specific capacity of production wells

Production well	Specific capacity [(gal/min)/ft]		Percent increase
	Before acidizing	After acidizing	
CB-11[1/]	110	147	34
CB-15[2/]	100	110	10
CB-16[1,3/]	66	70	6
CB-16A[2/]	108	111	3

1/ Leggette, Brashears, and Graham, Inc. (1980a).
2/ Leggette, Brashears, and Graham, Inc. (1981).
3/ Abandoned production well 1,000 feet west of CB-16A.

The lower part of the Avon Park Formation was shown in a separate specific capacity test to be an effective confining unit of the Upper Floridan aquifer. Miller (in press) shows the middle confining unit to be 300 feet thick in central Pasco County and to thicken toward the Gulf Coast. Test well B-1 was completed with an open interval between 1,002 and 1,314 feet below land surface and was considered to fully penetrate the unit. The specific capacity of the well was 0.05 gal/min per foot of drawdown. Based on this test and analytical methods described by Walton (1970, p. 318), the transmissivity of the confining unit was estimated to be about 10 ft^2/d. The estimated horizontal hydraulic conductivity of the confining unit is about 0.03 ft/d. Assuming isotropy, the maximum value for leakance of the middle confining unit is estimated (by dividing vertical hydraulic conductivity by thickness, 0.03 ft/d ÷ 300 feet) to be 0.0001 (ft/d)/ft, or about one-fifth the minimum value for the upper confining unit.

Ground-Water Levels and Movement

Water levels in the surficial and Upper Floridan aquifers are monitored periodically at sites in and near the well field. Hydrographs of water levels for the period 1980-81 in selected wells along the boundary, well B-1, in the interior of the well field, and Pasco Lake (fig. 7) indicate several important hydrologic features of the well field, including:

1. The water table and the potentiometric surface are at higher altitudes in the south than in the north and trends generally parallel one another.
2. There was generally less than 2 feet of head difference between the water table and the potentiometric surface under nonpumping conditions and in the absence of significant rainfall prior to April 1980.
3. The potentiometric surface dropped to about 2 to 5 feet below the water table under pumping conditions after April 1980.
4. The potentiometric surface at the perimeter of the well field responds to pumping and reaches equilibrium almost immediately, as evidenced by the abrupt water-level changes that occurred when pumping stopped in December 1980 and then started again in January 1981.
5. The water table at the perimeter does not respond immediately to pumping, based on observed water levels during the December 1980 to January 1981 nonpumping period.
6. The water table and potentiometric surface generally follow the trend of cumulative departure of rainfall from normal, indicating that rainfall affects water levels as much as or more than pumping.
7. The level of Pasco Lake (fig. 3) declined at a rate of about 2 feet per month during the below-normal period of rainfall from October 1980 to May 1981, while the water table and potentiometric surface in shallow and deep boundary wells declined less than 1 foot per month.
8. Interconnection between the surficial aquifer and Upper Floridan aquifer appears to be good based on parallelism of and the small head difference between the water table and potentiometric surface. This was not substantiated during the December 1980 to January 1981 nonpumping period, however, because no water-table response was detected. The immediate response in the potentiometric surface is related to confinement of the Upper Floridan aquifer. The response of the water table is subtle because the surficial aquifer is unconfined.

Since 1971, the U.S. Geological Survey has prepared maps that show the water table and potentiometric surface in the Cross Bar Ranch area for each May and September, representing seasonal low and high water-level periods, respectively. Water levels shown on these maps are considered to represent levels at or near the troughs and peaks of annual water-level hydrographs. Of the available maps, those for September 1976 and May 1977 (Ryder and Mills, 1977a; 1977b) apparently best represent high and low water levels under prepumping conditions before development of the well field in April 1980. The water table and potentiometric surface, derived as an average of high and low annual conditions from the maps, are considered to represent prepumping average water levels for the

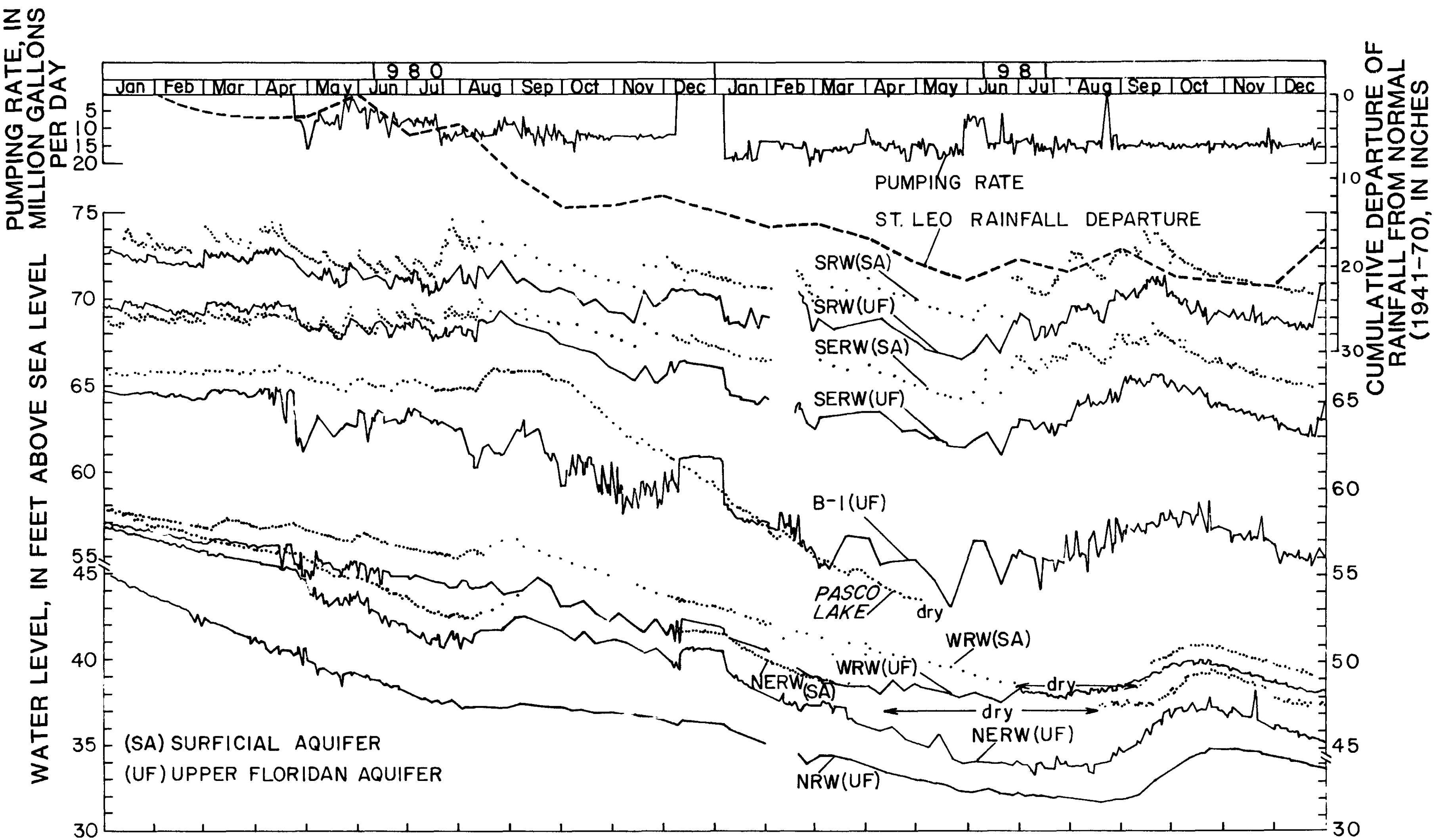

Figure 7.--Water levels in key observation wells and Pasco Lake, with pumping and rainfall.

year prior to May 1977 (figs. 8 and 9). Water levels from maps for September 1980 (Yobbi and others, 1980) and May 1981 (Yobbi and Woodham, 1981) were averaged to represent average water levels under pumping conditions (figs. 10 and 11). The average pumping rate for this period was 12.8 Mgal/d, or less than one-half the annual average permitted rate. The average water levels were used to calibrate and validate a digital model of steady-state ground-water flow.

Water in the surficial and Upper Floridan aquifers moves northwestward across the well field from an area of elevated water levels known as the "Pasco high." Under prepumping conditions, the gradient of the potentiometric surface (fig. 9) varies from about 3 ft/mi north and south of the well field to about 6 ft/mi within the well field. The changes in gradient apparently result from a "hydrologic anomaly" within the well field (Gilboy and Moore, 1982, p. 1).

Under pumping conditions, the water table (fig. 10) and potentiometric surface (fig. 11), areally, are 3 to 10 feet lower than under predevelopment conditions. The lower levels result from the combined effects of pumping and reduced recharge. Rainfall, and hence recharge, was below normal during the pumping period compared to predevelopment conditions (fig. 7).

The cone of depression in the water table in the northern part of the well field (fig. 10) is only partially related to pumping and probably indicates that the confining bed there is more leaky compared to the southern part. The cone is centered around production well CB-16A; however, this well had not been used for production because of its relatively low yield. A depression in the water table is indicated under prepumping conditions (fig. 8), but is less defined in part because few observation wells were available. More observation wells were available for defining the water table under pumping conditions.

Hydrologic Anomaly

A hydrologic anomaly occurs in the Upper Floridan aquifer in the northern part of the well field (fig. 12). The anomaly is reflected in the potentiometric surface as a steepening gradient (figs. 9 and 11). The change in gradient indicates a change in hydrogeology. Pumping test results also indicate the presence of the anomaly. During a 1979 pumping test of well N-12, very little water-level response occurred in wells NOW-1 and NOW-2 (fig. 12). During another test in 1978, well CB-13 was pumped and the response at well C-1 was about half that observed in the equidistant well C-2. During an irrigation cycle pumping of the Rovan Farms well, the drawdown in well B-2 was only 25 percent of that in well B-3. In each case, the water-level response in observation wells on the opposite side of the hydrologic anomaly from the pumped well was significantly less than expected. Based on the pumping tests, the hydrologic anomaly is placed between wells N-12 and NOW-1, CB-13 and C-1, and B-3 and B-2.

Gilboy and Moore (1982) observed that the hydrologic anomaly was almost exactly beneath the 70-foot topographic contour. The 70-foot level is suspected to represent a brief stand of sea level during the late Pliocene or early Pleistocene age, and the gently sloping flatlands on either side of the

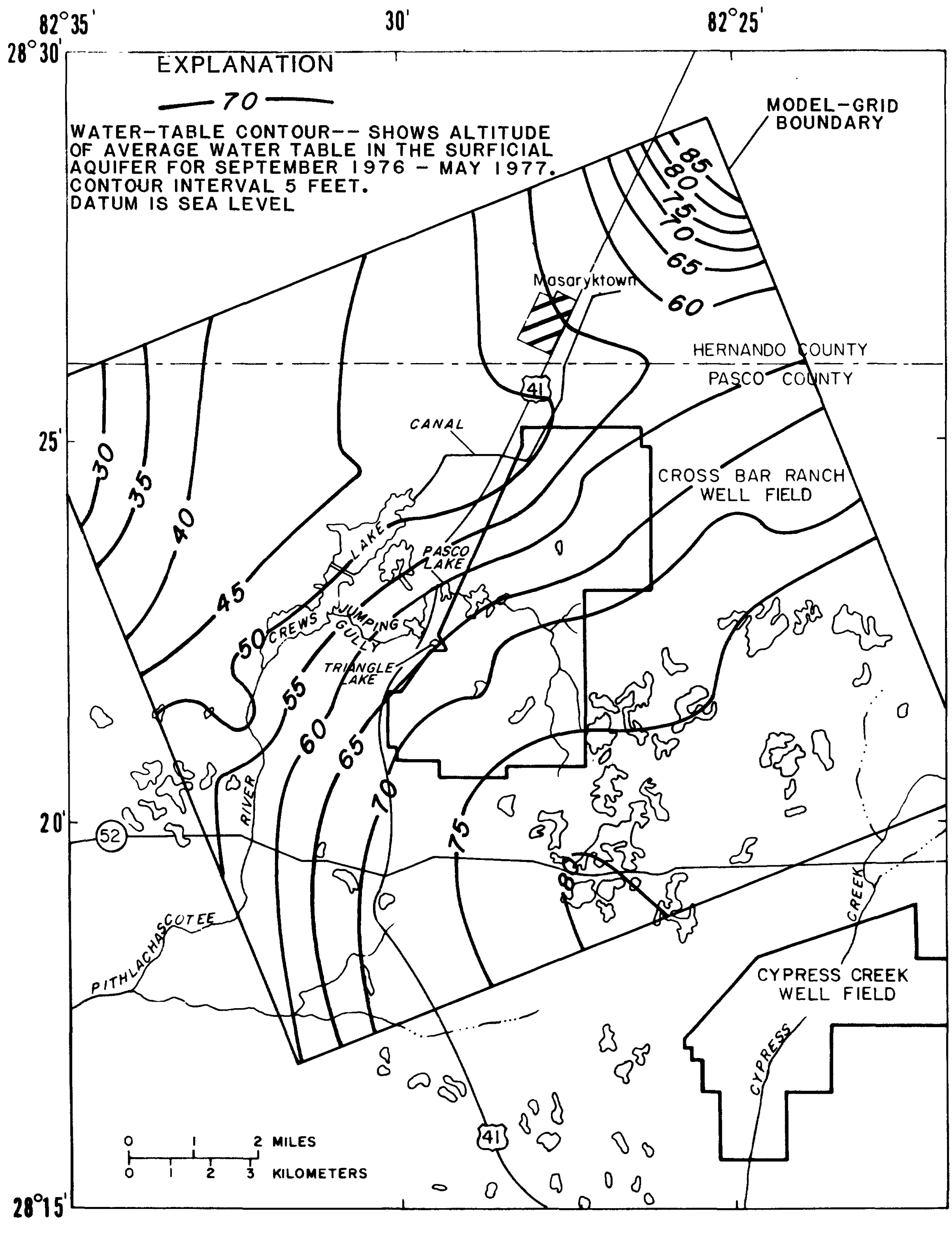

Figure 8.--Average water table in the surficial aquifer, September 1976 to May 1977.

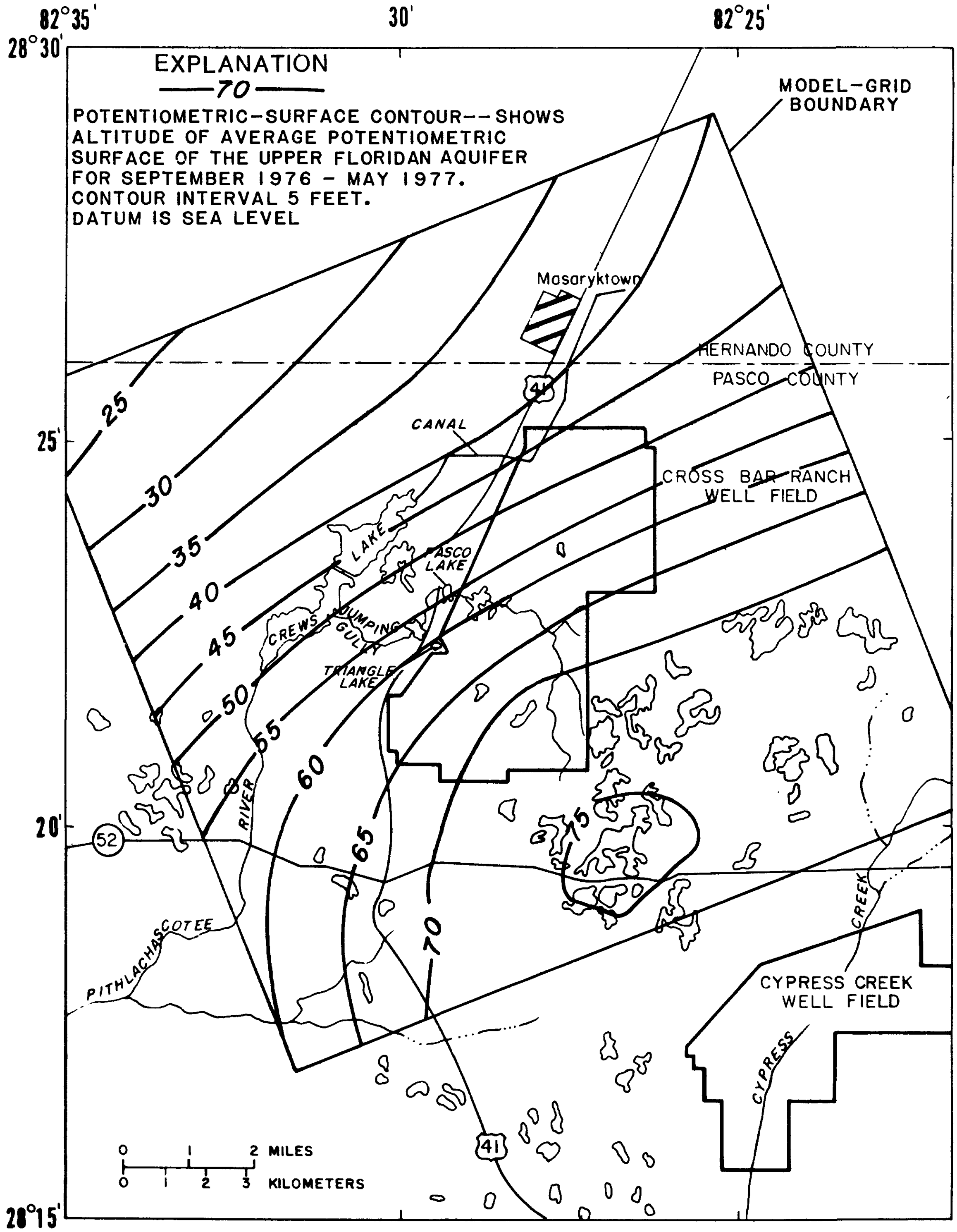

Figure 9.--Average potentiometric surface of the Upper Floridan aquifer, September 1976 to May 1977.

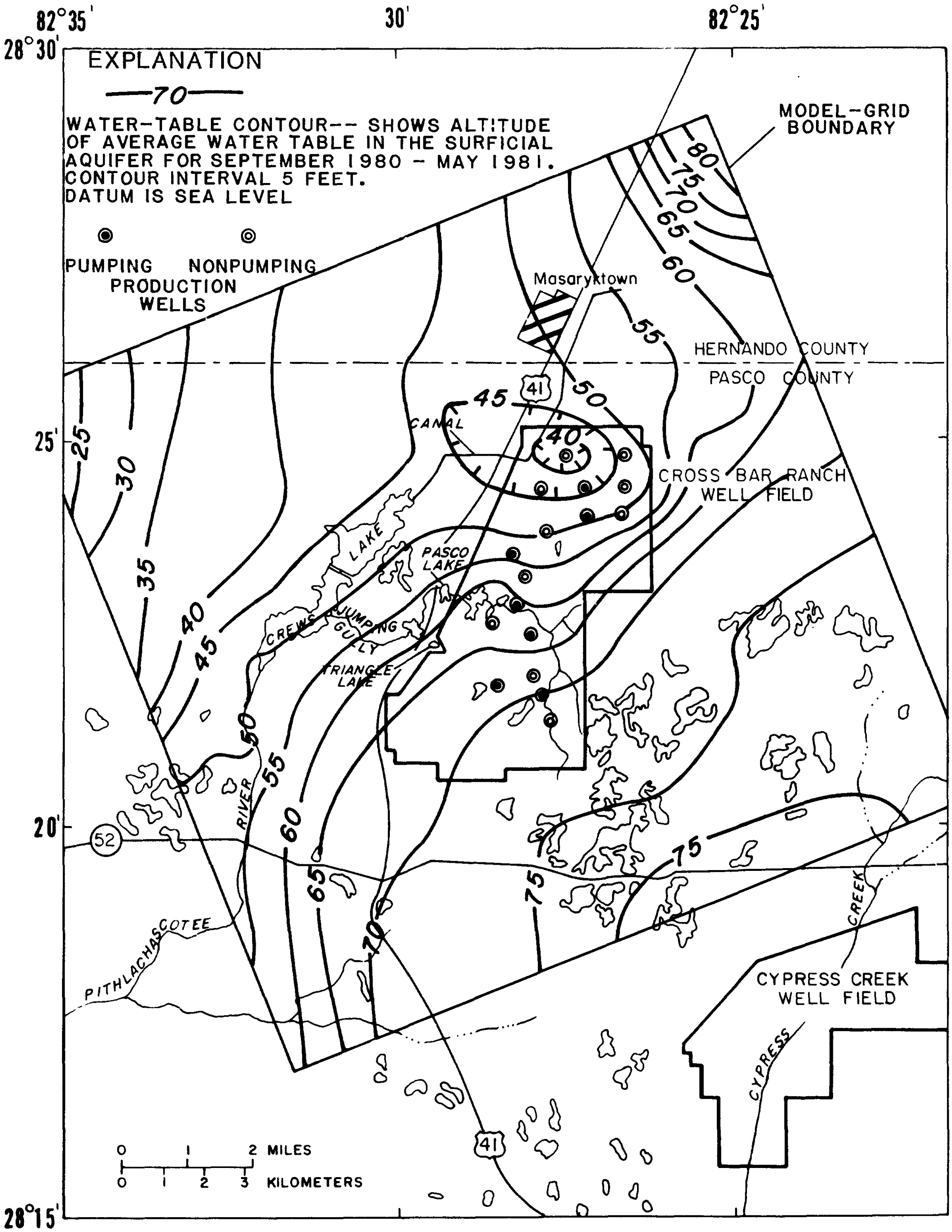

Figure 10.--Average water table in the surficial aquifer, September 1980 to May 1981.

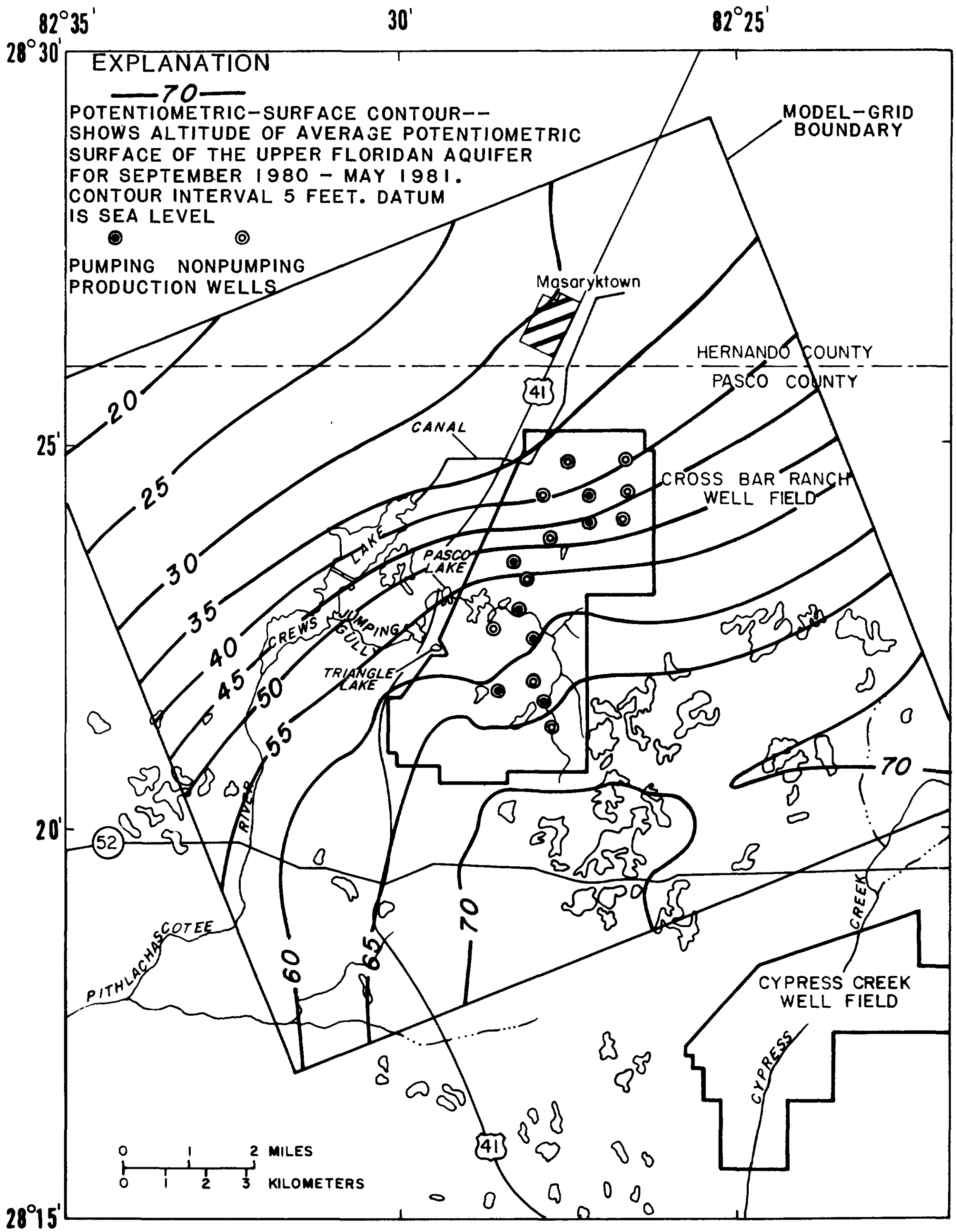

Figure 11.--Average potentiometric surface of the Upper Floridan aquifer, September 1980 to May 1981.

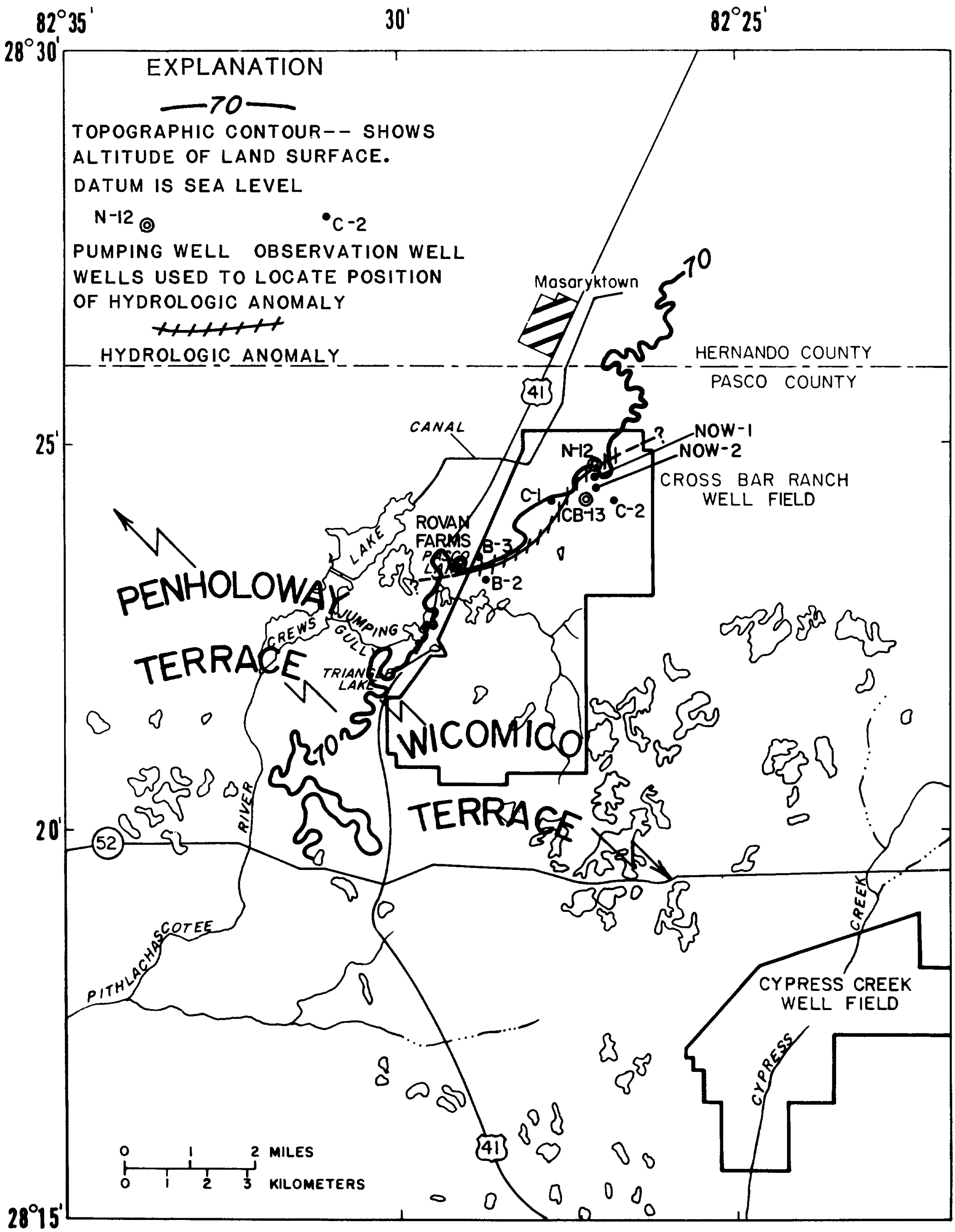

Figure 12.--Location of the hydrologic anomaly and Pleistocene terraces.

contour represent the Wicomico and Penholoway marine terraces (Alt and Brooks, 1965; Healy, 1975). Presuming that near-surface geologic structure controlled the hydrologic anomaly, Gilboy and Moore (1982) analyzed the shallow stratigraphy using lithologic logs and electrical-resistivity data. They concluded that:

> "... nothing unusual was encountered through the geophysical (and lithologic) work. ... the answer (to the hydrologic anomaly) rests at depth in the highly transmissive dolomite/limestone sequence of the Avon Park Formation."

The hydrologic anomaly might be explained by a hypothesis of Altschuler and Young (1960) who suggest that ancient shorelines in central Florida are associated with uplift. The demarcation line between the terraces may actually be a fault scarp. Faulting could explain the hydrologic anomaly in two ways.

1. Faulting could create a condition where permeable beds are displaced and butted against less permeable beds, thereby lowering the transmissivity of a narrow strip of the aquifer if the fault block is narrow. If a well is pumped on one side of the fault, little effect would be observed on the other side because of the near-vertical seal of the fault. This is common in clastic aquifers and oil-producing sands of the Gulf Coast where water or oil is trapped structurally, but not common in limestone aquifers of Florida.

2. Faulting could create a brecciated zone, thereby increasing the transmissivity of a narrow strip of the aquifer (Moore and Stewart, 1983). If a well is pumped on one side of the fault, little effect would be seen on the opposite side due to movement of large quantities of water along the fault zone toward the pumping well. This is common in limestone aquifers. Miller (1977) used fracture trace analysis as the basis for siting production wells along suspected fault zones in the well field. However, production well CB-16 (abandoned well 1,000 feet west of CB-16A), subsequently drilled along the suspected hydrologic anomaly, proved to have a lower specific capacity than those drilled at random between traces (H. F. Oleson, Leggette, Brashears, and Graham, Inc., oral commun., 1983).

The location of the hydrologic anomaly within the well field was based on local pumping tests. More testing is needed to determine the position of the anomaly outside the well-field boundary. In the modeling phase of this study, the hydrologic anomaly was represented by a narrow strip of the Upper Floridan aquifer with extremely low and extremely high transmissivities. A better calibration of the model was obtained using the low transmissivity value.

Surface Water-Ground Water Relations

The study area contains numerous streams and lakes that interact with the ground-water system. The major streams are the Pithlachascotee River, Masaryktown-Crews Lake flood-control canal, and Jumping Gully (fig. 3). Lakes of particular interest are Crews Lake, Pasco Lake, and Triangle Lake.

The Pithlachascotee River derives its flow from overland runoff, outflow from Crews Lake, and upward leakage from the Upper Floridan aquifer. Streamflow measured periodically at a gaging station at State Highway 52 from 1972 to 1981 has ranged between zero and 37 ft^3/s. The average of 64 measurements during this 10-year period is 4.5 ft^3/s, or 0.4 in/yr from the 150-mi^2 drainage area above the gage. Base flow, which represents ground water contributed to streamflow, is estimated to be about 3.1 ft^3/s, or 0.3 in/yr, based on measurements during March, April, October, and November (typically months of low rainfall and runoff).

The Masaryktown-Crews Lake canal was dug in the mid-1960's to divert floodwater from Masaryktown to Crews Lake. The 20-foot deep by 50-foot wide canal cuts through and drains water from the northern part of the well field during periods of heavy rainfall. Although flow in the canal is not gaged, it is known to be zero during most of the year.

The Cross Bar Ranch well field is drained primarily by Jumping Gully, which discharges into Crews Lake. For the 17-year period of record from October 1964 to September 1981, the average runoff from the stream's 43-mi^2 drainage area east of U.S. Highway 41 was 2.2 in/yr. This was mostly flood flow. Most of the base flow was retained by a dam on the east side of the highway.

Lakes in the study area are considered conceptually to be "windows" in the surficial aquifer through which the water table can be observed. Hydrographs of the stages of Crews Lake, Pasco Lake, and Triangle Lake and the water table in wells WRW shallow and S1 for the period 1977-82 are shown in figure 13. Also shown are pumpage and rainfall data.

Crews Lake, 2 miles west of the well field, exemplifies the internal drainage of the Lakes Terrace physiographic unit (fig. 2). Crews Lake is less than 20 feet deep, has a surface area of 1.2 mi^2, and is divided into two nearly equal parts by a dike. Water from Jumping Gully flows into the lake, forming the headwaters of the Pithlachascotee River, and then flows southwestward to the Gulf of Mexico. There probably is little downward leakage through the bed of the lake in the wet season because the potentiometric surface of the Upper Floridan aquifer is at about the same level as the lake. In dry seasons, pumping and differences in confined and unconfined storage factors cause the potentiometric surface of the Upper Floridan aquifer to decline more rapidly than the level of the lake. This causes drainage through a sinkhole in the northern part of the lake and virtually dries up the lake north of the dike. During these periods, flow is north through a culvert in the dike rather than the usual southerly direction. Flow into the sinkhole has been estimated at 20 to 25 ft^3/s, or 13 to 16 Mgal/d (U.S. Geological Survey, Sixth Advanced Ground-Water Seminar, unpublished field trip guidebook, 1970).

Pasco Lake was formed by dredging and damming of Jumping Gully. Stages of Pasco Lake and the water table at nearby shallow well S1 generally parallel water levels measured at other sites during periods of near normal rainfall. However, during drought and wet periods, their water levels fall or rise more rapidly than those of other nearby sites. This can be seen in figure 13 by comparing levels of Pasco Lake and well S1 with Triangle and Crews Lakes during the drought periods of late 1978 and late 1980 to mid-1981 and the subsequent recovery periods of early 1979 and mid-1982.

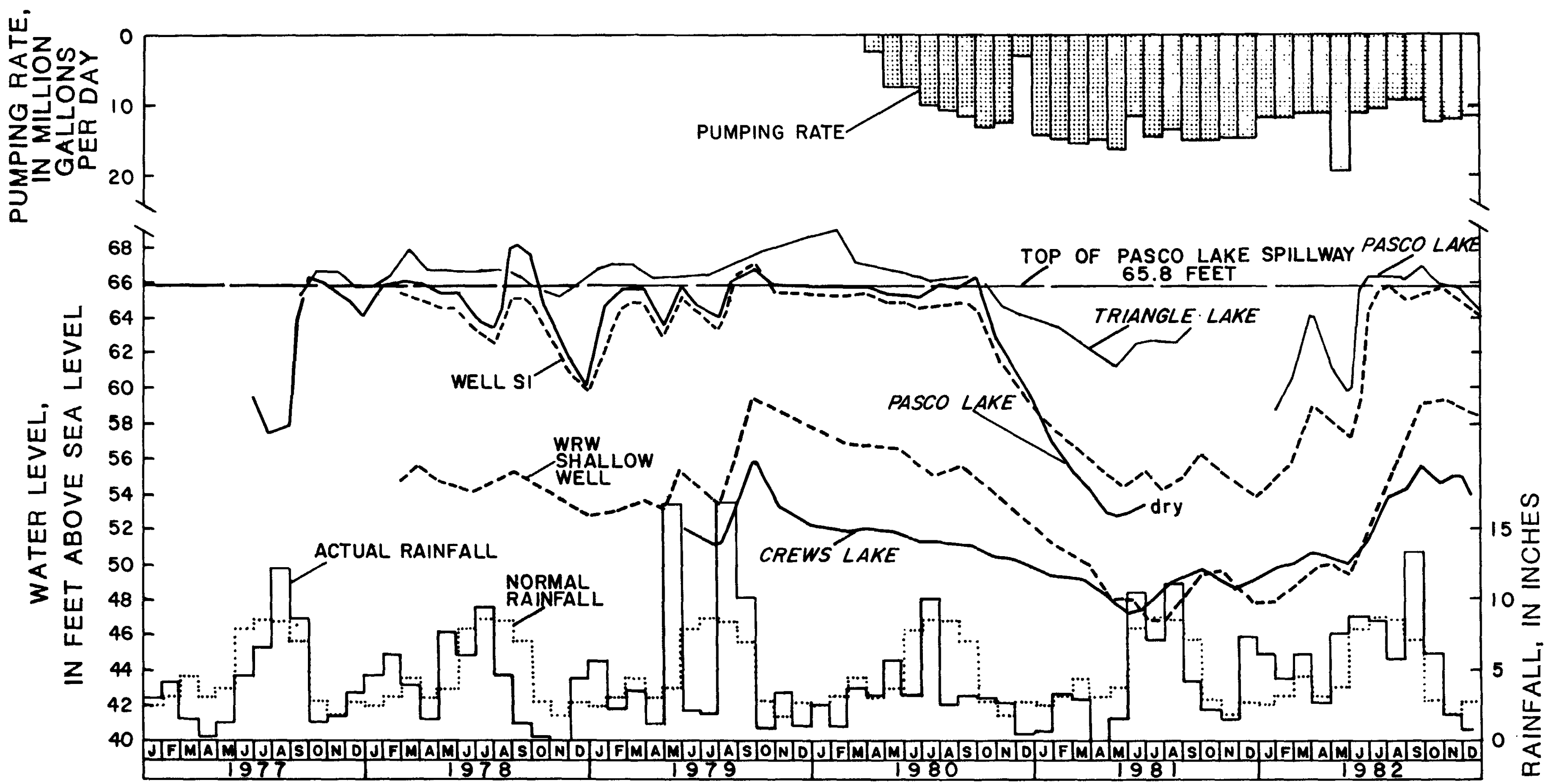

Figure 13.--Relations between lake stage and ground-water levels, rainfall, and pumping, 1977-82.

Homeowners around Pasco Lake have expressed concern that the lake's rapid decline in 1980-81 was related to pumping from the Cross Bar Ranch well field. Gilboy and Moore (1982) determined that the confining bed beneath Pasco Lake is between 42 and 79 feet below land surface and that dredging of the lake bottom had not breached the confining bed. If leakage characteristics of the confining bed beneath the lake correspond with regional leakage characteristics, pumping from the well field would not cause the level of Pasco Lake to decline more rapidly than other nearby lakes and ground-water levels.

It is likely that damming of Jumping Gully to form Pasco Lake had created a ground-water mound that is maintained by discharge from Jumping Gully. When flow in Jumping Gully stops, recharge to the lake ceases, and the mound decays by lateral movement in all directions from the lake plus some vertical leakage. In contrast, water is lost regionally from the surficial aquifer more from vertical leakage than lateral movement. These relations are substantiated in the hydrograph of figure 13 during the 1980-81 drought. The stage of Pasco Lake was higher than the water table in shallow well S1 during late 1980 due to buildup of the ground-water mound. In early 1981, the level of the lake fell below the water table in S1 as the mound decayed. Water had not spilled out of Pasco Lake for 3 months, and the east to west regional water-table gradient probably was restored to natural conditions.

Ground-Water Quality

Ground-water quality was tested prior to and during development of the Cross Bar Ranch well field. Chemical-quality data that were collected during drilling and testing phases are tabulated in numerous status reports by Leggette, Brashears, and Graham, Inc. The consumptive-use permit requires operators of the well field to routinely test the quality of water from each production well. The primary concern and reason for continued sampling are that pumping may induce upward movement of deep saline water into the producing zone.

Typical analyses of water quality in the surficial aquifer, Upper Floridan aquifer, and middle confining unit are listed in table 4. Although sodium and potassium concentrations were not reported, it is known that these minerals are prevalent in Florida's ground water and that sodium is the dominant mineral. Sodium was estimated as a residual of the ionic balance between the major anions and cations.

The surficial aquifer and Upper Floridan aquifer contain calcium bicarbonate type water that meets State water-quality standards for municipal supply (Florida Department of Environmental Regulation, 1982, p. 102). Geophysical logs of well B-1 indicate that water quality in the Upper Floridan aquifer is uniform (Leggette, Brashears, and Graham, Inc., 1979e). Salinity begins to increase at a depth of 960 feet near the contact with the middle confining unit. The middle confining unit contains highly mineralized sodium chloride to sodium sulfate type water that is associated with intergranular evaporites of the lower part of the Avon Park Formation.

Table 4.--Chemical analyses of ground water in the well field

Hydrogeologic unit	Surficial aquifer[1]	Upper Floridan aquifer[2]	Middle confining unit[3]
Depth of well (feet)	25	688	1,260
Depth of casing (feet)	22	146	1,235
Date of sample	1978-79	12-14-82	8-9-79
Bicarbonate (mg/L)	72	227	396
Chloride (mg/L)	8	11.1	7,250
Sulfate (mg/L)	4	1.7	3,920
Calcium (mg/L)	13	71.5	848
Magnesium (mg/L)	6	2.7	462
Sodium (mg/L)[4]	8	70	4,800
Iron (mg/L)	2	.2	15
Dissolved solids (mg/L)	85	215	18,930

Production wells

Well	Dissolved-solids concentration[5] (mg/L)	Well	Dissolved-solids concentration[5] (mg/L)
CB-1	219	CB-10	197
CB-2	219	CB-11	188
CB-3	219	CB-12	190
CB-4	221	CB-13	190
CB-5	226	CB-14	204
CB-6	201	CB-15	225
CB-7	190	CB-16A	181
CB-8	202	CB-17	193
CB-9	210		

1/ Estimated from partial analyses of samples from 14 wells (Leggette, Brashears, and Graham, Inc., 1979d, appendix VII, table 5).

2/ Average of samples from 17 production wells reported by the West Coast Regional Water Supply Authority in the December 1982 monthly report for Cross Bar Ranch well field.

3/ Sample from deep monitor well B-1 (Leggette, Brashears, and Graham, Inc., 1980c, appendix V, table 5).

4/ Sodium concentrations were estimated as residual of the ionic balance: $(HCO_3 + Cl + SO_4) - (Mg + Ca) \simeq Na$.

5/ Data for wells sampled on 10/27/81 supplied by the West Coast Regional Water Supply Authority.

Figure 14 shows the dissolved-solids concentration in water from the producing zone and relates the concentrations to pumping from the well field. The graph indicates that dissolved-solids concentrations in water from production well CB-7 range between about 180 mg/L and 270 mg/L. There has not been any significant change in water quality since the well was first tested in 1978. There is little or no indication of saline water leaking upward through the confining unit at the base of the Upper Floridan aquifer, although upconing might not be detected for a long time. The dissolved-solids concentration in water from production well CB-7 is similar to concentrations in other production wells (table 4) and closely matches that of the blended water from all wells influent to the treatment plant (fig. 14). Analysis of figure 14 and table 4 indicates that, areally, the Upper Floridan aquifer contains water of uniform quality.

HYDROLOGIC CYCLE

Elements of the hydrologic cycle in west-central Florida are rainfall, surface and subsurface runoff, evapotranspiration (ET), leakage to or from the Upper Floridan aquifer, pumping, and changes in amounts of water in storage in the surficial and Upper Floridan aquifers. In the ground-water model analysis, all time-dependent hydrologic parameters, including ground-water levels, are considered as long-term averages; therefore, short-term fluctuations in amounts of water in storage in the surficial and Upper Floridan aquifers are neglected. Pumping from the surficial aquifer is so small that it is neglected.

The nearest rain gages with long-term data operated by the National Oceanic and Atmospheric Administration are at Chinsegut Hill, 14 miles north of the well field, and at St. Leo, about 18 miles to the east (fig. 1). In west-central Florida, mean annual rainfall is about 55 inches and is seasonally distributed as about 7 inches in winter, 10 inches in spring, 25 inches in summer, and 13 inches in autumn (Hughes and others, 1971). Aquifers gradually become depleted in the winter and spring when pumping, natural outflow, and ET exceed recharge. Aquifers are replenished by summer and autumn rains.

Runoff from the Cross Bar Ranch area is low. Much of the area is "internally drained" in that surface runoff flows into sinkholes or lakes where it eventually leaks downward or evaporates. Surface runoff from the well field is primarily through Jumping Gully, which flows into Crews Lake. The gaged outflow for the 17-year period of record from October 1964 to September 1981 was shown to be 2.2 in/yr, or about 4 percent of the total rainfall.

ET is a major component of the hydrologic cycle in west-central Florida. It occurs in essentially three modes involving either evaporation or transpiration: (1) from plant surfaces, open-water bodies, and bare ground; (2) from the unsaturated zone (above the water table but beneath land surface); and (3) from the water table. The potential ET from a free-water surface in west-central Florida is about 46 to 50 in/yr (Koehler and others, 1959; Dohrenwend, 1977). However, actual ET is less than the potential in much of west-central Florida. In areas where the water table is far below land surface, water in the surficial aquifer is less subject to uptake by plants (transpiration) or direct evaporation than where the water table is at or near land surface.

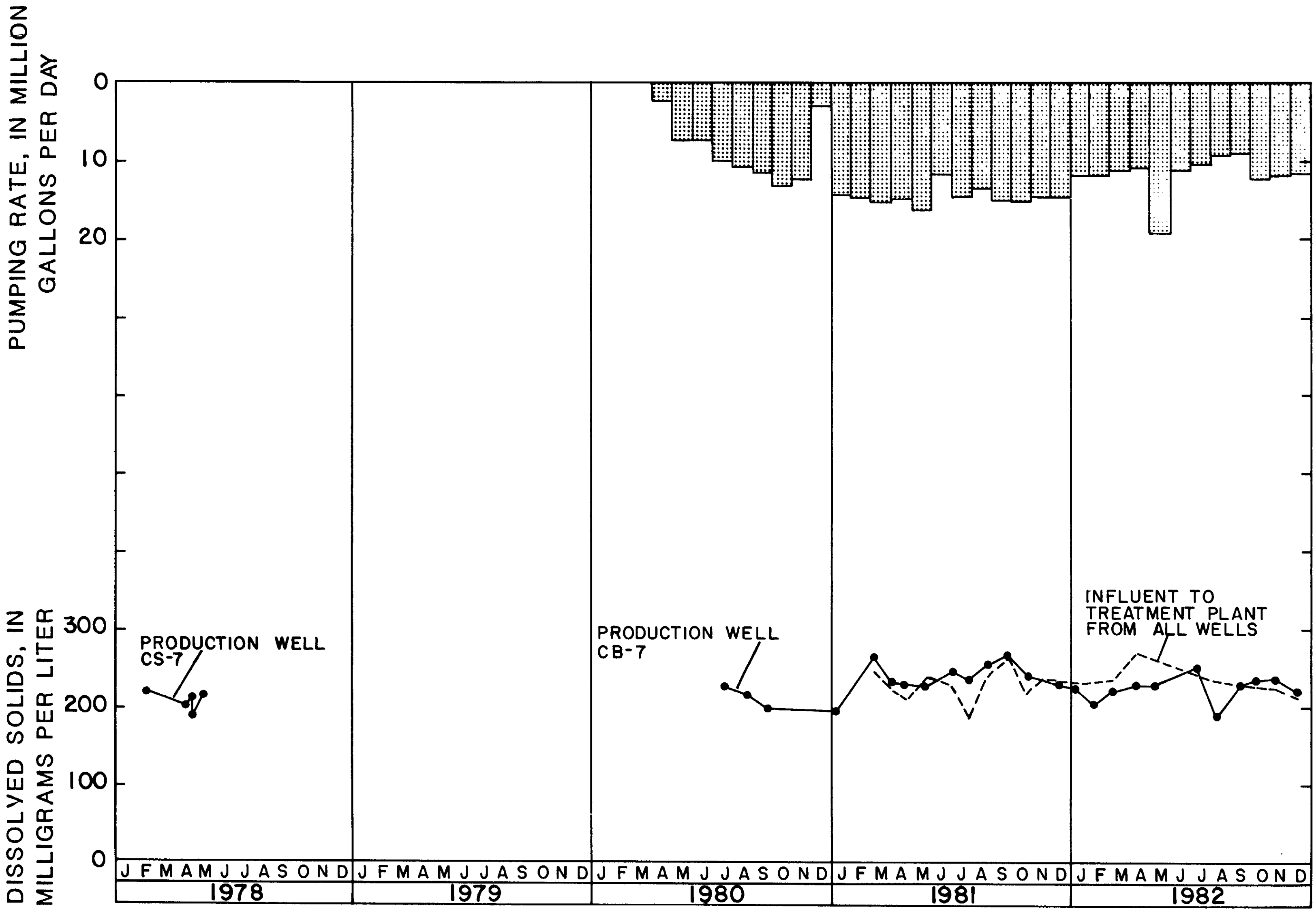

Figure 14.--Concentrations of dissolved solids in water from the producing zone.

No matter how far below land surface the water table stands, there is some minimum or base rate of ET. This base rate is determined by evaporation and transpiration that take place before any rainfall can percolate to the water table. Estimates of this base rate of ET range from 25 to 35 in/yr (Tibbals, 1978).

The actual ET rate depends upon depth to water table, soil type, type of plant community, humidity, and amount of incoming energy (sunlight and wind). On an areal and long-term annual basis, humidity, incoming energy, and rainfall can be regarded as fairly constant and uniformly distributed in west-central Florida. Soil types and plant communities are not uniformly distributed. For modeling purposes, these differences are not considered major factors in determining variability of ET because depth to water table helps determine the plant community and the soil type. Therefore, depth to the water table is used as the factor for proportioning the rate of ET.

The Upper Floridan aquifer is recharged by downward leakage from the surficial aquifer. Based on a digital model of predevelopment hydrologic conditions (Hutchinson, 1984a), the average downward leakage in a 121-mi^2 area that includes the Cross Bar Ranch well field was estimated to be about 13 in/yr. Pumping lowers the potentiometric surface, thereby inducing additional leakage from the surficial aquifer to the Upper Floridan aquifer.

CONCEPTUAL MODEL

A generalized conceptual model of the hydrogeologic system is shown schematically in figure 15. The Upper Floridan aquifer is confined above and below. Above the upper confining unit, it is overlain by the unconfined surficial aquifer. Rainfall either runs off or percolates downward and recharges the surficial aquifer. Once in the surficial aquifer, water may move laterally to discharge where it intersects land surface, be lost as ET, or leak downward to the Upper Floridan aquifer. Water in the Upper Floridan aquifer moves laterally to lowland discharge areas, such as the Pithlachascotee River and Gulf Coast, where it leaks upward. Pumping from the Upper Floridan aquifer reduces the natural coastward flow of water through the aquifer. It also changes the rate and possibly the direction of leakage and results in a decline of the water table in the surficial aquifer. When the water table is lowered, ET is reduced. Surface runoff may also be reduced because of the aquifer's ability to accept recharge in areas where excess water formerly was rejected.

The water balance for an aquifer accounts for inflows, outflows, and changes in ground-water storage. Water balances for each aquifer were estimated as a basis for developing a computer model of the hydrologic system in the 121-mi^2 study area. Under steady-state conditions, change in storage is zero and inflows and outflows are equated as follows:

	INFLOW		OUTFLOW	
SURFICIAL AQUIFER:	R + UL + BIS	=	ETRO + DL + BOS	(1)
UPPER FLORIDAN AQUIFER:	DL + BIUF	=	UL + BOUF + P	(2)

where

R = recharge from rainfall;
UL = upward leakage through the upper confining unit;
BIS = boundary inflow, surficial aquifer;
ETRO = evapotranspiration plus runoff from the water table;
BOS = boundary outflow, surficial aquifer;
DL = downward leakage through the upper confining unit;
BIUF = boundary inflow, Upper Floridan aquifer;
BOUF = boundary outflow, Upper Floridan aquifer; and
P = pumpage.

Under normal climatological conditions with no pumping, estimated total inflow to the surficial aquifer is 28 in/yr. Surficial aquifer boundary outflow or inflow is negligible because of the aquifer's low transmissivity and low water-table gradient. Less than 0.1 in/yr leaks upward from the Upper Floridan aquifer, so about 28 in/yr is recharge computed as the residual of rainfall (55 in/yr) minus overland runoff (2 in/yr) and minimum base rate of ET (25 in/yr). About 13 in/yr leaks downward from the surficial aquifer to the Upper Floridan aquifer. The remaining 15 in/yr of inflow is lost from the aquifer as ET from the water table and lateral discharge to streams.

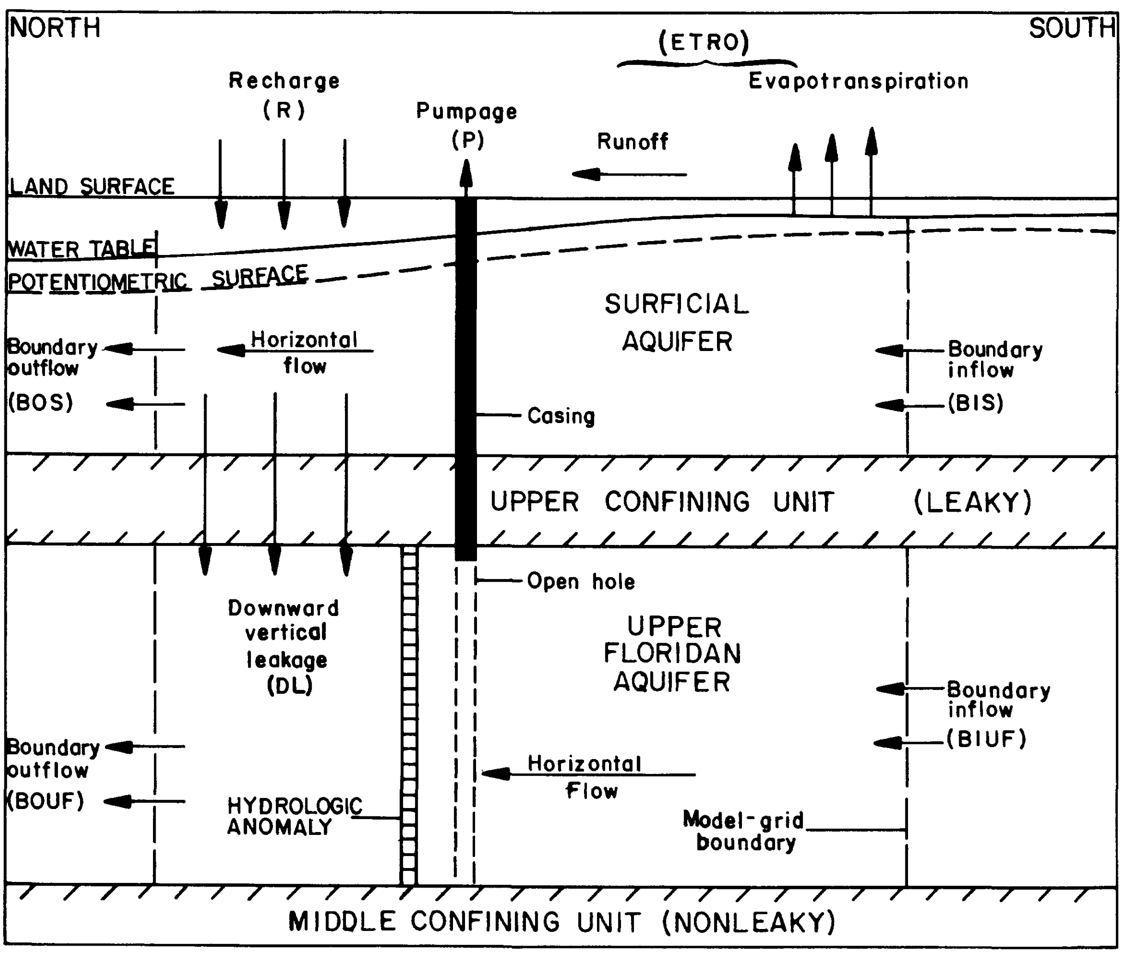

Figure 15.--Conceptual model of the hydrogeologic system.

The Upper Floridan aquifer receives inflow by downward leakage and ground-water flow across the boundary from outside the model grid. Under nonpumping conditions, downward leakage averages about 13 in/yr and boundary inflow about 2 in/yr. This water is lost through boundary outflow of about 15 in/yr and upward leakage of less than 0.1 in/yr.

The water balance within the surficial aquifer may be altered significantly by pumping from the Upper Floridan aquifer. Pumping induces downward leakage, thereby lowering the water table. Surface-water runoff, ET, and ground-water discharge to streams (the three combined are referred to hereafter as ET-runoff) may be reduced when the water table is lowered. In the model, these reductions are computed by an ET-runoff capture function that relates the rate of capture to water-table depth. In the model conceptualization, it is assumed that all ET from the water table (15 inches) plus approximately half the runoff (1 inch) could be salvaged by lowering the water table from its average depth to 10 feet below land surface. It is recognized that this may not be practical from a management standpoint because widespread lowering of water levels could dry up lakes, alter natural vegetation, cause pump failure in shallow wells, and induce sinkhole development. Although ET from the water table is shut off, there probably would be an increase in uncapturable ET from the much thicker unsaturated zone. The ET-runoff capture rate has not been verified by field measurements; however, model results of this study indicate that, for each foot of water-table decline, about 3.8 inches of water will not run off or evapotranspire. This value was used in the regional well-fields model that encompasses the Cross Bar Ranch study area (Hutchinson, 1984a).

The ET-runoff capture rate and depth at which capture ceases probably vary within the Cross Bar Ranch area, but for lack of validation, they were considered to be areally uniform in the model. Because ET-runoff capture is based on reducing water-table ET and runoff as the water table declines, recharge should approach maximum potential rates. In internally drained areas, recharge should not exceed rainfall (55 in/yr) minus minimum ET (25 in/yr), or about 30 in/yr.

Except at the lateral boundaries, the model apportions recharge to leakage and ET-runoff using equation 1. For example, if recharge to the surficial aquifer in a grid block was 20 in/yr and downward leakage was 5 in/yr under nonpumping conditions, the model would allocate 15 in/yr as ET-runoff. If pumping from the Upper Floridan aquifer were to increase leakage from 5 in/yr to 12.6 in/yr, then the water table would drop an average of 2 feet to capture the 7.6-in/yr leakage increase, and ET-runoff would be reduced from 15 in/yr to 7.4 in/yr. Should pumping capture all the 15-in/yr ET-runoff reserve, then the total recharge of 20 in/yr would leak down to the Upper Floridan aquifer. Further pumping increases would not capture additional ET or runoff, with the result being accelerated water-table declines.

The model conceptualization considers recharge to the surficial aquifer to be high because rainfall is high and the area is internally drained. ET from the water table is considered to be low in the northern part of the model area where the water table is nearly 10 feet below land surface and moderate in the southern area where the water table is generally less than 5 feet deep. Leakage to the Upper Floridan aquifer is considered to be high throughout the area because the upper confining unit is fairly thin and because sinkholes probably increase the leakage rate. Transmissivity of the surficial aquifer is very low relative to transmissivity of the Upper Floridan aquifer.

SIMULATED IMPACT OF PUMPING

Digital models of steady-state ground-water flow were utilized in this study to improve the understanding of hydrogeologic conditions and the impact of pumping from the Cross Bar Ranch well field on the hydrogeologic system. A regional model of a 932-mi^2 area (Hutchinson, 1984a) was used to provide boundary flows for input into a local model of the 121-mi^2 study area. This nested modeling technique allowed the study area to be small and still allowed for simulation of regional interference caused by pumping from wells outside the study area. The model program and modeling procedures are described in the "Supplemental Data" section.

Four combinations of hydrologic conditions and well-field operation were simulated using the nested modeling technique.

1. Predevelopment conditions, with no pumping.--Long-term average conditions with no stresses are simulated. The heads from this simulation are used as initial conditions for subsequent model runs.

2. Regional pumping adjacent to Cross Bar Ranch.--This model run simulates impact at Cross Bar Ranch resulting from regional pumping for irrigation and municipal supply.

3. Pump 30 Mgal/d, with no regional pumping.--This run simulates the impact on the aquifers of pumping the Cross Bar Ranch well field at its average annual permitted rate.

4. Pump 45 Mgal/d, with no regional pumping.--This run simulates the impact on the aquifers of pumping the well field at its maximum permitted rate.

Inflow, outflow, and drawdown were simulated under each combination of conditions to determine the sources of water and the extent and magnitude of pumping effects.

The model simulates steady-state conditions where changes in outflow caused by pumping equal changes in inflow. Actual changes in water levels and flow depend upon the duration of pumping, boundary conditions, and upon transient rainfall conditions. Because the steady-state analysis is not time dependent, the time required for computed heads to reach equilibrium cannot be determined from this model. Because the model simulates long-term average water-level changes, short-term extremes could be significantly different from simulated conditions. Finally, because calibration errors are carried over into the predictive modeling phase, using the model to predict water-level changes is more valid than using it to define a new head condition.

The sources of water pumped are determined by comparing model-computed water balances developed using equations 1 and 2. The water balances are summarized in table 5. The following four sections describe hydrologic conditions simulated by the model. The fifth section concerns limitations of the model analysis.

Table 5.--Summary of water-balance and water-level data simulated by the model under varying conditions of pumping

A. WATER BALANCE FOR SURFICIAL AQUIFER

	R Recharge (in/yr)	BI Boundary inflow (in/yr)	ETRO ET-runoff from water table (in/yr)	UL Upward leakage (in/yr)	DL Downward leakage (in/yr)	BO Boundary outflow (in/yr)
Predevelopment conditions ---	28	<0.1	14.7	<0.1	13.3	<0.1
Pump adjacent to Cross Bar Ranch --------	28	<0.1	13.4	<0.1	14.6	<0.1
Pump 30 Mgal/d -------	28	<0.1	11.5	<0.1	16.5	<0.1
Pump 45 Mgal/d -------	28	<0.1	10.1	<0.1	17.9	<0.1

Water balance: R + UL + BIS = ETRO + DL + BOS

B. WATER BALANCE FOR UPPER FLORIDAN AQUIFER

	UL Upward leakage (in/yr)	DL Downward leakage (in/yr)	BIUF Boundary inflow (in/yr)	BOUF Boundary outflow (in/yr)	Pumpage (in/yr)
Predevelopment conditions ---	<0.1	13.3	1.5	14.8	0.0
Pump adjacent to Cross Bar Ranch ----------------------	<0.1	14.6	1.3	15.9	0.0
Pump 30 Mgal/d --------------	<0.1	16.5	1.6	12.9	5.2
Pump 45 Mgal/d --------------	<0.1	17.9	1.7	11.8	7.8

Water balance: DL + BI = UL + BO + P

C. AVERAGE DRAWDOWN OVER MODEL AREA

	Water table in surficial aquifer (feet)	Potentiometric surface of Upper Floridan aquifer (feet)
Predevelopment conditions -------------------	0.0	0.0
Pump adjacent to Cross Bar Ranch -----------	0.3	0.6
Pump 30 Mgal/d ------------------------------	2.4	4.0
Pump 45 Mgal/d ------------------------------	4.6	6.9

Predevelopment Conditions, With No Pumping

An estimate of hydrologic conditions prior to development of ground-water resources was necessary to simulate the impact of development. The predevelopment simulation represents inflow, outflow, and water levels under long-term average climatic conditions with no pumping, either locally or regionally. It is the basis for comparing subsequent model runs that simulate effects of ground-water withdrawal on the hydrologic system. The model-simulated water table in the surficial aquifer and potentiometric surface of the Upper Floridan aquifer are shown in figures 16 and 17.

The average model-simulated predevelopment water table and potentiometric surface (figs. 16 and 17) are slightly higher than those observed for the September 1976 to May 1977 validation period (figs. 8 and 9). Predevelopment water levels represent a period of average rainfall (55 in/yr), whereas validation levels reflect a 51.6-in/yr rainfall condition. The average water levels for validation were also slightly lowered by regional pumping outside the modeled area. The water balance for the surficial aquifer (table 5) indicates that under predevelopment conditions, boundary flow is negligible, and of the 28-in/yr recharge to the water table, about half leaves the aquifer as ET-runoff and about half leaks downward to the Upper Floridan aquifer. Hence, the water balance indicates that downward leakage from the surficial aquifer is an important source of recharge to the Upper Floridan aquifer. Lateral inflow to the Upper Floridan aquifer accounts for only 1.5 in/yr due to the relatively flat hydraulic gradient along the southern boundary of the modeled area.

Regional Pumping Adjacent to Cross Bar Ranch

From a water-resources management standpoint, it is useful to estimate how the Cross Bar Ranch well field is affected by regional pumping for municipal supply and irrigation. An average permitted pumping rate of 157 Mgal/d for nine municipal well fields plus 53 Mgal/d for irrigation was simulated by the regional model (Hutchinson, 1984a) that includes the nonpumping Cross Bar Ranch well-field area. The regional model simulated the change in flow at the Cross Bar Ranch model boundary. Predevelopment boundary flows in the Upper Floridan aquifer in the Cross Bar Ranch model were then adjusted to reflect these changes. The model was then run with the new constant-flow boundary condition to simulate localized effects of regional pumping adjacent to the well field.

Model-simulated drawdowns in the surficial and Upper Floridan aquifers, resulting from regional pumping, are shown in figures 18 and 19. Across the modeled area, drawdown averages 0.3 foot in the water table and 0.6 foot in the potentiometric surface of the Upper Floridan aquifer (table 5). Drawdowns are greatest in the southeast part of the modeled area, primarily due to pumping of 30 Mgal/d from the nearby Cypress Creek well field. Within the Cross Bar Ranch well field, maximum drawdowns caused by regional pumping occur at the southeast corner of the well field. There, the water table and potentiometric surface have been drawn down about 0.6 foot and 1 foot, respectively. The least impact occurred at the northern boundary of the well field where drawdown in each aquifer was less than 0.2 foot.

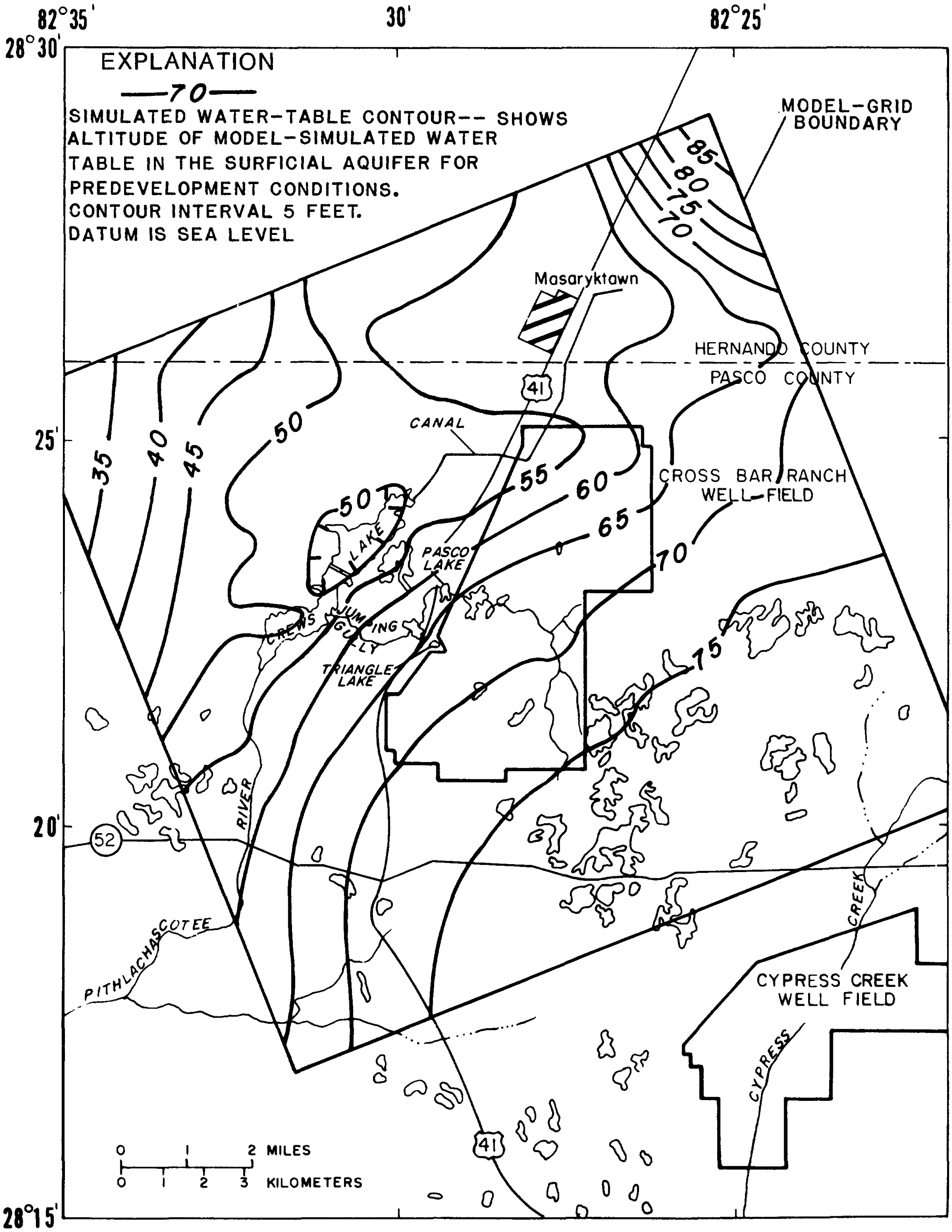

Figure 16.--Model-simulated water table in the surficial aquifer for predevelopment conditions.

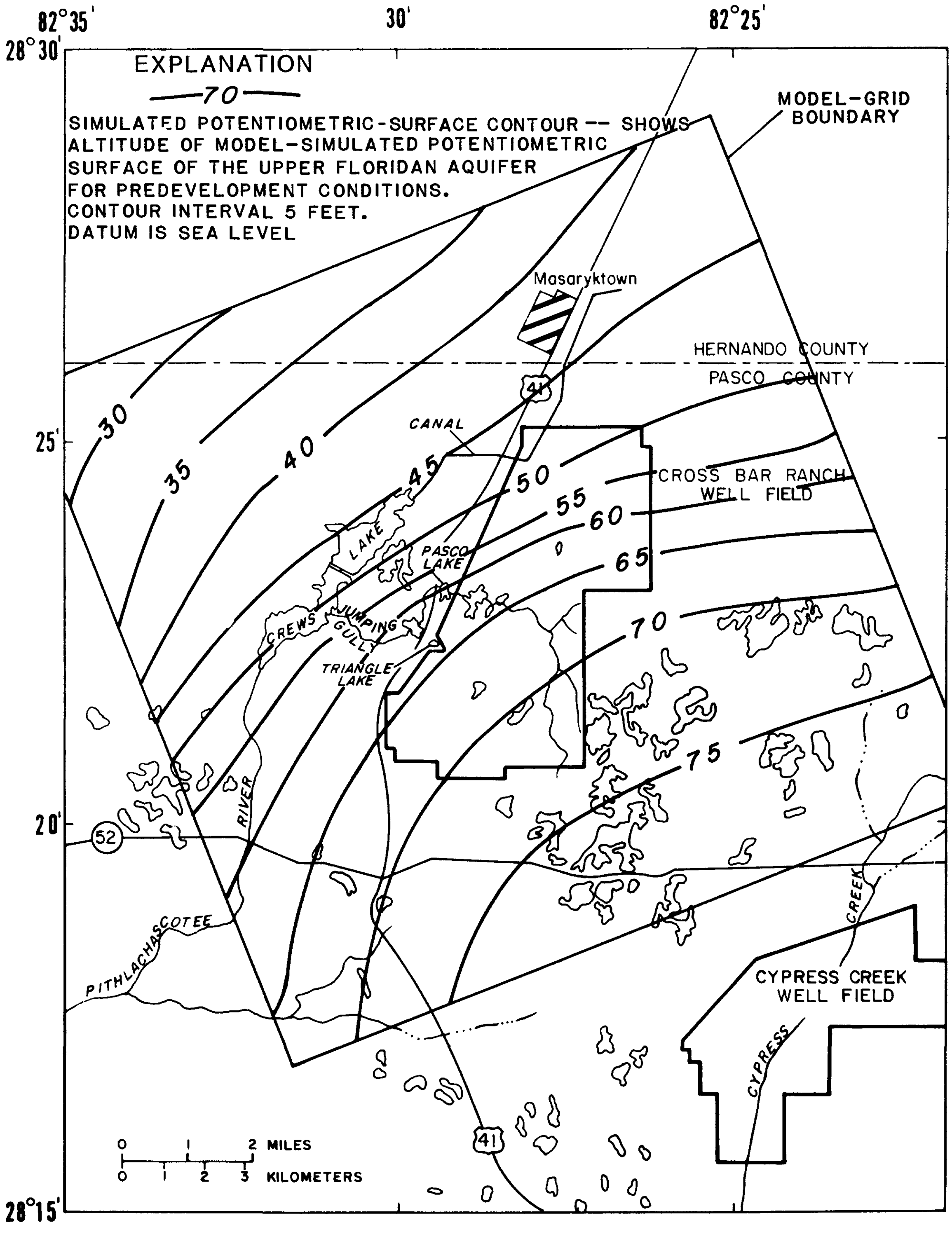

Figure 17.--Model-simulated potentiometric surface of the Upper Floridan aquifer for predevelopment conditions.

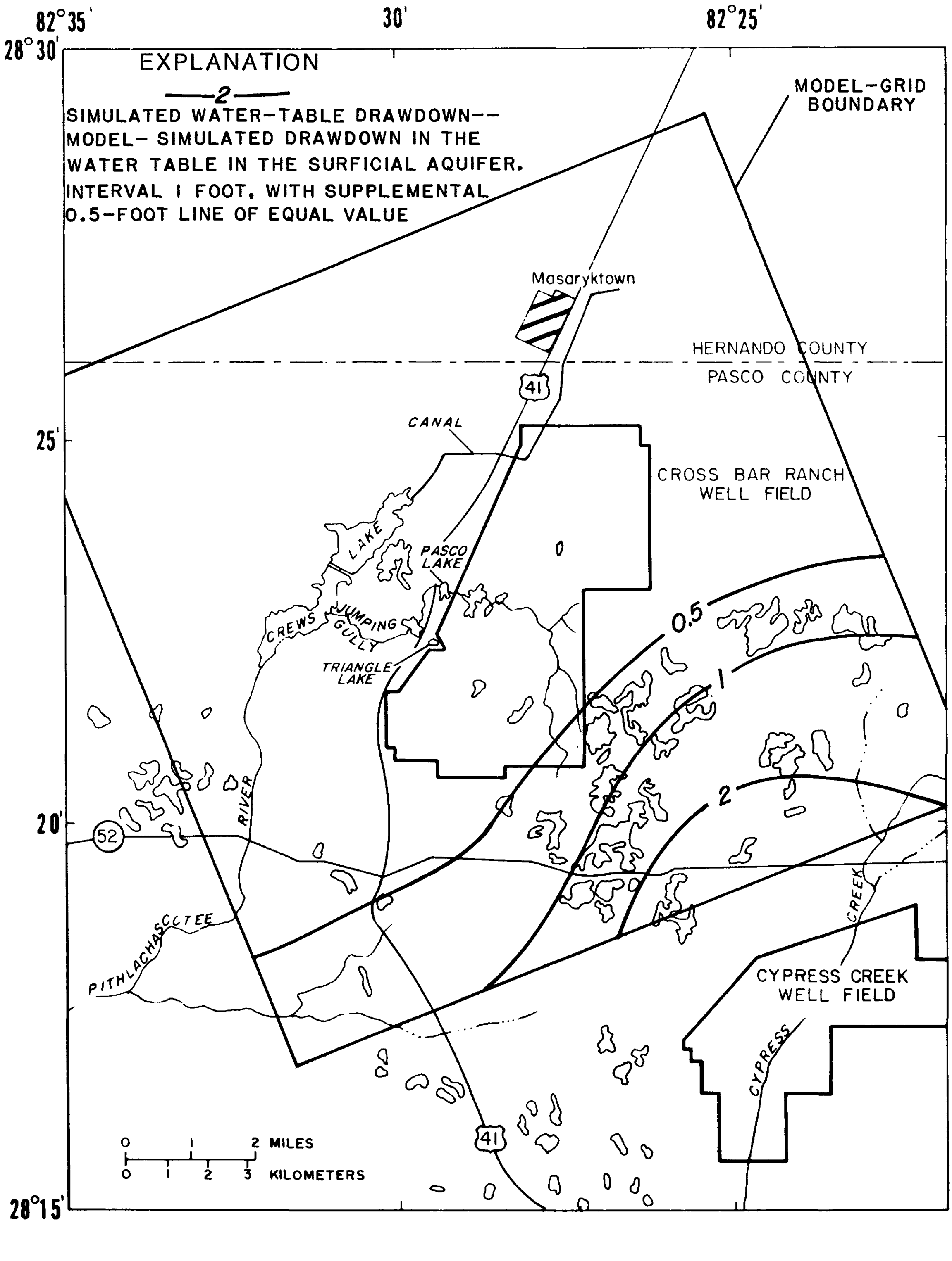

Figure 18.--Model-simulated drawdown in the water table in the surficial aquifer, resulting from regional pumping adjacent to the Cross Bar Ranch well field.

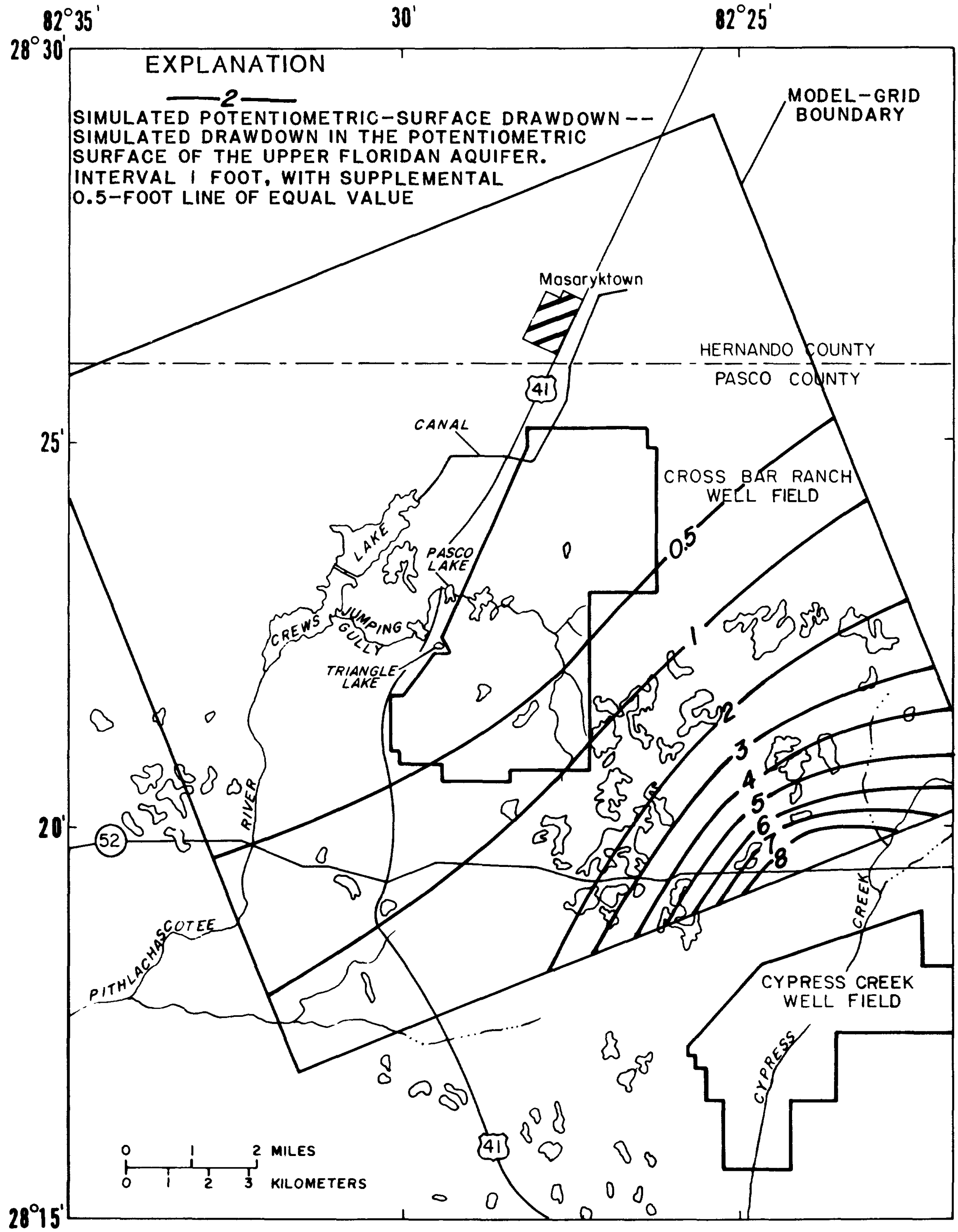

Figure 19.--Model-simulated drawdown in the potentiometric surface of the Upper Floridan aquifer, resulting from regional pumping adjacent to the Cross Bar Ranch well field.

The water balance for pumping adjacent to the Cross Bar Ranch well field indicates that regional simulated pumping from the Upper Floridan aquifer would result in a 0.2-in/yr decrease in boundary inflow and a 1.1-in/yr increase in boundary outflow (table 5). This 1.3-in/yr total loss from the Upper Floridan aquifer is balanced by a 1.3-in/yr increase in downward leakage. The ultimate source of the pumped water is a 1.3-in/yr net loss in ET-runoff from the water table in the surficial aquifer.

Pumping 30 Million Gallons Per Day

The average annual permitted pumping rate for the Cross Bar Ranch well field is 30 Mgal/d. The modeling procedure for simulating the impact of this pumping rate on the aquifer system included running the regional predevelopment model with only the Cross Bar Ranch well field being pumped to simulate changes in flows at the Cross Bar Ranch model boundary. Predevelopment boundary flows in the Upper Floridan aquifer in the Cross Bar Ranch model were then adjusted to reflect these changes. The Cross Bar Ranch model was then run to simulate the effects on the well-field area of pumping 30 Mgal/d.

The configurations of the model-simulated water table in the surficial aquifer and potentiometric surface of the Upper Floridan aquifer when the well field is pumped at 30 Mgal/d (each production well was pumped at 1.76 Mgal/d) are shown in figures 20 and 21. Contours have been displaced to the southeast with respect to predevelopment levels represented in figures 16 and 17. The cones of depression in the water table and potentiometric surface are shown in figures 22 and 23, respectively. Drawdown in the water table at the well-field boundary ranges from about 2 to 9 feet, and in the potentiometric surface, drawdown at the boundary ranges from about 3 to 10 feet. Average drawdown in the water table is 2.4 feet (table 5) and is between 5 and 17 feet over an 8-mi^2 area centered in the well field. Average drawdown in the potentiometric surface is 4.0 feet and is between 5 and 21 feet over a 15-mi^2 area, mostly within the well field. The hydrologic anomaly appears to restrict the northwesterly spread of the cone of depression in the Upper Floridan aquifer.

The water balance for the Upper Floridan aquifer simulated for the 30-Mgal/d pumping rate shows a 0.1-in/yr increase in boundary inflow and a 1.9-in/yr decrease in boundary outflow compared with predevelopment boundary flows (table 5). Downward leakage increases 3.2 in/yr over the predevelopment rate to provide the total of 5.2 in/yr pumped from the modeled area. The increased leakage causes the water table to decline to a level resulting in 3.2 in/yr being captured from ET-runoff. ET-runoff capture ceased in 164 grid blocks where the water table declined to more than 10 feet below land surface. Consequently, average drawdown was greater than the 0.84 foot anticipated on the basis of the conceptual model (3.8 in/yr of ET-runoff is captured per foot of drawdown in the water table).

Pumping 45 Million Gallons Per Day

The maximum daily permitted pumping rate for the Cross Bar Ranch well field is 45 Mgal/d for short time periods. Modeling procedures for simulating the impact of this pumping were the same as those used to simulate the effects of pumping at the rate of 30 Mgal/d. Results of the model simulations are depicted by water-level maps in figures 24 and 25 and by drawdown maps in figures 26 and 27.

Water-table and potentiometric-surface contours were displaced to the southeast about 1 mile further than the displacement for 30 Mgal/d. Extensive cones of depression 20 to 25 feet deep develop in both aquifers in the north-central part of the well field. Drawdown in the water table at the well-field boundary ranges from about 3 feet to 15 feet, and the surficial aquifer has been completely dewatered in three grid blocks (fig. 26). Drawdown in the potentiometric surface ranges from about 30 feet in the center of the well field to about 5 to 20 feet at the well-field boundary. Average drawdown in the water table is 4.6 feet (table 5) and is between 5 and 26 feet over a 16-mi^2 area centered around the pumping. Average drawdown in the potentiometric surface is 6.9 feet and is between 5 and 35 feet over a 28-mi^2 area that includes the well field.

The water balance for the Upper Floridan aquifer under the 45-Mgal/d pumping condition shows a 0.2-in/yr increase in inflow and a 3.0-in/yr reduction in outflow along the model boundaries with respect to predevelopment conditions. Downward leakage increases 4.6 in/yr to provide part of the total of 7.8 in/yr pumped from the well field. The increased leakage is water captured by reducing ET-runoff from the water table in the surficial aquifer. ET-runoff capture ceased in 222 grid blocks resulting in accelerated drawdown in the water table.

SUMMARY AND CONCLUSIONS

The 13-mi^2 Cross Bar Ranch well field is scheduled to provide 30 Mgal/d of water to Pinellas and western Pasco Counties. This study of the well-field area has been directed toward specific objectives as follows:

1. Describe the hydrogeologic framework.--The Cross Bar Ranch area is blanketed by a layer of fine sand about 35 feet thick that forms the low-yielding surficial aquifer. A sand and clay bed, 10 to 20 feet thick, underlies the surficial aquifer and forms a leaky upper confining unit between the surficial aquifer and the underlying Upper Floridan aquifer. The major producing zone is the Upper Floridan aquifer that is composed of a sequence of limestone and dolomite about 900 feet thick. The Upper Floridan aquifer is underlain by a middle confining unit of limestone and dolomite with porosity plugged by intergranular gypsum and anhydrite.

Under natural conditions, the water table in the surficial aquifer and the potentiometric surface of the Upper Floridan aquifer generally lie within 10 feet of land surface. Because the Upper Floridan aquifer is highly transmissive and the upper confining unit is moderately leaky, pumping large quantities of water from a small area, such as the well field, induces broad cones

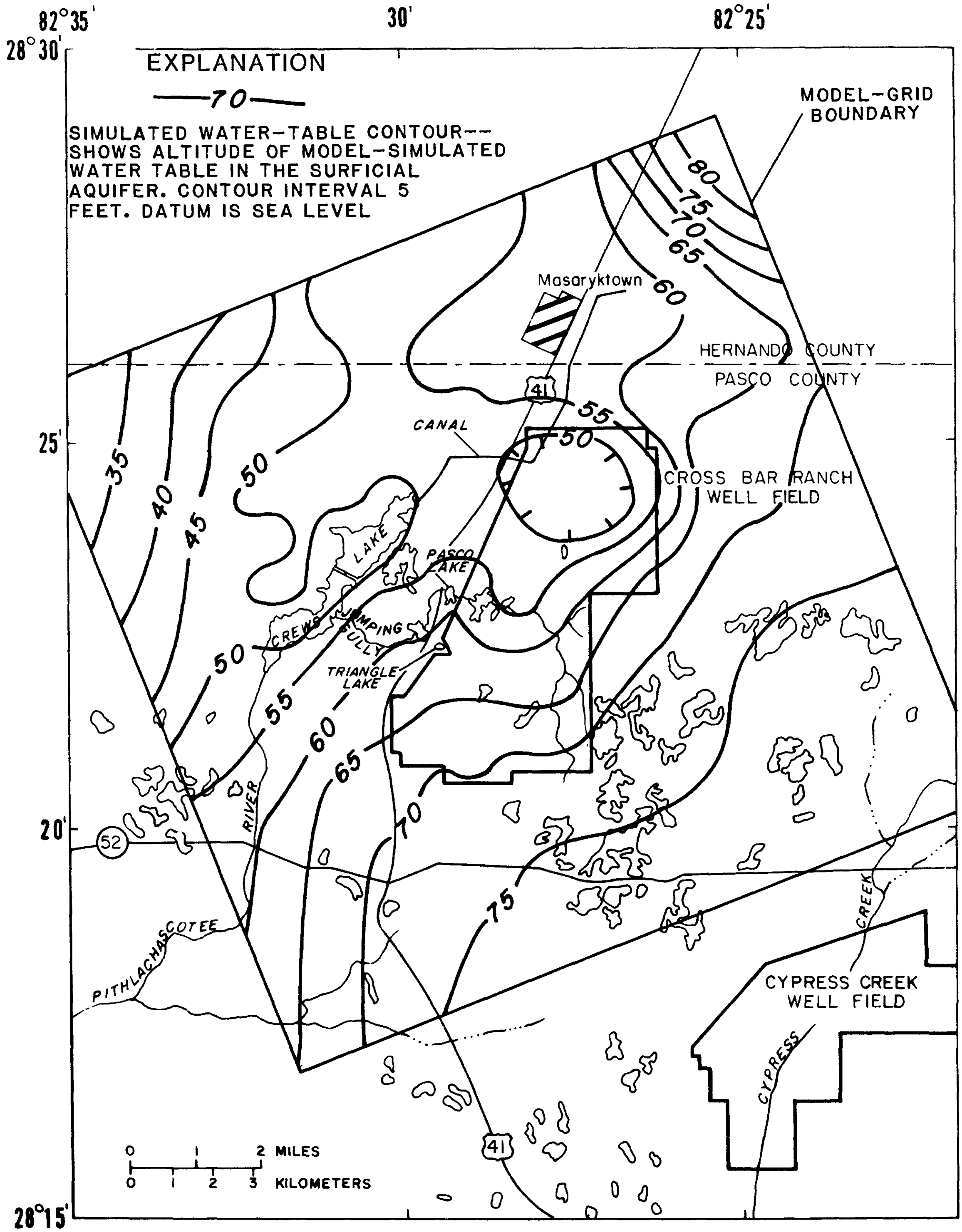

Figure 20.--Model-simulated water table in the surficial aquifer with the Cross Bar Ranch well field pumping 30 million gallons per day.

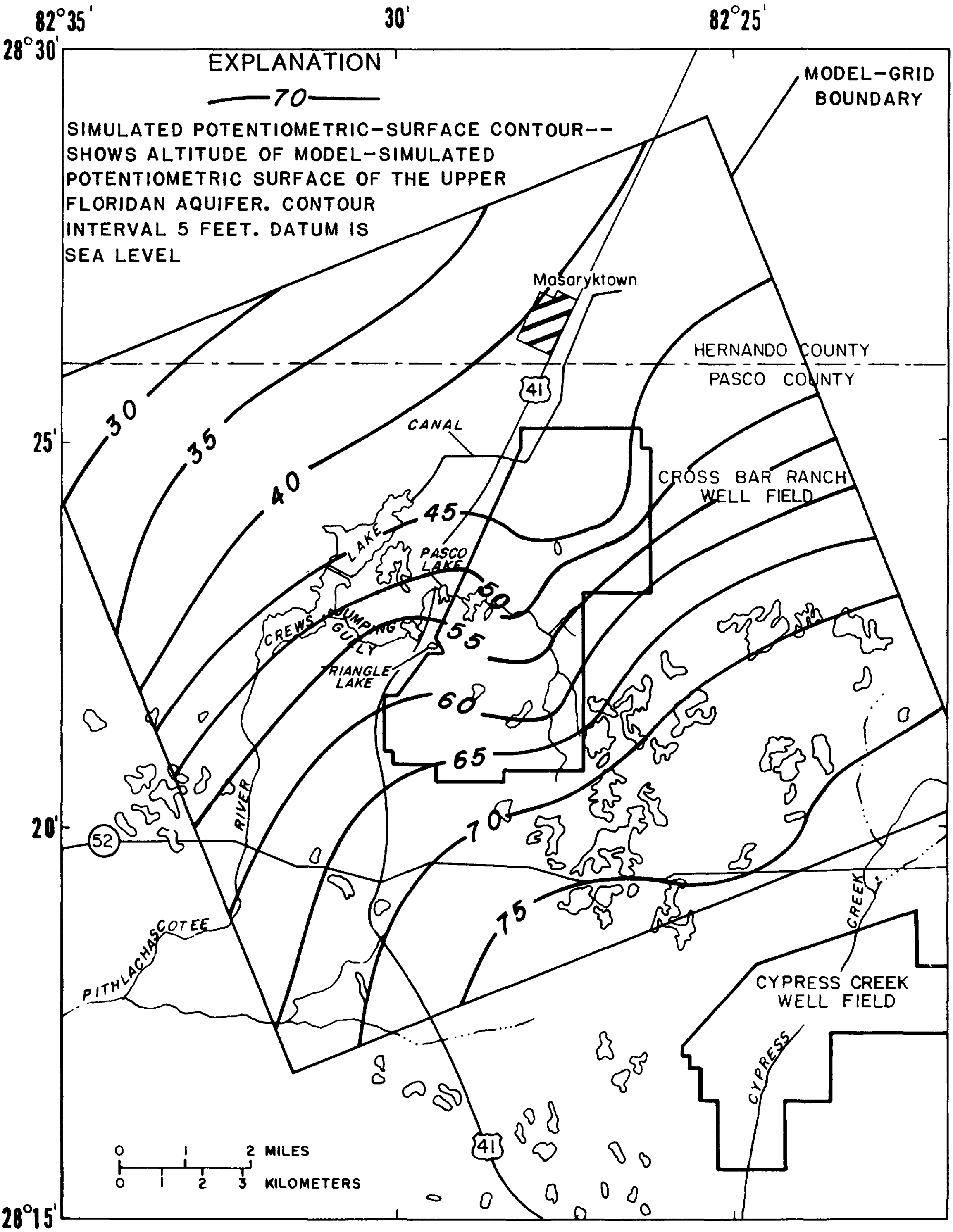

Figure 21.--Model-simulated potentiometric surface of the Upper Floridan aquifer with the Cross Bar Ranch well field pumping 30 million gallons per day.

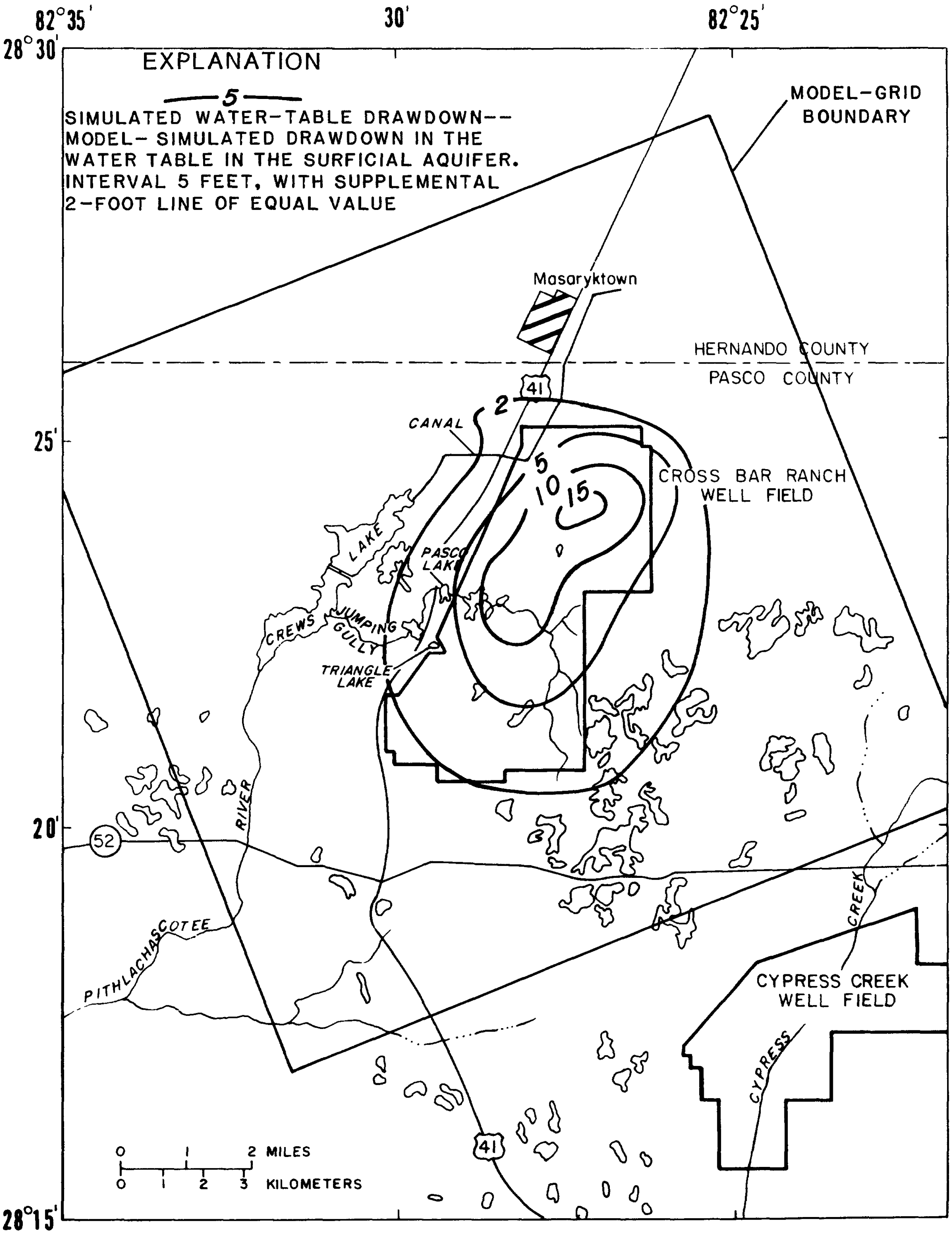

Figure 22.--Model-simulated drawdown in the water table in the surficial aquifer with the Cross Bar Ranch well field pumping 30 million gallons per day.

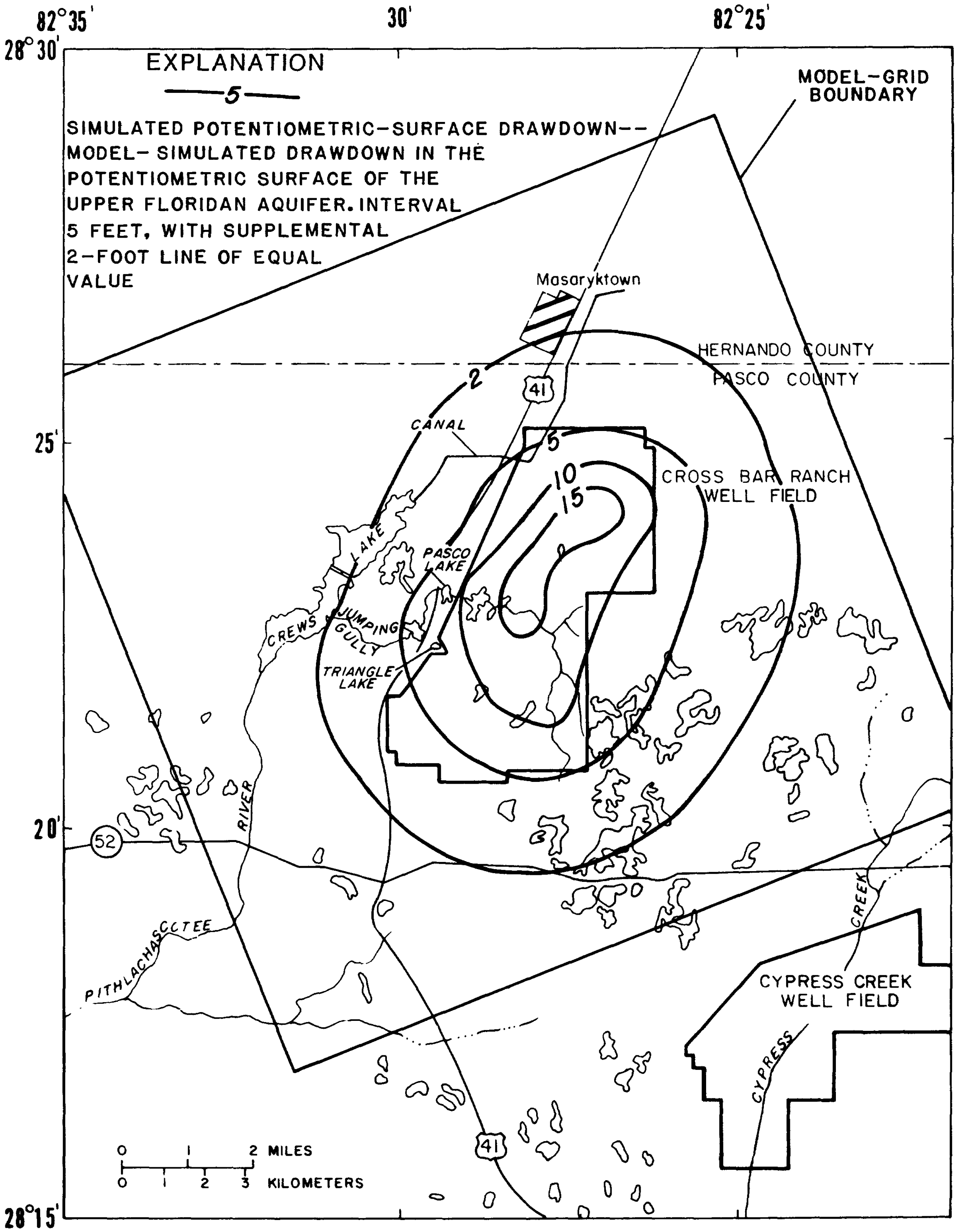

Figure 23.--Model-simulated drawdown in the potentiometric surface of the Upper Floridan aquifer with the Cross Bar Ranch well field pumping 30 million gallons per day.

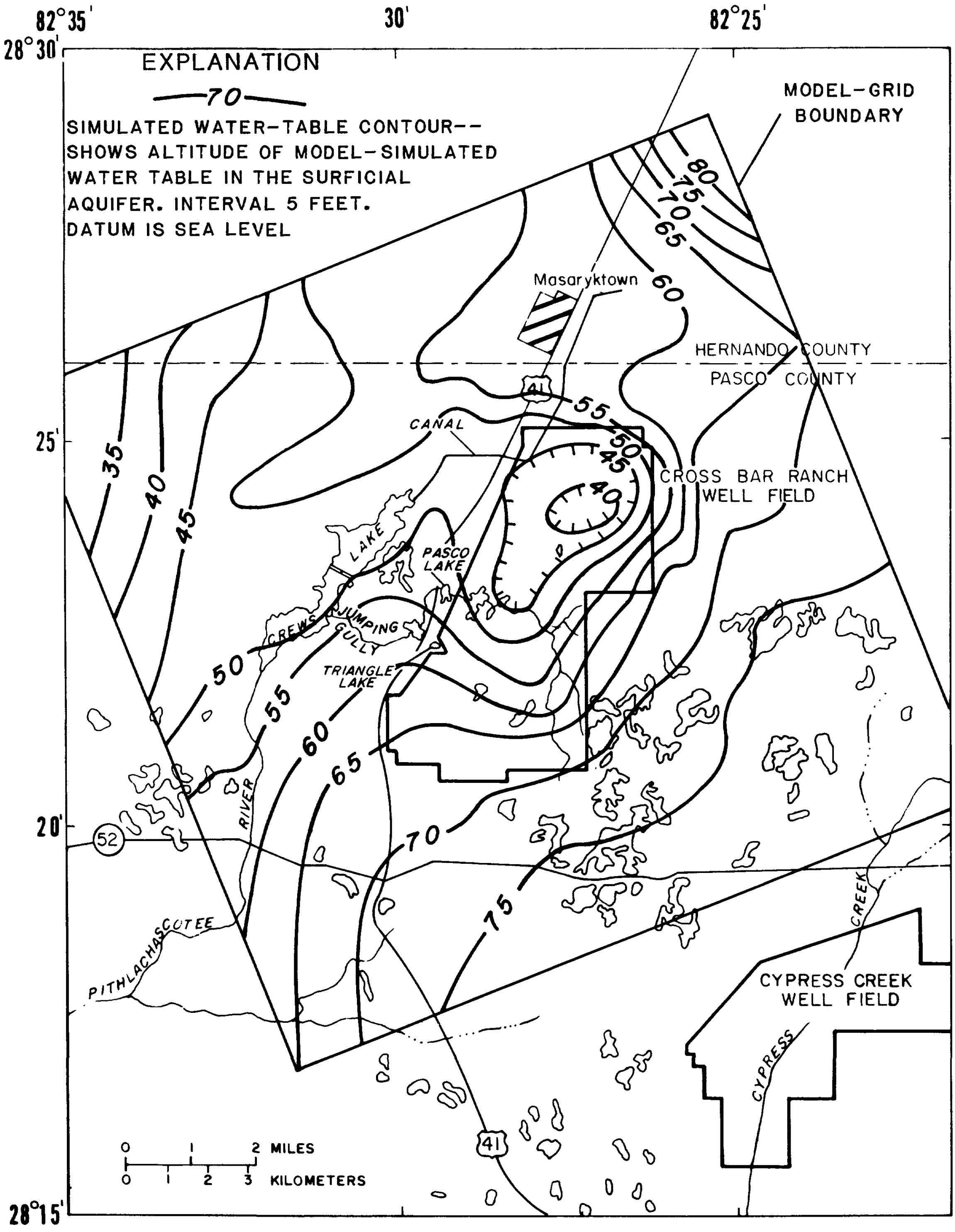

Figure 24.--Model-simulated water table in the surficial aquifer with the Cross Bar Ranch well field pumping 45 million gallons per day.

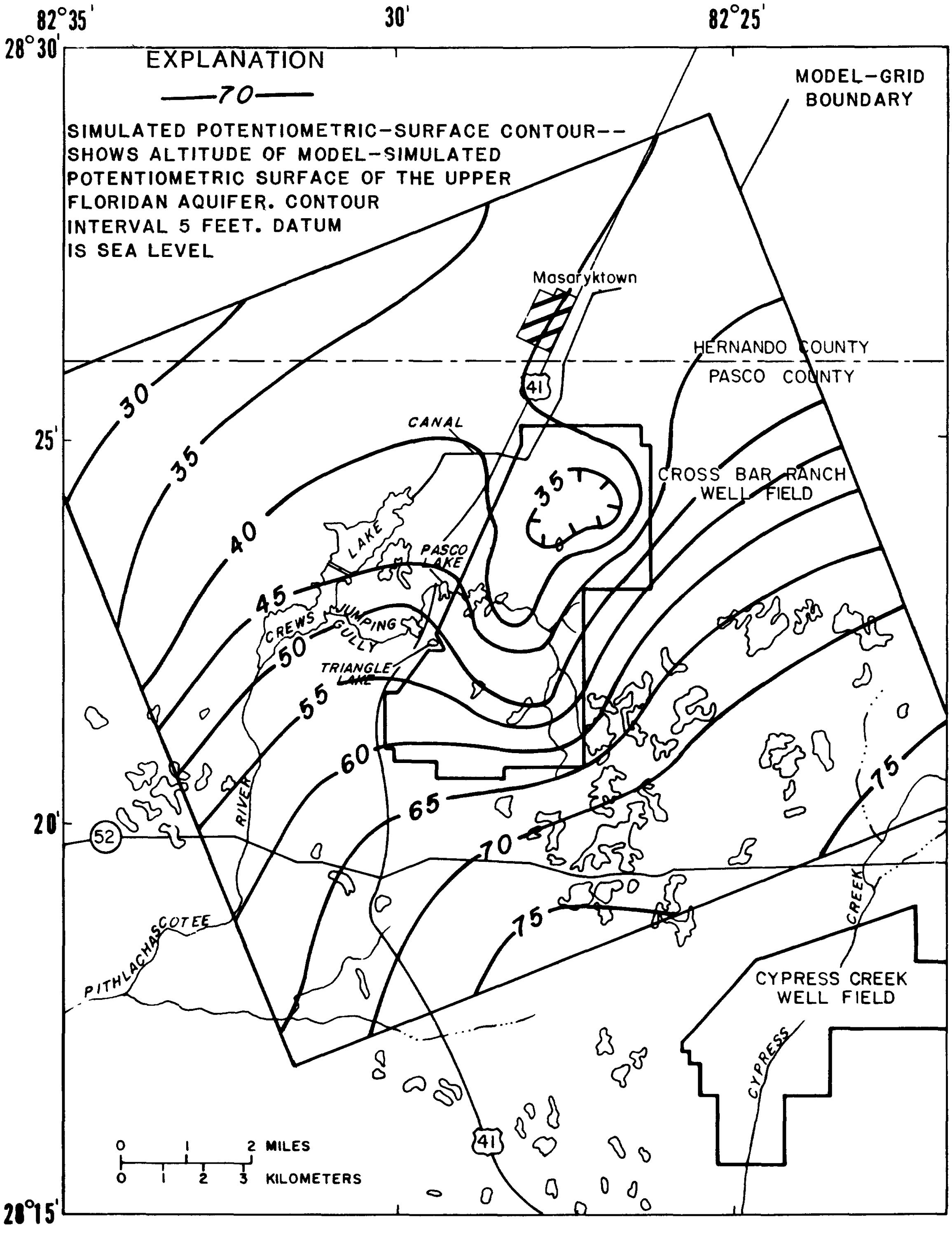

Figure 25.--Model-simulated potentiometric surface of the Upper Floridan aquifer with the Cross Bar Ranch well field pumping 45 million gallons per day.

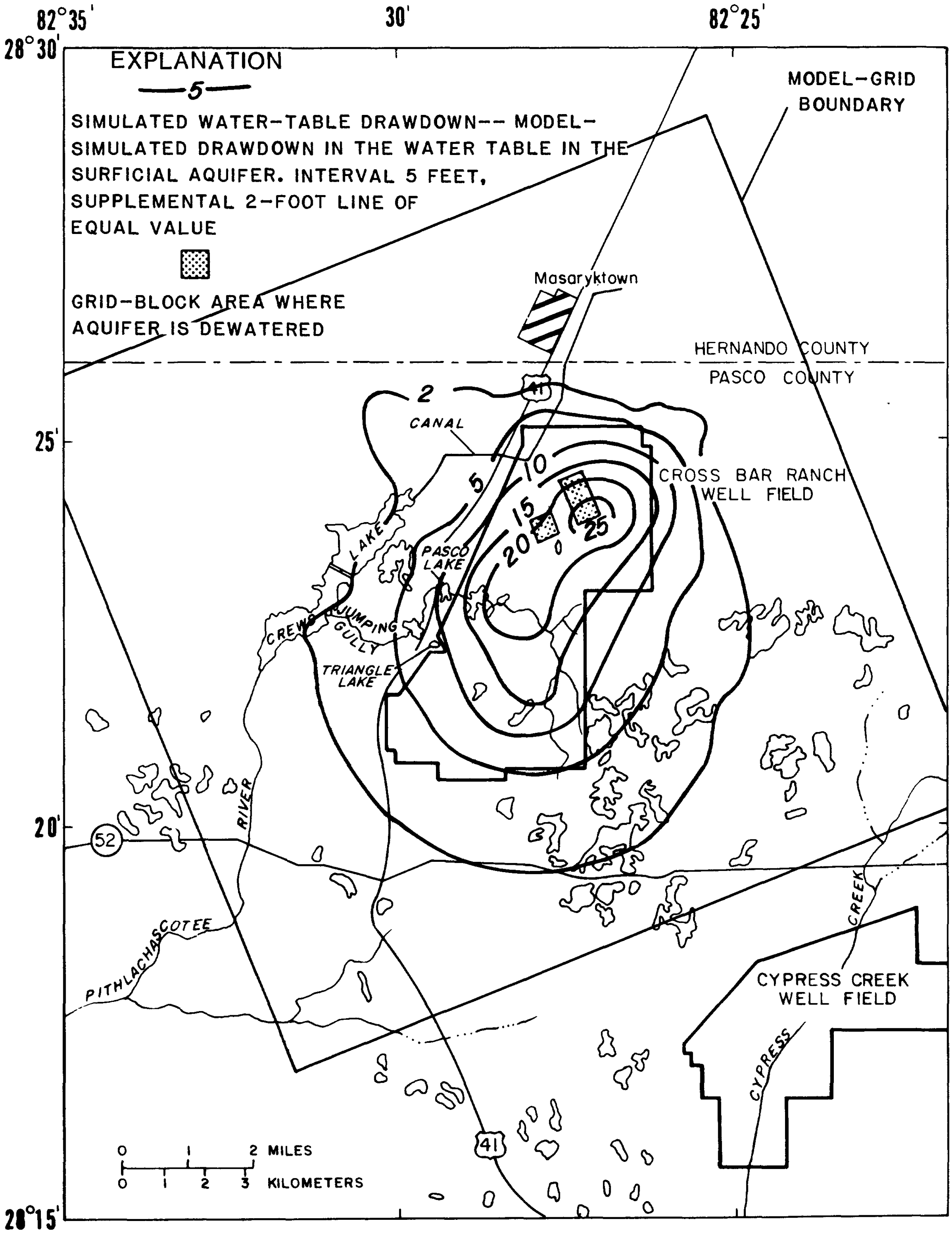

Figure 26.--Model-simulated drawdown in the water table in the surficial aquifer with the Cross Bar Ranch well field pumping 45 million gallons per day.

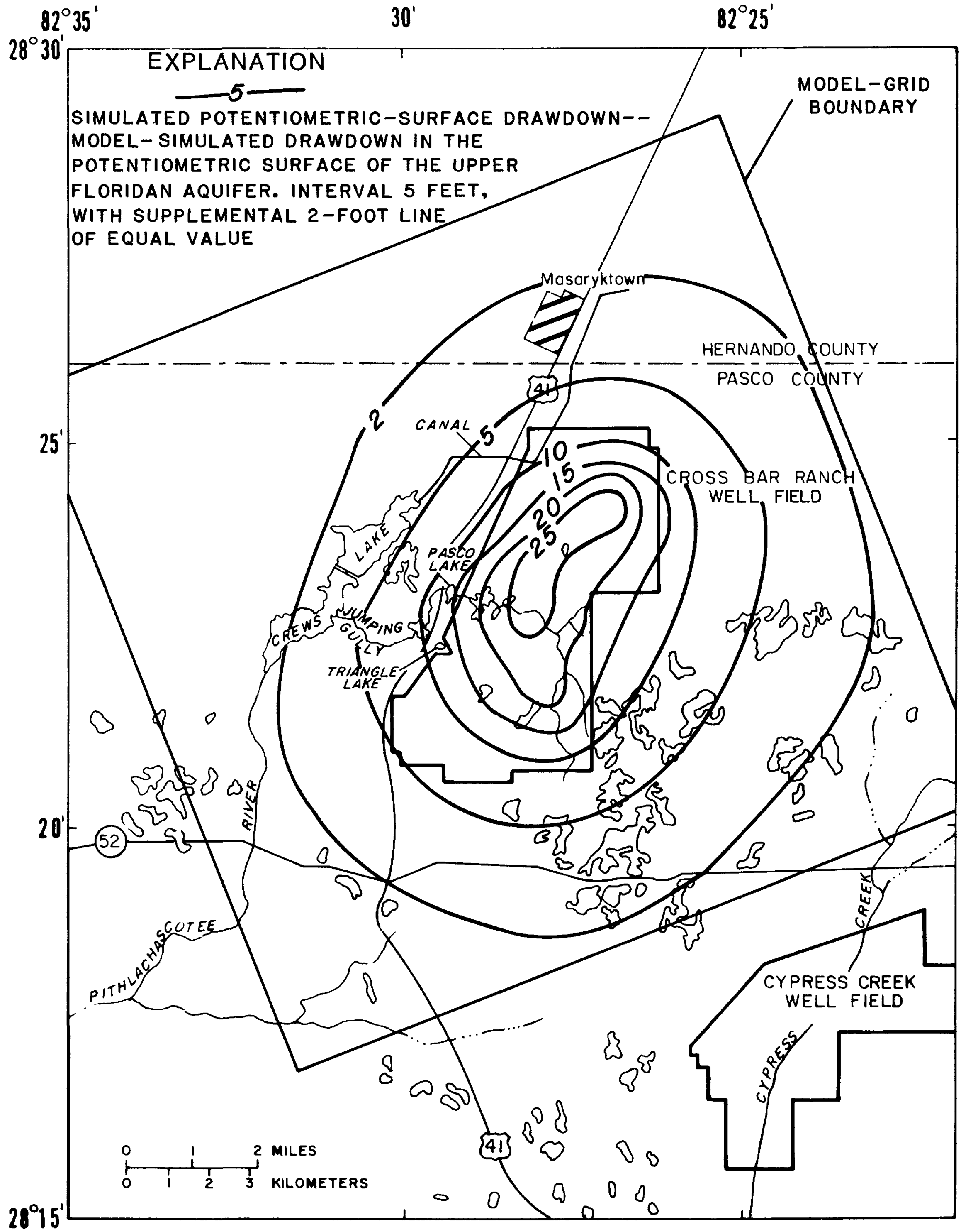

Figure 27.--Model-simulated drawdown in the potentiometric surface of the Upper Floridan aquifer with the Cross Bar Ranch well field pumping 45 million gallons per day.

of depression several miles in diameter but only a few feet deep. The shapes of the cones, or water-level trends within them, are altered by local inhomogeneities in the hydrogeologic framework. Pasco Lake is actually a dammed-up stream and its stage fluctuates over a larger range than the interconnecting water table. Within the Upper Floridan aquifer, there is a hydrologic anomaly, or zone of low transmissivity, that cuts across the northern part of the well field. The hydrologic anomaly has been delineated on the basis of differences in rates of water-level decline in observation wells during pumping tests.

Dissolved-solids concentrations in water from the Upper Floridan aquifer are generally less than 300 mg/L. The aquifer contains water of uniform quality areally and vertically. The middle confining unit contains saline water with a dissolved-solids concentration of about 19,000 mg/L. The low measured permeability of the middle confining unit precludes rapid upward movement of large quantities of saline water into the producing zone. Water moves laterally into a pumping center much faster than it moves vertically from the confining unit. The quality of water from production wells changed little with the pumping rate between 1978 and 1982, thereby indicating that upward leakage has not yet been significant. Because the well field has not yet been stressed at the maximum short-term production level of 45 Mgal/d, the potential impact of upconing could not be assessed.

2. Quantify the ground-water flow system.--The water balance for the hydrologic system under predevelopment conditions, assuming long-term average recharge and no pumping, allows 28 in/yr of water as potential recharge to the surficial aquifer. About 13 in/yr leaks downward to the Upper Floridan aquifer, and about 15 in/yr of inflow is lost as ET-runoff. The Upper Floridan aquifer receives, in addition, about 2 in/yr from boundary inflow. Water is lost from the Upper Floridan aquifer through boundary outflow of about 15 in/yr. The water balance is altered significantly by pumping. Vertical leakage from the surficial aquifer to the Upper Floridan aquifer is increased, while ET-runoff from the water table in the surficial aquifer is reduced.

3. Project the impact of pumping.--A digital model of steady-state ground-water flow for a 121-mi^2 area encompassing the Cross Bar Ranch well field simulates changes in water levels and the water balance under various levels of well-field operation. This model is alined with a larger regional well-field area model to incorporate boundary effects of pumping from within or outside the well field. For water-management purposes, using the model to predict water-level changes is more valid than using it to define new head conditions.

Regional pumping outside the Cross Bar Ranch well field causes drawdowns to be greatest in the southeastern part of the well field. At the southeast corner of the well field, the model-simulated water-table and potentiometric-surface declines are 0.6 foot and 1 foot, respectively. These drawdowns primarily result from pumping 30 Mgal/d at the Cypress Creek well field, about 5 miles southeast of Cross Bar Ranch.

The model was used to simulate the effects of pumping from the Upper Floridan aquifer at the Cross Bar Ranch well field at an average annual permitted rate of 30 Mgal/d and a maximum daily rate of 45 Mgal/d. The simulation runs produced maps showing cones of depression beneath the well field in the water table in the surficial aquifer and the potentiometric surface of the Upper Floridan aquifer. Under the 30-Mgal/d pumping rate, simulated drawdown ranged between 5 feet and 17 feet in the water table over 8 mi^2 and between 5 feet and 21 feet in the potentiometric surface over 15 mi^2. Under the 45-Mgal/d pumping rate, simulated drawdown ranged between 5 feet and 26 feet in the water table over 16 mi^2 and between 5 feet and 35 feet in the potentiometric surface over 28 mi^2. The areal extent of the cone of depression approximately doubles when the pumping rate is increased from 30 Mgal/d to 45 Mgal/d. The surficial aquifer could possibly be completely dewatered in a small area in the northern part of the well field when it is pumped at the maximum permitted rate. Because lakes are hydraulically connected to the surficial aquifer, levels of lakes in and near the well field could decline substantially as a result of pumping. Pumping increases downward leakage from the surficial aquifer to the Upper Floridan aquifer and, ultimately, results in reduced ET and surface runoff.

SELECTED REFERENCES

Alt, David, and Brooks, H. K., 1965, Age of the Florida marine terraces: Journal of Geology, v. 73, no. 2, p. 406-411.

Aultschuler, Z. S., and Young, E. J., 1960, Residual origin of the Pleistocene sand mantle in central Florida uplands and its bearing on marine terraces and Cenozoic uplift: U.S. Geological Survey Professional Paper 400-B, p. 202-207.

Buono, Anthony, Spechler, R. M., Barr, G. L., and Wolansky, R. M., 1979, Generalized thickness of the confining bed overlying the Floridan aquifer, Southwest Florida Water Management District: U.S. Geological Survey Water-Resources Investigations Open-File Report 79-1171, 1 sheet.

Cherry, R. N., Stewart, J. W., and Mann, J. A., 1970, General hydrology of the Middle Gulf area, Florida: Florida Bureau of Geology Report of Investigations 56, 96 p.

Dohrenwend, R. E., 1977, Evapotranspiration patterns in Florida: Florida Scientist, v. 40, no. 2, p. 184-192.

Florida Department of Environmental Regulation, 1982, Public drinking water systems: Chapter 17-22, _in_ Florida Administrative Code, p. 89-109.

Gilboy, A. E., and Moore, David, 1982, Hydrogeologic analysis Cross Bar Ranch well field: Southwest Florida Water Management District Staff Report, 32 p.

Healy, H. G., 1975, Terraces and shorelines of Florida: Florida Bureau of Geology Map Series 71.

Heath, Gene, 1983, Developing and monitoring municipal groundwater supplies in Florida: Journal of American Water Works Association, v. 75, no. 2, p. 64-67.

Hughes, G. H., Hampton, E. R., and Tucker, D. F., 1971, Annual and seasonal rainfall in Florida: Florida Bureau of Geology Map Series 40.

Hutchinson, C. B., 1984a, Hydrogeology of well-field areas near Tampa, Florida, phase 2--development and documentation of a quasi-three-dimensional finite-difference model for simulation of steady-state ground-water flow: U.S. Geological Survey Water-Resources Investigations Report 84-4002, 174 p.

----- 1984b, Ground-water models as a management tool in Florida: U.S. Geological Survey Water-Resources Investigations 84-4016, 26 p.

Hutchinson, C. B., Johnson, D. M., and Gerhart, J. M., 1981, Hydrogeology of well-field areas near Tampa, Florida, phase 1--development and documentation of a two-dimensional finite-difference model for simulation of steady-state ground-water flow: U.S. Geological Survey Open-File Report 81-630, 129 p.

Koehler, M. A., Nordenson, T. J., and Baker, D. E., 1959, Evaporation maps for the United States: U.S. Weather Bureau Technical Paper 37, 13 p., 5 pl.

Leggette, Brashears, and Graham, Inc., 1976, Hydrogeologic investigation of the Norris cattle tract, Pasco County, Florida: Tampa, Florida, 58 p.

----- 1977, Proposed test-drilling and test-pumping program at the Cross Bar Ranch, Pasco County, Florida: Tampa, Florida, 27 p.

----- 1978, Hydrogeological supplement to the consumptive-use permit application: Tampa, Florida, 34 p.

----- 1979a, Development and testing program--Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--October, November, December 1978: Tampa, Florida.

----- 1979b, Development and testing program--Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--January, February, March 1979: Tampa, Florida.

----- 1979c, Development and testing program--Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--April, May, June 1979: Tampa, Florida.

----- 1979d, Development and testing program--Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--July, August, September 1979: Tampa, Florida.

----- 1979e, Construction and testing of the deep water-quality well B-1: Status report--October 1979: Tampa, Florida.

----- 1980a, Development and testing program--Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--October, November, December 1979: Tampa, Florida.

----- 1980b, Development and testing program--Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--January, February, March 1980: Tampa, Florida.

----- 1980c, Development and testing program--Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--April, May, June 1980: Tampa, Florida.

----- 1980d, Development and testing program--Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--July, August, September 1980: Tampa, Florida.

Leggette, Brashears, and Graham, Inc., 1981, Development and testing program --Cross Bar Ranch well field, Pasco County, Florida: Quarterly status report--October, November, December 1980: Tampa, Florida.

Miller, J. A., in press, Hydrogeologic framework of the Floridan aquifer system in Florida and in parts of Georgia, South Carolina, and Alabama: U.S. Geological Survey Professional Paper 1403-B.

Miller, J. C., 1977, Fracture trace analysis for well siting in carbonate karst terrane, Cross Bar Ranch well field, Pasco County, Florida: West Coast Regional Water Supply Authority, 12 p.

Moore, D. L., and Stewart, M. T., 1983, Geophysical signatures of fracture traces in a karst aquifer (Florida, U.S.A.): Journal of Hydrology, v. 61, p. 325-340.

Parker, G. G., Ferguson, G. E., Love, S. K., and others, 1955, Water resources of southeastern Florida, with special reference to geology and ground water of the Miami area: U.S. Geological Survey Water-Supply Paper 1255, 965 p.

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

Ryder, P. D., and Mills, L. R., 1977a, Water table in the surficial aquifer and potentiometric surface of the Floridan aquifer in selected well fields, west-central Florida, September 1976: U.S. Geological Survey Open-File Report 77-551, 13 p. and 4 sheets.

----- 1977b, Water table in the surficial aquifer and potentiometric surface of the Floridan aquifer in selected well fields, west-central Florida, May 1977: U.S. Geological Survey Open-File Report 77-642, 15 p. and 4 sheets.

Sinclair, W. C., 1974, Hydrogeologic characteristics of the surficial aquifer in northwest Hillsborough County, Florida: Florida Bureau of Geology Information Circular 86, 97 p.

Tibbals, C. H., 1978, Effects of paved surfaces on recharge to the Floridan aquifer in east-central Florida--a conceptual model: U.S. Geological Survey Water-Resources Investigations 78-76, 42 p.

Trescott, P. C., 1975, Documentation of finite-difference model for simulation of three-dimensional ground-water flow: U.S. Geological Survey Open-File Report 75-438, 32 p.

Trescott, P. C., and Larson, S. P., 1976, Supplement to open-file report 75-438, documentation of a finite-difference model for simulation of three-dimensional ground-water flow: U.S. Geological Survey Open-File Report 76-591, 21 p.

Walton, W. C., 1970, Groundwater resource evaluation: New York, McGraw-Hill Series in Water Resources and Environmental Engineering, 664 p.

Wetterhall, W. S., 1964, Geohydrologic reconnaissance of Pasco and southern Hernando Counties, Florida: Florida Geological Survey Report of Investigations 34, 28 p.

White, W. A., 1970, Geomorphology of the Florida peninsula: Florida Bureau of Geology Bulletin 51, 164 p.

Wolansky, R. M., Spechler, R. M., and Buono, Anthony, 1979, Generalized thickness of the surficial deposits above the confining bed overlying the Floridan aquifer, Southwest Florida Water Management District: U.S. Geological Survey Water-Resources Investigations Open-File Report 79-1071, 1 sheet.

Yobbi, D. K., Mills, L. R., and Woodham, W. M., 1980, Ground-water levels in selected well fields in west-central Florida, September 1980: U.S. Geological Survey Open-File Report 81-77, 2 sheets.

Yobbi, D. K., and Woodham, W. M., 1981, Ground-water levels in selected well fields and in west-central Florida, May 1981: U.S. Geological Survey Open-File Report 81-1106, 2 sheets.

SUPPLEMENTAL DATA: MODELING PROCEDURES

A digital model can be used to simulate a hydrologic system and its response to hydrologic stresses, such as pumping or injection. A numerical solution using a finite-difference method is used to solve partial differential equations of ground-water flow. A digital model was selected over analytical techniques because of complexity of the hydrologic system at the Cross Bar Ranch well field. For example, complex patterns of pumping can be represented in a digital model, whereas it is cumbersome to represent more than two pumping centers analytically.

The three-dimensional ground-water flow model by Trescott (1975) and Trescott and Larson (1976), as modified by Hutchinson (1984a), was selected because: (1) the model has the ability to simulate hydrologic conditions in more than one aquifer; and (2) it allows for ET-runoff capture from the upper aquifer. The model is "quasi-three-dimensional" in that it computes two-dimensional (x,y) flow in two layers that are linked in the z dimension by leakage. Because the hydrologic system approaches an equilibrium condition within about 30 days after pumping begins at a constant rate, the system is considered to rapidly achieve a quasi-steady-state condition. Therefore, a steady-state model does not relate to a specific time period adequately and simply portrays the effects of most pumping scenarios.

Modeling procedures and their application to the Cross Bar Ranch well-field area are diagrammed in figure 28. The continuous aquifer region was discretized into a finite number of grid blocks, boundary conditions were established, and aquifer properties and ground-water withdrawal were estimated for each grid block. Input parameters were adjusted by trial and error within limits during model calibration until simulated heads under pumping conditions matched observed average heads measured in wells and lakes for September 1980 to May 1981. The model received additional validation when simulated heads under nonpumping conditions matched average heads for September 1976 to May 1977. Because the regional well-fields model (Hutchinson, 1984a) was based on this time period, it was also selected for the Cross Bar Ranch model validation. This allowed a check on the compatibility of the two models. Tests were made to assess the sensitivity of the model to extreme ranges in the input parameters. The model was then used to simulate response of the hydrologic system to various rates and distributions of pumping.

Model Grid

The continuous aquifer system was discretized by means of a finite-difference grid. The grid of 25 horizontal rows and 25 vertical columns was centered over the Cross Bar Ranch well field. The first and last row and column form the border and are required to be inactive by the model. This results in a 23 by 23 active grid that encompasses the 121-mi^2 area (fig. 29). Grid size is variable, with dimensions of individual blocks ranging from 5,280 feet by 5,280 feet at the corners of the model to 1,760 feet by 1,760 feet within the well field. At the center of each grid block is a node for which data are input to and output from the model.

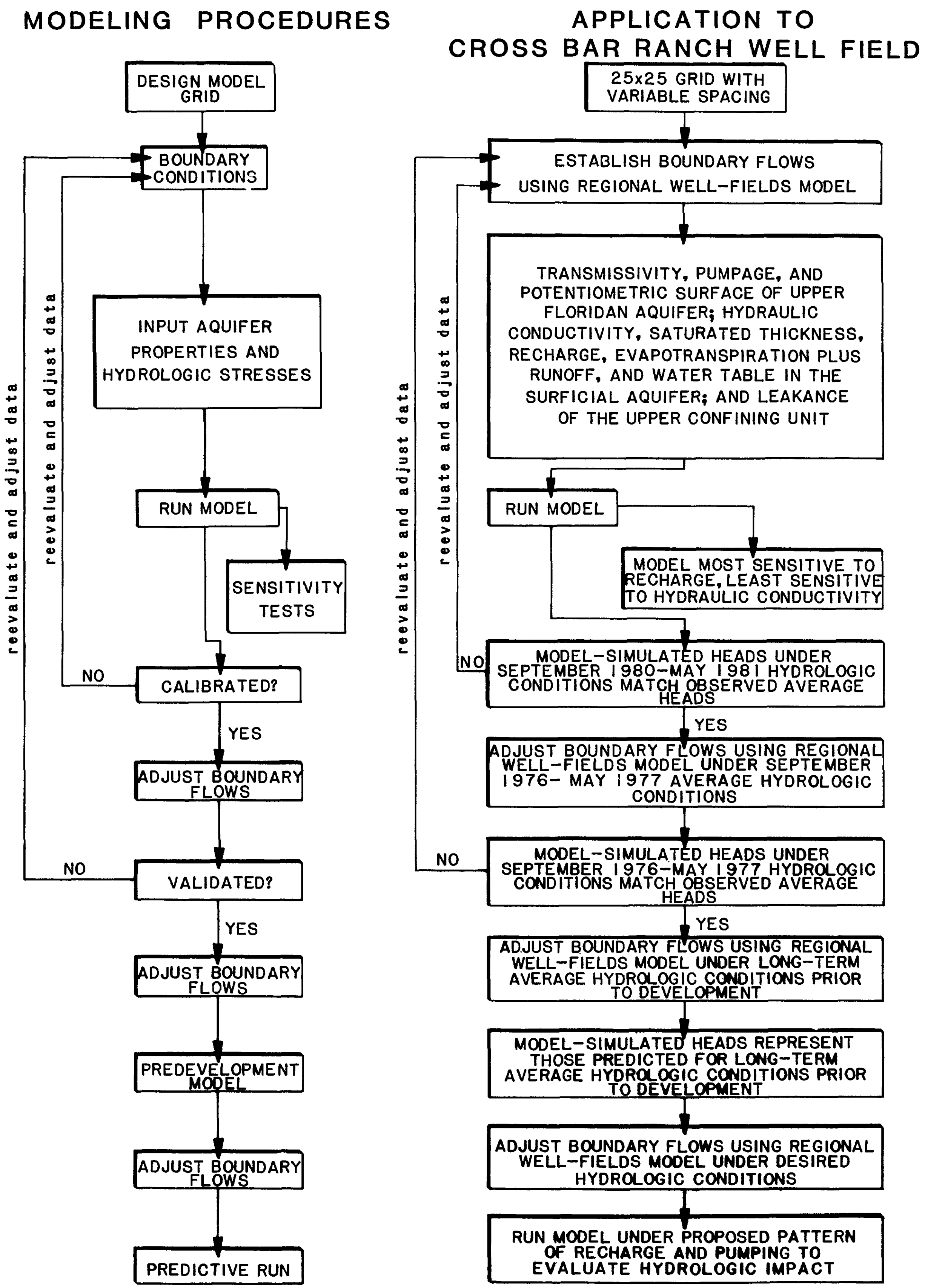

Figure 28.--Modeling procedures.

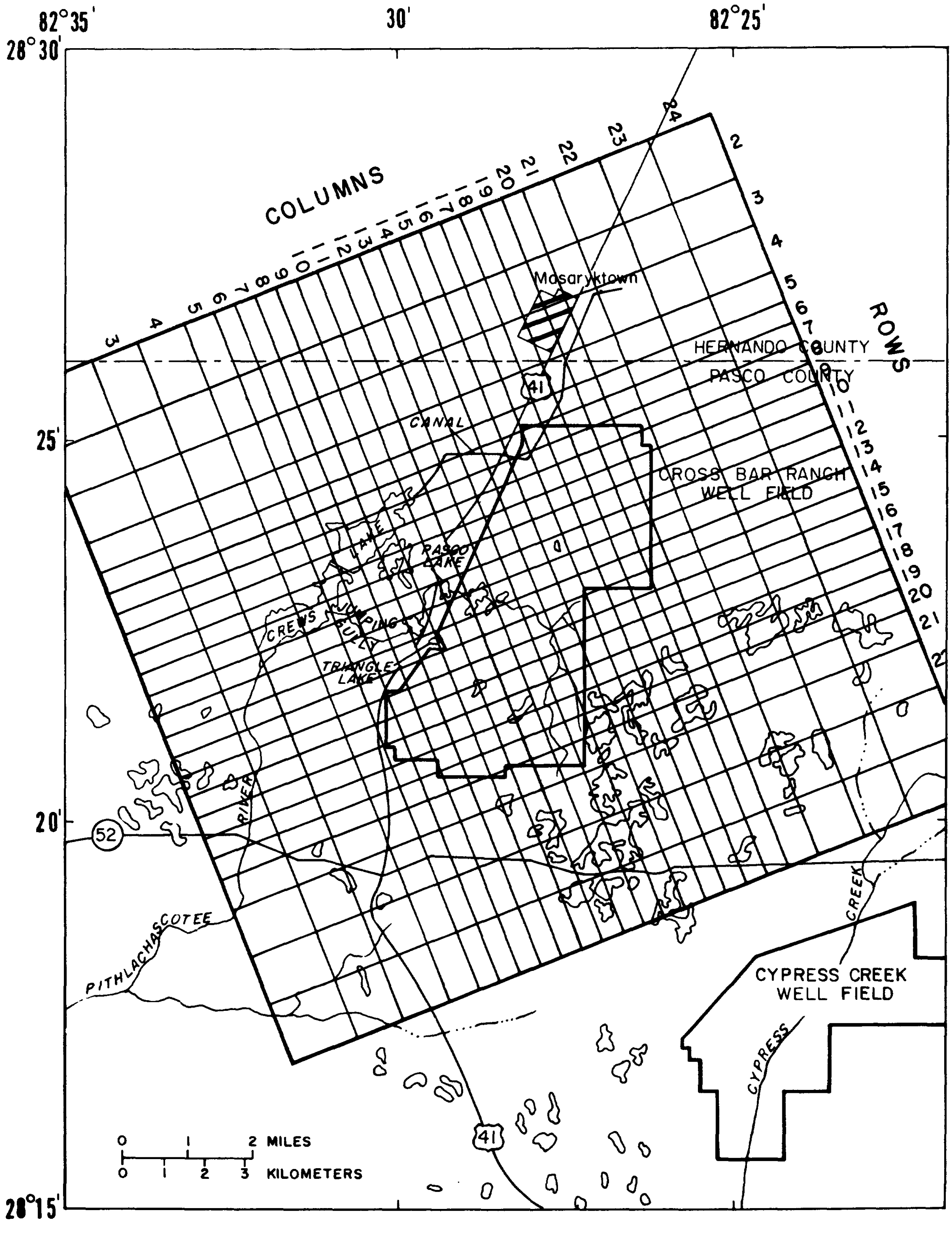

Figure 29.--Model grid encompassing the Cross Bar Ranch well field.

The model grid is alined with the much larger regional model grid, consisting of 1-mile squares (Hutchinson, 1984a), that encompasses 10 well-field areas north of Tampa (fig. 30). The two models can be interfaced for analysis of special ground-water problems. For example, when pumping from the Cypress Creek well field lowers water levels within the Cross Bar Ranch model area, the regional model with the same specified stresses can be used to provide boundary conditions in the Cross Bar Ranch model, which is then used for making detailed predictions. Also, if the cone of depression caused by pumping from the Cross Bar Ranch well field extends to the model boundary, the regional model can likewise be run to obtain correct boundary heads and flows for the small-scale model. The compatibility of the two models allowed the Cross Bar Ranch grid to be compact, thereby facilitating calibration of the model.

Boundary Conditions

The major criterion used to define hypothetical boundaries for the model was to determine the area that might be affected by future pumping. Hutchinson (1984a, fig. 25) used a ground-water model to estimate that, under the average permitted pumping rate of 30 Mgal/d, the area of the cone of depression around the Cross Bar Ranch well field would be about 140 mi^2. Based upon this estimate, a square model with boundaries 13 miles on a side was centered over the well field. Because inactive grid blocks are required along the perimeter of the model, only 121 mi^2 actively respond to hydrologic stresses.

Volumetric flow rates were derived from the regional model (Hutchinson, 1984a) to approximate changes in flow in the Upper Floridan aquifer across 44 grid-block faces that abut 88 grid blocks along the Cross Bar Ranch model boundary (fig. 30). The computer program (Hutchinson, 1984a) was modified by inserting the following cards after line 13070:

```
C     ---COMPUTE AND PUNCH BNDRY FLOWS AT CROSS BAR RANCH WELL FIELD---
      WRITE(7,349)
      DO 31 K=1,1
      DO 32 I=1,I1
      DO 32 J=1,J1
      TC(I,J,K)=TC(I,J,K)*DELY(I)*(PHI(I,J,K)-PHI(I+1,J,K))
   32 TR(I,J,K)=TR(I,J,K)*DELX(J)*(PHI(I,J,K)-PHI(I,J+1,K))
      DO 33 I=2,2
      DO 33 J=21,31
   33 WRITE(7,305)I,J,TC(I,J,K)
      DO 34 I=3,13
      DO 34 J=20,20
   34 WRITE(7,305)I,J,TR(I,J,K)
      DO 35 I=3,13
      DO 35 J=31,31
   35 WRITE(7,305)I,J,TR(I,J,K)
      DO 36 I=13,13
      DO 36 J=21,31
   36 WRITE(7,305)I,J,TC(I,J,K)
   31 CONTINUE
      IF (NCH.EQ.0) GO TO 250
      WRITE(6,270)
      WRITE(6,280) ((JFLO(I,J),J=1,3),FLOW(I),I=1,NCH)
  250 CONTINUE
```

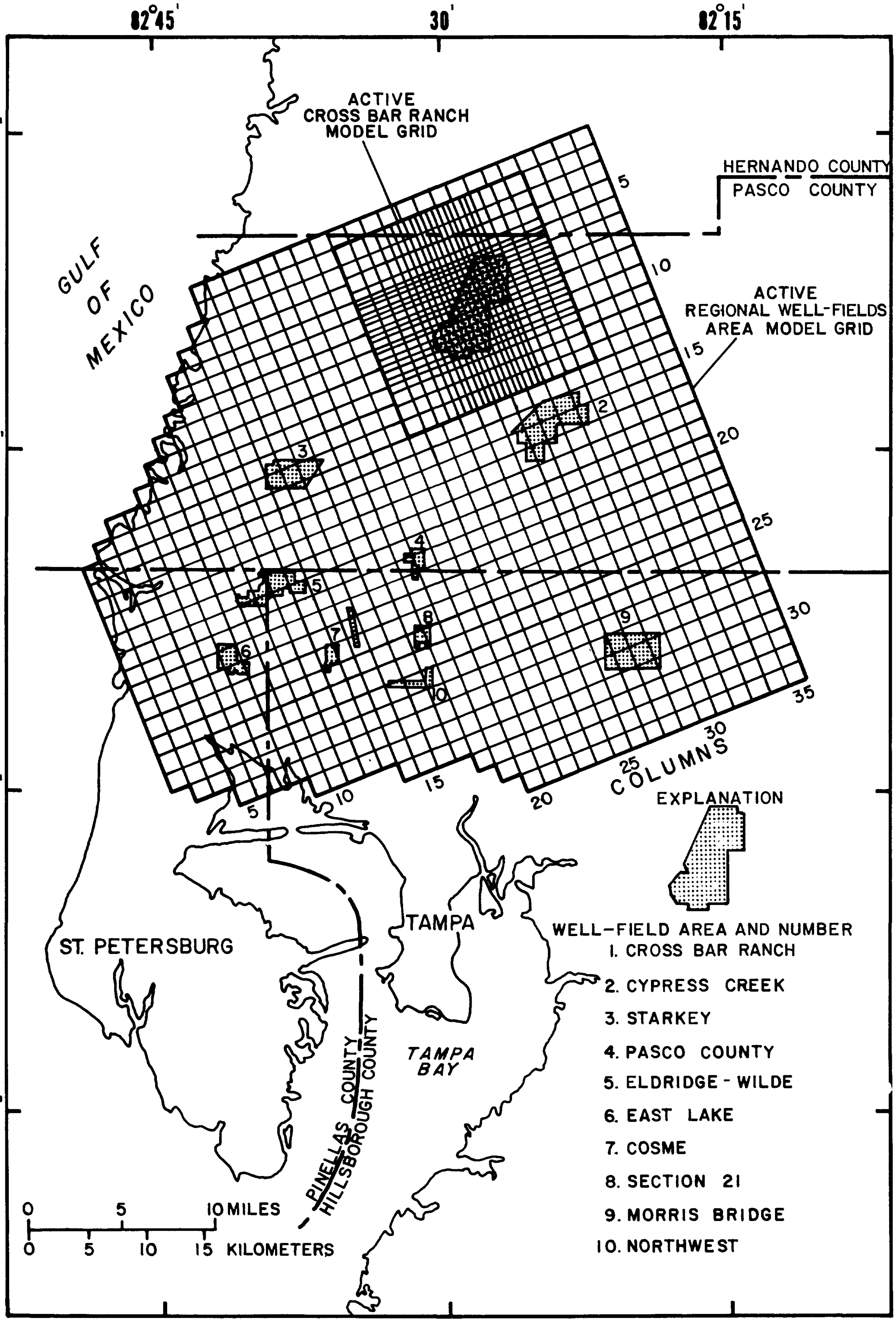

Figure 30.--Cross Bar Ranch model grid and its relation to the regional well-fields area model grid.

The following format statements were inserted after line 13430:

```
305 FORMAT(2I10,E15.5)
349 FORMAT(5X,'BOUNDARY FLOWS AT CROSS BAR RANCH MODEL FOLLOW')
```

The TR and TC coefficients are computed in the COEF subroutine as the harmonic mean of transmissivity in adjacent grid blocks divided by flow distance along columns and rows, respectively. Multiplying by the length of the grid-block face and the hydraulic gradient results in a volumetric flow rate across the (I, J + 1/2, K) grid-block face for the TR coefficient and across the (I + 1/2, J, K) grid-block face for the TC coefficient. Flows are computed in the regional model across grid-block faces between rows 2 and 3, columns 20 and 21, columns 31 and 32, and rows 13 and 14 (fig. 30).

Boundary flow rates computed by the regional model were not apportioned directly to corresponding grid blocks in the Cross Bar Ranch model because calibration parameters vary slightly between the models. To minimize errors, boundary flows in the Cross Bar Ranch model were changed by the differences in flow between predevelopment and stressed conditions in the regional model. For the model predictions, boundary flows were apportioned to the Cross Bar Ranch model using the FORTRAN program listed below.

The program computes stressed boundary flow (CS) by adding some fraction of the difference (DIF) between predevelopment (RP) and stressed (RS) flows in the regional model to predevelopment flow (CP) in the Cross Bar Ranch model. For example, lines 78-80 of the program show that flow in the regional model along row 9 and across the grid face between columns 31 and 32 is divided equally in the Cross Bar Ranch model among rows 15, 16, and 17 in column 24. The adjusted boundary flows are input to the pumping array of the Cross Bar Ranch model prior to making a predictive run.

Under various pumping test runs of the model, water levels rose in the northwest corner, indicating that changes in boundary outflow there were greater in the regional model than in the Cross Bar Ranch model. The flow discrepancies were attributed to transmissivity variations between the models. To partially compensate for the transmissivity variations, changes in boundary flow at 11 grid blocks were reduced by 10 percent (multiplied by 0.9) before being input to the Cross Bar Ranch model.

Boundary flows in the surficial aquifer were held constant at rates determined in the calibration. Apparently, head changes in the surficial aquifer are related more to ET-runoff and vertical leakage than to lateral flow. Lateral flow is very low because of the aquifer's low transmissivity and relatively flat water-table gradient. When drawdown occurs at the model boundary, worst-case conditions are portrayed because additional flow (no matter how small it really is) cannot be induced from outside the modeled area. Had constant-head boundaries been used, the effects of ET-runoff and vertical leakage would be ignored, resulting in an erroneous condition with no drawdown at the model boundary.

```
C     PROGRAM TO COMPUTE BOUNDARY FLOW IN CROSS BAR MODEL
C     RP = REGIONAL MODEL, PREDEVELOPMENT FLOW AT GRID FACE
C     RS = REGIONAL MODEL, STRESSED FLOW AT GRID FACE
C     CP = CROSS BAR MODEL, PREDEVELOPMENT BOUNDARY FLOW
C     CS = CROSS BAR MODEL, STRESSED FLOW AT BOUNDARY
      DIMENSION RS(34,36),RP(34,36),CP(24,24),CS(24,24),
     1DIF(34,36)
   10 READ(5,100)I,J,RS(I,J)
      IF(I.EQ.13.AND.J.EQ.31) GO TO 20
      GO TO 10
   20 READ(5,100)I,J,RP(I,J)
      IF(I.EQ.13.AND.J.EQ.31) GO TO 30
      GO TO 20
   30 DO 40 I=2,13
      DO 40 J=20,31
      IF (RP(I,J).EQ.0..OR.RS(I,J).EQ.0.) GO TO 40
      DIF(I,J)=RP(I,J)-RS(I,J)
   40 CONTINUE
      READ(5,200)I,J,CP(I,J)
      IF(I.EQ.24.AND.J.EQ.24) GO TO 50
      GO TO 40
   50 CS(2,2)=CP(2,2)+.9*(DIF(2,21)+DIF(3,20))
      CS(2,3)=CP(2,3)+(.9*DIF(2,22))
      CS(2,4)=CP(2,4)+(.9*(DIF(2,23)/2.))
      CS(2,5)=CP(2,5)+(.9*(DIF(2,23)/2.))
      CS(2,6)=CP(2,6)+(.9*(DIF(2,24)/3.))
      CS(2,7)=CP(2,7)+(.9*(DIF(2,24)/3.))
      CS(2,8)=CP(2,8)+(.9*(DIF(2,24)/3.))
      CS(2,9)=CP(2,9)+(.9*(DIF(2,25)/3.))
      CS(2,10)=CP(2,10)+(.9*(DIF(2,25)/3.))
      CS(2,11)=CP(2,11)+(.9*(DIF(2,25)/3.))
      CS(2,12)=CP(2,12)+(DIF(2,26)/3.)
      CS(2,13)=CP(2,13)+(DIF(2,26)/3.)
      CS(2,14)=CP(2,14)+(DIF(2,26)/3.)
      CS(2,15)=CP(2,15)+(DIF(2,27)/3.)
      CS(2,16)=CP(2,16)+(DIF(2,27)/3.)
      CS(2,17)=CP(2,17)+(DIF(2,27)/3.)
      CS(2,18)=CP(2,18)+(DIF(2,28)/3.)
      CS(2,19)=CP(2,19)+(DIF(2,28)/3.)
      CS(2,20)=CP(2,20)+(DIF(2,28)/3.)
      CS(2,21)=CP(2,21)+(DIF(2,29)/2.)
      CS(2,22)=CP(2,22)+(DIF(2,29)/2.)
      CS(2,23)=CP(2,23)+DIF(2,30)
      CS(2,24)=CP(2,24)+DIF(2,31)-DIF(3,31)
      CS(3,2)=CP(3,2)+(.9*DIF(4,20))
      CS(4,2)=CP(4,2)+(.9*(DIF(5,20)/2.))
      CS(5,2)=CP(5,2)+(.9*(DIF(5,20)/2.))
      CS(6,2)=CP(6,2)+(DIF(6,20)/3.)
      CS(7,2)=CP(7,2)+(DIF(6,20)/3.)
      CS(8,2)=CP(8,2)+(DIF(6,20)/3.)
      CS(9,2)=CP(9,2)+(DIF(7,20)/3.)
      CS(10,2)=CP(10,2)+(DIF(7,20)/3.)
      CS(11,2)=CP(11,2)+(DIF(7,20)/3.)
      CS(12,2)=CP(12,2)+(DIF(8,20)/3.)
```

```
CS(13,2)=CP(13,2)+(DIF(8,20)/3.)
CS(14,2)=CP(14,2)+(DIF(8,20)/3.)
CS(15,2)=CP(15,2)+(DIF(9,20)/3.)
CS(16,2)=CP(16,2)+(DIF(9,20)/3.)
CS(17,2)=CP(17,2)+(DIF(9,20)/3.)
CS(18,2)=CP(18,2)+(DIF(10,20)/3.)
CS(19,2)=CP(19,2)+(DIF(10,20)/3.)
CS(20,2)=CP(20,2)+(DIF(10,20)/3.)
CS(21,2)=CP(21,2)+(DIF(11,20)/2.)
CS(22,2)=CP(22,2)+(DIF(11,20)/2.)
CS(23,2)=CP(23,2)+DIF(12,20)
CS(3,24)=CP(3,24)-DIF(4,31)
CS(4,24)=CP(4,24)-(DIF(5,31)/2.)
CS(5,24)=CP(5,24)-(DIF(5,31)/2.)
CS(6,24)=CP(6,24)-(DIF(6,31)/3.)
CS(7,24)=CP(7,24)-(DIF(6,31)/3.)
CS(8,24)=CP(8,24)-(DIF(6,31)/3.)
CS(9,24)=CP(9,24)-(DIF(7,31)/3.)
CS(10,24)=CP(10,24)-(DIF(7,31)/3.)
CS(11,24)=CP(11,24)-(DIF(7,31)/3.)
CS(12,24)=CP(12,24)-(DIF(8,31)/3.)
CS(13,24)=CP(13,24)-(DIF(8,31)/3.)
CS(14,24)=CP(14,24)-(DIF(8,31)/3.)
CS(15,24)=CP(15,24)-(DIF(9,31)/3.)
CS(16,24)=CP(16,24)-(DIF(9,31)/3.)
CS(17,24)=CP(17,24)-(DIF(9,31)/3.)
CS(18,24)=CP(18,24)-(DIF(10,31)/3.)
CS(19,24)=CP(19,24)-(DIF(10,31)/3.)
CS(20,24)=CP(20,24)-(DIF(10,31)/3.)
CS(21,24)=CP(21,24)-(DIF(11,31)/2.)
CS(22,24)=CP(22,24)-(DIF(11,31)/2.)
CS(23,24)=CP(23,24)-DIF(12,31)
CS(24,2)=CP(24,2)-DIF(13,21)+DIF(13,20)
CS(24,3)=CP(24,3)-DIF(13,22)
CS(24,4)=CP(24,4)-(DIF(13,23)/2.)
CS(24,5)=CP(24,5)-(DIF(13,23)/2.)
CS(24,6)=CP(24,6)-(DIF(13,24)/3.)
CS(24,7)=CP(24,7)-(DIF(13,24)/3.)
CS(24,8)=CP(24,8)-(DIF(13,24)/3.)
CS(24,9)=CP(24,9)-(DIF(13,25)/3.)
CS(24,10)=CP(24,10)-(DIF(13,25)/3.)
CS(24,11)=CP(24,11)-(DIF(13,25)/3.)
CS(24,12)=CP(24,12)-(DIF(13,26)/3.)
CS(24,13)=CP(24,13)-(DIF(13,26)/3.)
CS(24,14)=CP(24,14)-(DIF(13,26)/3.)
CS(24,15)=CP(24,15)-(DIF(13,27)/3.)
CS(24,16)=CP(24,16)-(DIF(13,27)/3.)
CS(24,17)=CP(24,17)-(DIF(13,27)/3.)
CS(24,18)=CP(24,18)-(DIF(13,28)/3.)
CS(24,19)=CP(24,19)-(DIF(13,28)/3.)
CS(24,20)=CP(24,20)-(DIF(13,28)/3.)
CS(24,21)=CP(24,21)-(DIF(13,29)/2.)
CS(24,22)=CP(24,22)-(DIF(13,29)/2.)
CS(24,23)=CP(24,23)-DIF(13,30)
CS(24,24)=CP(24,24)-DIF(13,31)
```

```
      DO 60 I=2,24
      DO 60 J=2,26
      IF (CS(I,J).EQ.0.0) GO TO 60
      WRITE(6,300)I,J,CS(I,J)
   60 CONTINUE
  100 FORMAT(2I10,E15.5)
  200 FORMAT(10X,2I10,F10.0)
  300 FORMAT(9X,'1',2I10,F10.2)
      STOP
      END
```

Input Parameters

The steady-state model requires input parameters for each grid block including:

1. Altitude of the observed potentiometric surface of the Upper Floridan aquifer;
2. Altitude of the observed water table in the surficial aquifer;
3. Storage coefficient of the Upper Floridan aquifer (defined as zero);
4. Storage coefficient (defined as zero) and constant-head nodes of the surficial aquifer;
5. Transmissivity of the Upper Floridan aquifer;
6. Leakance of the upper confining unit;
7. Hydraulic conductivity of the surficial aquifer;
8. Altitude of the bottom of the surficial aquifer;
9. Recharge rate to the surficial aquifer;
10. Maximum ET-runoff capture rate from the water table divided by maximum depth at which ET-runoff capture occurs;
11. Altitude of the bottom of the zone in which ET-runoff occurs;
12. Altitude of land surface;
13. Model-grid spacing; and
14. Pumping rate from the Upper Floridan aquifer and cross-boundary flow.

The model utilizes many input parameters directly in ground-water flow equations. Others are used indirectly to compute parameters that vary with head, such as transmissivity of the surficial aquifer or ET-runoff capture rate. Ranges for hydrologic input parameters for the steady-state calibration are presented in table 6. The parameter values were based on analyses of aquifer tests (fig. 5) and on preliminary estimates derived from the regional well-fields model (Hutchinson, 1984a).

Table 6.--Values for hydrologic parameters of the calibrated steady-state model

Parameter	Value	Source of data
Potentiometric-surface altitude	23-74 ft	Ryder and Mills (1977a; 1977b).
Water-table altitude	27-76 ft	Ryder and Mills (1977a; 1977b).
Storage coefficient, both aquifers	0	----
Transmissivity of Upper Floridan aquifer	6,600-221,000 ft^2/d	Published aquifer-test results and model calibration (Leggette, Brashears, and Graham, Inc., 1978).
Transmissivity of surficial aquifer	54-324 ft^2/d	Model computed, based on hydraulic conductivity measurements of Sinclair (1974).
Leakance	0.0002-0.0009 (ft/d)/ft	Published aquifer-test results and model calibration (Leggette, Brashears, and Graham, Inc., 1978).
Hydraulic conductivity of surficial aquifer	10 ft/d	Sinclair (1974).
Altitude of the bottom of surficial aquifer	-1 -(+65) ft	Wolansky and others (1979).
Saturated thickness of surficial aquifer	5.4-32.4 ft	Model computed, based on difference between water table and estimated bottom of aquifer.
Recharge rate to surficial aquifer	20 in/yr	Estimated by summing leakage and ET-runoff from water table.
Surficial aquifer boundary flow	0-0.60 ft^3/s in	Derived during calibration.
Upper Floridan aquifer boundary flow	1.0 ft^3/s in -5.6 ft^3/s out	Based on regional model.
ET-runoff rate from water table	0-24 in/yr	Model computed.
Altitude of land surface	34-100 ft	USGS topographic maps.
Pumping rate from Upper Floridan aquifer at individual nodes	2,290,000 gal/d	SWFWMD water-use permits, pumping reports, and irrigation requirements.
Total pumping rate from Upper Floridan aquifer	12,800,000 gal/d	----

Potentiometric surface: Water levels in the lower layer (Upper Floridan aquifer) were obtained by overlaying the model grid upon maps of the average potentiometric surface under nonpumping and pumping conditions (figs. 9 and 11). Average water levels were assigned to each grid block, resulting in an array of starting heads for input to layer 1 of the model for each condition.

Water table: Water levels in the upper layer (surficial aquifer) were obtained by overlaying the model grid upon maps of the average water table under nonpumping and pumping conditions (figs. 8 and 10). Average water levels were assigned to each grid block, resulting in an array of starting heads for input to layer 2 of the model for each condition.

Storage coefficient: The storage coefficient was set at zero. Because the model represents steady-state, or stabilized aquifer conditions, inflows and outflows balance, and there is no change in ground-water storage. Setting the storage coefficient matrices to zero in the model is for computational efficiency so that steady state can be reached in one time step.

The storage coefficient matrix is also used to assign constant-head values to selected grid blocks. For the calibration and validation runs, known heads were simulated by the model; therefore, constant-head grid blocks were designated at the perimeter of the model.

Transmissivity of the Upper Floridan aquifer: Transmissivity of the Upper Floridan aquifer increases gradationally from south to north from about 28,000 ft^2/d to 221,000 ft^2/d (fig. 31). Based on pumping tests, the transmissivity of a 400-foot wide zone corresponding to the hydrologic anomaly was computed to be 2,000 ft^2/d (Leggette, Brashears, and Graham, Inc., 1979d). In the center of the model, the hydrologic anomaly was defined by a low transmissivity of 6,600 ft^2/d based on a grid-block width of 1,760 feet.

Leakance: Leakance is the modeling mechanism that allows vertical flow between the surficial and Upper Floridan aquifers. Leakance is the vertical hydraulic conductivity of the upper confining unit divided by its thickness. Estimates of leakance were distributed in the model by relating values derived from pumping tests in the well field (fig. 5) to confining bed thickness and head difference between the water table and potentiometric surface. Leakance, as shown in figure 32, is lowest in the area of the Brooksville Ridge physiographic unit (fig. 2) where the confining unit is known to be thick (Buono and others, 1979) and the head difference is great. Leakance is highest in the Lakes Terrace physiographic unit where the confining unit has been breached by sinkholes and there is a small head difference. Figure 33 depicts leakage rates as derived in the model that simulates predevelopment conditions. Leakage is upward in the area of the Pithlachascotee River. Elsewhere, leakage is downward from the surficial to the Upper Floridan aquifer.

Hydraulic conductivity of the surficial aquifer: Hydraulic conductivity of the surficial aquifer was estimated at a uniform 10 ft/d. This estimate is based on laboratory measurements for surficial materials in northwest Hillsborough County (Sinclair, 1974). The model computes transmissivity of the surficial aquifer by multiplying hydraulic conductivity by saturated thickness, determined as the difference between the simulated water table and the bottom of the surficial aquifer. For the calibration, transmissivity of the surficial aquifer ranged from 54 ft^2/d to 324 ft^2/d.

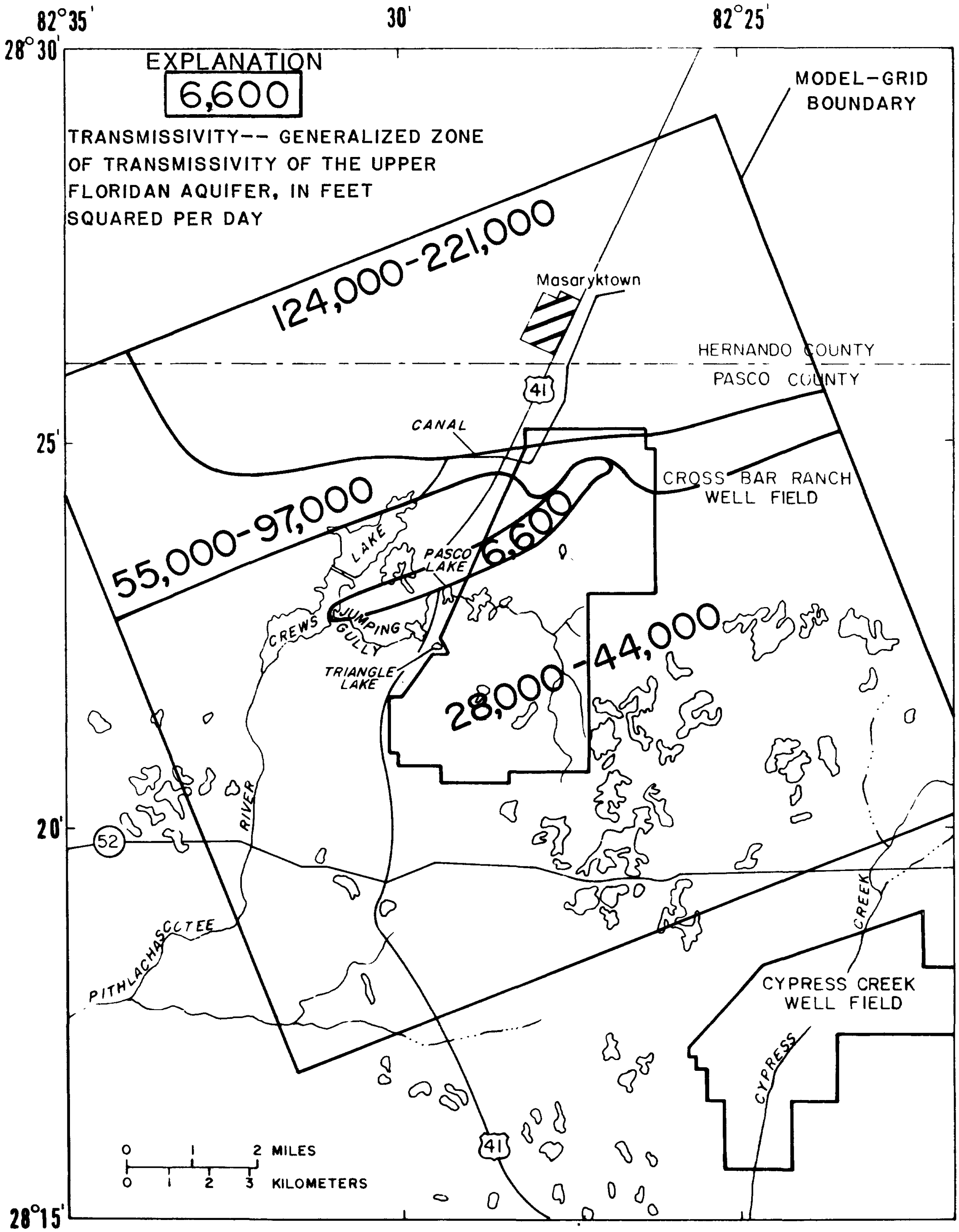

Figure 31.--Transmissivity of the Upper Floridan aquifer.

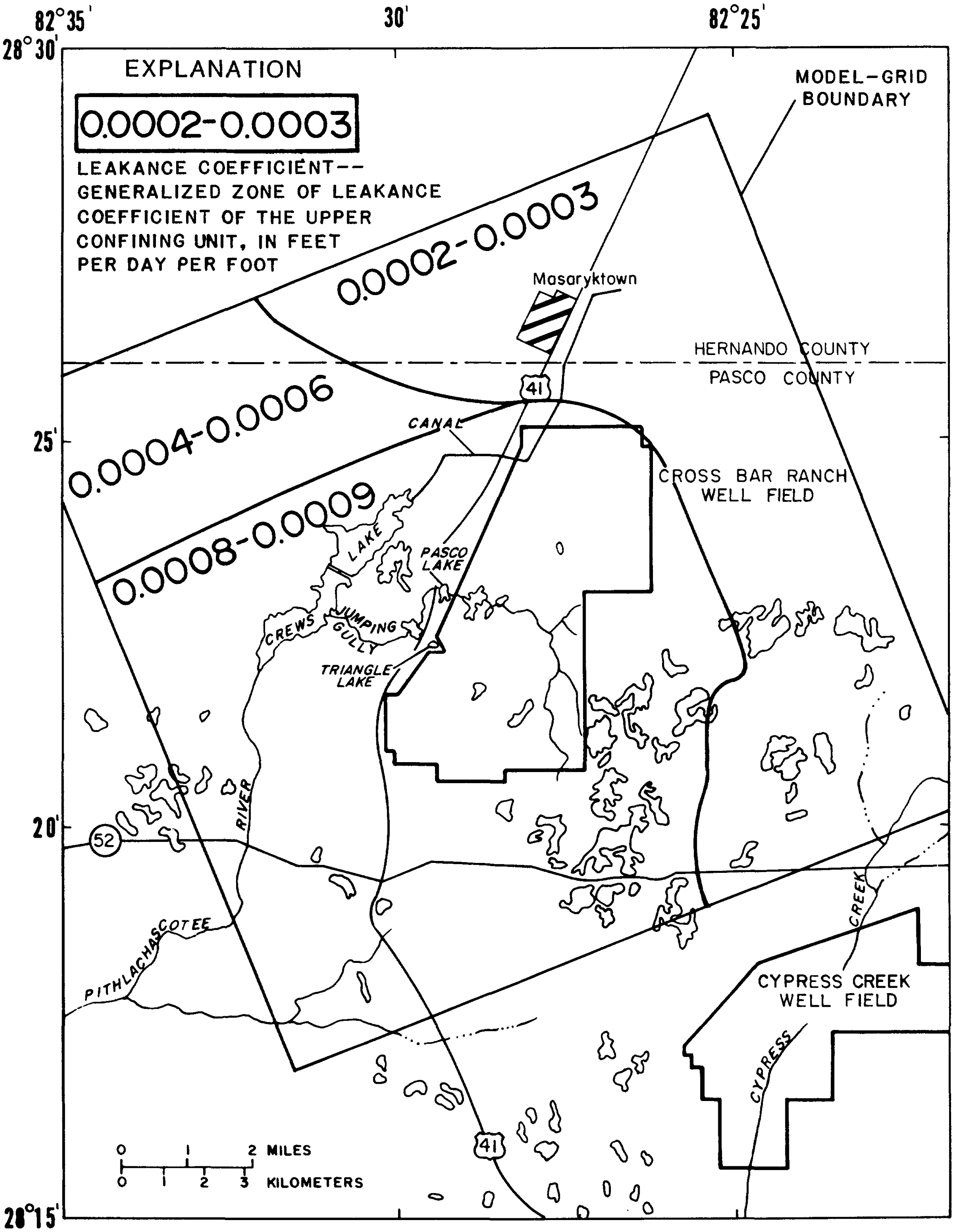

Figure 32.--Leakance of the upper confining unit.

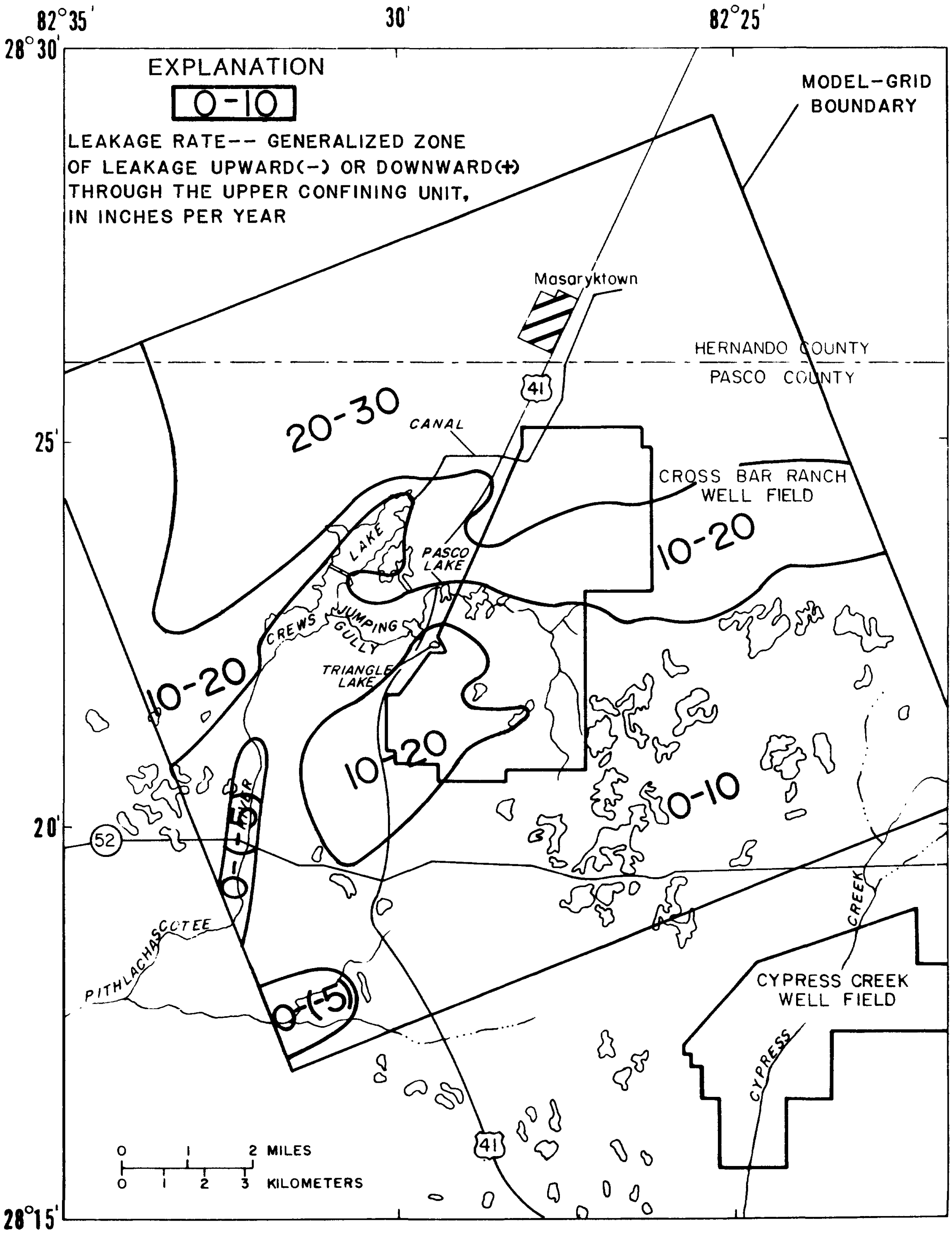

Figure 33.--Leakage rates through the upper confining unit for predevelopment conditions.

Bottom of surficial aquifer: The altitude of the bottom of the surficial aquifer was estimated from maps of the thickness of surficial deposits (Wolansky and others, 1979) and from lithologic logs within the well field. The saturated thickness of the surficial aquifer averages about 20 feet.

Recharge: Recharge conditions vary for the calibration, validation, and predictive phases of the modeling process and were computed as follows:

PHASE	RAINFALL	-	MINIMUM EVAPOTRANSPIRATION	+	RUNOFF	=	RECHARGE
CALIBRATION	45	- [	25	+	0]	=	20
VALIDATION	51.6	- [	25	+	1.6]	=	25
PREDICTION	55	- [	25	+	2]	=	28

Actual measurements of rainfall and runoff were used for the calibration and validation phases. Long-term average values were used for the prediction phase. Rainfall was measured at Chinsegut Hill, and runoff was measured at Jumping Gully. Recharge was estimated to be constant over the entire modeled area.

ET-runoff capture rate: Capture of ET from the water table and runoff was considered to be the variable source from which pumped water is derived since recharge is held constant in the model. Under normal climatological conditions, pumping will lower the water table, thereby creating the potential for extra recharge during the wet season and, subsequently, less runoff. Thus, the modeled ET-runoff capture parameter not only represents ET from the water table, but also represents changes in recharge and runoff.

ET-runoff capture depth: Capture of ET from the water table and runoff was assumed to occur in the zone between land surface and a depth of 10 feet. The ET-runoff capture rate derived in the conceptual model is that for each foot of water-table decline, 3.8 in/yr of water can be captured. The potential ET-runoff rate from the water table is 38 in/yr in areas where the water table is at land surface and zero where the water table is 10 feet or more below land surface. The regional pattern of ET-runoff for average predevelopment conditions is shown in figure 34. It should be emphasized that ET is from the water in the surficial aquifer and, thus, is only a component of the total ET found in standard hydrologic budget analyses (for example, Cherry and others, 1970). ET from water and land surfaces, the unsaturated zone, and from flood runoff are not represented in the model.

Land surface: The average altitude of land surface in each grid block was obtained from U.S. Geological Survey 1:24,000 topographic maps. Topographic highs usually correspond to the Brooksville Ridge and Lakes Terrace physiographic units, and topographic lows correspond to the Central Swamp and Lowlands Plain units.

Pumpage: Average withdrawals from the Upper Floridan aquifer for the period from September 1980 to May 1981 were estimated from records of the Southwest Florida Water Management District and the West Coast Regional Water Supply Authority. Pumping for municipal supply from the well field during this period averaged 12.8 Mgal/d and was distributed among pumping wells in figure 11

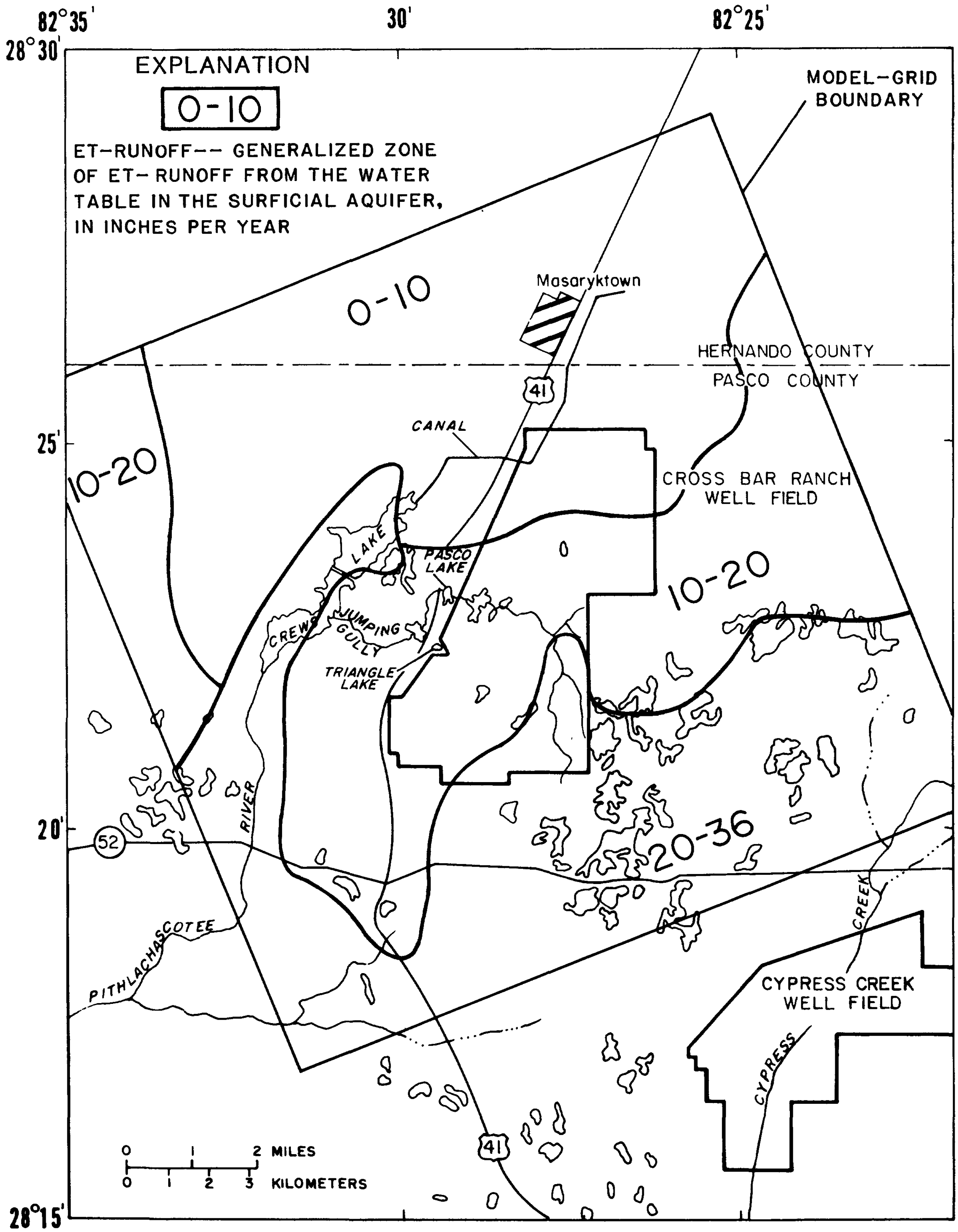

Figure 34.--ET-runoff from the water table in the surficial aquifer for predevelopment conditions.

in accordance with records of operation for each well. Pumping for agricultural and domestic uses was not included in the model because these withdrawals were small. As of 1979, agricultural consumptive-use permits issued by the District totaled about 0.7 Mgal/d within the modeled area. Although several hundred domestic wells lie within 2 miles of the well field (Heath, 1983), their impact on the ground-water flow system is probably small.

Boundary conditions: Initially, a no-flow boundary was input for the surficial aquifer. Flow in the surficial aquifer was considered to be insignificant due to the flat water-table gradient and low hydraulic conductivity. However, a better calibration was obtained by inputting flow rates arbitrarily between 0.1 and 0.6 ft^3/s in 19 grid blocks along the northeast boundary of the model grid where the water-table gradient is steep.

Boundary flow rates in the Upper Floridan aquifer were estimated using the regional well-fields area model (Hutchinson, 1984a). The FORTRAN program was modified to have the regional model compute flow across grid-block faces that coincide with the Cross Bar Ranch model (fig. 30). These flows were apportioned to appropriate grid blocks in the model and then adjusted during calibration. Boundary inflow is small compared to outflow and occurs primarily along the southern edge of the model. Boundary outflow is large along the northern edge of the model grid. The range over individual boundary nodes for the model calibration is from 1 ft^3/s of inflow to 5.6 ft^3/s of outflow.

Calibration

The model was calibrated by systematically adjusting input parameters within acceptable limits until simulated heads in the surficial and Upper Floridan aquifers matched average levels observed between September 1980 and May 1981 (figs. 10 and 11). Because the response of the ground-water system to stress is rapid, lowering recharge and imposing pumping would simply lower water levels to a new steady-state level represented by averaging the maps. Leakance of the upper confining unit, transmissivity of the Upper Floridan aquifer, ET-runoff capture rate, and boundary flow derived from the regional model (Hutchinson, 1984a) were adjusted during calibration of the model.

The model calibration was based on matching simulated heads with observed heads within 5 feet. The ± 5 foot error limit is based on probable errors in averaging heads and aquifer properties over a grid block and constructing average water-level maps. For example, a well in a corner of a grid block may have a significantly different observed water level than is computed at the center of the block. Add this error to map error, which is normally one-half the contour interval (in this case 2.5 feet), and ± 5 feet seemed to be a reasonable error criterion.

The results of the calibration are assessed by comparing model-simulated and observed water levels in the 529 grid blocks that comprise the model. Model-simulated water levels at nine key grid blocks matched observed levels in wells and at Pasco Lake within the ± 5-foot error limit for both the surficial and Upper Floridan aquifers (table 7). Average observed and model-simulated water levels in both aquifers are compared statistically in table 8.

Table 7.--Observed and simulated water levels for model calibration and validation

Well or lake name[1/]		Node in model	Observed water level for September 1980-May 1981 calibration (feet)	Model-simulated water level for calibration (feet)	Estimated water level for September 1976-May 1977 validation (feet)	Model-simulated water level for validation (feet)
Masaryktown	S	5-17	47	50	50	56
	D		32	36	39	42
NRW	S	8-20	47	46	57	54
	D		37	40	48	47
WRW	S	11-13	52	52	59	61
	D		51	48	54	56
NERW	S	11-21	51	52	63	61
	D		45	47	56	54
B-1	S	13-13	60	57	65	65
	D		57	52	60	63
SERW	S	17-15	67	64	71	68
	D		63	61	69	68
SRW	S	20-9	71	68	74	71
	D		69	65	70	69
Gowers Corner	S	23-13	76	73	79	75
	D		71	71	76	74
Pasco Lake		12-11	58	58	61	62

[1/] S denotes shallow well in surficial aquifer; D denotes deep well in Upper Floridan aquifer. See figure 3 for site locations.

Table 8.--Statistics of model calibration

Statistic	September 1980-May 1981 average observed versus model-simulated	
	Water table	Potentiometric surface
Number of active nodes	529	529
Maximum range in residuals[1/] (feet)	6.3 to (-6.1)	5.5 to (-4.5)
Mode of residuals (feet)	-1.2	-3.6
Median residual (feet)	1.4	-0.2
Mean residual (feet)	1.3	-0.2
Mean of absolute values of residuals (feet)	2.2	2.2
Standard deviation of residuals (feet)	2.3	2.6
Correlation coefficient	0.9871	0.9900

[1/] Residuals were computed by subtracting model-simulated water levels from the long-term average potentiometric surface and water table. A negative residual indicates that the model-simulated water level is higher than the long-term average water level, and the reverse is indicated by a positive residual.

Residuals for the 529 grid blocks were nearly within the ±5-foot limit. The standard deviation about the 1.3-foot mean of the residuals for the water table was 2.3 feet. That is, the model-simulated water table matched the average observed level within a range of 1.0 foot above to 3.6 feet below at about 68 percent of the nodes. Similarly, the model-simulated potentiometric surface matched the September 1980 to May 1981 average level at 68 percent of the nodes within a range of 2.8 feet above to 2.4 feet below, based on a standard deviation of 2.6 feet about a residual mean of 0.2 foot above the average level. The correlation coefficients were near one, indicating near-perfect association between the average observed and model-simulated water levels in both aquifers.

The statistics for the calibration are based on the assumption that the residuals between observed and computed water levels are normally distributed about the mean of the residuals. This central tendency is verified when the mean, median, and mode coincide. When the difference between the mean and median is about one-third the difference between the mean and mode, the frequency distribution is moderately skewed, and confidence in the statistical techniques is reduced. Statistics of the model calibration indicate symetrical (no skewness) distributions of residuals for the water table and potentiometric surface, and there is a good match between observed and computed water levels.

Validation

A model gains additional validation as a predictive tool when it is successfully tested against a data set that represents hydrologic conditions different from those used for calibration. Average estimated water levels for September 1976 to May 1977 (figs. 8 and 9) were used to validate the Cross Bar Ranch model. All pumpage was removed from the calibrated steady-state model, boundary flows were adjusted using the regional well-fields model, and the September 1976 to May 1977 heads were input. Finally, the recharge rate was increased from 20 in/yr to 25 in/yr, based on the assumption that rainfall, and therefore recharge, was 5 inches above that of the September 1980 to May 1981 calibration period. The long-term average recharge rate is assumed to be 28 in/yr. Thus, the model would simulate water levels under predevelopment conditions with slightly lower than normal recharge.

The validation results were assessed by comparing model-simulated and estimated water levels in the 529 grid blocks that comprise the model. Model-simulated water levels at nine key grid blocks matched estimated levels and at Pasco Lake within ±6 feet for both the surficial and Upper Floridan aquifers (table 7). Statistics of comparisons at all 529 grid blocks are listed in table 9. Comparisons are good statistically; thus, the model was considered to be adequately validated.

Table 9.--Statistics of model validation

Statistic	September 1976-May 1977 average observed versus model-simulated	
	Water table	Potentiometric surface
Number of active nodes	529	529
Maximum range in residuals[1/] (feet)	4.9 to (-7.7)	6.0 to (-5.0)
Mode of residuals (feet)	0.8	0.6
Median residual (feet)	0.4	0.4
Mean residual (feet)	-0.1	0.2
Standard deviation of residuals (feet)	2.8	1.9
Mean of absolute values of residuals (feet)	2.3	1.6
Correlation coefficient	0.9784	0.9922

[1/] Residuals were computed by subtracting model-simulated water levels from the calibrated steady-state water table and estimated prestressed potentiometric surface, respectively. A negative residual indicates that the model-simulated water level is higher than the water level with which it is compared, and the reverse is indicated by a positive residual.

The model results indicate that, on the average, the simulated water table was 0.1 foot above the average estimated level. The maximum deviation was 7.7 feet above the estimated water table. The standard deviation of 2.8 feet about the mean indicates that, at about 68 percent of the grid blocks, the model-simulated water table remained within a range of 2.7 feet below and 2.9 feet above the estimated level. A correlation coefficient of 0.9784 indicates a good correlation between the two surfaces.

Comparison of model-simulated and September 1976-May 1977 potentiometric surfaces was good statistically. Over the 529 nodes within the model-grid boundary, the simulated potentiometric surface ranged from 5.0 feet above to 6.0 feet below the estimated level. The mean was 0.2 foot below the estimated level. The standard deviation about the mean of the residuals was 1.9 feet, which indicates the model-simulated potentiometric surface matched within a range of 1.7 feet above to 2.1 feet below the estimated level at about 68 percent of the nodes. A correlation coefficient of 0.9922 indicates a good correlation between the two surfaces. Analyses for normality indicate moderate skewness in the distributions of residuals for the water table and potentiometric surface. Although confidence in the statistics of the model validation is reduced, they strongly indicate that there is a good match between estimated and computed water levels.

Sensitivity Analysis

Sensitivity analysis tests model response to changes in input parameters. Separate model simulations are made with individual parameters varied in turn over a reasonable range of values within which they could occur. The model was not recalibrated each time parameter values were changed because this would be impractical in terms of time and cost. Exact values of head changes from sensitivity analyses should be viewed critically, but relative changes can provide insight as to the degree to which a change in any parameter may affect results of model simulation.

Model sensitivity was tested by varying ET-runoff rate and depth, recharge, hydraulic conductivity of the surficial aquifer, transmissivity of the Upper Floridan aquifer and hydrologic anomaly, leakance of the upper confining unit, and boundary flows. Table 10 summarizes ranges in water-level change in response to uniform changes in parameter values. Figure 35 shows deviations from the predevelopment water table and potentiometric surface due to changing maximum ET-runoff capture depth (ETD) by ±5 feet, recharge rate (R) by ±20 percent, and potential ET-runoff capture rate (ETR) by ±20 percent. Figure 36 shows deviations due to changing boundary flow (FLO) in the Upper Floridan aquifer by ±20 percent, transmissivity (T) of the Upper Floridan aquifer by factors of 2 and 0.5, leakance (TK) of the upper confining unit by factors of 2 and 0.5, and increasing transmissivity of the hydrologic anomaly from 6,600 to 1,000,000 ft^2/d. The cross sections in both figures depict model-simulated heads along column 13 of the model. This column passes through the center of the model and intersects the hydrologic anomaly. The two cross sections were used in conjunction with drawdown maps output by the model to supply areal perspective to the sensitivity analysis.

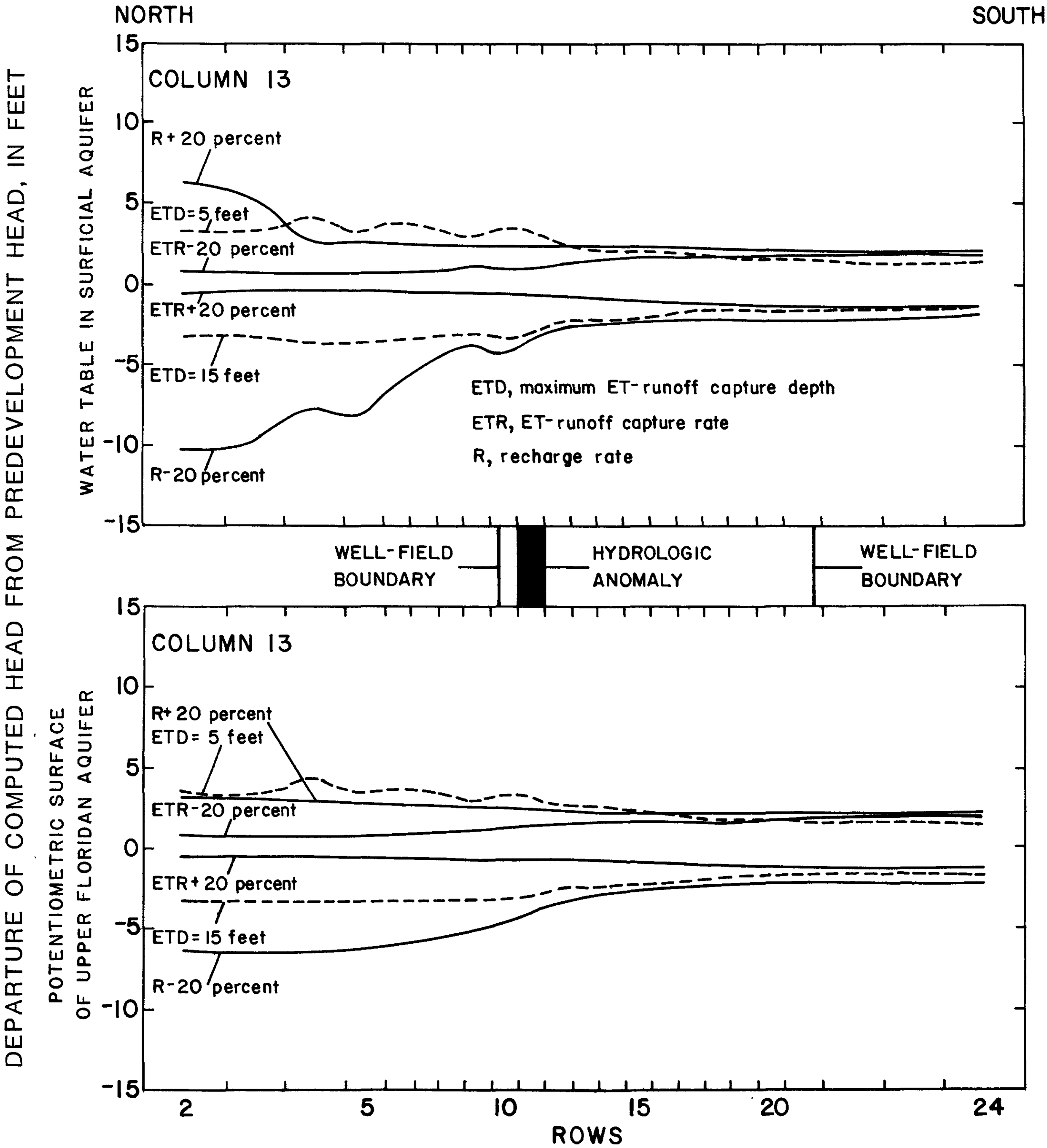

Figure 35.--Effects of varying ET-runoff and recharge parameters.

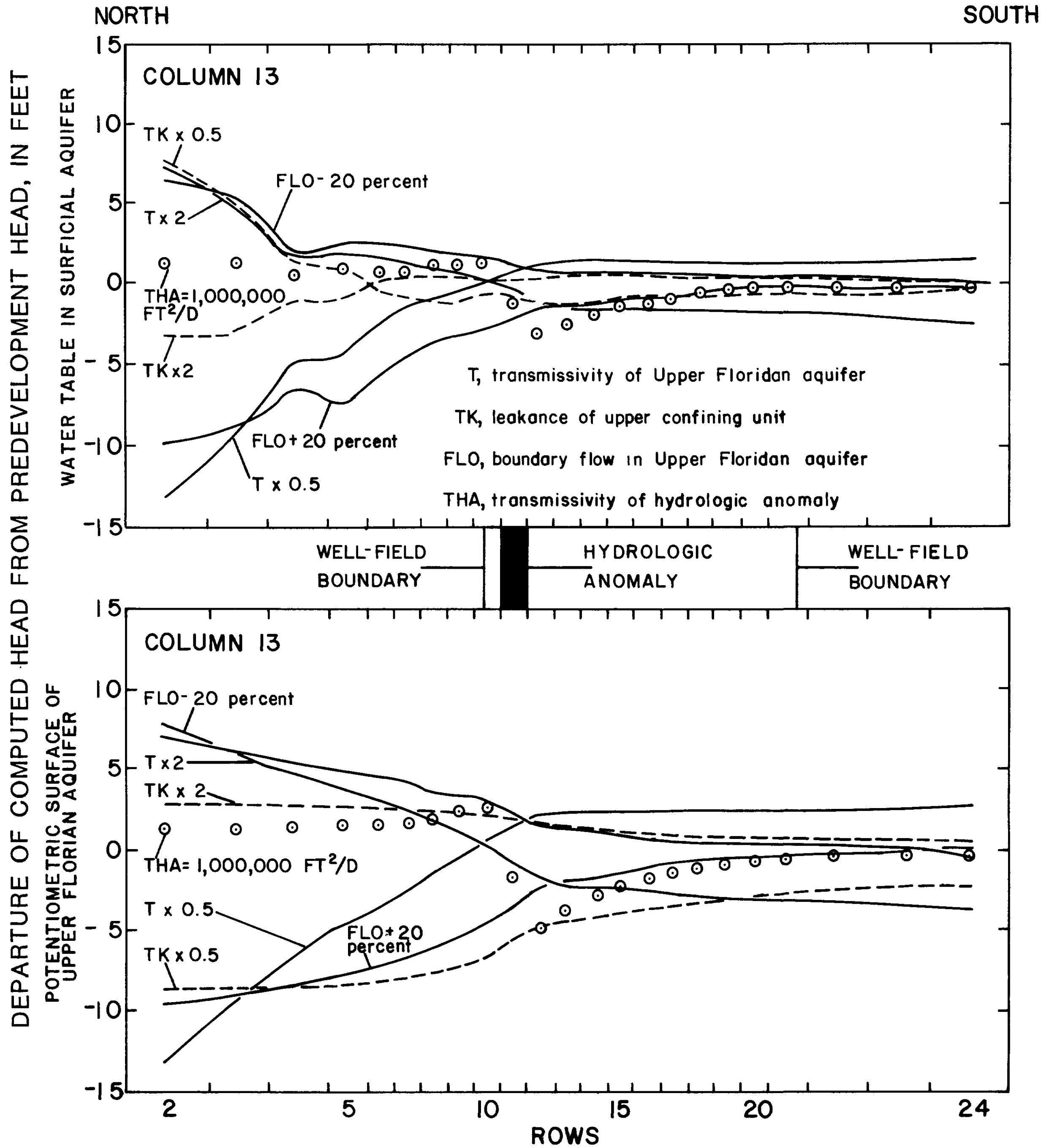

Figure 36.--Effects of varying boundary flow and hydraulic parameters.

Table 10.--Range in head fluctuations resulting from model-sensitivity tests

Parameter and change	Range[1/] of head fluctuation below (-) and above (+) starting head (feet)	
	Water table in surficial aquifer	Potentiometric surface of Upper Floridan aquifer
Hydraulic conductivity of surficial aquifer x 3	-1.8 to +0.9	-0.9 to +0.1
Increase ET-runoff rate by 20 percent	-2.3 to 0.0	-1.6 to 0.0
Decrease ET-runoff rate by 20 percent	0.0 to 5.0	0.0 to 3.6
Increase ET-runoff depth to 15 feet	-4.2 to 0.0	-3.4 to 0.0
Decrease ET-runoff depth to 5 feet	0.0 to +4.3	0.0 to +3.3
Increase recharge rate by 20 percent	0.0 to +6.5	0.0 to +3.7
Decrease recharge rate by 20 percent	-12.3 to 0.0	-6.6 to 0.0
Change leakance x 2	-10.5 to +1.3	0.0 to +3.5
Change leakance x 0.5	-2.9 to +8.2	-10.5 to 0.0
Change transmissivity of Upper Floridan aquifer x 2	-2.7 to 7.6	-4.6 to +9.7
Change transmissivity of Upper Floridan aquifer x 0.5	-13.6 to 3.4	-13.4 to +4.4
Increase boundary flow by 20 percent	-9.9 to +0.3	-9.9 to +0.4
Decrease boundary flow by 20 percent	-0.3 to +6.9	-0.5 to +7.0
Transmissivity of hydrologic anomaly = 10^6 ft^2/d	-3.0 to +3.1	-5.0 to +4.2

[1/] Represents range of model-computed residuals between starting and ending heads for 529 grid blocks.

There is a marked contrast in the model's sensitivity north and south of the hydrologic anomaly. This contrast appears to be linked more to ET-runoff capture than to the presence of the anomaly. ET-runoff is the variable source from which water is derived in the model. South of the anomaly, where the water table is within 10 feet of land surface, head changes are dampened by the capture of ET-runoff. For example, if 3.8 inches of water are captured in a grid block by lowering the water table 1 foot, large quantities of water would have to be removed to significantly lower heads. North of the hydrologic anomaly, the water table generally is below the ET-runoff capture zone. Changes in flux north of the anomaly (caused by changing model parameters) are absorbed by ET-runoff capture south of the anomaly because other fluxes (recharge and boundary) are constant in the model. Water levels in the north must change to such a degree as to induce changes in ET-runoff capture in the south. Thus, head changes are less in the south compared to changes in the north because of the south's proximity to the source of water.

The hydrologic anomaly has an important role in the model's sensitivity. It acts as the hinge line between areas of high and low response to parameter changes. Because the anomaly is modeled as a zone of low transmissivity in the Upper Floridan aquifer, it acts as a dam that retards flow northward through the aquifer. Head changes north of the anomaly must be large to induce compensating changes in flow through the low transmissivity zone. Increasing the transmissivity of the anomaly to a very high value (1,000,000 ft^2/d) results in drawdown in the south and buildup in the north because water easily flows through this zone. Observed conditions are better simulated when the anomaly acts as a low-transmissivity zone that dams up water in the south.

Of the parameters tested, the model is very sensitive to probable ranges of change in transmissivity and boundary flow within the Upper Floridan aquifer and leakance. Varying these parameters generally resulted in a range in head fluctuations greater than 10 feet in one or both aquifers. For the principal aquifer (Upper Floridan aquifer), the model is moderately sensitive to changes in ET-runoff and recharge parameters as these changes produce a range of head fluctuations generally between 2 and 10 feet. The model is relatively insensitive to changes in the hydraulic conductivity of the surficial aquifer.

Limitations of Model Application

A conceptual approach to ground-water modeling was used in the application of this model. The hydrogeologic system was conceptualized, its parameters identified and estimated, and it was transformed to the mathematical analog. The mathematical model approximates the physical processes that control the conceptual model, but it is only an approximate representation of the prototype.

The hydrogeology has been simplified to the extent that an operational mathematical model could be constructed. The mathematical solution is an approximate solution to the differential equations that define the system. Although the model is local in nature, it is not practical to track the movement of every drop of water in the system. Therefore, the very localized impact of pumping small quantities of water will not be accurately simulated. The impact of pumping large quantities of water near the model-grid boundary may not be accurately depicted because changes in boundary flow through large grid blocks in the regional model may not be accurately apportioned to small grid blocks in the Cross Bar Ranch model. A model limitation that could lead to significant errors occurs when the water table rises above land surface or falls to the base of the surficial aquifer. Theoretically, the water table cannot rise above land surface because runoff would occur. When the water table falls below the base of the surficial aquifer in a grid block, as was the case under the 45-Mgal/d pumping rate, that block becomes inactive, resulting in cessation of leakage to the Upper Floridan aquifer. When boundary grid blocks go dry, the cone of depression expands to dewater adjacent grid blocks and eventually causes a chain reaction. The model will flag grid blocks where the computed water table is above land surface or below the bottom of the aquifer. The model also only grossly accounts for changes in recharge, ET, and runoff that result from changes in the water table. Because the model assumes a steady-state condition, the solution is not time dependent, and the time required for computed heads to reach these levels cannot be determined from this model.

The Cross Bar Ranch predictive-model runs exemplify the types of analyses possible with the ground-water flow model. Generally, the model can be used to compute water-balance and water-level changes in response to various distributions of pumping and conditions of recharge. Because the model simulates long-term average water-level changes, short-term high or low conditions could be significantly different from simulated conditions. Ideally, the model should represent all characteristics of the prototype, but realistically, it represents a few of the more important characteristics of the hydrologic system. The model reasonably simulates the ground-water system in the Cross Bar Ranch well-field area. Additional limitations that pertain to modeling applications in Florida are discussed by Hutchinson (1984b).

Listing of Model-Input Data

A sample input-data listing is provided for the predictive run where the well field is pumped at 30 Mgal/d. The listing contains 662 lines or computer cards, including one card for each of the 17 pumping wells. Each card is keyed to data-deck instructions (Hutchinson, 1984a) by group number, card number, and variable name. The listing is convenient for looking up a particular input parameter for any grid block in the model.

There are four groups of cards in the data deck:

Group I. This group contains data that dimensions the model into a 25 x 25 array and provides several job-control options.

Group II. This group contains scalar parameters for mapping computed drawdowns, head, head difference, recharge, ET-runoff, leakage, pumping, and boundary flow. It also provides tolerances for computational errors.

Group III. This group contains the data matricies, 17 of which comprise the input parameters to this model. To reduce programming time and the number of layers, a "leakance" array replaces transmissivity, storage, and head arrays that would be necessary to represent the confining bed.

Group IV. This group controls the distribution of pumping and boundary flow over the model area. The model computes the response of the hydrologic system that will result from imposing pumping upon the system.

Usually, Groups I, II, and III remain unchanged from the calibrated model. To determine the effects of pumping stresses on the system, Group IV is the only group in which cards are changed.

SAMPLE INPUT DATA DECK FOR CROSS BAR RANCH WELL FIELD PUMPAGE PROBLEM

```
                                      DATA SET                                          GROUP   CARD      VARIABLE
--------------------------------------------------------------------------------------------------------------------
CROSS BAR RANCH MODEL PREDICTIVE RUN                                                      I       1       HEADING
 PUMP AT 30 MGAL/D                                                                                2       HEADING
     25         25          2         50          0                                               3
DRAW HEAD MASS          WATE RECH      PUN2 ITKR                                                  4
--------------------------------------------------------------------------------------------------------------------
      1          1        .01          2         1.0                                      II      1
  5280    5280      1  112     112      11       12       12       11      -11       MILES         2
                                                                                                  3
                                                                                                  4
                                                                                                  5
--------------------------------------------------------------------------------------------------------------------
      1          1          0                                                             III     1       STRT1
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0
   0.0      25.0018    26.0369    27.5603    28.5982    29.3013    29.8460    30.3312
 30.7027    31.0650    31.4307    31.7826    32.1443    32.5581    32.9844    33.4651
 33.9319    34.5761    35.2085    35.9281    36.7964    37.9428    38.9345    40.0893
   0.0
   0.0      27.5421    29.9818    31.8083    32.9920    33.6862    34.1848    34.6191
 34.9421    35.2574    35.5870    35.9369    36.2731    36.6103    36.9710    37.3511
 37.7925    38.2659    38.7233    39.1904    39.7625    40.5331    41.1899    41.6796
   0.0
   0.0      29.9313    32.8957    34.3648    36.1381    36.8473    37.3415    37.7641
 38.1108    38.4563    38.8026    39.1191    39.3747    39.6880    40.0101    40.3495
 40.7109    41.0621    41.3993    41.7463    42.1744    42.7303    43.1477    43.2553
   0.0
   0.0      31.9194    35.1838    37.2835    38.6001    39.3063    39.7901    40.2222
 40.6110    40.9722    41.2834    41.5124    41.7453    42.0022    42.2571    42.5460
 42.8383    43.1115    43.3866    43.6908    44.0783    44.5295    44.7511    44.5568
   0.0
   0.0      33.1363    36.6912    38.9356    40.2566    40.9478    41.4234    41.8577
 42.2527    42.6036    42.8965    42.9798    43.1593    43.3367    43.5957    43.9782
 44.2146    44.3821    44.6100    44.9318    45.3836    45.7954    45.8816    45.5019
   0.0
   0.0      34.1629    37.8332    40.1551    41.4507    42.1060    42.5473    42.9840
 43.3946    43.7678    44.1362    44.4628    44.7386    44.9544    45.1495    45.2689
 45.3532    45.4169    45.6573    46.0581    46.5429    46.8939    46.8681    46.4127
   0.0
   0.0      35.4912    39.6189    41.9814    43.2129    43.7466    44.1160    44.5492
 45.0160    45.5127    46.0452    46.5687    46.9117    47.1495    47.2603    47.1287
 47.0156    46.7547    47.0168    47.7889    47.8847    48.1298    47.9661    47.4836
   0.0
   0.0      37.3613    41.8102    44.1760    45.3795    45.6906    46.0760    46.5570
 47.1060    47.7479    48.2954    48.7314    49.0844    49.3710    49.5079    49.4119
 49.1701    51.1755    51.4792    50.4238    50.0654    49.4807    49.1144    48.5864
   0.0
   0.0      39.3559    43.8746    46.1924    47.4365    47.4187    47.8915    48.4447
 48.9568    49.6403    50.2203    50.6758    51.0369    51.3270    51.5618    51.7584
 54.3663    56.2498    55.7771    53.8568    52.7743    51.4177    50.7671    50.0976
   0.0
   0.0      41.9767    46.4947    48.9141    50.6028    52.0415    53.3423    54.1939
 54.8137    55.6430    56.4231    56.9299    57.2788    57.5199    57.6950    57.9641
 59.2478    58.8232    58.1707    56.9594    55.4064    53.8600    52.9424    52.0155
   0.0
   0.0      44.7368    49.0035    51.7503    54.0919    56.5072    57.9435    59.0417
 59.9461    60.7715    61.4214    61.9419    62.2936    62.4909    62.5174    62.2172
 61.6251    61.1602    60.6095    59.7929    58.4216    56.7482    55.6112    54.3272
   0.0
   0.0      46.9709    50.9014    53.8358    56.2239    58.0507    59.3416    60.3951
 61.2881    62.0858    62.7169    63.2129    63.5594    63.7683    63.8430    63.7638
 63.5152    63.2333    62.8339    62.2319    61.2931    59.7349    58.4533    56.8706
   0.0
   0.0      49.1416    52.7344    55.7287    58.0941    59.6778    60.8439    61.8351
 62.6763    63.3969    63.9911    64.4608    64.8001    65.0247    65.1516    65.2121
 65.1686    65.0402    64.7523    64.2835    63.6282    62.2569    60.9230    59.1186
   0.0
   0.0      51.2195    54.4984    57.5553    59.8191    61.2506    62.3111    63.2436
 64.0317    64.6975    65.2431    65.6762    66.0025    66.2337    66.3996    66.5539
 66.6290    66.6165    66.4444    66.1016    65.6264    64.4117    63.0906    61.2205
   0.0
   0.0      53.1797    56.2181    59.2914    61.4613    62.7673    63.7350    64.5955
 65.3319    65.9604    66.4660    66.8453    67.1549    67.3733    67.5655    67.8047
 67.9638    67.9935    67.8922    67.6374    67.2900    66.2437    65.0041    63.1830
   0.0
   0.0      54.9120    57.9305    60.9200    62.9844    64.2046    65.1084    65.9069
 66.5710    67.1416    67.6258    67.9884    68.2640    68.4697    68.6750    68.9540
 69.1466    69.2093    69.1535    68.9586    68.7116    67.8237    66.7212    65.0906
```

0.0							
0.0	56.4040	59.5469	62.4329	64.4046	65.5405	66.4049	67.1406
67.7678	68.3159	68.7483	69.0728	69.3122	69.5298	69.7435	70.0255
70.2290	70.3129	70.2850	70.1512	69.9632	69.2020	68.2572	66.8830
0.0							
0.0	57.7118	60.9417	63.7822	65.6584	66.7465	67.5409	68.2126
68.7989	69.3460	69.7574	70.0421	70.2773	70.5026	70.7184	70.9655
71.1600	71.2612	71.2550	71.1699	71.0040	70.3676	69.5932	68.5468
0.0							
0.0	58.9115	62.1744	64.9616	66.7715	67.8077	68.5441	69.1941
69.7648	70.2568	70.6497	70.9423	71.1775	71.3877	71.5706	71.7800
71.9584	72.0883	72.0785	72.0060	71.8501	71.3453	70.7406	70.0072
0.0							
0.0	60.1377	63.5788	66.2772	68.0394	69.0196	69.7056	70.3475
70.9206	71.3787	71.7307	71.9970	72.2022	72.3677	72.5049	72.6573
72.7795	72.8438	72.8366	72.7625	72.6608	72.3631	71.9541	71.5331
0.0							
0.0	61.6206	65.2921	67.9992	69.8207	70.8020	71.4839	72.0755
72.5780	72.9880	73.2547	73.4386	73.5583	73.6380	73.6957	73.7547
73.7889	73.7908	73.7684	73.7182	73.6744	73.5367	73.3335	73.0922
0.0							
0.0	63.4934	67.1023	69.8402	71.6575	72.6955	73.4302	74.0540
74.5543	74.9374	75.1337	75.1717	75.0905	74.9897	74.9114	74.8430
74.7504	74.6397	74.5915	74.5564	74.5271	74.4586	74.4392	74.3217
0.0							
0.0	66.1656	68.9967	71.5569	73.6179	74.9515	75.9864	76.8481
77.3812	77.6748	77.6349	77.2965	76.7332	76.1646	75.7154	75.3889
75.1919	75.1216	75.0654	75.0203	74.9745	74.8463	75.2036	74.9288
0.0							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0							

---

1 1 0 III 1 STRT2

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0							
0.0	29.1864	33.5015	40.4997	41.0161	43.2728	44.0477	45.1306
50.1722	50.6357	52.3419	52.9572	53.3638	53.7710	54.2083	54.6800
55.1281	55.2686	56.3280	57.1609	58.4712	59.0774	66.9548	84.4168
0.0							
0.0	31.3765	36.1540	43.8958	46.8838	47.7114	48.2261	48.6969
49.1898	50.0973	55.5014	56.6169	57.1398	57.5126	57.8467	58.0594
58.1786	58.2972	58.4252	58.5537	58.7315	59.0201	65.3596	81.1143
0.0							
0.0	34.7873	39.1427	45.0774	49.9564	50.8486	51.3253	51.7407
52.1032	52.5425	53.0587	53.7011	56.2275	56.4042	56.5575	56.6757
56.7714	56.8623	56.9558	57.1151	58.5674	58.7959	61.2393	70.7107
0.0							
0.0	36.8252	44.3258	50.6271	52.2094	52.6996	51.3499	51.4349
51.6972	54.2191	54.7919	55.0086	54.8444	50.5515	55.1981	56.9303
57.1140	57.2136	57.4101	57.5818	59.0940	59.3696	61.5749	70.1675
0.0							
0.0	38.2024	44.5167	47.6382	48.9529	49.6450	49.8129	50.1471
50.3312	50.4220	50.7775	50.8568	50.9269	50.8704	51.1904	52.6025
52.9446	53.5157	57.3045	57.7792	60.7746	63.0127	61.8523	64.3680
0.0							
0.0	41.0986	45.1178	48.5492	48.9279	50.0399	47.9469	49.3664
49.4634	46.4059	50.9756	51.3436	51.4800	51.5787	51.6720	51.7841
51.9016	53.3886	54.4314	55.4416	61.0846	63.4767	62.2345	64.3094
0.0							
0.0	41.5883	47.0343	49.4227	49.4080	49.3322	46.0621	46.1853
46.5383	47.8143	51.6975	52.0372	52.2131	52.4105	52.3203	52.2648
52.2743	53.5635	54.4355	55.7936	61.8594	63.9558	64.5524	64.8457
0.0							
0.0	43.4060	48.1196	49.6834	51.0591	46.8740	46.9465	47.3250
49.3063	54.2913	55.1586	53.2838	53.4600	55.7155	55.7436	55.7188
55.7578	57.5683	58.3805	57.6766	58.3076	66.2024	66.9600	68.9971
0.0							
0.0	44.2886	48.9557	47.4153	48.4821	47.9190	52.3285	54.5342
51.2139	55.7406	56.3252	56.4851	56.6727	56.9722	58.5814	58.9548
60.5799	61.5332	62.1807	60.9163	60.5548	66.8374	67.5202	69.6568
0.0							
0.0	45.6846	50.2769	48.3496	49.3963	54.3690	'57.4652	58.0430
57.0523	59.0006	61.4897	61.8887	62.0752	62.2073	62.3723	62.5258
63.1155	62.9676	62.7514	63.0253	62.6965	67.4864	68.0439	70.1649
0.0							
0.0	48.8499	52.0248	52.9430	55.4640	58.1774	59.9392	60.5328
61.0251	63.6073	63.3857	64.8708	65.1040	65.2076	65.2259	65.0950
64.8393	64.2811	64.8953	65.8124	65.4771	68.2414	68.0908	70.7481

```
 0.0
 0.0       50.0826   53.0508   56.7774   58.1692   59.2804   61.2361   61.4442
61.9835    64.5068   64.9449   65.6809   65.8827   65.9902   66.0283   65.9909
65.9266    66.6575   67.3724   67.3570   66.9258   69.0546   68.8131   71.3879
 0.0
 0.0       51.2326   53.9587   57.1096   60.1075   61.8845   63.8314   64.4178
64.8603    65.3510   66.0882   66.7892   66.9862   67.0999   67.1660   67.2187
67.6482    68.5203   68.6415   69.4352   68.1675   70.4332   70.1258   71.9644
 0.0
 0.0       53.2098   54.4316   59.8050   61.5869   63.2500   64.7521   66.1063
66.5680    66.9517   67.2707   67.8667   68.0812   68.1633   68.2510   68.3930
68.5340    69.8174   70.4107   71.8005   70.5248   72.3205   71.3733   72.4280
 0.0
 0.0       55.1276   54.9991   62.1431   64.2248   64.9925   65.9838   66.9425
67.7484    68.8828   69.1781   68.2186   69.0834   68.3699   68.4926   69.9172
70.4746    70.5994   71.1373   71.8698   71.3859   72.8974   71.9567   72.3058
 0.0
 0.0       56.0478   58.1646   64.0104   65.6345   66.6808   67.7061   68.9392
68.5125    68.4816   69.9018   70.0764   70.1363   68.9974   69.1315   70.9948
71.1997    71.2640   71.7209   71.2967   72.0925   73.4151   73.1237   73.3904
 0.0
 0.0       56.4135   62.1629   66.2309   68.1360   68.0271   70.5341   71.0009
71.2728    72.0310   71.9173   71.9374   70.8144   70.8327   71.0367   72.4764
72.6440    72.6936   72.6662   71.8470   73.6021   75.0534   74.8349   73.9589
 0.0
 0.0       57.4997   63.0505   67.8632   68.9043   69.9015   71.1917   70.7313
70.3000    72.9912   73.2396   71.7398   71.3486   71.8917   72.8366   73.0608
73.1724    73.2939   73.2615   73.2189   74.1796   75.4501   75.2873   75.6576
 0.0
 0.0       58.1703   63.7564   68.5077   69.4772   70.4447   70.8442   71.1739
71.4830    71.8686   72.4785   72.5705   72.6828   73.2178   73.3721   73.4876
73.6504    75.3170   74.5685   74.5291   74.6554   75.7127   75.5892   76.0822
 0.0
 0.0       59.7429   66.2822   69.1975   70.1343   70.6045   70.1556   71.3461
72.9535    73.2689   73.4487   73.5819   73.6862   73.7818   73.8546   73.9312
73.9963    74.0709   74.0819   74.6569   75.9645   75.9937   75.8927   75.8129
 0.0
 0.0       61.9485   67.2241   70.1048   72.4437   72.9672   73.3050   73.6190
73.9334    74.9815   74.2942   74.3454   74.3957   74.4357   74.4696   74.4991
74.5157    74.5128   74.5356   74.9390   76.2814   76.3075   76.2571   76.2080
 0.0
 0.0       62.9299   68.6303   72.4527   73.4218   73.9504   74.3239   74.6447
74.9678    76.4855   76.6434   76.6215   75.7188   75.6385   76.0256   76.0102
75.9364    75.2662   76.4438   76.5688   77.2395   77.2429   77.2484   77.9426
 0.0
 0.0       64.7507   69.5930   72.8628   74.4030   75.0874   75.6075   76.0431
76.3871    77.8602   77.9167   77.7957   78.3477   77.2038   76.4985   76.3327
76.6829    76.6873   76.6862   76.6761   76.6510   75.9214   76.0137   77.3899
 0.0
 0.0        0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0        0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0        0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0
----------------------------------------------------------------------------------------------------
     0.0          0          C                                                    III      1      S1
----------------------------------------------------------------------------------------------------
     0.0          0          C                                                    III      1      S2
----------------------------------------------------------------------------------------------------
    .0058         1          C        1.0       1.0


    175 175 225 225 225 225 225 290 290 290 350 350 350 350 400 400 400 400 400
400 400 400 400
    175 175 225 225 225 225 225 290 290 290 290 350 350 350 350 350 400 400 400
400 400 400 400
    175 175 225 225 225 225 225 225 225 225 290 290 290 290 290 290 350 350 350
350 350 350 350
    175 175 175 175 175 175 175 175 175 175 225 225 290 290 290 290 350 350 350
350 350 350 350
    175 175 175 175 175 175 175 175 175 175 225 225 225 225 225 225 290 290 290
290 290 290 290
    175 175 175 175 175 175 175 175 175 175 100 100 100 100 225 225 225 225 225
290 290 290 290
     80  80  80  80  80  80  80  80  80  80  80  80  80  80 100 100 100 100 100
225 225 225 225
     80  80  80  80  80  80  80  80  80  80  80  80  80  80 100 100  12  12 100
100 225 225 225
     80  80  80  80  80  80  80  80  80  80  80  80  80  80  80  12  50  50  50
```

```
100 100 100 100
     50  50  50   50  12  12  12  12  12  12  12  12  12  12  12  50  50  50  50
 82  82  82  82
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50
     80  80  80   80  80  80  80  80  80  80  80  80  80  80  50  50  50  50  50
 50  50  50  50

--------------------------------------------------------------------------------------------
          C           0           C           1          1                          III        1        T2
--------------------------------------------------------------------------------------------
  3.5E-10             1           C                                                 III        1        TK

     15  15  15   15  15  15  15  10  10  10  10  10  10  10  10  10  10  10  10
 10  10   6   6
     15  15  15   15  15  15  15  15  15  10  10  10  10  10  10  10  10  10  10
 10  10   6   6
     15  15  15   15  15  15  15  15  15  15  15  10  10  10  10  10  10  10  10
 10  10  10  10
     15  15  15   15  15  15  15  15  15  15  15  15  28  15  10  10  10  10  10
 10  10  10  10
     25  25  25   25  25  25  25  25  25  25  25  25  25  25  25  25  25  10  10
 10  10  10  10
     25  25  25   25  25  25  25  25  25  25  25  25  25  25  25  25  25  25  20
 10  10  10  10
     28  28  28   28  28  28  28  28  28  28  28  28  28  30  30  30  30  30  28
 10  10  10  10
     28  28  28   28  28  28  28  28  28  28  28  28  28  30  30  30  30  30  30
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  30
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  30
 30  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  30
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  28
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  28  15
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  28  15
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  28  15
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  28  15
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  30
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  30
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  30
 28  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  10
 10  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  30  30  10
 10  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  30  10  10  10
 10  10  10  10
     30  30  30   30  30  30  30  30  30  30  30  30  30  30  30  10  10  10  10
 10  10  10  10
```

```
-----------------------------------------------------------------------------------------------------------
   1.2E-04          0          0                                                      III      1      PERM
-----------------------------------------------------------------------------------------------------------
         1          1          0                                                      III      1      BOTTOM

    -1.0 5.015.015.020.020.025.025.025.030.030.030.035.035.035.033.030.033.033.0
33.033.039.065.0
     1.0 7.018.027.028.030.030.030.030.035.035.035.035.035.033.033.033.033.033.0
33.033.038.055.0
     5.010.018.025.030.033.033.033.033.030.030.030.030.030.030.030.030.030.030.0
32.032.035.045.0
     7.017.030.030.030.025.025.025.030.030.030.030.030.030.030.030.030.030.030.0
32.032.035.045.0
    10.019.030.027.027.025.025.025.025.025.025.025.025.025.030.030.030.030.030.0
34.037.035.035.0
    15.019.025.023.025.020.023.023.015.025.025.025.025.025.025.025.028.030.029.0
34.037.035.035.0
    15.024.025.023.023.015.015.015.017.025.025.025.025.025.025.025.028.030.035.0
35.037.038.035.0
    17.022.023.025.015.015.015.019.030.030.025.025.030.030.030.030.032.035.037.0
40.040.041.041.0
    17.022.016.017.015.025.030.020.030.030.030.030.030.035.035.035.035.037.037.0
40.040.041.041.0
    17.022.015.015.025.030.030.027.030.035.035.035.035.035.035.035.035.035.037.0
40.040.041.041.0
    21.023.022.025.028.030.030.030.035.035.036.036.036.036.036.036.035.037.040.0
40.040.040.041.0
    21.023.028.028.028.031.030.030.035.035.036.036.036.036.036.036.038.040.040.0
40.040.040.041.0
    21.023.026.030.032.035.035.035.035.036.037.037.037.037.037.038.040.040.040.0
40.041.041.041.0
    23.022.030.031.033.035.037.037.037.037.038.038.038.038.038.038.041.042.043.0
43.043.042.042.0
    25.021.033.035.035.036.037.038.040.040.037.039.037.037.040.041.041.042.042.0
43.043.042.042.0
    25.026.035.036.037.038.040.038.037.040.040.040.037.037.041.041.041.042.040.0
43.043.043.043.0
    24.033.038.040.038.043.043.043.044.043.043.040.040.040.043.043.043.043.041.0
45.045.045.044.0
    25.033.040.040.041.043.043.039.045.045.041.040.041.043.043.043.043.043.043.0
45.045.045.046.0
    25.033.040.040.041.041.041.041.041.042.042.042.043.043.043.043.047.045.045.0
45.045.045.046.0
    27.037.040.040.040.038.040.043.043.043.043.043.043.043.043.043.043.043.043.0
45.045.045.045.0
    30.037.040.043.043.043.043.043.045.043.043.043.043.043.043.043.043.043.043.0
45.045.045.045.0
    30.038.043.043.043.043.043.043.046.046.046.044.044.045.045.045.043.045.045.0
46.046.046.047.0
    31.038.042.043.043.043.043.043.046.046.046.048.046.045.045.045.045.045.045.0
45.044.044.046.0

-----------------------------------------------------------------------------------------------------------
       0.0          0          0                                                      III      1      QRE1
-----------------------------------------------------------------------------------------------------------
  2.64E-09          0          0                                                      III      1      QRE2

     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
 28  28  28  28
     28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
```

```
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28
    28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28  28
28  28  28  28

----------------------------------------------------------------------------------------------
        0.0          0         0                                       III       1        CSS1
----------------------------------------------------------------------------------------------
   1.02E-08          0         0                                       III       1        CSS2
----------------------------------------------------------------------------------------------
        0.0          0         0                                       III       1        HSS1
----------------------------------------------------------------------------------------------
          1          1         0                                       III       1        HSS2

    24.030.040.040.045.045.050.050.050.055.055.060.065.062.062.060.055.058.058.0
58.058.064.090.0
    26.032.043.052.053.055.055.060.060.065.065.060.060.060.058.058.058.058.058.0
58.058.063.080.0
    30.035.043.050.055.060.060.065.062.055.055.055.055.055.055.055.055.055.055.0
57.057.060.070.0
    32.042.055.055.055.050.050.050.055.055.055.055.055.055.055.055.055.055.055.0
57.057.060.070.0
    35.044.055.052.052.050.050.050.050.050.050.050.050.050.055.055.055.055.055.0
59.062.060.060.0
    40.044.050.048.050.045.048.048.040.050.050.050.050.050.050.050.053.055.054.0
59.062.060.060.0
    40.049.050.048.048.040.040.040.042.050.050.050.050.050.050.050.053.055.060.0
60.062.063.060.0
    42.047.048.050.040.040.040.044.055.055.050.050.055.055.055.055.057.060.062.0
65.065.066.066.0
    42.047.041.042.040.050.055.045.055.055.055.055.055.060.060.060.060.062.062.0
65.065.066.066.0
    42.047.040.040.050.055.055.052.055.060.060.060.060.060.060.060.060.060.062.0
65.065.066.066.0
    46.048.047.050.053.055.055.055.060.058.061.061.061.061.061.061.060.062.065.0
65.065.065.066.0
    46.048.053.053.053.056.055.055.060.060.061.061.061.061.061.061.063.065.065.0
65.065.065.066.0
    46.048.051.055.057.060.060.060.060.061.062.062.062.062.062.063.065.065.065.0
65.066.066.066.0
    48.047.055.056.058.060.062.062.062.062.063.063.063.063.063.063.066.067.068.0
68.068.067.067.0
    50.046.058.060.060.061.062.063.065.065.062.064.062.062.065.066.066.067.067.0
68.068.067.067.0
    50.051.060.061.062.063.065.063.062.065.065.065.062.062.066.066.066.067.065.0
68.068.068.068.0
    49.058.063.065.063.068.068.068.069.068.068.065.065.065.068.068.068.068.066.0
70.070.070.069.0
    50.058.065.065.066.068.066.064.070.070.066.065.066.068.068.068.068.068.068.0
70.070.070.071.0
    50.058.065.065.066.066.066.066.066.067.067.067.068.068.068.068.072.070.070.0
70.070.070.071.0
    52.062.065.065.065.063.065.068.068.068.068.068.068.068.068.068.068.068.068.0
70.070.070.070.0
    55.062.065.068.068.068.068.068.070.068.068.068.068.068.068.068.068.068.068.0
70.070.070.070.0
    55.063.068.068.068.068.068.068.071.071.071.069.069.070.070.070.068.070.070.0
71.071.071.072.0
    56.063.067.068.068.068.068.068.071.071.071.073.071.070.070.070.070.070.070.0
70.069.069.071.0
```

```
----------------------------------------------------------------------------------------------------------
         0          0          C                                                   III        1        HB1
----------------------------------------------------------------------------------------------------------
         1          1          0                                                   III        1        HB2

      34  40  50  50  55  55  60  60  60  65  65  70  75  72  72  70  65  68  68
  68  68  74 100
      36  42  53  62  63  65  65  70  70  75  75  70  70  70  68  68  68  68  68
  68  68  73  90
      40  45  53  60  65  70  70  72  70  65  65  65  65  65  65  65  65  65  65
  67  67  70  80
      42  52  65  65  65  60  60  60  65  65  65  65  65  65  65  65  65  65  65
  67  67  70  80
      45  54  65  62  62  60  60  60  60  60  60  60  60  60  65  65  65  65  65
  69  72  70  70
      50  54  60  58  60  55  58  58  50  60  60  60  60  60  60  60  63  65  64
  69  72  70  70
      50  59  60  58  58  50  50  50  52  60  60  60  60  60  60  60  63  65  70
  70  72  73  70
      52  57  58  60  50  50  50  54  65  65  60  60  65  65  65  65  67  70  72
  75  75  76  76
      52  57  51  52  50  60  65  55  65  65  65  65  65  70  70  70  70  72  72
  75  75  76  76
      52  57  50  50  60  65  65  62  65  70  70  70  70  70  70  70  70  70  72
  75  75  76  76
      56  58  57  60  63  65  65  65  70  68  71  71  71  71  71  71  70  72  75
  75  75  75  76
      56  58  63  63  63  66  65  65  70  70  71  71  71  71  71  71  73  75  75
  75  75  75  76
      56  58  61  65  67  70  70  70  70  71  72  72  72  72  72  73  75  75  75
  75  76  76  76
      58  57  65  66  68  70  72  72  72  72  73  73  73  73  73  73  76  77  78
  78  78  77  77
      60  56  68  70  70  71  72  73  75  75  72  74  72  72  75  76  76  77  77
  78  78  77  77
      60  61  70  71  72  73  75  73  72  75  75  75  72  72  76  76  76  77  75
  78  78  78  78
      59  68  73  76  73  79  79  79  80  79  79  76  76  76  79  79  79  79  77
  81  81  81  80
      60  68  76  76  77  79  77  75  81  81  77  76  77  79  79  79  79  79  79
  81  81  81  82
      60  68  76  76  77  77  77  77  77  78  78  78  79  79  79  79  82  81  81
  81  81  81  82
      62  72  76  76  76  73  76  79  79  79  79  79  79  79  79  79  79  79  79
  81  81  81  81
      65  72  76  79  79  79  79  79  81  79  79  79  79  79  79  79  79  79  79
  81  81  81  81
      65  73  79  79  79  79  79  79  82  82  82  80  80  81  81  81  79  81  81
  82  82  82  82
      66  73  78  79  79  79  79  79  82  82  82  83  82  81  81  81  81  81  81
  81  80  80  82

----------------------------------------------------------------------------------------------------------
         1          1          0                                                   III        1       DELX
      5280       5280       3960       3960       2640       1760       1760       1760
      1760       1760       1760       1760       1760       1760       1760       1760
      1760       1760       1760       1760       2640       3960       3960       5280
      5280
----------------------------------------------------------------------------------------------------------
         1          1          0                                                   III        1       DELY
      5280       5280       3960       3960       2640       1760       1760       1760
      1760       1760       1760       1760       1760       1760       1760       1760
      1760       1760       1760       1760       2640       3960       3960       5280
      5280
----------------------------------------------------------------------------------------------------------
         1                                                                         III        1       DELZ
----------------------------------------------------------------------------------------------------------
         1          0        124          1          1          1         24
         1         19         13      -2.73         CB-1
         1         18         13      -2.73         CB-2
         1         17         11      -2.73         CB-3
         1         17         13      -2.73         CB-4
         1         15         14      -2.73         CB-5
         1         14         12      -2.73         CB-6
         1         14         13      -2.73         CB-7
         1         13         14      -2.73         CB-8
         1         12         14      -2.73         CB-9
         1         11         16      -2.73         CB-10
         1         11         18      -2.73         CB-11
         1         12         19      -2.73         CB-12
```

1	10	18	-2.73	CB-13
1	11	20	-2.73	CB-14
1	9	16	-2.73	CB-15
1	8	18	-2.73	CB-16A
1	9	20	-2.73	CB-17
1	2	2	-4.19	
1	2	3	-5.01	
1	2	4	-5.73	
1	2	5	-3.93	
1	2	6	-2.57	
1	2	7	-2.37	
1	2	8	-2.37	
1	2	9	-3.16	
1	2	10	-2.96	
1	2	11	-3.06	
1	2	12	-3.44	
1	2	13	-3.74	
1	2	14	-3.44	
1	2	15	-3.73	
1	2	16	-3.83	
1	2	17	-3.83	
1	2	18	-3.66	
1	2	19	-3.86	
1	2	20	-2.86	
1	2	21	-3.72	
1	2	22	-4.82	
1	2	23	-4.58	
1	2	24	-2.77	
1	3	2	-2.53	
1	3	24	-0.43	
1	4	2	-2.95	
1	4	24	-1.02	
1	5	2	-1.95	
1	5	24	-1.02	
1	6	2	-1.55	
1	6	24	-0.92	
1	7	2	-1.45	
1	7	24	-0.72	
1	8	2	-1.25	
1	8	24	-0.12	
1	9	2	-1.48	
1	9	24	-0.07	
1	10	2	-1.28	
1	10	24	0.03	
1	11	2	-0.98	
1	11	24	-0.07	
1	12	2	-1.28	
1	12	24	-0.28	
1	13	2	-0.88	
1	13	24	-0.28	
1	14	2	-0.68	
1	14	24	-0.38	
1	15	2	-0.58	
1	15	24	-0.38	
1	16	2	-0.38	
1	16	24	-0.38	
1	17	2	-0.28	
1	17	24	-0.28	
1	18	2	-0.28	
1	18	24	-0.23	
1	19	2	-0.38	
1	19	24	-0.13	
1	20	2	-0.18	
1	20	24	-0.03	
1	21	2	-0.57	
1	21	24	0.07	
1	22	2	-1.57	
1	22	24	-0.03	
1	23	2	-1.54	
1	23	24	-0.01	
1	24	2	0.37	
1	24	3	0.57	
1	24	4	0.48	
1	24	5	0.48	
1	24	6	0.46	
1	24	7	0.76	
1	24	8	1.06	
1	24	9	0.97	
1	24	10	0.97	
1	24	11	0.87	
1	24	12	0.71	
1	24	13	0.21	
1	24	14	0.01	

1	24	15	-0.14
1	24	16	-0.14
1	24	17	-0.04
1	24	18	0.04
1	24	19	0.04
1	24	2C	0.04
1	24	21	0.08
1	24	22	-0.12
1	24	23	0.44
1	24	24	-0.04
2	2	21	0.10
2	2	22	0.20
2	2	23	0.30
2	2	24	0.60
2	3	24	0.50
2	4	24	0.60
2	5	24	0.30
2	6	24	0.30
2	7	24	0.30
2	8	24	0.30
2	9	24	0.30
2	10	24	0.30
2	11	24	0.30
2	12	24	0.30
2	13	24	0.30
2	14	24	0.30
2	15	24	0.20
2	16	24	0.10
2	17	24	0.10

*U.S. GOVERNMENT PRINTING OFFICE: 1985-544-130/ 10031 Region 4.