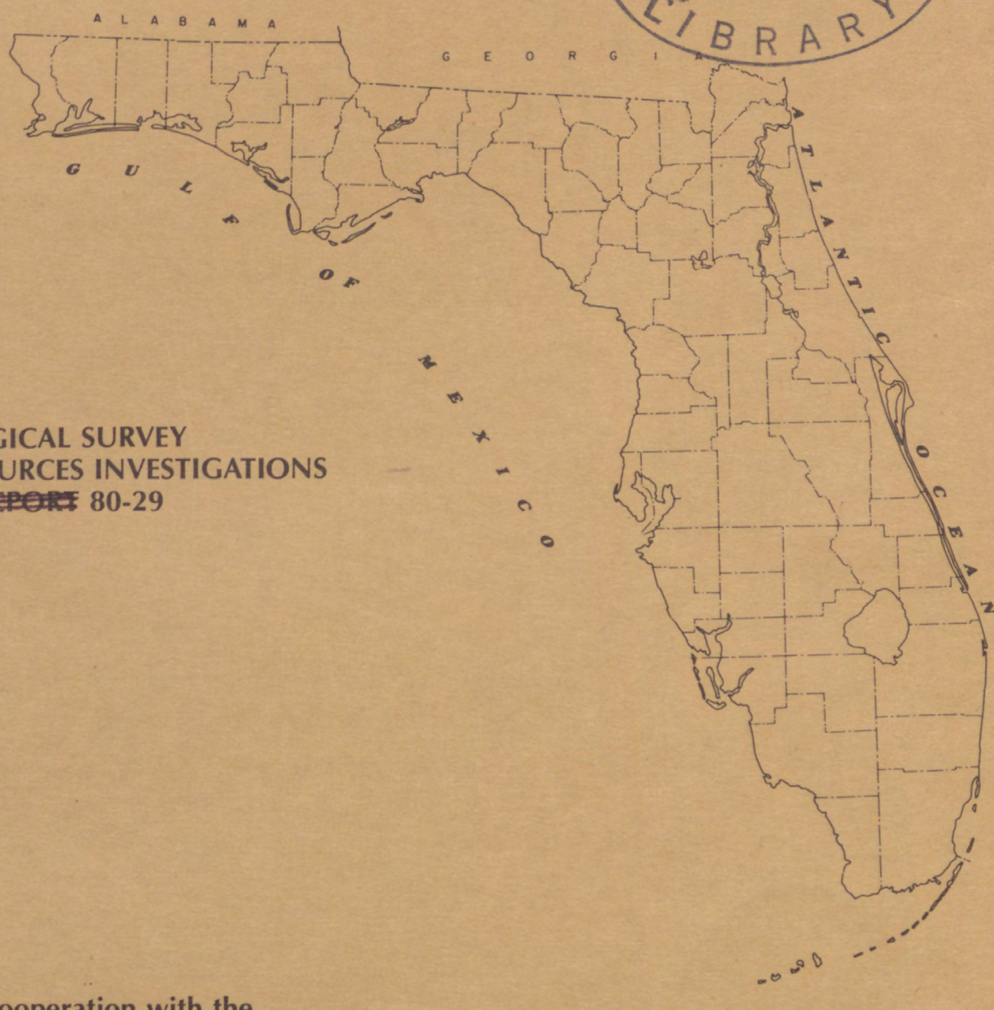
# MODEL EVALUATION OF THE HYDROGEOLOGY OF THE MORRIS BRIDGE WELL FIELD AND VICINITY IN WEST-CENTRAL FLORIDA



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WATER-RESOURCES INVESTIGATIONS
~~OPEN-FILE REPORT~~ 80-29

Prepared in cooperation with the

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

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16. Abstract (Limit: 200 words)

The Morris Bridge well field is being developed to augment the city of Tampa's water supply that now comes from the Hillsborough River. The maximum well-field withdrawal may equal 40 million gallons per day.

The water will be pumped from the Floridan aquifer--a sequence of carbonate rocks about 1,000 feet thick underlying surficial sand and clay deposits. A highly fractured and transmissive zone about 500 feet below National Geodetic Vertical Datum of 1929 will supply a large portion of the water.

Two-dimensional and three-dimensional digital flow models were used to evaluate the hydrogeology of the area. The model-derived leakance distribution (a property of the confining bed) for a 285-square-mile area ranged from $2 \times 10^{-5}$ to $8 \times 10^{-3}$ day$^{-1}$. Model-derived transmissivity values for the Floridan aquifer ranged from 37,000 to 600,000 feet squared per day. Model-derived specific yield values for the surficial aquifer ranged from 0.05 to 0.30.

The three-dimensional model was used to predict drawdowns in both the Floridan and surficial aquifers in response to a 40 million gallon per day stress. Mass-balance data from a 30-day simulation with no recharge from rainfall show percentage of withdrawn water that is derived from: (1) aquifer storage, (2) the Hillsborough River, and (3) reduction of evapotranspiration losses.

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 80-29

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SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

1980

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

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## CONVERSION FACTORS

The inch-pound units used in this report can be converted to equivalent SI (metric) units as follows:

| Multiply inch-pound unit | By | To obtain SI (metric) unit |
|---|---|---|
| inch (in.) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| foot per second (ft/s) | 0.3048 | meter per second (m/s) |
| foot per day (ft/d) | 0.3048 | meter per day (m/d) |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second ($m^3/s$) |
| gallon per minute (gal/min) | $6.309 \times 10^{-2}$ | liter per second (L/s) |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second ($m^3/s$) |
| square foot per day ($ft^2/d$) | 0.0929 | square meter per day ($m^2/d$) |

* * * * * * * * * * * *

| | | |
|---|---|---|
| mean sea level (msl) | --- | National Geodetic Vertical Datum of 1929 (NGVD of 1929) |

# MODEL EVALUATION OF THE HYDROGEOLOGY OF THE MORRIS BRIDGE WELL FIELD AND VICINITY IN WEST-CENTRAL FLORIDA

By Paul D. Ryder, Dale M. Johnson, and James M. Gerhart

## ABSTRACT

Morris Bridge well field is being developed to augment the city of Tampa water supply that now comes from a reservoir on the Hillsborough River. The well field is designed for a maximum withdrawal of 40 million gallons per day. The hydrogeologic framework within the 6-square-mile well field consists of a surficial sand aquifer ranging in thickness from zero to 40 feet, a confining clay layer ranging in thickness from 1 to 25 feet, and a sequence of carbonate rocks, approximately 1,100 feet thick, called the Floridan aquifer.

Most recharge to the Floridan aquifer is derived from the overlying surficial sand aquifer by downward percolation through the confining material. Part of this recharge is returned to surficial deposits within the area as upward leakage, and most of the remainder leaves the area as it flows downgradient within the Floridan aquifer.

Most water derived from test wells open to the Floridan aquifer comes from a dolomitic section of the Avon Park Limestone containing highly fractured zones at about 500 and 550 feet below the National Geodetic Vertical Datum of 1929. Highly transmissive zones are also present in parts of the Tampa Limestone, particularly to the south and southwest of the well field.

The hydrogeology of the study area was evaluated by digital-model simulation. A two-dimensional finite-difference model was calibrated under steady-state conditions and refined by simulating aquifer tests that were conducted in May 1977 and April-May 1978. Leakance (ratio of vertical hydraulic conductivity to confining-bed thickness) derived from the model was mapped for a 285 square-mile area encompassing the well field. Leakance ranged from about $2 \times 10^{-5}$ to $8 \times 10^{-3}$/day. Transmissivity derived from the model ranged from 37,000 to 600,000 feet squared per day. A storage coefficient of 0.001, estimated from aquifer tests, was satisfactory and was used in model simulations.

These values were entered into a three-dimensional model in which the surficial aquifer also became an active layer, and the Hillsborough River was allowed to interact with the surficial aquifer. The model was calibrated by varying specific yield of the surficial aquifer during a 13-day transient simulation of the May 1977 aquifer test when as much as 20 million gallons of water per day were withdrawn. Specific yield derived from the model was mapped and ranged from 0.05 to 0.30. Hydraulic conductivity of the surficial aquifer, rate of evapotranspiration, and storage coefficient of the Floridan aquifer were not varied during calibration, but sensitivity tests were made in which each parameter was varied within a feasible range to assess its relative effect on results of a 30-day transient simulation.

Because streambed leakance is the least understood of all parameters in the hydrologic system, it was modeled under two conditions--partial connection and complete connection to the surficial aquifer--in a predictive simulation. The model was run for 30 days with no pumpage from the well field; it was run again for 30 days with 40 million gallons per day being withdrawn. Results are shown as water-level change contour maps and as total-drawdown contour maps. Within the well field, total drawdown in the Floridan aquifer is as much as 15 feet; total drawdown in the surficial aquifer is as much as 7 feet.

Increased accuracy of the three-dimensional model calibration and subsequent predictions could be obtained by: (1) better definition of the surficial aquifer with respect to head distribution (particularly near the Hillsborough River), specific yield, and natural decline in head during periods of no rainfall; (2) better knowledge of areal distribution of the rate of evapotranspiration based upon study and mapping of vegetational types; and (3) more accurate monitoring of individual well pumping rates during well-field withdrawal tests.

# INTRODUCTION

Morris Bridge well field is located in northern Hillsborough County, about 20 miles northeast of Tampa Bay (fig. 1), and has an area of 6 $mi^2$. The Hillsborough River flows past the southern boundary of the well field (fig. 2). A dam across the Hillsborough River, about 15 miles downstream from the well field, forms a reservoir that has supplied the city of Tampa's water needs in the past. During dry spring months, reservoir levels have become critically low. Thus, the city of Tampa is developing the well field, with a peak pumping capacity of 40 Mgal/d, to augment the municipal water supply. This study was undertaken as part of a continuing cooperative program between the U.S. Geological Survey and the Southwest Florida Water Management District to determine the impact of well-field withdrawals on the environment.

## Purpose and Scope

The objective of this study was to describe the hydrogeologic framework of the area and to provide a quantitative description of the flow system so that the impact of well-field withdrawals on ground-water and surface-water flow could be assessed. The approach was to construct and analyze a digital model of the aquifer flow system. Modeling results serve as a basis for evaluating alternative management schemes so that the impact of well-field withdrawals on the total environment can be minimized. This report describes the hydrology and geologic framework within a 285-$mi^2$ area encompassing the 6-$mi^2$ well-field area.

## Methods of Investigation

During the investigation, all available hydrologic and geologic records from the Morris Bridge well-field area were examined and analyzed. Records included: rainfall, streamflow, lake, and ground-water level data; aquifer-test data; geologic data including geophysical logs, geologists' logs, drillers' logs, well cuttings, and streambed borings. Many of these data were used in a digital simulation model of ground-water flow in a 285-$mi^2$ area, including the 6-$mi^2$ well field.

## Previous Investigations

A discussion of the geology and hydrology of the general area is presented by Cherry and others (1970), and Menke and others (1961). Robertson and Mallory (1977) completed a regional digital model of the Floridan aquifer in an 875-$mi^2$ area, including Morris Bridge well field. Richard Wolansky of the U.S. Geological Survey (written commun., September 1976) analyzed available aquifer-test data. Motz (1975) studied the hydrologic effects of the Tampa Bypass Canal system in the southwestern part of the study area. Stewart and others (1978) completed a hydrogeologic study in the Temple Terrace area, which comprises the southwestern corner of the study area. Stewart (1977) analyzed an

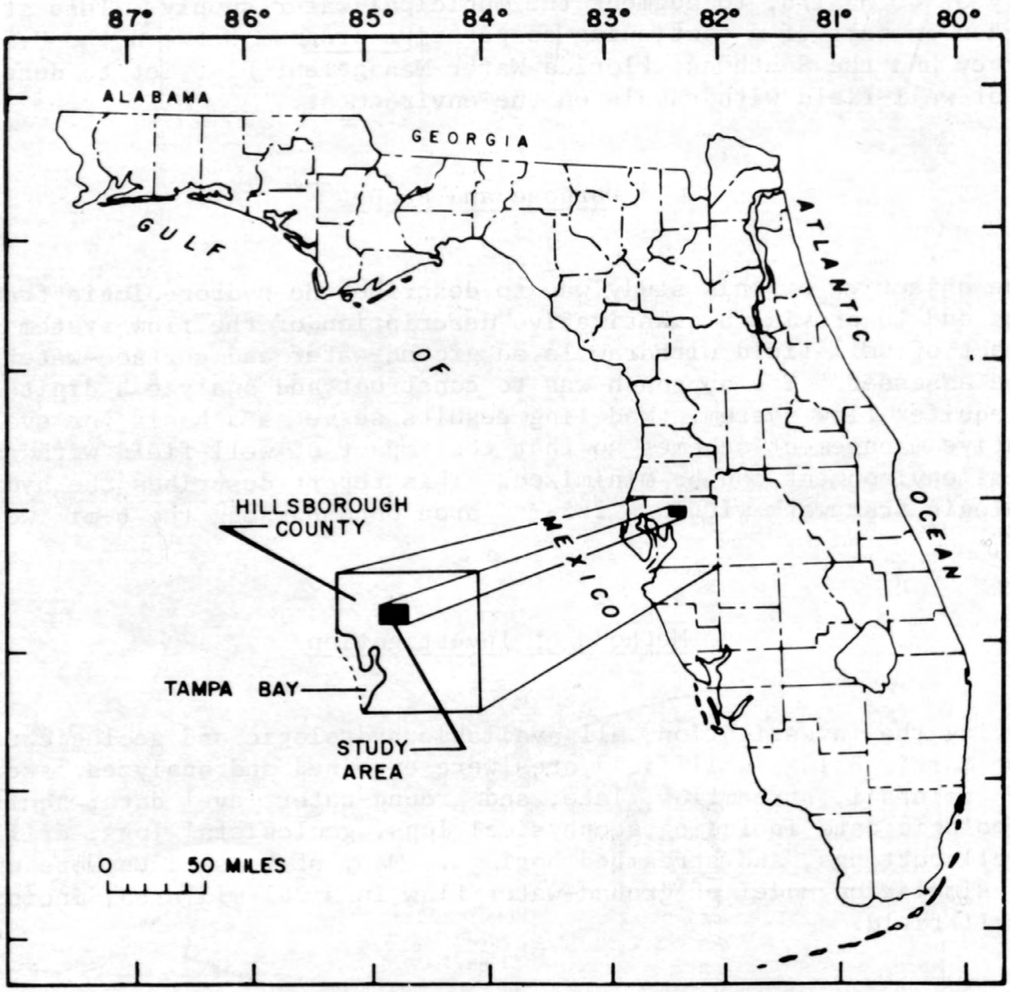
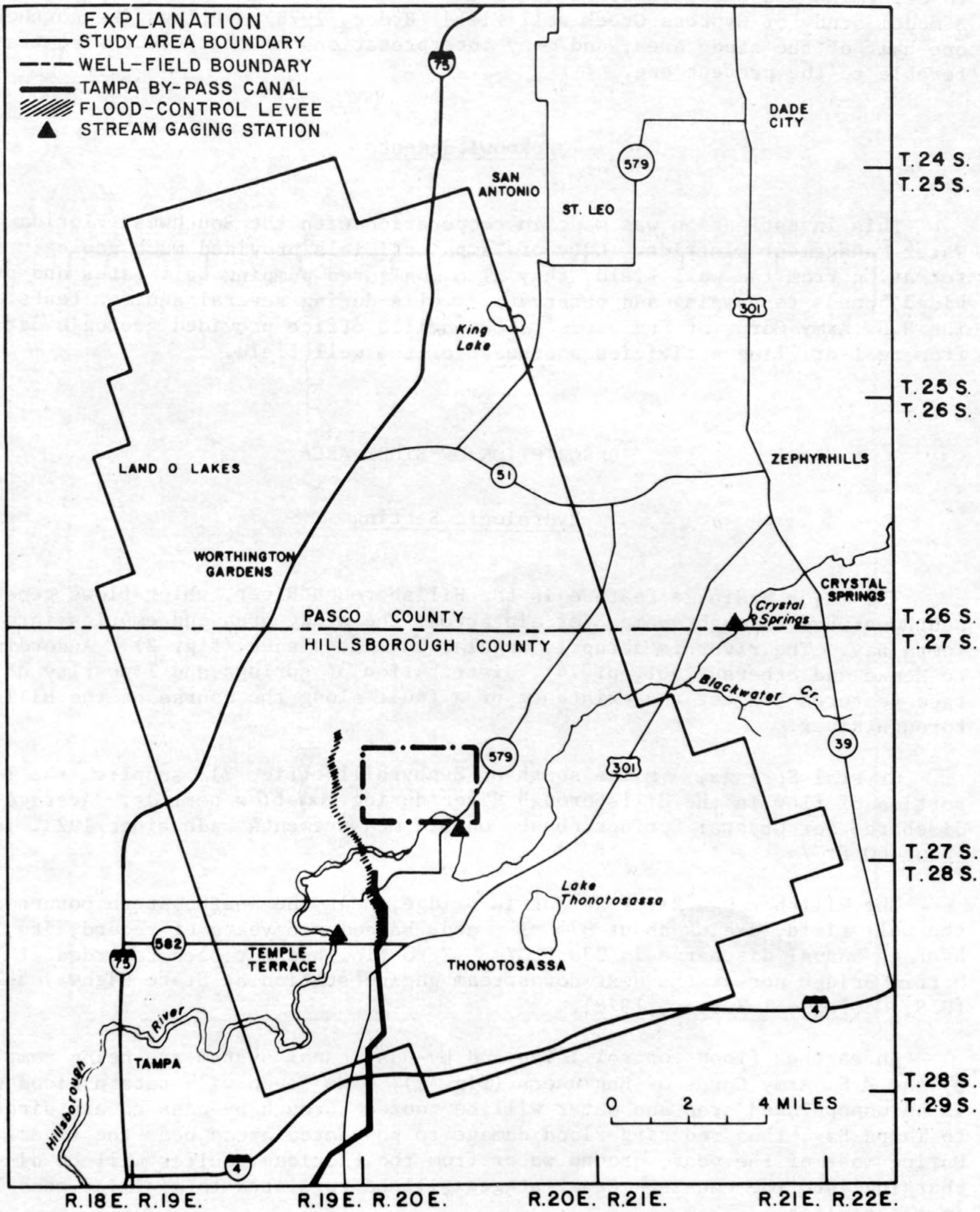



Figure 1.--Location of the study area.




BASE MODIFIED FROM FLORIDA DEPARTMENT OF TRANSPORTATION COUNTY HIGHWAY MAP

Figure 2.--Location of Morris Bridge well field and study area.

aquifer test at a large sink 1.5 miles south of the Morris Bridge well field to determine the feasibility of using the sink to supplement municipal supply. A model study of Cypress Creek well field (Ryder, 1978) overlaps the northern one-half of the study area, and many interpretations of that study were transferable to the present one.

### Acknowledgments

This investigation was made in cooperation with the Southwest Florida Water Management District. City of Tampa officials provided much geologic information from the well field; they also monitored pumping well rates and provided access to pumping and observation wells during several aquifer tests. The U.S. Army Corps of Engineers' Jacksonville office provided geologic data from test-drilling activities southwest of the well field.

## DESCRIPTION OF STUDY AREA

### Hydrologic Setting

The major drainage feature is the Hillsborough River, which flows generally southwestward through swampy terrain across the study area and empties into Tampa Bay. The river is abruptly angular in many places (fig. 2). According to Menke and others (1961, p. 74), distribution of springs and linearity of surface features suggest the existence of a fault along the course of the Hillsborough River.

Crystal Springs, 4 miles south of Zephyrhills (fig. 2), supplies the major portion of flow in the Hillsborough River during low-flow periods. Average discharge for Crystal Springs, based on 324 measurements made since 1923, is about 60 $ft^3/s$.

The Hillsborough River at Morris Bridge, near the southeastern corner of the well field, drains about 375 $mi^2$, and, based on 5 years of record, its average annual discharge is 230 $ft^3/s$. Zero flow has not been recorded at Morris Bridge nor at the next downstream gaging station at State Highway 582 (U.S. Geological Survey, 1978).

An earthen flood-control levee and by-pass canal system are being completed by the U.S. Army Corps of Engineers (fig. 2). The levee will retain flood water in an unpopulated area and water will be routed through by-pass canals directly to Tampa Bay, thus reducing flood damage to populated areas near the river. During most of the year, ground water from the Floridan aquifer will be discharging into the canals. Canal stages will be regulated to minimize head loss in the aquifer.

Long-term average annual rainfall is about 56 inches. About 60 percent occurs during summer--June through September (Pride and others, 1966, p. 24).

## Geologic Formations and Water-Bearing Characteristics

A generalized geologic column of the Morris Bridge well-field area is shown in figure 3. Rocks range in age from Eocene to Holocene and are described in the illustration.

The Lake City Limestone of Eocene age is the oldest formation shown in figure 3. The presence of anhydrite- or gypsum-filled voids in the limestone accounts for a highly mineralized (high sulfate) water and a relatively low formation permeability. The depth to the contact with the overlying Avon Park Limestone is uncertain in the well-field area.

The Avon Park Limestone contains a dolomitic section with highly fractured zones. Field tests indicate that these zones probably supply most of the water to pumping wells in the Morris Bridge well field.

The Ocala Limestone overlies the Avon Park and is also of Eocene age. Water-bearing zones in this formation are near the zone of contact with the overlying Suwannee Limestone. The Suwannee Limestone of Oligocene age is relatively permeable.

The Tampa Limestone of Miocene age overlies the Suwannee Limestone. Numerous sinks that contain large volumes of water and highly transmissive zones that underlie confining beds occur in the Tampa Limestone, particularly in nearby areas south and southwest of the well field. Supply wells in the well field are reportedly cased to depths greater than 200 feet to avoid sand-pumping and land-subsidence problems associated with these cavernous zones. Logs of wells, however, indicate these zones are probably not as well developed as in areas farther to the south.

The erosional or depositional edge of the Hawthorn Formation, Miocene age, probably occurs near the southern and western margins of the well field. The formation thickens to the south and west. Logs from the Corps of Engineers' test drilling for Structure 155 (fig. 4), near the confluence of Trout Creek and the Hillsborough River, show alternating beds of chert, limestone, silt, and clay that are characteristic of the Hawthorn.

The Hawthorn Formation is apparently absent in the well field, and the Tampa Limestone is overlain by unconsolidated deposits of sand, clay, and mixed sand and clay of Pleistocene and Holocene age. The sandy materials often supply enough water for domestic use, but they have the more important role of receiving and storing rainfall and transmitting water to the underlying limestone aquifer.

Geologic sections (figs. 4-7) show variations in thickness and character of the unconsolidated deposits. Confining-bed thickness ranges from about 1 foot in the center of the well field to about 20 feet along the eastern and western margins (fig. 8). The clay and silt layer is very thin in some areas, but generally retards vertical movement of water between the sand and the underlying limestone.

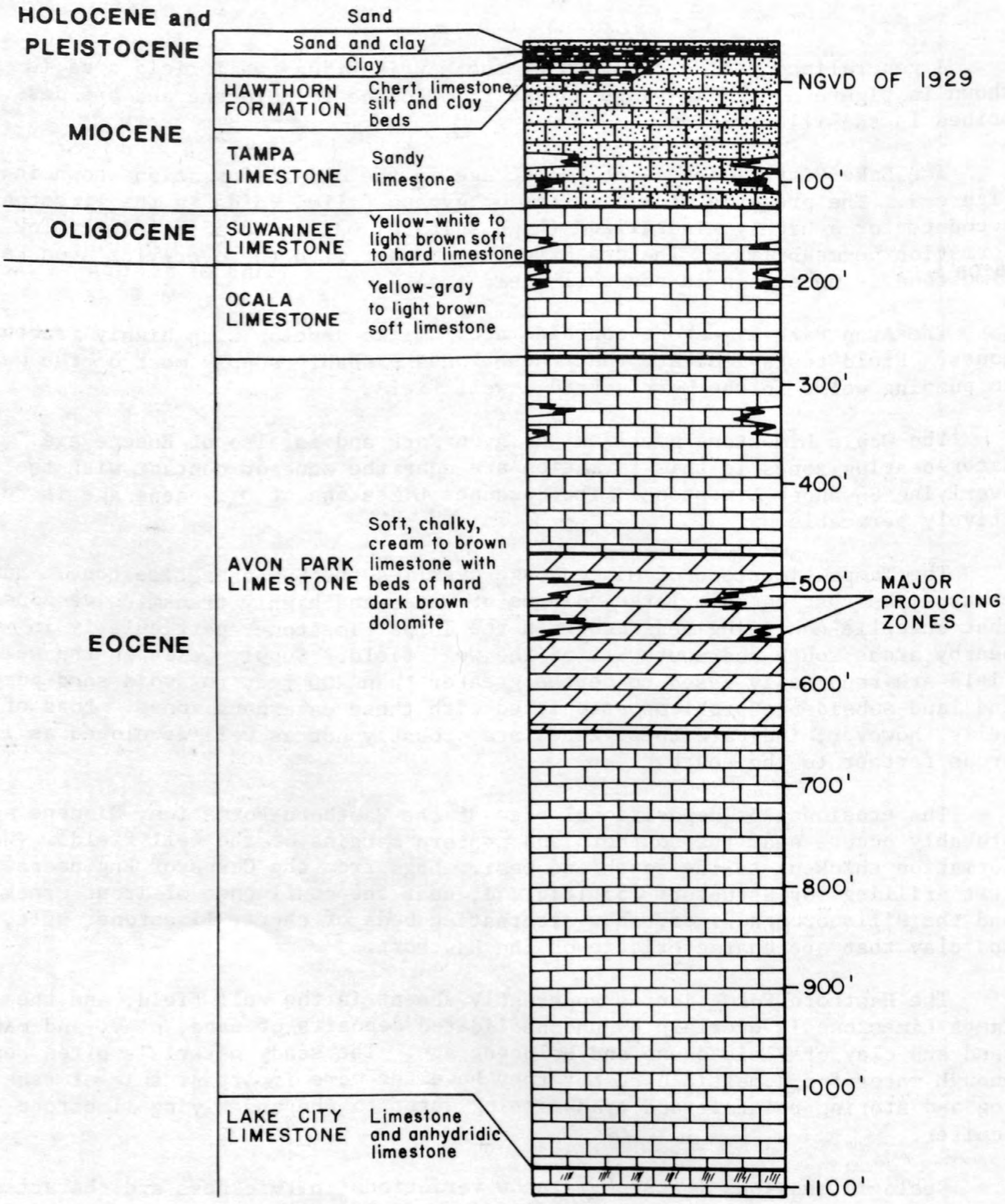



Figure 3.--Generalized geologic column of the Morris Bridge well field area.

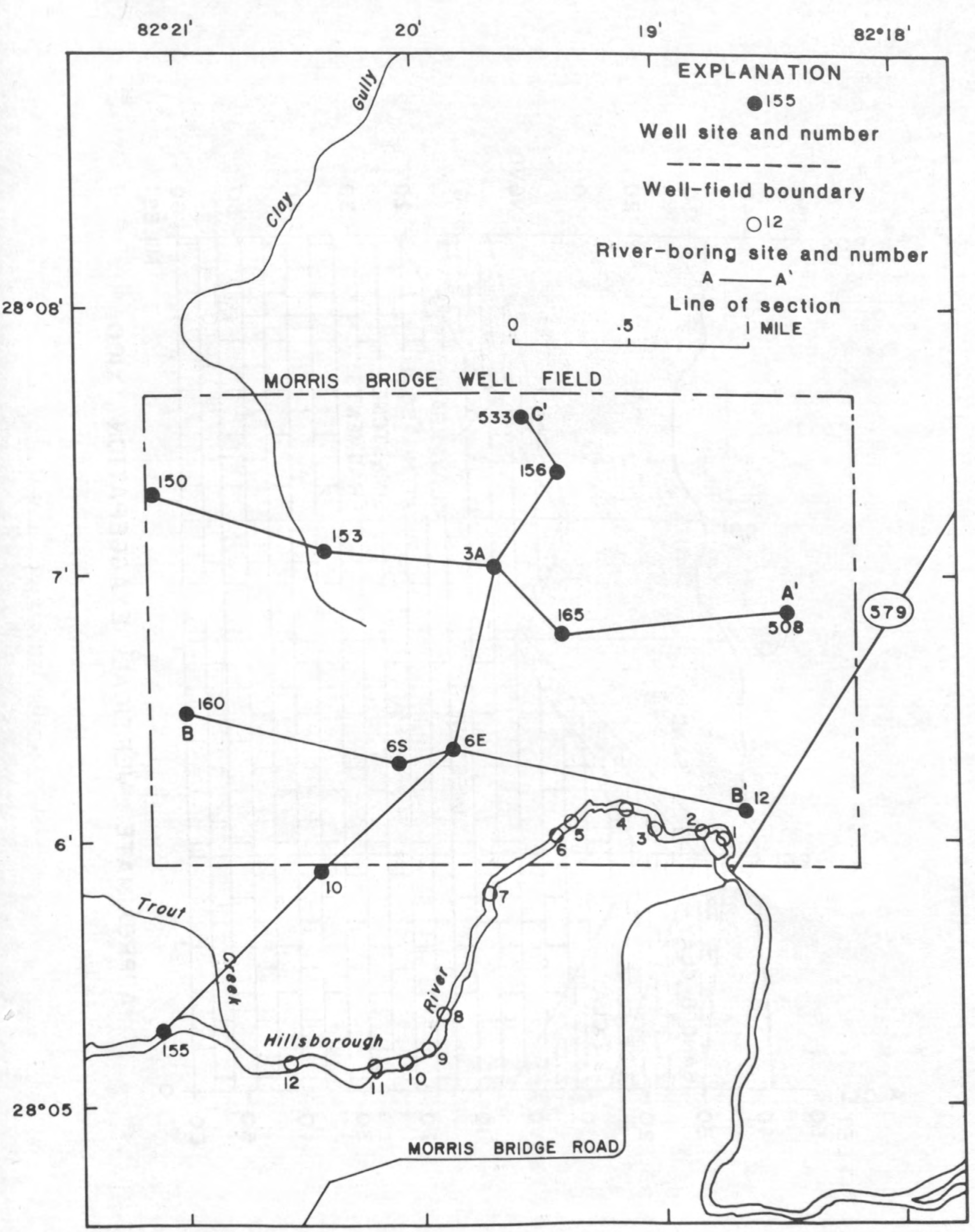



Figure 4.--Location of data sites used in constructing hydrogeologic sections in figures 5, 6, and 7.

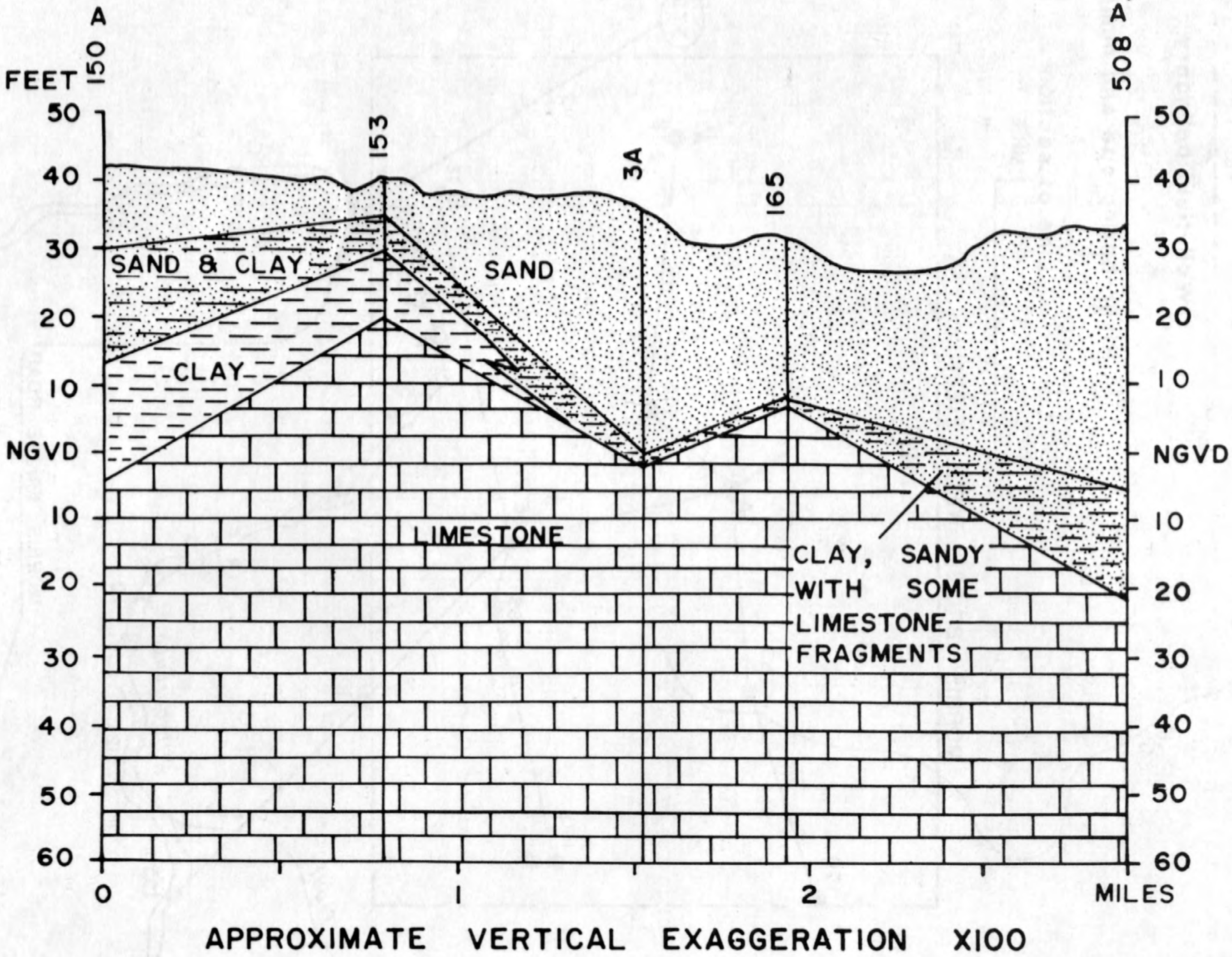



Figure 5.--Geologic section A-A'.

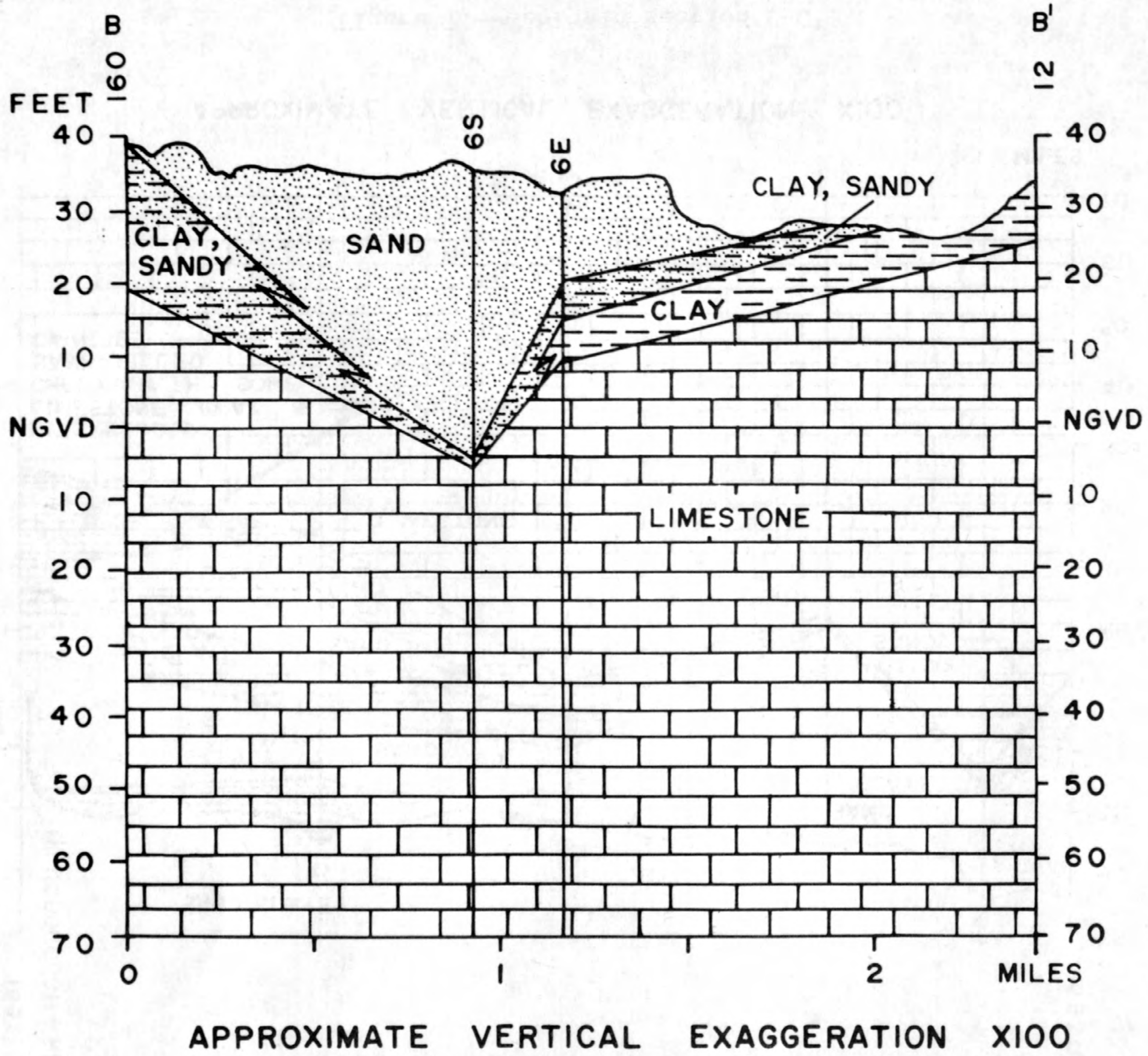



Figure 6.--Geologic section B-B'.

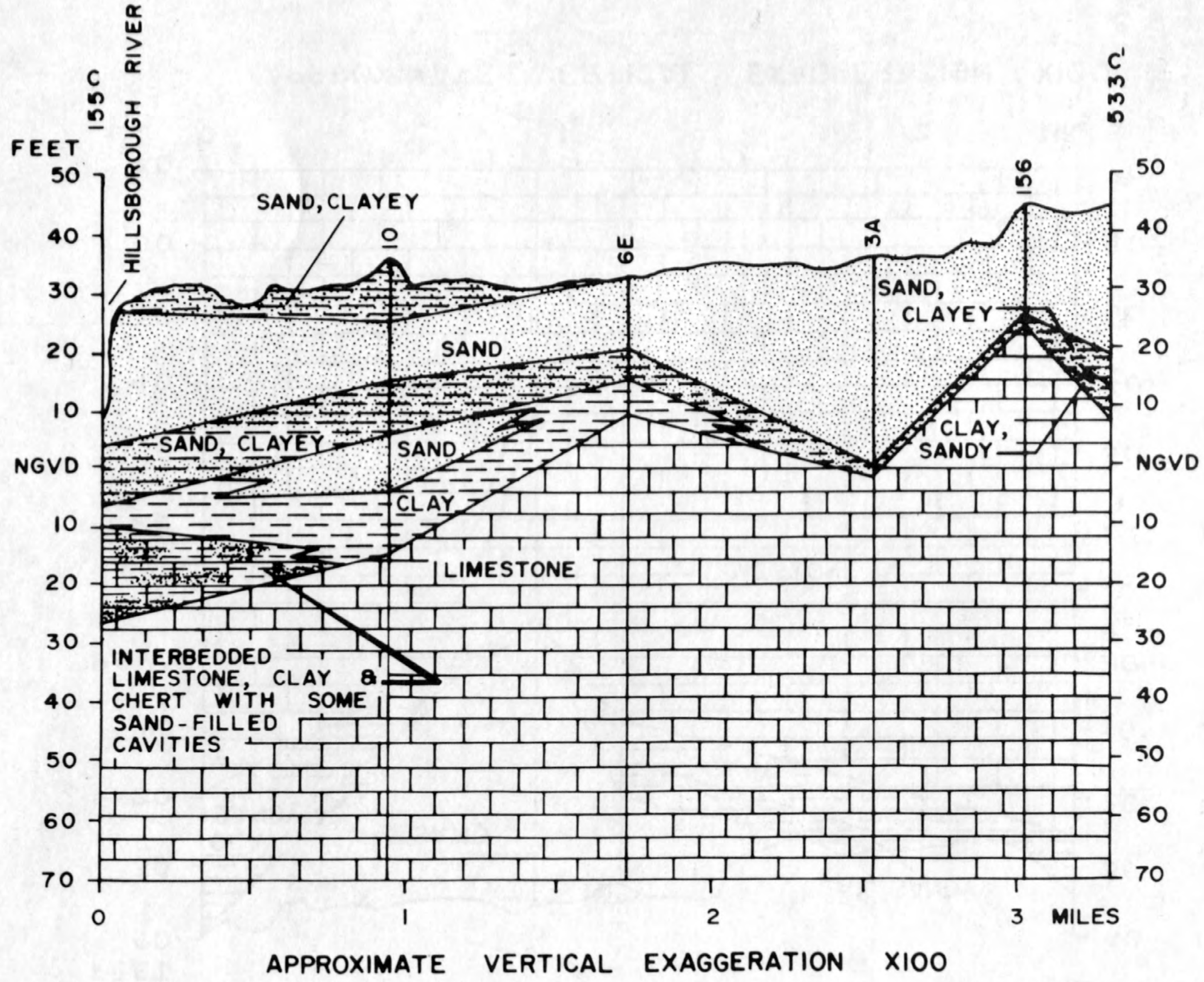



Figure 7.--Geologic section C-C'.

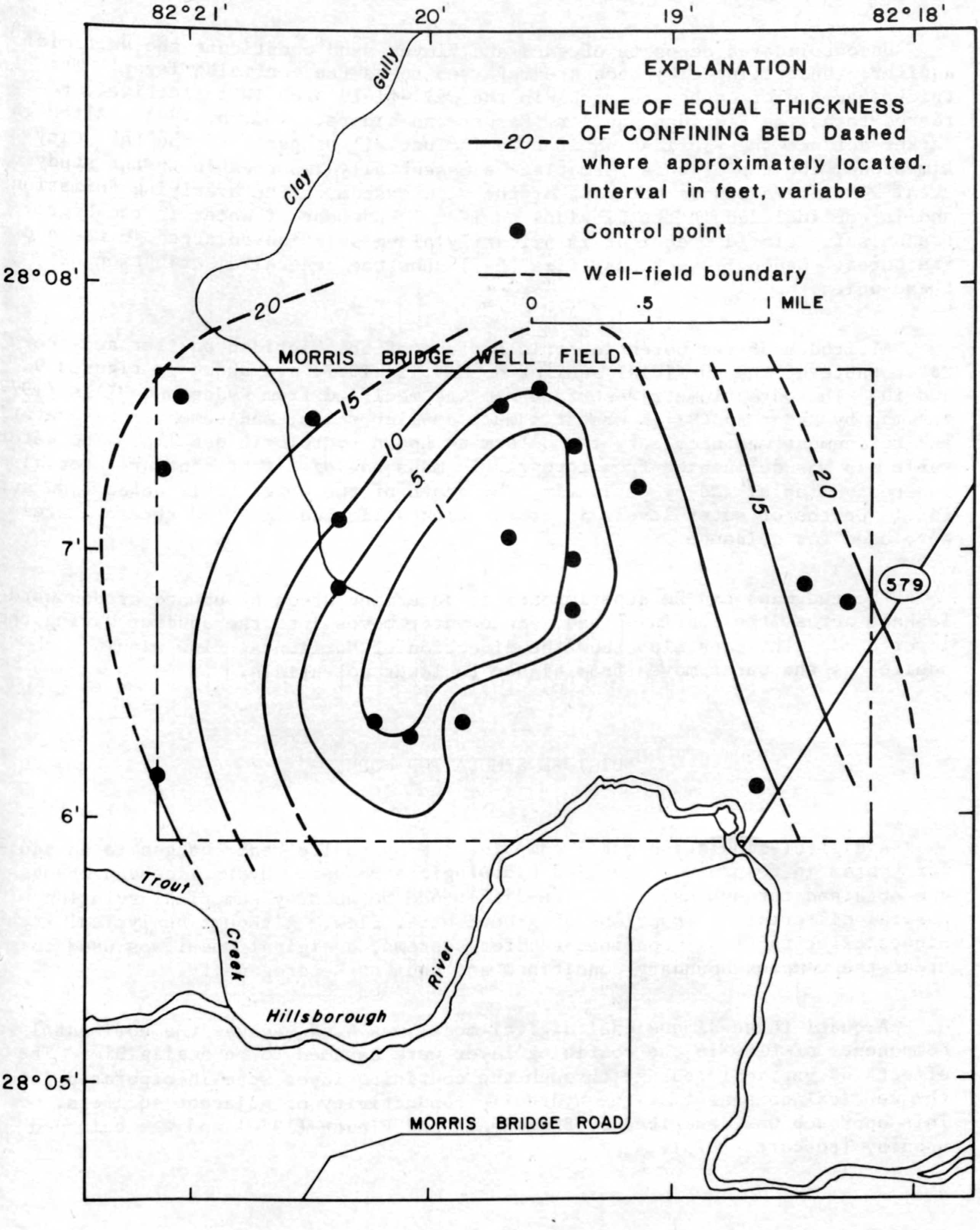



Figure 8.--Thickness of confining bed.

## Ground Water

Unconsolidated deposits of sand and clayey sand constitute the surficial aquifer. Underlying clay beds are referred to as the confining layer. The thick sequence of carbonate rocks in the well-field area is collectively referred to as the Floridan aquifer (Parker and others, 1955, p. 189). Although Parker defined the Floridan aquifer to include all or parts of the Lake City Limestone, the top of this formation is essentially impermeable in the study area. The formation is not part of the flow system of the overlying formations and is not included in the Floridan aquifer. Movement of water in the highly transmissive Floridan aquifer is primarily along solution-enlarged joints and fractures. Geologic sections (figs. 5-7) show the general distribution of these units.

Altitudes of the potentiometric surface of the Floridan aquifer and the water table of the surficial aquifer on May 11, 1977, are shown in figures 9 and 10. The potentiometric-surface map was modified from Ryder and Mills (1977); the map by Ryder and Mills was at a much smaller scale, and some reinterpretation and refinement was necessary to conform to known hydrologic details. The water-table map was delineated from topographic maps having 2-foot contour intervals (where available) and by estimating the depth of the water table below land surface. Depths of water levels in observation wells and lake and stream stages were used for guidance.

The two maps can be superimposed to determine areas of upward or downward leakage across the confining bed, since water moves into the aquifer having the lower head. The maps also show the direction of horizontal flow within each aquifer as the water moves from higher to lower potentials.

# DIGITAL SIMULATION MODEL

A digital-simulation model computes the hydraulic-head changes in an aquifer system in response to applied hydrologic stresses. Hydraulic-head changes are obtained through use of finite-difference methods by numerical solution of partial differential equations of ground-water flow. Although analytical techniques exist for leaky confined-aquifer systems, a digital model was used to treat the complex boundary conditions and aquifer heterogeneity.

A quasi-three-dimensional digital model was used because the horizontal components of flow in the confining layer were assumed to be negligible. The effects of vertical leakage through the confining layer were incorporated into the vertical component of the hydraulic conductivity of adjacent aquifers. This approach was described by Bredehoeft and Pinder (1970) and was enlarged upon by Trescott (1975).

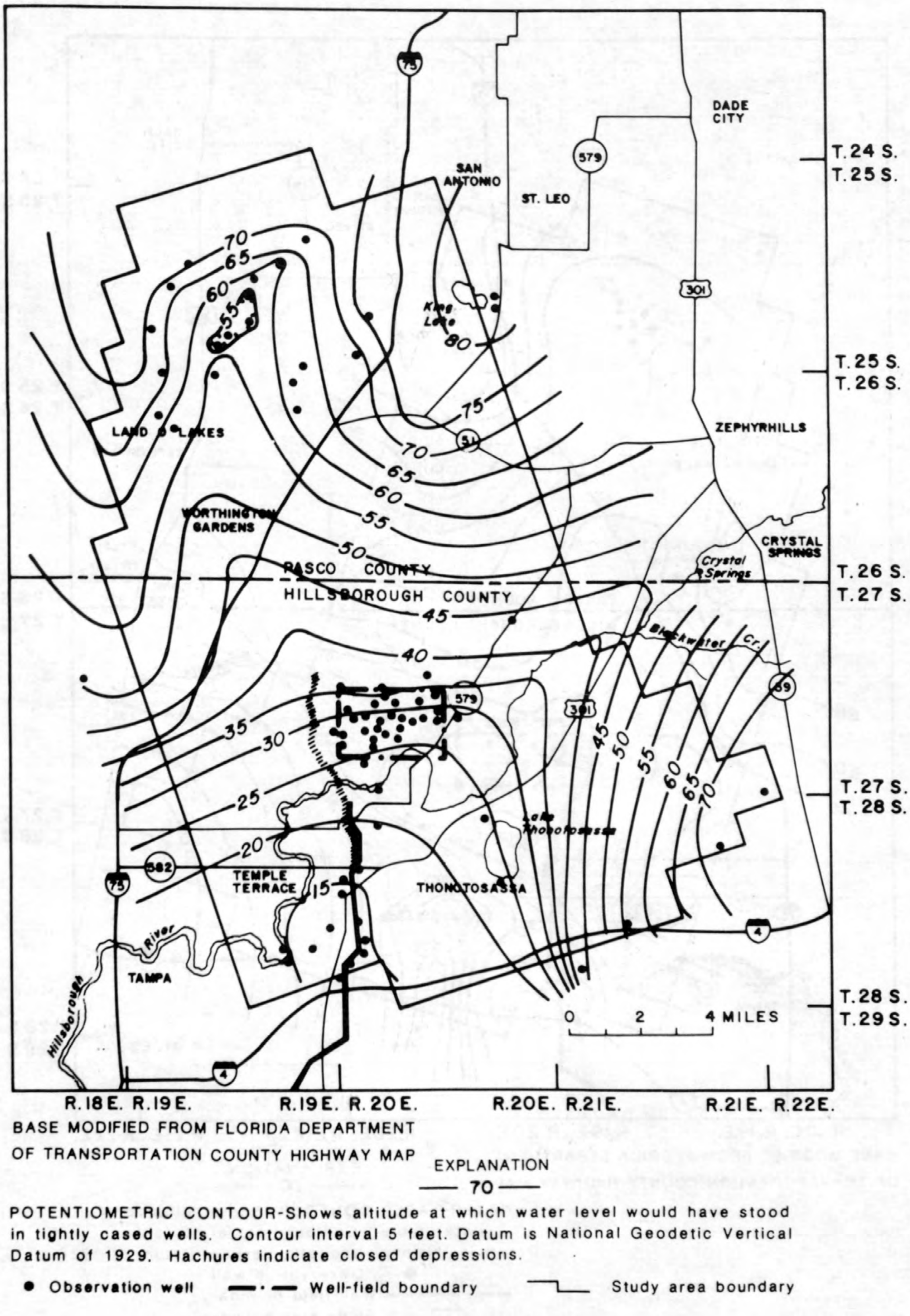



Figure 9.--Potentiometric surface of the Floridan aquifer, May 11, 1977.

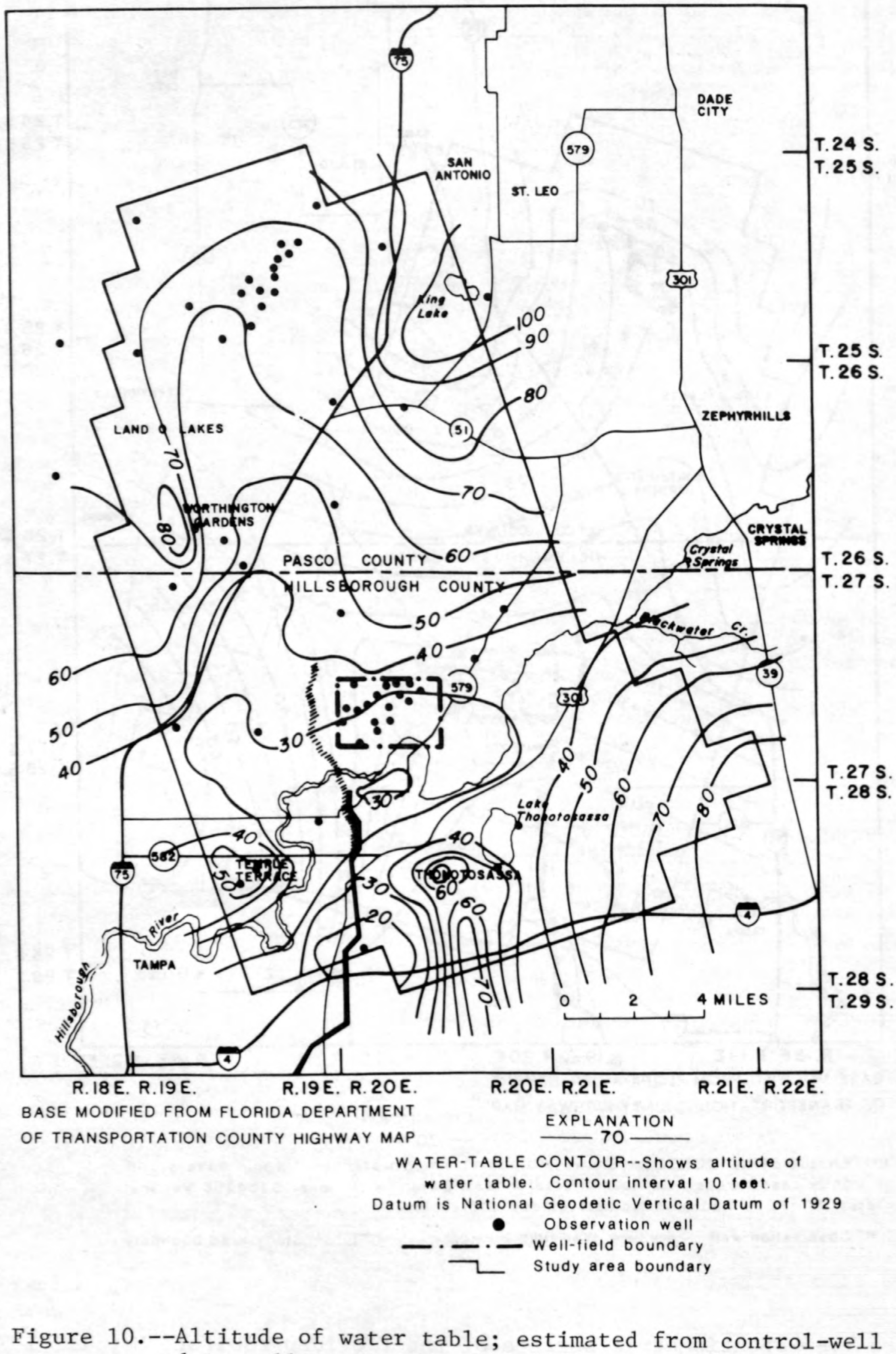



Figure 10.--Altitude of water table; estimated from control-well data collected on May 11, 1977.

## Flow Equation

The following partial differential equation of ground-water flow in a confined aquifer in three dimensions is given by Trescott (1975, p. 3) for the case where the coordinate axes are parallel to the principal directions of the hydraulic conductivity tensor:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)=S_s\frac{\partial h}{\partial t}+W(x,y,z,t) \qquad (1)$$

where $K_{xx}$, $K_{yy}$, and $K_{zz}$ are components of the hydraulic conductivity tensor ($LT^{-1}$);

h is hydraulic head (L);

t is time (T);

$S_s$ is specific storage ($L^{-1}$);

W(x,y,z,t) is volumetric flux per unit volume ($T^{-1}$).

If a hydrologic unit is to be represented by a single layer of nodes, equation 1 is multiplied by the thickness of the hydrologic unit, giving:

$$\frac{\partial}{\partial x}\left(T_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_{yy}\frac{\partial h}{\partial y}\right)+b\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)=S\frac{\partial h}{\partial t}+bW(x,y,z,t) \qquad (2)$$

where $T_{xx}$ and $T_{yy}$ are principal components of the transmissivity tensor ($L^2T^{-1}$);

S is storage coefficient (dimensionless);

b is thickness of the hydrologic unit (L).

The quasi-three-dimensional model described by Trescott (1975) was modified to provide for evapotranspiration and to allow interaction between the river and the uppermost hydrologic unit (S. P. Larson, U.S. Geological Survey, written communs., June 1976 and June 1977). The modifications are contained in the source program listing at the end of this report (Supplement I). The approach used in adding these modifications was similar to that used in the two-dimensional model described by Trescott and others (1976).

Solution to the flow equation is based on the following assumptions:

1. The Floridan and surficial aquifers are single-layer, isotropic media, with water moving in a horizontal plane.
2. Vertical movement of water between the two aquifers occurs through a confining layer.
3. The Hillsborough River is connected only to the surficial aquifer through a semiconfining streambed.
4. The limestone underlying the Floridan aquifer is impermeable.
5. Horizontal flow and storage in the confining layer are negligible.

## Finite-Difference Method

For a heterogeneous aquifer with irregular boundaries, equation 2 is solved by replacing continuous derivatives with finite-difference approximations at each node of a grid. Each node is located at the center of a block in which the hydrologic properties of the aquifer are said to be uniform. Equation 2 is written for each node where the head is unknown. This results in a system of simultaneous linear equations that are then solved by the strongly implicit procedure (SIP) described by Stone (1968). Further details of the finite-difference method and the SIP solution scheme can be found in Trescott (1975) and Trescott and others (1976).

## Discretization of Input Data

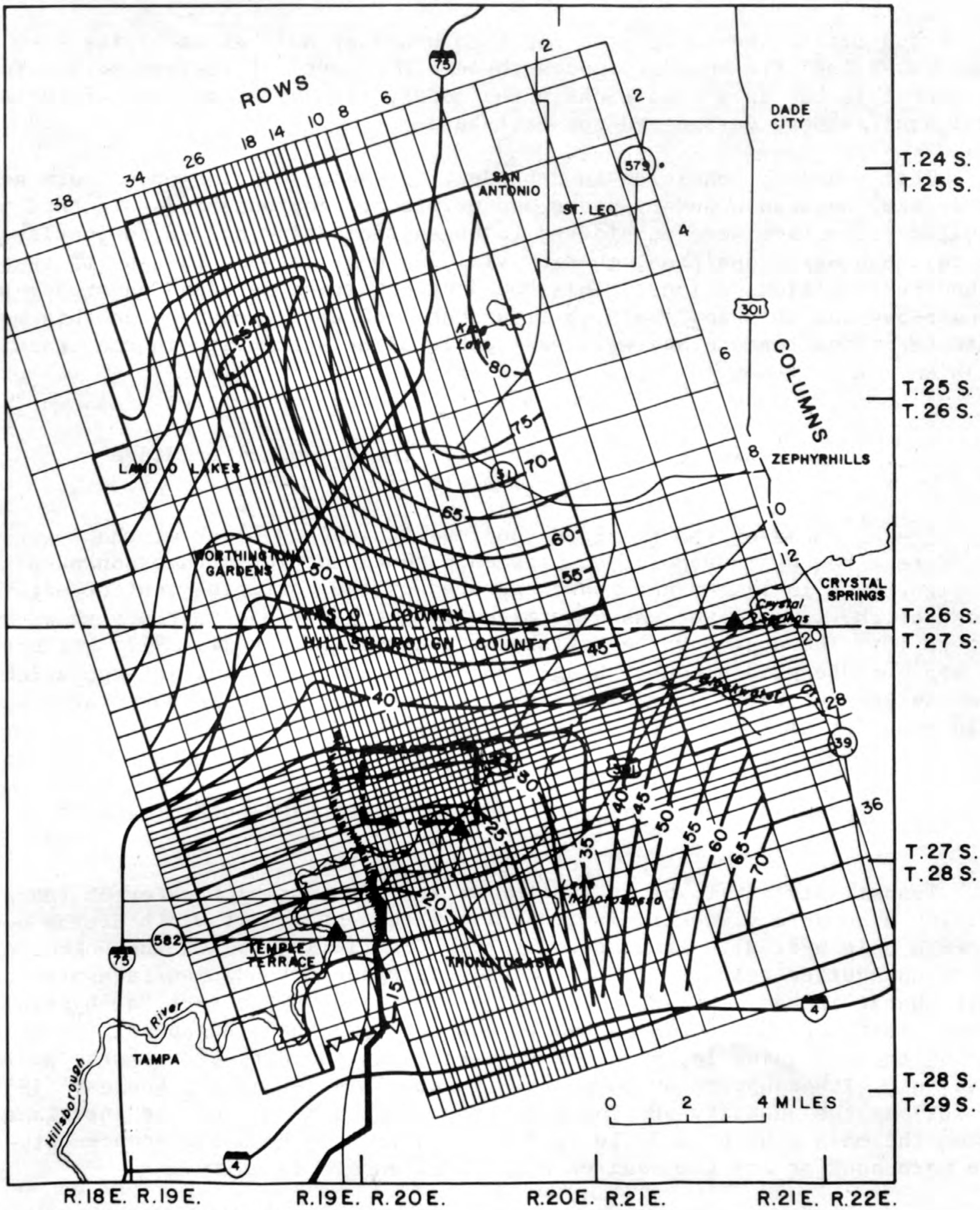
### Finite-Difference Grid and Boundary Conditions

A finite-difference grid was constructed that subdivides the study area into two layers of rectangular blocks of various sizes; the grid consists of 41 rows and 40 columns (fig. 11). The bottom layer of blocks corresponds to the Floridan aquifer and the top layer corresponds to the surficial aquifer. Blocks range in size from 1,000 x 1,000 feet in the vicinity of the well field to 9,600 x 5,000 feet near the model boundaries. Hydrologic properties of the Floridan aquifer and the surficial aquifer were assigned to each block within the modeled area according to existing data.

Two criteria were used in locating the limits of the modeled area: configuration of the potentiometric surface of the Floridan aquifer and distance to which the effects of pumping would extend. Model boundaries are generally perpendicular to the potentiometric contours on the May 1977 potentiometric-surface map (fig. 11). The model boundaries were placed sufficiently far from the well field in order to receive minimal effect from pumping stress. The area within the model boundaries is 285 $mi^2$.

Except for a short segment of the southern boundary, which was designated as constant-head because it marked the site of a stage-controlled canal, all lateral Floridan aquifer model boundaries were simulated using a head-controlled flux boundary condition. This boundary condition was selected because it allows boundary heads to change, as well as allowing cross-boundary flow to occur. The boundary condition is based on the assumption that beyond each boundary node there exists a point where the head in the Floridan aquifer will not change. For this model, constant-head locations were chosen at distances (25-80 miles) great enough to ensure that pumpages would not affect the heads there. When the effect of a stress reaches a boundary node, a change in head will cause influx to or efflux from that node of the following quantities of water:

1. Vertical leakage in that boundary node;
2. Approximate vertical leakage in the region between that boundary node and its corresponding constant-head point;
3. Lateral flow between that boundary node and its constant-head point.




BASE MODIFIED FROM FLORIDA DEPARTMENT OF TRANSPORTATION COUNTY HIGHWAY MAP

EXPLANATION

—65— POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells. Contour interval 5 feet. Datum is National Geodetic Vertical Datum of 1929.

—·— WELL-FIELD BOUNDARY

▽ MODEL BOUNDARY (constant head)

—— MODEL BOUNDARY (head-controlled flux)

▲ STREAM GAGING STATION

Figure 11.--Finite-difference grid superimposed on May 11, 1977, potentiometric surface.

These quantities are calculated for each boundary node at each time step and introduced into the boundary nodes through the vertical leakage term. To implement this boundary condition in the model, lateral boundaries of the surficial aquifer were designated constant-head.

This boundary condition is dependent on the assumption of uniform aquifer properties between boundary nodes and points of constant-head. In this model, aquifer properties were considered to be sufficiently uniform to justify use of this boundary condition, thereby yielding more reasonable results than other boundary-condition options. This boundary condition is based on steady-state conditions and does not apply to transient problems. However, in this model, effects of aquifer storage were negligible after a few days in the transient problem.

### Potentiometric Surface, Water Table, and River Stage

Average head of the Floridan aquifer within each block of the lower layer was determined by interpolating between potentiometric-surface contours shown in figure 9. In like manner, average head of the surficial aquifer within each block of the upper layer was determined from water-table contours shown in figure 10. The stage of the Hillsborough River for May 11, 1977, was entered in appropriate grid blocks. Stage was determined by linear interpolation between stage recorders at various points along the river. River stages were held constant with time for all simulations.

### Hydraulic Properties for Floridan Aquifer and Confining Layer

Transmissivity (T) of an aquifer is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. Storage coefficient (S) is the volume of water an aquifer releases from or adds to storage per unit surface area per unit change in head. Leakance (K'/b'), the ratio of the vertical hydraulic conductivity of the confining bed to the confining-bed thickness, is the ability of the confining layer to transmit water in the direction of the hydraulic gradient, either upward or downward. Leakance is defined by Hantush (1956, p. 702) as the quantity of flow that crosses a unit area of the interface between the main aquifer and the confining layer when head difference between the main aquifer and the aquifer supplying leakage is unity.

Aquifer and confining-bed properties (T, S, and K'/b') are generally determined by conducting aquifer tests in which potentiometric-level changes induced by pumping are recorded in nearby observation wells. By knowing the geologic framework, a mathematical model can be selected with which to analyze aquifer-test data.

Five aquifer-test sites and test results are shown in figure 12. Aquifer-test data were analyzed according to infinite leaky-aquifer models of Hantush and Jacob (1955) and Hantush (1956). Analyses support the premise that the quantity of water stored in the confining layer is negligible. Analyses of

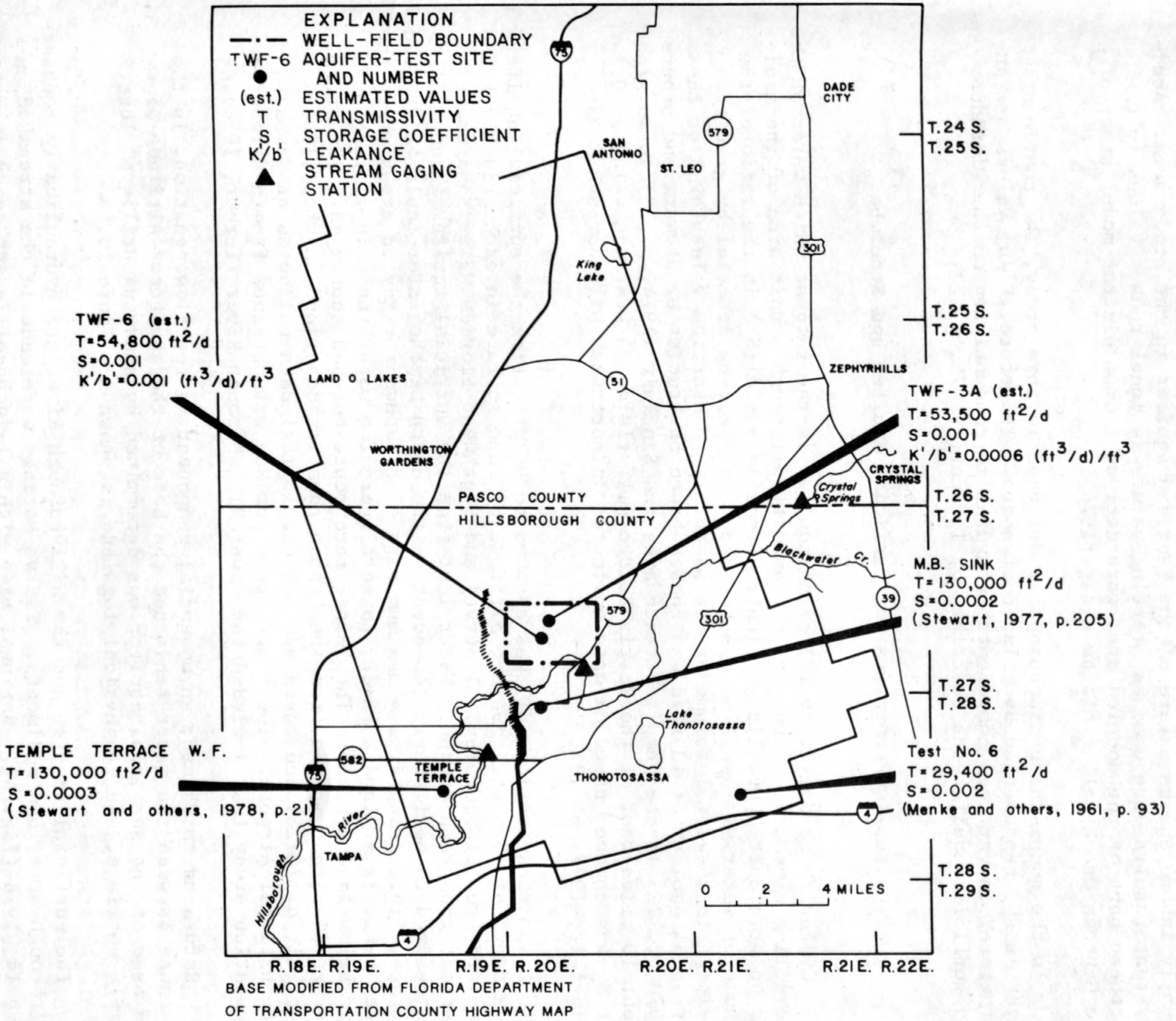



Figure 12.--Locations of aquifer-test sites and values of aquifer characteristics.

water-level changes in the Lake City Limestone during aquifer tests at Cypress Creek well field, about 12 miles to the northwest, indicate that no significant leakage occurs between the Floridan and underlying aquifers. The wide variation in T (29,400-130,000 $ft^2/d$) and S (0.0002-0.002) is indicative of the extremely inhomogeneous nature of the Floridan aquifer in the study area. Aquifer-test results were used as starting values in model runs. Values in the northern part of the modeled area were derived from a digital model study of the Cypress Creek well field by Ryder (1978).

In the quasi-three-dimensional model used in this study, the confining layer is not represented by a layer of nodes. Therefore, K'/b' values are incorporated in vertical components of hydraulic conductivity of the Floridan and surficial aquifers as described by Trescott (1975, p. 28).

### Hydraulic Properties for Surficial Aquifer and Streambed

Hydraulic conductivity (K) of an aquifer is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit area of the aquifer under a unit hydraulic gradient. Specific yield ($S_y$) is the ratio of the volume of water yielded from a saturated water-bearing material by gravity drainage to the total volume of the material. A starting value for K of the surficial aquifer of 13 ft/d was chosen based on studies by Stewart and others (1978, p. 22) in the Temple Terrace area and Sinclair (1974, p. 13) in an area about 10 miles west of the Morris Bridge well field. A starting value of 0.2 for $S_y$ was chosen, based on data collected in northwest Hillsborough County (Sinclair, 1977, p. 13).

Evapotranspiration (ET) was assumed to be affecting the surficial aquifer to a depth of 15 feet. Average altitude of land surface in each grid block was obtained from U.S. Geological Survey and Southwest Florida Water Management District topographic maps. Water lost from the surficial aquifer through ET was assumed to be linearly dependent on the depth of the water table below land surface, fluctuating from a maximum rate of 5 inches for May in areas where the water table is at land surface, to zero where the water table is 15 feet or more below land surface. The 5-inch rate represents an approximate long-term average ET rate computed from the Penman equation described in Chow (1964, chap. 11, p. 26-28) and based upon meteorological data collected at Tampa International Airport. The 5-inch rate for May was obtained from a streamflow simulation study that included the lower Hillsborough River (Turner, 1978).

Saturated thickness, an essential component in the flow equation, is the distance between the water table and the base of the aquifer. Altitude of the base of the surficial aquifer was determined by studying drillers' logs, sample cuttings, and geophysical logs and is shown in figure 13.

The surficial aquifer and the Hillsborough River are hydraulically connected through streambed sediments. Twelve borings were made in the streambed on June 14, 1978 (fig. 4). Borings, made with a 1-inch soil auger, gave an approximate indication of thickness and character of streambed material. At each site, boring was continued until further progress was not possible; mean depth

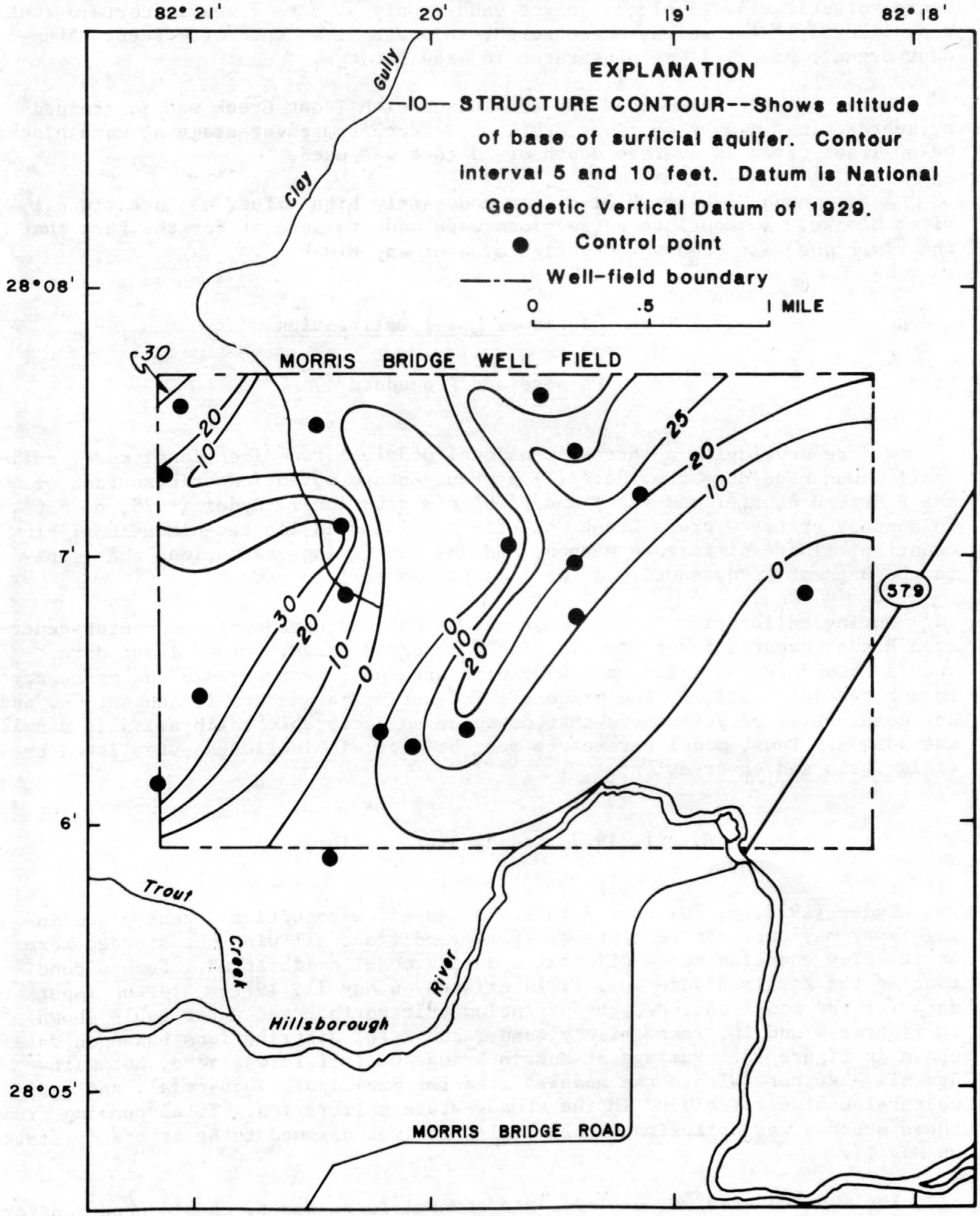



Figure 13.--Altitude of base of surficial aquifer.

of penetrated sediments was about 7 feet. Materials penetrated ranged from dense, plastic clay to clean, coarse sand. Only at site 7 was it certain that consolidated limestone was encountered; this was at a depth of 7 feet. Abundant organic material was penetrated in many borings.

Streambed altitude above the confluence with Trout Creek was determined by subtracting an average river depth of 3 feet from river stage at each block; below Trout Creek an average depth of 15 feet was used.

A streambed K'/b' of 0.01 $d^{-1}$, a moderately high value, was used in all river blocks. Appropriate corrections were made to account for the fact that the river does not occupy the entire area of any block.

## Two-Dimensional Model Calibration

### Purpose and Procedure

Before developing a three-dimensional model, a two-dimensional model calibration was needed to provide: (1) a steady-state potentiometric surface of the Floridan aquifer and (2) T and K'/b' distributions. Ryder (1978, p. 5-6), in a study of the Cypress Creek well field, discusses the two-dimensional flow equation, finite-difference method, and the underlying assumptions that apply to the present study equally as well as to the earlier study.

During calibration, aquifer parameters were adjusted until computer-generated heads compared favorably with field-observed heads. Other input data, such as boundary conditions and hydraulic stresses, were adjusted as necessary to achieve calibration. The process of adjusting parameters is subjective, and any combination of parameters that produces an acceptable calibration is usually not unique. Thus, model parameters must be kept within limits established by field tests and observations.

### May 11, 1977, Steady-State Calibration

Ryder (1978, p. 10) showed that a steady-flow condition across a confining layer may approximate a steady-state condition, allowing the storage term in the flow equation to be eliminated during model calibration. Such a condition in the Morris Bridge well field existed on May 11, 1977. Startup input data for the model included the potentiometric surface and water table shown in figures 9 and 10, respectively, and T and K'/b' distributions based on data shown in figure 12. Pumpage at Morris Bridge well field was zero, but withdrawals elsewhere within the modeled area for municipal, industrial, and agricultural use were included in the steady-state calibration. Total pumping from these sources was approximately 22 Mgal/d and was assumed to be at steady state on May 11.

The modeled area was divided into several large zones, chosen upon aquifer-test results and knowledge of the hydrogeologic framework. Aquifer parameters were adjusted in each zone in steady-state computer runs until the computed potentiometric surface closely approximated the observed May 11, 1977, surface. Steady-state calibration was accomplished by trial and error, and by employing a parameter-estimation model that computes parameters by performing a nonlinear regression analysis (R. L. Cooley and S. P. Larson, U.S. Geological Survey, written commun., March 1978).

## May 12-25, 1977, Transient Calibration

A natural-flow, steady-state calibration can be improved or refined by withdrawing large amounts of water from the principal aquifer and comparing observed drawdowns with drawdowns obtained by model simulation of actual pumpage. Aquifer parameters are adjusted until differences between observed and calculated drawdowns at each observation well are reduced to an acceptable value.

Such a withdrawal test was made within the Morris Bridge well field from May 12 to 31, 1977. A significant amount of rainfall occurred on or about May 26; therefore, only the first 13 days of the test were used. Figure 14 shows the location of pumping and observation wells for the test. For about the first 7 days, 5 wells were pumping a total of 10 Mgal/d, and for the remainder of the test, 10 wells (the same 5 plus 5 additional wells) were pumping 20 Mgal/d. Individual well pumping rates were metered, and no significant rainfall occurred until May 26. A storage coefficient of 0.001 was chosen for the simulations and was not changed during calibration. Computed drawdowns were superimposed on the natural-flow system as described in Trescott and others (1976, p. 30). A correction of 0.08 ft/d, obtained from hydrographs, was used to correct for natural recession of the potentiometric surface. Results for May 25, the last day of the 13-day transient simulation, are given in table 1.

## April 24-May 1, 1978, Transient Calibration

Location of pumping and observation wells for a withdrawal test from April 24 to May 1, 1978, are shown in figure 15. Several factors affected the test: (1) because of faulty equipment, individual pumping rates were not monitored during the test; (2) because of mechanical difficulties with pumping wells, they yielded less than the planned 40 Mgal/d; and (3) several heavy rains occurred during the first week of May. Nevertheless, pumping rates at individual wells were estimated, computed drawdowns were superimposed on the natural-flow system for the pre-rainfall period April 24-May 1, 1978, and appropriate recession corrections were made. This test was used in an approximate way to refine the calibration in the vicinity of three observation wells near the Hillsborough River, shown in figure 15 as well 12, Nature's Classroom, and TCR.

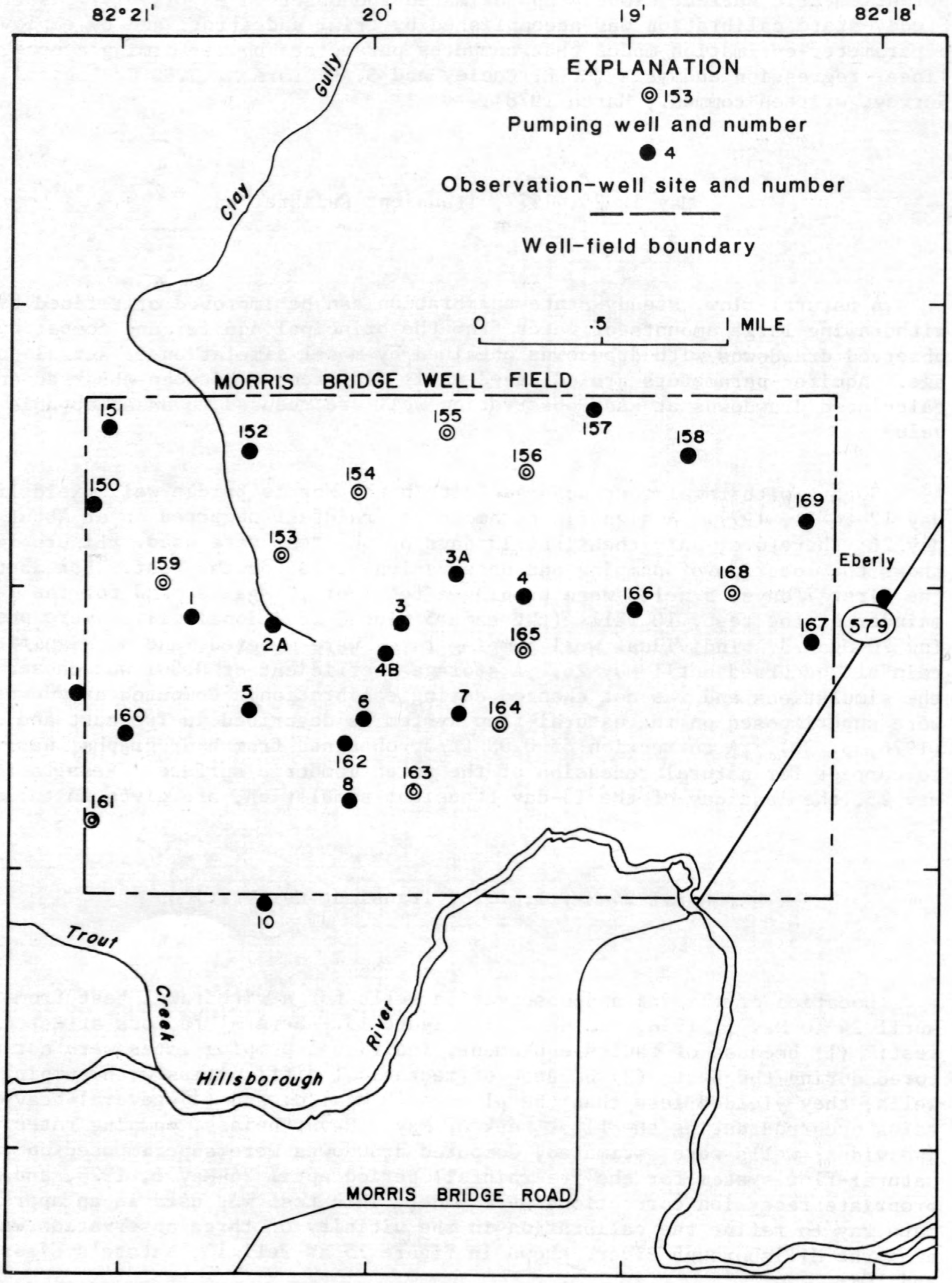



Figure 14.--Location of pumping wells and observation wells, May 12-25, 1977, transient conditions.

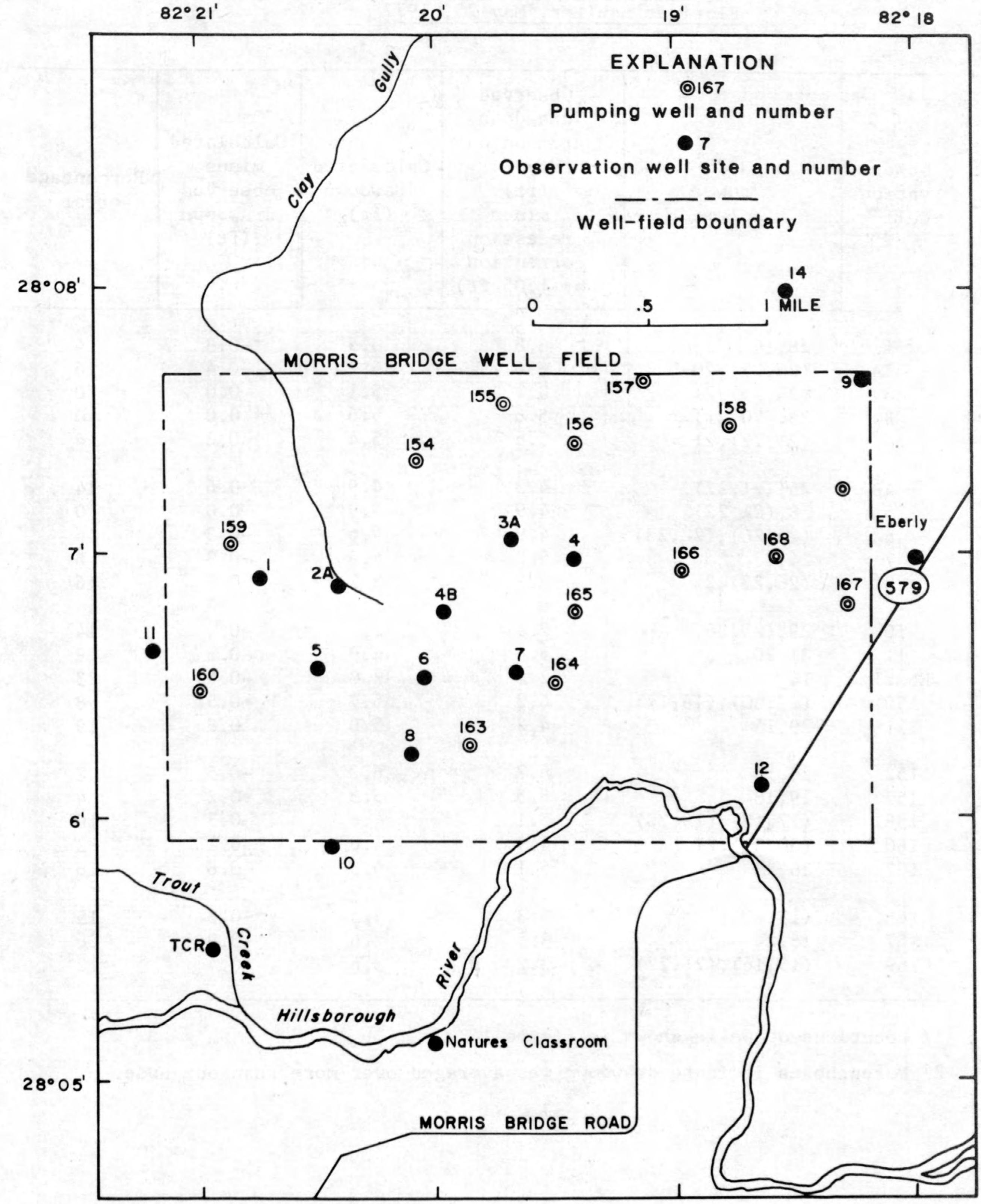



Figure 15.--Location of pumping wells and observation wells, April 24-May 1, 1978, transient conditions.

Table 1.--Observed and calculated drawdowns in wells tapping the Floridan aquifer, May 25, 1977

| Observation well 1/ | Node row, column | Observed drawdown at noon on May 25 (ft) (minus recession correction of 1.05 ft) | Calculated drawdown (ft) | Calculated minus observed drawdown (ft) | Percentage error |
|---|---|---|---|---|---|
| 1 | 28,19 | 6.8 | 6.5 | -0.3 | 4 |
| 2A | (26,27),20 2/ | 6.6 | 6.2 | -0.4 | 6 |
| 3 | (24,25),21 | 5.1 | 5.1 | 0.0 | 0 |
| 4 | 23,(20,21) | 5.6 | 5.6 | 0.0 | 0 |
| 4 | (21,22),21 | 5.6 | 5.4 | -0.2 | 4 |
| 4B | 25,(21,22) | 4.3 | 4.9 | 0.6 | 14 |
| 5 | 28,(21,22) | 4.9 | 4.9 | 0.0 | 0 |
| 6 | (25,26),(22,23) | 4.9 | 4.6 | -0.3 | 6 |
| 7 | 24,23 | 5.2 | 4.9 | -0.3 | 6 |
| 8 | (26,27),24 | 3.2 | 3.7 | 0.5 | 16 |
| 10 | 29,(25,26) | 2.9 | 2.5 | -0.4 | 14 |
| 11 | 31,20 | 5.4 | 4.9 | -0.5 | 9 |
| Eberly | 14,24 | 2.6 | 2.0 | -0.6 | 23 |
| 150 | (29,30),(16,17) | 6.2 | 5.7 | -0.5 | 8 |
| 151 | 29,15 | 4.2 | 5.0 | 0.8 | 19 |
| 152 | 26,16 | 6.7 | 6.2 | -0.5 | 7 |
| 157 | 19,18 | 5.5 | 5.3 | -0.2 | 4 |
| 158 | (17,18),(19,20) | 5.1 | 4.6 | -0.5 | 10 |
| 160 | (30,31),21 | 4.9 | 4.8 | -0.1 | 2 |
| 162 | 26,23 | 5.1 | 4.3 | -0.8 | 16 |
| 166 | (19,20),22 | 5.3 | 4.5 | -0.8 | 15 |
| 167 | 16,24 | 3.5 | 2.6 | -0.9 | 26 |
| 169 | (15,16),(21,22) | 3.2 | 3.6 | 0.4 | 12 |

1/ Locations of wells shown in figure 14.

2/ Parentheses indicate drawdown was averaged over more than one node.

Refined May 11, 1977, Steady-State Calibration

Comparison of computed and observed potentiometric surface for May 11, 1977, using aquifer parameters as refined by the two withdrawal tests, are shown in figure 16. Residuals were plotted to test for normal distribution with zero mean and constant variance, and were analyzed for mean, standard deviation, and minimum and maximum deviation. Results are presented in the following table:

| | Mean | Standard deviation | Minimum deviation | Maximum deviation |
|---|---|---|---|---|
| At all 1,380 nodes | -0.3 ft | 1.02 ft | -4.5 ft | 3.5 ft |
| At 77 observation-well nodes | -0.4 ft | 1.01 ft | -3.0 ft | 2.0 ft |

Estimates of transmissivity and leakance derived from the two-dimensional model calibration are shown in figures 17 and 18, respectively. Transmissivity ranges from 37,000 $ft^2/d$ in the southeastern part of the study area to 600,000 $ft^2/d$ in the southwestern part. Comparison of figures 17 and 12 shows the model-derived transmissivity of 600,000 $ft^2/d$ is several times greater than the aquifer-test transmissivity of 130,000 $ft^2/d$. This may be accounted for by the fact that test wells at Temple Terrace well field penetrated less than 400 feet of the highly anisotropic aquifer, which is about 1,100 feet thick at this site. Model-derived leakance ranges from about $2 \times 10^{-5}$ $d^{-1}$ ($23 \times 10^{-9}$ $sec^{-1}$) in the southwest to about $8 \times 10^{-3}$ $d^{-1}$ ($92 \times 10^{-9}$ $sec^{-1}$) within and southeast of the well field (fig. 18).

## Three-Dimensional Model Calibration

Using the same grid configuration, T and K'/b' distributions derived from the two-dimensional (2-D) calibration were used as input into the quasi-three-dimensional (3-D) model. Additional input data for the now-active upper layer and the stream-aquifer interconnection were previously discussed. The potentiometric surface that was calculated for the 2-D steady-state calibration became the starting head for the Floridan aquifer in the 3-D model. Boundaries that were used in the Floridan aquifer in the 2-D model were retained in the 3-D model. Boundary nodes in the surficial aquifer in the 3-D model were made constant head.

### May 12-25, 1977, Transient Calibration

Surficial-aquifer and streambed parameters, including $S_y$, K, ET, and streambed K/b, were varied within feasible limits to test the system's sensitivity to each based on drawdowns for the May 12-25, 1977, test. Results,

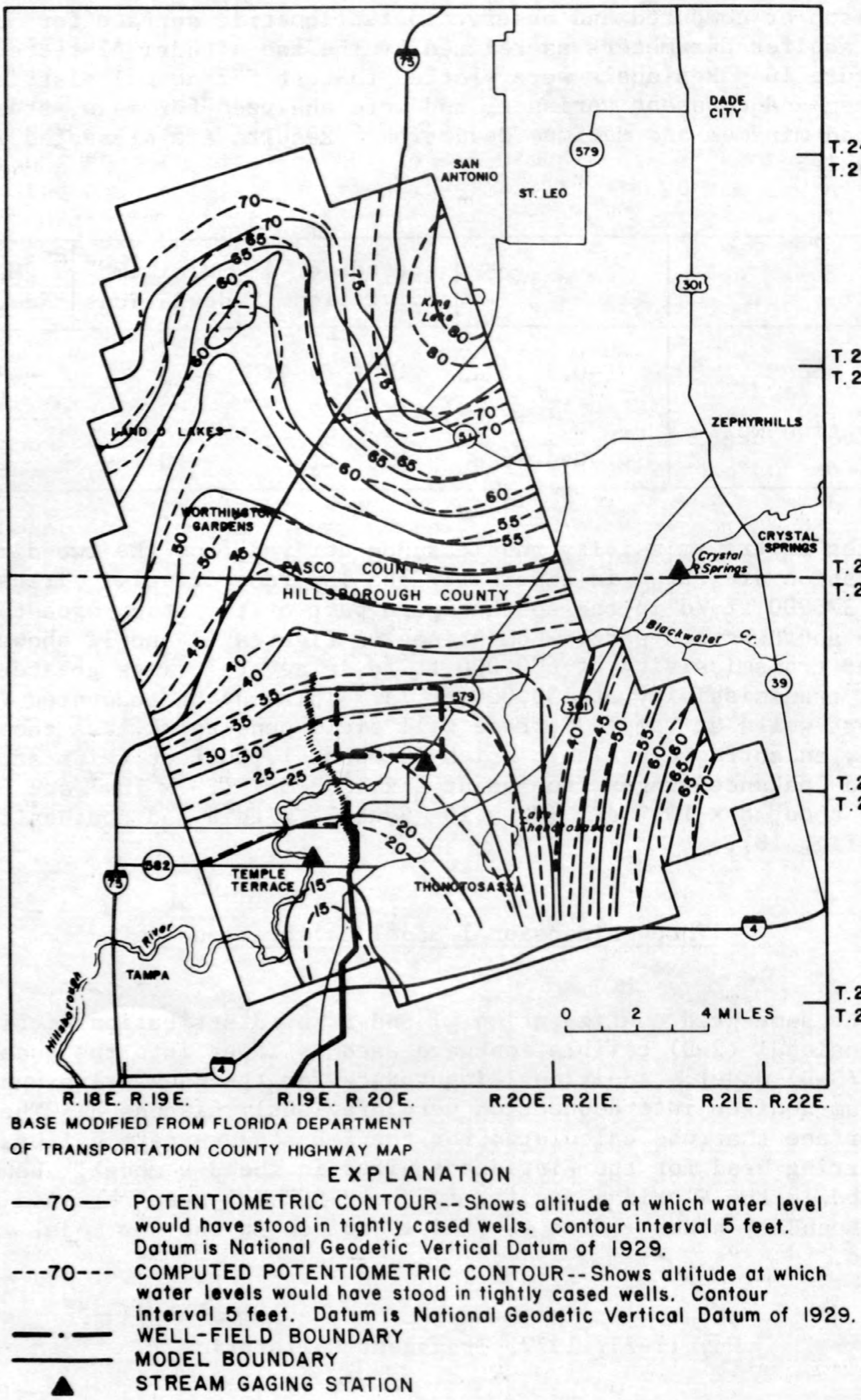



Figure 16.--Observed and computed potentiometric surface, May 11, 1977.

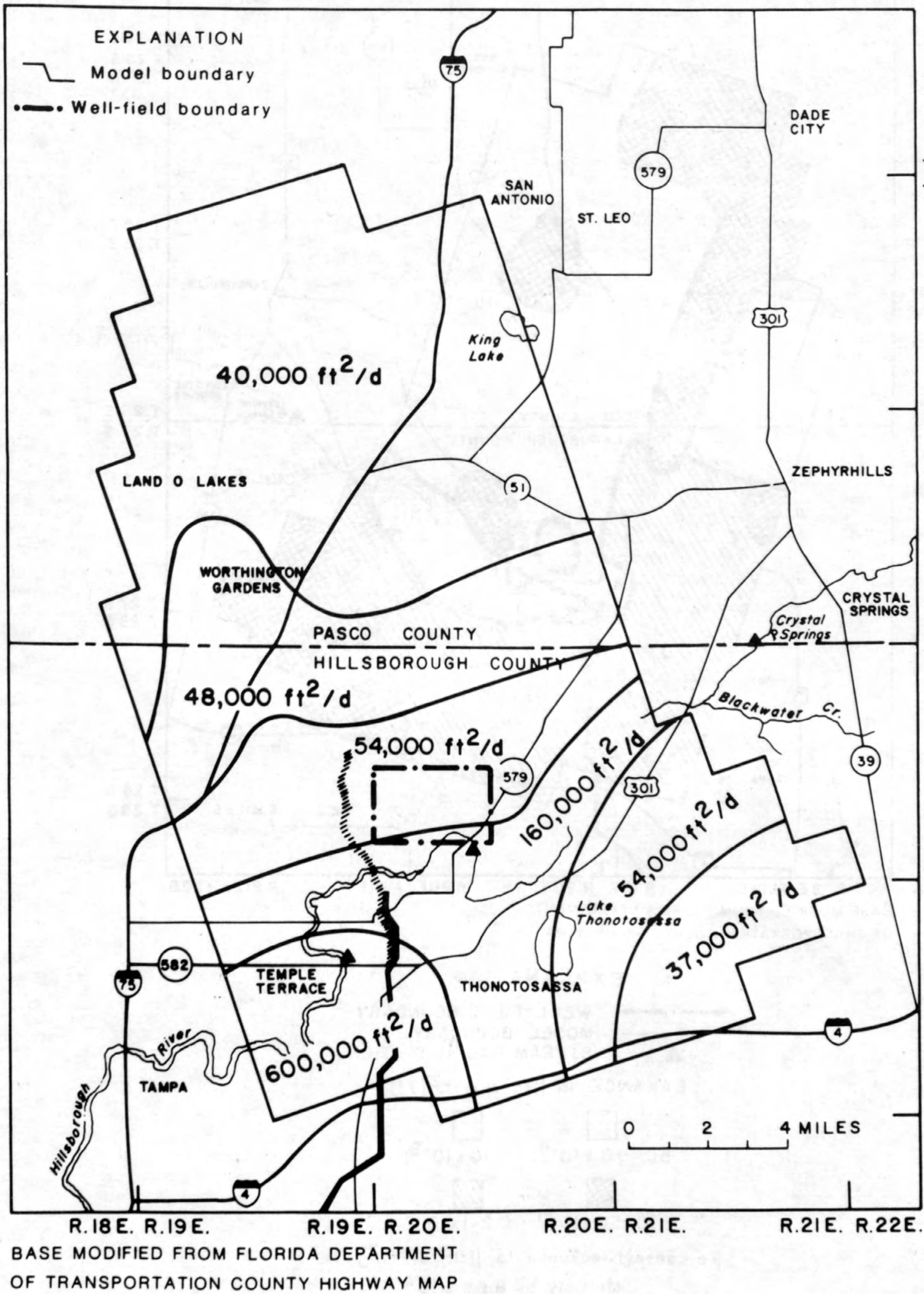



Figure 17.--Transmissivity distribution derived from model calibration.

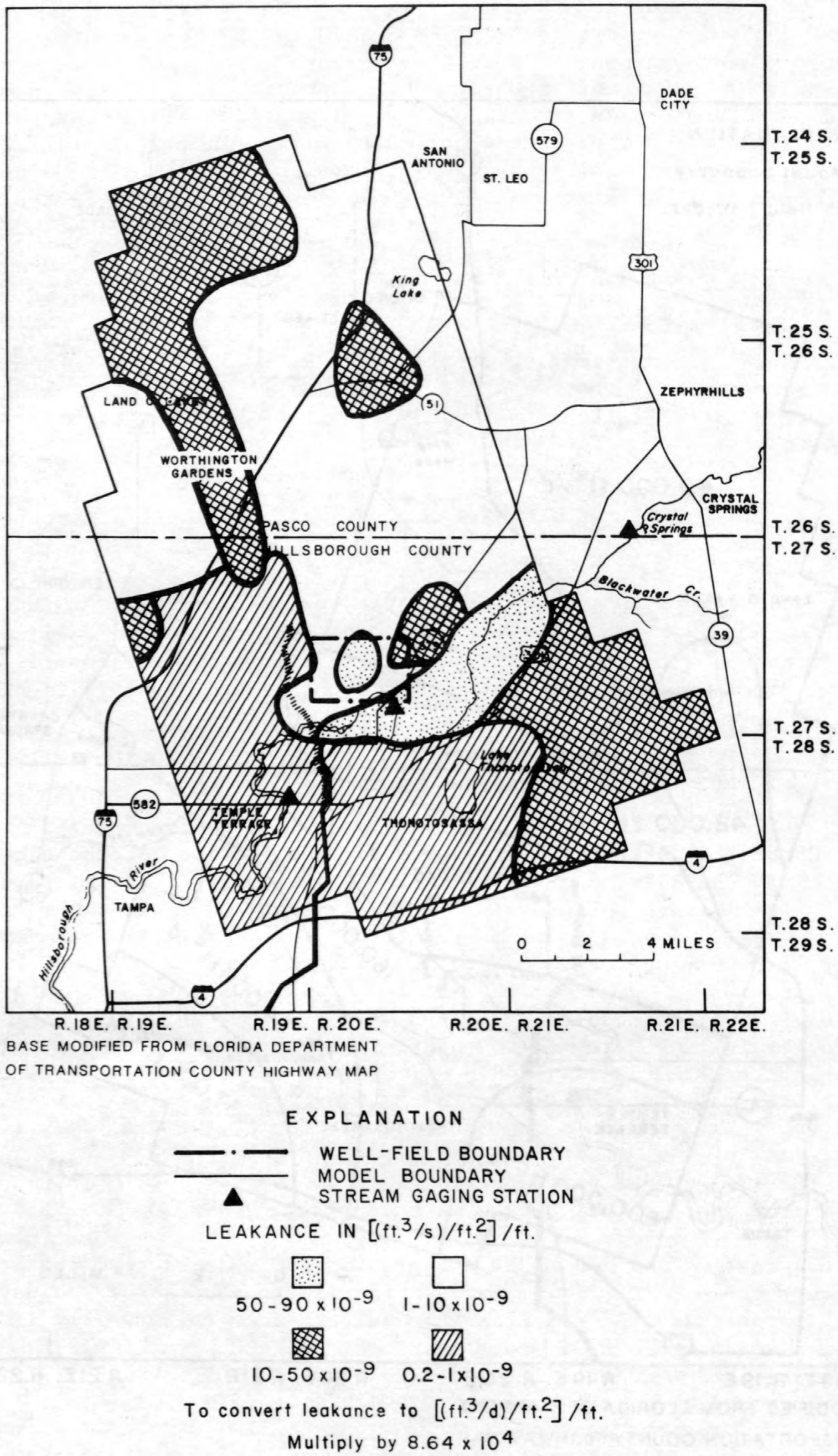



Figure 18.--Leakance distribution derived from model calibration.

particularly those at observation-well nodes in the surficial aquifer, show that drawdowns are most sensitive to changes in $S_y$; they are fairly sensitive to changes in ET, and almost insensitive to changes in K and K/b. Therefore, $S_y$ was varied to achieve an acceptable 3-D calibration. Adequate geologic data were available for the general well-field area, including drillers' logs, sample cuttings, and natural gamma logs, to assign reasonable $S_y$ values to individual wells and to interpolate between sites to define broad zones of $S_y$.

## Test and Refinement of Model Calibration

Because the 3-D transient calibration was started with an estimated water table, and because $S_y$ had to be varied to achieve an acceptable calibration, estimated water-table altitudes contained errors that had to be eliminated before calibration could be finalized, and before an accurate water table could be computed for use in subsequent predictive-modeling runs.

The 3-D calibration was tested and refined in the following manner:

1. Flow equation for the surficial aquifer was linearized by converting it to a confined aquifer equation and the 13-day simulated test was rerun; computed drawdowns were superimposed on the natural flow system and the initial potentiometric surfaces for the system were horizontal (Trescott, 1975, p. 27).
2. Simulated drawdowns in the surficial aquifer were corrected for (a) water-table conditions, using a method described by Jacob (1944), and (b) natural decline of the water table, using a correction of 0.05 ft/d.
3. Corrected water-table drawdowns for the last day of the simulation were added to water-table heads for the last day of the initial 3-D calibration. These altitudes for the water table were then used to rerun the 13-day simulated test from initial conditions.

Table 2 shows the results of rerunning the May 12-25, 1977, simulation with corrected initial water-table heads. Mean percentage error for residuals in 23 Floridan aquifer wells is only slightly larger in the 3-D calibration than in the 2-D calibration (table 1). Mean percentage error for residuals in the eight surficial aquifer wells is about 27 percent. Hydrographs (observed and calculated) of the 8 surficial aquifer wells and the 23 Floridan aquifer wells for the 13-day test period are shown in figures 19-21. Distribution of $S_y$ derived from the 3-D calibration is shown in figure 22.

A final test of the 3-D model calibration was made because the predictive model run described in the following section is for a period of 30 days. Starting heads in the surficial and Floridan aquifers used to rerun the 13-day test were again used to begin a 30-day simulation. For this run, well-field pumpage, evapotranspiration, and river leakage were removed from the model. A system at steady state would show zero drawdown at each node of each layer at the end of the 30-day run. Any residual would reflect an imbalance in the system due to inaccuracies in the 3-D calibration and consequent corrected starting water-table heads.

Table 2.--Observed and calculated drawdowns in wells tapping the Floridan and surficial aquifers, May 25, 1977

| Observation well[1/] | Node row, column | Observed drawdown at noon on May 25 (ft) | Calculated drawdown (ft) | Calculated minus observed drawdown (ft) | Percentage error |
|---|---|---|---|---|---|
| Floridan aquifer | | | | | |
| 1 | 28,19 | 7.8 | 7.2 | -0.6 | 8 |
| 2A | (26,27),20[2/] | 7.6 | 7.1 | -0.5 | 6 |
| 3 | (24,25),21 | 6.2 | 6.1 | -0.1 | 2 |
| 3A | 23,(20,21) | 6.7 | 6.5 | -0.2 | 3 |
| 4 | (21,22),21 | 6.6 | 6.2 | -0.4 | 6 |
| 4B | 25,(21,22) | 5.4 | 5.9 | 0.5 | 9 |
| 5 | 28,(21,22) | 6.0 | 5.7 | -0.3 | 5 |
| 6 | (25,26),(22,23) | 5.9 | 5.6 | -0.3 | 5 |
| 7 | 24,23 | 6.3 | 5.9 | -0.4 | 6 |
| 8 | (26,27),24 | 4.2 | 4.7 | 0.5 | 12 |
| 10 | 29,(25,26) | 3.9 | 3.3 | -0.6 | 15 |
| 11 | 31,20 | 6.5 | 5.5 | -1.0 | 15 |
| Eberly | 14,24 | 3.6 | 2.7 | -0.9 | 25 |
| 150 | (29,30),(16,17) | 7.2 | 6.3 | -0.9 | 12 |
| 151 | 29,15 | 5.3 | 5.5 | 0.2 | 4 |
| 152 | 26,16 | 7.8 | 6.9 | -0.9 | 12 |
| 157 | 19,18 | 6.6 | 6.0 | -0.6 | 9 |
| 158 | (17,18),(19,20) | 6.2 | 5.3 | -0.9 | 14 |
| 160 | (30,31),21 | 6.0 | 5.5 | -0.5 | 8 |
| 162 | 26,23 | 6.0 | 5.3 | -0.7 | 12 |
| 166 | (19,20),22 | 6.4 | 5.3 | -1.1 | 17 |
| 167 | 16,24 | 4.5 | 3.7 | -1.0 | 22 |
| 169 | (15,16),(21,22) | 4.3 | 4.4 | 0.1 | 2 |
| Surficial aquifer | | | | | |
| 1 | 28.19 | 1.04 | 0.97 | -0.07 | 7 |
| 3A | 23,(20,21) | .86 | .84 | -0.02 | 2 |
| 4 | (21,22),21 | .92 | .60 | -0.32 | 35 |
| 5 | 28,(21,22) | .79 | .96 | 0.17 | 22 |
| 6 | (25,26),(22,23) | .64 | 1.02 | 0.38 | 59 |
| 7 | 24,23 | .57 | 1.02 | 0.45 | 79 |
| 8 | (26,27),24 | 1.02 | .94 | -0.08 | 8 |
| 10 | 29,(25,26) | .82 | .78 | -0.04 | 5 |

1/ Locations of wells shown in figure 14.
2/ Parentheses indicate drawdown was averaged over more than one node.

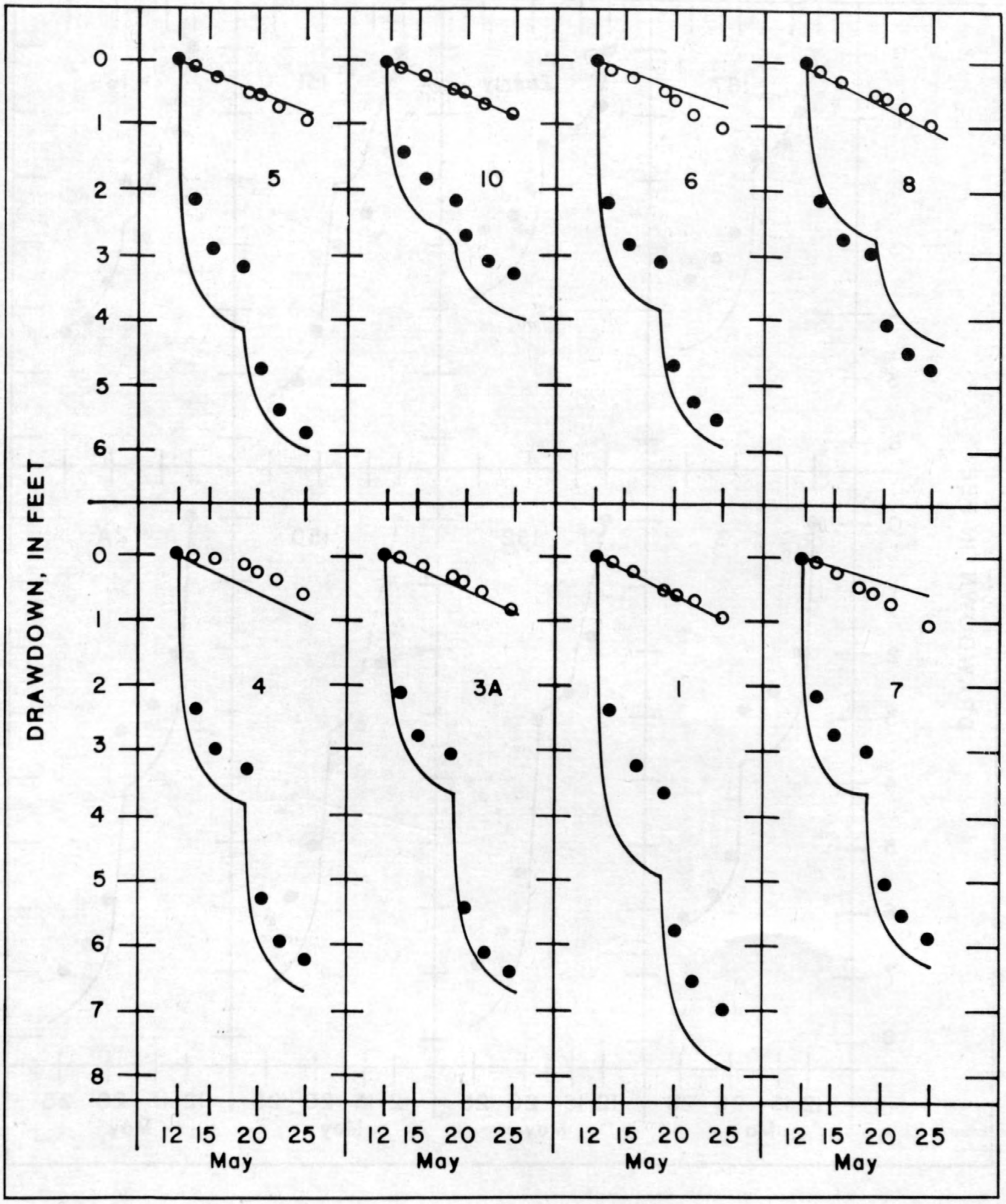



Figure 19.--Hydrographs showing observed and calculated drawdowns in Floridan and surficial aquifers, May 12-25, 1977.

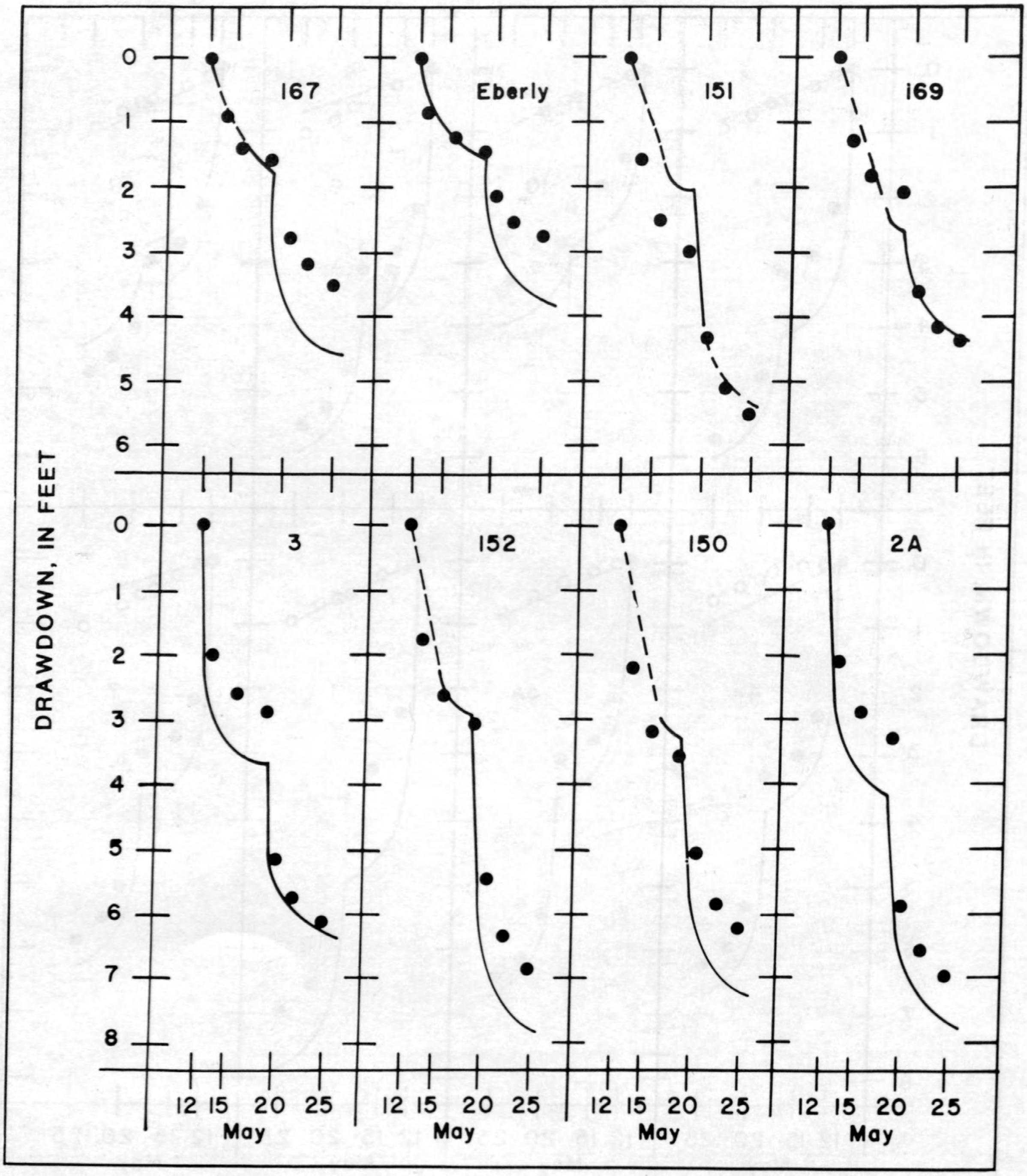



Figure 20.--Hydrographs showing observed and calculated drawdowns in Floridan aquifer, May 12-25, 1977.

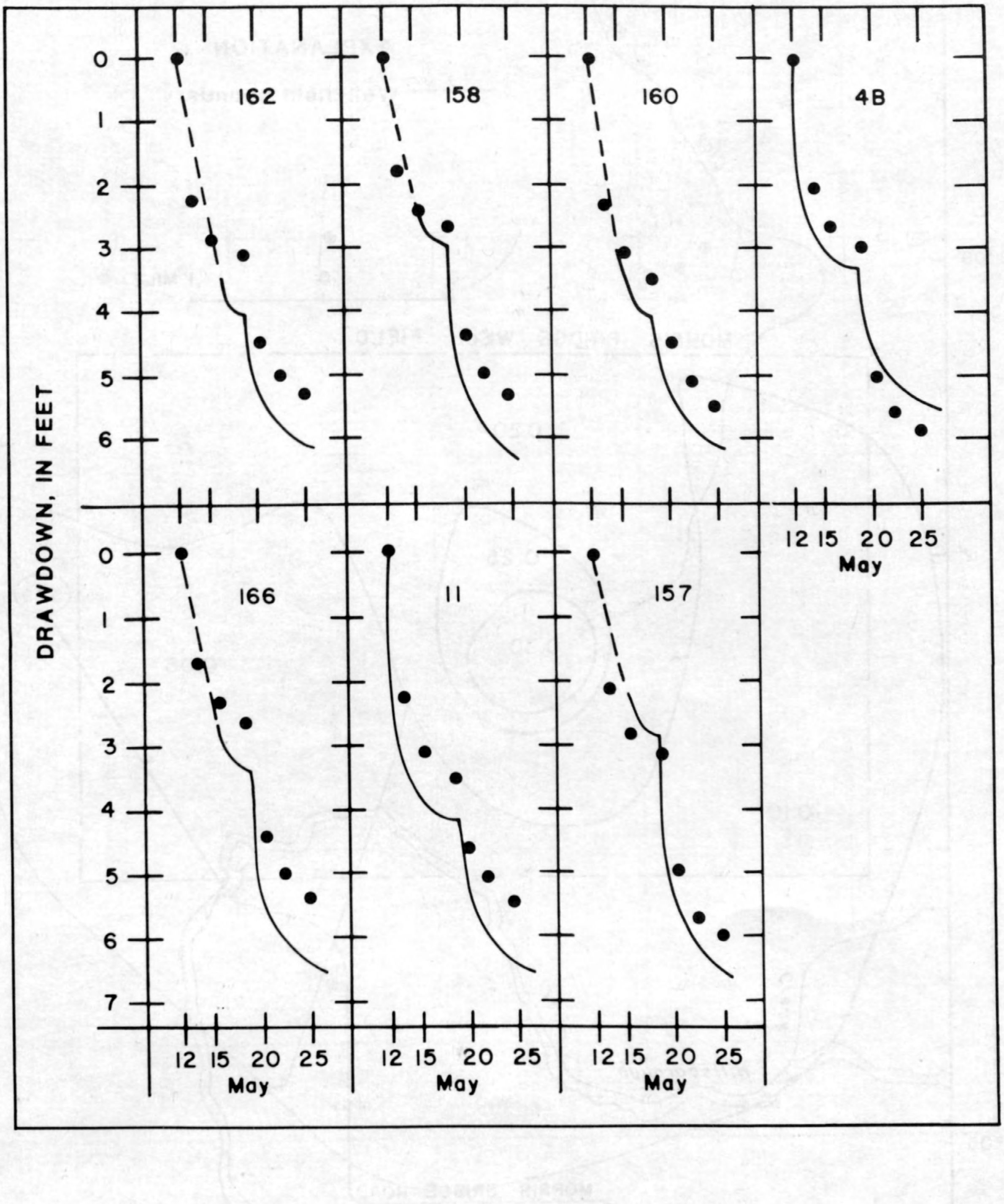



Figure 21.--Hydrographs showing observed and calculated drawdowns in Floridan aquifer, May 12-25, 1977.

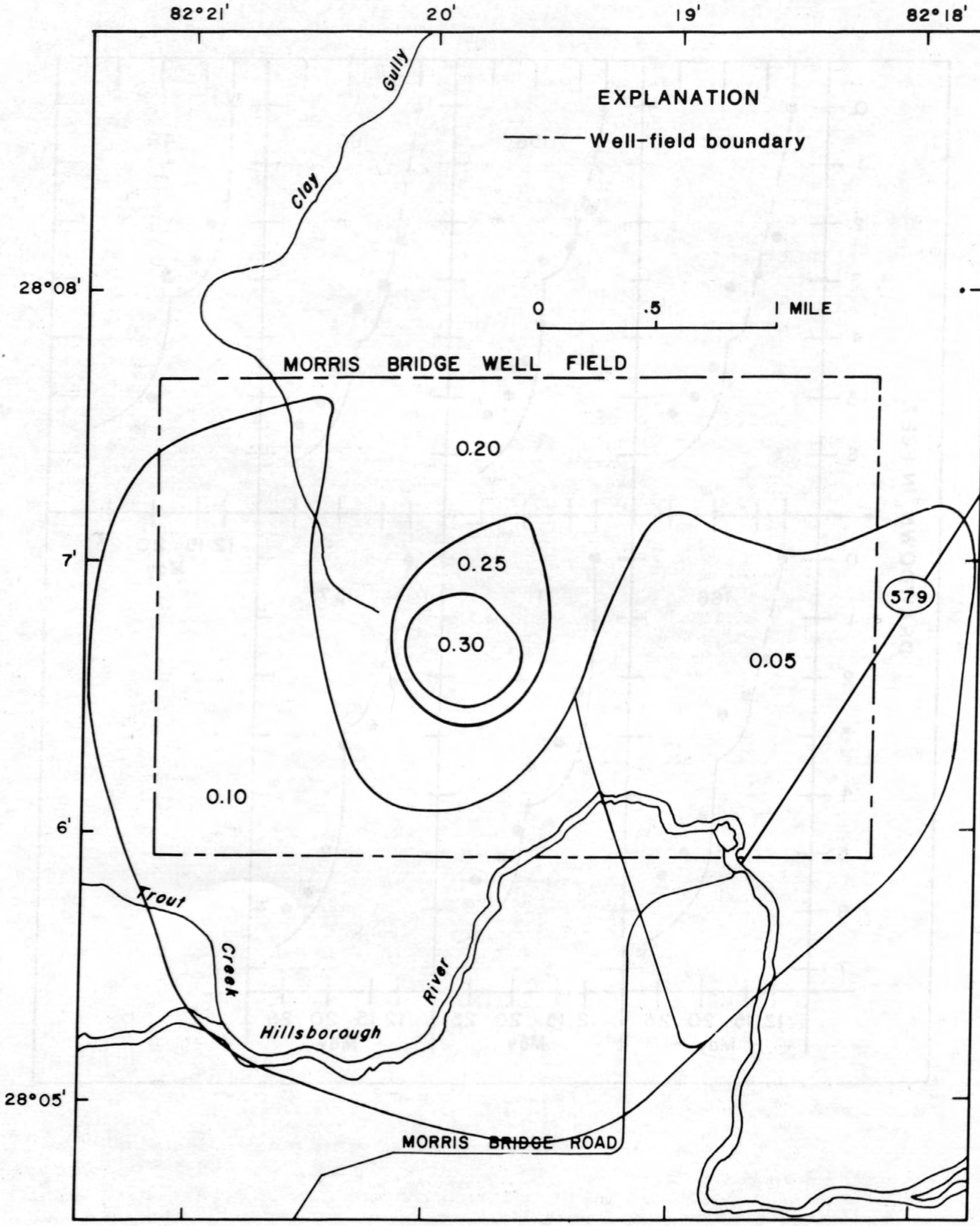



Figure 22.--Distribution of specific yield ($S_y$) of surficial aquifer derived from three-dimensional model calibration.

Head changes in the Floridan aquifer at the end of the 30-day run averaged only a few tenths of a foot; they barely exceeded 1 foot in a small area at a great distance north of the well field. Head changes in the water table at the end of the 30-day run were larger and more randomly distributed; this might be expected since no attempt was made to improve the 3-D calibration in areas distant from the well field. Head changes, including drawdown and buildup, exceeded 2 feet at several nodes; average change for all nodes was less than 1 foot.

## Example of Predictive Modeling

The calibrated 3-D model can be used as a predictive tool to assess the impact of well-field withdrawals on the hydrologic system under any given starting condition. For a prediction analysis, the following must be specified: (1) starting heads in the Floridan and surficial aquifers and stage in the Hillsborough River; (2) pumping schedules of wells; (3) a rate of evapotranspiration that is appropriate for the season of the year; and (4) length of simulation period.

The example chosen for predictive modeling consists of a 30-day run under full stress conditions, with starting heads as calculated for May 12, 1977. Considering that the Morris Bridge well field will probably be pumped at full capacity for only short periods during the dry season when streamflow and reservoir levels are low, the short-term (30-day) predictive modeling approach is appropriate. Long-term modeling, including recovery during recharge periods and cyclic pumping, is not warranted unless evidence suggests cumulative, adverse water-level changes over the years.

In the general area north of Tampa Bay, the confining layer has a relatively high K'/b'. Most hydrographs that show a water-table rise due to rainfall show a similar rise in the potentiometric surface with very little lag time. This is the case in the Morris Bridge well field. In the test run from April 20 to May 26, 1978, the potentiometric surface recovered rapidly to prepumping levels when the 30-Mgal/d withdrawal ceased (after correcting heads for natural water-level decline that occurred during the test period). These observations indicate that water levels in the Floridan aquifer at the well field will recover fully from one year to the next, assuming no drastic departure from long-term rainfall patterns.

### Effect of 40 Million Gallons per Day Withdrawal

Figure 23 shows the location of production wells 150 through 169. A hypothetical pumpage of 40 Mgal/d was divided equally among the 20 wells. A 30-day model simulation was made, starting with aquifer heads, river stages, and streambed leakances that were used in the refined 3-D calibration. Stresses on the system included well-field pumpage, steady-state pumpage from the 2-D calibration, and an evapotranspiration rate of 5 inches per month. The total declines in head after 30 days are shown in figure 24 for the Floridan aquifer and in figure 25 for the surficial aquifer.

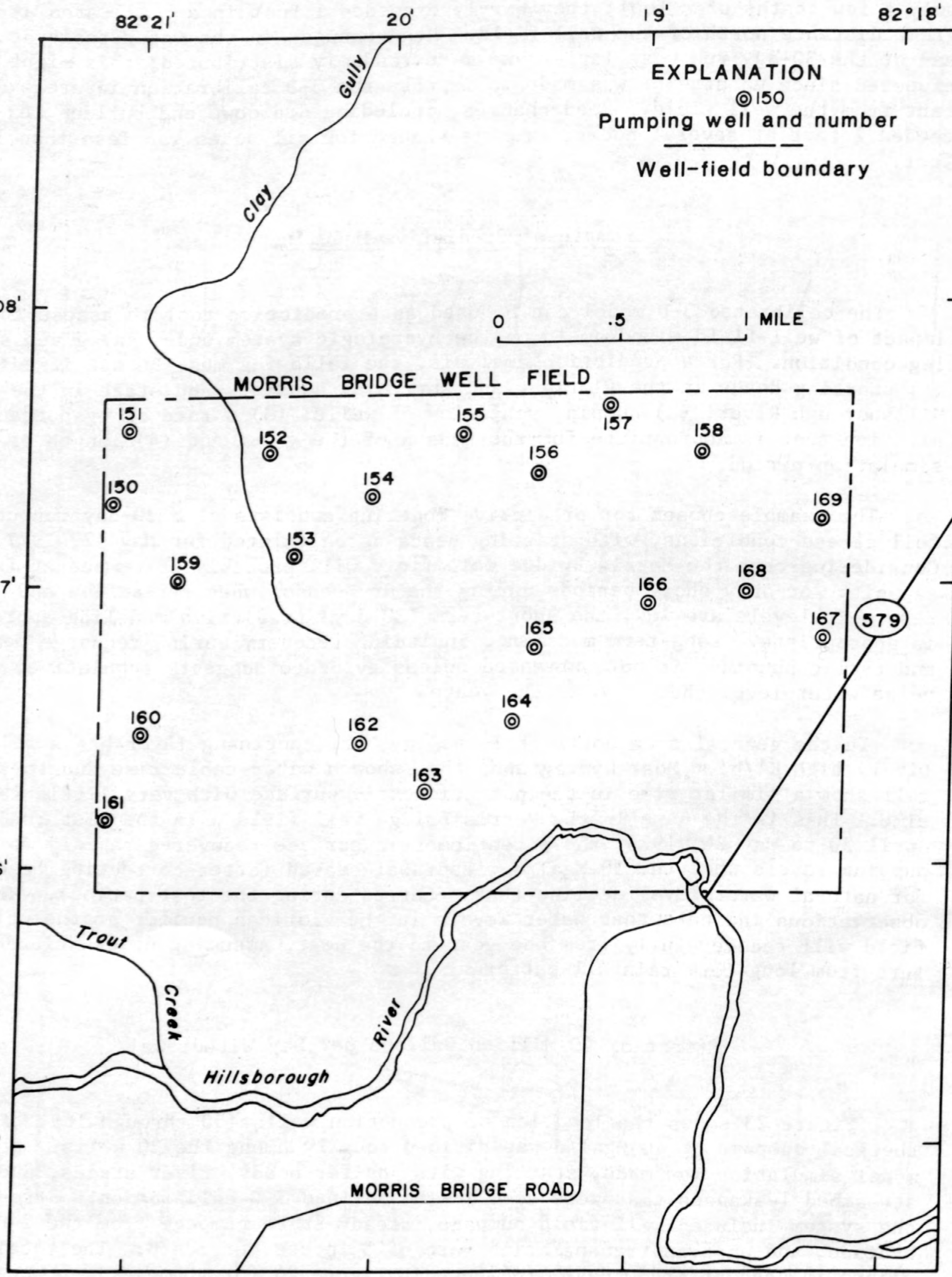



Figure 23.--Location of production wells used for hypothetical pumpage of 40 million gallons per day.

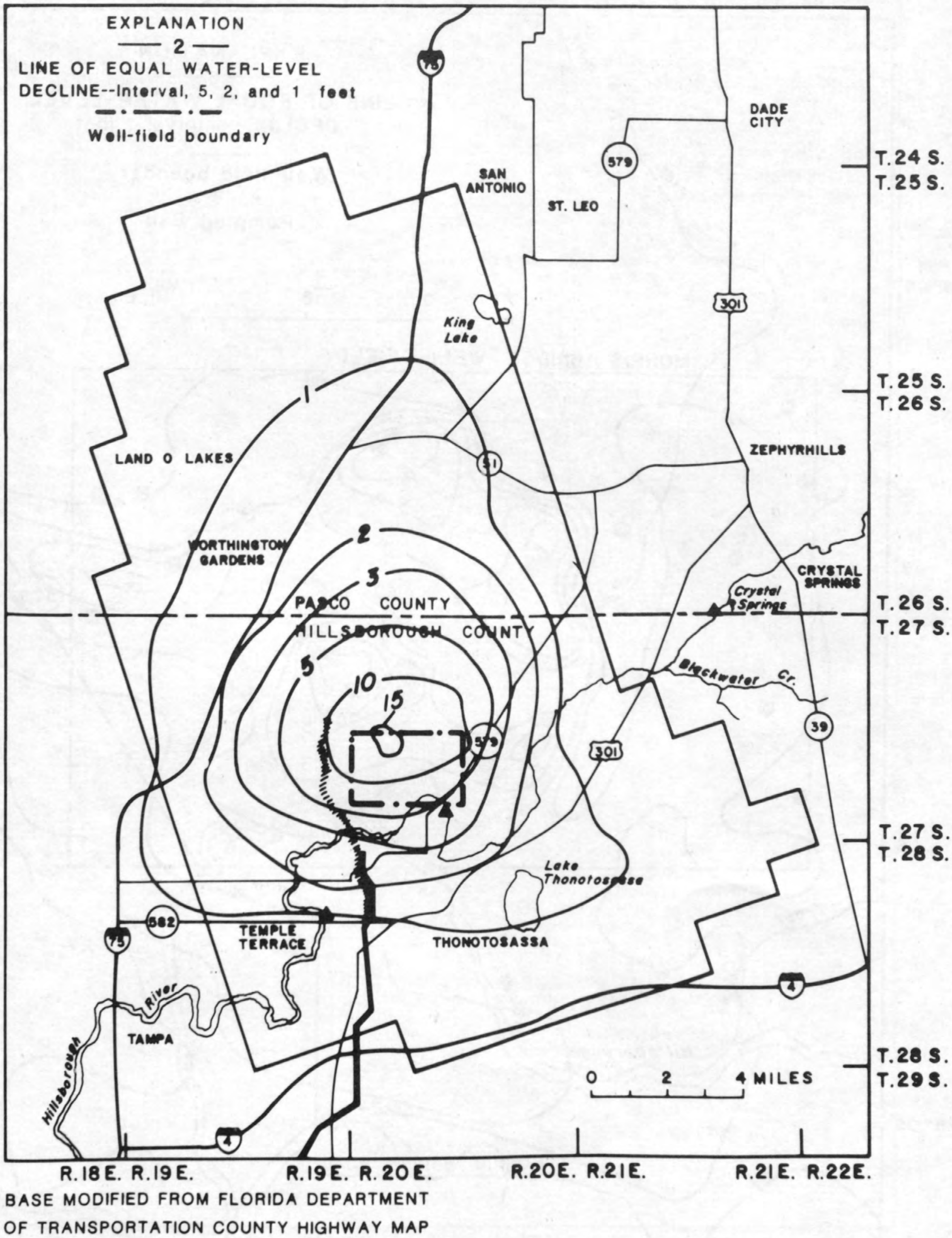



Figure 24.--Hypothetical decline of the Floridan potentiometric surface after 30 days of a well-field pumpage of 40 million gallons per day.

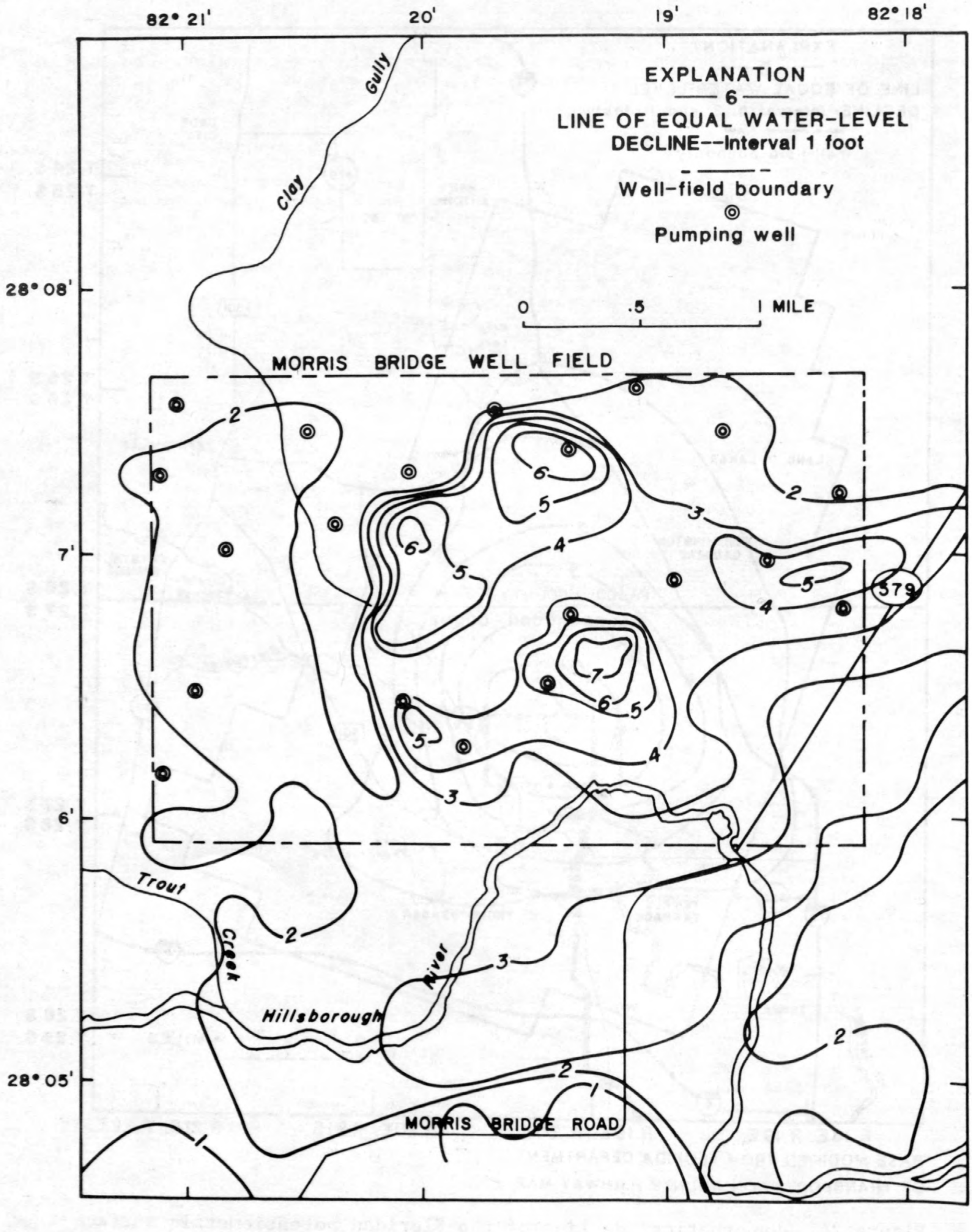



Figure 25.--Hypothetical decline of the water table after 30 days of field pumpage of 40 million gallons per day.

Another 30-day simulation was made with all model inputs the same as above except that the well-field pumpage of 40 Mgal/d was omitted. By subtracting the head declines in this simulation from the head declines in figures 24 and 25, the portion of the decline in head in each aquifer that was caused by the 40 Mgal/d well-field pumpage was obtained. These drawdowns are shown in figure 26 (Floridan aquifer) and figure 27 (surficial aquifer).

Mass-balance data from the two simulations indicate that 71 percent (about 160,000,000 $ft^3$) of the pumpage from the well field was derived from storage, 22 percent from inflow from boundary nodes, and 7 percent from a decrease in evapotranspiration. Only 0.1 percent was from the river.

An additional set of runs was made to show the effect of connecting the river directly to the surficial aquifer. The river was allowed to occupy the entire area of each grid block through which it passed, and the water table in those blocks was made equal to river stage. The change in altitude of the potentiometric surface of the Floridan aquifer was not appreciably different from that shown in figure 24. Water-level change for the surficial aquifer (fig. 28) does not differ radically from those shown in figure 25. However, mass-balance data show that 64 percent of well-field pumpage was derived from storage and 10 percent came from induced leakage from the river; reduction in evapotranspiration and net inflow from boundary nodes remained essentially the same as when the river was only partly connected to the surficial aquifer.

## Model Sensitivity to Changes in Parameters

Using a range of values for streambed K/b and assessing the consequent effect on the simulation constitutes a sensitivity analysis. Other parameters are known with a greater degree of certainty than streambed K/b. These parameters were varied uniformly in scale and within a narrower range of limits for the 30-day run just described. Relative distribution of parameter values (in space) did not change. Lower streambed K/b was used in all sensitivity-analysis simulations.

The 3-D model calibration is based upon a distribution of parameters that permit start-up conditions to be approximately at steady state. Changing the magnitude of a parameter to test its effects on simulation results necessitates adjusting other parameters to restore steady-state start-up conditions. This adjustment would have to be applied each time a parameter is varied for a sensitivity test.

The model was not recalibrated each time parameter values were changed; to do so would be impractical in terms of time and cost. However, even with reduced effectiveness caused by omitting recalibration, sensitivity tests provide useful information. Absolute values of head changes during sensitivity tests should be viewed critically, but relative changes can provide insight into the importance of any parameter in affecting results of model simulation.

Twelve simulations were run in which the following parameters were first increased by 40 percent over calibrated values, and then decreased by 40 percent: (1) ET; (2) K of the surficial aquifer; (3) $S_y$ of the surficial aquifer; (4) K'/b' of the confining layer; (5) T of the Floridan aquifer; and (6) S of

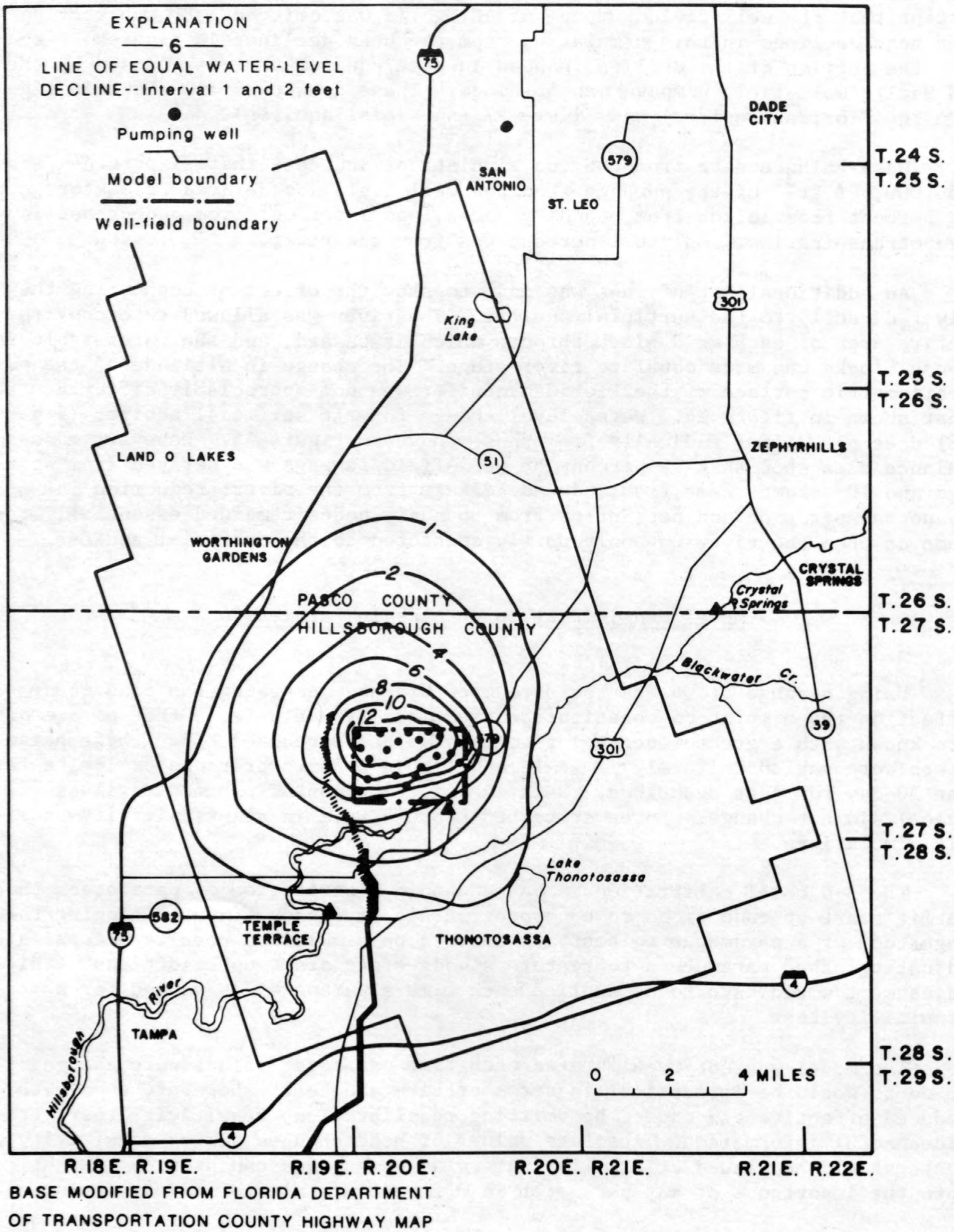



Figure 26.--Hypothetical decline of the Floridan potentiometric surface due only to well-field pumpage of 40 million gallons per day for a 30-day period; partial connection between river and surficial aquifer.

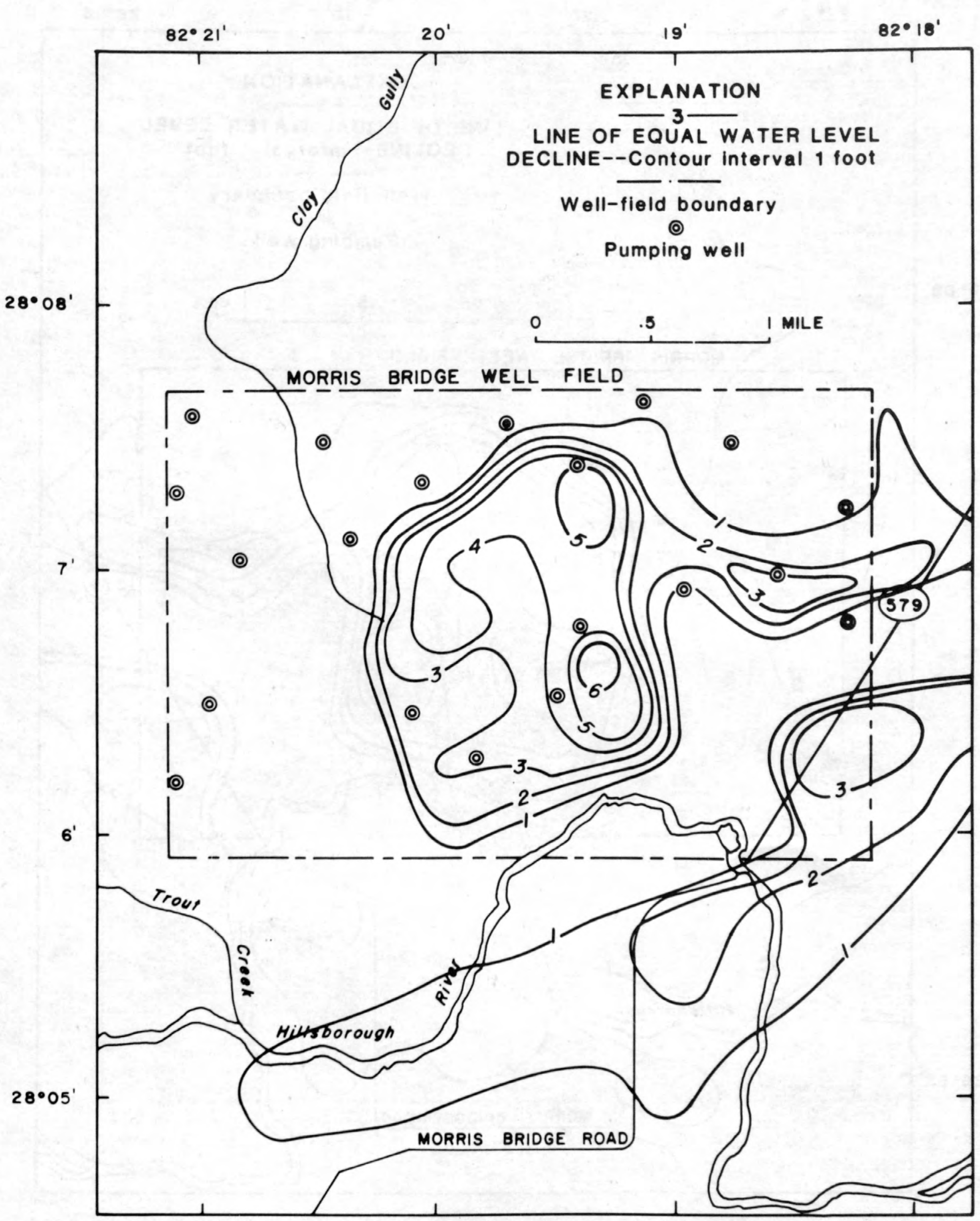



Figure 27.--Hypothetical decline in the water table due only to well-field pumpage of 40 million gallons per day for a 30-day period; streambed leakance ranging from about $8 \times 10^{-4}$ to $3 \times 10^{-5}$ $day^{-1}$.

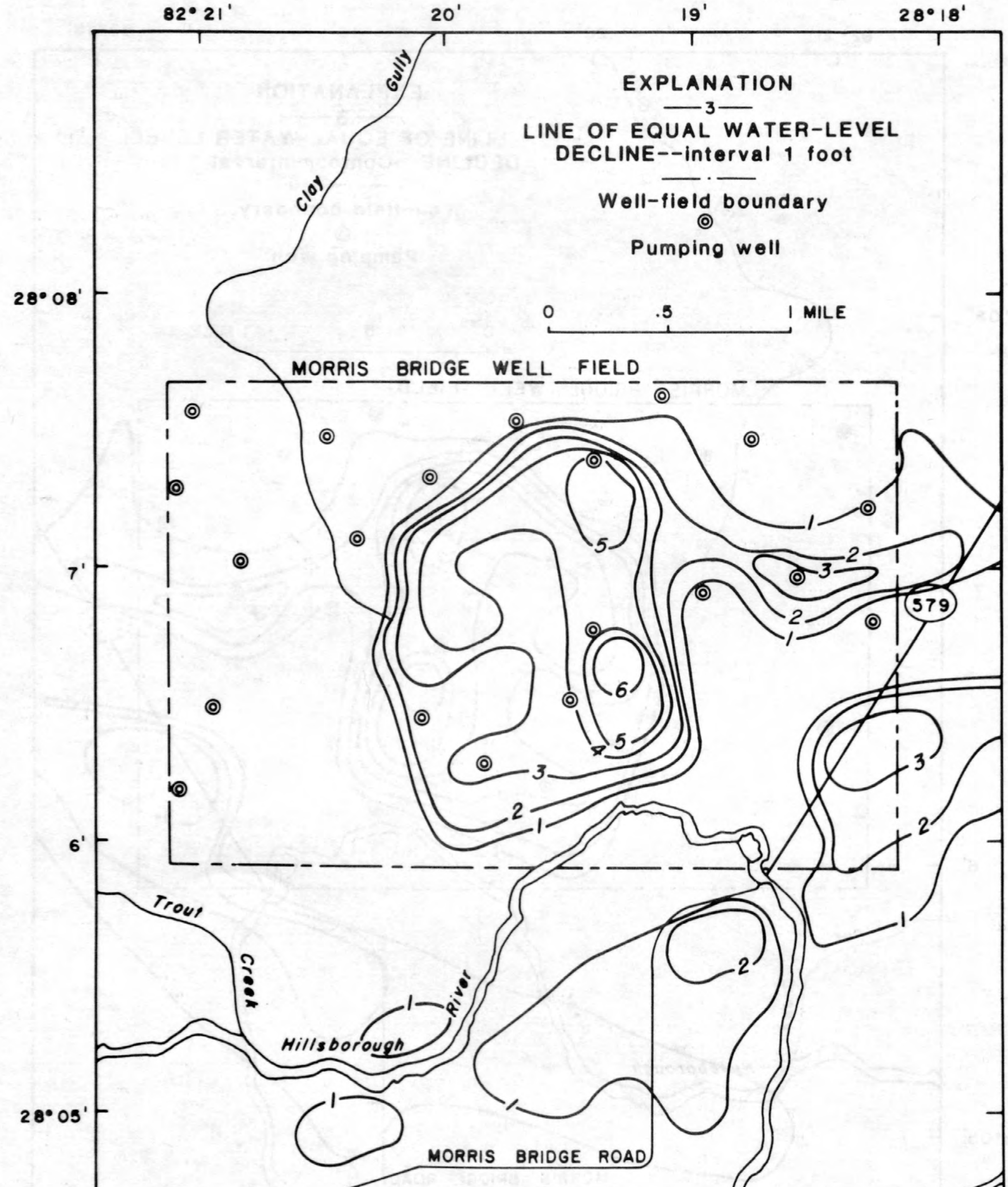



Figure 28.--Difference in altitude of the water table between 30-day model runs with and without well-field pumpage of 40 million gallons per day, with river directly connected to the surficial aquifer.

the Floridan aquifer. The effects on water-level changes in both aquifers caused by the changes are shown by distance-drawdown graphs, at the end of the 30-day runs, along section A-A' (figs. 29-35).

Water-level changes caused by varying ET (fig. 30) are intermediate with respect to the other parameters. Changes are greater in the surficial aquifer than in the Floridan aquifer, but changes in both aquifers are fairly uniform along the entire section.

Results of changing the K of the surficial aquifer are shown in figure 31. Water levels are virtually insensitive to changes in K. Relatively low values of K and thin saturated thicknesses of sand, coupled with relatively low hydraulic gradients, may account for this response.

Figure 32 shows the response to changes in specific yield. Response is relatively large in both aquifers, particularly in the area of the well field.

Changes in water levels due to changes in K'/b' of the confining bed (fig. 33) are relatively small in the surficial aquifer, but relatively large in the Floridan aquifer. The changes are largest in the Floridan aquifer in the well-field area.

The largest water-level change in the Floridan aquifer is caused by varying the T of the Floridan aquifer (fig. 34). Response in the water table is relatively large in the area of the well field.

Results of changing the S of the Floridan aquifer are shown in figure 35. Water levels in both aquifers are virtually insensitive to changes in S. One reason is that, although there is a considerable amount of water being taken from storage after 30 days of pumping, nearly all of this water is being derived from storage in the surficial aquifer. The average ratio of $S_y$ to S is about 200 to 1 in the model.

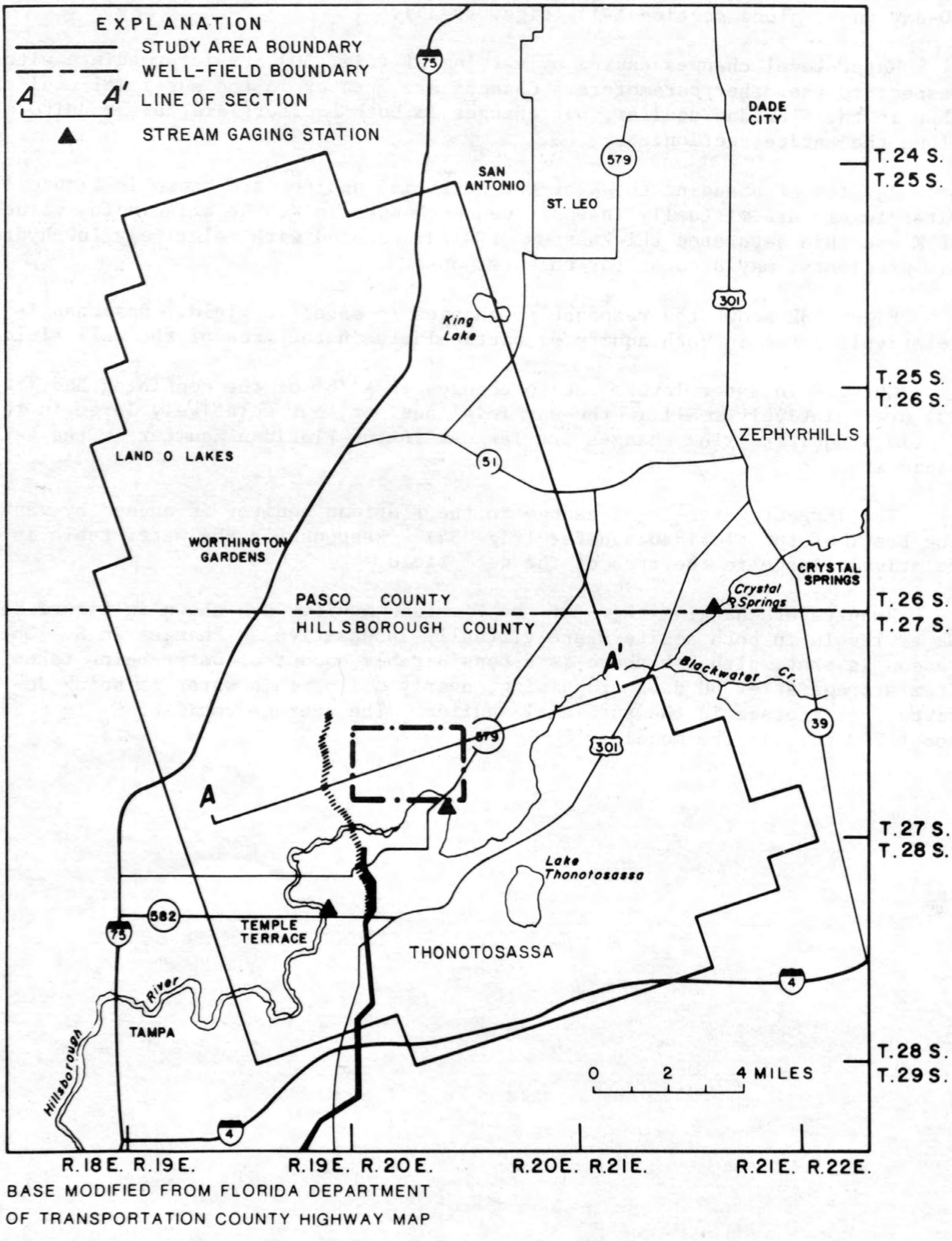



Figure 29.--Location of section A-A' (column 22) used for sensitivity-analysis.

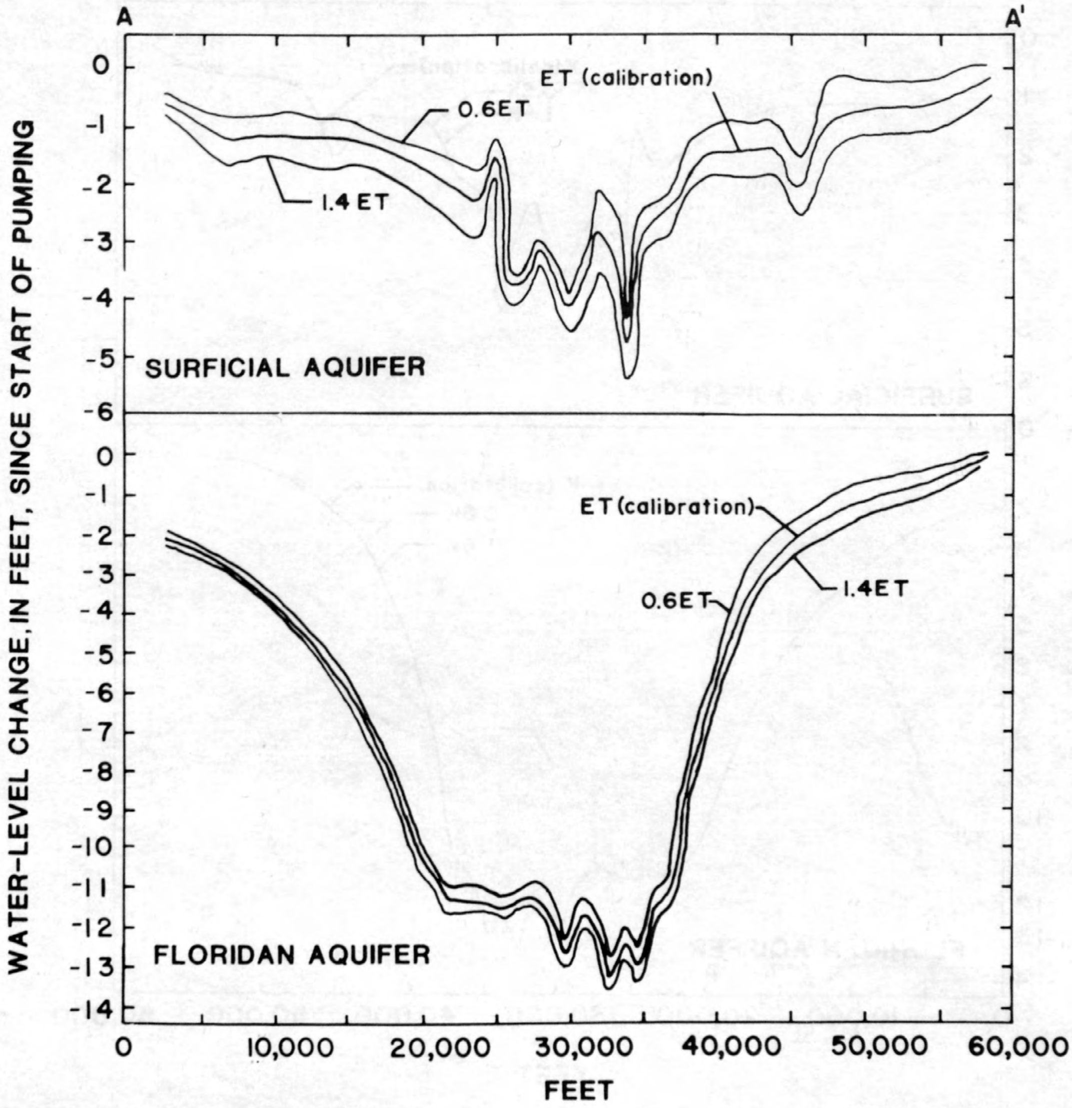



Figure 30.--Changes in water levels along section A-A' resulting from varying ET.

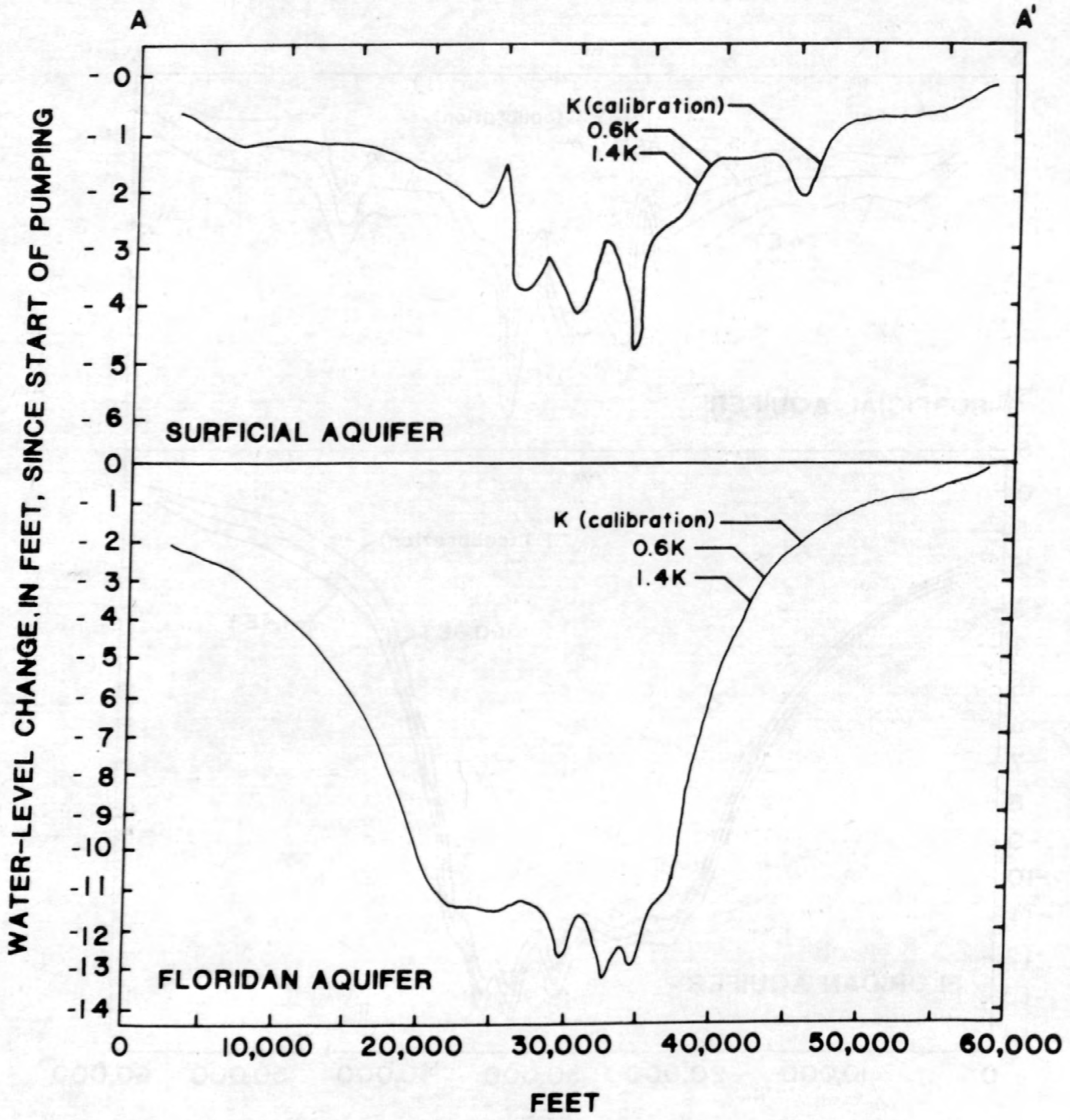



Figure 31.--Changes in water levels along section A-A' resulting from varying K.

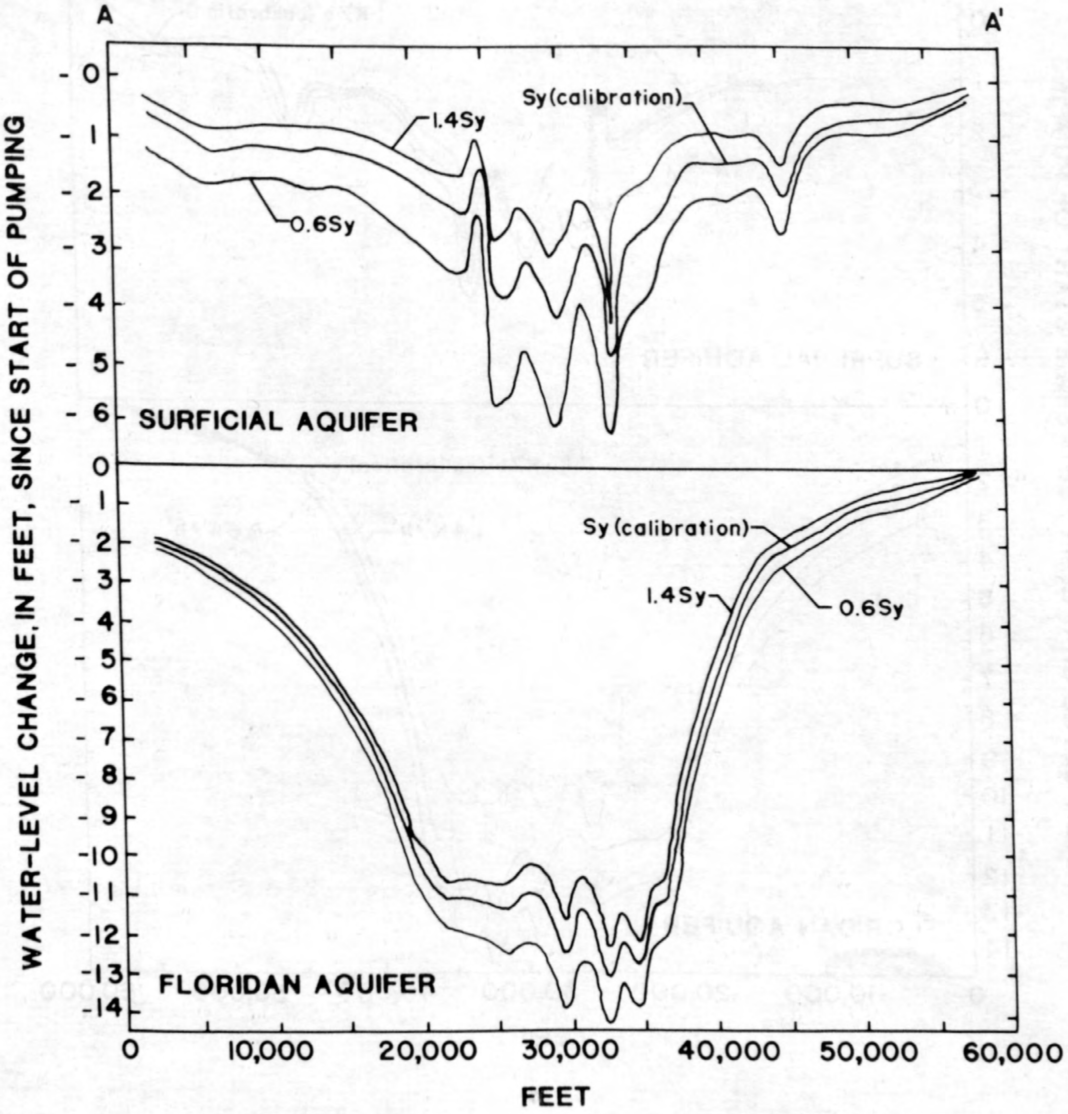



Figure 32.--Changes in water levels along section A-A' resulting from varying $S_y$.

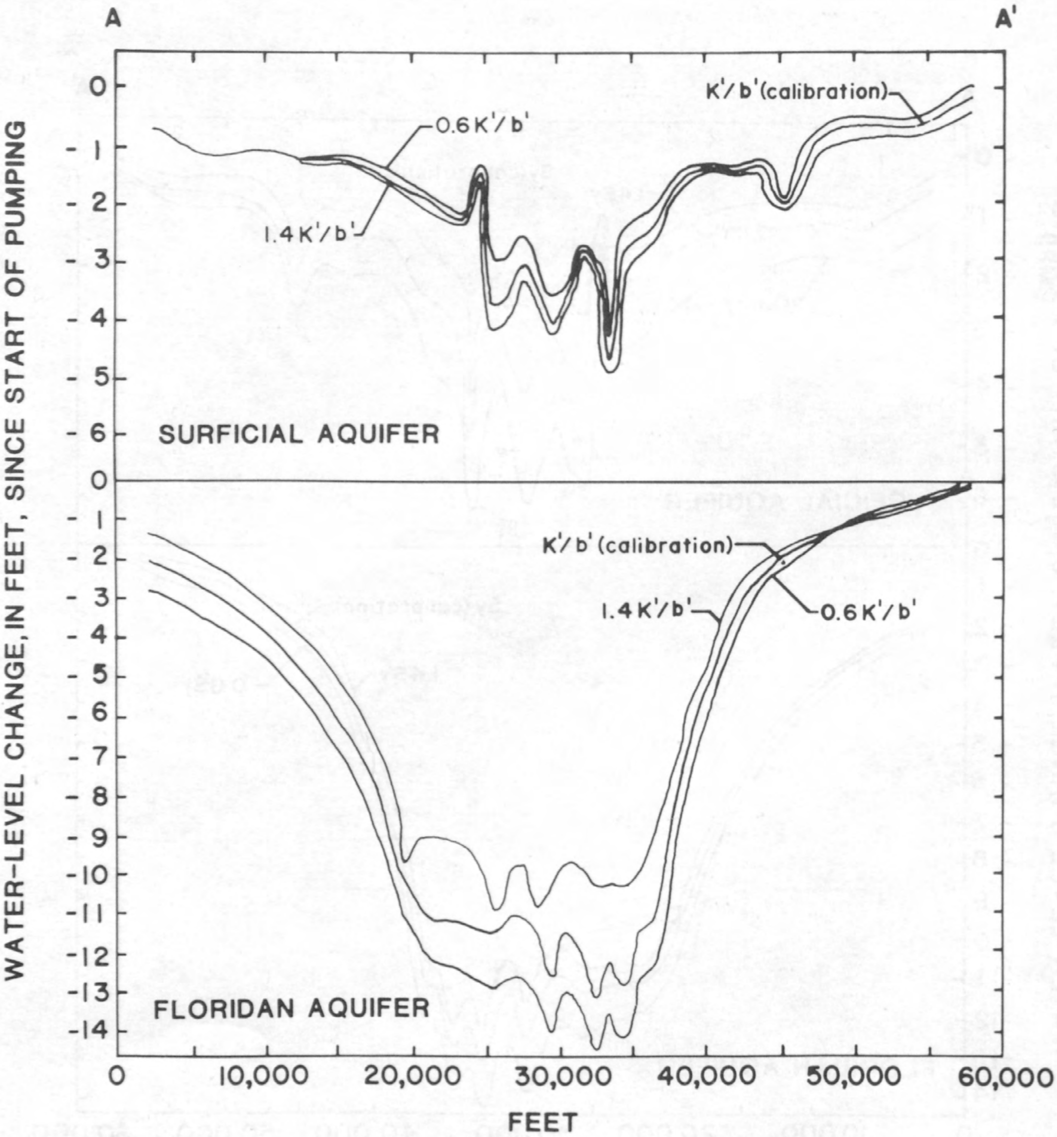



Figure 33.--Changes in water levels along section A-A' resulting from varying K'/b' of the confining bed.

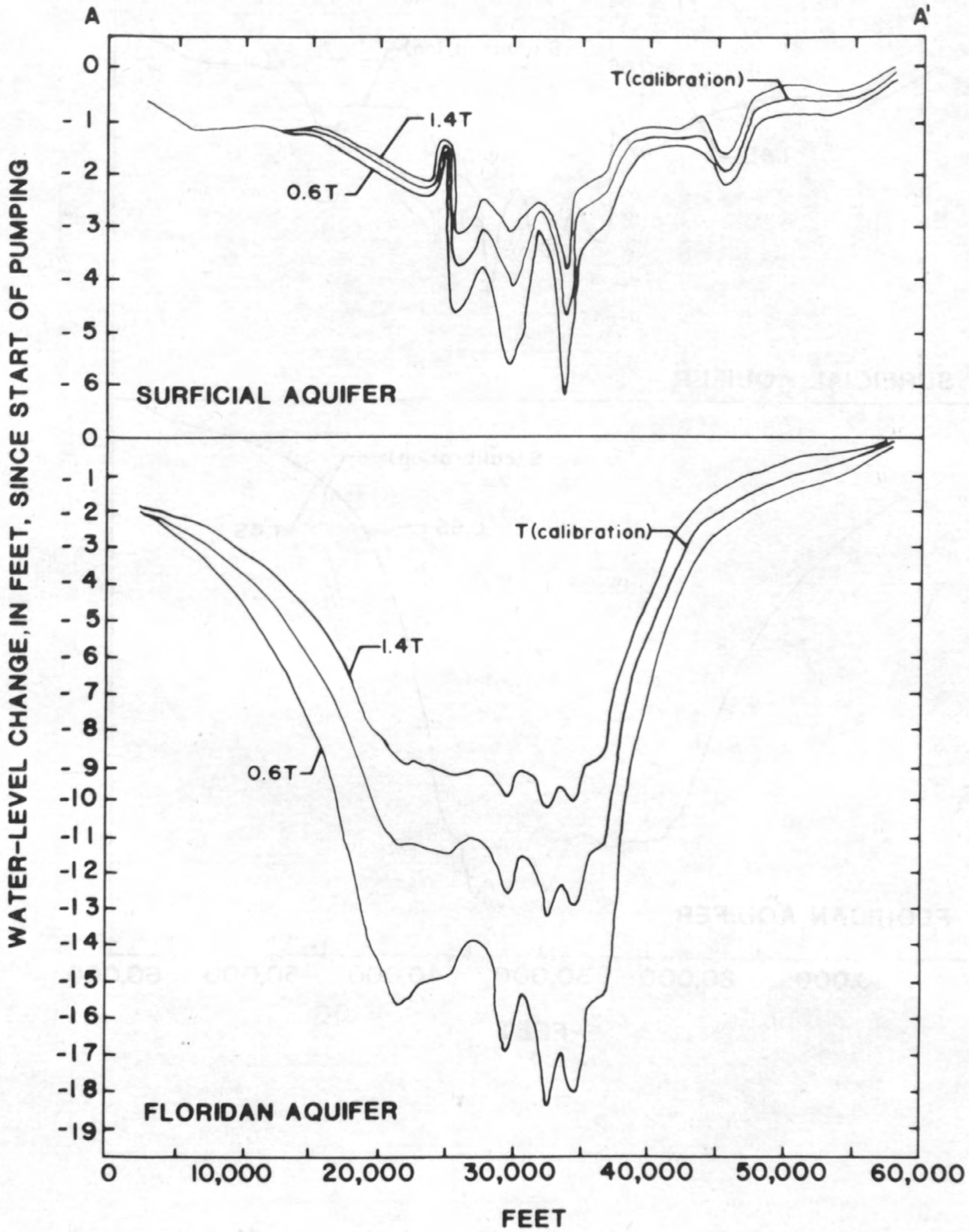



Figure 34.--Changes in water levels along section A-A' resulting from varying T.

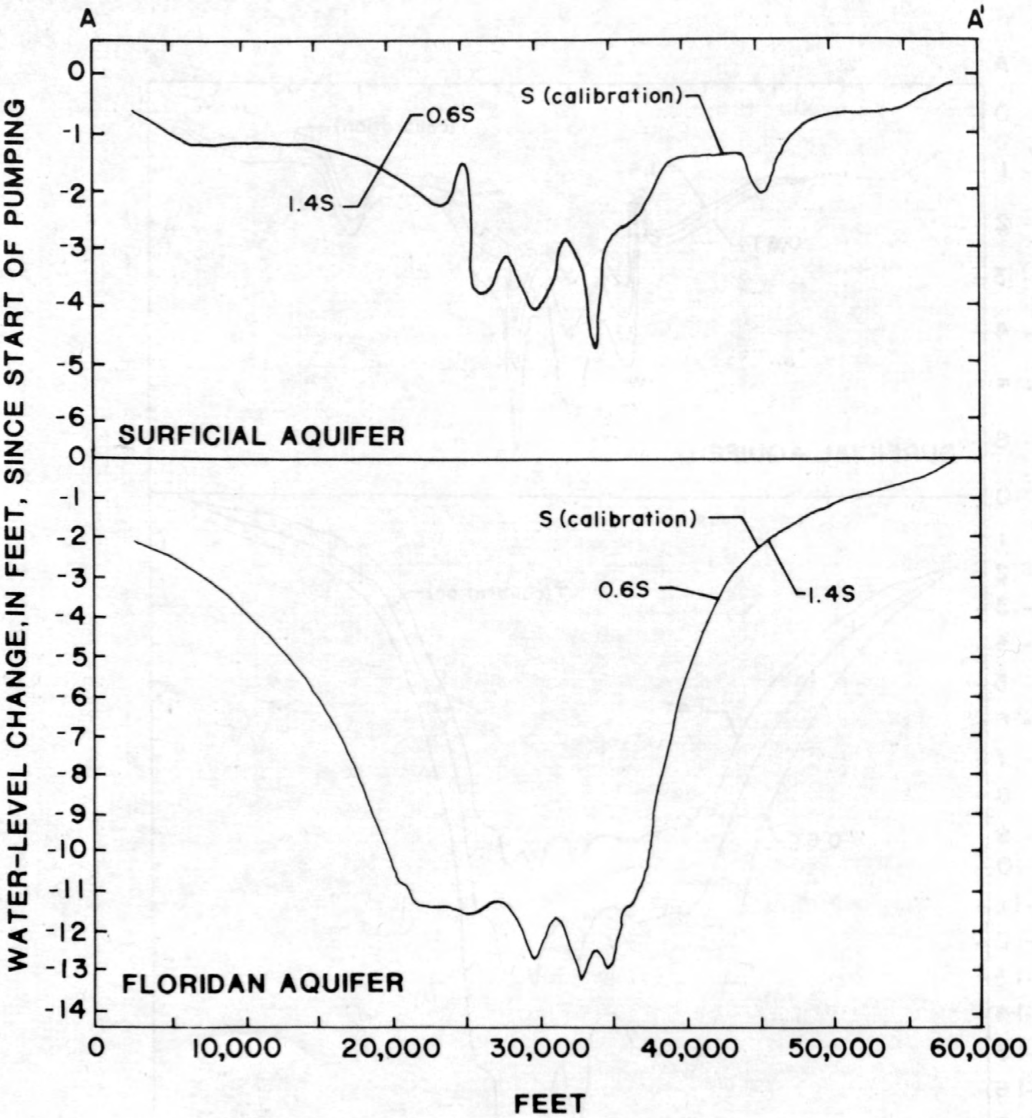



Figure 35.--Changes in water levels along section A-A' resulting from varying S.

## SUMMARY AND CONCLUSIONS

1. To analyze the flow system of the Morris Bridge well-field area, the hydrogeologic system was conceptualized as follows: the surficial aquifer is separated from the Floridan aquifer (to a minor degree in some areas) by a confining clay layer. The major source of water to the wells is from two highly fractured zones of a dolomitic section of the Avon Park Limestone, approximately 500 and 550 feet below sea level. Highly transmissive zones also occur in the Tampa Limestone.

Surficial aquifer thickness ranges from zero to 40 feet in the well field. Borings in the streambed of the Hillsborough River indicate that the surficial aquifer and the river are hydraulically connected through streambed sediments. Clayey material at the base of the surficial aquifer ranges from about 1 to 25 feet in thickness.

Most recharge to the Floridan aquifer is derived from the overlying surficial aquifer by downward percolation through the confining layer. Part of this recharge is returned to the surficial aquifer as upward leakage, and most of the remainder flows downgradient within the Floridan aquifer.

2. A two-dimensional digital model of the conceptualized hydrogeologic system was developed. The model was calibrated by simulating May 11, 1977, conditions, assuming steady-state conditions. Calibration was refined by simulating a 13-day test period in May 1977 in which as much as 20 Mgal/d were withdrawn from the Floridan aquifer. Further refinement was possible by adding observation wells along the Hillsborough River and simulating a 7-day test period in April-May 1978 in which up to 30 Mgal/d were withdrawn. Leakance derived from the model was mapped for a 285-$mi^2$ area encompassing the well field. Leakance ranged from about 2 x $10^{-5}$ to 8 x $10^{-3}$ $day^{-1}$. Transmissivity derived from the model ranged from 37,000 to 600,000 $ft^2/d$. The storage coefficient of 0.001, estimated from aquifer tests, was not varied during calibration.

3. Leakance, transmissivity, and storage coefficients were entered into a three-dimensional model in which the surficial aquifer became an active layer, and the Hillsborough River was allowed to interact with the surficial aquifer. The model was calibrated by varying specific yield of the surficial aquifer during the 13-day pumping period in 1977. Specific yield derived from the model ranged from 0.05 to 0.30. Hydraulic conductivity of the surficial aquifer and maximum rate of evapotranspiration were not varied during calibration.

4. Errors were eliminated from the initial estimated water table and the 13-day test was run again. Results, shown in a table and a series of hydrographs, show model calibration to be satisfactory. A further check of model calibration was made by removing well-field pumpage, evapotranspiration, and river leakage. A run of 30 days was simulated; any water-level changes would indicate that the system was not at steady state. At the end of 30 days, water-level changes in the Floridan aquifer averaged only a few tenths of a foot; in the surficial aquifer, generally less than 1 foot.

5. In the general area north of Tampa Bay, including Morris Bridge well field, the confining layer has a relatively high leakance. Most hydrographs show that for a given rainfall event, the rise in the water table and in the

potentiometric surface are similar, with very little lag time. In addition, in the April-May 1978 test, the potentiometric surface recovered completely and rapidly after the 30-Mgal/d withdrawal ceased (after correcting heads for natural decline during the test period). Although some permanent lowering of the water table with time is possible, such lowering probably will involve very small areas where leakance is high. Furthermore, Morris Bridge well field will probably be pumped at full capacity only occasionally during the dry season when streamflow and reservoir levels are low. Therefore, the short-term, dry-season testing period for model calibration, and the short-term (30-day) predictive modeling approach are appropriate.

6. A 30-day predictive model run was made using May 1977 starting conditions, including calculated steady-state heads in both aquifers. A simulated run of 30 days was made without pumpage from the well field, and again for 30 days with 40 Mgal/d being withdrawn from the well field. Because streambed leakance is the least understood of all parameters in the aquifer system, it was modeled under two conditions--partial connection and complete connection to the surficial aquifer.

The results are shown as water-level change maps, and as total drawdown contour maps. Water-level change in the Floridan aquifer, caused only by well-field pumpage, exceeds 12 feet; changes in the water table exceed 6 feet. Water-level change maps for both aquifers appear very similar whether hydraulic connection between the Hillsborough River and the surficial aquifer is complete or only partial.

Under conditions of partial connection between the streambed and surficial aquifer, total drawdown in the Floridan aquifer exceeds 15 feet along the northern boundary of the well field. Total drawdown in the surficial aquifer exceeds 7 feet in the east-central part of the well field.

7. Mass-balance data from the 30-day runs show that of the pumpage from the well field--totaling about 160,000,000 $ft^3$--71 percent came from storage; 22 percent from inflow from boundary nodes; 7 percent from a decrease in ET; and only 0.1 percent from a reduction in flow to the river (assuming partial connection between river and surficial aquifer).

With the river directly connected to the surficial aquifer and occupying the entire area of each grid block through which it passed, mass-balance data from the 30-day runs show that the percentage of total well-field pumpage derived from storage was reduced to 64 percent, while 10 percent came from induced leakage from the river; reduction of ET and inflow from boundary nodes remained essentially the same as when the river was partially connected to the surficial aquifer.

8. A series of sensitivity tests were made by varying six selected parameters through a feasible range of limits during a hypothetical 30-day run with wells in the well field pumping. The effect on the simulation was assessed by showing, for both aquifers, distance-drawdown graphs drawn across the modeled area and transecting the well field. Sensitivity tests show that the response of water levels in both aquifers is: (1) highest with respect to changes in transmissivity of the Floridan aquifer; (2) relatively high with respect to changes in leakance of the confining layer and specific yield of the surficial aquifer; (3) intermediate with respect to changes in evapotranspiration; and

(4) virtually insensitive with respect to changes in hydraulic conductivity of the surficial aquifer and storage coefficient of the Floridan aquifer.

9. The following measures could produce more accurate results in model calibration and subsequent model predictions: (1) install recorders in more water-table wells, and insure that they are operating for several months prior to the start of an aquifer test; this would allow for a more accurate determination of natural changes of the water table; (2) install additional water-table wells at selected points adjacent to the Hillsborough River; in addition to gaining a more accurate observed starting head for model calibration, comparison of water-table heads and river stages during a withdrawal test could provide insight into relative streambed leakance; (3) insure that meters are installed and properly functioning on each pumping well during a well-field withdrawal test; the time when each pumping well is started and stopped should be carefully recorded; (4) study the types and distribution of vegetation in the well field, and map zones of similar vegetation; this would provide a knowledge of relative ET rates based upon characteristics of each vegetational zone; (5) obtain better estimates of surficial aquifer characteristics by conducting aquifer tests in same.

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C     -----------------------------------------------------------------MAN0010
C     FINITE-DIFFERENCE MODEL FOR SIMULATION OF GROUND-WATER FLOW IN    MAN0020
C     THREE DIMENSIONS, SEPTEMBER, 1975 BY P.C. TRESCOTT, U. S. G. S.   MAN0030
C     WITH CONTRIBUTIONS TO MAIN, DATAI AND SOLVE BY S.P. LARSON        MAN0040
C     -----------------------------------------------------------------MAN0050
C                                                                       MAN0060
C     SPECIFICATIONS:                                                   MAN0070
      REAL *8YSTR                                                       MAN0080
C                                                                       MAN0090
      DIMENSION Y(060000), L(32), HEADNG(33), NAME(42), INFT(2,2), IOFT(MAN0100
     19,4), DUM(3)                                                      MAN0110
C                                                                       MAN0120
      EQUIVALENCE (YSTR,Y(1))                                           MAN0130
C                                                                       MAN0140
      COMMON /INTEGR/ IO,JO,KO,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NMAN0150
     1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NCMAN0160
     2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK         MAN0170
      COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,IOK           MAN0180
      COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)
C                                                                       MAN0200
      DATA NAME/2*4H    ,4H   S,4HTART,4HING ,4HHEAD,4H    ,4H STO,4HRAGMAN0210
     1E,4H COE,4HFFIC,4HIENT,2*4H    ,4H  TR,4HANSM,4HISSI,4HVITY,5*4H  MAN0220
     2  ,4H  TK,4H  HY,4HDRAU,4HLIC ,4HCOND,4HUCTI,4HVITY,2*4H    ,4HBOTMAN0230
     3T,4HOM E,4HLEVA,4HTION,2*4H    ,4H   R,4HECHA,4HRGE ,4HRATE/      MAN0240
      DATA INFT/4H(20F,4H4.0),4H(8F1,4H0.4)/                            MAN0250
      DATA IOFT/4H(1H0,4H,I2,,4H2X,2,4H0F6.,4H1/(5,4HX,20,4HF6.1,4H))  ,MAN0260
     14H    ,4H(1H0,4H,I5,,4H14F9,4H.5/(,4H1H ,,4H5X,1,4H4F9.,4H5)) ,4H MAN0270
     2   ,4H(1H0,4H,I5,,4H10E1,4H2.5/,4H(1H ,4H,5X,,4H10E1,4H2.5),4H)   MAN0280
     3,4H(1H0,4H,I5,,4H10E1,4H1.3/,4H(1H ,4H,5X,,4H10E1,4H1.3),4H)   /  MAN0290
C                                                                       MAN0300
      DEFINE FILE 2(8,1520,U,KKK)                                       MAN0310
C     .................................................................MAN0320
C                                                                       MAN0330
C     ---READ TITLE, PROGRAM SIZE AND OPTIONS---                        MAN0340
    5 READ(5,200) HEADNG
      WRITE (6,190) HEADNG                                              MAN0360
      READ (5,160) IO,JO,KO,ITMAX,NCH,ND,NRIV,IOK                       MAN0370
      WRITE (6,180) IO,JO,KO,ITMAX,NCH,ND,NRIV                          MAN0380
      READ (5,210) IDRAW,IHEAD,IFLO,IDK1,IDK2,IWATER,IQRE,IPU1,IPU2,ITK MAN0390
     1,IEQN                                                             MAN0395
      WRITE (6,220) IDRAW,IHEAD,IFLO,IDK1,IDK2,IWATER,IQRE,IPU1,IPU2,ITKMAN0400
     1,IEQN                                                             MAN0405
      IERR=0                                                            MAN0410
C                                                                       MAN0420
C     ---COMPUTE DIMENSIONS FOR ARRAYS---                               MAN0430
      J1=JO-1                                                           MAN0440
      I1=IO-1                                                           MAN0450
      K1=KO-1                                                           MAN0460
      I2=IO-2                                                           MAN0470
      J2=JO-2                                                           MAN0480
      K2=KO-2                                                           MAN0490
      IMAX=MAXO(IO,JO)                                                  MAN0500
      NCD=MAXO(1,NCH)                                                   MAN0510
      ITMX1=ITMAX+1                                                     MAN0520
      ISIZ=IO*JO*KO                                                     MAN0530
      IK1=IO*JO                                                         MAN0540
      IK2=MAXO(IK1*K1,1)                                                MAN0550
```

```
      ISUM=2*ISIZ+1
      L(1)=1
      DO 30 I=2,14
      IF (I.NE.8) GO TO 20
      L(8)=ISUM
      ISUM=ISUM+IK2
      IF (IK2.EQ.1) GO TO 10
      IK=IO
      JK=JO
      K5=K1
      GO TO 30
   10 IK=1
      JK=1
      K5=1
      GO TO 30
   20 L(I)=ISUM
      ISUM=ISUM+ISIZ
   30 CONTINUE
      L(15)=ISUM
      ISUM=ISUM+JO
      L(16)=ISUM
      ISUM=ISUM+IO
      L(17)=ISUM
      ISUM=ISUM+KO
      L(18)=ISUM
      ISUM=ISUM+IMAX
      L(19)=ISUM
      ISUM=ISUM+KO*3
      L(20)=ISUM
      ISUM=ISUM+ITMX1
      L(21)=ISUM
      ISUM=ISUM+3*NCD
      L(22)=ISUM
      ISUM=ISUM+NCD
      L(23)=ISUM
      IF (IWATER.NE.ICHK(6)) GO TO 40
      ISUM=ISUM+IK1
      L(24)=ISUM
      ISUM=ISUM+IK1
      IP=IO
      JP=JO
      GO TO 50
   40 ISUM=ISUM+1
      L(24)=ISUM
      ISUM=ISUM+1
      IP=1
      JP=1
   50 L(25)=ISUM
      IF (IQRE.NE.ICHK(7)) GO TO 60
      ISUM=ISUM+IK1
      IQ=IO
      JQ=JO
      GO TO 70
   60 ISUM=ISUM+1
      IQ=1
      JQ=1
   70 IF(ND.EQ.0) GO TO 75
```

```
      L(26)=ISUM
      ISUM=ISUM+IK1
      L(27)=ISUM
      ISUM=ISUM+ND
      L(28)=ISUM
      ISUM=ISUM+ND
      GO TO 76
   75 L(26)=ISUM
      ISUM=ISUM+1
      L(27)=ISUM
      ISUM=ISUM+1
      L(28)=ISUM
      ISUM=ISUM+1
   76 IF(NRIV.EQ.0) GO TO 77
      L(29)=ISUM
      ISUM=ISUM+IK1
      L(30)=ISUM
      ISUM=ISUM+NRIV
      L(31)=ISUM
      ISUM=ISUM+NRIV
      L(32)=ISUM
      ISUM=ISUM+NRIV
      GO TO 78
   77 L(29)=ISUM
      L(30)=ISUM+1
      L(31)=ISUM+2
      L(32)=ISUM+3
      ISUM=ISUM+4
   78 WRITE(6,170) ISUM
C                                                                       MAN1130
C     ---PASS INITIAL ADDRESSES OF ARRAYS TO SUBROUTINES---             MAN1140
      CALL DATAI(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7))MAN1150
     1,Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(23)),Y(L(MAN1160
     224)),Y(L(25)),Y(L(26)),Y(L(27)),Y(L(28)),Y(L(29)),Y(L(30)),
     3 Y(L(31)),Y(L(32)))
      CALL STEP(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),MAN1180
     1Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(18)),Y(L(2MAN1190
     20)))                                                              MAN1200
      CALL SOLVE(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7))MAN1210
     1,Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(10)),Y(L(MAN1220
     211)),Y(L(12)),Y(L(13)),Y(L(14)),Y(L(20)),Y(L(25)),Y(L(23)),
     3 Y(L(26)),Y(L(27)),Y(L(28)),Y(L(29)),Y(L(30)),Y(L(31)),Y(L(32)),
     4 ND,NRIV)
      CALL COEF(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),MAN1240
     1Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(23)),Y(L(2MAN1250
     24)),Y(L(25)))                                                     MAN1260
      CALL CHECKI(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)MAN1270
     1),Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(21)),Y(LMAN1280
     2(22)),Y(L(25)),                                                   MAN1290
     3 Y(L(26)),Y(L(27)),Y(L(28)),Y(L(29)),Y(L(30)),Y(L(31)),Y(L(32)),
     4 ND,NRIV)
      CALL PRNTAI(Y(L(1)),Y(L(2)),Y(L(4)),Y(L(5)),Y(L(9)),Y(L(15)),Y(L(1MAN1300
     16)))                                                              MAN1310
C                                                                       MAN1320
C     ---START COMPUTATIONS---                                          MAN1330
C     ************************                                          MAN1340
C     ---READ AND WRITE DATA FOR GROUPS II AND III---                   MAN1350
```

```
      CALL DATAIN                                                       MAN1360
      IRN=1                                                             MAN1370
      NIJ=IO*JO                                                         MAN1380
      DO 80 K=1,KO                                                      MAN1390
      LOC=L(2)+(K-1)*NIJ                                                MAN1400
   80 CALL ARRAY(Y(LOC),INFT(1,2),IOFT(1,1),NAME(1),IRN,DUM)            MAN1410
      DO 90 K=1,KO                                                      MAN1420
      LOC=L(5)+(K-1)*NIJ                                                MAN1430
   90 CALL ARRAY(Y(LOC),INFT(1,1),IOFT(1,2),NAME(7),IRN,DUM)            MAN1440
      DO 100 K=1,KO                                                     MAN1450
      LOC=L(4)+(K-1)*NIJ                                                MAN1460
      L1=L(19)+K-1                                                      MAN1470
      L2=L(19)+KO+K-1                                                   MAN1480
      L3=L(19)+2*KO+K-1                                                 MAN1490
      CALL ARRAY(Y(LOC),INFT(1,1),IOFT(1,2),NAME(13),IRN,DUM)           MAN1500
      Y(L1)=DUM(1)                                                      MAN1510
      Y(L2)=DUM(2)                                                      MAN1520
      Y(L3)=DUM(3)                                                      MAN1530
  100 WRITE (6,230) K,Y(L1),Y(L2),Y(L3)                                 MAN1540
      IF (ITK.NE.ICHK(10)) GO TO 120                                    MAN1550
      DO 110 K=1,K1                                                     MAN1560
      LOC=L(8)+(K-1)*NIJ                                                MAN1570
  110 CALL ARRAY(Y(LOC),INFT(1,1),IOFT(1,3),NAME(19),IRN,DUM)           MAN1580
  120 IF (IWATER.NE.ICHK(6)) GO TO 130                                  MAN1590
      K=KO                                                               MAN1595
      CALL ARRAY(Y(L(23)),INFT(1,1),IOFT(1,4),NAME(25),IRN,DUM)         MAN1600
      CALL ARRAY(Y(L(24)),INFT(1,1),IOFT(1,1),NAME(31),IRN,DUM)         MAN1610
  130 IF (IQRE.EQ.ICHK(7)) CALL ARRAY(Y(L(25)),INFT(1,1),IOFT(1,4),NAME(MAN1620
     137),IRN,DUM)                                                      MAN1630
      CALL MDAT                                                         MAN1640
      IF(ND.NE.0) CALL DDAT(ND)
      IF(NRIV.NE.0) CALL DDAT2(NRIV)
C                                                                       MAN1650
C     ---COMPUTE TRANSMISSIVITY FOR UNCONFINED LAYER---                 MAN1660
      IF (IWATER.EQ.ICHK(6)) CALL TRANS(1)                              MAN1670
C                                                                       MAN1680
C     ---COMPUTE T COEFFICIENTS---                                      MAN1690
      CALL TCOF                                                         MAN1700
C                                                                       MAN1710
C     ---COMPUTE ITERATION PARAMETERS---                                MAN1720
      CALL ITER                                                         MAN1730
C                                                                       MAN1740
C     ---READ TIME PARAMETERS AND PUMPING DATA FOR A NEW PUMPING PERIOD-MAN1750
  140 CALL NEWPER                                                       MAN1760
C                                                                       MAN1770
      KT=0                                                              MAN1780
      IFINAL=0                                                          MAN1790
C                                                                       MAN1800
C     ---START NEW TIME STEP COMPUTATIONS---                            MAN1810
  150 CALL NEWSTP                                                       MAN1820
C                                                                       MAN1830
C     ---START NEW ITERATION IF MAXIMUM NO. ITERATIONS NOT EXCEEDED---  MAN1840
      CALL NEWITA                                                       MAN1850
      IF(IERR.EQ.2)GO TO 151
C                                                                       MAN1860
C     ---PRINT OUTPUT AT DESIGNATED TIME STEPS---                       MAN1870
      CALL OUTPUT                                                       MAN1880
```

```
      IF(IERR.EQ.2) GO TO 151
C                                                                       MAN1890
C     ---LAST TIME STEP IN PUMPING PERIOD ?---                          MAN1900
      IF (IFINAL.NE.1) GO TO 150                                        MAN1910
C                                                                       MAN1920
C     ---CHECK FOR NEW PUMPING PERIOD---                                MAN1930
      IF (KP.LT.NPER) GO TO 140                                         MAN1940
C                                                                       MAN1950
C     ---CHECK FOR NEW PROBLEM---
  151 READ(5,160,END=152) NEXT
      IF(NEXT.EQ.0) GO TO 5
  152 STOP
C                                                                       MAN1970
C     ---FORMATS---                                                     MAN1980
C                                                                       MAN1990
C                                                                       MAN2000
C                                                                       MAN2010
  160 FORMAT (8I10)                                                     MAN2020
  170 FORMAT ('0',54X,'WORDS OF VECTOR Y USED =',I7)                    MAN2030
  180 FORMAT ('0',62X,'NUMBER OF ROWS =',I5/60X,'NUMBER OF COLUMNS =',I5MAN2040
     1/61X,'NUMBER OF LAYERS =',I5//39X,'MAXIMUM PERMITTED NUMBER OF ITEMAN2050
     2RATIONS =',I5//48X,'NUMBER OF CONSTANT HEAD NODES =',I5,          MAN2060
     3 /,56X,'NUMBER OF DRAIN NODES =',I5,
     4 /,56X,'NUMBER OF RIVER NODES=',I5)
  190 FORMAT ('1',33A4)                                                 MAN2070
  200 FORMAT (20A4)                                                     MAN2080
  210 FORMAT (16(A4,1X))                                                MAN2090
  220 FORMAT ('-SIMULATION OPTIONS:   ',11(A4,4X))                      MAN2100
  230 FORMAT (1H0,44X,'DIRECTIONAL TRANSMISSIVITY MULTIPLICATION FACTORSMAN2110
     1 FOR LAYER',I3,/,76X,'X =',G15.7/76X,'Y =',G15.7/76X,'Z =',G15.7) MAN2120
      END                                                               MAN2130
```

```
      SUBROUTINE DATAI(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FACDAT0010
     1T,PERM,BOTTOM,QRE,ID,LD,ELD,IDR,RH,RC,RB)
C     ------------------------------------------------------------------DAT0030
C     READ AND WRITE DATA                                               DAT0040
C     ------------------------------------------------------------------DAT0050
C                                                                       DAT0060
C     SPECIFICATIONS:                                                   DAT0070
      REAL *8PHI                                                        DAT0080
      REAL *8XLABEL,YLABEL,TITLE,XN1,MESUR                              DAT0090
      REAL*4 LD
C                                                                       DAT0100
      DIMENSION PHI(IO,JO,KO), STRT(IO,JO,KO), OLD(IO,JO,KO), T(IO,JO,KODAT0110
     1), S(IO,JO,KO), TR(IO,JO,KO), TC(IO,JO,KO), TK(IK,JK,K5), WELL(IO,DAT0120
     2JO,KO), DELX(JO), DELY(IO), DELZ(KO), FACT(KO,3), PERM(IP,JP), BOTDAT0130
     3TOM(IP,JP), QRE(IQ,JQ), TF(3), A(IO,JO), IN(6), IOFT(9), INFT(2)  DAT0140
     4 ,ID(IO,JO),LD(1),ELD(1),IDR(IO,JO),RH(1),RC(1),RB(1)
C                                                                       DAT0150
      COMMON /INTEGR/ IO,JO,KO,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NDAT0160
     1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NCDAT0170
     2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK         DAT0180
      COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,IOK           DAT0190
      COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)
      COMMON /CK/ ETFLXT,STORT,QRET,CHST,CHDT,FLUXT,PUMPT,CFLUXT,FLXNT  DAT0210
      COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANKDAT0220
     1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),DAT0230
     2YN(13),NA(4),N1,N2,N3,YSCALE,FACT1,FACT2                          DAT0240
      COMMON /EVAPO/ ETDIST,QET,GRND(50,50)
      COMMON /B/ BETA
      RETURN                                                            DAT0250
C     ..................................................................DAT0260
C     ********************                                              DAT0270
      ENTRY DATAIN                                                      DAT0280
C     ********************                                              DAT0290
C                                                                       DAT0300
C     ---READ AND WRITE SCALAR PARAMETERS---                            DAT0310
      READ (5,330) NPER,KTH,ERR,LENGTH,QET,ETDIST,BETA                  DAT0320
      WRITE (6,340) NPER,KTH,ERR,LENGTH,QET,ETDIST                      DAT0330
      WRITE(6,346) BETA
      READ (5,460) XSCALE,YSCALE,DINCH,FACT1,(LEVEL1(I),I=1,9),FACT2,(LEDAT0340
     1VEL2(I),I=1,9),MESUR                                              DAT0350
      IF (XSCALE.NE.0.) WRITE (6,470) XSCALE,YSCALE,MESUR,MESUR,DINCH,FADAT0360
     1CT1,LEVEL1,FACT2,LEVEL2                                           DAT0370
C                                                                       DAT0380
C     ---READ CUMULATIVE MASS BALANCE PARAMETERS---                     DAT0390
      READ (5,450) SUM,SUMP,PUMPT,CFLUXT,QRET,CHST,CHDT,FLUXT,STORT,ETFLDAT0400
     1XT,FLXNT                                                          DAT0410
      IF (IDK1.EQ.ICHK(4)) GO TO 20                                     DAT0420
      IF (IPU1.NE.ICHK(8)) GO TO 50                                     DAT0430
C                                                                       DAT0440
C     ---READ INITIAL HEAD VALUES FROM CARDS---                         DAT0450
      DO 10 K=1,KO                                                      DAT0460
      DO 10 I=1,IO                                                      DAT0470
   10 READ (5,360) (PHI(I,J,K),J=1,JO)                                  DAT0480
      GO TO 30                                                          DAT0490
C                                                                       DAT0500
C     ---READ INITIAL HEAD AND MASS BALANCE PARAMETERS FROM DISK---      DAT0510
   20 READ (4) PHI,SUM,SUMP,PUMPT,CFLUXT,QRET,CHST,CHDT,FLUXT,STORT,ETFLDAT0520
```

```
     1XT,FLXNT
      REWIND 4
   30 WRITE (6,430) SUM
      DO 40 K=1,KO
      WRITE (6,440) K
      DO 40 I=1,IO
   40 WRITE (6,350) I,(PHI(I,J,K),J=1,JO)
C
   50 DO 60 K=1,KO
      DO 60 I=1,IO
      DO 60 J=1,JO
      WELL(I,J,K)=0.
      TR(I,J,K)=0.
      TC(I,J,K)=0.
      IF (K.NE.KO) TK(I,J,K)=0.
   60 CONTINUE
      IF(QET.EQ.0)GO TO 69
      READ (5,330) FAC,IPRN
      DO 65 I=1,IO
      READ (5,66) (GRND(I,J),J=1,JO)
      DO 65 J=1,JO
   65 GRND(I,J)=GRND(I,J)*FAC
   66 FORMAT (20F4.0)
      IF(IPRN.EQ.1) GO TO 69
      WRITE(6,345)
      DO 67 I=1,IO
   67 WRITE (6,350) I,(GRND(I,J),J=1,JO)
   69 CONTINUE
      RETURN
C     **********************
      ENTRY ARRAY(A,INFT,IOFT,IN,IRN,TF)
C     **********************
      READ (5,330) FAC,IVAR,IPRN,TF,IRECS,IRECD
      IC=4*IRECS+2*IVAR+IPRN+1
      GO TO (70,70,90,90,120,120), IC
   70 DO 80 I=1,IO
      DO 80 J=1,JO
   80 A(I,J)=FAC
      WRITE (6,280) IN,FAC,K
      GO TO 140
   90 IF (IC.EQ.3) WRITE (6,290) IN,K
      DO 110 I=1,IO
      READ (5,INFT) (A(I,J),J=1,JO)
      DO 100 J=1,JO
  100 A(I,J)=A(I,J)*FAC
  110 IF (IC.EQ.3) WRITE (6,IOFT) I,(A(I,J),J=1,JO)
      GO TO 140
  120 READ (2'IRN) A
      IF (IC.EQ.6) GO TO 140
      WRITE (6,290) IN,K
      DO 130 I=1,IO
  130 WRITE (6,IOFT) I,(A(I,J),J=1,JO)
  140 IF (IRECD.EQ.1) WRITE (2'IRN) A
      IRN=IRN+1
      RETURN
C     **********************
      ENTRY MDAT
```

```
C     **********************
      DO 150 K=1,KO
      DO 150 I=1,IO
      DO 150 J=1,JO
      IF (I.EQ.1.OR.I.EQ.IO.OR.J.EQ.1.OR.J.EQ.JO) T(I,J,K)=0.
      IF (IDK1.NE.ICHK(4).AND.IPU1.NE.ICHK(8)) PHI(I,J,K)=STRT(I,J,K)
      IF (K.NE.KO.OR.IWATER.NE.ICHK(6)) GO TO 150
      IF (I.EQ.1.OR.I.EQ.IO.OR.J.EQ.1.OR.J.EQ.JO) PERM(I,J)=0.
  150 CONTINUE
C     .............................. DELX ...............................
      READ (5,330) FAC,IVAR,IPRN
      IF (IVAR.EQ.1) READ (5,330) (DELX(J),J=1,JO)
      DO 170 J=1,JO
      IF (IVAR.NE.1) GO TO 160
      DELX(J)=DELX(J)*FAC
      GO TO 170
  160 DELX(J)=FAC
  170 CONTINUE
      IF (IVAR.EQ.1.AND.IPRN.NE.1) WRITE (6,370) (DELX(J),J=1,JO)
      IF (IVAR.EQ.0) WRITE (6,300) FAC
C     .............................. DELY ...............................
      READ (5,330) FAC,IVAR,IPRN
      ETQ=0.0
      IF (IVAR.EQ.1) READ (5,330) (DELY(I),I=1,IO)
      DO 190 I=1,IO
      IF (IVAR.NE.1) GO TO 180
      DELY(I)=DELY(I)*FAC
      GO TO 190
  180 DELY(I)=FAC
  190 CONTINUE
      IF (IVAR.EQ.1.AND.IPRN.NE.1) WRITE (6,380) (DELY(I),I=1,IO)
      IF (IVAR.EQ.0) WRITE (6,310) FAC
C     .............................. DELZ ...............................
      READ (5,330) FAC,IVAR,IPRN
      IF (IVAR.EQ.1) READ (5,330) (DELZ(K),K=1,KO)
      DO 210 K=1,KO
      IF (IVAR.NE.1) GO TO 200
      DELZ(K)=DELZ(K)*FAC
      GO TO 210
  200 DELZ(K)=FAC
  210 CONTINUE
      IF (IVAR.EQ.1.AND.IPRN.NE.1) WRITE (6,390) (DELZ(K),K=1,KO)
      IF (IVAR.EQ.0) WRITE (6,320) FAC
C
C     ---INITIALIZE VARIABLES---
      B=0.
      D=0.
      F=0.
      H=0.
      SU=0.
      Z=0.
      IF (XSCALE.NE.0.) CALL MAP
      RETURN
C     ***************
      ENTRY DDAT(ND)
C     ***************
      NK=1
```

```
      DO 500 I=1,IO
      READ 510, (ID(I,J),J=1,JO)
  510 FORMAT (80I1)
      DO 500 J=1,JO
      IF(ID(I,J).EQ.0) GO TO 500
      ID(I,J)=NK
      NK=NK+1
  500 CONTINUE
      NK=NK-1
      IF(NK.EQ.ND) GO TO 520
      PRINT 515,NK,ND
  515 FORMAT ('  ERROR****NK.NE.ND   NK=',I5,5X,'ND=',I5)
      STOP
  520 READ 330, FAC
      READ 530, (LD(I),I=1,ND)
  530 FORMAT(40F2.0)
      PRINT 540,(LD(I),I=1,ND)
  540 FORMAT(/,(20(1X,F5.0)))
      DO 550 I=1,IO
      DO 550 J=1,JO
      K=ID(I,J)
      IF(K.EQ.0) GO TO 550
      LD(K)=LD(K)*FAC*T(I,J,KO)/(DELX(J)*DELY(I))
  550 CONTINUE
      READ 330, FAC
      READ 560,(ELD(I),I=1,ND)
      PRINT 540,(ELD(I),I=1,ND)
  560 FORMAT (20F4.0)
      DO 570 I=1,ND
  570 ELD(I)=ELD(I)*FAC
      RETURN
C     ***************
      ENTRY DDAT2(NRIV)
C     ***************
      NK=1
      DO 580 I=1,IO
      READ 510,(IDR(I,J),J=1,JO)
      DO 580 J=1,JO
      IF(IDR(I,J).EQ.0) GO TO 580
      IDR(I,J)=NK
      NK=NK+1
  580 CONTINUE
      NK=NK-1
      IF(NK.EQ.NRIV) GO TO 600
      PRINT 585,NK,NRIV
  585 FORMAT('   ERROR****NK.NE.NRIV    NK=',I5,5X,'NRIV=',I5)
      STOP
  600 READ 330,FAC
      READ 560,(RH(I),I=1,NRIV)
      DO 610 I=1,NRIV
  610 RH(I)=RH(I)*FAC
      PRINT 539
  539 FORMAT(/,5X,'RIVER WATER LEVEL',/,5X,17('-'))
      PRINT 540,(RH(I),I=1,NRIV)
      READ 330,FAC
      READ 560,(RB(I),I=1,NRIV)
      DO 620 I=1,NRIV
```

```
  620 RB(I)=RB(I)*FAC
      PRINT 538
  538 FORMAT(/,5X,'RIVER BOTTOM ELEVATION',/,5X,22('-'))
      PRINT 540,(RB(I),I=1,NRIV)
      READ 330,FAC
      READ 625,(RC(I),I=1,NRIV)
  625 FORMAT(10F8.0)
      DO 630 I=1,NRIV
  630 RC(I)=RC(I)*FAC
      PRINT 634
  634 FORMAT(/,5X,'RIVER LEAKANCE',/,5X,14('-'))
      PRINT 635,(RC(I),I=1,NRIV)
  635 FORMAT(/(14(1X,E8.2)))
      RETURN
C     ...............................................................DAT1500
C     ---READ TIME PARAMETERS AND PUMPING DATA FOR A NEW PUMPING PERIOD-DAT1510
C     **********************                                         DAT1520
      ENTRY NEWPER                                                   DAT1530
C     **********************                                         DAT1540
C                                                                    DAT1550
      READ (5,330) KP,KPM1,NWEL,TMAX,NUMT,CDLT,DELT,IRECH            DAT1560
      IF(IRECH.EQ.1) READ(3) QRE
C                                                                    DAT1570
C     ---COMPUTE ACTUAL DELT AND NUMT---                             DAT1580
      DT=DELT/24.                                                    DAT1590
      TM=0.0                                                         DAT1600
      DO 220 I=1,NUMT                                                DAT1610
      DT=CDLT*DT                                                     DAT1620
      TM=TM+DT                                                       DAT1630
      IF (TM.GE.TMAX) GO TO 230                                      DAT1640
  220 CONTINUE                                                       DAT1650
      GO TO 240                                                      DAT1660
  230 DELT=TMAX/TM*DELT                                              DAT1670
      NUMT=I                                                         DAT1680
  240 WRITE (6,400) KP,TMAX,NUMT,DELT,CDLT                           DAT1690
      DELT=DELT*3600.                                                DAT1700
      TMAX=TMAX*86400.                                               DAT1710
      SUMP=0.0                                                       DAT1720
C                                                                    DAT1730
C     ---READ AND WRITE WELL PUMPING RATES---                        DAT1740
      WRITE (6,410) NWEL                                             DAT1750
      IF (NWEL.EQ.0) GO TO 260                                       DAT1760
      DO 245 K=1,KO                                                   DAT1761
      DO 245 I=1,IO                                                   DAT1762
      DO 245 J=1,JO                                                   DAT1763
  245 WELL(I,J,K)=0.0                                                 DAT1764
      DO 250 II=1,NWEL                                               DAT1770
      READ (5,330) K,I,J,WELL(I,J,K)                                 DAT1780
      WRITE (6,420) K,I,J,WELL(I,J,K)                                DAT1790
  250 WELL(I,J,K)=WELL(I,J,K)/(DELX(J)*DELY(I))                      DAT1800
  260 RETURN                                                         DAT1810
C                                                                    DAT1820
C     ---FORMATS---                                                  DAT1830
C                                                                    DAT1840
C                                                                    DAT1850
C                                                                    DAT1860
  280 FORMAT (1H0,52X,6A4,' =',G15.7,' FOR LAYER',I3)                DAT1870
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```
290 FORMAT (1H1,45X,6A4,' MATRIX, LAYER',I3/46X,41('-'))                DAT1880
300 FORMAT ('0',72X,'DELX =',G15.7)                                     DAT1890
310 FORMAT ('0',72X,'DELY =',G15.7)                                     DAT1900
320 FORMAT ('0',72X,'DELZ =',G15.7)                                     DAT1910
330 FORMAT (8G10.0)                                                     DAT1920
340 FORMAT ('0',51X,'NUMBER OF PUMPING PERIODS =',I5/49X,'TIME STEPS BDAT1930
   1ETWEEN PRINTOUTS =',I5//51X,'ERROR CRITERIA FOR CLOSURE =',G15.7//DAT1940
   257X,'ITERATION PARAMETERS=',I5//62X,'MAXIMUM ET RATE=',G15.7//53X,DAT1945
   3'DEPTH AT WHICH ET CEASES=',G15.7/)                                 DAT1946
345 FORMAT('1',45X,'LAND SURFACE ALTITUDE'/45X,21('-')//)
346 FORMAT('0',72X,'BETA = ',F4.2)
350 FORMAT ('0',I2,2X,20F6.1/(5X,20F6.1))                               DAT1950
360 FORMAT (8F10.4)                                                     DAT1960
370 FORMAT (1H1,46X,40HGRID SPACING IN PROTOTYPE IN X DIRECTION/47X,40DAT1970
   1('-')//('0',12F10.0))                                               DAT1980
380 FORMAT (1H-,46X,40HGRID SPACING IN PROTOTYPE IN Y DIRECTION/47X,40DAT1990
   1('-')//('0',12F10.0))                                               DAT2000
390 FORMAT (1H-,46X,40HGRID SPACING IN PROTOTYPE IN Z DIRECTION/47X,40DAT2010
   1('-')//('0',12F10.0))                                               DAT2020
400 FORMAT ('-',50X,'PUMPING PERIOD NO.',I4,':',F10.2,' DAYS'/51X,38('DAT2030
   1-')//53X,'NUMBER OF TIME STEPS=',I6//59X,'DELT IN HOURS =',F10.3//DAT2040
   253X,'MULTIPLIER FOR DELT =',F10.3)                                  DAT2050
410 FORMAT ('-',63X,I4,' WELLS'/65X,9('-')//50X,'K',9X,'I',9X,'J    PUDAT2060
   1MPING RATE'/)                                                       DAT2070
420 FORMAT (41X,3I10,2F13.2)                                            DAT2080
430 FORMAT ('-',40X,' CONTINUATION - HEAD AFTER ',G20.7,' SEC PUMPING DAT2090
   1'/42X,58('-'))                                                      DAT2100
440 FORMAT ('1',55X,'INITIAL  HEAD MATRIX, LAYER',I3/56X,30('-'))       DAT2110
450 FORMAT (4G20.10)                                                    DAT2120
460 FORMAT (3G10.0,2(G10.0,9I1,1X),A8)                                  DAT2130
470 FORMAT ('0',30X,'ON ALPHAMERIC MAP:'/40X,'MULTIPLICATION FACTOR FODAT2140
   1R X DIMENSION =',G15.7/40X,'MULTIPLICATION FACTOR FOR Y DIMENSION DAT2150
   2=',G15.7/55X,'MAP SCALE IN UNITS OF  ',A11/50X,'NUMBER OF ',A8,' PDAT2160
   3ER INCH =',G15.7/43X,'MULTIPLICATION FACTOR FOR DRAWDOWN =',G15.7,DAT2170
   4' PRINTED FOR LAYERS',9I2/47X,'MULTIPLICATION FACTOR FOR HEAD =',GDAT2180
   515.7,' PRINTED FOR LAYERS',9I2)                                     DAT2190
    END                                                                 DAT2200
```

```
      SUBROUTINE STEP(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FACT
     1,DDN,TEST3)
C     ------------------------------------------------------------------
C     INITIALIZE DATA FOR A NEW TIME STEP AND PRINT RESULTS
C     ------------------------------------------------------------------
C
C     SPECIFICATIONS:
      REAL *8PHI
      REAL *8XLABEL,YLABEL,TITLE,XN1,MESUR
C
      DIMENSION PHI(IO,JO,KO), STRT(IO,JO,KO), OLD(IO,JO,KO), T(IO,JO,KO
     1), S(IO,JO,KO), TR(IO,JO,KO), TC(IO,JO,KO), TK(IK,JK,K5), WELL(IO,
     2JO,KO), DELX(JO), DELY(IO), DELZ(KO), FACT(KO,3), DDN(IMAX), TEST3
     3(ITMX1), ITTO(50)
C
      COMMON /INTEGR/ IO,JO,KO,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,N
     1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NC
     2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK
      COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,IOK
      COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)
      COMMON /CK/ ETFLXT,STORT,QRET,CHST,CHDT,FLUXT,PUMPT,CFLUXT,FLXNT
      COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANK
     1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),
     2YN(13),NA(4),N1,N2,N3,YSCALE,FACT1,FACT2
      RETURN
C     ..................................................................
C     *********************
      ENTRY NEWSTP
C     *********************
      KT=KT+1
      IT=0
      DO 10 K=1,KO
      DO 10 I=1,IO
      DO 10 J=1,JO
   10 OLD(I,J,K)=PHI(I,J,K)
      DELT=CDLT*DELT
      SUM=SUM+DELT
      SUMP=SUMP+DELT
      DAYSP=SUMP/86400.
      YRSP=DAYSP/365.
      HRS=SUM/3600.
      SMIN=HRS*60.
      DAYS=HRS/24.
      YRS=DAYS/365.
      RETURN
C
C     ---PRINT OUTPUT AT DESIGNATED TIME STEPS---
C     *********************
      ENTRY OUTPUT
C     *********************
      IERR=1
      IF (KT.EQ.NUMT) IFINAL=1
      ITTO(KT)=IT
      IF (IT.LE.ITMAX) GO TO 20
      IT=IT-1
      ITTO(KT)=IT
      IERR=2
```

```
C
C     ---IF MAXIMUM ITERATIONS EXCEEDED,WRITE RESULTS ON DISK OR CARDS--
      IF (IDK2.EQ.ICHK(5)) WRITE (4) PHI,SUM,SUMP,PUMPT,CFLUXT,QRET,CHST
     1,CHDT,FLUXT,STORT,ETFLXT,FLXNT
      IF (IPU2.EQ.ICHK(9)) WRITE (7,230) SUM,SUMP,PUMPT,CFLUXT,QRET,CHST
     1,CHDT,FLUXT,STORT,ETFLXT,FLXNT
C
   20 IF (IFLO.EQ.ICHK(3)) CALL CHECK
      IF (IERR.EQ.2) GO TO 30
      IF (MOD(KT,KTH).NE.0.AND.IFINAL.NE.1) RETURN
   30 WRITE (6,210) KT,DELT,SUM,SMIN,HRS,DAYS,YRS,DAYSP,YRSP
      IF (IFLO.EQ.ICHK(3)) CALL CWRITE
      IT=IT+1
      WRITE (6,180) (TEST3(J),J=1,IT)
      I3=1
      I5=0
  352 I5=I5+40
      I4=MIN0(KT,I5)
      WRITE (6,240) (I,I=I3,I4)
      WRITE (6,260)
      WRITE (6,250) (ITTO(I),I=I3,I4)
      WRITE (6,260)
      IF(KT.LE.I5) GO TO 353
      I3=I3+40
      GO TO 352
C
C     ---PRINT MAPS---
  353 IF (XSCALE.EQ.0.) GO TO 70
      IF (FACT1.EQ.0.) GO TO 50
      DO 40 IA=1,9
      II=LEVEL1(IA)
      IF (II.EQ.0) GO TO 50
   40 CALL PRNTA(1,II)
   50 IF (FACT2.EQ.0.) GO TO 70
      DO 60 IA=1,9
      II=LEVEL2(IA)
      IF (II.EQ.0) GO TO 70
   60 CALL PRNTA(2,II)
   70 IF (IDRAW.NE.ICHK(1)) GO TO 100
C
C     ---PRINT DRAWDOWN---
      DO 90 K=1,KO
      WRITE (6,200) K
      DO 90 I=1,IO
      DO 80 J=1,JO
   80 DDN(J)=STRT(I,J,K)-PHI(I,J,K)
      IF(K.EQ.1) WRITE(6,169) I,(DDN(J),J=1,JO)
      IF(K.NE.1) WRITE(6,170) I,(DDN(J),J=1,JO)
   90 CONTINUE
  100 IF (IHEAD.NE.ICHK(2)) GO TO 120
C
C     ---PRINT HEAD MATRIX---
      DO 110 K=1,KO
      WRITE (6,190) K
      DO 110 I=1,IO
  110 WRITE (6,170) I,(PHI(I,J,K),J=1,JO)
C
```

```
C     ---WRITE ON DISK---
  120 IF (IERR.EQ.2) GO TO 130
      IF (KP.LT.NPER.OR.IFINAL.NE.1) RETURN
      IF (IDK2.EQ.ICHK(5)) WRITE (4) PHI,SUM,SUMP,PUMPT,CFLUXT,QRET,CHST
     1,CHDT,FLUXT,STORT,ETFLXT,FLXNT
C
C     ---PUNCHED OUTPUT---
  130 IF (IPU2.NE.ICHK(9)) GO TO 160
      IF (IERR.EQ.2) GO TO 140
      WRITE (7,230) SUM,SUMP,PUMPT,CFLUXT,QRET,CHST,CHDT,FLUXT,STORT,ETF
     1LXT,FLXNT
  140 DO 150 K=1,KO
      DO 150 I=1,IO
  150 WRITE (7,220) (PHI(I,J,K),J=1,JO)
  160 RETURN
C
C     ---FORMATS---
C
C
C
  169 FORMAT('0',I4,20F6.1/(5X,20F6.1))
  170 FORMAT ('0',I4,20F6.2/(5X,20F6.2))
  180 FORMAT ('0MAXIMUM HEAD CHANGE FOR EACH ITERATION:'/' ',39('-')/('0
     1',10F12.4))
  190 FORMAT ('1',55X,'HEAD MATRIX, LAYER',I3/56X,21('-'))
  200 FORMAT ('1',55X,'   DRAWDOWN, LAYER',I3/59X,18('-'))
  210 FORMAT (1H1,44X,57('-')/45X,'!',14X,'TIME STEP NUMBER =',I9,14X,'!
     1'/45X,57('-')//50X,29HSIZE OF TIME STEP IN SECONDS=,F14.2//55X,'TO
     2TAL SIMULATION TIME IN SECONDS=',F14.2/80X,8HMINUTES=,F14.2/82X,6H
     3HOURS=,F14.2/83X,5HDAYS=,F14.2/82X,'YEARS=',F14.2///45X,'DURATION
     4OF CURRENT PUMPING PERIOD IN DAYS=',F14.2/82X,'YEARS=',F14.2//)
  220 FORMAT (8F10.4)
  230 FORMAT (4G20.10)
  240 FORMAT ('0TIME STEP :',40I3)
  250 FORMAT ('0ITERATIONS:',40I3)
  260 FORMAT (' ',10('-'))
      END
```

```
      SUBROUTINE SOLVE(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FAC
     1T,EL,FL,GL,V,XI,TEST3,QRE,PERM,ID,FLD,ELD,IDR,RH,RC,RB,IDRAIN,
     2 IRIV)
C     ------------------------------------------------------------------
C     SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
C     ------------------------------------------------------------------
C
C     SPECIFICATIONS:
      REAL *8PHI,RHO,B,D,F,H,Z,SU,RHOP,W,WMIN,RHO1,RHO2,RHO3,XPART,YPART
     1,ZPART,DMIN1,WMAX,XT,YT,ZT,DABS,DMAX1,DEN,TXM,TYM,TZM
      REAL*8 UX,UXR
      REAL *8E,AL,BL,CL,A,C,G,WU,TU,U,DL,RES,SUPH,GLXI,ZPHI
C
      DIMENSION PHI(1), STRT(1), OLD(1), T(1), S(1), TR(1), TC(1), TK(1)
     1, WELL(1), DELX(1), DELY(1), DELZ(1), FACT(KO,3), RHOP(20), TEST3(
     21), EL(1), FL(1), GL(1), V(1), XI(1), QRE(1)
     3,ID(1),FLD(1),ELD(1),PERM(1),IDR(1),RH(1),RC(1),RB(1)
C
      COMMON /INTEGR/ IO,JO,KO,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,N
     1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NC
     2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK
      COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,IOK
      COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)
      COMMON /EVAPO/ ETDIST,QET,GRND(50,50)
      COMMON /B/ BETA
      RETURN
C     ..................................................................
C     **********************
      ENTRY ITER
C     **********************
C     ---COMPUTE AND PRINT ITERATION PARAMETERS---
      WRITE (6,240)
      WMIN=1.DO
      DELT=1.
      P2=LENGTH-1
      NT=IO*JO*KO
      NIJ=IO*JO
      XT=3.141593**2/(2.*J2*J2)
      YT=3.141593**2/(2.*I2*I2)
      ZT=3.141593**2/(2.*KO*KO)
      RHO1=0.DO
      RHO2=0.DO
      RHO3=0.DO
      DO 40 K=1,KO
      DO 40 I=2,I1
      DO 40 J=2,J1
      N=I+(J-1)*IO+(K-1)*NIJ
      IF (T(N).EQ.O.) GO TO 40
      D=TR(N-IO)/DELX(J)
      F=TR(N)/DELX(J)
      B=TC(N-1)/DELY(I)
      H=TC(N)/DELY(I)
      SU=0.DO
      Z=0.DO
      IF (K.NE.1) Z=TK(N-NIJ)/DELZ(K)
      IF (K.NE.KO) SU=TK(N)/DELZ(K)
      RHO=S(N)/DELT
```

```
      QR=0.
      IF (K.NE.KO) GO TO 10
      IF (IQRE.EQ.ICHK(7)) QR=QRE(I+(J-1)*IO)
   10 CONTINUE
      TXM=DMAX1(D,F)
      TYM=DMAX1(B,H)
      TZM=DMAX1(SU,Z)
      DEN=DMIN1(D,F)
      IF (DEN.EQ.0.DO) DEN=TXM
      IF (DEN.EQ.0.DO) GO TO 20
      RHO1=DMAX1(RHO1,TYM/DEN)
   20 DEN=DMIN1(B,H)
      IF (DEN.EQ.0.DO) DEN=TYM
      IF (DEN.EQ.0.DO) GO TO 30
      RHO2=DMAX1(RHO2,TXM/DEN)
   30 DEN=DMIN1(SU,Z)
      IF (DEN.EQ.0.DO) DEN=TZM
      IF (DEN.EQ.0.DO) GO TO 40
      RHO3=DMAX1(RHO3,TXM/DEN)
   40 CONTINUE
      XPART=XT/(1.DO+RHO1)
      YPART=YT/(1.DO+RHO2)
      ZPART=ZT/(1.DO+RHO3)
      WMIN=DMIN1(WMIN,XPART,YPART,ZPART)
      WMAX=1.DO-WMIN
      PJ=-1.
      DO 50 I=1,LENGTH
      PJ=PJ+1.
   50 RHOP(I)=1.DO-(1.DO-WMAX)**(PJ/P2)
      WRITE (6,230) LENGTH,BETA,(RHOP(J),J=1,LENGTH)
      RETURN
C     ...................................................................
C
C     ---INITIALIZE DATA FOR A NEW ITERATION---
   60 IT=IT+1
      IF (IT.LE.ITMAX) GO TO 70
      WRITE (6,220)
      CALL OUTPUT
      RETURN
   70 IF (MOD(IT,LENGTH)) 80,80,90
C     **********************
      ENTRY NEWITA
C     **********************
   80 NTH=0
   90 NTH=NTH+1
      W=RHOP(NTH)
      TEST3(IT+1)=0.
      TEST=0.0
      BIG=0.
      DO 100 I=1,NT
      EL(I)=0.
      FL(I)=0.
      GL(I)=0.
      V(I)=0.
  100 XI(I)=0.
C
C     ---COMPUTE TRANSMISSIVITY AND T COEFFICIENTS FOR UPPER
```

```
C     HYDROLOGIC UNIT WHEN IT IS UNCONFINED---                      SP31090
      IF (IWATER.NE.ICHK(6)) GO TO 110                              SP31100
      CALL TRANS(0)                                                 SP31110
C                                                                   SP31120
C     ---CHOOSE SIP NORMAL OR REVERSE ALGORITHM---                  SP31130
  110 IF (MOD(IT,2)) 120,120,170                                    SP31140
  120 DO 150 K=1,KO                                                 SP31150
      DO 150 I=2,I1                                                 SP31160
      DO 150 J=2,J1                                                 SP31170
      N=I+(J-1)*IO+(K-1)*NIJ                                        SP31180
      NIA=N+1                                                       SP31190
      NIB=N-1                                                       SP31200
      NJA=N+IO                                                      SP31210
      NJB=N-IO                                                      SP31220
      NKA=N+NIJ                                                     SP31230
      NKB=N-NIJ                                                     SP31240
C                                                                   SP31250
C     ---SKIP COMPUTATIONS IF NODE OUTSIDE MODEL---                 SP31260
      IF (T(N).EQ.O..OR.S(N).LT.O.) GO TO 150                       SP31270
C                                                                   SP31280
C     ---COMPUTE COEFFICIENTS---                                    SP31290
      D=TR(NJB)/DELX(J)                                             SP31300
      F=TR(N)/DELX(J)                                               SP31310
      B=TC(NIB)/DELY(I)                                             SP31320
      H=TC(N)/DELY(I)                                               SP31330
      SU=O.DO                                                       SP31340
      Z=O.DO                                                        SP31350
      IF (K.NE.1) Z=TK(NKB)/DELZ(K)                                 SP31360
      IF (K.NE.KO) SU=TK(N)/DELZ(K)                                 SP31370
      RHO=S(N)/DELT                                                 SP31380
      ETQB=O.
      ETQD=O.
      IF(K.NE.KO) GO TO 126
      IF(QET.EQ.O.) GO TO 126
      IF(PHI(N).LE.GRND(I,J) - ETDIST) GO TO 126
      IF (PHI(N).GT.GRND(I,J)) GO TO 125
      ETQB=QET/ETDIST
      ETQD=ETQB*(ETDIST-GRND(I,J))
      GO TO 126
  125 ETQD=QET
  126 CONTINUE
      QR=O.                                                         SP31390
      UXR=O.
      UX=O.
      IF (K.NE.KO) GO TO 130                                        SP31400
      IF (IQRE.EQ.ICHK(7)) QR=QRE(I+(J-1)*IO)                       SP31410
C                                                                   SP31420
      IF(IRIV.LE.O) GO TO 128
      ND=IDR(I+(J-1)*IO)
      IF(ND.EQ.O) GO TO 128
      IF(PHI(N).GT.RB(ND)) GO TO 124
      QR=QR+RC(ND)*(RH(ND)-RB(ND))
      GO TO 128
  124 UXR=RC(ND)
      QR=QR+RC(ND)*RH(ND)
  128  IF(IDRAIN.LE.O) GO TO 130
      ND=ID(I+(J-1)*IO)
```

```
      IF(ND.EQ.0) GO TO 130
      IF(ELD(ND).GT.PHI(N)) GO TO 130
      UX=FLD(ND)
      QR=QR+FLD(ND)*ELD(ND)
C     ---SIP NORMAL ALGORITHM---
C     ---FORWARD SUBSTITUTE, COMPUTING INTERMEDIATE VECTOR V---
  130 E=-B-D-F-H-SU-Z-RHO-ETQD-UX-UXR
      BL=B/(1.+W*(EL(NIB)+GL(NIB)))
      CL=D/(1.+W*(FL(NJB)+GL(NJB)))
      C=BL*EL(NIB)
      G=CL*FL(NJB)
      WU=CL*GL(NJB)
      U=BL*GL(NIB)
      IF (K.EQ.1) GO TO 140
      AL=Z/(1.+W*(EL(NKB)+FL(NKB)))
      A=AL*EL(NKB)
      TU=AL*FL(NKB)
      DL=E+W*(A+C+G+WU+TU+U)-CL*EL(NJB)-BL*FL(NIB)-AL*GL(NKB)
      EL(N)=(F-W*(A+C))/DL
      FL(N)=(H-W*(G+TU))/DL
      GL(N)=(SU-W*(WU+U))/DL
      SUPH=0.D0
      IF (K.NE.KO) SUPH=SU*PHI(NKA)
      RES=-B*PHI(NIB)-D*PHI(NJB)-E*PHI(N)-F*PHI(NJA)-H*PHI(NIA)-SUPH-Z*P
     1HI(NKB)-WELL(N)-RHO*OLD(N)-QR+ETQD
      RES=BETA*RES
      V(N)=(RES-AL*V(NKB)-BL*V(NIB)-CL*V(NJB))/DL
      GO TO 150
  140 DL=E+W*(C+G+WU+U)-CL*EL(NJB)-BL*FL(NIB)
      EL(N)=(F-W*C)/DL
      FL(N)=(H-W*G)/DL
      GL(N)=(SU-W*(WU+U))/DL
      SUPH=0.D0
      IF (K.NE.KO) SUPH=SU*PHI(NKA)
      RES=-B*PHI(NIB)-D*PHI(NJB)-E*PHI(N)-F*PHI(NJA)-H*PHI(NIA)-SUPH-WEL
     1L(N)-RHO*OLD(N)-QR
      RES=BETA*RES
      V(N)=(RES-BL*V(NIB)-CL*V(NJB))/DL
  150 CONTINUE
C
C     ---BACK SUBSTITUTE FOR VECTOR XI---
      DO 160 K=1,KO
      K3=KO-K+1
      DO 160 I=1,I2
      I3=IO-I
      DO 160 J=1,J2
      J3=JO-J
      N=I3+(J3-1)*IO+(K3-1)*NIJ+I-I
      IF (T(N).EQ.0..OR.S(N).LT.0.) GO TO 160
      GLXI=0.D0
      IF (K3.NE.KO) GLXI=GL(N)*XI(N+NIJ)
      XI(N)=V(N)-EL(N)*XI(N+IO)-FL(N)*XI(N+1)-GLXI
C
C     ---COMPARE MAGNITUDE OF CHANGE WITH CLOSURE CRITERIA---
      TCHK=ABS(XI(N))
      IF (TCHK.GT.BIG) BIG=TCHK
      PHI(N)=PHI(N)+XI(N)
```

```
  160 CONTINUE
      IF (BIG.GT.ERR) TEST=1.
      TEST3(IT+1)=BIG
      IF (TEST.EQ.0.) RETURN
      GO TO 60
C ......................................................................
  170 DO 200 KK=1,KO
      K=KO-KK+1
      DO 200 II=1,I2
      I=IO-II
      DO 200 J=2,J1
      N=I+(J-1)*IO+(K-1)*NIJ
      NIA=N+1
      NIB=N-1
      NJA=N+IO
      NJB=N-IO
      NKA=N+NIJ
      NKB=N-NIJ
C
C     ---SKIP COMPUTATIONS IF NODE OUTSIDE AQUIFER---
      IF (T(N).EQ.0..OR.S(N).LT.0.) GO TO 200
C
C     ---COMPUTE COEFFICIENTS---
      D=TR(NJB)/DELX(J)
      F=TR(N)/DELX(J)
      B=TC(NIB)/DELY(I)
      H=TC(N)/DELY(I)
      SU=0.DO
      Z=0.DO
      IF (K.NE.1) Z=TK(NKB)/DELZ(K)
      IF (K.NE.KO) SU=TK(N)/DELZ(K)
      RHO=S(N)/DELT
      ETQB=0.
      ETQD=0.
      IF(K.NE.KO) GO TO 176
      IF(PHI(N).LE.GRND(I,J) - ETDIST) GO TO 176
      IF (PHI(N).GT.GRND(I,J)) GO TO 175
      ETQB=QET/ETDIST
      ETQD=ETQB*(ETDIST-GRND(I,J))
      GO TO 176
  175 ETQD=QET
  176 CONTINUE
      QR=0.
      UXR=0.
      UX=0.
      IF (K.NE.KO) GO TO 180
      IF (IQRE.EQ.ICHK(7)) QR=QRE(I+(J-1)*IO)
      IF(IRIV.LE.0) GO TO 178
      ND=IDR(I+(J-1)*IO)
      IF(ND.EQ.0) GO TO 178
      IF(PHI(N).GT.RB(ND)) GO TO 174
      QR=QR+RC(ND)*(RH(ND)-RB(ND))
      GO TO 178
  174 UXR=RC(ND)
      QR=QR+RC(ND)*RH(ND)
  178 IF(IDRAIN.LE.0) GO TO 180
      ND=ID(I+(J-1)*IO)
```

```
      IF(ND.EQ.0) GO TO 180
      IF(ELD(ND).GT.PHI(N)) GO TO 180
      UX=FLD(ND)
      QR=QR+FLD(ND)*ELD(ND)
C
C     ---SIP REVERSE ALGORITHM---
C     ---FORWARD SUBSTITUTE, COMPUTING INTERMEDIATE VECTOR V---
  180 E=-B-D-F-H-SU-Z-RHO-ETQB-UX-UXR
      BL=H/(1.+W*(EL(NIA)+GL(NIA)))
      CL=D/(1.+W*(FL(NJB)+GL(NJB)))
      C=BL*EL(NIA)
      G=CL*FL(NJB)
      WU=CL*GL(NJB)
      U=BL*GL(NIA)
      IF (K.EQ.KO) GO TO 190
      AL=SU/(1.+W*(EL(NKA)+FL(NKA)))
      A=AL*EL(NKA)
      TU=AL*FL(NKA)
      DL=E+W*(C+G+A+WU+TU+U)-AL*GL(NKA)-BL*FL(NIA)-CL*EL(NJB)
      EL(N)=(F-W*(C+A))/DL
      FL(N)=(B-W*(G+TU))/DL
      GL(N)=(Z-W*(WU+U))/DL
      ZPHI=0.DO
      IF (K.NE.1) ZPHI=Z*PHI(NKB)
      RES=-B*PHI(NIB)-D*PHI(NJB)-E*PHI(N)-F*PHI(NJA)-H*PHI(NIA)-SU*PHI(N
     1KA)-ZPHI-WELL(N)-RHO*OLD(N)-QR
      RES=BETA*RES
      V(N)=(RES-AL*V(NKA)-BL*V(NIA)-CL*V(NJB))/DL
      GO TO 200
  190 DL=E+W*(C+G+WU+U)-BL*FL(NIA)-CL*EL(NJB)
      EL(N)=(F-W*C)/DL
      FL(N)=(B-W*G)/DL
      GL(N)=(Z-W*(WU+U))/DL
      ZPHI=0.DO
      IF (K.NE.1) ZPHI=Z*PHI(NKB)
      RES=-B*PHI(NIB)-D*PHI(NJB)-E*PHI(N)-F*PHI(NJA)-H*PHI(NIA)-ZPHI-WEL
     1L(N)-RHO*OLD(N)-QR+ETQD
      RES=BETA*RES
      V(N)=(RES-BL*V(NIA)-CL*V(NJB))/DL
  200 CONTINUE
C
C     ---BACK SUBSTITUTE FOR VECTOR XI---
      DO 210 K=1,KO
      DO 210 I=2,I1
      DO 210 J=1,J2
      J3=JO-J
      N=I+(J3-1)*IO+(K-1)*NIJ
      IF (T(N).EQ.0..OR.S(N).LT.0.) GO TO 210
      GLXI=0.DO
      IF (K.NE.1) GLXI=GL(N)*XI(N-NIJ)
      XI(N)=V(N)-EL(N)*XI(N+IO)-FL(N)*XI(N-1)-GLXI
C
C     ---COMPARE MAGNITUDE OF CHANGE WITH CLOSURE CRITERIA---
      TCHK=ABS(XI(N))
      IF (TCHK.GT.BIG) BIG=TCHK
      PHI(N)=PHI(N)+XI(N)
  210 CONTINUE
```

```
      IF (BIG.GT.ERR) TEST=1.                                           SP32800
      TEST3(IT+1)=BIG                                                   SP32810
      IF (TEST.EQ.0.) RETURN                                            SP32820
      GO TO 60                                                          SP32830
C     ..................................................................SP32840
C                                                                       SP32850
C     ---FORMATS---                                                     SP32860
C                                                                       SP32870
C                                                                       SP32880
C                                                                       SP32890
  220 FORMAT ('0EXCEEDED PERMITTED NUMBER OF ITERATIONS'//' ',39('*'))  SP32900
  230 FORMAT (///1H0,I5,5X,F4.2,22H ITERATION PARAMETERS:,6E15.7/(/28X,6
     1E15.7/))
  240 FORMAT ('-',44X,'SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE'/45X,SP32920
     143('_'))                                                          SP32930
      END                                                               SP32940-
```

```
      SUBROUTINE COEF(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FACT
     1,PERM,BOTTOM,QRE)
C     ------------------------------------------------------------------
C     COMPUTE COEFFICIENTS
C     ------------------------------------------------------------------
C
C     SPECIFICATIONS:
      REAL *8PHI
C
      DIMENSION PHI(IO,JO,KO), STRT(IO,JO,KO), OLD(IO,JO,KO), T(IO,JO,KO
     1), S(IO,JO,KO), TR(IO,JO,KO), TC(IO,JO,KO), TK(IK,JK,K5), WELL(IO,
     2JO,KO), DELX(JO), DELY(IO), DELZ(KO), FACT(KO,3), PERM(IP,JP), BOT
     3TOM(IP,JP), QRE(IQ,JQ)
C
      COMMON /INTEGR/ IO,JO,KO,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,N
     1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NC
     2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK
      COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,IOK
      COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)
      RETURN
C     ..................................................................
C     ---COMPUTE TRANSMISSIVITY FOR UPPER HYDROLOGIC UNIT WHEN
C     IT IS UNCONFINED---
C     **********************
      ENTRY TRANS(N3)
C     **********************
      DO 10 I=2,I1
      DO 10 J=2,J1
      IF (PERM(I,J).EQ.0.) GO TO 10
      T(I,J,KO)=PERM(I,J)*(PHI(I,J,KO)-BOTTOM(I,J))
      IF (T(I,J,KO).GT.0.) GO TO 10
      IF (WELL(I,J,KO).LT.0.) WRITE (6,60) I,J,KO
      IF (WELL(I,J,KO).GE.0.) WRITE (6,70) I,J,KO
      PERM(I,J)=0.
      T(I,J,KO)=0.
      TR(I,J-1,KO)=0.
      TR(I,J,KO)=0.
      TC(I,J,KO)=0.
      TC(I-1,J,KO)=0.
      IF (KO.NE.1) TK(I,J,K1)=0.
      PHI(I,J,KO)=1.D30
   10 CONTINUE
      IF (N3.EQ.1) RETURN
      N1=KO
      N2=KO
      N4=K1
      GO TO 20
C     ---COMPUTE T COEFFICIENTS---
C     **********************
      ENTRY TCOF
C     **********************
      N1=1
      N2=KO
      N4=1
   20 DO 40 K=N1,N2
      DO 40 I=1,I1
      DO 40 J=1,J1
```

```
      IF (T(I,J,K).EQ.0.) GO TO 40
      IF (T(I,J+1,K).EQ.0.) GO TO 30
      TR(I,J,K)=(2.*T(I,J+1,K)*T(I,J,K))/(T(I,J,K)*DELX(J+1)+T(I,J+1,K)*
     1DELX(J))*FACT(K,1)
   30 IF (T(I+1,J,K).EQ.0.) GO TO 40
      TC(I,J,K)=(2.*T(I+1,J,K)*T(I,J,K))/(T(I,J,K)*DELY(I+1)+T(I+1,J,K)*
     1DELY(I))*FACT(K,2)
   40 CONTINUE
      IF (KO.EQ.1.OR.ITK.EQ.ICHK(10)) RETURN
      DO 50 K=N4,K1
      DO 50 I=2,I1
      DO 50 J=2,J1
      IF (T(I,J,K+1).EQ.0.) GO TO 50
      T1=T(I,J,K)*FACT(K,3)
      T2=T(I,J,K+1)*FACT(K+1,3)
      TK(I,J,K)=(2.*T2*T1)/(T1*DELZ(K+1)+T2*DELZ(K))
   50 CONTINUE
      RETURN
C
C
   60 FORMAT('-',20('*'),'WELL',2I3,' IN LAYER',I3,' GOES DRY',2X,'(DURI
     1NG NEXT TIME STEP)')
   70 FORMAT('-',20('*'),'NODE',2I3,' IN LAYER',I3,' GOES DRY',2X,'(DURI
     1NG NEXT TIME STEP)')
      END
```

```
      SUBROUTINE CHECKI(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FA
     1CT,JFLO,FLOW,QRE,ID,FLD,ELD,IDR,RH,RC,RB,IDRAIN,IRIV)
C     ------------------------------------------------------------------
C     COMPUTE A VOLUMETRIC BALANCE
C     ------------------------------------------------------------------
C
C     SPECIFICATIONS:
      REAL *8PHI
C
      DIMENSION PHI(IO,JO,KO), STRT(IO,JO,KO), OLD(IO,JO,KO), T(IO,JO,KO
     1), S(IO,JO,KO), TR(IO,JO,KO), TC(IO,JO,KO), TK(IK,JK,K5), WELL(IO,
     2JO,KO), DELX(JO), DELY(IO), DELZ(KO), FACT(KO,3), JFLO(NCH,3), FLO
     3W(NCH), QRE(IQ,JQ), IQQ(40,38),XRAY(50,50),YRAY(50,50)
     4,ID(IO,JO),FLD(1),ELD(1),IDR(IO,JO),RH(1),RC(1),RB(1)
C
      COMMON /INTEGR/ IO,JO,KO,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,N
     1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NC
     2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK
      COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,IOK
      COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)
      COMMON /CK/ ETFLXT,STORT,QRET,CHST,CHDT,FLUXT,PUMPT,CFLUXT,FLXNT
      COMMON /EVAPO/ ETDIST,QET,GRND(50,50)
      RETURN
C     ..................................................................
C     ********************
      ENTRY CHECK
C     ********************
C     ---INITIALIZE VARIABLES---
      PUMP=0.
      STOR=0.
      FLUXS=0.0
      CHD1=0.0
      CHD2=0.0
      QREFLX=0.
      CFLUX=0.
      FLUX=0.
      ETFLUX=0.
      FLXN=0.0
      II=0
C     ..................................................................
C
C     ---COMPUTE RATES,STORAGE AND PUMPAGE FOR THIS STEP---
      DO 220 K=1,KO
      DO 220 I=2,I1
      DO 220 J=2,J1
      IF (T(I,J,K).EQ.0.) GO TO 220
      AREA=DELX(J)*DELY(I)
      VOLUME=AREA*DELZ(K)
      IF (S(I,J,K).GE.0.) GO TO 180
C
C     ---COMPUTE FLOW RATES TO AND FROM CONSTANT HEAD BOUNDARIES---
      II=II+1
      FLOW(II)=0.
      JFLO(II,1)=K
      JFLO(II,2)=I
      JFLO(II,3)=J
      IF (S(I,J-1,K).LT.0..OR.T(I,J-1,K).EQ.0.) GO TO 30
```

```
      X=(PHI(I,J,K)-PHI(I,J-1,K))*TR(I,J-1,K)*DELY(I)                   CHK 550
      IF(IEQN.EQ.ICHK(11)) X=X*DELZ(K)                                   CHK 555
      FLOW(II)=FLOW(II)+X                                               CHK 560
      IF (X) 10,30,20                                                   CHK 570
   10 CHD1=CHD1+X                                                       CHK 580
      GO TO 30                                                          CHK 590
   20 CHD2=CHD2+X                                                       CHK 600
   30 IF (S(I,J+1,K).LT.0..OR.T(I,J+1,K).EQ.0.) GO TO 60                CHK 610
      X=(PHI(I,J,K)-PHI(I,J+1,K))*DELY(I)*TR(I,J,K)                     CHK 620
      IF(IEQN.EQ.ICHK(11)) X=X*DELZ(K)                                   CHK 625
      FLOW(II)=FLOW(II)+X                                               CHK 630
      IF (X) 40,60,50                                                   CHK 640
   40 CHD1=CHD1+X                                                       CHK 650
      GO TO 60                                                          CHK 660
   50 CHD2=CHD2+X                                                       CHK 670
   60 IF (K.EQ.1) GO TO 90                                              CHK 680
      IF (S(I,J,K-1).LT.0..OR.T(I,J,K-1).EQ.0.) GO TO 90                CHK 690
      X=(PHI(I,J,K)-PHI(I,J,K-1))*TK(I,J,K-1)*AREA*2./(DELZ(K)+DELZ(K-1 CHK 700
     1)                                                                  CHK710
      FLOW(II)=FLOW(II)+X                                               CHK 720
      IF (X) 70,90,80                                                   CHK 730
   70 CHD1=CHD1+X                                                       CHK 740
      GO TO 90                                                          CHK 750
   80 CHD2=CHD2+X                                                       CHK 760
   90 IF (K.EQ.KO) GO TO 120                                            CHK 770
      IF (S(I,J,K+1).LT.0..OR.T(I,J,K+1).EQ.0.) GO TO 120               CHK 780
      X=(PHI(I,J,K)-PHI(I,J,K+1))*TK(I,J,K)*AREA*2./(DELZ(K)+DELZ(K+1))  CHK 790
      FLOW(II)=FLOW(II)+X                                               CHK 800
      IF (X) 100,120,110                                                CHK 810
  100 CHD1=CHD1+X                                                       CHK 820
      GO TO 120                                                         CHK 830
  110 CHD2=CHD2+X                                                       CHK 840
  120 IF (S(I-1,J,K).LT.0..OR.T(I-1,J,K).EQ.0.) GO TO 150               CHK 850
      X=(PHI(I,J,K)-PHI(I-1,J,K))*TC(I-1,J,K)*DELX(J)                   CHK 860
      IF(IEQN.EQ.ICHK(11)) X=X*DELZ(K)                                   CHK 865
      FLOW(II)=FLOW(II)+X                                               CHK 870
      IF (X) 130,150,140                                                CHK 880
  130 CHD1=CHD1+X                                                       CHK 890
      GO TO 150                                                         CHK 900
  140 CHD2=CHD2+X                                                       CHK 910
  150 IF (S(I+1,J,K).LT.0..OR.T(I+1,J,K).EQ.0.) GO TO 220               CHK 920
      X=(PHI(I,J,K)-PHI(I+1,J,K))*TC(I,J,K)*DELX(J)                     CHK 930
      IF(IEQN.EQ.ICHK(11)) X=X*DELZ(K)                                   CHK 935
      FLOW(II)=FLOW(II)+X                                               CHK 940
      IF (X) 160,220,170                                                CHK 950
  160 CHD1=CHD1+X                                                       CHK 960
      GO TO 220                                                         CHK 970
  170 CHD2=CHD2+X                                                       CHK 980
      GO TO 220                                                         CHK 990
C                                                                       CHK1000
C     ---RECHARGE AND WELLS---                                          CHK1010
  180 IF (K.EQ.KO.AND.IQRE.EQ.ICHK(7)) QREFLX=QREFLX+QRE(I,J)*AREA      CHK1020
      IF (WELL(I,J,K)) 190,210,200                                      CHK1030
  190 PUMP=PUMP+WELL(I,J,K)*AREA                                        CHK1040
      GO TO 210                                                         CHK1050
  200 CFLUX=CFLUX+WELL(I,J,K)*AREA                                      CHK1060
C                                                                       CHK1070
```

```
C     ---COMPUTE VOLUME FROM STORAGE---                                 CHK1080
  210 STOR=STOR+S(I,J,K)*(OLD(I,J,K)-PHI(I,J,K))*AREA                   CHK1090
      IF(K.NE.KO.OR.IRIV.LE.0) GO TO 212
C     COMPUTE LEAKAGE TO RIVER
      ND=IDR(I,J)
      IF(ND.EQ.0) GO TO 212
      IF(PHI(I,J,K).GT.RB(ND)) GO TO 211
      FLXN=RC(ND)*(RH(ND)-RB(ND))*AREA+FLXN
      GO TO 212
  211 FLXN=RC(ND)*(RH(ND)-PHI(I,J,K))*AREA+FLXN
  212 IF(K.NE.KO.OR.IDRAIN.LE.0) GO TO 213
C     COMPUTE LEAKAGE TO DRAIN
      ND=ID(I,J)
      IF(ND.EQ.0) GO TO 220
      IF(ELD(ND).GT.PHI(I,J,K)) GO TO 220
      FLUX=FLUX+FLD(ND)*AREA*(ELD(ND)-STRT(I,J,K))
      FLXN=FLXN+FLD(ND)*AREA*(ELD(ND)-PHI(I,J,K))
      FLUXS=FLXN
  213 IF(K.NE.KO)GO TO 220
C     COMPUTE EVAPOTRANSPIRATION
      IF(PHI(I,J,K).GE.GRND(I,J)-ETDIST) GO TO 215
      GO TO 217
  215 IF(PHI(I,J,K).LE.GRND(I,J)) GO TO 216
      ETQ=QET
      GO TO 217
  216 ETQ=QET/ETDIST*(PHI(I,J,K)+ETDIST-GRND(I,J))
  217 ETFLUX=ETFLUX-ETQ*AREA
      FLUXS=FLXN
  220 CONTINUE                                                          CHK1100
C     ..................................................................CHK1110
C                                                                       CHK1120
C     ---COMPUTE CUMULATIVE VOLUMES, TOTALS, AND DIFFERENCES---         CHK1130
      FLXPT=0.0                                                         CHK1140
      FLXNT=FLXNT-FLXN*DELT
      ETFLXT=ETFLXT-ETFLUX*DELT
      STORT=STORT+STOR                                                  CHK1150
      STOR=STOR/DELT                                                    CHK1160
      QRET=QRET+QREFLX*DELT                                             CHK1170
      CHDT=CHDT-CHD1*DELT                                               CHK1180
      CHST=CHST+CHD2*DELT                                               CHK1190
      PUMPT=PUMPT-PUMP*DELT                                             CHK1200
      CFLUXT=CFLUXT+CFLUX*DELT                                          CHK1210
      TOTL1=STORT+QRET+CFLUXT+CHST+FLXPT                                CHK1220
      TOTL2=CHDT+PUMPT+ETFLXT+FLXNT                                     CHK1230
      SUMR=QREFLX+CFLUX+CHD2+CHD1+PUMP+ETFLUX+FLUXS+STOR                CHK1240
      DIFF=TOTL2-TOTL1                                                  CHK1250
      PERCNT=0.0                                                        CHK1260
      IF (TOTL2.EQ.0.) GO TO 230                                        CHK1270
      PERCNT=DIFF/TOTL2*100.                                            CHK1280
  230 RETURN                                                            CHK1290
C     ..................................................................CHK1300
C                                                                       CHK1310
C     ---PRINT RESULTS---                                               CHK1320
C     ************************                                          CHK1330
      ENTRY CWRITE                                                      CHK1340
C     ************************                                          CHK1350
C                                                                       CHK1360
```

```
      WRITE (6,260) STOR,QREFLX,STORT,CFLUX,QRET,PUMP,CFLUXT,ETFLUX,CHSTCHK1370
     1,FLXPT,CHD2,TOTL1,CHD1,FLUX,FLUXS,ETFLXT,CHDT,SUMR,PUMPT,FLXNT,TOTCHK1380
     2L2,DIFF,PERCNT                                                    CHK1390
      IF (NCH.EQ.0) GO TO 240                                           CHK1400
      WRITE (6,270)                                                     CHK1410
      WRITE (6,280) ((JFLO(I,J),J=1,3),FLOW(I),I=1,NCH)                 CHK1420
C                                                                       CHK1430
C     ---COMPUTE VERTICAL FLOW---                                       CHK1440
  240 X=0.                                                              CHK1450
      Y=0.                                                              CHK1460
      IF (KO.EQ.1) RETURN                                               CHK1470
      DO 250 I=2,I1                                                     CHK1480
      DO 250 J=2,J1                                                     CHK1490
      XRAY(I,J)=0.0
      YRAY(I,J)=0.0
      Z=0
      Z=(PHI(I,J,1)-PHI(I,J,2))*TK(I,J,1)*DELX(J)*DELY(I)*2./(DELZ(1)+DE
     1LZ(2))
      X=X+Z
      XRAY(I,J)=Z
      Z=0
      Z=(PHI(I,J,K1)-PHI(I,J,KO))*TK(I,J,K1)*DELX(J)*DELY(I)*2./(DELZ(K1
     1)+DELZ(KO))
      Y=Y+Z
  250 YRAY(I,J)=Z
      IF(IOK.EQ.0)GO TO 251
      WRITE(6,297)
      DO 252 I=2,I1
  252 WRITE(6,296) I,(XRAY(I,J),J=2,J1)
      WRITE(6,298)
      DO 253 I=2,I1
  253 WRITE(6,296) I,(YRAY(I,J),J=2,J1)
  251 WRITE(6,290) Y,X
      RETURN                                                            CHK1550
C                                                                       CHK1560
C     ---FORMATS---                                                     CHK1570
C                                                                       CHK1580
C     ------------------------------------------------------------------CHK1590
C                                                                       CHK1600
C                                                                       CHK1610
C                                                                       CHK1620
  260 FORMAT ('0',10X,'CUMULATIVE MASS BALANCE:',16X,'L**3',23X,'RATES FCHK1630
     1OR THIS TIME STEP:',16X,'L**3/T'/11X,24('-'),43X,25('-')//20X,'SOUCHK1640
     2RCES:',69X,'STORAGE =',F20.4/20X,8('-'),68X,'RECHARGE =',F20.4/27XCHK1650
     3,'STORAGE =',F20.2,35X,'CONSTANT FLUX =',F20.4/26X,'RECHARGE =',F2CHK1660
     40.2,41X,'PUMPING =',F20.4/21X,'CONSTANT FLUX =',F20.2,30X,'EVAPOTRCHK1670
     5ANSPIRATION =',F20.4/21X,'CONSTANT HEAD =',F20.2,34X,'CONSTANT HEACHK1680
     6D:'/27X,'LEAKAGE =',F20.2,46X,'IN =',F20.4/21X,'TOTAL SOURCES =',FCHK1690
     720.2,45X,'OUT =',F20.4/96X,'LEAKAGE:'/20X,'DISCHARGES:',45X,'FROM CHK1700
     8PREVIOUS PUMPING PERIOD =',F20.4/20X,11('-'),60X,'RIVER LEAKAGE ='CHK1710
     9,F20.4/16X,'EVAPOTRANSPIRATION =',F20.2/21X,'CONSTANT HEAD =',F20.CHK1720
     &2,36X,'SUM OF RATES =',F20.4/19X'QUANTITY PUMPED =',F20.2/21X,'RIVCHK1730
     &ER LEAKAGE =',F20.2/19X,'TOTAL DISCHARGE =',F20.2//17X,'DISCHARGE-CHK1740
     &SOURCES =',F20.2/15X,'PER CENT DIFFERENCE =',F20.2//)             CHK1750
  270 FORMAT ('1FLOW RATES TO CONSTANT HEAD NODES:'//' ',34('-')//' ',3(9CHK1760
     1X,'K',4X,'I',4X,'J',5X,'RATE (L**3/T)')/' ',3(9X,'-',4X,'-',4X,'-'CHK1770
     2,5X,13('-'))/)                                                    CHK1780
```

```
280 FORMAT (/(1X,3(I10,2I5,G18.7)))                                    CHK1790
290 FORMAT ('OFLOW TO TOP LAYER =',G15.7,'   FLOW TO BOTTOM LAYER =',GCHK1800
  115.7,'       POSITIVE UPWARD')                                      CHK1810
296 FORMAT('0',1X,I2,10F12.7,3(/4X,10F12.7))
297 FORMAT('1',52X,'FLOW TO BOTTOM LAYER BY NODE'//)
298 FORMAT('1',52X,'FLOW TO TOP LAYER BY NODE'//)
    END                                                                CHK1820-
```

```
      SUBROUTINE PRNTAI(PHI,STRT,T,S,WELL,DELX,DELY)
C     ---------------------------------------------------------------------
C     PRINT MAPS OF DRAWDOWN AND HYDRAULIC HEAD
C     ---------------------------------------------------------------------
C
C     SPECIFICATIONS:
      REAL *8PHI,Z,XLABEL,YLABEL,TITLE,XN1,MESUR
      REAL *4K
C
      DIMENSION PHI(IO,JO,KO), STRT(IO,JO,KO), S(IO,JO,KO), WELL(IO,JO,K
     1O), DELX(JO), DELY(IO), T(IO,JO,KO)
C
      COMMON /INTEGR/ IO,JO,KO,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,N
     1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NC
     2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK
      COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANK
     1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),
     2YN(13),NA(4),N1,N2,N3,YSCALE,FACT1,FACT2
      RETURN
C     .....................................................................
C
C     ---INITIALIZE VARIABLES FOR PLOT---
C     *********************
      ENTRY MAP
C     *********************
      YDIM=0.
      WIDTH=0.
      DO 10 J=2,J1
   10 WIDTH=WIDTH+DELX(J)
      DO 20 I=2,I1
   20 YDIM=YDIM+DELY(I)
   30 XSF=DINCH*XSCALE
      YSF=DINCH*YSCALE
      NYD=YDIM/YSF
      IF (NYD*YSF.LE.YDIM-DELY(I1)/2.) NYD=NYD+1
      IF (NYD.LE.12) GO TO 40
      DINCH=YDIM/(12.*YSCALE)
      WRITE (6,330) DINCH
      IF (YSCALE.LT.1.0) WRITE (6,340)
      GO TO 30
   40 NXD=WIDTH/XSF
      IF (NXD*XSF.LE.WIDTH-DELX(J1)/2.) NXD=NXD+1
      N4=NXD*N1+1
      N5=NXD+1
      N6=NYD+1
      N8=N2*NYD+1
      NA(1)=N4/2-1
      NA(2)=N4/2
      NA(3)=N4/2+3
      NC=(N3-N8-10)/2
      ND=NC+N8
      NE=MAX0(N5,N6)
      VF1(3)=DIGIT(ND)
      VF2(3)=DIGIT(ND)
      VF3(3)=DIGIT(NC)
      XLABEL(3)=MESUR
      YLABEL(6)=MESUR
```

```
      DO 60 I=1,NE
      NNX=N5-I
      NNY=I-1
      IF (NNY.GE.N6) GO TO 50
      YN(I)=YSF*NNY/YSCALE
   50 IF (NNX.LT.0) GO TO 60
      XN(I)=XSF*NNX/YSCALE
   60 CONTINUE
      RETURN
C     ..........................................................................
C
C     ********************
      ENTRY PRNTA(NG,LA)
C     ********************
C     ---VARIABLES INITIALIZED EACH TIME A PLOT IS REQUESTED---
      DIST=WIDTH-DELX(J1)/2.
      JJ=J1
      LL=1
      Z=NXD*XSF
      IF (NG.EQ.1) WRITE (6,300) (TITLE(I),I=1,3),LA
      IF (NG.EQ.2) WRITE (6,300) (TITLE(I),I=4,6),LA
      DO 290 I=1,N4
C
C     ---LOCATE X AXES---
      IF (I.EQ.1.OR.I.EQ.N4) GO TO 70
      PRNT(1)=SYM(12)
      PRNT(N8)=SYM(12)
      IF ((I-1)/N1*N1.NE.I-1) GO TO 90
      PRNT(1)=SYM(14)
      PRNT(N8)=SYM(14)
      GO TO 90
C
C     ---LOCATE Y AXES---
   70 DO 80 J=1,N8
      IF ((J-1)/N2*N2.EQ.J-1) PRNT(J)=SYM(14)
   80 IF ((J-1)/N2*N2.NE.J-1) PRNT(J)=SYM(13)
C
C     ---COMPUTE LOCATION OF NODES AND DETERMINE APPROPRIATE SYMBOL---
   90 IF (DIST.LT.0..OR.DIST.LT.Z-XN1*XSF) GO TO 240
      YLEN=DELY(2)/2.
      DO 220 L=2,I1
      J=YLEN*N2/YSF+1.5
      IF (T(L,JJ,LA).EQ.0.) GO TO 160
      IF (S(L,JJ,LA).LT.0.) GO TO 210
      INDX3=0
      GO TO (100,110), NG
  100 K=(STRT(L,JJ,LA)-PHI(L,JJ,LA))*FACT1
C     -TO CYCLE SYMBOLS FOR DRAWDOWN, REMOVE C FROM COL. 1 OF NEXT CARD-
C     K=AMOD(K,10.)
      GO TO 120
  110 K=PHI(L,JJ,LA)*FACT2
  120 IF (K) 130,160,140
  130 IF (J-2.GT.0) PRNT(J-2)=SYM(13)
      N=-K+.5
      IF (N.LT.100) GO TO 150
      GO TO 190
  140 N=K+.5
```

```
      IF (N.LT.100) GO TO 150                                          PRN1150
      IF (N.GT.999) GO TO 190                                          PRN1160
      INDX3=N/100                                                      PRN1170
      IF (J-2.GT.0) PRNT(J-2)=SYM(INDX3)                               PRN1180
      N=N-INDX3*100                                                    PRN1190
  150 INDX1=MOD(N,10)                                                  PRN1200
      IF (INDX1.EQ.0) INDX1=10                                         PRN1210
C     -TO CYCLE SYMBOLS FOR DRAWDOWN, REMOVE C FROM COL. 1 OF NEXT CARD-PRN1220
C     IF (NG.Eq.1) GO TO 170                                           PRN1230
      INDX2=N/10                                                       PRN1240
      IF (INDX2.GT.0) GO TO 180                                        PRN1250
      INDX2=10                                                         PRN1260
      IF (INDX3.EQ.0) INDX2=15                                         PRN1270
      GO TO 180                                                        PRN1280
  160 INDX1=15                                                         PRN1290
  170 INDX2=15                                                         PRN1300
  180 IF (J-1.GT.0) PRNT(J-1)=SYM(INDX2)                               PRN1310
      PRNT(J)=SYM(INDX1)                                               PRN1320
      GO TO 220                                                        PRN1330
  190 DO 200 II=1,3                                                    PRN1340
      JI=J-3+II                                                        PRN1350
  200 IF (JI.GT.0) PRNT(JI)=SYM(11)                                    PRN1360
  210 IF (S(L,JJ,LA).LT.0.) PRNT(J)=SYM(16)                            PRN1370
  220 YLEN=YLEN+(DELY(L)+DELY(L+1))/2.                                 PRN1380
  230 DIST=DIST-(DELX(JJ)+DELX(JJ-1))/2.                               PRN1390
      JJ=JJ-1                                                          PRN1400
      IF (JJ.EQ.0) GO TO 240                                           PRN1410
      IF (DIST.GT.Z-XN1*XSF) GO TO 230                                 PRN1420
  240 CONTINUE                                                         PRN1430
C                                                                      PRN1440
C     ---PRINT AXES,LABELS, AND SYMBOLS---                             PRN1450
      IF (I-NA(LL).EQ.0) GO TO 260                                     PRN1460
      IF ((I-1)/N1*N1-(I-1)) 270,250,270                               PRN1470
  250 WRITE (6,VF1) (BLANK(J),J=1,NC),(PRNT(J),J=1,N8),XN(1+(I-1)/6)   PRN1480
      GO TO 280                                                        PRN1490
  260 WRITE (6,VF2) (BLANK(J),J=1,NC),(PRNT(J),J=1,N8),XLABEL(LL)      PRN1500
      LL=LL+1                                                          PRN1510
      GO TO 280                                                        PRN1520
  270 WRITE (6,VF2) (BLANK(J),J=1,NC),(PRNT(J),J=1,N8)                 PRN1530
C                                                                      PRN1540
C     ---COMPUTE NEW VALUE FOR Z AND INITIALIZE PRNT---                PRN1550
  280 Z=Z-2.*XN1*XSF                                                   PRN1560
      DO 290 J=1,N8                                                    PRN1570
  290 PRNT(J)=SYM(15)                                                  PRN1580
C                                                                      PRN1590
C     ---NUMBER AND LABEL Y AXIS AND PRINT LEGEND---                   PRN1600
      WRITE (6,VF3) (BLANK(J),J=1,NC),(YN(I),I=1,N6)                   PRN1610
      WRITE (6,320) (YLABEL(I),I=1,6)                                  PRN1620
      IF (NG.EQ.1) WRITE (6,310) FACT1                                 PRN1630
      IF (NG.EQ.2) WRITE (6,310) FACT2                                 PRN1640
      RETURN                                                           PRN1650
C                                                                      PRN1660
C     ---FORMATS---                                                    PRN1670
C                                                                      PRN1680
C     -----------------------------------------------------------------PRN1690
C                                                                      PRN1700
C                                                                      PRN1710
```

```
300 FORMAT ('1',49X,3A8,'LAYER',I4//)                                   PRN1720
310 FORMAT ('OEXPLANATION'//' ',11('-')///' R = CONSTANT HEAD BOUNDARY'/PRN1730
   1' *** = VALUE EXCEEDED 3 FIGURES'//' MULTIPLICATION FACTOR =',F8.3)PRN1740
320 FORMAT ('0',39X,6A8)                                                PRN1750
330 FORMAT ('0',25X,10('*'),' TO FIT MAP WITHIN 12 INCHES, DINCH REVISPRN1760
   1ED TO',G15.7,1X,10('*'))                                            PRN1770
340 FORMAT ('0',45X,'NOTE: GENERALLY SCALE SHOULD BE > OR = 1.0')     PRN1780
    END                                                                 PRN1790
```

```
      BLOCK DATA
C     ----------
C
C     SPECIFICATIONS:
      REAL *8XLABEL,YLABEL,TITLE,XN1,MESUR
C
      COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)
      COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANK
     1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),
     2YN(13),NA(4),N1,N2,N3,YSCALE,FACT1,FACT2
C     ******************************************************************
C
      DATA ICHK/'DRAW','HEAD','MASS','DK1','DK2','WATE','RECH','PUN1','P
     1UN2','ITKR','EQN3',2*0/
      DATA SYM/'1','2','3','4','5','6','7','8','9','0','*','!','-','+','
     1 ','R','W'/
      DATA PRNT/122*' '/,N1,N2,N3,XN1/6,10,133,.833333333D-1/,BLANK/60*'
     1 '/,NA(4)/1000/
      DATA XLABEL/' X DIS- ','TANCE IN','  MILES '/,YLABEL/'DISTANCE',' 
     1FROM OR','IGIN IN ','Y DIRECT','ION, IN ','MILES   '/,TITLE/'PLOT 
     2OF ','DRAWDOWN',' ','PLOT OF ','HYDRAULI','C HEAD'/
      DATA DIGIT/'1','2','3','4','5','6','7','8','9','10','11','12','13'
     1,'14','15','16','17','18','19','20','21','22','23','24','25','26',
     2'27','28','29','30','31','32','33','34','35','36','37','38','39','
     340','41','42','43','44','45','46','47','48','49','50','51','52','5
     43','54','55','56','57','58','59','60','61','62','63','64','65','66
     5','67','68','69','70','71','72','73','74','75','76','77','78',' 79
     6','80','81','82','83','84','85','86','87','88','89','90','91','92'
     7,'93','94','95','96','97','98','99','100','101','102','103',' 104'
     8,'105','106','107','108','109','110','111','112','113','114','115'
     9,'116','117','118','119','120','121','122'/
      DATA VF1/'(1H ',',','     ','A1,F','10.2',')'/
      DATA VF2/'(1H ',',','     ','A1,1','X,A8',')'/
      DATA VF3/'(1H0',',','     ','A1,F','3.1,','12F1','0.2)'/
C     ******************************************************************
      END
```



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