HYDROGEOLOGY OF WELL-FIELD AREAS NEAR TAMPA, FLORIDA, PHASE 2--
DEVELOPMENT AND DOCUMENTATION OF A QUASI-THREE-DIMENSIONAL FINITE-
DIFFERENCE MODEL FOR SIMULATION OF STEADY-STATE GROUND-WATER FLOW

By C. B. Hutchinson

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FOR SIMULATION OF STEADY-STATE GROUND-WATER FLOW

By C. B. Hutchinson

ABSTRACT

A quasi-three-dimensional finite-difference model was developed for simula-
tion of steady-state ground-water flow in two aquifers throughout a 932-square-
mile area that contains 10 municipal well fields. In the model, the surficial
aquifer is unconfined and is hydraulically connected to the underlying Floridan
aquifer by a leakage term that represents flow through a confining layer separat-
ing the two aquifers. Utilization of the head-controlled flux condition allows
head and flow in the Floridan aquifer to vary at model-grid boundaries. The
water table is held constant at model-grid lateral boundaries and at large sur-
face-water bodies, but is allowed to fluctuate elsewhere in response to changes
in evapotranspiration, recharge, and leakage.

Procedures are described to calibrate the model, test its sensitivity to
input-parameter errors, and validate its accuracy for predictive purposes. Also
included are attachments that describe operation of the model. Example model-
interrogation runs simulate water-level and water-balance changes that can be
expected as a result of pumping all 10 well fields simultaneously at annual aver-
age permitted rates totaling 186.9 million gallons per day from the Floridan
aquifer with recharge varying 20 percent more and less than the long-term aver-
age rate. Maps are also presented that estimate the extent and depth of cones
of depression in the water table and potentiometric surface around well fields
as they are pumped individually.

Maximum drawdown in the Floridan aquifer simulated by the quasi-three-
dimensional model is greater in every well field and averages about 4 feet more
than maximum drawdown simulated by the two-dimensional model previously develop-
ed for the area. Under average recharge conditions, about 75 percent of the
pumped water is derived by increasing downward leakage. The remaining 25 per-
cent is gained by reducing natural upward leakage in swamp and marsh areas and
by slightly reducing outflow along the model boundary. Ultimately, more than
95 percent of the pumped water is derived by reducing evapotranspiration and
surface discharge from the water table.

When well fields are pumped individually, drawdown in the potentiometric
surface is less than when all 10 well fields are pumped simultaneously. Draw-
down is much greater in the center of the modeled area where well fields are in
close proximity to one another, thus increasing interference effects. Interfer-
ence effects range from about 0.1 foot of additional drawdown at Morris Bridge
well field to 6.1 feet of additional drawdown at Northwest well field.
Ten municipal well fields have been established or are planned for a 932-mi² area north of Tampa, Fla. (fig. 1). Permits have been granted or are being considered for a combined average withdrawal rate of 186.9 Mgal/d (Southwest Florida Water Management District, written commun., 1982). In addition, several well fields for large housing subdivisions are being developed or are planned for development. Ground-water withdrawals from the Floridan aquifer in this area may eventually total several hundred million gallons per day.

A ground-water flow model that encompasses the well-field areas is needed to gain an understanding of the hydrology and to facilitate planning for the efficient utilization of water resources while conserving the environment. The model may be interrogated under various water-management alternatives to simulate water-level changes in the Floridan and surficial aquifers. The simulation runs may be used to assess adverse impacts of pumping, such as excessive drawdown, potential for saltwater encroachment, or destruction of wetlands.

The objective of this investigation is to evaluate the hydrogeology of an area encompassing the major well fields north of Tampa through development of a finite-difference digital ground-water flow model. The investigation includes two phases:

1. Develop and document a steady-state model with two-dimensional flow in one active layer.

2. Develop and document a steady-state quasi-three-dimensional model with two-dimensional flow in two active layers using the phase 1 model as a working base.

The phase 1 two-dimensional model is described by Hutchinson and others (1981). That model assisted in providing data for ground-water resource management decisions during development of the phase 2 model. Certain descriptions of the study area and modeling approach in this report are identical to or supersede those in the phase 1 report.

This report describes development of the phase 2 model and is intended as a guide for using the quasi-three-dimensional model. The aquifer system north of Tampa is conceptualized and formulated in the hydrologic model. The computer program and its application to a typical field problem in west-central Florida are described. The applicability of the model to the field problem is demonstrated through three interrogation runs.

The documentation assumes that the reader is familiar with the physics of ground-water flow, numerical methods of solving partial-differential equations, and the FORTRAN IV computer language. The report was prepared as part of a hydrogeologic investigation made by the U.S. Geological Survey in cooperation with the Southwest Florida Water Management District.
Figure 1.—Location of the modeled area near Tampa, Florida.
PREVIOUS INVESTIGATIONS

Numerous ground-water flow models of the Floridan aquifer have been or are being constructed that include all or some of the well-field areas north of Tampa (fig. 2). Cherry and others (1970) developed a conceptual model of the ground-water flow regime in the middle Gulf area. Robertson and Mallory (1977) constructed a regional model for an 875-mi$^2$ area that included eight major well fields. Individual well-field models have been constructed for the Cypress Creek (Seaburn and Robertson, Inc., 1977; Ryder, 1978), Morris Bridge (Ryder and others, 1980), and Cross Bar Ranch (Leggette, Brashears, and Graham, Inc., 1979) well fields. A well-field model is being constructed by the U.S. Geological Survey for the Cross Bar Ranch well field. A regional model, with relatively large grid-spacing (4-mile centers), covering an area of about 10,000 mi$^2$ and including the study area, has been constructed by the U.S. Geological Survey (Ryder, 1982). A companion report to this one (Hutchinson and others, 1981) describes a two-dimensional flow model of the Floridan aquifer in the well-field areas near Tampa. All the above modeling reports give detailed information concerning the hydrogeology of the area.

The model documented herein expands the Robertson and Mallory (1977) model area, includes subsequent aquifer-test results, and incorporates information from the individual well-field models. The model grid is aligned with Ryder's (1982) coarsely gridded regional model so that they may be interfaced.

HYDROLOGIC MODEL

Description

The modeled area and its relation to the 10 municipal well fields are shown in figure 2. The model grid comprises an orthogonal array of 34 horizontal rows and 36 vertical columns; each grid block is 1 mile square. At the center of each grid block is a node through which data are input to or output from the model. Along the Gulf of Mexico and Tampa Bay coasts, the grid generally follows the shoreline.

The hydrologic setting is one of a coastal, karstic environment. The hydrologic system is represented by an unconfined surficial aquifer separated from the underlying Floridan aquifer by a relatively impermeable confining bed. The landscape is dotted with sinkhole depressions and the water table is near land surface. The general direction of ground-water movement is west toward the Gulf of Mexico and south toward Tampa Bay. The regional flow regime is modified by pumping from the well-field areas and by ground water discharging to streams.

Hydrologic Cycle

The elements of the hydrologic cycle in west-central Florida are rainfall, surface and subsurface runoff, evapotranspiration (ET), leakage to or from the Floridan aquifer, pumpage, and changes in amounts of water in storage in the...
Figure 2.—Model grid and well-field areas.
surficial and Floridan aquifers. In this study, all time-dependent hydrologic parameters including ground-water levels are considered to be long-term averages, therefore, short-term fluctuations in amounts of water in storage in the surficial and Floridan aquifers are neglected. Pumpage from the surficial aquifer is so small that it is neglected.

In west-central Florida, mean annual rainfall is about 55 inches and is distributed unevenly as 7 inches in winter, 10 inches in spring, 25 inches in summer, and 13 inches in autumn (Hughes and others, 1971). At St. Leo, in east-central Pasco County, the extreme low rainfall of 36.61 inches fell in 1961, and the extreme high rainfall of 81.93 inches was recorded in 1945 (National Oceanic and Atmospheric Administration, 1958-81; and U.S. Department of Commerce, 1964).

Annual runoff ranges from near zero in internally drained areas to about 14 inches in the Anclote River basin and, in general, is directly proportional to rainfall. Under normal rainfall conditions, with no pumping, runoff from the modeled area probably averages about 10 inches per year. Five inches can be considered as overland runoff and 5 inches as contribution to base streamflow. Cherry and others (1970) indicate that up to 20 percent of the runoff from watersheds in the modeled area is derived from upward leakage from the Floridan aquifer. Parker (1975) estimated that average runoff from the Brooker Creek watershed, just east of Lake Tarpon, had declined substantially (possibly 50 percent) since the Eldridge-Wilde, Cosme, and Section 21 well fields were installed.

Evapotranspiration is a major item in the hydrologic cycle. It occurs in essentially three modes: (1) from plant surfaces and bare ground, (2) from the unsaturated zone (above the water table but beneath land surface), and (3) directly from the water table. The maximum potential evapotranspiration from a free water surface in west-central Florida is about 46 to 50 inches per year (Koehler and others, 1959; Dohrenwend, 1977). However, potential evapotranspiration is not maximum over all of west-central Florida because in much of the area the water table is below land surface and, in some areas, below plant root zones. In areas where the water table is far below land surface, water in the surficial aquifer is less subject to uptake by plants (transpiration) or direct evaporation from the water table than where the water table is at land surface and acts as a free water surface.

No matter how far below land surface the water table stands, there most likely is some minimum or base rate of evapotranspiration. This base rate is determined by evaporation and transpiration that takes place before any water can percolate to the water table. Estimates of this base rate of evapotranspiration range from 25 to 35 inches per year (Tibbals, 1978).

The actual evapotranspiration rate depends upon depth to water table, soil type, type of plant community, humidity, the amount of incoming energy (sunlight and wind), and the availability of water subject to evapotranspiration. On an areal and long-term annual basis, humidity, incoming energy, and available water can be regarded as fairly constant and uniformly distributed in west-central Florida. Soil types and plant communities are not uniformly distributed. For modeling purposes, these differences are not considered major factors in determining variability of actual evapotranspiration because depth to water table helps determine the plant community and the soil type. Therefore, depth to water table is used as the indicator of the actual rate of evapotranspiration.
The Floridan aquifer is recharged about 6 inches annually by downward leakage from the surficial aquifer. In swampy areas, about 1 inch of water discharges from the Floridan aquifer by leaking upward to the surficial aquifer. The net leakage is downward and is estimated to be roughly 5 inches per year under nonpumping conditions, based on a digital model of predevelopment flow developed by Ryder (1982). Pumping lowers the potentiometric surface, thereby inducing additional leakage from the surficial aquifer. For the calibration period, pumping 133 Mgal/d was estimated to have increased leakage to about 9 inches per year.

**Conceptual Model**

A generalized conceptual model of the hydrologic system is shown schematically in figure 3. The Floridan aquifer is the principal source of ground-water supply. It is confined above and below and is overlain by the unconfined surficial aquifer.

Gross water budgets for each aquifer were conceptualized as a basis for modeling the hydrologic system. Inflows and outflows from each aquifer under steady-state conditions are equated as follows:

\[
\begin{align*}
\text{INFLOW} & \quad \text{OUTFLOW} \\
\text{SURFICIAL:} & \quad R + UL = ETRO + DL & (1) \\
\text{FLORIDAN:} & \quad DL + BI = UL + BO + P & (2)
\end{align*}
\]

where
- \( R \) = recharge by seepage of rainfall;
- \( UL \) = upward leakage through the upper confining bed;
- \( ETRO \) = evapotranspiration plus runoff from the water table;
- \( DL \) = downward leakage through the upper confining bed;
- \( BI \) = boundary inflow;
- \( BO \) = boundary outflow; and
- \( P \) = pumpage.

Under normal climatological conditions, with no pumping, total inflow to the surficial aquifer averages about 26 inches per year. About 1 inch leaks upward from the Floridan aquifer, and about 25 inches is recharge computed as the residual of rainfall (55 inches) minus overland runoff (5 inches) and minimum evapotranspiration (25 inches from plant surfaces, bare land, and the unsaturated zone). About 6 inches leaks downward from the surficial aquifer to the Floridan aquifer and 5 inches seeps to streams. The remaining 15 inches of inflow is lost from the aquifer as evapotranspiration from the water table.

The Floridan aquifer receives inflow by downward leakage and across the boundary from outside the model grid. Under nonpumping conditions, downward leakage averages about 6 inches per year and boundary inflow about 1 inch per year. This water is lost through upward leakage at a rate of about 1 inch per year and boundary outflow of about 6 inches per year.
Figure 3.—Generalized conceptual model of the hydrogeologic system (modified from Wilson and Gerhart, 1980).
The water balance within the surficial aquifer may be altered significantly by pumping. Recharge may be increased, while surface-water runoff, ET, and ground-water discharge from the surficial aquifer (referred to hereafter as ET-runoff) are reduced. The mechanism in the model for handling these changes is the ET-runoff capture rate that relates the rate of capture to water-table depth. Based on the model conceptualization, all ET from the water table (15 inches) plus approximately half the runoff (6 inches) could be salvaged by lowering the water table from its average depth of about 4.5 feet to 10 feet. From a management standpoint, this may not be practical because widespread lowering of water levels could dry up lakes, alter the natural vegetation, cause pump failure in shallow wells, and induce sinkhole development. Although the ET-runoff capture rate has not been documented by field studies, results of this investigation indicate that for each foot of water-table decline about 3.8 inches of water may be salvaged.

The ET-runoff capture rate and depth probably vary within the modeled area, but for lack of validation, they were held constant. Instead, the model calibration was based on varying recharge to the surficial aquifer. Because ET-runoff capture is based on reducing water-table ET and runoff as the water table declines, recharge should approach maximum potential rates. In internally drained areas, recharge should not exceed rainfall (55 inches per year) minus minimum ET from plant surfaces and the unsaturated zone (25 inches per year), or about 30 inches per year.

The model apportions recharge to leakage and ET-runoff using the ET-runoff capture function, which is the quotient of the maximum capture rate divided by maximum capture depth. For example, if recharge is 20 inches per year and downward leakage is 5 inches per year under nonpumping conditions, the model will allocate 15 inches per year as ET-runoff. If pumping increases leakage from 5 inches per year to 12.6 inches per year, then the water table will drop 2 feet to capture the 7.6-inch-per-year leakage increase, and ET-runoff will be reduced from 15 inches per year to 7.4 inches per year. Should pumping capture all the 15-inch-per-year ET-runoff reserve, then the total recharge of 20 inches per year will leak down to the Floridan aquifer. Further pumping increases will not capture additional ET or runoff, with the result being accelerated water-table declines.

Six physiographic units were delineated (fig. 4) to conceptualize recharge to, evapotranspiration and leakage from, and transmissivity of the surficial aquifer:

<table>
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<tr>
<th>Physiographic unit</th>
<th>Area (mi²)</th>
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<th>Evapotranspiration</th>
<th>Leakage</th>
<th>Transmissivity</th>
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<td>1. Coastal marsh</td>
<td>46</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>2. Coastal sand ridge</td>
<td>19</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>3. Lowlands plain</td>
<td>561</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
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<tr>
<td>4. Lakes terrace</td>
<td>156</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>5. Central swamp</td>
<td>84</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>6. Brooksville ridge</td>
<td>66</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>High</td>
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Figure 4.—Physiography of the modeled area.
Recharge to the surficial aquifer was considered to be low in marsh and swamp areas where the high water table is maintained by upward leakage from the Floridan aquifer; moderate in the moderately drained lowlands plain and the well-drained ridge areas; and high in the internally drained lakes terrace where hundreds of sinkhole lakes perforate the upper confining bed. Evapotranspiration from the water table was considered to be low along ridge areas where the water table is deep; moderate in the lowlands plain and lakes terrace where the water table is shallow; and high in marshy and swampy areas where the water table is at or near land surface. Leakage to the Floridan aquifer was considered to be low in the marsh and swamp areas where the water table generally lies below the potentiometric surface; moderate in the lowlands plain where the water table lies a few feet above the potentiometric surface; moderate in the ridge areas where the head difference between the water table and potentiometric surface is high, but the upper confining bed is relatively thick; and high in the lakes terrace where sinkholes increase the leakage rate. Transmissivity of the surficial aquifer is very low relative to transmissivity of the Floridan aquifer, but was considered to be lowest in the marsh and swamp areas where the sand is thin; moderate in the lowland plain and lakes terrace where the sand is moderately thick; and highest in the ridges where the saturated thickness is greatest.

Modeling Procedure

Modeling procedures consisted of selecting representative input parameters, adjusting them within a reasonable range of values during calibration, testing the model's sensitivity to errors in the input parameters, and running the calibrated model under a separate set of pumping and climatological conditions to validate its accuracy. Prior to implementation of these modeling procedures, the adequacy of a steady-state model was evaluated and a time period was selected for the calibration.

Aquifer tests at the major well fields indicate that water levels in the Floridan aquifer rapidly stabilize. All the water pumped from the Floridan aquifer is soon accounted for by an increase in downward leakage from or a reduction in upward leakage to the surficial aquifer. Stewart (1968, p. 171 and 187) confirms that the potentiometric surface at the Section 21 and Eldridge-Wilde well fields approaches steady-state in less than 100 days of pumping.

Because the aquifer system approaches a steady-state condition shortly after pumping begins, a transient-state model of short-term water-level changes was deemed unnecessary. For a large region containing several well fields, a steady-state model representing long-term average conditions should adequately and simply portray the effects of pumping.

The time period selected for the steady-state calibration was May 1976-April 1977. For this period, average stream discharge of eight watersheds in the modeled area was 4.3 inches per year, or 70 percent of long-term average. Rainfall recorded by the National Oceanic and Atmospheric Administration at four sites (Tampa, Tarpon Springs, Cosme well field, and St. Leo) averaged 48.64 inches, or about 88 percent of the 55-inch long-term average. Average water levels in the Floridan and surficial aquifers were considered to be slightly below normal, based upon streamflow and climatological conditions.
Recharge to the surficial aquifer was considered to be directly proportional to rainfall. For the calibration period, recharge was assumed to be 91 percent of normal. The modeling procedure for subsequent predictive runs, representative of long-term average climatological conditions, included increasing recharge by 10 percent above that determined through calibration.

The hydrologic model assumes that:
1. Ground-water movement in the surficial and Floridan aquifers is horizontal.
2. Water moves vertically into and out of the Floridan aquifer through the upper confining bed.
3. The upper confining bed has negligible storage.
4. Changes in ground-water storage in the surficial and Floridan aquifers occur instantaneously with changes in hydraulic head.
5. Transmissivity of the Floridan aquifer and leakance coefficient of the upper confining bed do not change with time.
6. Head changes in the surficial and Floridan aquifers caused by an imposed stress will eventually stabilize; that is, a condition of steady state will be reached.
7. Constant-head conditions accurately represent the hydrologic conditions of the surficial aquifer at the model-grid boundary and Lake Tarpon.
8. Head-controlled flux (HCF) conditions accurately represent the hydrologic conditions of the Floridan aquifer near the model-grid boundary.
9. Recharge to and evapotranspiration from the surficial aquifer occur instantaneously.
10. Movement of the saltwater-freshwater interface has little or no effect on computed heads.

Input Parameters

The steady-state model requires input parameters for each grid block including:
1. Altitude of the observed potentiometric surface of the Floridan aquifer;
2. Altitude of the observed water table in the surficial aquifer;
3. Storage coefficient of the Floridan aquifer (defined as zero);
4. Storage coefficient (defined as zero) and constant-head nodes of the surficial aquifer;
5. Transmissivity of the Floridan aquifer;
6. Leakance coefficient of the upper confining bed;
7. Hydraulic conductivity of the surficial aquifer;
8. Altitude of the bottom of the surficial aquifer;
9. Recharge rate to the surficial aquifer;
10. HCF condition leakage factor for the Floridan aquifer;
11. Maximum evapotranspiration-runoff capture rate from the water table divided by maximum depth at which evapotranspiration-runoff capture occurs;
12. HCF condition head factor for the Floridan aquifer;
13. Altitude of the bottom of the zone in which evapotranspiration occurs;
14. Altitude of land surface;
15. Model-grid spacing; and
16. Pumping rate from the Floridan aquifer.

The model utilizes many input parameters directly in ground-water flow equations. Others are used indirectly to compute parameters that vary with head, such as transmissivity of the surficial aquifer, evapotranspiration rate, or boundary flux. Ranges for the model parameters are presented in table 1.

Since 1971, the U.S. Geological Survey has prepared maps showing the potentiometric surface of the well-field areas for each May and September that represent seasonal low and high water-level periods, respectively. Water-levels shown on these maps may be considered to represent levels of the potentiometric surface at the trough and peak of an annual water-level hydrograph. Of the available maps, those for September 1976 and May 1977 (Ryder and Mills, 1977a; 1977b) were considered to best represent high and low water-level conditions, respectively. The average potentiometric surface, derived from the two maps for input to the model, was considered to represent the average steady-state potentiometric surface for the calibration period.

The water table in the surficial aquifer was mapped using field measurements of wells and estimates from topographic maps. It was estimated to be at or a few feet below land surface in swampy areas and the lakes terrace and at depths greater than about 5 feet below land surface for the lowlands plain and ridge areas. The water table is lower than the potentiometric surface over a 177-mi² area (20 percent of the modeled area). In this primarily swampy area, upward flow occurs from the Floridan aquifer to the surficial aquifer and streams. Within the ridge areas, the water table is 20 to 100 feet higher than the potentiometric surface.

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

The storage coefficient matrix is also used to assign constant-head values to nodes, such as at the model boundary, where water levels are not expected to change. Because the model will allow heads to change at the model-grid boundary in the Floridan aquifer (by means of the HCF condition), constant-head nodes are not designated in this modeled layer. Pumping from the Floridan aquifer is expected to have little impact on the water table in the surficial aquifer at the edges of the model; therefore, constant-head boundary conditions were assigned in the surficial aquifer. Even if head changes in grid blocks adjacent to the boundary are large, changes in lateral boundary flow would be negligible due to an aquifer transmissivity of only about 300 ft²/d. For example, if a 10-foot
### Table 1.--Values for hydrologic parameters of the calibrated steady-state model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potentiometric-surface altitude.</td>
<td>1-87 ft</td>
<td>Ryder and Mills (1977a; 1977b).</td>
</tr>
<tr>
<td>Water-table altitude.</td>
<td>0-160 ft</td>
<td>Ryder and Mills (1977a; 1977b).</td>
</tr>
<tr>
<td>Storage coefficient, both aquifers.</td>
<td>0</td>
<td>----</td>
</tr>
<tr>
<td>Transmissivity of Floridan aquifer.</td>
<td>25,900-475,000 ft²/d</td>
<td>Published aquifer-test results.</td>
</tr>
<tr>
<td>Transmissivity of surficial aquifer.</td>
<td>74-359 ft²/d</td>
<td>Model computed, based on hydraulic conductivity measurements of Sinclair (1974).</td>
</tr>
<tr>
<td>Leakance coefficient of upper confining bed.</td>
<td>0.00015-0.0008 (ft/d)/ft</td>
<td>Published aquifer-test results.</td>
</tr>
<tr>
<td>Altitude of the bottom of the surficial aquifer.</td>
<td>-10- (+130) ft</td>
<td>Wolansky and others (1979).</td>
</tr>
<tr>
<td>Saturated thickness of surficial aquifer.</td>
<td>7.4-35.9 ft</td>
<td>Model computed, based on difference between water table and estimated bottom of aquifer.</td>
</tr>
<tr>
<td>Recharge rate to surficial aquifer.</td>
<td>9-28 in/yr</td>
<td>Estimated by summing leakage and ET-runoff from water table.</td>
</tr>
<tr>
<td>Floridan aquifer boundary flux.</td>
<td></td>
<td>Model computed.</td>
</tr>
<tr>
<td>ET-runoff rate from water table.</td>
<td>0-38 in/yr</td>
<td>Model computed.</td>
</tr>
<tr>
<td>Altitude of land surface.</td>
<td>0-200 ft</td>
<td>USGS topographic maps.</td>
</tr>
<tr>
<td>Pumping rate from Floridan aquifer at individual nodes.</td>
<td>0-7,920,000 gal/d</td>
<td>SWFWMD water-use permits, pumping reports, and irrigation requirements.</td>
</tr>
<tr>
<td>Total pumping rate from Floridan aquifer.</td>
<td>133,400,000 gal/d</td>
<td>----</td>
</tr>
</tbody>
</table>
head change were to occur, by Darcy's formula, boundary flow would change by only 15 gal/min along the 1-mile-long face of the grid block adjacent to the boundary ($\Delta Q = 300 \text{ ft}^2/\text{d} \times 10 \text{ ft/mi} \times 1 \text{ mi} = 3,000 \text{ ft}^2/\text{d} = 15 \text{ gal/min}$). The storage coefficient matrix for the surficial aquifer designates 118 constant-head nodes, 111 along the model-grid boundary, 5 at Lake Tarpon, and 2 at Tampa Bay. Crews Lake, the other large lake in the modeled area, fluctuates with the water table; therefore, constant-head nodes were not assigned there.

Transmissivity of the Floridan aquifer and leakance coefficient of the upper confining bed were based on analyses of aquifer tests (table 2) and on preliminary values derived from the phase 1 two-dimensional model calibration (Hutchinson and others, 1981). Transmissivity is high north of the Cross Bar Ranch well field and in the area of the Hillsborough River. Transmissivity is lowest beneath the lakes terrace physiographic unit (fig. 5).

Leakance coefficient of the upper confining bed is model-derived in areas outside the well fields (fig. 6). Leakance coefficient is lowest in the ridge areas and is based on a relatively large head difference between the water table and potentiometric surface. Leakance coefficient is highest in the lakes terrace, coastal marsh, and along the Hillsborough River where the confining bed has been thinned by erosion or breached by sinkholes. Figure 7 depicts leakage rates in each physiographic unit as derived in the calibrated model. Leakage is upward in the coastal marsh and central swamp physiographic units; elsewhere leakage is downward.

Hydraulic conductivity of the surficial aquifer was estimated at a uniform 10 ft/d. This estimate is based on laboratory measurements for surficial materials in northwest Hillsborough County (Sinclair, 1974). The model computes transmissivity of the surficial aquifer by multiplying hydraulic conductivity by saturated thickness, determined as the difference between the simulated water table and the bottom of the aquifer. A map showing distribution of transmissivity of the surficial aquifer is presented in figure 8.

The bottom of the surficial aquifer was mapped by subtracting the thickness of surficial deposits defined by Wolansky and others (1979) from land surface. The saturated thickness was then mapped. It was found to be 10 feet or less in the coastal marsh and central swamp and 15 to 30 feet elsewhere. Figure 9 shows the bottom configuration as input to the model and the saturated thickness simulated in the steady-state calibration.

Recharge to the surficial aquifer, considered to be derived from rainfall, irrigation return, and lake augmentation, was initially computed at each node as the sum of the phase 1 two-dimensional model-computed leakage rate (Hutchinson and others, 1981) and the estimated ET-runoff capture rate from the water table. The regional pattern of recharge was then modified to conform to controls assumed by the six physiographic units (fig. 10). For the calibration period, it was estimated that average recharge varies from a minimum of 15 inches per year in the central swamp to a maximum of 28 inches per year in the lakes terrace.
Table 2.—Aquifer-test results

<table>
<thead>
<tr>
<th>Well field</th>
<th>Transmissivity from aquifer test (ft²/d)</th>
<th>Transmissivity in model (ft²/d)</th>
<th>Leakance coefficient from aquifer test [(ft/d)/ft]</th>
<th>Leakance coefficient in model [(ft/d)/ft]</th>
<th>Source of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Bar Ranch</td>
<td>47,500-115,000</td>
<td>25,900-194,400</td>
<td>0.0005-0.0027</td>
<td>0.0004-0.0008</td>
<td>Leggette, Brashears and Graham, Inc. (1978)</td>
</tr>
<tr>
<td>Cypress Creek</td>
<td>31,500-53,600^1/</td>
<td>25,900-41,500</td>
<td>0.0003-.0009^1/</td>
<td>0.0015-.0008</td>
<td>Ryder (1978)</td>
</tr>
<tr>
<td>Starkey</td>
<td>40,000^2/</td>
<td>57,000</td>
<td>.003</td>
<td>.0003</td>
<td>Robertson and Mallory (1977)</td>
</tr>
<tr>
<td>Pasco County</td>
<td>53,000</td>
<td>51,800-57,000</td>
<td>.0003</td>
<td>.0003-.0004</td>
<td>Robertson and Mallory (1977)</td>
</tr>
<tr>
<td>Eldridge-Wilde</td>
<td>33,000^2/</td>
<td>57,000</td>
<td>.0003</td>
<td>.0004-.0005</td>
<td>Robertson and Mallory (1977)</td>
</tr>
<tr>
<td>East Lake</td>
<td>40,000^2/</td>
<td>57,000</td>
<td>.001</td>
<td>.0003</td>
<td>Robertson and Mallory (1977)</td>
</tr>
<tr>
<td>Cosme</td>
<td>----</td>
<td>57,000</td>
<td>----</td>
<td>.0003</td>
<td>----</td>
</tr>
<tr>
<td>Section 21</td>
<td>29,400-86,900</td>
<td>51,800</td>
<td>.0002-.0015</td>
<td>.0004</td>
<td>Stewart (1968)</td>
</tr>
<tr>
<td>Morris Bridge</td>
<td>53,500-130,000^1/</td>
<td>41,500-237,600</td>
<td>.0006-.001</td>
<td>.0003-.0006</td>
<td>Ryder and others (1980)</td>
</tr>
<tr>
<td>Northwest</td>
<td>----</td>
<td>25,900-51,800</td>
<td>----</td>
<td>.0003-.0004</td>
<td>----</td>
</tr>
</tbody>
</table>

^1/ Range includes values from aquifer tests near the well field.

^2/ Pumped well did not top the full thickness of the Floridan aquifer (partially penetrating).
Figure 5.—Transmissivity of the Floridan aquifer.
Figure 6.—Leakance coefficient of the upper confining bed.
Figure 7.--Leakage rates through the upper confining bed, as computed in the steady-state model calibration.
Figure 8.—Transmissivity of the surficial aquifer.
Figure 9.—Bottom configuration and saturated thickness of the surficial aquifer.
Figure 10.—Recharge to the water table in the surficial aquifer, as input for the steady-state calibration.
The HCF condition leakage factor for steady-state flow is computed analytically (using variable names that appear in the model code) by the equation:

\[
CSS = \frac{T\lambda}{\Delta X} \cdot \left( \frac{1-e^{-2\lambda L/\lambda}}{1+e^{-2\lambda L/\lambda}} \right), \quad i = 1, 2
\]

where

- **CSS** = HCF condition leakage factor (feet per second per foot);
- **T** = transmissivity of the Floridan aquifer (feet squared per second);
- **\( \lambda \)** = \( TK/T \); \( TK \) is the leakance coefficient of the upper confining bed (feet per second per foot); \( k/b \), where \( k \) is the hydraulic conductivity, and \( b \) is the thickness of the bed;
- **L** = distance from model-grid boundary to constant-head point beyond (feet); and
- **\( \Delta X_i \)** = model-grid length parallel to boundary flow (feet), either \( DEGX \) or \( DEGY \) grid spacings.

The equation, formulated by S. P. Larson and J. V. Tracy (written commun., 1979) and derived later in this report, solves for the factor CSS. When CSS is multiplied by the difference between the head factor and potentiometric surface, flux at the model-grid boundary is computed.

The head factor in the HCF condition is the effective head in the surficial aquifer at an arbitrary distance of 15 miles from the model-grid boundary necessary to yield boundary flux calculated by the phase 1 two-dimensional model. A distance of 15 miles was selected as being beyond the effects of any stress that could be applied in the modeled area. For input to the quasi-three-dimensional model, the factor was computed using a form of Darcy's law:

\[
HSS = \frac{XHCF}{CSS} + PHI
\]

where

- **HSS** = HCF condition head factor for the surficial aquifer (feet);
- **XHCF** = boundary flux from two-dimensional model calibration (feet cubed per second per foot squared, or feet per second);
- **CSS** = HCF condition leakage factor (feet per second per foot), computed from equation 1; and
- **PHI** = head in Floridan aquifer at the model-grid boundary (feet).

The equation, rearranged to compute XHCF, is essentially that contained in the model for computing flux at the model-grid boundary (statement 11690 in computer program listing of Attachment A). Because this flux had already been computed in the phase 1 two-dimensional calibration, it was used to compute the head factor, which normally would be estimated.

Capture of evapotranspiration (ET) from the water table and runoff may be considered to be the variable source from which pumped water is derived since recharge is held constant in the model. Under normal climatological conditions, pumping will lower the water table, thereby creating the potential for extra recharge during the wet season and, subsequently, less runoff. Thus, the modeled ET-runoff capture parameter not only represents ET from the water table, but also changes in recharge and runoff.
Capture of ET from the water table and runoff was assumed to occur in the zone between land surface and a depth of 10 feet. The ET-runoff capture rate derived in the conceptual model is that for each foot of water-table decline, 3.8 inches per year of water can be captured. The maximum potential ET-runoff rate from the water table is 38 inches per year in areas where the water table is at land surface and zero where the water table is 10 feet or more below land surface. Regional patterns of ET-runoff were adjusted to conform to controls of the six physiographic units (fig. 11). It should be emphasized that ET is from the water table in the surficial aquifer and, thus, is only a component of the total ET found in standard hydrologic budget analyses (for example, Cherry and others, 1970). ET from land surface and the unsaturated zone and flood runoff are not represented in the model.

The average altitude of land surface in each grid block was obtained from U.S. Geological Survey 1:24,000 topographic maps. Topographic highs usually correspond to the ridge and terrace physiographic units, and closed basins or lows correspond to swamps and coastal marsh units.

Average withdrawals from the Floridan aquifer for the period September 1976 to May 1977 were estimated from records of the Southwest Florida Water Management District and from estimates of water requirements for citrus (University of Florida, 1977). These included withdrawals for municipal supply, miscellaneous municipal supply and treatment, citrus irrigation, and miscellaneous crop, pasture, and lake augmentation (table 3). Water pumped from private domestic wells was assumed to be small and was not considered for input to the model. The distribution of pumpage as input to the model is shown in figure 12. Pumping is distributed mainly along the Gulf Coast and in the southern part of the modeled area. The largest withdrawals occur in the well-field areas.

**Calibration**

The model was calibrated by systematically adjusting input parameters until simulated heads in the Floridan and surficial aquifers matched long-term average steady-state levels. Leakance coefficient of the upper confining bed and transmissivity of the Floridan aquifer had been calibrated previously in the phase 1 two-dimensional model, and these parameters were readjusted during calibration of the quasi-three-dimensional model. Error limits for the steady-state quasi-three-dimensional model calibration were set at ±5 feet of head in each aquifer. Statistics of the model calibration are listed in table 4.

The comparison of observed long-term average water levels with model-simulated values in both aquifers was good statistically, thus the model was considered to be adequately calibrated. Residuals were nearly within the ±5-foot limit and were normally distributed about means near zero. The standard deviation about the mean of the residuals for the water table was 1.3 feet. That is, the model-simulated water table matched the estimated long-term average levels within a range of 0.9 foot above to 1.7 feet below at about 68 percent of the nodes. Similarly, the model-simulated potentiometric surface matched the September 1976 to May 1977 average levels at 68 percent of the nodes within a range of 1.9 feet above to 2.3 feet below, based on a standard deviation of
Figure 11.—Evapotranspiration plus runoff from the water table in the surficial aquifer, as computed in the steady-state calibration.
Figure 12.—Distribution of average pumpage in the modeled area, September 1976 to May 1977.
Table 3.--Average pumpage from the Floridan aquifer, September 1976 to May 1977

<table>
<thead>
<tr>
<th>Use</th>
<th>Mgal/d</th>
<th>ft³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal ¹/</td>
<td>87</td>
<td>134</td>
</tr>
<tr>
<td>Miscellaneous municipal and treatment ²/</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Citrus irrigation ³/</td>
<td>24</td>
<td>37</td>
</tr>
<tr>
<td>Miscellaneous crop, pasture, and lake augmentation ⁴/</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>133</td>
<td>206</td>
</tr>
</tbody>
</table>

¹/ Obtained from pumping records on file at Southwest Florida Water Management District.

²/ Computed as 75 percent of the daily pumpage permitted by Southwest Florida Water Management District.

³/ Computed by the method outlined by University of Florida (1977) using a 75-percent seepage efficiency.

⁴/ Computed as 50 percent of the daily pumpage permitted by Southwest Florida Water Management District.

2.1 feet about a residual mean of 0.2 foot below the average level. The correlation coefficients were near 1.000, indicating near-perfect association between the long-term average and model-simulated water levels in both aquifers. Comparisons between the long-term average and model-simulated water table and potentiometric surface are shown in figures 13 and 14, respectively. Water levels simulated by the steady-state calibration run were used as starting water levels for subsequent model-sensitivity runs.

Sensitivity Analysis

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

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Figure 13.—Comparison of September 1976 to May 1977 estimated average and model-simulated water tables, representing steady-state calibration.
Figure 14.—Comparison of September 1976 to May 1977 average and model-simulated potentiometric surfaces, representing steady-state calibration.
<table>
<thead>
<tr>
<th>Statistic</th>
<th>Long-term average versus model-simulated</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water table</td>
<td>Potentiometric surface</td>
</tr>
<tr>
<td>Number of active nodes</td>
<td>814</td>
<td>932</td>
</tr>
<tr>
<td>Maximum range in residuals</td>
<td>4.4 to (-5.0)</td>
<td>5.3 to (-4.9)</td>
</tr>
<tr>
<td>Mode of residuals (feet)</td>
<td>.1</td>
<td>.2</td>
</tr>
<tr>
<td>Median residual (feet)</td>
<td>.4</td>
<td>.3</td>
</tr>
<tr>
<td>Mean residual (feet)</td>
<td>.4</td>
<td>.2</td>
</tr>
<tr>
<td>Mean of absolute value of residuals</td>
<td>1.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Standard deviation of residuals</td>
<td>1.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Correlation coefficient</td>
<td>.9987</td>
<td>.9961</td>
</tr>
</tbody>
</table>

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

Model sensitivity was tested by varying ET-runoff and recharge parameters and hydraulic parameters of the surficial and Floridan aquifers and the confining bed. Figure 15 shows deviations from the steady-state calibration water table and potentiometric surface by varying maximum ET-runoff capture depth (ETD) by ±5 feet, recharge rate (QRE) by ±20 percent, and maximum potential ET-runoff capture rate (ETR) by ±20 percent. Figure 16 shows deviations due to varying hydraulic conductivity (PERM) of the surficial aquifer by a factor of 3, transmissivity (T) of the Floridan aquifer by factors of 2 and 0.5, and leakance coefficient (TK) of the upper confining bed by factors of 2 and 0.5. The cross sections in both figures depict model-simulated heads along row 20 of the model. This row, through the center of the model, intersects five of the six physiographic units. The two cross sections exemplify and were used in conjunction with maps that supply areal perspective to the sensitivity analysis.
Figure 15.—Effects of varying evapotranspiration-runoff and recharge parameters on the steady-state calibration.
Figure 16.—Effects of varying aquifer and confining bed hydraulic parameters on the steady-state calibration.
Varying the ET-runoff capture rate and recharge has a slightly greater effect on the water table than the potentiometric surface. One might expect to see a much larger effect on the water table because these changes directly apply to inflow to and outflow from the surficial aquifer. But, due to the relatively high leakage rate from the surficial aquifer through the upper confining bed and the dampening effect on heads in this aquifer by the ET-runoff capture function, head deviations from the steady-state calibration are nearly the same in each aquifer. Although not depicted in figure 15, the ridge areas are sensitive to recharge. The water table in the ridges responds dramatically to small changes in recharge because the leakance coefficient is low and the water table generally lies 10 feet or more below land surface, thereby nullifying the dampening effect of ET-runoff capture. Other than in ridge areas, the effects of increasing or reducing recharge are dampened by increasing or reducing ET-runoff outflow. In the swampy areas ET-runoff is high and changing this parameter strongly influences the calibration, as can be seen at columns 25-26 of figure 15.

Because the model is sensitive to ET-runoff capture and recharge, better estimates of these input parameters would produce a more accurate model. A preliminary model was calibrated that assumed the water table would drop 1 foot for each 1.8 inches captured from ET and runoff. This preliminary calibration produced about twice the observed water-table fluctuations under different pumping conditions and, thus, was a poor validation. Subsequently, the model was recalibrated using a higher potential ET-runoff capture rate where the water table would drop 1 foot for each 3.8 inches of water captured. This resulted in more realistic fluctuations of the water table. Overall, the model indicates that better definition is needed of (1) recharge rate of various soil types and physiographic units, (2) relation between recharge and depth of water table, (3) potential evapotranspiration rate from the water table, and (4) relation between evapotranspiration and depth of water table.

Of the hydraulic parameters tested, the model is most sensitive to changes in leakance coefficient of the upper confining bed, moderately sensitive to transmissivity of the Floridan aquifer, and least sensitive to hydraulic conductivity of the surficial aquifer. Average deviations in the water table are relatively small compared to those in the potentiometric surface, showing again the dampening effect of ET-runoff. For example, when leakance was doubled, the potentiometric surface rose 4.6 feet at column 15 (fig. 16), but the water table declined only about 0.5 foot. The increased downward leakage in the center of the modeled area was composed entirely of captured ET-runoff. In ridge areas where the water table generally is 10 feet or more below land surface, evapotranspiration from the water table and the potential for capturing runoff are nil, and small changes in the potentiometric surface sometimes result in large fluctuations in water-table levels.

Tests of the model's sensitivity to boundary conditions were made during the predictive-modeling phase of the study. Ten well fields were pumped at a combined rate of 186.9 Mgal/d and drawdowns in the Floridan aquifer were observed under constant-head, constant-flow, and HCF boundary conditions. Average drawdown at the boundary was zero under constant-head conditions, 1.2 feet under HCF conditions, and 2.5 feet under constant-flow conditions. Average drawdown over the modeled area was 3.4, 3.6, and 4.2 feet, respectively, under these conditions. Had the distance from the model-grid boundary to the constant-head point beyond been less than 15 miles, boundary drawdowns would be equal to or less than 1.2 feet, observed using the 15-mile distance. Increasing distance greater than 15 miles would produce boundary drawdowns equal to or slightly greater than the HCF level.
The sensitivity analysis exemplifies an important limitation of the model whereby the water table can rise above land surface, when actually it can rise only to land surface and becomes surface water with additional rise. Unless ponding occurs, rises at these nodes are not possible because the water table already lies at land surface. Errors in the water-table levels will lead to errors in computed leakage rate through the upper confining bed and potentiometric head in the underlying Floridan aquifer. When using the model for predictive purposes, this limitation should be kept in mind and areas of water-table rise above land surface should be recognized. The model code was modified to flag these areas.

Validation

Model validation is a technique for testing the accuracy of a calibrated model for predictive purposes. The test case chosen for validation involved removing all pumpage from the calibrated steady-state model; recharge in pumping nodes was reduced by subtracting 20 percent of the previous irrigation pumpage (because irrigation-return flow would cease) and 100 percent of the lake augmentation pumpage (all water pumped for lake augmentation was considered to be recharge, and hence, would cease). The natural recharge rate was increased by 10 percent, based on the assumption that rainfall, and subsequently recharge, was 10 percent below normal during the calibration period. The model-simulated water table was compared with the steady-state calibrated water table to check if water-level changes in the surficial aquifer were plausible. The model-simulated potentiometric surface was compared with an estimated potentiometric surface generally unaffected by pumping, mapped by Johnston and others (1980), that represents predevelopment conditions. Statistics of these comparisons are listed in table 5. Comparisons are good statistically; thus, the model was considered to be adequately validated.

The model-simulated predevelopment water table rose a maximum of 10.7 feet above the calibrated water table. The model indicated an average water-table rise of 1.4 feet. The standard deviation of 1.1 feet about the mean indicates that, in about 68 percent of the nodes, the model-simulated water table remained within a range of 0.3 foot lower and 2.5 feet higher than the steady-state calibrated level. The greatest rise occurred at the Eldridge-Wilde well field. In other well fields, the rise due to cessation of pumpage was 2 to 4 feet. Estimated average water levels for 1976-77 are assumed to represent stressed conditions. Figure 17 indicates that should all pumping cease, the water would recover in some areas. Although not discernible at the scale of figure 17, there was a rebound of water-table levels to smooth out depressions caused by pumping in all the well fields. The water table simulated by the validation run was used as the predevelopment starting water table upon which predictive model runs are based.

Comparison of predevelopment and model-simulated potentiometric surfaces was good statistically. Over the 932 nodes within the model-grid boundary, the simulated predevelopment potentiometric surface ranged from 9.4 feet higher than to 11.6 feet lower than the estimated level. The mean was 1.8 feet higher than the estimated level. The standard deviation about the mean of the residuals was 3.5 feet, which indicates that the model-simulated potentiometric surface matched within a range of 5.3 feet higher than to 1.7 feet lower than the estimated pre-development level at about 68 percent of the nodes. A correlation coefficient of 0.9899 indicates a good correlation between the two surfaces.
Figure 17.--Comparison of steady-state calibrated and model-simulated predevelopment water tables, representing model validation.
Table 5.—Statistics of model validation

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Calibrated steady-state versus model-simulated water table</th>
<th>Estimated prestressed versus model-simulated potentiometric surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of active nodes</td>
<td>814</td>
<td>932</td>
</tr>
<tr>
<td>Maximum range in residuals (feet)</td>
<td>0 to (-10.7)</td>
<td>11.6 to (-9.4)</td>
</tr>
<tr>
<td>Mode of residuals (feet)</td>
<td>-.7</td>
<td>-3.7</td>
</tr>
<tr>
<td>Median residual (feet)</td>
<td>-1.1</td>
<td>-1.9</td>
</tr>
<tr>
<td>Mean residual (feet)</td>
<td>-1.4</td>
<td>-1.8</td>
</tr>
<tr>
<td>Standard deviation of residuals (feet)</td>
<td>1.1</td>
<td>3.5</td>
</tr>
<tr>
<td>Correlation coefficient</td>
<td>.9992</td>
<td>.9899</td>
</tr>
</tbody>
</table>

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

Comparison between the estimated and simulated potentiometric surfaces for predevelopment conditions is shown in figure 18. The wide range in model residuals between the two surfaces (21 feet) may be due to several factors. For example, the map of the estimated historic potentiometric surface may be in error where data are sparse and specifically in areas where the predevelopment head is lower than the average steady-state head. Errors could be greater along the coasts of the Gulf of Mexico and Tampa Bay where upwelling of freshwater results in upward flow in the aquifer and where channel dredging may have changed the hydraulic properties of the upper confining bed between predevelopment and September 1976 to May 1977 average maps. Although these errors may not represent model-calibration errors, they serve to increase the statistical errors of the model validation.

The model validation represents average hydrologic conditions prior to pumping. The water balance under these conditions will differ from that of the calibrated model in that recharge and pumpage have been altered. These alterations in turn affect ET-runoff from the water table and leakage. Table 6 lists the model-computed water balance for the surficial aquifer in each physiographic unit and for the surficial and Floridan aquifers over the total modeled area. It conforms to the conceptual model and is the water balance upon which all predictive runs of the model are based.
Figure 18.—Comparison of estimated and model-simulated potentiometric surfaces for predevelopment conditions, representing model validation.
Table 6.—Water balance for the surficial and Floridan aquifers simulated by the model under average hydrologic conditions prior to pumping

A. SURFICIAL AQUIFER BY PHYSIOGRAPHIC UNIT

<table>
<thead>
<tr>
<th>Physiographic unit</th>
<th>Area (mi²)</th>
<th>Recharge (in/yr)</th>
<th>ET-runoff from water table (in/yr)</th>
<th>Net leakage up (-) or down (+) (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal marsh</td>
<td>25</td>
<td>18.6</td>
<td>25.0</td>
<td>-6.3</td>
</tr>
<tr>
<td>Lowlands plain</td>
<td>496</td>
<td>25.9</td>
<td>20.4</td>
<td>5.4</td>
</tr>
<tr>
<td>Brooksville ridge</td>
<td>41</td>
<td>20.6</td>
<td>8.9</td>
<td>11.3</td>
</tr>
<tr>
<td>Lakes terrace</td>
<td>159</td>
<td>30.0</td>
<td>19.4</td>
<td>10.5</td>
</tr>
<tr>
<td>Central swamp</td>
<td>82</td>
<td>16.3</td>
<td>26.9</td>
<td>-10.6</td>
</tr>
<tr>
<td>Coastal sand ridge</td>
<td>11</td>
<td>20.4</td>
<td>10.0</td>
<td>9.4</td>
</tr>
</tbody>
</table>

B. SURFICIAL AQUIFER

<table>
<thead>
<tr>
<th>Area (mi²)</th>
<th>QRE Recharge (in/yr)</th>
<th>ETRO ET-runoff from water table (in/yr)</th>
<th>UL Upward leakage (in/yr)</th>
<th>DL Downward leakage (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for model</td>
<td>814</td>
<td>25.1</td>
<td>20.3</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Water balance: QRE + UL = ETRO + DL

C. FLORIDAN AQUIFER

<table>
<thead>
<tr>
<th>Area (mi²)</th>
<th>UL Upward leakage (in/yr)</th>
<th>DL Downward leakage (in/yr)</th>
<th>BI Boundary inflow (in/yr)</th>
<th>BO Boundary outflow (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for model</td>
<td>932</td>
<td>1.6</td>
<td>6.7</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Water balance: DL + BI = UL + BO
The water table and potentiometric surface simulated by the validation run were used as predevelopment starting heads upon which predictive-model runs are based. This zeros out the drawdown array computed by the model and puts the system in equilibrium for the start of a predictive run. Had the estimated predevelopment potentiometric surface been input as the starting head, then the system would only be near equilibrium, and predicted drawdowns under an anticipated pumping condition would contain errors carried over from the validation run.

PREDICTIVE MODELING

The quasi-three-dimensional model may be applied to various field problems. An example presented here illustrates options available in the program. An example field problem is presented, and results are compared to the phase 1 two-dimensional model results.

Example Field Problem

The field problem involves determining water-balance and water-level changes that can be expected as a result of pumping all 10 well fields at their annual average permitted or proposed rates with recharge varying 20 percent above and below the average rate. The model simulates wet conditions when recharge is above average and dry conditions where recharge is below average. The well fields currently (1981) are permitted by the Southwest Florida Water Management District to pump 186.9 Mgal/d from 164 wells (table 7). Within each well field, all wells were assumed to pump at the same rate and were assigned to the square-mile grid block in which they occur. Thus, pumpage was distributed as a function of well location rather than evenly throughout each well field.

Attachment C illustrates the data deck for the model interrogation of average recharge conditions. Attachment D illustrates the model output generated by the data deck. Figures 19-22 compare anticipated drawdowns in the water table and potentiometric surface under high, low, and average recharge conditions. Table 8 summarizes water-balance and water-level data under the various simulation runs and compares these values with initial nonpumping conditions.

The drawdown maps show a series of coalescing cones of depression. Because the well fields are close together, the cones will overlap or interfere with one another as they spread out. It should be realized that drawdown in the proximity of a single well field is increased by pumping from nearby well fields. Attachment E shows the model-simulated limits of cones of depression that should develop in the surficial and Floridan aquifers as the 10 well fields are pumped individually. Attachment E also shows three-dimensional graphical plots of the water table and potentiometric surface before and after pumping 10 well fields simultaneously.

When all 10 well fields are pumped simultaneously under average recharge conditions, the water table can be expected to drop 2 feet or more from nonpumping conditions over an area of about 163 mi². A 2-foot or greater decline in the potentiometric surface would occur over an area of about 505 mi². The maximum drawdowns occur at the well fields. For the entire modeled area, average drawdowns of 1.3 feet and 3.6 feet would occur in the surficial aquifer and Floridan aquifer, respectively. Recharge accounts for about 90 percent of the
inflow to the system, and ET-runoff from the water table accounts for about 58 percent of the outflow. Of the 187 Mgal/d pumped, 159 Mgal/d were derived from reduced ET-runoff and the remainder from a combination of increased boundary inflow and downward leakage (table 8). Although the amount of water captured from ET-runoff seems high, it represents reduced ET and runoff from the water table and possibly increased recharge when the water table is lowered.

Under high recharge conditions, the 2-foot cone of depression decreases from 163 to 41 mi² in the water table and from 505 to 323 mi² in the Floridan aquifer. More than 90 percent (178 of 194 Mgal/d) of the increased recharge would be lost to evapotranspiration, however, leaving little of this increased quantity of water to leak to the Floridan aquifer.

Compared to average recharge conditions, inflow and outflow trends under low recharge conditions are reversed with respect to wet recharge conditions. The 2-foot cone of depression would expand from 163 mi² under average recharge conditions to 460 mi² under low recharge conditions in the water table and from 505 to 755 mi² in the Floridan aquifer. The water table would decline about 3.2 feet, or 1.9 feet more than under average recharge conditions. The average decline in the potentiometric surface would be less than the water-table decline, about 1.4 feet more than under average recharge conditions. In the ridge areas and north of the Cross Bar Ranch well field where there is little or no ET-runoff,
Simulated drawdown in the water table in the surficial aquifer when well-field pumping is at the annual average permitted rate. Solid line represents drawdown under average recharge conditions. Dashed line represents drawdown under wet conditions when recharge is 20 percent above average. Intervals 2, 3, and 5 feet.
Figure 20.—Model-simulated drawdown in the water table in the surficial aquifer under average and low recharge conditions with well fields pumping at the annual average permitted rates.
Figure 21.—Model-simulated drawdown in the potentiometric surface of the Floridan aquifer under average and high recharge conditions with well fields pumping at the annual average permitted rates.
Figure 22.—Model-simulated drawdown in the potentiometric surface of the Floridan aquifer under average and low recharge conditions with well fields pumping at the annual average permitted rates.
Table 8.—Summary of water-balance and water-level data simulated by the model under varying conditions of recharge and pumping

A. WATER BALANCE FOR SURFICIAL AQUIFER (814 mi²)

<table>
<thead>
<tr>
<th></th>
<th>QRE Recharge (in/yr)</th>
<th>ETRO ET-runoff from water table (in/yr)</th>
<th>UL Upward leakage (in/yr)</th>
<th>DL Downward leakage (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial nonpumping condition</td>
<td>25.1</td>
<td>20.3</td>
<td>1.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Pumping with high recharge</td>
<td>30.1</td>
<td>20.8</td>
<td>1.0</td>
<td>10.3</td>
</tr>
<tr>
<td>Pumping with average recharge</td>
<td>25.1</td>
<td>16.2</td>
<td>1.0</td>
<td>9.9</td>
</tr>
<tr>
<td>Pumping with low recharge</td>
<td>20.0</td>
<td>11.7</td>
<td>1.0</td>
<td>9.4</td>
</tr>
</tbody>
</table>

Water balance: QRE + UL = ETRO + DL

B. WATER BALANCE FOR FLORIDAN AQUIFER (932 mi²)

<table>
<thead>
<tr>
<th></th>
<th>UL Upward leakage (in/yr)</th>
<th>DL Downward leakage (in/yr)</th>
<th>BI Boundary inflow (in/yr)</th>
<th>BO Boundary outflow (in/yr)</th>
<th>Pumpage (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial nonpumping condition</td>
<td>1.6</td>
<td>6.7</td>
<td>1.1</td>
<td>6.2</td>
<td>0</td>
</tr>
<tr>
<td>Pumping with high recharge</td>
<td>1.1</td>
<td>10.1</td>
<td>1.2</td>
<td>6.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Pumping with average recharge</td>
<td>1.1</td>
<td>9.8</td>
<td>1.2</td>
<td>5.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Pumping with low recharge</td>
<td>1.0</td>
<td>9.4</td>
<td>1.2</td>
<td>5.4</td>
<td>4.2</td>
</tr>
</tbody>
</table>

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

C. WATER-LEVEL CHANGE DATA

<table>
<thead>
<tr>
<th>Recharge condition</th>
<th>Water table</th>
<th>Potentiometric surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Average</td>
</tr>
<tr>
<td>Area encompassing 2 feet or more drawdown (mi²)</td>
<td>41</td>
<td>163</td>
</tr>
<tr>
<td>Area encompassing 5 feet or more drawdown (mi²)</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td>Maximum rise (feet)</td>
<td>10.2</td>
<td>0</td>
</tr>
<tr>
<td>Maximum drawdown (feet)</td>
<td>9.9</td>
<td>14.9</td>
</tr>
<tr>
<td>Average drawdown (+) or rise (-) (feet)</td>
<td>1.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>
relatively large declines develop in the water table. These declines resemble cones of depression, but probably result more from reduced recharge than from pumping. In areas where the water table is within 10 feet of land surface, a reduction in recharge results in a reduction in ET-runoff, and the water table declines moderately. The water-table decline is dampened by the capture of ET-runoff. In parts of the ridge areas, the water table is below the maximum ET-runoff capture depth (10 feet). This results in no dampening and an increased water-table decline.

Figures 19 through 22 illustrate water-level changes from predevelopment conditions due to the combined effects of pumping and varying recharge. Just the effects of pumping are illustrated under the average recharge condition. Under the high and low recharge conditions the effects of varying recharge could be negated by running the model with no pumping and varying recharge by 20 percent. The respective simulated water levels could then be input as starting heads for simulations under pumping conditions with high and low recharge. This modeling technique would filter out the effects of varying recharge and produce maps of drawdown caused only by pumping. A test of this type indicated that less than 3 feet of the water-table drawdown northeast of the Cross Bar Ranch well field was caused by pumping under the low recharge condition.

The constant-head boundary limits the accuracy for simulating changes in the water table near the perimeter of the model. For example, where a cone of depression reaches the boundary, the constant-head condition holds the water table constant, indicating that the boundary is an infinite source of water for the aquifer. Had a constant-flow boundary been used in the surficial aquifer, no change in boundary flow could be induced by pumping, and the water table would be lowered in excess of what might actually occur. Based on the sensitivity analysis of boundary conditions in the Floridan aquifer, the HCF condition would produce a water table somewhere near the extremes simulated under the constant-head and constant-flow conditions. However, the CSS and HSS arrays used for HCF in the Floridan aquifer were already dedicated to the ET-runoff capture function in the surficial aquifer, thus they were not available for HCF. The user should be aware that the model has a limited capability for predicting changes in hydrologic conditions within the surficial aquifer near the boundary.

Comparisons of Quasi-Three-Dimensional and Two-Dimensional Model Simulations

The phase 1 two-dimensional (2-D) model and phase 2 quasi-three-dimensional (Q-3-D) model produce different results when interrogated under the same pumping conditions. Because boundary conditions and hydraulic characteristics of the upper confining bed and Floridan aquifer are similar in both models, the differences may be attributed primarily to activating the water table in the Q-3-D model.

Maximum drawdowns in the potentiometric surface in the well fields simulated by each model are listed in table 9. Drawdown predicted by the Q-3-D model when the 10 well fields are pumped simultaneously at permitted capacities (table 7) is greater in every well field and averages about 4 feet more than that simulated by the 2-D model. In the 2-D model, the water table is held constant, but
Table 9.—Comparison of maximum drawdowns at 10 well fields simulated by the quasi-three-dimensional and two-dimensional models under various pumping conditions

<table>
<thead>
<tr>
<th>Well field</th>
<th>Pumping rate (Mgal/d)</th>
<th>Maximum drawdown (feet)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pump 10 well fields</td>
<td>Pump individual well fields</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potentiometric surface</td>
<td>Water table</td>
<td>Potentiometric surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q-3-D</td>
<td>2-D</td>
<td>Q-3-D</td>
<td>Q-3-D</td>
<td></td>
</tr>
<tr>
<td>Cross Bar Ranch</td>
<td>30</td>
<td>18.3</td>
<td>7.8</td>
<td>14.6</td>
<td>17.9</td>
<td></td>
</tr>
<tr>
<td>Cypress Creek</td>
<td>30</td>
<td>23.2</td>
<td>19.8</td>
<td>7.2</td>
<td>22.8</td>
<td></td>
</tr>
<tr>
<td>Starkey</td>
<td>8</td>
<td>7.5</td>
<td>5.5</td>
<td>1.5</td>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>Pasco County</td>
<td>16.9</td>
<td>15.5</td>
<td>13.0</td>
<td>3.1</td>
<td>11.5</td>
<td></td>
</tr>
<tr>
<td>Eldridge-Wilde</td>
<td>35.2</td>
<td>21.3</td>
<td>14.6</td>
<td>9.1</td>
<td>19.3</td>
<td></td>
</tr>
<tr>
<td>East Lake</td>
<td>3</td>
<td>6.5</td>
<td>4.4</td>
<td>.6</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Cosme</td>
<td>19</td>
<td>13.5</td>
<td>10.3</td>
<td>2.5</td>
<td>9.9</td>
<td></td>
</tr>
<tr>
<td>Section 21</td>
<td>18</td>
<td>19.5</td>
<td>11.2</td>
<td>4.1</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>Morris Bridge</td>
<td>18</td>
<td>7.7</td>
<td>6.3</td>
<td>1.9</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Northwest</td>
<td>8.8</td>
<td>13.9</td>
<td>--</td>
<td>2.2</td>
<td>7.8</td>
<td></td>
</tr>
</tbody>
</table>

1/ Because 10 well fields are pumped simultaneously, maximum drawdown in the proximity of a single well field is increased by pumping from nearby well fields.

2/ Northwest well field was not proposed at time of 2-D model run.

In the Q-3-D model, it declines in response to the change in leakage induced by lowering the potentiometric surface at the well fields. Because leakage is proportional to head difference between the potentiometric surface and water table, the potentiometric surface must be drawn down more in the Q-3-D model than the 2-D model to induce a similar quantity of leakage. The additional drawdown results in a larger cone of depression around each well field and greater drawdown at the well-field boundaries than predicted by the 2-D model.

The comparison of maximum drawdowns in the well fields adds perspective to the 2-D and Q-3-D model simulations. The 2-D model minimizes drawdown, whereas the Q-3-D model depicts more realistic movement of the potentiometric surface. The two models may be used for comparing or bracketing expected drawdowns. However, the Q-3-D model, the final product of this two-phased investigation, is considered to more accurately represent the hydrogeologic system.

Comparison of model results between the Q-3-D model and the 2-D model of Robertson and Mallory (1977) could not be made as their model did not simulate drawdown in the Floridan aquifer. But, because leakage coefficient of the upper confining bed and transmissivity of the Floridan aquifer varies as much as 100 percent outside the well field areas where data are sparse, the models should not agree precisely.
At the Cypress Creek well field, a 2-D model by Ryder (1978) indicated that drawdown in the potentiometric surface would be at least 5 feet over an area of about 7 mi² and that maximum drawdown should be about 15 feet when the well field is pumped at 30 Mgal/d. Again, this model contains a fixed water table, so drawdown should be less than that simulated by the Q-3-D model. The map of drawdown at Cypress Creek well field presented in attachment E supports this contention in that the 5-foot cone of depression in the Floridan aquifer should expand over a 27-mi² area and maximum drawdown should be about 23 feet. Maximum drawdown in the water table should be about 7 feet. Note that the head difference between the water table and potentiometric surface in the grid block of maximum drawdown is 16 feet, which compares favorably with Ryder's (1978) 15-foot head difference.

At the Morris Bridge well field, the Q-3-D model by Ryder and others (1980) indicated that when the well field is pumped at 40 Mgal/d, drawdown in the potentiometric surface would be 5 feet or more over an area of 20 mi² and that maximum drawdown should be about 15 feet. In the current Q-3-D model study, the well field was pumped at its permitted average rate of 18 Mgal/d, thus drawdown and spread of the cone of depression should be about half those predicted by the model developed by Ryder and others (1980). The map of drawdown at Morris Bridge well field presented in attachment E indicates that drawdown of 5 feet or more should spread over 8 mi² and maximum drawdown in the potentiometric surface should be about 7.6 feet. Water-table declines simulated by the two models were similar.

LIMITATIONS OF MODEL APPLICATION

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

The hydrogeology has been simplified to the extent that an operational mathematical model could be constructed. The mathematical solution is an approximate solution to the differential equations that define the system. Because the model grid is on a coarse regional scale of 1 mi², the localized impact of pumping small quantities of water will not be accurately depicted. Also, because of mathematical approximations associated with simulating boundary flow, the impact of pumping large quantities of water near the model-grid boundary may not be accurately depicted. Boundary assumptions also limit the accuracy for simulating drawdown in the water table near the perimeter of the model under other than average recharge conditions. Additional computational errors may be introduced in coastal areas, particularly in the East Lake, Eldridge-Wilde, and Starkey well fields, because the model does not consider movement of the freshwater-saltwater interface and the resultant displacement of a less dense fluid by another of greater density. A model limitation that could lead to significant errors occurs when the water table rises above land surface or falls to the base of the surficial aquifer. The model will flag areas where those phenomena occur. The model also only grossly accounts for changes in recharge and runoff that result from changes in the water table. Finally, because the model assumes a steady-state condition, the solution is not time dependent, and the time required for computed heads to reach these levels cannot be determined from this model.
The predictive-model runs exemplify the types of analyses possible with the Q-3-D model. Generally, it can be used to compute water-balance and regional water-level changes in response to various distributions of pumping and conditions of recharge. Local changes such as inflections in the water table near streams cannot be computed because any stream generally occupies less than one-fiftieth the area of a node. Because the model simulates long-term average water-level changes that should result from pumping, extreme high or low conditions could be significantly different from simulated conditions. Ideally, the model should represent all characteristics of the prototype, but realistically, it represents a few of the more important characteristics of the hydrologic system. The model simulates ground-water flow on a megascopic scale.

**COMPUTER PROGRAM**

The computer program documented here is written for the AMDAHL 470-V6 MVS system installed at the U.S. Geological Survey office in Reston, Va. The generic program is documented in Trescott (1975) with an expansion of the documentation in Trescott and Larson (1976). The program was modified for this study to (1) include the HCF condition in the lower layer, (2) compute ET-runoff capture from the upper layer, (3) produce parameter maps, (4) generate drawdown data in a format compatible with the CALCOMP (California Computer Products, Inc., 1971) contouring program, and (5) replace or add certain iteration parameters used in the strongly implicit procedure. Because the FORTRAN code of Trescott was modified extensively, the model may be considered as developed specifically for the well-field area. The model is not recommended for other applications unless the code is reviewed. A complete listing of the computer program is presented in attachment A.

Memory requirements and running time depend upon the size and complexity of the physical situation being simulated. For the field application documented herein, which utilized 1,224 nodes per layer over two layers, an average model run required 144,000 bytes of core memory on the FORTRAN G1 compiler, 300,000 bytes for executing the program, and about 15 seconds of Central Processing Unit time on the Geological Survey's computer.

**Head-Controlled Flux Condition**

**Theory**

In a recent modeling investigation (Wilson and Gerhart, 1980), a head-controlled flux (HCF) condition was introduced. The HCF condition allows head and flux to change at the model-grid boundary, thus adding flexibility to the Q-3-D model (Trescott, 1975) that previously incorporated only constant-head and constant-flux conditions. Under the HCF condition, flux across the model-grid boundary in the Floridan aquifer varies as a function of the potentiometric surface.

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1 The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.
at the HCF grid block. Because transmissivity of the surficial aquifer is low, boundary flux is not considered to be significant, and the HCF condition was not applied to the upper layer.

The HCF condition is useful in situations where simulated stresses spread to a model boundary (thus rendering constant head or constant flux unrealistic), and it is undesirable to increase the size of the modeled area by expanding the grid to a point where stress effects are negligible. Although the physical boundaries of the model grid remain stable, the HCF condition calculates a boundary-flow component based on a strip of aquifer as wide as the HCF grid-block edge and extending laterally a specified distance to a point of constant head. Thus, the HCF condition does not expand the model area or the grid upon which numerical solutions to the flow equation are calculated.

Figure 23 is a conceptualization of the HCF condition. The assumptions are made that (1) there is a point beyond the model grid (at distance L) where the water table (HSS) and the stressed potentiometric surface (PHI) will remain constant and are equal to the starting potentiometric surface (STRT); and (2) the transmissivity (T) and confining-bed leakance (TK) are constant in the aquifer strip between the model-grid boundary and the constant-head boundary. The assumptions allow reasonable finite boundaries to be placed on extensive aquifer systems that lack natural hydrologic boundaries.

Equations for solving boundary discharge under the HCF condition were developed at the U.S. Geological Survey's Northeast Region Research Project Office (J. V. Tracy and S. P. Larson, written commun., 1979). Names of variables used here conform to names of variables used in the model code. The governing equation for steady flow in the region 0 ≤ x ≤ L outside the modeled area is:

\[
\frac{\partial^2 \text{PHI}_x}{\partial x^2} - \frac{\text{TK}}{T} \left( \text{PHI}_x - \text{HSS} \right) = 0, \quad (5)
\]

where

\( \text{PHI}_x \) = altitude of the stressed potentiometric surface at distance \( x \) (feet);

\( \text{HSS} \) = altitude of the water table (feet);

\( \text{TK} \) = confining-bed leakance (feet per second per foot);

\( T \) = transmissivity of the Floridan aquifer (feet squared per second);

\( x \) = the distance from the model-grid boundary, for which the equation is to be solved (feet).

Under the assumption that the water table is constant in the aquifer strip:

\[
\frac{\partial^2 \text{HSS}}{\partial x^2} = 0, \quad (6)
\]

when subtracted from both sides of equation 5

\[
\frac{\partial^2 \text{PHI}_x}{\partial x^2} - \frac{\partial^2 \text{HSS}}{\partial x^2} - \frac{\text{TK}}{T} \left( \text{PHI}_x - \text{HSS} \right) = 0. \quad (7)
\]
Figure 23.—Conceptualization of the head-controlled flux (HCF) condition, as applied to boundaries of the quasi-three-dimensional model.
Therefore

\[ \frac{\partial^2 s}{\partial x^2} - \lambda s = 0, \]  

(8)

where

\[ s = \text{PHI}_x - \text{HSS}, \text{ and} \]

\[ \lambda = \frac{TK}{T}. \]

Verruijt (1970, p. 30) showed the solution to be of the form:

\[ s = c_1 e^{x/\sqrt{\lambda}} + c_2 e^{-x/\sqrt{\lambda}}. \]  

(9)

Boundary conditions are

\[ s = \text{PHI} - \text{HSS} = s_0 \text{ at } x = 0, \text{ and} \]

\[ s = 0 \text{ at } x = L. \]

Therefore

\[ s_0 = c_1 e^0 + c_2 e^{-0} = c_1 + c_2, \]  

(10)

\[ 0 = c_1 e^{L/\sqrt{\lambda}} + c_2 e^{-L/\sqrt{\lambda}}. \]  

(11)

Solving 10 and 11 simultaneously for \( c_1 \) and \( c_2 \)

\[ c_1 = \frac{-s_0 e^{-2L/\sqrt{\lambda}}}{(1-e^{-2L/\sqrt{\lambda}})}, \]  

(12)

\[ c_2 = \frac{s_0}{(1-e^{-2L/\sqrt{\lambda}})}, \]  

(13)

and

\[ s = s_0 \frac{e^{x/\sqrt{\lambda}} - e^{(x-2L)/\sqrt{\lambda}}}{1 - e^{-2L/\sqrt{\lambda}}}. \]  

(14)
If equation 8 is solved for s, then Darcy's law may be applied at the model-grid boundary (x = 0) to solve for lateral boundary flux, XHCF:

\[
XHCF_0 = -\left. \frac{\partial s}{\partial x} \right|_{x=0} = -T \left. \frac{-\sqrt{\lambda} e^{-x\sqrt{\lambda}} - \sqrt{\lambda} e^{(x-2L)\sqrt{\lambda}}}{(1 - e^{-2L\sqrt{\lambda}})} \right|_{x=0}
\]

\[
= -T s_0 \left( \frac{-\sqrt{\lambda} - \sqrt{\lambda} e^{-2L\sqrt{\lambda}}}{(1 - e^{-2L\sqrt{\lambda}})} \right)
\]

\[
= -T s_0 \left( \frac{\sqrt{\lambda} (1 + e^{-2L\sqrt{\lambda}})}{(1 - e^{-2L\sqrt{\lambda}})} \right)
\]

\[
= -T s_0 \left( \frac{\sqrt{\lambda} (1 + e^{-2L\sqrt{\lambda}})}{(1 - e^{-2L\sqrt{\lambda}})} \right)
\]

\[
XHCF_0 = -CSSs_0 = -CSS (HSS - PHI).
\]

Inflow to the model area is \(-XHCF_0\), or \(CSS(HSS-PHI)\). XHCF is the volumetric flow per unit width and this must be multiplied by the grid-block width (DELY, in fig. 23) to obtain the horizontal volumetric flow rate Q across the grid face:

\[
Q = -XHCF_0 \cdot DELY.
\]

This volume of water is distributed in the model as vertical leakage over the HCF grid block by dividing Q by the grid-block area:

\[
XHCF = \frac{-XHCF_0 \cdot DELY}{DELY \cdot DELX}
\]

XHCF is really only normalized to be consistent dimensionally with the other fluxes computed by the model. The true flux is the quotient of Q and the grid face area (DELY \cdot b). The grid-block area is used as the divisor instead because DELX \cdot DELY is used as a multiplier in the CHECKI subroutine to convert all fluxes to volumetric flow rates.

Substituting equation 19 for XHCF results in the equation:

\[
XHCF = (HSS - PHI) \cdot \frac{T\sqrt{\lambda}}{DELY} \cdot \frac{(1 + e^{-2L\sqrt{\lambda}})}{(1 - e^{-2L\sqrt{\lambda}})}
\]

which is the product of the head difference in the boundary grid block (HSS-PHI) and the HCF condition leakage factor, CSS, described earlier in equation 3. The resulting function for boundary flux:
is a form of equation 4 and is listed several times in the SOLVE and CHECKI subroutines of the program code in Attachment A. CSS is the HCF condition leakage factor comprising transmissivity, leakance, length of the aquifer strip outside the model-grid boundary, and length of HCF grid block parallel to the boundary flux (see equation 3).

Equation 24 is a generalized expression for discharge as a function of head—hence the name "head-controlled flux." It is generalized in the sense that the constant CSS will be different for other system conceptualizations. For example, if the aquifer beyond the model-grid boundary were not leaky, CSS would be different, but equation 24 would still be valid.

The expression for lateral flux (XHCF) at a boundary is exactly analogous to vertical leakage; the constant CSS can be considered as a "leakance." This constant is added to the vertical leakage in the HCF grid block(s). With this increased vertical leakage, the amount of water flowing into or out of the HCF grid block is the sum of true vertical leakage and lateral flow at the edge.

Assumptions and Restrictions

An important assumption in using the HCF condition is that of uniform aquifer properties beyond the model-grid boundary. Transmissivity, vertical hydraulic conductivity of the confining bed, confining bed thickness, and so forth, are all considered to be uniform and equal to their respective values in the HCF grid blocks from which they derive. If the data support this assumption, then the HCF condition can be a fair approximation; however, if the data show a wide range of values or an irregular distribution of values, then the use of the HCF condition should be qualified.

A source of error in the HCF condition is in the estimation of flow across the model-grid boundary at the corners of the model area. Figure 24 indicates that there is a substantial area at each corner in which the amount of boundary flow caused by a head change is ignored.

Use

The programming changes and additions that are necessary to include the HCF condition in the Q-3-D model are listed in attachment A. The data-deck instructions listed in attachment B include instructions used to specify the HCF condition in a model run.

An HCF grid block is defined as a grid block on the edge of the model grid that has an outside edge perpendicular to the main direction of flow that will be caused by a change in head in the HCF grid block (fig. 24). In irregularly shaped grids, there may be many grid blocks that could be designated corner grid blocks (grid blocks with two edges corresponding to the model-grid boundary). To avoid overlapping of the aquifer strips extending out from each boundary grid.
Figure 24.—Well-fields area model with head-controlled flux (HCF) condition, showing HCF and corner grid blocks, areas of lost boundary flow, and orientation of aquifer strips (modified from Hutchinson and others, 1981).
block, the program changes outlined in attachments A and B require that the user designate only four of these possible corners as corner grid blocks. An additional requirement is that between two corner grid blocks, a boundary must be straight or convex with respect to the model area. Between two corner grid blocks, all the aquifer strips extend out in the same direction from the model-grid boundary. The model area in figure 24 is a typical case that conforms to the above requirements specified in the program changes in attachment A.

Flow rates at each HCF grid block may be printed out by removing the "C" from column 1 of card 11710 of the program code (attachment A). The total leakage that is due to lateral HCF flow into or out of the model-grid boundary nodes is included as leakage in the mass balance printout.

Finally, if the HCF condition is to be used in a steady-state calibration, the water levels in the grid blocks adjacent to the HCF grid blocks and just across the boundary from them must be included in the STRT matrix. The transmissivities in these grid blocks must be zero, however, since they are beyond the model-grid boundary.

Evapotranspiration-Runoff Capture

Evapotranspiration (ET) from the water table and runoff (RO) captured by lowering the water table are modeled together as a head-dependent outflow function. Coding changes for incorporating ET-runoff into the model (Trescott, 1975) were described by J. V. Tracy and S. P. Larson (written commun., in an advanced modeling seminar at the U.S. Geological Survey Training Center in Denver, Colo. The mathematical form of the equation for determining the volumetric ET-runoff rate in the model is equivalent to equation 24:

\[ \text{ETFLUX} = \text{CSS} \cdot (\text{HSS} - \text{PHI}) \]

where
- \( \text{ETFLUX} \) = ET-runoff flux (feet per second);
- \( \text{CSS} \) = maximum ET-runoff rate (per unit area) divided by maximum depth at which ET-runoff capture occurs (feet per second per foot);
- \( \text{HSS} \) = altitude of the base of the ET-runoff capture zone (feet);
- \( \text{PHI} \) = altitude of the water table (feet).

Corrections to the computed ET-runoff flux must be made under two conditions:
1. The water table lies below the base of the ET-runoff capture zone--ET-runoff would become positive, representing inflow to the system.
2. The water table rises above land surface--ET-runoff would exceed the potential ET-runoff capture rate, representing excessive outflow from the system.

Program modifications were made to check for and correct these special cases. This was accomplished by first computing a total ET-runoff flux using equation 25. Then a check was made for conditions 1 and 2 above. The total ET-runoff flux was then adjusted by subtracting the extra inflow or adding back the excessive outflow. Thus, the same arrays are utilized in the model to compute head-controlled flux across the perimeter of the modeled area in the Floridan aquifer (layer 1) and ET-runoff flux from the surface of the water table in the surficial aquifer (layer 2).
Parameter Maps

The original computer program of Trescott (1975) produced maps of head and drawdown and listed input parameters in tabular form. To expedite the calibration procedure, C. H. Tibbals (U.S. Geological Survey, written commun., 1981) modified the program to produce maps of transmissivity and leakage. This modification was expanded upon for the well-field areas model so that the program would produce additional maps of head difference between the water table and potentiometric surface, recharge rate to the water table, ET-runoff rate from the water table, leakage rate through the upper confining bed, and the distribution of pumpage.

The parameter maps provide a useful tool for assessing predictive model runs and simplifying the calibration procedure. For example, under predicted pumping conditions, areas of greatest change in ET-runoff, leakage, and reversal of head can be easily detected. The map of pumpage distribution allows correlation of pumping centers with the other parameter maps and helps locate errors in pumping rates input to the model for predictive runs.

Contour Mapping

A program modification that proved useful during the modeling process was the ability to punch drawdown and hydraulic head in the format used by the CALCOMP (California Computer Products, 1971) contouring program. All contoured illustrations in this report were traced from machine-drawn maps produced by the CALCOMP contouring program.

To punch the model output in CALCOMP format, cards 6290 and 6500 of the program are activated manually. The punched cards are then combined with control cards described in the CALCOMP manual (1971) and submitted as a separate program to the Survey's computer. Contour maps output from the CALCOMP contouring program are displayed on a Tektronix 4014-1 terminal at the U.S. Geological Survey Tampa Subdistrict Office. The output was written to magnetic tape for processing on a flat-bed plotter that draws contours on translucent paper to overlay base maps of any scale.

SAS/GRAPH, a program published by the SAS Institute, Inc. (1980), was used to portray three-dimensional graphical representations of the water table and potentiometric surface under predevelopment and pumping conditions (attachment E). The procedure for 3-D plotting is the same as that for the CALCOMP plots. The 3-D plots exhibit depth perspective that cannot be perceived from contour maps.

Iteration Parameters

The strongly implicit procedure (SIP) utilizes an iterative scheme to solve the flow matrix in the model. In this approach, a modifying matrix is added to the flow matrix thereby simplifying factorization. The iterative technique results in considerable savings in computer time and storage over the method of Gaussian elimination (Trescott, 1975, p. 12).
The original version of the model cycles a sequence of iteration parameters ranging from zero to 1 until convergence is achieved. The minimum parameter is not critical and zero is normally chosen. Trescott (1975, p. 25) recommends that,

"if the sequence of parameters computed by the equations in the program are all (except the first parameter) close to 1.0 and if this results in slow convergence or even divergence, bypass the computations in the model and insert WMAX = 0.99863."

For expediency in the well-fields model, line 7430 was inserted to override computation of the maximum iteration parameter, setting it equal to the value recommended by Trescott.

Convergence may be achieved more rapidly by multiplying the finite-difference residual by an acceleration parameter, BETA, based on test results of Trescott and others (1976, p. 27) that emphasize the advantages of this extra SIP iteration parameter. BETA was introduced as a multiplier in lines 8300, 8430, 9210, and 9340 of the computer program. In the early stages of the well-field model development, several values were chosen for BETA based on an optimum range of 0.1 to 1.5 inferred by Trescott and others (1976). Early test runs indicated that this model is relatively insensitive to BETA values near 1.0, so it was held constant at unity during the calibration, validation, and prediction phases of the modeling process.

SUMMARY AND CONCLUSIONS

Ten well fields north of Tampa are proposed or are currently supplying the city of Tampa and Gulf Coast municipalities with freshwater. A Q-3-D model of ground-water flow was developed to gain a better understanding of the hydrology and to facilitate water-resources planning and management. This report describes development of the Q-3-D model and its application in assessment of the impact of existing and proposed well fields. The study was preceded by a phase 1 two-dimensional model, used for planning and management during development of the more complex phase 2 model.

The Q-3-D model accounts for inflow to and outflow from two aquifers (surficial and Floridan) separated by a leaky confining bed. Water pumped from the Floridan aquifer at a well field at steady state is supplied by reducing outflow or increasing inflow laterally across the model boundary and by reducing upward leakage or increasing downward leakage through the overlying confining bed. Changes in the amount of vertical leakage induce declines in the water table of the surficial aquifer. Lowering the water table reduces the supply of water available for evapotranspiration by surface vegetation, reduces base streamflow and storm runoff, and increases the aquifer's capacity for accepting recharge. Ultimately, the source of the pumped water is by capture of water that would normally be subject to evapotranspiration or runoff. Thus, the model may be used to assess the effects of pumping one well field, or the interference effects of pumping multiple well fields, on drawdown in the aquifers, changes in leakage, ET-runoff, and lateral flow.
The Q-3-D model has advantages over the 2-D model in that the upper layer (surficial aquifer) is active and the water table may vary. Because the water table in the 2-D model was held constant, drawdown in the Floridan aquifer was minimized. The Q-3-D model more accurately simulates the physical system by allowing movement of the water table, thereby minimizing leakage changes and maximizing drawdowns.

Example model-interrogation runs simulate water-level and water-balance changes that can be expected as a result of pumping all 10 well fields simultaneously at annual average permitted rates totaling 186.9 Mgal/d from the Floridan aquifer with recharge varying 20 percent more and less than the long-term average rate. Under these conditions, water-level and water-balance changes with respect to nonpumping conditions should be as follows:

1. Under high recharge conditions, the water table should decline an average of 1.0 foot, and the potentiometric surface should decline an average of 2.5 feet. If average recharge increases from 25 to 30 inches per year, downward leakage should increase from 6.7 to 10.1 inches per year, and ET-runoff from the water table should increase from 20.3 to 20.8 inches per year.

2. Under average recharge conditions, the water table should decline an average of 1.3 feet, and the potentiometric surface should decline an average of 3.6 feet. If recharge remains at 25 inches per year, downward leakage should increase from 6.7 to 9.8 inches per year, and ET-runoff should decrease from 20.3 to 16.2 inches per year.

3. Under low recharge conditions, the water table should decline an average of 3.2 feet, and the potentiometric surface should decline an average of 5.0 feet. If recharge is reduced from 25 to 20 inches per year, downward leakage should increase from 6.7 to 9.4 inches per year, and ET-runoff should decrease from 20.3 to 11.7 inches per year.

Maximum drawdown in the Floridan aquifer simulated by the Q-3-D model is greater in every well field and averages about 4 feet more than maximum drawdown simulated by the 2-D model previously developed for the area. Under average recharge conditions, about 75 percent of the pumped water is derived by increasing downward leakage. The remaining 25 percent is gained by reducing natural upward leakage in swamp and marsh areas and by slightly reducing outflow along the model boundary. Ultimately, more than 95 percent of the pumped water is derived by reducing evapotranspiration from the water table and runoff.

When well fields are pumped individually, drawdown in the potentiometric surface is less than when all 10 well fields are pumped simultaneously. Drawdown is much greater in the center of the modeled area where well fields are in close proximity to one another, thus increasing interference effects. Interference effects range from about 0.1 foot of additional drawdown at Morris Bridge well field to 6.1 feet of additional drawdown at Northwest well field.

Conclusions drawn from this modeling study concerning hydrology of the aquifer system and impact of pumping include:

1. Transmissivity of the Floridan aquifer ranges from about 26,000 to 475,000 ft²/d.
2. Leakance coefficient of the upper confining bed ranges from about 0.00015 to 0.008 (ft/d)/ft.

3. Recharge rate to the surficial aquifer ranges from near zero in the coastal marsh and central swamp physiographic units to 30 inches per year in the lakes terrace physiographic unit.

4. Evapotranspiration plus runoff from the water table in the surficial aquifer ranges from zero in some ridge areas where the water table is deep to 38 inches per year in some swampy areas where the water table lies at land surface and is maintained by upward leakage from the Floridan aquifer.

5. The annual water balance for the surficial aquifer, representing long-term average hydrologic conditions prior to pumping, equates inflow and outflow as:

\[
\text{Recharge} + \text{Upward leakage} = \text{Evapotranspiration plus runoff} + \text{Downward leakage from water table}
\]

\[
25.1 \text{ inches} + 1.6 \text{ inches} = 20.3 \text{ inches} + 6.4 \text{ inches}
\]

6. The annual water balance for the Floridan aquifer equates inflow and outflow as:

\[
\text{Downward leakage} + \text{Boundary inflow} = \text{Upward leakage} + \text{Boundary outflow}
\]

\[
6.7 \text{ inches} + 1.1 \text{ inches} = 1.6 \text{ inches} + 6.2 \text{ inches}
\]

7. Nearly all of the water pumped from the Floridan aquifer is derived by increasing leakage.

8. Pumpage from the Floridan aquifer is ultimately derived by capturing water that would normally be subject to evapotranspiration or runoff.

9. Well-field interference significantly increases drawdown at the Starkey, Pasco County, Eldrige-Wilde, East Lake, Cosme, Section 21, and Northwest well fields, which are in close proximity to one another.

10. Concentrated pumping from the Floridan aquifer develops extensive cones of depression in the potentiometric surface and the water table.

11. Possible adverse impacts of pumping from the municipal well fields include upconing of deep saline water, saltwater encroachment along the coast, interference with existing private wells, lowering lake levels, inducing sinkhole collapse, and alteration of vegetal cover.

   The well-field areas model results could be improved by increasing the accuracy of the input data. Additional data are needed to define the distribution of potential evapotranspiration and how it varies with depth. An evaluation of recharge potential based on soil type, topography, and depth to water table would allow the model to be programmed so that recharge varies in response to water-table fluctuations. The model could then forecast the decline in recharge as the water table rises to land surface, or conversely, the increase in recharge over former swampy areas that go dry.

The Q-3-D model has been developed for regional assessment of environmental impact and management of the ground-water reservoir to avoid potentially large
drawdowns. The model can also aid water resources managers, hydrologists, and the general public in the following:

1. Regulating drawdowns;
2. Evaluating well permits;
3. Considering economic constraints of power consumption and well spacing;
4. Assessing the potential for saltwater intrusion;
5. Assessing the potential impact of well-field development on lake levels;
6. Siting water-level and water-quality monitoring wells;
7. Relating water-table fluctuations to changes in vegetation; and
8. Designing aquifer tests.

Although the guidelines presented here are general, they provide a framework for the effective utilization of the model. The decisionmaker should be able to understand the model, recognize its limitations and predictive capabilities, and make knowledgeable evaluations of its output.
REFERENCES


Leggette, Brashears, and Graham, Inc., 1979, Development, and testing program—phase II, Cross Bar Ranch well field, Pasco County, Florida, evaluation and effects of the hydrologic properties in the northwestern portion of the well field: West Coast Regional Water Supply Authority, 8 p.


Seaburn and Robertson, Inc., 1977, Cypress Creek operation and management plan, phase II, interim plan development: Southwest Florida Water Management District, Pinellas-Anclote River Basin Board, Hillsborough River Basin Board, 246 p.


ATTACHMENT A: COMPUTER PROGRAM LISTING

The generic FORTRAN program by Trescott (1975) for simulating three-dimensional ground-water flow has been modified to a 1,576-card program. Major coding changes were made in the "SOLVE" subroutine to accommodate the HCF condition, ET-runoff capture, and iteration parameters. The "CHECKI" subroutine was modified to incorporate ET-runoff and boundary flux in the mass balance and to compute statistics. The "PRINTAI" subroutine was modified to produce parameter maps.
ATTACHMENT A: COMPUTER PROGRAM LISTING (modified from Trescott, 1975)

--- SPECIFICATIONS ---
REAL *8YSTR
DIMENSION YC52000)
9/4)/ DUM(3)
EQUIVALENCE (YSTR/YC1))
L(25)/ HEADNGC33)/ NAMEC42)/ INFTC2/2)/
-00000010
00000020
00000030
00000040
00000050
00000060
00000070
00000080
00000090
19/4)/ DUM(3)
REAL *8YSTR
DIMENSION YC52000)
9/4)/ DUM(3)
EQUIVALENCE (YSTR/YC1))
L(25)/ HEADNGC33)/ NAMEC42)/ INFTC2/2)/
-00000010
00000020
00000030
00000040
00000050
00000060
00000070
00000080
00000090
19/4)/ DUM(3)
COMMON /INTEGR/ IO/KO/I1/J1/K1/JK/NPER/KTH/ITMAX/LENGTH/KP
COMMON /SPARAM/ TMAX/CDLT/DELT/ERR/TEST/SUM/SUMP/QR
COMMON /SARRAY/ ICHK(14)/LEVEL1(4)/LEVEL2(4)/LEVEL3(4)/LEVEL4(4)/LEVEL5(4)/LEVEL6(4)/LEVEL7(4)/
DATA NAME/2*4H /4H S/4HTART/4HING /4HHEAD/4H /4H STO/4HRAG0.00000180
1E-4/4H COE/4HFFIC/4HIENT/2*4H /4H TR/4HANSM/4HMISSI/4HVITY /4H 0.00000190
2 /4H TK/4H HY/4HDRAU/4HLIC /4HCOND/4HUCTI/4HVITY /4H 2*4H /4HBOT0.00000200
3 /4HOM E/4MLEVA/4HTION /4H 2*4H /4H 4H /4HHECHA/4HRGE /4HRATE/
DATA INFT/4H(20F/4H4.0)/4H(8F1/4H0.4)/
DATA IOFT/4H(1HO/4H/4H2/2/4H0F6. /4H1/(5./4H4X/20./4HF6.1/4H))/
14/4H /4H(1HO/4H/I5/4H14F9/4H4.5/4H4H1H/4H5/4H4X/1/4H4F9/4H5)/
2 /4H(1HO/4H/I5/4H10E1/4H4H2.5/4H4H5/4X/4H10E1/4H4H2.5)/
3 /4H(1HO/4H/I5/4H10E1/4H4H1.3/4H4H5/4X/4H10E1/4H4H1.3)/
DEFINE FILE 2(200/1200/U/KKK),3(150/U/KKK),4(124/U/KKK),8(31/U/KKK)/
1KKK/93.1200/U/KKK)
--- READ TITLE, PROGRAM SIZE AND OPTIONS ---
READ (5,200) HEADNG
WRITE (6,190) HEADNG
READ (5,160) IO/KO/I0/ITMAX/NCH
WRITE (6,150) IO/KO/I0/ITMAX/NCH
READ (5,210) IDRAW/IHEAD/IFLO/IDK1/IDK2/IWATER/IQRE/IPU1/IPU2/ITK
1/IEQN
WRITE (6,220) IDRAW/IHEAD/IFLO/IDK1/IDK2/IWATER/IQRE/IPU1/IPU2/ITK
1/IEQN
IERR=0
--- COMPUTE DIMENSIONS FOR ARRAYS ---
J1=JO-1
I1=IO-1
K1=KO-1
I2=IO-2
J2=JO-2
K2=KO-2
IMAX=MAXO(IO/JC)
NCD=MAXO(1,NCH)
ITMX1=ITMAX+1
ISIZ=IO*JO*KO
IK1=IO*JO
IK2=MAXO(IK1*K1,1)
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 (IWARN.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
**MAIN**

50 L(25)=ISUM
IF (IQRE.NE.HCHK(7)) GO TO 60
ISUM=ISUM+ISIZ
IQ=IO
JQ=JO
KQ=KO
GO TO 70
60 ISUM=ISUM+1
IQ=1
JQ=1
KQ=1
70 LCSM=ISUM
ISUM=ISUM+ISIZ
LHSS=ISUM
ISUM=ISUM+ISIZ
LHIB=ISUM
ISUM=ISUM+ISIZ
LETRAT=ISUM
ISUM=ISUM+ISIZ
WRITE (6,170) ISUM
C   PASS INITIAL ADDRESSES OF ARRAYS TO SUBROUTINES---
CALL DATAI(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7))),YCL(8),Y(LC9),Y(L(15)),Y(L(16)),Y(L(17)),Y(LC19),Y(L(23)),Y(L(25)))
CALL STEP(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(18)),Y(L(20)),Y(L(25)))
CALL SOLVE(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(18)),Y(L(20)),Y(L(25)),Y(LH),Y(LCSS),Y(LHSS),Y(LH3))
CALL COE(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(18)),Y(L(20)),Y(L(25)))
CALL CHECKY(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(18)),Y(L(20)),Y(L(25)),Y(LCSS),Y(LHSS),Y(LHIB),Y(LETRAT))
CALL PRNTAI(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),Y(L(8)),Y(LETRAT))
C   START COMPUTATIONS---
C   READ AND WRITE DATA FOR GROUPS II AND III---
CALL DATAIN
C   READ AND WRITE DATA FOR GROUPS II AND III---
C   READ AND WRITE DATA FOR GROUPS II AND III---
MAIN

LOC=L(4)+(K-1)*NIJ
L1=L(19)+K-1
L2=L(19)+K0+K-1
L3=L(19)+2*K0+K-1
CALL ARRAY(Y(LOC),INFT(1,1),IOFT(1,2),NAME(13),IRN,DUM)
Y(L1)=DUM(1)
Y(L2)=DUM(2)
Y(L3)=DUM(3)

100 WRITE (6,230) K,Y(L1),Y(L2),Y(L3)
   IF (ITK.NE.ICHK(10)) GO TO 120
   DO 110 K=1,K1
      LOC=L(8)+(K-1)*NIJ
      CALL ARRAY(Y(LOC),INFT(1,1),IOFT(1,1),NAME(19),IRN,DUM)
      IF (IWATER.NE.ICR(IK)) GO TO 130
      CALL ARRAY(Y(L(23)),INFT(1,1),IOFT(1,4),NAME(25),IRN,DUM)
      CALL ARRAY(Y(L(24)),INFT(1,1),IOFT(1,1),NAME(31),IRN,DUM)
   130 IF (IQRE.NE.ICHK(7)) GO TO 132
   DO 131 K=1,K0
      LOC=LCSS+(K-1)*NIJ
      CALL ARRAY(Y(LOC),INFT(1,1),IOFT(1,4),NAME(37),IRN,DUM)
      CALL MDAT
      COMPUTE
      CALL TCOF
      COMPUTE
      CALL ITER
      READ TIME
      140 CALL NEWPER
      KT=0
      IFINAL=0
      CALL NEWSTP
      IF (IFINAL.NE.1) GO TO 150

C ---COMPUTE TRANSMISSIVITY FOR UNCONFINED LAYER---
   IF (IWATER.EQ.ICHK(6)) CALL TRANS(1)
C ---COMPUTE T COEFFICIENTS---
   CALL TCOF
C ---COMPUTE ITERATION PARAMETERS---
   CALL ITER
C ---READ TIME PARAMETERS AND PUMPING DATA FOR A NEW PUMPING PERIOD---
140 CALL NEWPER
   KT=0
   IFINAL=0
C ---START NEW TIME STEP COMPUTATIONS---
150 CALL NEWSTP
C ---START NEW ITERATION IF MAXIMUM NO. ITERATIONS NOT EXCEEDED---
   CALL NEWITA
C ---PRINT OUTPUT AT DESIGNATED TIME STEPS---
   CALL OUTPUT
C ---LAST TIME STEP IN PUMPING PERIOD ?---
   IF (IFINAL.NE.1) GO TO 150

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MAIN

C ---CHECK FOR NEW PUMPING PERIOD---
IF (KP.LT.NPER) GO TO 140
STOP
C

---FORMATS---
160 FORMAT (8I10)
170 FORMAT ('0',54X,'WORDS OF VECTOR Y USED =',I7)
190 FORMAT ('1',33A4)
200 FORMAT (20A4)
210 FORMAT (16(A4,1X))
220 FORMAT ('-SIMULATION OPTIONS: ',13(A4,4X))
230 FORMAT (1HO,44X,'DIRECTIONAL TRANSMISSIVITY MULTIPLICATION FACTORS000021701 FOR LAYER',I3/76X,'X =',G15.7/76X,'Y =',G15.7/76X,'Z =',G15.7)

C SPECIFICATIONS:
REAL *8PHI
REAL *8XLABEL/YLABEL/TITLE/XN1/MESUR
DIMENSION PHI(IO,J0/K0),STRT(IO,J0/K0),OLD(IO,J0/K0),T(IO,J0/K0),SC(IO,J0/K0),TRC(IO,J0/K0),TC(IO,J0/K0),TK(IK/JK/K5),WELL(IO,J0/K0),3TOT(IP,JP),QRE(IQ,JQ/KQ),TF(3),A(IO,J0),IN(6),IOFT(9),INFT(20002310)
4),IWELLO(10)
COMMON /INTEGR/IO,J0/K0,J1/K1,J1/K,J,K,NPER/KTH/ITMAX/LENGTH/CP/N00002320
1WEI/NUMT/IFINAL/IT/K/ITHEAD/IDRAW/I2/I2/K2/ITMAX/ITMX1/N00002340
COMMON /SPARAM/ TMAX/CDLT/DELT/ERR/TEST/SUM/SUMP/QR
COMMON /SARRAY/ICHK(14),LEVEL1(I),LEVEL2(I),LEVEL3(I),LEVEL4(I),LEVEL5(I),LEVEL6(I),LEVEL7(I)
COMMON /CK/ETFLXT/STORT/QRET/CHST/CHDT/FLUXT/PUMPT/CFLUXT/FLXNT
COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1/MESUR,PRNT(122),BLANK60/60/DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE/DINCH/SYM(17),XN(100),00002410
3ACT7
COMMON /B/ BETA
RETURN
C ****************************
C ********************
ENTRY DATAIN
C ********************
C  READ AND WRITE SCALAR PARAMETERS---
READ (5,330) NPER,KTH,ERR,LENGTH,BETA
WRITE (6,340) NPER,KTH,ERR
WRITE(6,346) BETA
READ (5,460) X SCALE/Y SCALE/DINCH/FACT1/(LEVEL1(I),I=1,4)/FACT2/(LEVEL2(I),I=1,4)/FACT3/(LEVEL3(I),I=1,4)/FACT4/(LEVEL4(I),I=1,4)/FACT5/(LEVEL5(I),I=1,4)/FACT6/(LEVEL6(I),I=1,4)/FACT7/(LEVEL7(I),I=1,4)/MESUR
C  READ CUMULATIVE MASS BALANCE PARAMETERS---
READ (5,450) SUMSUMP/PUMPT/CFLUXT/QRET/CHST/CHDT/FLUXT/STORT/ETFLXNT
1XT/FLXNT
IF (IPU1.EQ.ICKH(8)) GO TO 50
IF (IPU1.NE.ICKH(8)) GO TO 50
C  ---READ INITIAL HEAD VALUES FROM CARDS---

DATA1

DO 10 K=1,K0
DO 10 I=1,IO
10 READ (5,360) (PHI(I,J,K),J=1,JO)
GO TO 30
C ---READ INITIAL HEAD AND MASS BALANCE PARAMETERS FROM DISK---
20 READ (4) PHI,SUM,SUMP,PUPT,CFLXT,GRET,CHST,CHDT,FLUXT,STORT,ETF
   1XT,FLXNT
   00002730
RENDAR 4
30 WRITE (6,430) SUM
   00002750
   DO 40 K=1,K0
   WRITE (6,440) K
   DO 40 I=1,IO
40 WRITE (6,350) I,(PHI(I,J,K),J=1,JO)
50 DO 60 K=1,K0
   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.K0) TK(I,J,K)=0.
60 CONTINUE
   00002870
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 ***********************
DATAI

NCHCK=0
DO 150 K=1/K0
   DO 150 I=1/I0
   DO 150 J=1/J0
      IF (I.EQ.1.0 .OR. I.EQ.IO OR J.EQ.1.0 .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 (IWATER .EQ. ICHK(6) .AND. K .EQ. K0) GO TO 147
      IF (T(I/J/K) .EQ. 0. .OR. S(I/J/K) .GE. 0) GO TO 147
      NCHCK=NCHCK+1
   CONTINUE
   150 CONTINUE
      IF(NCHCK.EQ.NCH)GO TO 152
      WRITE(6/475)NCHCK/NCH
      DELX
      IRN3=1
      READ (5/330) FAC/IPRV/IPRN/TF/IRECS/IRECD
      IF(IRECS.EQ.1) READ(3/IRN3) DELX
      IF(IRECS.EQ.1) GOTO 171
      IF (IVAR.EQ.1) READ (5/330) (DELX(J),J=1/J0)
      DO 170 J=1/J0
         IF (IVAR.NE.1) GO TO 160
         DELX(J)=DELX(J)*FAC
         GO TO 170
      CONTINUE
      152 IRN3=1
      WRITE(3/IRN3)
      IF (IVAR .EQ. 1 .AND. IPRN .NE. 1) WRITE (6/340) FAC
      IF (IVAR .EQ. 0 .AND. IPRN .NE. 1) WRITE (6/310)
      C
      DELX
      DELY
      DELZ
      IRN4=1
      READ (5/330) FAC/IPRV/IPRN/TF/IRECS/IRECD
      IF(IRECS.EQ.1) READ(4/IRN4) DELY
      IF(IRECS.EQ.1) GOTO 191
      IF (IVAR.EQ.1) READ (5/330) (DELY(I),I=1/I0)
      DO 190 I=1/I0
         IF (IVAR .NE. 1) GO TO 180
         DELY(I)=DELY(I)*FAC
         GO TO 190
      CONTINUE
      170 CONTINUE
      171 IF(IRECD.EQ.1) WRITE(4/IRN4) DELY
      IF (IVAR .EQ. 1 .AND. IPRN .NE. 1) WRITE (6/380) (DELY(I),I=1/I0)
      IF (IVAR .EQ. 0) WRITE (6/310) FAC
      C
      DELY
      IRN8=1
      READ (5/330) FAC/IPRV/IPRN/TF/IRECS/IRECD
      IF(IRECS.EQ.1) READ(8/IRN8) DELZ
      IF(IRECS.EQ.1) GOTO 211
      IF (IVAR.EQ.1) READ (5/330) (DELZ(K),K=1/KO)
      00003190
      00003200
      00003210
      00003220
      00003230
      00003240
      00003250
      00003260
      00003270
      00003280
      00003290
      00003300
      00003310
      00003320
      00003330
      00003340
      00003350
      00003360
      00003370
      00003380
      00003390
      00003400
      00003410
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      00003580
      00003590
      00003600
      00003610
      00003620
      00003630
      00003640
      00003650
      00003660
      00003670
      00003680
      00003690
      00003700

72
DATAI

DO 210 K=1/K0
   IF (IRECD.EQ.1) WRITE(6,IRN8) DELZ
   IRN8=IRN8+1
   IF (IVAR.NE.1) GO TO 200
   DELZ(K)=DELZ(K)*FAC
   GO TO 210
200 DELZ(K)=FAC
   CONTINUE
   IF (IVAR.EQ.1.AND.IPRN.NE.1) WRITE (6,390) (DELZ(K),K=1,K0)
   IF (IVAR.EQ.0) WRITE (6,320) FAC
C    ---INITIALIZE VARIABLES---
   B=0.
   D=0.
   F=0.
   H=0.
   SU=0.
   Z=0.
   IF (XSCALE.NE.0.) CALL MAP
   RETURN

C    ************************************************************
C    ---READ TIME PARAMETERS AND PUMPING DATA FOR A NEW PUMPING PERIOD---
C    **************
C    ENTRY NEWPER
C    **************
   IRN9=1
   READ (5,330) KP,KPM1,NWEL,TMAX,NUMT,CDLT,DELT
   C    ---COMPUTE ACTUAL DELT AND NUMT---
   DT=DELT/24.
   TM=0.0
   DO 220 I=1,NUMT
      DT=CDLT*DT
      TM=TM+DT
   220 CONTINUE
   IF (TM.GE.TMAX) GO TO 230
   CONTINUE
   GO TO 240
230 DELT=TMAX/TM*DELT
   NUMT=I
   WRITE (6,400) KP,TMAX,NUMT,DELT,CDLT
   DELT=DELT*3600.
   TMAX=TMAX*36400.
   SUMP=0.0
   WRITE (6,410) NWEL
   C    ---READ AND WRITE WELL PUMPING RATES---
   WRITE (6,410) NWEL
   IF (NWEL.EQ.0) GO TO 260
   IF (SUMP.EQ.0.0) GO TO 241
   DO 246 K=1/K0
      READ(5,330) FAC,IVAR,IPRN,TF,IRECS,IRECD
      IF (IRECS.EQ.1) READ(9,IRN9) A
      IF (IRECS.EQ.1) GOTO 242
      IF (IVAR.EQ.0) GO TO 244
      DO 247 I=1,IO
         READ(5,331)(A(I,J),J=1,JO)
   247 CONTINUE
   246 CONTINUE
   244 CONTINUE
   242 CONTINUE
   241 CONTINUE
   230 CONTINUE
   220 CONTINUE
   210 CONTINUE
   200 CONTINUE
   190 CONTINUE
   180 CONTINUE
   170 CONTINUE
   160 CONTINUE
   150 CONTINUE
   140 CONTINUE
   130 CONTINUE
   120 CONTINUE
   110 CONTINUE
   100 CONTINUE
   90 CONTINUE
   80 CONTINUE
   70 CONTINUE
   60 CONTINUE
   50 CONTINUE
   40 CONTINUE
   30 CONTINUE
   20 CONTINUE
   10 CONTINUE
   0 CONTINUE
DATAI

DO 248 I=1/10
DO 248 J=1/JO
A(I,J)=A(I,J)*FAC
248 CONTINUE
GO TO 242

DO 249 I=1/10
DO 249 J=1/JO
WELL(I,J,K)=A(I,J)/(DELX(J)*DELY(I))
249 CONTINUE

DO 250 II=1/NWEL
READ (5,335) K,I,J,WELL(I,J,K),(IWELLO(KK),KK=1/10)
WELMGR=WELL(I,J,K)*646317
WRITE (6,420) K,I,J,WELL(I,J,K),WELMGR,(IWELLO(KK),KK=1/10)
250 CONTINUE

DO 260 RETURN
C

--- FORMATS ---

280 FORMAT (1HO/52X/6A4/"=",G15.7," FOR LAYER",I3)
290 FORMAT (1H/145X/6A4/" MATRIX",LAYER",I3/46X/41("="))
300 FORMAT ("O",72X,"DELX =",G15.7)
310 FORMAT ("O",72X,"DELY =",G15.7)
320 FORMAT ("O",72X,"DELZ =",G15.7)
330 FORMAT (8G10.4)
331 FORMAT (20F4.1)
332 FORMAT ("I2,10F8.1")
333 FORMAT ("0",72X,"PUMPING IN LAYER",2X/I2,2X,"="/G15.7)
335 FORMAT (4G10.0,10A4)
346 FORMAT ("O",72X,"BETA= ",F4.2)
350 FORMAT ("O",I2,2X,20F6.1/(5X,20F6.1))
360 FORMAT (8F10.4)
370 FORMAT (IH/146X/40HGRID SPACING IN PROTOTYPE IN X DIRECTION/47X,40000004690
1("=")/"(C",12F10.0))
380 FORMAT (IH/146X/40HGRID SPACING IN PROTOTYPE IN Y DIRECTION/47X,40000004710
1("=")/"(C",12F10.0))
390 FORMAT (IH/146X/40HGRID SPACING IN PROTOTYPE IN Z DIRECTION/47X,40000004730
1("=")/"(C",12F10.0))

00004230
00004240
00004250
00004260
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00004670
00004680
00004690
00004700
00004710
00004720
00004730
00004740
DATAI

400 FORMAT ("="/50X,"PUMPING PERIOD NO."/I4/":"F10.2/" DAYS"/51X,38(’00004750
1-")/53X,"NUMBER OF TIME STEPS="/I6/"F10.3/"
253X,"DELT IN HOURS =",F10.3)
18X,"CFS",10X,"MGD")
420 FORMAT (31X,3I10/2F13.2/10A4)
430 FORMAT ("="/40X,"CONTINUATION - HEAD AFTER "/G20.7/" SEC PUMPING")
440 FORMAT ("="/55X,"INITIAL HEAD MATRIX/ LAYER",/I3/56X/30(’-‘))
450 FORMAT (4G20.10)
460 FORMAT (3G7.0/7(G3.0/411)/5X/A5)
470 FORMAT ("="/30X,"ON ALPHAMERIC MAP;"/40X,"MULTIPLICATION FACTOR FOR X DIMENSION")
  1X" X DIMENSION =",G15.7/40X,"MULTIPLICATION FACTOR FOR Y DIMENSION 00004870
  2="/G15.7/55X,"MAP SCALE IN UNITS OF",A12/49X,"NUMBER OF",A8,"P"
  3ER INCH =",G15.7/43X,"MULTIPLICATION FACTOR FOR DRAWDOWN =",G15.7/00004890
  4="/G15.7/55X,"MULTIPLICATION FACTOR FOR HEAD =",G00004900
  515.7,"PRINTED FOR LAYERS",4I2/47X,"MULTIPLICATION FACTOR FOR HEAD DIFFERENCE00004920
  6="/G15.7/55X,"MULTIPLICATION FACTOR FOR LEAKAGE =",G15.7/00004940
  7="/G15.7/55X,"MULTIPLICATION FACTOR FOR ET-RUNOFF =",G15.7/00004960
  8="/G15.7/55X,"MULTIPLICATION FACTOR FOR PUMPAGE =",G15.7/00004980
  9="/G15.7/55X,"MULTIPLICATION FACTOR FOR LEAKAGE =",G15.7/00005000
475 FORMAT(1H0,10X/11(1H+)//11X,9H WARNING /1H*/11X,11(1H+)//5X,00004990
28TH THE NUMBER OF CONSTANT HEAD NODES CODED IN AND THE NUMBER COMputed =,I5/11X,21HTHE NUM00004990
3UTED DO NOT AGREE: /I5/, 21HTHE NUMBER COMPUTED =,I5/11X,21HTHE NUM00004990
4BER CODED IN =,I5/2X,100(1H*)
   00005000
   00005010
1/0DN/TEST3) 00005030
C
C INITIALIZE DATA FOR A NEW TIME STEP AND PRINT RESULTS 00005040
C
C SPECIFICATIONS:
C
REAL *8PHI 00005050
REAL *8XLABEL/YLABEL/TITLE/XN1/MESUR 00005060
DIMENSION PHI(IO,JO,KO), STRT(IO,JO,KO), OLD(IO,JO,KO), T(IO,JO,KO), W(00005070
1), S(IO,JO,KO), TR(IO,JO,KO), TC(IO,JO,KO), TK(IK,JK,K5), WELL(IO,00005080
2JO,KO), DELX(IO), DELY(IO), DELZ(KO), FACT(KO,3), DDN(IMAX), TEST30000509
3(ITMX1), ITTO(50)
COMMON /INTEGR/ IO,JO,KO,11,1,J,IK,JK,NPER,KTH,ITMAX,LENGTH,KP,N00005100
WEL,NUMT,IFINAL,IT,KTH,ITMAX,Length,KP,N00005110
1,2H,JD1,JD2,JWATER,IP1,IP2,IT,IEQN,00005120
KQ0
COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR 00005130
COMMON /SARRAY/ ICHKC1,LEVEL1(4),LEVEL2(4),LEVEL3(4),LEVEL4(4),LEVEL5(4),LEVEL6(4),LEVEL7(4)00005140
COMMON /CK/ ETFLXT,STORT,QRET,CHST,CHDT,FLUNT,PUMPT,CFLXT,FLXNT00005150
COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANK00005160
1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),00005170
2YN(13),NA(4),N1,N2,N3,N4,N5,N6,N7,FACT1,FACT2,FACT3,FACT4,FACT5,FACT6,FACT7,00005180
IWELLO(10)
RETURN 00005190
ENTRY NEWSTP
C
C *********************
C
KT=KT+1
IT=0
DO 10 K=1,10
DO 10 I=1,JO
DO 10 J=1,JO
10 OLD(I,J,K)=PHI(I,J,K)
DELT=CDLT*DELT
SUM=SUM+DELT
SUMP=SUMP+DELT
DAYS=SUMP/86400.
YRSP=DAYS/365.
HRS=SUMP/3600.
SMIN=HRS*60.
DAYS=HRS/24.
YRS=DAYS/365.
RETURN 00005200
C
C ***PRINT OUTPUT AT DESIGNATED TIME STEPS***
C
ENTRY OUTPUT
RETURN 00005220
STEP

C ********************* 00005490
IF (KT.EQ.NUMT) IFINAL=1 00005500
ITTO(KT)=IT 00005510
IF (IT.LE.UMAX) GO TO 20 00005520
IT=IT-1 00005530
ITTO(KT)=IT 00005540
IERR=2 00005550
---IF MAXIMUM ITERATIONS EXCEEDED, WRITE RESULTS ON DISK OR CARDS--- 00005560
IF (IDK2.EQ.ICHK(5)) WRITE (4) PHI/SUM/SUMP/PUMPT/CFLUXT/QRET/CHST00005570
1/CHDT/FLUXT/STORT/ETFLXT/FLXNT 00005580
IF (IPO2.EQ.ICHK(9)) WRITE (7,230) SUM/SUMP/PUMPT/CFLUXT/QRET/CHST00005590
1/CHDT/FLUXT/STORT/ETFLXT/FLXNT 00005600
20 IF (IFLO.EQ.ICHK(3)) CALL CHECK 00005610
IF (IERR.EQ.2) GO TO 30 00005620
IF (MOD(KT/KTH).NE.0.AND.IFINAL.NE.1) RETURN 00005630
30 WRITE (6/210) KT/DELT/SUM/SMIN/HRS/DAYS/YRS/DAYSP/YRSP 00005640
IF (IFLO.EQ.ICHKC3)) CALL CWRITE 00005650
IT=IT+1 00005660
---REMOVE C FROM NEXT CARD TO PRINT HEAD CHANGE FOR ITERATIONS--- 00005670
C WRITE (6,180) (TEST3(J),J=1,IT) 00005680
I3=1 00005690
I5=0 00005700
352 I5=I5+40 00005710
I4=MINDO(KT,I5) 00005720
WRITE (6,240) (I/I=I3,I4) 00005730
WRITE (6,260) 00005740
WRITE (6,250) (ITTO(I),I=I3,I4) 00005750
WRITE (6,260) 00005760
IF(KT.LE.45) GO TO 353 00005770
I3=I3+40 00005780
GO TO 352 00005790
C ---MAP DRAWDOWN/HEAD/HEAD DIFF/RECHARGE/ET-RUNOFF/LEAKAGE/PUMPAGE--- 00005800
353 IF (XSCALE.EQ.0.) GO TO 88 00005810
IF (FACT1.EQ.0.) GO TO 50 00005820
DO 40 IA=1,4 00005830
II=LEVEL1(IA) 00005840
IF (II.EQ.0) GO TO 50 00005850
40 CALL PRNTA(1,II) 00005860
50 IF (FACT2.EQ.0.) GO TO 65 00005870
DO 60 IA=1,4 00005880
II=LEVEL2(IA) 00005890
IF (II.EQ.0) GO TO 65 00005900
60 CALL PRNTA(2,II) 00005910
65 IF(FACT3.EQ.0.) GO TO 75 00005920
DO 67 IA=1,4 00005930
II=LEVEL3(IA) 00005940
IF(II.EQ.0) GO TO 75 00005950
67 CALL PRNTA(3,II) 00005960
75 IF(IQRE.NE.ICHK(7)) GO TO 79 00005970
IF(FACT4.EQ.0.) GO TO 79 00005980
DO 77 IA=1,4 00005990
II=LEVEL4(IA) 00006000
77
IF(II.EQ.0) GO TO 79

77 CALL PRNTA(4,II)

79 IF(FACT5.EQ.0) GO TO 82
DO 80 IA=1,4
II=LEVEL5(IA)
IF(II.EQ.0.) GO TO 82

80 CALL PRNTA(5,II)

82 IF(FACT6.EQ.0) GO TO 87
IF(IIK.NE.ICHK(1O)) GO TO 87
DO 84 IA=1,4
II=LEVEL6(IA)
IF(II.EQ.0.) GO TO 87

84 CALL PRNTA(6,II)

87 IF(FACT7.EQ.0) GO TO 88
DO 99 IA=1,4
II=LEVEL7(IA)
IF(II.EQ.0.) GO TO 88

99 CALL PRNTA(7,II)

88 IF (IDRAW.NE.ICHK(1)) GO TO 100

C ---PRINT DRAWDOWN---
DO 90 K=1,K0
WRITE (6,200) K
DO 90 I=1,I0
DO 89 J=1,JO
DDN(J)=STRT(I/J/K)-PHI(I/J/K)
IF(K.EQ.1.AND.T(I/J/K).EQ.O.O) GO TO 89
IF(K.EQ.2.AND.T(I/J/K-1).EQ.O.O) GO TO 89

REMOVE C FROM COL 1 OF NEXT CARD TO PUNCH DDN IN CALCOMP FORMAT-
WRITE(7/171) I/J/DDN(J)/K

CONTINUE

90 WRITE (6,170) I/(DDN(J)/J=1/JO)

100 IF (IHEAD.NE.ICHK(2)) GO TO 120

C ---PRINT HEAD MATRIX---
DO 110 K=1,K0
WRITE (6,190) K
DO 110 I=1,I0
DO 150 J=1,JO
WRITE (7/220) (PHI(I/J/K)/J=1/JO)

110 WRITE (6,170) I/(PHI(I/J/K)/J=1/JO)

C ---WRITE ON DISK---
120 IF (IERR.EQ.2) GO TO 130
IF (KP.LT.NPER.OR.IFINAL.NE.1) RETURN
IF (IOK2.EQ.ICHK(5)) WRITE (4) PHI,SUM,SUMP,PUMPT,CFLXRT,QRET,CHST

1/CHDT/FLXRT/STORT/ETFLXRT/FLXNT

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,CFLXRT,QRET,CHST,CHDT,FLXRT,STORT,ETF

1/LXT/FLXNT

140 DO 150 K=1,K0
DO 150 I=1,I0

150 WRITE (7/220) (PHI(I/J/K)/J=1,JO)

160 IF (IERR.EQ.2) STOP
RETURN
---FORMATS---
170 FORMAT ("D", I4, 18F7.2/(5X, 18F7.2))
171 FORMAT (2I5, F5.1, 20X, "ODN IN LAYER", I5)
180 FORMAT ("OMAXIMUM HEAD CHANGE FOR EACH ITERATION: ", 39(",")/("000006560
1", 10F12.4))
190 FORMAT ("1", 55X, "HEAD MATRIX", I3/56X, 21(",")
200 FORMAT ("1", 55X, "DRAWDOWN", I3/59X, 18(",")
210 FORMAT (1H1, 44X, 57("-"))/45X,"/14X,"TIME STEP NUMBER = "/I9, 14X,"|00006600
1"/45X,"/50X, 29HSIZE OF TIME STEP IN SECONDS = "/F14.2/55X,"T00006610
2TAL SIMULATION TIME IN SECONDS = "/F14.2/80X, 8HMINUTES = "/F14.2/82X, 6H00006620
1OF CURRENT PUMPING PERIOD IN DAYS = "/F14.2/82X, "YEARS = "/F14.2/45X,"DURATION 00006640
220 FORMAT (8F10.4)
230 FORMAT (4G20.10)
240 FORMAT ("TIME STEP :", 40I3)
250 FORMAT ("ITERATIONS: ", 40I3)
260 FORMAT ("", 10("-"))
END
SUBROUTINE SOLVE(PHI,SRIPT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FAC0006710
17,EL,FL,GL,V,TEST3,VI,RE,CSS,HSS,HB)
00006720
 SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE 00006740
 C SPECIFICATIONS:
 C REAL *8PHI,RHO,B,D,F,H/Z/SU,RHOP,WMIN,RHO1,RHO2,RHO3,XPART,YPART,00006770
 1,ZPART,DMIN1,WMAX,XT,YT,ZT,ABSO,DMIN1,DEN,TXM,TYM,TZM
 C REAL *8E,AL,CL,A,C,G,WU,TU,DL,RES,MP,SUP,GLXI,ZPHI
 C DIMENSION PHI(1), SRIPT(1), OLD(1), T(1), S(1), TR(1), TC(1), TK(1)
 C WELL(1), DELX(1), DELY(1), DELZ(1), FACT(KO,3), RHOP(20), TEST3(00006810
 21), EL(1), FL(1), GL(1), V(1), XI(1), QRE(1), CSS(1), HSS(1), HB(1)
 C COMMON /INTEGR/ IO,J0,KO,I1,K1,I,J,K1/K,K*/ITMAX/LENGTH/KP,00006840
 C WELL,NUMT,IFINAL,IT,KT,IHEAD,ITMAX,IFLO,IERR,MP,IP,NC00006840
 C IF,IK1,IK2,IP,IP,IK,JK,KS,IPU1,IPU2,ITK,IQN,KT00006850
 C COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM/SUMP,QR
 C COMMON /S ARRAY/ ICHECK,LEVEL1,LEVEL2,LEVEL3,LEVELA,LEVEL5,LEVEL6,
 C LEVEL7,LEVEL8
 C COMMON /B/ BETA 00006890
 C RETURN
 C *********************************************************
 C ENTRY ITER
 C *********************************************************
 C ---COMPUTE AND PRINT ITERATION PARAMETERS---
 C WRITE(6,240)
 C WMIN=1.DO
 C DELT=1.
 C P2=LENGTH-1
 C NT=IO*JO*KO
 C NIJ=IO*JO
 C XT=3.141593**2/(2.*J2*J2>
 C YT=3.141593**2/(2.*I2*I2)
 C ZT=3.141593**2/(2.*KO*KO>
 C RH01=0.DO
 C RH02=0.DO
 C RH03=0.DO
 C DO 40 K=1,K0
 C DO 40 I=2,I1
 C DO 40 J=2,J1
 C N=I+(J-1)*IO+(K-1)*NIJ
 C IF (T(N).EQ.O.) GO TO 40
 C D=TR(N-IO)/DELX(J)
 C F=TR(N)/DELY(I)
 C B=TC(N-1)/DELY(I)
 C H=TC(N)/DELY(I)
 C SU=0.DO
 C 00006910
 C 00006920
 C 00006930
 C 00006940
 C 00006950
 C 00006960
 C 00006970
 C 00006980
 C 00006990
 C 80
 C 00007000
 C 00007010
 C 00007020
 C 00007030
 C 00007040
 C 00007050
 C 00007060
 C 00007070
 C 00007080
 C 00007090
 C 00007100
 C 00007110
 C 00007120
Z=0.DO
IF (K.NE.1) Z=TK(N-NIJ)/DELZ(K)
IF (K.NE.KO) SU=TK(N)/DELZ(K)
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
RH01=DMAX1(RH01,TYM/DEN)
20 DEN=DMIN1(B/H)
IF (DEN.EQ.0.DO) DEN=TYM
IF (DEN.EQ.0.DO) GO TO 30
RH02=DMAX1(RH02,TXM/DEN)
30 DEN=DMIN1(SU/Z)
IF (DEN.EQ.0.DO) DEN=TZM
IF (DEN.EQ.0.DO) GO TO 40
RH03=DMAX1(RH03,TXM/DEN)
CONTINUE
XPART=XT/(1.DO+RH01)
YPART=YT/(1.DO+RH02)
ZPART=ZT/(1.DO+RH03)
WMIN=DMIN1(WMIN,XPART,YPART,ZPART)
WMAX=1.DO-WMIN
WMAX=.99363
PJ=-1.
DO 50 I=1/LENGTH
PJ=PJ+1.
50 RHOP(I)=1.00-(1.DO-WMAX)**(PJ/P2)
C ---REMOVE C FROM NEXT CARD TO PRINT ITERATION PARAMETERS---
C WRITE (6,230) LENGTH,(RHOP(J),J=1/LENGTH)
RETURN
C ----------------------------------------------
C ---INITIALIZE DATA FOR A NEW ITERATION---
C
60 IT=IT+1
IF (IT.LE.ITMAX) GO TO 70
WRITE (6,220)
CALL OUTPUT
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.
100
SOLVE

GL(I) = 0.
V(I) = 0.
100 XI(I) = 0.

C --- COMPUTE TRANSMISSIVITY AND T COEFFICIENTS FOR UPPER
C HYDROLOGIC UNIT WHEN IT IS UNCONFINED ---
IF (IWATER .NE. ICHK(6)) GO TO 110
CALL TRANS(0)

C --- CHOOSE SIP NORMAL OR REVERSE ALGORITHM ---
110 IF (MOD(IX+2) .EQ. 120, 120, 170)
120 DO 150 K=1, K0
    DO 150 I=2, I1
    DO 150 J=2, J1
    N=I+(J-1)*I0+(K-1)*NIJ
    NIA=N+1
    NIB=N-1
    NJA=N+IO
    NJB=N-IO
    NKA=N+NIJ
    NKB=N-NIJ

C --- SKIP COMPUTATIONS IF NODE OUTSIDE MODEL ---
IF (T(N) .EQ. 0. OR. S(N) .LT. 0.) GO TO 150
C --- COMPUTE COEFFICIENTS ---
D=TR(NJB)/DELY(J)
F=TR(N)/DELY(J)
B=TC(NIB)/DELY(I)
H=TC(N)/DELY(I)
SU=0.00
Z=O.DO
IF(IEQN.EQ.ICHK(11)) GO TO 124
Z=TK(NKB)
IF(IEQN.EQ.ICHK(11)) Z=Z/DELZ(K)
124 IF(K.EQ.KO) GO TO 125
SU=TK(N)
IF(IEQN.EQ.ICHK(11)) SU=SU/DELZ(K)
125 RHO=S(N)/DELT
QR=O.
IF (IQRE.EQ.ICHK(7)) QR=QRE(N)
C --- SIP NORMAL ALGORITHM ---
C --- FORWARD SUBSTITUTE, COMPUTING INTERMEDIATE VECTOR V ---
130 E=B-D-F-H-SU-Z-RHO-CSS(N)
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)
UC=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(NJB)-AL*GL(NKB)
EL(N)=(E-W*(A+C))/DL

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SOLVE

\[ FL(N) = \frac{(H-W^*(G+TU))}{DL} \]
\[ GL(N) = \frac{(SU-W^*(WU+U))}{DL} \]
\[ SUPH = 0.0 \]
\[ IF (K.NE.KO) SUPH = SU^*PHI(NKA) \]
\[ RES = -3*PHI(NIB) - D*PHI(NJB) - E*PHI(N) - F*PHI(NJA) - H*PHI(NIA) - SUPH - Z*P \]
\[ 1HI(NKB) = WELL(N) = RH0^*OLD(N) - QR^*CSS(N) - HSS(N) \]
\[ IF (PHI(N) LT HSS(N), AND K.EQ.2) RES = RES + CSS(N) * (HSS(N) - PHI(N)) \]
\[ IF (PHI(N) GT HB(N), AND K.EQ.2) RES = RES + CSS(N) * (HB(N) - PHI(N)) \]
\[ RES = BETA^*RES \]
\[ V(N) = (RES - AL^*V(NKB) - BL^*V(NIB) - CL^*V(NJB)) / DL \]

GO TO 150

140
\[ DL = E + W^*(C + G + WU + U) - CL^*EL(NJB) - BL^*FL(NIB) \]
\[ EL(N) = (F - W^*C) / DL \]
\[ FL(N) = (H - W^*G) / DL \]
\[ GL(N) = (SU - W^*(WU + U)) / DL \]
\[ SUPH = 0.0 \]
\[ IF (K.NE.KO) SUPH = SU^*PHI(NKA) \]
\[ RES = -8*PHI(NIB) - D*PHI(NJB) - E*PHI(N) - F*PHI(NJA) - H*PHI(NIA) - SUPH - WELL \]
\[ 1L(N) = RH0^*OLD(N) = QR^*CSS(N) = HSS(N) \]
\[ IF (PHI(N) LT HSS(N), AND K.EQ.2) RES = RES + CSS(N) * (HSS(N) - PHI(N)) \]
\[ IF (PHI(N) GT HB(N), AND K.EQ.2) RES = RES + CSS(N) * (HB(N) - PHI(N)) \]
\[ RES = BETA^*RES \]
\[ V(N) = (RES - BL^*V(NIB) - CL^*V(NJB)) / DL \]

GO TO 150

150
--- BACK SUBSTITUTE FOR VECTOR XI ---

C DO 160 K = 1, KO
K3 = KO - K + 1
DO 160 I = 1, I2
I3 = I0 - I
DO 160 J = 1, J2
J3 = J0 - J
N = I3 + (J3 - 1) * I0 + (K3 - 1) * NIJ + I
IF (T(N) LT 0.0 OR S(N) LT 0.0) GO TO 160
GLXI = 0.00
IF (K3.NE.KO) GLXI = GL(N) * XI(N+NIJ)
XI(N) = V(N) * EL(N) * XI(N+I0) - FL(N) * XI(N+1) - GLXI

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

C IF (BIG GT ERR) TEST = 1.
TEST3(IT + 1) = BIG
IF (TEST3 EQ 0) RETURN
GO TO 60

170

CONTINUE

C
SOLVE

NIA = N + 1
NIB = N - 1
NJA = N + 10
NJB = N - 10
NKA = N + NIJ
NKB = N - NIJ

C --- SKIP COMPUTATIONS IF NODE OUTSIDE AQUIFER ---
IF (T(N).EQ.0. OR. S(N).LT.0.) GO TO 200

C --- COMPUTE COEFFICIENTS ---
D = TR(NJB)/DELX(J)
F = TR(N)/DELX(J)
B = TC(NI3)/DELY(I)
H = TC(N)/DELY(I)
SU = 0. DO
Z = 0. DO
IF (K.EQ.1) GO TO 174
Z = TK(NKB)
IF (IEQN.EQ.ICHK(11)) Z = Z/DELZ(K)

174 IF (K.EQ.KO) GO TO 175
SU = DK(N)
IF (IEQN.EQ.ICHK(11)) SU = SU/DELZ(K)

175 RHO = S(N)/DELT
QR = 0.
IF (IQRE.EQ.ICHK(7)) QR = QRE(N)

C --- SIP REVERSE ALGORITHM ---
C FORWARD SUBSTITUTE/ COMPUTING INTERMEDIATE VECTOR V ---
180 E = -B - D - F - M - Z - RHO - CSS(N)
BL = H/(1. + W*(EL(NIA) + GL(NIA)))
CL = D/(1. + W*(FL(NJB) + GL(NJB)))
C = BL*EL(NIA)
G = CL*FL(NJ6)
WU = CL*GL(NJ6)
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 + 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.EQ.1) ZPHI = Z*PHI(NKB)
RES = B*PHI(NJB) - D*PHI(NJB) - E*PHI(N) - F*PHI(NJA) - H*PHI(NIA) - SU*PHI(N)
1KA = ZPHI - WELL(N) - RHO*OLD(N) - QR - CSS(N)*(HSS(N) - PHI(N))
1K = ZPHI - WELL(N) - RHO*OLD(N) - QR - CSS(N)*(HSS(N) - PHI(N))
RES = NPHI*RES
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

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SOLVE

\[ FL(N) = \frac{(B - W*G)}{DL} \]
\[ GL(N) = \frac{(Z - W*(W+U))}{DL} \]
\[ ZPHI = 0.00 \]
\[ \text{IF} (K \neq 1) \ ZPHI = Z*PHI(NKB) \]
\[ \text{RES} = -B*PHI(NIB) - D*PHI(NJB) - E*PHI(N) - F*PHI(NJA) - H*PHI(NIA) - ZPHI - RHO*OLD(N) - Q*R - CSS(N)*HSS(N) \]
\[ \text{IF} (\text{PHI}(N) < HSS(N) \text{ AND } K = 2) \text{RES} = \text{RES} + CSS(N)*(HSS(N) - \text{PHI}(N)) \]
\[ \text{IF} (\text{PHI}(N) > HB(N) \text{ AND } K = 2) \text{RES} = \text{RES} + CSS(N)*(HB(N) - \text{PHI}(N)) \]
\[ \text{RES} = \text{BETA*RES} \]
\[ V(N) = (\text{RES} - B*V(NIA) - C*V(NJB))/DL \]

200 CONTINUE

--- BACK SUBSTITUTE FOR VECTOR XI ---

DO 210 K = 1, KB
DO 210 I = 2, NI
DO 210 J = 1, NJ
J3 = J0 - J
N = I + (J3 - 1)*IO + (K - 1)*NIJ
\[ \text{IF} (T(N).EQ.0..OR.S(N).LT.0.) \text{GO TO 210} \]
\[ \text{GLXI} = 0.00 \]
\[ \text{IF} (K \neq 1) \text{GLXI} = \text{GL}(N) * \text{XI}(N-NIJ) \]
\[ \text{XI}(N) = \text{V}(N) - \text{EL}(N) * \text{XI}(N+1) - \text{FL}(N) * \text{XI}(N-1) - \text{GLXI} \]

--- COMPARE MAGNITUDE OF CHANGE WITH CLOSURE CRITERIA ---

\[ \text{TCHK} = \text{ABS(XI}(N)) \]
\[ \text{IF} (\text{TCHK} > \text{BIG}) \text{BIG} = \text{TCHK} \]
\[ \text{PHI}(N) = \text{PHI}(N) + \text{XI}(N) \]

210 CONTINUE

\[ \text{IF} (\text{BIG} > \text{ERR}) \text{TEST} = 1. \]
\[ \text{TEST3} (\text{IT} + 1) = \text{BIG} \]
\[ \text{IF} (\text{TEST} .EQ. 0.) \text{RETURN} \]

GO TO 60

--- FORMATS ---

220 FORMAT ('0EXCEEDED PERMITTED NUMBER OF ITERATIONS'/ '',39('*'))
230 FORMAT ('///1H0.15,22H ITERATION PARAMETERS:6E15.7/(/28X,6E15.7/)')
240 FORMAT ('-','-44X,'SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE'/45X')
END
SUBROUTINE COEF(PHI, STRT, OLD, T, STR, TC, TK, WELL, DELX, DELY, DELZ, FACT)
1. PERM, BOTTOM, QRE)

COMPUTE COEFFICIENTS

SPECIFICATIONS:

REAL *8 PHI

COMMON /INTEGR/ IO, JO, KO, I1, J1, K1, I, J, K, NPER, KTH, ITMAX, LENGTH, KP, N

1. COMMON /SPARAM/ TMAX, CDLT, DELT, TEST, SUM, SUMP, QR

COMMON /SARRAY/ ICHECK(4), LEVEL1(4), LEVEL2(4), LEVEL3(4), LEVEL4(4), LEVEL5(4), LEVEL6(4), LEVEL7(4)

DATA N3=1

RETURN

-- COMPUTE TRANSMISSIVITY FOR UPPER HYDROLOGIC UNIT WHEN

IT IS UNCONFINED--

ENTRY TRANS(N3)

DO 10 I=2, I1

CONTINUE

IF (N3.EQ.1) RETURN

GO TO 20

COMPUTE T COEFFICIENTS

86
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)*FACT(K+1))
   10 DELX(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)*FACT(K+2)
   10 DELY(I)*FACT(K+2)
40 CONTINUE
   IF (KO.EQ.1 .OR.ITK.EQ.ICHK(10).OR.N3.EQ.0) 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)+T2*DELZ(K))
   10 DELZ(K)
50 CONTINUE
RETURN
   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)+T2*DELZ(K))
   10 DELZ(K)
50 CONTINUE
RETURN
60 FORMAT ('-'/20('*')/ 'WELL'/'I3'/ 'IN LAYER'/'I3'/' GOES DRY'/'20('*')
70 FORMAT ('-'/20('*')/ 'NODE'/'I3'/ 'IN LAYER'/'I3'/' GOES DRY'/'20('*')
END
SUBROUTINE CHECK (PHI, STRT, OLD, T, ST, TC, TK, WELL, DELX, DELY, DELZ, FA
1CT, JFLO, FLOW, QRE, CSS, HSS, HB, ETAT)

COMPUTE A VOLUMETRIC BALANCE

SPECIFICATIONS:

REAL *8 PHI

DIMENSION PHI, STRT, OLD, T, ST, TC, TK, WELL, DELX, DELY, DELZ, FACT, JFLO, FLO,

COMMON /INTEGR/ I0, J0, K0, I1, J1, K1, I, J, K, NPER, KTH, ITMAX, LENGTH, KP, N

1WEL, NUMT, IFINAL, IT, KT, IHEAD, IDRAW, IFLO, IERR, IZ, JZ, KZ, IMAX, ITMX1, NCO

2H, IK1, IK2, IWATER, IQRE, IP, JP, IQ, JK, K5, IPU1, IPU2, ITK, IEQN, KQ

COMMON /SPARAM/ TMAX, CDLT, DELT, ERR, TEST, SUM, SUMP, QR

COMMON /SARRAY/ ICHK, LEVEL1, LEVEL2, LEVEL3, LEVEL4, LEVEL5, LEVEL6, LEVEL7

COMMON /CK/ ETFLXT, STORT, QRET, CHST, CHD, FLUX, PUMPT, CFLUX, FLXNT

RETURN

ENTRY CHECK

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

--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 (SCI(J,K).GE.0.) GO TO 180

---COMPUTE FLOW RATES TO AND FROM CONSTANT HEAD BOUNDARIES---

II=II+1
CHECKI

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)
IF (IEQN.EQ.ICHK(11)) X=X*DELZ(K)
FLOW(II)=FLOW(II)+X
IF (X) 10,30,20
10  CHD1=CHD1+X
    GO TO 30
20  CHD2=CHD2+X
30 IF (S(I,J+1,K).LT.0. OR.T(I,J+1,K).EQ.0.) GO TO 60
    X=(PHI(I,J,K)-PHI(I,J+1,K))*DELY(I)*TR(I,J,K)
    IF (IEQN.EQ.ICHK(11)) X=X*DELZ(K)
    FLOW(II)=FLOW(II)+X
    IF (X) 40,60,50
40  CHD1=CHD1+X
    GO TO 60
50  CHD2=CHD2+X
60 IF (K.EQ.1) GO TO 90
    IF (S(I,J,K-1).LT.0. OR.T(I,J,K-1).EQ.0.) GO TO 90
    X=(PHI(I,J,K)-PHI(I,J,K-1))*TK(I,J,K)*AREA
    FLOW(II)=FLOW(II)+X
    IF (X) 70,90,80
70  CHD1=CHD1+X
    GO TO 90
80  CHD2=CHD2+X
90 IF (K.EQ.KO) GO TO 120
    IF (S(I,J,K+1).LT.0. OR.T(I,J,K+1).EQ.0.) GO TO 120
    X=(PHI(I,J,K)-PHI(I,J,K+1))*TK(I,J,K)*AREA
    FLOW(II)=FLOW(II)+X
    IF (X) 100,120,110
100 CHD1=CHD1+X
    GO TO 120
110 CHD2=CHD2+X
120 IF (S(I-1,J,K).LT.0. OR.T(I-1,J,K).EQ.0.) GO TO 150
    X=(PHI(I,J,K)-PHI(I-1,J,K))*TC(I-1,J,K)*DELX(J)
    IF (IEQN.EQ.ICHK(11)) X=X*DELZ(K)
    FLOW(II)=FLOW(II)+X
    IF (X) 130,150,140
130 CHD1=CHD1+X
    GO TO 150
140 CHD2=CHD2+X
150 IF (S(I+1,J,K).LT.0. OR.T(I+1,J,K).EQ.0.) GO TO 220
    X=(PHI(I,J,K)-PHI(I+1,J,K))*TC(I,J,K)*DELX(J)
    IF (IEQN.EQ.ICHK(11)) X=X*DELZ(K)
    FLOW(II)=FLOW(II)+X
    IF (X) 160,220,170
160 CHD1=CHD1+X
    GO TO 220
170 CHD2=CHD2+X

89
GO TO 220

C   ---CHECK FOR EQUATION BEING SOLVED---
00011390
180 IF(I EQ. EQ. ICHK(11)) GO TO 211
00011400
C   ---EQUATION 4---
00011410
C   ---RECHARGE AND WELLS---
00011420
IF(QRE.EQ.ICHK(7)) QREFLX=QREFLX+QRE(I,J,K)*AREA
00011430
IF (WELL(I,J,K)) 190,210,200
00011440
190 PUMP=PUMP+WELL(I,J,K)*AREA
00011450
GO TO 210
00011460
200 CFLUX=CFLUX+WELL(I,J,K)*AREA
00011470
C   ---COMPUTE VOLUME FROM STORAGE---
00011480
210 STOR=STOR+S(I,J,K)*(OLD(I,J,K)-PHI(I,J,K))*AREA
00011490
HDD=PHI(I,J,K)
00011500
IF(HDD.LT.HSS(I,J,K) AND K.EQ.2) HDD=HSS(I,J,K)
00011510
IF(HDD.GT.HB(I,J,K) AND K.EQ.2) HDD=HB(I,J,K)
00011520
XNET=(HSS(I,J,K)-HDD)*CSS(I,J,K)*AREA
00011530
IF(K.EQ.1) GO TO 261
00011540
ETFLUX=ETFLUX+XNET
00011550
GO TO 262
00011560
261 FLUXS=FLUXS+XNET
00011570
IF(XNET.LT.O) FLXN=FLXN-XNET
00011580
C   COMPUTE ET-RUNOFF RATES IN INCHES PER YEAR--
00011590
262 IF(K.EQ.1) GO TO 219
00011600
IF(HDD.GT.HB(I,J,K)) ETRAT(I,J,K)=3.784E03*CSS(I,J,K)*(HB(I,J,K)-
00011610
1HSS(I,J,K))
00011620
IF(HDD.LE.HB(I,J,K) AND HDD.GT.HSS(I,J,K))ETRAT(I,J,K)=
00011630
13.784E08*CSS(I,J,K)*(HSS(I,J,K)-
00011640
1HB(I,J,K))
00011650
IF(HDD.LE.HSS(I,J,K))ETRAT(I,J,K)=0.0
00011660
C   ---PRINT HCF FLOW RATE AT MODEL-GRID BOUNDARY---
00011670
219 IF (K.NE.1) GO TO 220
00011680
XHCF=(HSS(I,J,K)-PHI(I,J,K))*CSS(I,J,K)
00011690
IF(XHCF.EQ.0.0)GO TO 220
00011700
WRITE(6,295)I,J,XHCF
00011710
WRITE(7,295)I,J,XHCF
00011720
GO TO 220
00011730
C   ---EQUATION 3---
00011740
C   ---RECHARGE AND WELLS---
00011750
211 IF(QRE.EQ.ICHK(7)) QREFLX=QREFLX+QRE(I,J,K)*VOLUME
00011760
IF (WELL(I,J,K)) 212,214,213
00011770
212 PUMP=PUMP+WELL(I,J,K)*VOLUME
00011780
GO TO 214
00011790
213 CFLUX=CFLUX+WELL(I,J,K)*VOLUME
00011800
C   ---COMPUTE VOLUME FROM STORAGE---
00011810
214 STOR=STOR+S(I,J,K)*(OLD(I,J,K)-PHI(I,J,K))*VOLUME
00011820
HDD=PHI(I,J,K)
00011830
IF(HDD.LT.HSS(I,J,K) AND K.EQ.2) HDD=HSS(I,J,K)
00011840
IF(HDD.GT.HB(I,J,K) AND K.EQ.2) HDD=HB(I,J,K)
00011850
XNET=(HSS(I,J,K)-HDD)*CSS(I,J,K)*VOLUME
00011860
IF(K.EQ.1) GO TO 271
00011870
ETFLUX=ETFLUX+XNET
00011880
GO TO 220
00011890
271 FLUXS=FLUXS+XNET
00011900
IF(XNET.LT.0) FLXN=FLXN-XNET

CONTINUE

---DETERMINE IF WATER TABLE RISES ABOVE LAND SURFACE---
DO 221 K=2,2
DO 221 I=1,I0
DO 221 J=1,J0
RISE=PHI(I,J,K)-HB(I,J,K)

-REMOVE C FROM NEXT CARD TO PREVENT WT RISE ABOVE LAND
IF(RISE.GT.0.0) PHI(I,J,K)=HB(I,J,K)

---REMOVE C FROM COL 1 OF NEXT 4 CARDS TO PUNCH ET-RUNOFF---
WRITE(7,298)

DO 222 K=2,2
DO 222 I=1,I0
WRITE(7,297) (ETRAT(I,J,K),J=1,J0)

---COMPUTE CUMULATIVE VOLUMES, TOTALS, AND DIFFERENCES---
FLXPT=0.0
STORT=STORT+STOR
STOR=STOR/DELT
FLXNT=FLXNT+FLXN*DELT
FLXPT=FLXPT+FLXNT
QRET=QRET+QREFLX*DELT
ETFLXT=ETFLXT-ETFLUX*DELT
CHDT=CHDT-CHD1*DELT
CHST=CHST+CHD2*DELT
PUMPT=PUMPT-PUMP*DELT
CFLUXT=CFLUXT+CFLUX*DELT
TOTL1=STORT+QRET+CFLUXT+CHST+FLXPT
TOTL2=CHDT+PUMPT+ETFLXT+FLXNT
SUMR=QREFLX+CFLUX+CHD2+CHD1+PUMP+ETFLUX+FLUXS+STOR
DIFF=TOTL2-TOTL1
PERCNT=0.0
IF (TOTL2.EQ.0.) GO TO 230
PERCNT=DIFF/TOTL2*100.
RETURN

---PRINT RESULTS---
WRITE (6,290) STOR,QREFLX,STORT,CFLUX,QRET,PUMP,CFLUXT,ETFLUX,CHST
FLXPT,CHDT,CHD1,FLUX,FLUXS,ETFLXT,CHDT,SUMR,PUMPT,FLXNT,TOTL2
2L2,DIFF,PERCNT
WRITE(6,291)
DO 500 K=1,K0
ACTNOD=0.
TOTABR=0.
TOTPCT=0.
TTOT=0.
RTOT=0.
RPOS=0.
RNEG=0.
POSNOD=0.
RNEGND=0.
RMAXD=0.
RMIND=0.
RMINT=1000000.
RMAXT=0.
RMAXR=0.
RMINR=0.
MROW=0
MCOL=0
NROW=0
NCOL=0
DO 400 I=2, I1
DO 400 J=2, J1
IF(T(I,J,K).EQ.O.OR.S(I,J,K).LT.O) GO TO 400
ACTNOD=ACTNOD+1.
DDN=STRT(I,J,K)-PHI(I,J,K)
IF (STRT(I,J,K).EQ.O,O) GO TO 390
PCT=(ABS(DDN)/STRT(I,J,K))*100.
TOTPCT=TOTPCT+PCT
390 TOTABR=TOTABR+ABS(DDN)
IF(DDN.LT.RMAXD) GO TO 391
RMAXD=DDN
MROW=I
MCOL=J
IF(DDN.GT.RMIND) GO TO 392
RMIND=DDN
NROW=I
NCOL=J
392 TDUM=T(I,J,K)/(1.5472E-06)
TTOT=TTOT+TDUM
IF(TDUM.GE.RMAXT) RMAXT=TDUM
IF(TDUM.LE.RMINT) RMINT=TDUM
IF(IQRE.NE.ICHK(7)) GOTO 400
IF(K.NE.KO) GOTO 400
RDUM=QRE(I,J,K)/(2.64E-09)
RTOT=RTOT+RDUM
IF(RDUM.GE.RMAXR) RMAXR=RDUM
IF(RDUM.LE.RMINR) RMINR=RDUM
IF(RDUM.GT.O) RPOS=RPOS+RDUM
IF(RDUM.GT.O) POSNOD=POSNOD+1.
IF(RDUM.LT.O) RNEG=RNEG+RDUM
IF(RDUM.LT.O) RNEGND=RNEGND+1.
400 CONTINUE
IF(ACTNOD)500,500,418
AVABER=TOTABR/ACTNOD
AVPCT=TOTPCT/ACTNOD
TAV=TTOT/ACTNOD
WRITE(6,292) K,AVABER,AVPCT,RMAXD,MROW,MCOL,RMIND,NROW,NCOL,TAV,
RMAXT,RMINT,ACTNOD
CHECKI

IF(IQRE.NE.ICHK(7)) GOTO 500
IF(K.NE.KO) GOTO 500
RAV=RTOT/ACTNOD

IF(POSNOD) AVPOSR=RTOT/POSNOD
GO TO 440

AVNEGR=RNEG/RNEGND
WRITE(6/293) K,RAV,AVPOSR,POSNOD,AVNEGR,RNEGND,RMAXR,RMINR
CONTINUE
RETURN

FORMATS
260 FORMAT ('0'/10X,'CUMULATIVE MASS BALANCE:','16X,'L**3','23X,'RATES F00013120
10 FOR THIS TIME STEP:','16X,'L**3/T','11X,24E-5','43X,25E-5',/20X,'SOU00013130
2RCES:','69X,'STORAGE =','F20.4/20X,'8E-5','68X,'RECHARGE =','F20.4/27X00013140
3X,'STORAGE =','F20.4/35X,'CONSTANT FLUX =','F20.4/26X,'RECHARGE =','F200013150
40.2/41X,'PUMPING =','F20.4/21X,'CONSTANT FLUX =','F20.2/30X',00013160
5 ET-RUNOFF =','F20.4/21X,'CONSTANT HEAD =','F20.2/34X,'CONSTANT HEAD 00013170
6D:','27X,'LEAKAGE =','F20.4/46X,'IN =','F20.4/21X,'TOTAL SOURCES =','F200013180
720.2/45X,'OUT =','F20.4/96X,'LEAKAGE:','20X,'DISCHARGES:','45X,'FROM 00013190
8PREVIOUS PUMPING PERIOD =','F20.4/10013200
96X,'ET-RUNOFF =','F20.2/21X,'CONSTANT HEAD =','F20.2/36X',500013210
$SUM OF RATES =','F20.4/19X,'QUANTITY PUMPED =','F20.2/27X,'LEAKAGE=00013220
$F20.2/19X,'TOTAL DISCHARGE =','F20.2/17X,'DISCHARGE-SOURCES =','F200013230
$.2/15X,'PER CENT DIFFERENCE =','F20.2//',)00013240
270 FORMAT ('0'/10X,'FLOW RATES TO CONSTANT HEAD NODES:','/16X,'K','I','J','RATE (IN/YR )/')00013250
1X,'K','I','J','4X','-','-','-','-','3X','RATE (IN/YR )')/'14(5X,00013260
23X,13(''-')//00013270
280 FORMAT ('/1X,'I16.2I5,F10.16X'))00013280
291 FORMAT('0'/17X,'AVG','2X','ABS CHG','5X','MAX DON','7X','MAX RISE','12X',00013290
1AVG T (GPD/FT)','11X','MAX T','7X','MIN T','4X,'ACTIVE NODES')00013300
292 FORMAT('0.1X','LAYER','2X','I4','X','F4.1','3X','F4.1','X','3X','F5.1','1X','("','I12','00013310
1"','I12','"')/2X,'F5.1','1X','("','I12','"','I12','")/6X,'F11.0','10X','F11.0','4X','F8.000013320
2X,'F10.0')00013330
293 FORMAT('0.1X','AVG RECHG (IN/YR)','7X','AVG POS RECHG','3X','NO. POS',00013340
1 NODES','3X','AVG NEG RECHG','3X','NO. NEG NODES','3X','MAX RECHG','7X',00013350
2X DISCHG')00013360
294 FORMAT('0.1X','LAYER','2X','I4','6X','F6.1','16X','F6.1','9X','F7.0','10X','F6.1','10X',00013370
1F7.0','8X','F6.1','10X','F6.1')00013380
295 FORMAT('11X,'I2','6X','I2','3X','E15.5','30X','HCF FLOW')00013390
296 FORMAT('0WATER TABLE RISES','F6.1',' FEET ABOVE LSD AT ROW','I5',' COL')00013400
1'='I5')00013410
297 FORMAT(20F4.1)00013420
298 FORMAT(5X,'ET RATES FOLLOW')00013430
END
SUBROUTINE PRNTAI(PHI, STR, T, S, DELX, DELY, QRE, TK, ETTRAT)

C PRINT MAPS OF DRAWDOWN, HYDRAULIC HEAD, HEAD DIFFERENCE, RECHARGE, ET-RUNOFF RATE, LEAKAGE RATE, AND PUMPING RATE

C SPECIFICATIONS:
REAL *3PHI, Z, XLAB, YLABEL, TITLE, XN1, MESUR
REAL *4K
DIMENSION PHI(IO, JO, KO), STR(T, IO, JO, KO), S(IO, JO, KO), WELL(IO, JO, KO)
IO), DELX(JJ), DELY(IO), T(IO, JO, KO), QRE(IQ, JQ, KQ), TK(IK, JK, K5)
RETURN

SPECIFICATIONS:
REAL *3PHI, Z, XLAB, YLABEL, TITLE, XN1, MESUR
REAL *4K
DIMENSION PHI(IO, JO, KO), STR(T, IO, JO, KO), S(IO, JO, KO), WELL(IO, JO, KO)
IO), DELX(JJ), DELY(IO), T(IO, JO, KO), QRE(IQ, JQ, KQ), TK(IK, JK, K5)
RETURN

C ---INITIALIZE VARIABLES FOR PLOT---
C ******************************
C ENTRY MAP
C ******************************
YDIM=0.
WIDTH=0.
DO 10 J=2/J1
WIDTH=WIDTH+DELX(J)
DO 20 I=2/I1
YDIM=YDIM+DELY(I)
XSF=DINCH*XSCALE
YSF=DINCH*YSCALE
NYO=YDIM/YSF
IF (NYO*YSF.LE.YDIM-DELY(I1))/2.) NYD=NYO+1
IF (NYO.LE.12) GO TO 40
DINCH=YDIM/(12.*YSCALE)
WRITE (6/330) DINCH
IF (YSCALE.LT.1.0) GO TO 30
NXD=WIDTH/XSF
IF (NXD/XSF.LE.WIDTH-DELX(J1))/2.) NXD=NXD+1
N4=NXD*N1+1
N8=NXD*N1+1
N14=NXD*N1+1
N4=NXD*N1+1
N5=NXD+1
N6=NYD+1
N8=NYD+1
NA(1)=N4/2-1
NA(2)=N4/2
RETURN
PRNTAI

NA(3)=N4/2+3
NC=(N3-N8-10)/2
ND=NC+N8
NE=MAXO(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
  IF (NNX.LT.O) GO TO 60
  XN(I)=XSF*NNX/YSCALE
  CONTINUE
  RETURN

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.AND.LA.EQ.1) WRITE(6,300)
IF (NG.EQ.1.AND.LA.EQ.2) WRITE(6,301)
IF (NG.EQ.2.AND.LA.EQ.1) WRITE(6,302)
IF (NG.EQ.2.AND.LA.EQ.2) WRITE(6,303)
IF (NG.EQ.3) WRITE(6,295)
IF (NG.EQ.4) WRITE(6,297)
IF (NG.EQ.5) WRITE(6,298)
IF (NG.EQ.6) WRITE(6,299)
IF (NG.EQ.7) WRITE(6,311)
DO 290 I=1,N4
  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

---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

---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

---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.

95
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 (100,110,112,114,116,118,119), NG
100 K=(STRT(L/JJ/LA)-PHI(L/JJ/LA))*FACT1
GO TO 120
110 K=PHI(L/JJ/LA)*FACT2
GO TO 120
112 K=PHI(L/JJ/LA+1)-PHI(L/JJ/LA)
GO TO 120
114 K=QRE(L/JJ/LA)*FACT4/(2.6424E-09)
GO TO 120
116 K=ETRAT(L/JJ/LA)*FACT5
GO TO 120
118 K=T(L/JJ/LA)*(PHI(L/JJ/LA+1)-PHI(L/JJ/LA))/FACT6/(2.6424E-09)
C --REMOVE C FROM COL 1 OF NEXT CARD TO PUNCH LEAKAGE RATE--
WRITE(7,350)L/JJ/K
GO TO 120
119 K=WELL(L/JJ/LA)*.646317*FACT7*DELX(JJ)*DELY(L)
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
IF (N.GT.999) GO TO 190
INDX3=N/100
IF (J-2.GT.0) PRNT(J-2)=SYM(INDX3)
N=N-INDX3*100
150 INDX1=MOD(N,10)
IF (INDX1.EQ.0) INDX1=10
INDX2=N/10
IF (INDX2.GT.0) GO TO 180
INDX2=10
IF (INDX3.EQ.0) INDX2=15
GO TO 130
160 INDX1=15
170 INDX2=15
180 IF (J-1.GT.0) PRNT(J-1)=SYM(INDX2)
PRNT(J)=SYM(INDX1)
GO TO 220
190 DO 200 II=1,3
JI=J-3+II
200 IF (JI.GT.0) PRNT(JI)=SYM(11)
210 IF (S(L/JJ/LA).LT.0.) PRNT(J)=SYM(16)
220 YLEN=YLEN+(DELY(L)+DELY(L+1))/2.
230 DIST=DIST-(DELX(JJ)+DELX(JJ-1))/2.
JJ=JJ-1
IF (JJ.EQ.0) GO TO 240

96
IF (DIST.GT.Z-XN1*XSF) GO TO 230

CONTINUE

---PRINT AXES, LABELS, AND SYMBOLS---

IF (I-NA(LL).EQ.0) GO TO 260

IF ((I-1)/N1*N1-(I-1)) 270, 250, 270

WRITE (6, VF1) (BLANK(J), J=1, NC), (PRNT(J), J=1, N8), XN(1+(I-1)/6)

GO TO 280

WRITE (6, VF2) (BLANK(J), J=1, NC), (PRNT(J), J=1, N8), XLABEL(LL)

GO TO 280

WRITE (6, VF2) (BLANK(J), J=1, NC), (PRNT(J), J=1, N8)

---COMPUTE NEW VALUE FOR Z AND INITIALIZE PRNT---

Z=Z-2.*XN1*XSF

DO 290 J=1, N8

PRNT(J)=SYM(15)

NUMBER AND LABEL Y AXIS AND PRINT LEGEND

WRITE (6, VF3) (BLANK(J), J=1, NC), (YN(I), I=1, N6)

WRITE (6, 320) (YLABEL(I), I=1, 6)

IF (NG.EQ.1) WRITE (6, 310) FACT1

IF (NG.EQ.2) WRITE (6, 310) FACT2

RETURN

---FORMATS---

295 FORMAT ('1', 36X, 'HEAD DIFFERENCE *WATER TABLE MINUS POTENTIOMETRIC', 0.00015190)
1 SURFACE* FEET'///)

1 SURFACE* FEET'///)

297 FORMAT ('1', 40X, 'RATE OF RECHARGE TO SURFICIAL AQUIFER, INCHES PER YEAR', 0.00015210)

298 FORMAT ('1', 39X, 'ET-RUNOFF FROM SURFICIAL AQUIFER, INCHES PER YEAR', 0.00015230)

299 FORMAT ('1', 40X, 'RATE OF LEAKAGE TO FLORIDAN AQUIFER, INCHES PER YEAR', 0.00015250)

300 FORMAT ('1', 40X, 'DRAWDOWN IN FLORIDAN AQUIFER, FEET',///)

301 FORMAT ('1', 40X, 'DRAWDOWN IN SURFICIAL AQUIFER, FEET',///)

302 FORMAT ('1', 35X, 'ALTITUDE OF POTENTIOMETRIC SURFACE OF THE FLORIDA', 0.00015290)

303 FORMAT ('1', 35X, 'ALTITUDE OF WATER TABLE IN THE SURFICIAL AQUIFER', 0.00015310)

304 FORMAT ('1', 35X, 'ALTITUDE OF WATER TABLE IN THE SURFICIAL AQUIFER', 0.00015310)

310 FORMAT ('1', 40X, 'NOTE: GENERALLY SCALE SHOULD BE > OR = 1.0',///)

1 FEET'///)

1 FEET'///)

311 FORMAT ('1', 40X, 'PUMPING RATE FROM FLORIDAN AQUIFER, MGAL/D',///)

320 FORMAT ('0', 39X, 6A8)

330 FORMAT ('0', 25X, 10(''),///)

340 FORMAT ('0', 45X, 'FIT MAP WITHIN 12 INCHES, DINCH REVIS', 0.00015370)

350 FORMAT (I5, I5, F10.1, 40X, 'LEAK')
ATTACHMENT B: DATA-DECK INSTRUCTIONS

The data deck supplies input to a FORTRAN program tailored specifically to the hydrogeologic system conceptualized for the well-field areas near Tampa. Instructions for assembling the data deck have been modified from those presented in Trescott (1975). The modifications pertain mainly to setting up the deck to accommodate the HCF condition in the Floridan aquifer (layer 1), ET-runoff from the water table in the surficial aquifer (layer 2), and the addition of an acceleration parameter BETA. Additionally, the instructions have been modified to produce maps that were not available in the original model. These include maps of head difference between the water table and potentiometric surface, recharge rate to the water table, ET-runoff rate from the water table, leakage rate through the upper confining bed, and the distribution of pumpage. All data-deck modifications are denoted by an asterisk.
ATTACHMENT B: DATA-DECK INSTRUCTIONS
[modified from Trescott (1975); * denotes modification]

Group I: Title, Simulation Options, and Problem Dimensions

This group of cards that are read by the main program contain data required to dimension the model. To specify an option on card 4, punch the characters underlined in the definition. For an option not used, that section of card 4 can be left blank.

Note: Default typing of variables applies for all data input.

<table>
<thead>
<tr>
<th>CARD</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-80</td>
<td>20A4</td>
<td>HEADING</td>
<td>Any title the user wishes to print on one line at the start of output.</td>
</tr>
<tr>
<td>2</td>
<td>1-52</td>
<td>13A4</td>
<td>do.</td>
<td>do.</td>
</tr>
<tr>
<td>3</td>
<td>1-10</td>
<td>I10</td>
<td>I0</td>
<td>Number of rows.</td>
</tr>
<tr>
<td>11-20</td>
<td>I10</td>
<td>JO</td>
<td>Number of columns.</td>
<td></td>
</tr>
<tr>
<td>21-30</td>
<td>I10</td>
<td>KO</td>
<td>Number of layers.</td>
<td></td>
</tr>
<tr>
<td>31-40</td>
<td>I10</td>
<td>ITMAX</td>
<td>Maximum number or iterations per time step.</td>
<td></td>
</tr>
<tr>
<td>41-50</td>
<td>I10</td>
<td>NCH</td>
<td>Number of constant head nodes.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1-4</td>
<td>A4</td>
<td>IDRAW</td>
<td>DRAW to print drawdown.</td>
</tr>
<tr>
<td>6-9</td>
<td>A4</td>
<td>IHEAD</td>
<td>HEAD to print hydraulic head.</td>
<td></td>
</tr>
<tr>
<td>11-14</td>
<td>A4</td>
<td>IFLOW</td>
<td>MASS to compute a mass balance.</td>
<td></td>
</tr>
<tr>
<td>16-18</td>
<td>A3</td>
<td>IDK1</td>
<td>DK1 to read initial head, elapsed time, and mass balance parameters from unit 4 on disk.</td>
<td></td>
</tr>
<tr>
<td>21-23</td>
<td>A3</td>
<td>IDK2</td>
<td>DK2 to write computed head, elapsed time, and mass balance parameters on unit 4 (disk).</td>
<td></td>
</tr>
<tr>
<td>26-29</td>
<td>A4</td>
<td>IWATER</td>
<td>WATE if the upper hydrologic unit is unconfined.</td>
<td></td>
</tr>
<tr>
<td>31-34</td>
<td>A4</td>
<td>IQRE</td>
<td>RECH for a constant recharge that may be a function of space.</td>
<td></td>
</tr>
<tr>
<td>36-39</td>
<td>A4</td>
<td>IPU1</td>
<td>PUN1 to read initial head, elapsed time, and mass balance parameters from cards.</td>
<td></td>
</tr>
<tr>
<td>41-44</td>
<td>A4</td>
<td>IPU2</td>
<td>PUN2 to punch computed head, elapsed time, and mass balance parameters on cards.</td>
<td></td>
</tr>
</tbody>
</table>
GROUP II: SCALAR PARAMETERS

The parameters required in every problem are underlined. The other parameters are required as noted; when not required, their location on the card can be left blank. The G format is used to read E, F, and I format data. Minimize mistakes by always right-justifying data in the field. If F format data do not contain significant figures to the right of the decimal point, the decimal point can be omitted.

<table>
<thead>
<tr>
<th>CARD</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>G10.0</td>
<td>NPER</td>
<td>Number of pumping periods for the simulation.</td>
</tr>
<tr>
<td></td>
<td>11-20</td>
<td>G10.0</td>
<td>KTH</td>
<td>Number of time steps between printouts.</td>
</tr>
<tr>
<td></td>
<td>21-30</td>
<td>G10.0</td>
<td>ERR</td>
<td>Error criterion for closure (L).</td>
</tr>
</tbody>
</table>

Note: To print only the results for the final time step in a pumping period, make KTH greater than the expected number of time steps. The program always prints the results for the final time step.

<table>
<thead>
<tr>
<th>CARD</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-40</td>
<td>G10.0</td>
<td>LENGTH</td>
<td>Number of iteration parameters.</td>
<td></td>
</tr>
<tr>
<td>*41-50</td>
<td>G10.0</td>
<td>BETA</td>
<td>Acceleration parameter: probable range is 0.5 to 1.5; less than 1 if diverging; greater than 1 if converging too slowly.</td>
<td></td>
</tr>
</tbody>
</table>

| 2    | 1-7     | G10.0  | XSCALE  | Factor to convert model length unit to unit used in X direction on maps (for example, to convert from feet to miles, XSCALE = 5,280). |
|      |         |        |         | For no maps, card 2 is blank. |
| *8-14| G10.0   | YSCALE | Factor to convert model length unit to unit used in Y direction on maps. |
| *15-21| G10.0  | DINCH  | Number of map units per inch. |

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<table>
<thead>
<tr>
<th>CARD</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>*22-24</td>
<td>G3.0</td>
<td>FACT1</td>
<td>Factor to adjust value of drawdown printed.†</td>
</tr>
<tr>
<td></td>
<td>*25-28</td>
<td>4I1</td>
<td>LEVEL1</td>
<td>Layers for which drawdown maps are to be printed. List the layers starting in column 41; the first zero entry terminates the printing of drawdown maps.</td>
</tr>
<tr>
<td></td>
<td>*29-31</td>
<td>G3.0</td>
<td>FACT2</td>
<td>Factor to adjust value of head printed.</td>
</tr>
<tr>
<td></td>
<td>*32-35</td>
<td>4I1</td>
<td>LEVEL2</td>
<td>Layers for which head maps are to be printed.</td>
</tr>
<tr>
<td></td>
<td>*36-38</td>
<td>G3.0</td>
<td>FACT3</td>
<td>Factor to adjust value of head difference printed.</td>
</tr>
<tr>
<td></td>
<td>*39-42</td>
<td>4I1</td>
<td>LEVEL3</td>
<td>If map of head difference between water table and potentiometric surface is desired, put a 1 in column 39.</td>
</tr>
<tr>
<td></td>
<td>*43-45</td>
<td>G3.0</td>
<td>FACT 4</td>
<td>Factor to adjust value of recharge rate printed.</td>
</tr>
<tr>
<td></td>
<td>*46-49</td>
<td>4I1</td>
<td>LEVEL4</td>
<td>Layers for which maps of recharge rate are to be printed.</td>
</tr>
<tr>
<td></td>
<td>*50-52</td>
<td>G3.0</td>
<td>FACT5</td>
<td>Factor to adjust value of ET-runoff rate printed.</td>
</tr>
<tr>
<td></td>
<td>*53-56</td>
<td>4I1</td>
<td>LEVEL5</td>
<td>Layers for which maps of ET-runoff rate are to be printed.</td>
</tr>
<tr>
<td></td>
<td>*57-59</td>
<td>G3.0</td>
<td>FACT6</td>
<td>Factor to adjust value of leakage rate printed.</td>
</tr>
<tr>
<td></td>
<td>*60-63</td>
<td>4I1</td>
<td>LEVEL6</td>
<td>If map of leakage rate through the upper confining bed is desired, put a 1 in column 60.</td>
</tr>
<tr>
<td></td>
<td>*64-64</td>
<td>G3.0</td>
<td>FACT7</td>
<td>Factor to adjust value of pumping rate printed.</td>
</tr>
<tr>
<td></td>
<td>*67-70</td>
<td>4I1</td>
<td>LEVEL7</td>
<td>Layers for which maps of pumping rate are to be printed.</td>
</tr>
<tr>
<td></td>
<td>*76-80</td>
<td>A5</td>
<td>MESUR</td>
<td>Name of map length unit.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value of drawdown or head</th>
<th>FACT1 or</th>
<th>Printed value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FACT2</td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>52.57</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>526</td>
<td></td>
</tr>
<tr>
<td>100.0</td>
<td>†††</td>
<td></td>
</tr>
</tbody>
</table>

†Value of drawdown or head.
### Parameters in which elapsed time and cumulative volumes for mass balance are stored.

For the start of a simulation, insert three blank cards. For continuation of a previous run using cards as input, replace the three blank cards with the first three cards of punched output from the previous run. Using data from disk for input, leave the three blank cards in the data deck.

### Group III: Array Data

Each of the following data sets (except data set 1) consists of a parameter card and, if the data set contains variable data, a set of data cards for each layer in the model. Each parameter card contains at least five variables.

<table>
<thead>
<tr>
<th>CARD</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1-20</td>
<td>G20.10</td>
<td>SUM</td>
<td></td>
</tr>
<tr>
<td>21-40</td>
<td>G20.10</td>
<td>SUMP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-60</td>
<td>G20.10</td>
<td>PUMPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>61-80</td>
<td>G20.10</td>
<td>CFLUXT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1-20</td>
<td>G20.10</td>
<td>QRET</td>
<td></td>
</tr>
<tr>
<td>21-40</td>
<td>G20.10</td>
<td>CHST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-60</td>
<td>G20.10</td>
<td>CHDT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>61-80</td>
<td>G20.10</td>
<td>FLUXT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1-20</td>
<td>G20.10</td>
<td>STORT</td>
<td></td>
</tr>
<tr>
<td>21-40</td>
<td>G20.10</td>
<td>ETFLXT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-60</td>
<td>G20.10</td>
<td>FLXNT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **FAC**: Multiplication factor for transmissivity in x direction.
- **IVAR**: = 0 if no data cards are to be read for this layer, = 1 if data cards for this layer follow.
- **IPRN**: = 0 if input data for this layer are to be printed, = 1 if input data for the layer are not to be printed.
- **FACT(K,1)**: Multiplication factor for transmissivity in x direction.
- **FACT(K,2)**: Multiplication factor for transmissivity in the y direction.
- **FACT(K,3)**: Multiplication factor for hydraulic conductivity in the z direction. (Not used when confining bed nodes are eliminated and TK values are read.)
When data cards are included, start each row on a new card. To prepare a set of data cards for an array that is a function of space, the general procedure is to overlay the finite-difference grid on a contoured map of the parameter and record the average value of the parameter for each finite-difference block on coding forms according to the appropriate format. In general, record only significant digits and no decimal points (except for data set 2); use the multiplication factor to convert the data to their appropriate values. For example, if DELX ranges from 1000 to 15000 feet, coded values should range from 1-15; the multiplication factor (FAC) would be 1000.

<table>
<thead>
<tr>
<th>DATA SET</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-80</td>
<td>8F 10.4</td>
<td>PHI(I,J,K)</td>
<td>Head values for continuation of a previous run (L).</td>
</tr>
<tr>
<td>2</td>
<td>1-80</td>
<td>8F 10.4</td>
<td>STRT(I,J,K)</td>
<td>Starting head matrix (L).</td>
</tr>
<tr>
<td>3</td>
<td>1-80</td>
<td>20F 4.0</td>
<td>S(I,J,K)</td>
<td>Storage coefficient (dimensionless).</td>
</tr>
<tr>
<td>4</td>
<td>1-80</td>
<td>20F 4.0</td>
<td>T(I,J,K)</td>
<td>Transmissivity (L^2/T).</td>
</tr>
<tr>
<td>5</td>
<td>1-80</td>
<td>20F 4.0</td>
<td>TK(I,J,K)</td>
<td>Leakance coefficient [(L/T)/L].</td>
</tr>
<tr>
<td>6</td>
<td>1-80</td>
<td>20F 4.0</td>
<td>PERM(I,J)</td>
<td>Hydraulic conductivity (L/T) (see note 1 for data set 4).</td>
</tr>
<tr>
<td>7</td>
<td>1-80</td>
<td>20F 4.0</td>
<td>BOTTOM(I,J)</td>
<td>Altitude of bottom of water-table unit (L).</td>
</tr>
</tbody>
</table>

Note: For a new simulation, this data set is omitted. Do not include a parameter card with this data set.

Note: Code in HCF potentiometric head in nodes just outside model-grid boundary.

Note: This matrix is also used to locate constant head boundaries by coding a negative number at constant head nodes. At these nodes, T must be greater than zero.

Note (1): Zero values are required around the perimeter of the T matrix for each layer for reasons inherent in the computation scheme. This is done automatically by the program.

Note (2): See the previous page for the additional requirements on the parameter cards for this data set.

Note (3): If the upper active layer is unconfined and PERM and BOTTOM are to be read for this layer, insert a parameter card for this layer with only the values for FACT on it.

Note: This data set is read only if specified in the options. The number of layers of TK values = K' - 1.

Note: Data sets 6 and 7 are required only for simulating unconfined conditions in the upper hydrologic unit.
<table>
<thead>
<tr>
<th>DATA SET</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1-80</td>
<td>20F 4.0</td>
<td>QRE(I,J)</td>
<td>Recharge rate (L/T).</td>
</tr>
<tr>
<td>9</td>
<td>*1-80</td>
<td>20F 4.0</td>
<td>CSS(I,J,1)</td>
<td>HCF condition leakage factor for layer 1 (\frac{(L/T)}{L}).</td>
</tr>
<tr>
<td>10</td>
<td>*1-80</td>
<td>20F 4.0</td>
<td>CSS(I,J,2)</td>
<td>Maximum ET-runoff capture rate divided by maximum ET-runoff capture depth for layer 2 (\frac{(L/T)}{L}).</td>
</tr>
<tr>
<td>11</td>
<td>*1-80</td>
<td>20F 4.0</td>
<td>HSS(I,J,1)</td>
<td>HCF condition head factor for layer 1 (L).</td>
</tr>
<tr>
<td>12</td>
<td>*1-80</td>
<td>20F 4.0</td>
<td>HSS(I,J,2)</td>
<td>Altitude of the bottom of the ET-runoff capture zone for layer 2 (L).</td>
</tr>
<tr>
<td>13</td>
<td>*1-80</td>
<td>20F 4.0</td>
<td>HB(I,J,1)</td>
<td>Blank card.</td>
</tr>
<tr>
<td>14</td>
<td>*1-80</td>
<td>20F 4.0</td>
<td>HB(I,J,2)</td>
<td>Altitude of land surface (L).</td>
</tr>
<tr>
<td>15</td>
<td>1-80</td>
<td>8G10.0</td>
<td>DELX(J)</td>
<td>Grid spacing in x direction (L).</td>
</tr>
<tr>
<td>16</td>
<td>1-80</td>
<td>8G10.0</td>
<td>DELY(I)</td>
<td>Grid spacing in y direction (L).</td>
</tr>
<tr>
<td>17</td>
<td>1-80</td>
<td>8G10.0</td>
<td>DELZ(K)</td>
<td>Grid spacing in z direction (L).</td>
</tr>
</tbody>
</table>

Group IV: Parameters That Change with the Pumping Period

The program has two options for the simulation period:

1. To simulate a given number of time steps, set TMAX to a value larger than the expected simulation period. The program will use NUMT, CDLT, and DELT as coded.

2. To simulate a given pumping period, set NUMT larger than the number required for the simulation period (for example, 100). The program will compute the exact DELT (which will be \(\leq\)DELT coded) and NUMT to arrive exactly at TMAX on the last time step.

<table>
<thead>
<tr>
<th>CARD</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>G10.0</td>
<td>KP</td>
<td>Number of the pumping period.</td>
</tr>
<tr>
<td></td>
<td>11-20</td>
<td>G10.0</td>
<td>KPM1</td>
<td>Number of the previous pumping period.</td>
</tr>
</tbody>
</table>

**Note:** KPM1 is currently not used.

| 21-30 | G10.0 | NWEL | Number of wells for this pumping period. |
| 31-40 | G10.0 | TMAX | Number of days in this pumping period. |
| 41-50 | G10.0 | NUMT | Number of time steps. |
| 51-60 | G10.0 | CDLT | Multiplying factor for DELT. |

**Note:** 1.5 is commonly used.

| 61-70 | G10.0 | DELT | Initial time step in hours. |

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If NWEL = 0, the following set of cards is omitted.

<table>
<thead>
<tr>
<th>DATA SET</th>
<th>COLUMNS</th>
<th>FORMAT</th>
<th>VARIABLE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (NWEL cards)</td>
<td>1-10</td>
<td>G10.0</td>
<td>K</td>
<td>Layer in which well is located.</td>
</tr>
<tr>
<td></td>
<td>11-20</td>
<td>G10.0</td>
<td>I</td>
<td>Row location of well.</td>
</tr>
<tr>
<td></td>
<td>21-30</td>
<td>G10.0</td>
<td>J</td>
<td>Column location of well.</td>
</tr>
<tr>
<td></td>
<td>31-40</td>
<td>G10.0</td>
<td>WELL(I,J,K)</td>
<td>Pumping rate (\text{L}^3/\text{T}), negative for a pumping well.</td>
</tr>
</tbody>
</table>

**Note:** Radius is required only for those wells, if any, where computation of drawdown at a real well radius is to be made.
The sample input data deck contains 1,097 cards. Each card is keyed to the data-deck instructions (Attachment B) by group number, card number, and variable name.

There are four groups of cards in the data deck:

Group I. This group contains data that dimensions the model into a 34 x 36 array and provides several job-control options, including the HCF condition.

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

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

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

Normally, Groups I, II, and III remain unchanged from the calibrated model. To determine the effects of pumping stresses on the system, Group IV is the only group in which cards are changed.
## ATTACHMENT C: SAMPLE INPUT DATA DECK FOR WELL-FIELD PUMPAGE PROBLEM

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<th>VARIABLE</th>
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<td>HEADING</td>
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<td>PUMP ALL WELL FIELDS AT PERMITTED AVG./RECHARGE AVG.</td>
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<td>2</td>
<td>HEADING</td>
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<td>DRAW HEAD MASS</td>
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<td>PUMP ITKR</td>
<td>4</td>
<td>112</td>
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| 5280 | 5280 | 2 | 112 | 12 | 12 | 11 | -101 | MILES |

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</table>
The sample model printout lists only the pumpage data because it is assumed that all other input arrays will be unchanged for predictive runs. Also listed is a mass balance for the system with helpful statistics. The distributions of drawdown, hydraulic head, head difference, recharge, evapotranspiration, leakage, and pumpage comprise a series of useful maps. In addition to the printout, the model punches cards containing drawdown and hydraulic head.
ATTACHMENT D: SAMPLE MODEL OUTPUT FOR WELL-FIELD PUMPAGE FIELD PROBLEM

NORTH TAMPA WELL-FIELD AREAS QUASI 3-DIMENSIONAL MODEL (FL-33200)

PUMP ALL WELL FIELDS AT PERMITTED AVG, RECHARGE AVG

NUMBER OF ROWS = 34
NUMBER OF COLUMNS = 36
NUMBER OF LAYERS = 2
MAXIMUM PERMITTED NUMBER OF ITERATIONS = 100
NUMBER OF CONSTANT HEAD NODES = 118

SIMULATION OPTIONS: DRAW HEAD MASS
WATE RECH PUN2 ITKR

WORDS OF VECTOR Y USED = 50872

NUMBER OF PUMPING PERIODS = 1
TIME STEPS BETWEEN PRINTOUTS = 1
ERROR CRITERIA FOR CLOSURE = .1000000E01

BETA = 1.00

ON ALPHAMERIC MAP:
MULTIPLICATION FACTOR FOR X DIMENSION = 5280.000
MULTIPLICATION FACTOR FOR Y DIMENSION = 5280.000
MAP SCALE IN UNITS OF MILES
NUMBER OF MILES PER INCH = 2.000000
MULTIPLICATION FACTOR FOR DRAWDOWN = 1.000000
MULTIPLICATION FACTOR FOR HEAD = 1.000000
MULT FACTOR FOR HEAD DIFFERENC = 1.000000
MULTIPLICATION FACTOR FOR RECH = 1.000000
MULTIPLICATION FACT FOR ET-RUNOFF = 1.000000
MULTIPLICATION FACT FOR LEAKAGE = 1.000000
MULTIPLICATION FACT FOR PUMPAGE = -10.000000
PRINTED FOR LAYERS 1 2 0 0
PRINTED FOR LAYERS 1 2 0 0
PRINTED FOR LAYERS 1 0 0 C
PRINTED FOR LAYERS 2 0 0 0
PRINTED FOR LAYERS 2 0 0 0
PRINTED FOR LAYERS 1 0 0 C
PRINTED FOR LAYERS 1 0 0 C

STORAGE COEFFICIENT = .0

DIRECTIONAL TRANSMISSIVITY MULTIPLICATION FACTORS FOR LAYER 1
X = 1.000000
Y = 1.000000
Z = .0

TRANSMISSIVITY = .0

DIRECTIONAL TRANSMISSIVITY MULTIPLICATION FACTORS FOR LAYER 2
X = 1.000000
Y = 1.000000
Z = .0

RECHARGE RATE = .0

ET-RUNOFF/DEPTH = .1020000E07

LAND SURFACE = .0

DELX = 5280.000
DELY = 5280.000
DELZ = 1.000000
SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

PUMPING PERIOD NO. 1: 1.00 DAYS

NUMBER OF TIME STEPS= 1
DELT IN HOURS = 24.000
MULTIPLIER FOR DELT = 1.000

53 WELLS

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SIZE OF TIME STEP IN SECONDS = 86400.00

TOTAL SIMULATION TIME IN SECONDS = 86400.00

MINUTES = 1440.00

HOURS = 24.00

DAYS = 1.00

YEARS = 0.00

DURATION OF CURRENT PUMPING PERIOD IN DAYS = 1.00

YEARS = 0.00

CUMULATIVE MASS BALANCE:

L**3

RATES FOR THIS TIME STEP:

L**3/T

SOURCES:

---

STORAGE = 0.0

RECHARGE = 130152846.0

CONSTANT FLUX = 0.0

CONSTANT HEAD = 7171670.00

LEAKAGE = 7066848.00

TOTAL SOURCES = 144391376.0

DISCHARGES:

---

ET-RUNOFF = 84067936.0

CONSTANT HEAD = 1086423.00

QUANTITY PUMPED = 25038592.0

LEAKAGE = 34199408.0

TOTAL DISCHARGE = 144392352.0

DISCHARGE-SOURCES = 976.00

PER CENT DIFFERENCE = 0.00

AVG ABS CHG MAX DDN MAX RISE AVG T (GPD/FT) MAX T MIN T ACTIVE NODES

LAYER 1 3.6 11.4% 23.2 (15.29) 0.0 (0, 0) 624853. 3554809. 193899. 932. 932.

LAYER 2 1.3 3.8% 14.9 (8.26) 0.0 (0, 0) 1407. 2958. 226. 814. 814.

AVG RECHG (IN/YR) AVG POS RECHG NO. POS NODES AVG NEG RECHG NO. NEG NODES MAX RECHG MAX DISCHG

LAYER 2 25.1 25.1 814. 0.0 0. 30.8 0.0

TIME STEP : 1

-----

ITERATIONS: 38

---
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| 0 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 8 | 11 | 17 | 15 | 10 | 8 | 6 | 5 | 4 | 3 | 3 | 2 | 2 | 1 |
| 0 | 1 | 1 | 2 | 2 | 3 | 4 | 6 | 8 | 10 | 9 | 8 | 7 | 6 | 4 | 4 | 3 | 2 | 2 | 1 |

1 1 1 2 2 3 4 5 6 6 6 6 5 4 3 2 2 1 1
1 1 1 2 2 3 4 4 4 4 4 4 3 3 3 3 3 3 3 3 3 3
1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

0.0 2.67 5.33 8.00 10.67 13.33 16.00 18.67 21.33 24.00 26.67 29.33 32.00

**DISTANCE FROM ORIGIN IN Y DIRECTION, IN MILES**

**EXPLANATION**

- *R* = CONSTANT HEAD BOUNDARY
- *** = VALUE EXCEEDED 3 FIGURES
- MULTIPLICATION FACTOR = 1.000
**DRAWDOWN IN SURFICIAL AQUIFER, FEET**

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### EXPLANATION

- **R** = Constant Head Boundary
- ******* = Value exceeded 3 figures
- **Multiplication Factor** = 1.000

---

**Distance from Origin in Y Direction, in Miles**

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## ALTITUDE OF POTENTIOMETRIC SURFACE OF THE FLORIDAN AQUIFER, FEET

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<tr>
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Note: The table lists the altitude of the potentiometric surface of the Floridan Aquifer at various distances in miles.

X Distance In Miles: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

Altitude of Potentiometric Surface of the Floridan Aquifer, Feet: 34.67, 32.00, 29.33, 26.67, 24.00, 21.33, 18.67, 16.00, 13.33, 10.67, 8.00, 5.33, 2.67, 0.00
EXPLANATION

R = CONSTANT HEAD BOUNDARY
*** = VALUE EXCEEDED 3 FIGURES
MULTIPLICATION FACTOR = 1.000
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</table>

**EXPLANATION**

- **R** = CONSTANT HEAD BOUNDARY
- ******* = VALUE EXCEEDED 3 FIGURES
- **MULTIPLICATION FACTOR** = **1.000**
|    | 74 | 114107 | 71 | 77 | 47 | 40 | 43 | 48 | 41 | 34 | 26 | 15 | 11 | 8 | 9 | 25 | 32 | 24 | 23 | 25 | 16 | 10 | 7 | 8 | 6 | 2 | 3 | 7 | 11 | 11 | 9 |
|----|----|--------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    | 81 | 90 | 89 | 77 | 69 | 66 | 68 | 45 | 56 | 44 | 20 | 21 | 12 | 11 | 15 | 19 | 24 | 22 | 17 | 13 | 12 | 9 | 7 | 9 | 6 | 7 | 3 | 5 | 11 | 10 | 10 |
|    | 70 | 94 | 74 | 49 | 31 | 34 | 53 | 38 | 23 | 51 | 17 | 10 | 11 | 11 | 13 | 19 | 23 | 27 | 24 | 15 | 15 | 12 | 7 | 7 | 7 | 1 | 7 | -5 | -1 | 8 | 11 | 12 |
|    | 44 | 42 | 43 | 23 | 15 | 21 | 24 | 23 | 16 | 23 | 17 | 8 | 7 | 9 | 2 | 10 | 23 | 24 | 18 | 14 | 15 | 14 | 11 | 10 | 6 | 1 | 7 | 8 | -1 | 0 | 3 | 13 |
|    | 41 | 49 | 39 | 20 | 13 | 14 | 11 | 7 | 7 | 4 | 4 | 5 | 11 | 4 | 2 | 1 | 15 | 18 | 16 | 14 | 11 | 13 | 9 | 8 | 4 | 6 | 5 | 7 | 7 | 6 | 1 | 8 |
|    | 24 | 24 | 19 | 15 | 14 | 16 | 12 | 6 | 5 | 3 | 3 | 5 | 10 | 9 | 7 | 3 | 2 | 5 | 12 | 9 | 7 | 6 | 9 | 8 | 7 | 6 | 2 | 5 | 7 | 7 | 4 | 6 |
|    | 20 | 21 | 18 | 17 | 11 | 14 | 9 | 8 | 5 | 4 | 4 | 6 | 10 | 14 | 10 | 6 | 6 | 7 | 9 | 2 | 4 | 3 | 2 | 6 | 9 | 5 | 5 | -5 | 0 | 5 | 7 | 12 | 5 |
|    | 18 | 18 | 16 | 12 | 10 | 9 | 9 | 9 | 6 | 4 | 4 | 7 | 8 | 9 | 11 | 7 | 4 | 5 | 4 | 3 | 3 | 1 | 4 | 7 | 7 | 7 | 5 | 1 | 6 | 5 | 20 | 22 |
|    | 18 | 17 | 14 | 10 | 9 | 7 | 9 | 9 | 7 | 5 | 4 | 4 | 6 | 0 | 3 | 1 | 2 | 0 | 1 | 2 | 3 | 3 | 2 | 0 | 4 | 8 | 8 | 2 | 6 | 10 | 13 | 25 |
|    | 16 | 15 | 13 | 10 | 10 | 9 | 9 | 9 | 9 | 5 | 5 | 5 | 5 | 4 | 5 | -2 | 3 | -3 | 3 | -6 | -6 | 6 | 6 | 6 | 7 | 0 | 5 | 6 | 2 | -4 | 14 | 13 | 20 |
|    | 15 | 15 | 12 | 10 | 10 | 9 | 9 | 9 | 8 | 5 | 5 | 4 | 3 | 4 | 4 | 4 | 6 | 8 | -7 | -8 | 4 | 6 | 4 | 0 | 2 | 1 | 1 | -2 | 6 | 13 | 15 |
|    | 14 | 14 | 12 | 10 | 12 | 6 | 8 | 6 | 6 | 7 | 5 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 1 | -9 | -9 | -2 | 1 | 4 | 1 | -2 | 0 | 10 | 11 |
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|    | 5 | 11 | 7 | 9 | 10 | 9 | 4 | 3 | 3 | 4 | 4 | 4 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 3 | -5 | 3 | 2 | 5 | 15 | 13 | 8 |
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|    | 12 | 5 | 6 | 6 | 5 | 6 | 4 | 4 | 3 | 4 | 6 | 5 | 5 | 8 | 10 | 9 | 6 | 7 | 6 | 5 | 7 | 7 | 5 | 5 | 9 | 11 | 13 | 16 | 10 | 6 |
|    | 7 | 8 | 3 | 4 | 4 | 5 | 3 | 3 | 4 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 4 | 8 | 11 | 11 | 9 | 12 | 9 | 9 | 7 | 6 | 6 | 11 | 8 | 1 | 4 | 1 |
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|    | -1 | 2 | -1 | 0 | 0 | 1 | 2 | 3 | 1 | 1 | 3 | 6 | 4 | 2 | 6 | 7 | 11 | 12 | 12 | 20 | 19 | 15 | 13 | 14 | 13 | 9 | 10 | 13 | 18 |
|    | -1 | 2 | -1 | 3 | 0 | 1 | 2 | 3 | 2 | 3 | 3 | 7 | 2 | 4 | 9 | 8 | 9 | 9 | 8 | 9 | 15 | 14 | 17 | 11 | 8 | 7 | 8 | 8 | 10 |
|    | -2 | -3 | -1 | 3 | 0 | 2 | 1 | 1 | 1 | 7 | 2 | 7 | 9 | 10 | 12 | 11 | 11 | 11 | 13 | 16 | 13 | 12 | 9 | 6 | 6 | 9 |

**Head Difference (Water Table Minus Potentiometric Surface) - Feet**

**Distance in MILES**

- 18.67
- 16.00
- 13.33
- 10.67

Page 14
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<th>2.67</th>
<th>5.33</th>
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DISTANCE FROM ORIGIN IN Y DIRECTION, IN MILES
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<tr>
<th>Distance in Miles</th>
<th>Rate of Recharge to Surficial Aquifer, Inches per Year</th>
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<td>13.33</td>
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<td>31.00</td>
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</table>

Note: The table provides a grid of numbers, likely representing data points or values pertaining to the rate of recharge to a surficial aquifer, with distances in miles and corresponding rates of recharge in inches per year.
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</tbody>
</table>
DISTANCE FROM ORIGIN IN Y DIRECTION, IN MILES

0.0  2.67  5.33  8.00  10.67  13.33  16.00  18.67  21.33  24.00  26.67  29.33  32.00

8.00  5.33  2.67  0.0'
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**Page 30**
Model-interrogation runs were made to evaluate well-field interference that may result from pumping all 10 well fields simultaneously. This involved separate simulations of drawdown at each well field for comparison with drawdown due to pumping all 10 well fields. Although not included in the main report, these separate simulations may be useful to water managers and planners. Figures 25-34 map the extent of cones of depression in the water table and Floridan aquifer as simulated by the model under average recharge conditions with pumping fixed at annual average permitted rates.

Three-dimensional graphical representations of the water table and potentiometric surface under predevelopment and pumping conditions were made using SAS/GRAPH (figs. 35-40). Although not useful technically, the plots exhibit depth perspective that cannot be perceived from contour maps. The plots clearly show cones of depression around the well fields and clearly indicate areas where well-field interference should occur. From a management standpoint, the graphical plots certainly simplify the conveyance of technical data to the general public.
Figure 25.—Model-simulated drawdown at Cross Bar Ranch well field.
Figure 26.—Model-simulated drawdown at Cypress Creek well field.
Figure 27.—Model-simulated drawdown at Starkey well field.
Figure 28.—Model-simulated drawdown at Pasco County well field.
Figure 29.—Model-simulated drawdown at Eldridge-Wilde well field.
Figure 30.—Model-simulated drawdown at East Lake well field.
Figure 31.—Model-simulated drawdown at Cosme well field.
Figure 32.—Model-simulated drawdown at Section 21 well field.
Figure 33.—Model-simulated drawdown at Morris Bridge well field.
Figure 34.—Model-simulated drawdown at Northwest well field.
Figure 35.—Water table in the surficial aquifer under nonpumping conditions.
PUMPING WATER TABLE
PUMP TEN WELL FIELDS AT 186.9 MGAL/D, RECHARGE IS AVERAGE

WELL-FIELD AREA AND NUMBER

1. Cross Bar Ranch
2. Cypress Creek
3. Starkey
4. Pace County
5. Eldridge-Wilde
6. East Lake
7. Cosme
8. Section 21
9. Merrie Bridge
10. Northwest

Figure 36.--Water table in the surficial aquifer under pumping conditions.
Figure 37.—Potentiometric surface of the Floridan aquifer under nonpumping conditions.
Figure 38.—Potentiometric surface of the Floridan aquifer under pumping conditions.
Figure 39.--Drawdown in the water table in the surficial aquifer under pumping conditions.
Figure 40.--Drawdown in the potentiometric surface of the Floridan aquifer under pumping conditions.