Digital Models of Ground-Water Flow in the Cape Cod Aquifer System, Massachusetts

WATER RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 80-67

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
COMMONWEALTH OF MASSACHUSETTS, WATER RESOURCES COMMISSION,
BARNSTABLE COUNTY, AND THE NATIONAL PARK SERVICE

DIGITAL MODELS OF GROUND-WATER FLOW IN THE
CAPE COD AQUIFER SYSTEM, MASSACHUSETTS

By John H. Guswa and Denis R. LeBlanc

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations

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UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information, write to:

U.S. Geological Survey
150 Causeway Street, Suite 1001
Boston, MA 02114

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FACTORS FOR CONVERTING INCH-POUND UNITS
TO INTERNATIONAL SYSTEM OF UNITS (SI)

The following factors can be used to convert inch-pound units to International System of Units (SI).

Multiply inch-pound units	By	To obtain SI Units
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per day per foot $\frac{[(ft/d)/ft]}{}$	0.3048	meter per day per meter $\frac{[(m/d)/m]}{}$
square foot per day (ft ² /d)	9.290×10^{-2}	square meter per day (m ² /d)
cubic foot per second (ft ³ /s)	2.832×10^{-2}	cubic meter per second (m ³ /s)
inch (in)	2.54	centimeter (cm)
inch per year (in/year)	2.54	centimeter per year (cm/year)
mile (mi)	1.609	kilometer (km)
gallon per minute (gal/min)	6.310×10^{-2}	liter per second (L/s)
ohm-foot	0.3048	ohm-meter

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level." NGVD of 1929 is referred to as sea level in this report.

DIGITAL MODELS OF GROUND-WATER FLOW IN THE CAPE COD AQUIFER SYSTEM, MASSACHUSETTS

By John H. Guswa and Denis R. LeBlanc

ABSTRACT

The Cape Cod aquifer system was simulated with three-dimensional finite-difference ground-water-flow models. Five areas were modeled to provide tools that can be used to evaluate the hydrologic impacts of regional water development and waste disposal.

The model boundaries were selected to represent the natural hydrologic boundaries of the aquifer. The boundary between fresh and saline ground water is treated as an interface along which there is no dispersion. The saline-water zone is treated as static (nonflowing).

Comparisons of calculated and observed values of head, position of the boundary between fresh and saline water, and ground-water discharge at locations where data are available indicate that the simulated ground-water reservoirs generally agree with field conditions.

Model analyses indicate that the total steady-state freshwater-flow rate through the five modeled areas is approximately 412 cubic feet per second.

INTRODUCTION

Background

Ground water is the principal source of freshwater for Cape Cod, Massachusetts. The Cape is composed of unconsolidated glacial moraines and outwash plains that form a hook-shaped peninsula extending 40 miles into the ocean (fig. 1). It is separated from the mainland by a sea-level canal connecting Buzzards Bay and Cape Cod Bay. A lens-shaped reservoir of fresh ground water is maintained in dynamic equilibrium beneath the Cape by recharge from precipitation and discharge to the sea.

Increases in the number of year-round residents and summer vacationers have added to local and State government concern over increased water demands, deterioration of water quality, changes in water-table and pond levels, and ecologic changes caused by changes in salinity of brackish-water bodies.

Management of ground-water resources generally encounters several problems. Hydrologic properties of aquifers are fundamentally dependent on geology, and their determination is usually complex and expensive. Local stresses can have regional hydraulic effects on an aquifer. Ground-water movement is slow; therefore, the consequences of management decisions may not be noticed for decades. The results may then be, for all practical purposes, irreversible. Ground-water movement cannot be observed directly and must be inferred from indirect measurements and abstract mathematical reasoning.

Flow in an aquifer can be described analytically by differential equations. These equations will yield direct solutions; however, owing to the complexity of most aquifer systems, direct solutions are generally not feasible. Approximate solutions of the flow equations describing aquifers with spatial variation of hydrologic properties and stresses and irregular geometries can be obtained using numerical methods. The reliability of these numerical solutions is dependent upon the accuracy of the input data and the size of the aquifer element which the flow equations describe. The use of a digital computer to obtain a numerical solution is called modeling the aquifer by digital simulation.

Figure 1.-- Physical features of Cape Cod (from Oldale, 1977)

Purpose and Scope

The purpose of this report is to describe digital simulation models prepared as part of a 4-year study of the ground-water resources of Cape Cod in cooperation with the Massachusetts Water Resources Commission, Divisions of Water Resources and Water Pollution Control; Barnstable County; and the National Park Service.

This report describes the sources and types of data used in constructing five models, model calibration, and possible sources of inaccuracies of the results. The five modeled areas and their names are shown in figure 2.

The models provide information regarding the regional behavior of the aquifer system. Detailed analyses of local hydrologic conditions are beyond the scope of this study. The principles used to construct these models can be used to construct more detailed models of smaller areas if sufficient data are available.

HYDROGEOLOGY OF CAPE COD

Geologic Framework and Water-Bearing Characteristics

The bedrock that underlies Cape Cod is overlain by unconsolidated sediments of Pleistocene and Holocene age (Oldale, 1976). The bedrock surface is irregular and is not exposed. It ranges in altitude from 80 feet below sea level near the Cape Cod Canal to more than 900 feet below sea level near Provincetown (Oldale, 1969).

The Pleistocene sediments consist of unconsolidated sand, gravel, silt, clay, and till. They are part of the complex of end moraines and outwash plains of late Wisconsinan age that characterize coastal New York (Long Island), Rhode Island, and Massachusetts (Oldale, 1976).

Sandy till mixed with stratified sand, gravel, and silt forms the Buzzards Bay and Sandwich moraines (fig. 1). These moraines are low, broad north- and east-trending ridges of moderately rugged topography. East of the Bass River, the east-trending Sandwich moraine deposits are buried by outwash-plain deposits.

Extreme lithologic variation over short distances and depths to water generally greater than 30 feet have discouraged exploration for water supply in the moraine areas. Projected yields of 4.5 ft³/s (2000 gal/min) have been reported (Thomas Mullen, Water Superintendent, Barnstable Fire District, oral commun., 1977) for 24-inch diameter gravel-packed wells screened in sand and gravel in the moraine area of Barnstable. Wells drilled in similar nearby areas of the moraine, however, have penetrated silt and clay layers which are several hundred feet thick and have been reported to be dry holes. The lack of test-hole information and the extreme lithologic variation in the moraine area does not permit stratigraphic correlation.

The western part of the outwash-plain deposits in Bourne, Sandwich, Falmouth, Mashpee, and western Barnstable is composed primarily of stratified sand and gravel but has local silt and clay layers. These deposits generally become finer grained with depth, especially to the south, where very fine sand, silt, and clay predominate below 100 feet in many places.

The eastern part of the outwash plain, in eastern Barnstable, Yarmouth, Dennis, Brewster, Harwich, Chatham, and Orleans, is composed of stratified sand and gravel which, in places, is mixed with till and ice-contact deposits, and silt and clay. The northern section of this part of the outwash plain is generally coarser grained than the southern section and is mixed with or overlies very coarse grained ice-contact deposits and till, especially in Yarmouth, Dennis, and Chatham. To the south, clay and silt layers are commonly interbedded with sand and gravel. Along Nantucket Sound, the eastern part of the outwash plain is underlain by a silt and clay deposit which is thicker than 150 feet in places. The silt and clay are reported to have been deposited in a lake that occupied the present site of eastern Nantucket Sound (Oldale, 1976).

The lithologic variation within the outwash plain deposits is not as extreme as within the moraine areas, and well yields range from 0.45 to 1.56 ft³/s (200 to 700 gal/min) or 0.05 to 0.16 ft³/s (20 to 70 gal/min) per foot of 24-inch diameter gravel-packed screen.

North of the Sandwich moraine are deposits of sand and gravel which, in some areas, grade northward into finer grained deposits (silt and clay). Results of test drilling along the southern shore of Cape Cod Bay (from the Cape Cod Canal to Brewster) indicate that silt and clay layers, in places more than 100 feet thick, are commonly interbedded with the sand and gravel beds.

Figure 2.-- Water-table map of Cape Cod, May 25-27, 1976, showing the freshwater-flow systems and the approximate boundaries of the modeled areas

These silt and clay deposits locally cause water to occur under confined conditions. At Corporation Beach in Dennis, a well drilled approximately 100 feet landward of the shoreline penetrated freshwater (chloride concentration less than 250 milligrams per liter) to bedrock at a depth of 316 feet. The head at this site was 5 feet higher below a 35-foot-thick silt and clay layer than the head above the layer; the silt and clay was penetrated from 78 feet to 113 feet below land surface.

From Orleans to Truro, the Cape is underlain by glacial outwash deposits consisting primarily of sand and gravel interbedded with silt and clay. Exposures of these deposits along the eastern shore of the outer Cape indicate that the silt and clay layers are contorted and discontinuous. Lack of well-log data precludes determining areal extent of the silt and clay layers. The only large-scale water-supply system developed in these deposits is in the town of Truro.

Holocene deposits include the salt marshes, beaches, spits, and dunes. They are composed of sand, silt, and clay. Few wells have been drilled in these deposits.

Hydraulic Properties of Sediments

The transmissivity of an aquifer may be estimated by multiplying a calculated or estimated hydraulic conductivity value by aquifer thickness. A more general method of calculating the transmissivity of an aquifer consisting of several hydrogeologic units is given by equation 1.

$$T = \sum_{i=1}^n K_i m_i \quad (1)$$

in which

- T is the transmissivity (L^2/T),
- K_i is the hydraulic conductivity of the i th hydrogeologic unit (L/T),
- m_i is the thickness of the i th hydrogeologic unit (L), and
- n is the number of hydrogeologic units within the specified aquifer thickness.

Analysis of Specific-Capacity Data

The hydraulic conductivities of different lithologies on Cape Cod were estimated by analyzing specific-capacity (well pumping rate/observed drawdown) data from 265 well-performance tests. The tested wells generally had short screens that tapped a small part of the total thickness of the aquifer. Within the screened interval, the lithology was generally consistent and could be identified.

The specific capacity of each well was converted to transmissivity for the screened interval using the nonsteady-flow equation for unconfined aquifers given by Theis (1963) and shown below:

$$T' = \frac{Q}{S} (K - 264 \log_{10} 5S + 264 \log_{10} t) \quad (2)$$

in which

- Q is the well discharge, in gallons per minute,
- s is the drawdown in the well, in feet,
- K is a factor equal to $-66 - 264 \log_{10} (3.74 r^2 \cdot 10^{-6})$,
- r is the radial distance to the well where the drawdown is observed, in feet,
- t is the length of the pumping period, in days,
- S is the aquifer specific yield (dimensionless), and
- T' is a value related to transmissivity by means of an equation given by Theis (1963, p. 332, equation 2), in gallons per day per foot.

The value of T' was converted to transmissivity, T , for the screened interval of the well by solving the relationship between T and T' presented by Theis:

$$T' = T - (264Q \log_{10}(T \cdot 10^{-5})) / s$$

The value of transmissivity for the screened interval was divided by the screened length of the well to obtain the average hydraulic conductivity of the screened interval.

The well-performance data and the calculated hydraulic conductivities were divided into groups according to the lithologic types reported for the screened intervals of the wells. The values within each group were averaged to obtain the estimated hydraulic conductivity for each type of material (table 1).

Table 1.—Estimates of average hydraulic conductivity for lithologic types calculated from specific-capacity data

Lithology	Number of samples	Hydraulic conductivity (ft/d)		
		Mean value	Standard deviation	Median value
Fine sand	34	450	310	440
Fine to medium sand	51	450	280	400
Medium sand	14	500	450	310
Medium to coarse sand	22	600	380	480
Coarse sand	11	430	220	400
Fine to coarse sand	42	580	290	520
All sand	174	500	310	400
Sand and gravel	16	630	430	420
Fine sand and gravel	48	530	370	420
Medium sand and gravel	9	740	460	730
Coarse sand and gravel	18	630	430	420
All sand and gravel	91	580	400	400

Because of the large deviation of values about the calculated means and because most of the available lithologic information did not have the same level of detail as shown in table 1, the sediment-type categories were grouped into larger classes, and average values were applied to each class (table 2).

Table 2.—Average hydraulic conductivity values for grouped lithologic types

Lithology	Hydraulic conductivity (ft/d)
Silt and (or) clay	1
Sand	450
Sand and gravel	500
Gravel	600

None of the wells were screened in silt, clay, or gravel only. The hydraulic conductivity of silt and clay is low relative to the other materials; therefore, a value of 1 ft/d was assigned. Gravel was assigned a hydraulic conductivity of 600 ft/d.

These values of hydraulic conductivity were applied by means of equation 1 to numerous locations on Cape Cod for which a lithologic log was available to determine transmissivities of selected zones of the aquifer. These zones correspond to different layers of the flow models and will be discussed in a later section.

During the process of estimating hydraulic conductivity from specific-capacity data, it was assumed that the storage coefficient was 0.2; well entrance losses were negligible; flow into the well was horizontal, radial, and uniform along the well screen; and the discharge was sustained by withdrawal from aquifer storage within the screened interval. Flow rates in these tests were generally low, and well-entrance losses were probably minimal. Errors generated by deviation from the remaining assumptions and by incorrect estimation of storage coefficient were assumed to be random and, therefore, would be minimized in the averaging process. These estimates of hydraulic conductivity may contain a small systematic error. The vertical span of the flow pattern toward the well screen would always exceed the screened interval of the well. This would cause the calculated values to be high.

The specific-capacity data and the lithologic information utilized in the hydraulic conductivity calculation were obtained from drillers' records. The method of specific-capacity testing varied from one driller to another, and the identification of lithologic type is somewhat subjective. The data, therefore, were of variable quality. The error due to the variable quality of the data probably is random and would be minimized in the averaging process.

Aquifer Test Analyses

Lateral hydraulic conductivity, the ratio between lateral and vertical hydraulic conductivity, and storage properties of the aquifer were also estimated from analysis of three aquifer tests. A 72-hour test in Truro, Massachusetts, on a well with a 70-foot screened interval (Guswa and Londquist, 1976) was used to estimate that the average lateral hydraulic conductivity for a predominantly very fine to coarse sand is approximately 220 ft/d. Analysis of 5-day tests in Orleans and Yarmouth, Massachusetts, indicated a lateral hydraulic conductivity of approximately 300 ft/d for a coarse to very coarse sand and very fine gravel with some medium sand, and 200 ft/d for a fine to medium sand.

Analysis of the Truro and Orleans aquifer-test data using a radial-flow model yielded a ratio of lateral to vertical hydraulic conductivity of less than 10:1. As no other field data were available, and as other studies (Getzen, 1977, p. 10; Meyer and others, 1975, p. 19) have indicated that this ratio is reasonable for glacial outwash material, the 10:1 ratio was applied to each lithologic type.

There are no reliable data available for the vertical hydraulic conductivity of the silt and clay lenses which are scattered throughout the Cape Cod aquifer system. A value of 0.1 ft/d, which is similar to that used in the analog-model analyses of ground-water flow on Long Island (Getzen, 1977) was used for these beds.

Field data for storage coefficients of the Cape Cod aquifer system are also meager. Palmer (1977, p. 45) reports a range of specific yield of 0.13 to 0.26. His values were based on analysis of aquifer tests in the Falmouth area. Analysis of the Truro (Guswa and Londquist, 1976) and Orleans aquifer-test data indicate a specific yield of between 0.10 and 0.15.

Hydrologic System

The Cape Cod aquifer system is the freshwater-saturated sediments through which water moves. The boundaries of this system are the water table, the saline surface-water boundaries, and either the bedrock surface (or other material of low hydraulic conductivity) or a boundary between fresh ground water and saline ground water.

The saline surface-water boundaries include the ocean, bays, streams, and marshes which are generally at a fixed elevation and serve as discharge boundaries for the ground-water-flow system. At several locations, these discharge boundaries extend sufficiently far inland to effectively subdivide the aquifer system into several nearly independent individual aquifers (fig. 2). Under existing hydrologic conditions, there is no flow between adjacent aquifers across the boundaries. Conditions of severe hydrologic stress may change the nature of these boundaries and cause water to flow between the individual aquifers.

Bedrock has a low hydraulic conductivity compared to the sand and gravel deposits that form the Cape and can be considered to be a no-flow boundary that is the bottom of the aquifer system. In some areas, particularly in Harwich and the southern portions of Dennis and Yarmouth, thick accumulations of silt and clay underlie the sand and gravel aquifer and overlie the bedrock (D. R. LeBlanc and J. H. Guswa, written commun., 1979). These sediments also have a low hydraulic conductivity and, where they directly overlie bedrock, their upper surface is considered to be the bottom of the aquifer system.

Fresh ground water is bounded by saline surface water at the shores of the ocean, Nantucket Sound, Buzzards Bay, Cape Cod Canal, and Cape Cod Bay (fig. 1) and by saline ground water at depth. Fresh ground water is slightly less dense than saline water and, therefore, "floats" as a lens-shaped body upon underlying saline water in the ground-water reservoir. The boundary between freshwater and saline water is a zone of mixing (or diffusion) of fresh and saline water. This mixing zone is the lower boundary of the aquifer system in those areas where it is above the bedrock surface or the thick silt and clay layers.

DIGITAL-SIMULATION MODEL

The purpose of the simulation model is to calculate the hydraulic head in an aquifer at specified locations under steady-flow conditions. This is achieved by solving the steady-state differential equation of ground-water flow, which requires that the hydraulic properties, boundaries, and inflow and outflow be defined for the modeled area.

A three-dimensional steady-state-flow model was chosen for this study because:

- (1) Existing hydrogeologic information and a previous study (Burns and others, 1975) indicated that the three-dimensional variability of the aquifer system had to be included in the analyses,
- (2) there were not sufficient long-term records of head and stress changes which could be used to calibrate a three-dimensional transient model, and
- (3) the approximation used to represent the boundary between fresh and saline ground water is valid only for equilibrium conditions.

Flow Equation

The differential equation describing three-dimensional steady-state flow in a porous medium is:

$$\frac{\partial}{\partial x} (K_{xx} \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y} (K_{yy} \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z} (K_{zz} \frac{\partial h}{\partial z}) = W(x, y, z) \quad (3)$$

in which

K_{xx}, K_{yy}, K_{zz} are the principal components of the hydraulic-conductivity tensor aligned with the principal Cartesian coordinate axes (L/T),

h is the hydraulic head (L), and

$W(x, y, z)$ is a volumetric flux per unit volume (l/T) and is referred to as a source term.

It is sometimes convenient to represent one or more hydrogeologic units as a single layer. If this is done, then equation 3 is multiplied by b , the saturated thickness of the layer, giving approximately:

$$\frac{\partial}{\partial x} (T_{xx} \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y} (T_{yy} \frac{\partial h}{\partial y}) + b \frac{\partial}{\partial z} (K_{zz} \frac{\partial h}{\partial z}) = bW(x, y, z) \quad (4)$$

in which

T_{xx}, T_{yy} are the principal components of the transmissivity tensor (L^2/T).

The source term $W(x,y,z)$ can include well discharge; recharge from precipitation or other sources such as septic tanks, sewage-treatment plants, and irrigation; and steady leakage into or out of the aquifer system through a stream, pond, marsh or ocean bottom.

In the model, this source term is computed as:

$$bW = \frac{Q_w}{\Delta x \Delta y} - Q_{re} - \frac{k_z}{m} (h_s - h) \quad (5)$$

in which

- Q_w is well discharge from a "block" or element of the aquifer (L^3/T),
- Δx is the length of the "block" in the x-direction (L),
- Δy is the length of the "block" in the y-direction (L),
- Q_{re} is aquifer recharge and is the volumetric flux per unit area of the uppermost hydrogeologic unit (L/T),
- k_z is the vertical hydraulic conductivity of the streambed or ocean bottom (L/T),
- m is the thickness of the streambed or ocean bottom (L),
- h_s is the hydraulic head in the streambed or ocean bottom (L), and
- h is the head in aquifer (L).

Direct solution of equation 4 is generally impossible, but a numerical solution of high accuracy can be obtained using a digital computer.

Numerical Method

To obtain a numerical solution, the partial differential equation is replaced by an approximating finite-difference equation (Trescott, 1975, and Trescott and Larson, 1976) and the aquifer is subdivided into discrete blocks. Each aquifer block has one finite-difference equation describing flow within it. This yields a set of finite-difference equations which must be solved simultaneously.

There are many procedures available for solving a large number of simultaneous equations. The one used in this study is the strongly implicit procedure (SIP) developed by Stone (1968). For a complete discussion of how the finite-difference equations are solved, see Trescott (1975) and Trescott and Larson (1976).

The computer code used in this study is a modification of the code developed by Trescott (1975). Input documentation and a source-code listing are included in the Supplemental Data section of this report.

APPLICATION OF SIMULATION MODEL

Model Specifications

Ground-water-flow models were developed for five areas of Cape Cod. The present flow pattern allowed construction of separate models for five of the six individual aquifers shown on figure 2. Limits of the modeled areas were selected to include or nearly coincide with the natural flow boundaries of the system. These lateral boundaries are discharge boundaries such as the seabed, streams, and marshes. They are modeled as specified-head seepage boundaries.

The modeled areas were subdivided into rectangular finite-difference grids with uniform horizontal spacing (figs. 3-7) and uneven vertical spacing. Table 3 summarizes the descriptive information for the individual finite-difference grids.

Figure 3. --Plan view of finite-difference grid for WCAPE model

Figure 4.-- Plan view of finite-difference grid for ECAPE model

EXPLANATION

- Specified-head boundary, layer 7
- Specified-head boundary, layer 6
- Area not modeled (all layers)

Figure 5.-- Plan view of finite-difference grid for ESTHM model

Figure 6. --Plan view of finite-difference grid for WLFLT model

0 1 2 MILES

EXPLANATION

- Specified-head boundary, layer 7
- Specified-head boundary, layer 6
- Specified-head boundary, layer 5
- Area not modeled (all layers)

E-E' Line of cross section for figure 19

Figure 7.-- Plan view of finite-difference grid for TRURO model

Table 3.—Descriptive information regarding finite-difference grids for modeled areas

Modeled area	Number of			Horizontal grid spacing (feet)	Elevation of bottom of layer (feet below sea level)						
	rows	columns	layers		Layer number						
					1	2	3	4	5	6	7
WCAPE	36	59	5	2640	400	240	140	70	20	--	--
ECAPE	25	37	5	2640	400	240	140	70	20	--	--
ESTHM	22	36	7	1320	600	450	300	200	110	50	10
WLFLT	26	32	7	1320	400	280	200	140	80	40	10
TRURO	20	26	7	1320	400	280	200	140	80	40	10

The layers of each model represent elevation horizons within the aquifer system. These horizons contain one or more hydrogeologic units. Aquifer properties and stresses are assumed to be uniform within any given block and must be defined at all nodes of the grid.

By convention, nodes are located at the centers of the blocks of the grid. Any specific node or block may be referenced by citing its row (i), column (j) and layer (k) location.

Water-Transmitting Properties of the Aquifer

At about 320 selected locations in the aquifer system, lithologic logs and the average values of hydraulic conductivity for the lithologic types in table 2 were used in equation 1 to calculate transmissivity values for layers of the model. An average, or equivalent, lateral hydraulic conductivity for each layer was also calculated using the relationship:

$$\bar{K} = \frac{\sum_{i=1}^n K_i m_i}{\sum_{i=1}^n m_i} \quad (6)$$

in which

$\bar{K}$ is the average lateral hydraulic conductivity (L/T),

K_i is the average lateral hydraulic conductivity of the i th hydrogeologic unit (L/T),

m_i is the thickness of the i th hydrogeologic unit (L), and

n is the number of hydrogeologic units which occur within a layer. The top of the uppermost layer coincides with the estimated position of the water table.

Maps of the spatial variation in transmissivity and lateral hydraulic conductivity were made for all layers and served as initial values of the water-transmitting properties of the aquifer.

Equivalent vertical hydraulic conductivities were also calculated from lithologic logs at the 320 locations. Darcy's Law and the analogy between flow in an aquifer and flow of electric current were used to calculate these values. One-dimensional steady-state flow through an aquifer prism can be defined by the following equation:

$$Q = KA \frac{\Delta h}{\Delta z} \quad (7)$$

in which

- Q is the rate of flow through the prism (L^3/T),
- K is the hydraulic conductivity of the aquifer in the direction of flow (L/T),
- A is the cross-sectional area of the prism (L^2),
- Δh is the head difference between two measuring points along the flow direction (L), and
- Δz is the length between the two measuring points (L).

The term $\frac{KA}{\Delta z}$ is analogous to electrical conductance (Prickett, 1975) and will be defined herein as hydraulic conductance, C . In a manner similar to calculating the equivalent electrical conductance when two or more conductors are connected in series, the equivalent vertical hydraulic conductance of a layered aquifer can be calculated using the relationship:

$$\frac{1}{C_{veq}} = \sum_{i=1}^n \frac{1}{C_{vi}} \quad (8)$$

in which

- C_{veq} is the equivalent vertical hydraulic conductance of an aquifer (L^2/T),
- C_{vi} is the vertical hydraulic conductance of the i th layer (L^2/T), and
- n is the number of layers of the aquifer.

As an example, figure 8 shows an aquifer that contains two layers.

Making the appropriate substitutions, equation 8 can be rewritten as:

$$\frac{\frac{1}{K_{veq} \cdot A}}{\Delta z_T} = \sum_{i=1}^n \frac{\frac{1}{K_{vi} \cdot A}}{\Delta z_i} \quad (9)$$

in which

- K_{veq} is the equivalent vertical hydraulic conductivity (L/T),
- A is the cross-sectional area of flow (L^2),
- Δz_T is the total thickness of the aquifer and is equal to $\sum_{i=1}^n \Delta z_i$ (L),
- K_{vi} is the vertical hydraulic conductivity of the i th layer (L/T), and
- Δz_i is the thickness of the i th layer (L).

Figure 8.-- Schematic representation of equivalent vertical hydraulic conductivity

Multiplying both sides of equation 9 by the constant A and rearranging terms yields:

$$K_{veq} = \Delta z_T \frac{1}{\sum_{i=1}^n \Delta z_i / K_{vi}} \quad (10)$$

which also can be written as:

$$K_{veq} = \frac{\sum_{i=1}^n \Delta z_i}{\sum_{i=1}^n \Delta z_i / K_{vi}} \quad (11)$$

Equivalent vertical hydraulic conductivity values for selected nodes were compared to the estimated lateral hydraulic conductivity values to determine a ratio between lateral and vertical hydraulic conductivity.

Using the lateral transmissivity, hydraulic conductivity, estimated ratio between lateral and vertical hydraulic conductivity, and thickness of each block, vertical flow coefficients (Trescott and Larson, 1976, p. X) were calculated.

During model calibration, it was necessary to adjust the initial estimates of transmissivity and lateral and vertical hydraulic conductivity. The final values used in the models are presented in the Supplemental Data section of this report.

Boundaries and Hydraulic Stresses

Well Discharge

Sites of known and significant well discharge within the study area were represented in the model by specifying a constant flux rate at the nodes representing the blocks which contain the wells. Well discharges are summarized in the Supplemental Data section of this report. These average withdrawal rates are based on actual pumpage for the years 1975 and 1976. The pumpage information was provided by the local water-service districts.

Boundary Between Fresh and Saline Water

The saline surface water which surrounds Cape Cod forms a surface boundary to the ground-water reservoir. The seabed is a specified-head boundary to the ground-water-flow system. The distribution of freshwater head along this boundary is a function of the saline-water depth and the density difference between freshwater and saline water. At the bottoms of the bays and the ocean, freshwater heads at the seabed-water interface must be equal to the equivalent freshwater head resulting from the saline surface-water column extending from the seabed to sea level. If the surface-water body is seawater, the resulting equivalent freshwater head above sea level is about 2.5 percent of the saline surface-water depth. It is proportionately less if the density of the surface-water body is less than the density of seawater. This equality of freshwater and saline-water head at the seabed must also exist at the boundary between fresh ground water and saline ground water if the boundary is a sharp interface, the saline ground water is static (nonflowing), dynamic equilibrium is to be maintained, and the only forces acting on the ground water are head gradients arising from gravitational forces (Hubbert, 1940). Figure 9 illustrates this relationship between fresh ground water and saline surface and ground water.

Figure 9.--Schematic hydrologic section of the seaward boundary of fresh ground-water flow. Along the seabed, freshwater heads must be equal to the equivalent freshwater head resulting from the saline surface water column extending from sea level to the seabed. Along the interface, freshwater head balances saline water head in the aquifer.

The seabed was modeled as a specified-head seepage boundary. The layers for which this boundary condition was specified were determined by comparing model layer elevations to the seabed elevation determined from bathymetric and topographic maps. The seabed elevation was specified as the source-bed bottom elevation. The equivalent freshwater head resulting from the density difference between freshwater and seawater was specified as the source-bed head. A leakance coefficient of 20 (ft/d)/ft was used. Sensitivity analyses indicate that changing this value by an order of magnitude has no significant effect on the calculated heads or flux rates. Provided sufficient precision is used in mass balance calculations, this is an acceptable way of approximating a constant-head condition (Trescott and others, 1976). Data on the spatial variability of vertical permeability and thickness of the seabed sediments can be easily incorporated into the models if they become available.

The boundary between fresh and saline ground water was modeled as an interface, and the saline-water zone was assumed to be static. This boundary is actually a zone of diffusion or mixing, but data collected concerning the thickness of this zone (LeBlanc and Guswa, written commun., 1979) suggest that it is narrow, and for the purposes of this study it can be treated as a sharp interface.

At specified iterations, the models calculate the position of this interface in accordance with the hydrodynamic model of Hubbert (1940). Starting with the bottom layer and proceeding through the grid in a systematic fashion, block transmissivity values are adjusted to reflect the percentage of the block thickness which is occupied by freshwater. For example, the transmissivity of a block in which only the upper 40 percent of the thickness contains freshwater is reduced to 40 percent of its original value. A block calculated to be wholly in the saline-water zone is assigned a transmissivity value of zero for the rest of the simulation. If a block contains partially or totally freshwater, then all blocks vertically above it are assumed to contain only freshwater. The vertical flow coefficients remain unchanged during a simulation unless the freshwater-saturated thickness of a block is determined to be zero. When this occurs, the coefficient describing flow between the block with zero freshwater thickness and the overlying block is set to zero. An identical adjustment for water-table conditions is described in Trescott and Larson (1976, p. XII).

The computational scheme requires that the starting head values be sufficiently large to define an interface position which is seaward of and deeper than the real interface position. During the iteration sequence, the calculated interface moves landward and upward until it is in balance with the freshwater-flow system.

Streams and Marshes

Many of the streams and marshes are significant boundaries to the freshwater-flow system. Their effect varies as a function of the head within the aquifer. They generally derive some or all of their flow from ground-water discharge or seepage, and at certain locations or times of the year may be a source of aquifer recharge. These boundaries were modeled as areas of specified head, separated from the aquifer by a streambed layer. The source-bed bottom elevation was defined to coincide with the altitude of the stream or marsh bottom, the source-bed head was set equal to the altitude of the stream or marsh surface, and a leakance coefficient of 20 (ft/d)/ft was used. This value might represent a 2-foot-thick sand layer.

Aquifer Recharge

Aquifer recharge is a combination of natural recharge from precipitation and artificial recharge from sources such as septic tanks and wastewater-treatment plants. LeBlanc and Guswa (written commun., 1979), using the Thornthwaite method (Thornthwaite and Mather, 1957), estimated the evapotranspiration for several locations on Cape Cod. This is an empirical determination and is based on analysis of climatological data. U.S. Weather Bureau data for 1947 to 1976 were used in the analysis. The calculated average evapotranspiration rate and the average precipitation rate for the same period were used to estimate an average rate of natural recharge. The rates obtained compare favorably with estimates of average natural recharge on Cape Cod made by Strahler (1972) and Palmer (1977). For each node in the top layer, this value was added to the estimated artificial recharge rate, where applicable, to obtain an average total recharge rate.

Estimated rates of artificial recharge were based on the assumption that artificial recharge occurs in those areas where the water disposal site is not in the same model block as the source of water supply. For example, the disposal lagoons of a wastewater-treatment plant and residential areas serviced by public water supply and onsite disposal systems were treated as areas of artificial recharge. No net artificial recharge or discharge was simulated in areas serviced by shallow domestic wells and onsite disposal systems.

The estimated artificial recharge rate was calculated on a town-by-town basis by making the assumptions that:

- (1) Those areas identified in the draft Cape Cod 208 Water Quality Management Plan (U.S. Environmental Protection Agency, 1978) as wastewater-management problem areas (U.S. Environmental Protection Agency, 1978, map 4.1) are areas of artificial recharge because they represent areas of high concentration of septic tanks and are serviced by public water supply, and
- (2) the rate of artificial recharge is uniform within these areas and proportional to the difference between the rate of withdrawal by the public water-supply system and any wastewater-treatment plant flow rates.

Another factor which influences the rates of aquifer recharge is the thickness of the unsaturated zone. Where the water table is close to land surface, more of the water that infiltrates the soil may be transpired by plants or evaporated. Consequently, a smaller portion of rainfall becomes a net addition to the ground-water reservoir in low-lying swampy areas than in areas with a thicker unsaturated zone. To approximate this effect for the WCAPE and ECAPE models, the calculated aquifer recharge was reduced proportionally (approximately 10 percent) in low-lying areas near the coast. The finer grid spacing of the ESTHM, WLFLT, and TRURO models allowed a closer approximation of the position of the streams and wetlands where the water table is close to land surface. These natural discharge areas were modeled as constant head zones. Consequently, net recharge rates did not have to be reduced.

Final recharge distributions used are presented in the Supplemental Data section of this report.

CALIBRATION OF THE STEADY-STATE FLOW MODELS

Purpose and Procedure

An important objective of calibrating the steady-state model is to improve the conceptual model of the aquifer. The conceptual model consists of an understanding of the physical and functional nature of the aquifer. This includes identifying sources of recharge and discharge, rates and direction of flow, variation of aquifer properties and hydraulic head, and the relation of the aquifer to surface water. The simulation model numerically integrates the effects of these factors. The computed results, therefore, are internally consistent with all input data, and one can determine if any element of the conceptual model must be revised. After initial best-estimates of the input data are made, model development is an evolutionary process in which results of previous simulations are interpreted to make modifications and adjustments to the model. The testing process of adjusting input data and comparing the calculated results to field observations (calibration) allows for a better understanding of the flow system and an improvement of the conceptual model.

To demonstrate that the flow models are reasonable, field observations must be closely correlated with model results. Field observations available for the Cape Cod aquifer system include observed water levels, position of the interface between fresh and saline ground water, and discharge measurements for selected stream segments. Based on records of water levels at selected long-term and short-term observation sites, LeBlanc and Guswa (written commun., 1979) prepared a map which shows the estimated average water table for the period from 1963 to 1976 and shows the interface position at several locations.

The calibration procedure minimizes differences between the observed and computed values by adjusting the input data (aquifer properties, boundary conditions, and hydraulic stresses). Because of the large number of interrelated factors affecting ground-water flow, this is a subjective procedure. The degree of allowable adjustment, however, of any parameter generally is directly related to the uncertainty of its value or specification. For example, withdrawal rates are well defined, and their values were not adjusted. Hydraulic conductivity and transmissivity, however, are generally imprecisely known because lithologic variation is usually not well defined and because the methods by which they are determined are subject to many limitations. During the calibration, these values were adjusted by as much as 20 percent for those areas where the variation of lithology was believed to be gradual. These areas generally, but not always, coincided with the outwash plains. For those areas of known extreme lithologic variation, particularly the moraine areas, the transmissivity and hydraulic conductivity values were adjusted by as much as a factor of ten.

Because the calibrated model is based on an interpretation of field observations, the accuracy of the model results is restricted by the accuracy of the interpretation. The water-table configuration and position of the interface between fresh and saline ground water are based on limited data. Approximately 150 sites for observation of water-table elevation; 27 sites for observation of head variation, chloride concentration, and specific conductance of ground water with depth; and two stream segment discharge measurements were used as control points for calibration of the models. If any major corrections, revisions, or additions are made to the data base, the models should be recalibrated to reflect a better knowledge of the aquifer system.

Results

WCAPE Model

For the WCAPE model the agreement between the observed average water levels and the calculated water levels under steady state conditions is shown in table 4 and on figure 10. Some of the disagreement, particularly in the higher elevations of the water table, is due to a lack of water-level and transmissivity information in the moraine area. Another reason for disagreement is that the observed average water level refers to the observation well location and the calculated water level refers to the center of the block which contains the well. Therefore, the discrepancy between the calculated and observed water levels is greatest where the hydraulic gradient is steep. This is common to all five models.

Figures 11 to 13 show calculated altitudes of the interface between fresh and saline ground water for selected cross sections (fig. 3). Measured chloride concentrations and a resistivity log of a test hole drilled in Mashpee are also included on figure 11. The resistivity measurement corresponding to the depth from which the lowermost sample in figure 11(a) was taken is approximately 750 ohm-meters. This is interpreted as being within the transition zone between fresh and saline ground water. On figure 11(b), the nearly vertical resistivity line from approximately -310 feet to -400 feet represents a chloride concentration which is equal to or greater than 15,000 mg/L. This is interpreted as representing the saline ground-water zone.

Evaluation of model accuracy in simulating discharge to surface-water bodies was hindered by the lack of streamflow data. Stream discharges for two river segments in Falmouth were measured when streamflow on the Cape was about average and represented ground-water discharge. The measured discharges were 13 and 19 ft³/s, and the calculated discharges to the nodes chosen to represent these stream segments were 9 and 20 ft³/s. Collection of additional streamflow data will help improve the model and provide a better data base for future calibration.

A mass balance was calculated during each simulation. As part of these calculations, a hydrologic budget for the aquifer is computed and tabulated. The hydrologic budget provides a measure of the importance of each element of the budget. For the WCAPE model, the steady-state-recharge rate is 267 ft³/s, the rate of withdrawal by wells is 17 ft³/s, and discharge to the streams, marshes and ocean is 250 ft³/s.

Table 4.—Comparison of calculated nodal head values and observed average water levels for the period 1963 to 1976 for selected wells, WCAPE model

Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level		Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level	
		observed average	calculated at center of grid block			observed average	calculated at center of grid block
5,24,5	SDW 263	36.7	39.5	20,56,5	YAW 111	7.5	5.0
7,14,5	BHW 62	7.2	3.1	21,14,5	FSP 4	34.9	33.3
8,17,5	BHW 215	46.0	36.2	21,15,5	FSP 4	34.9	35.6
9,15,5	BHW 211	27.3	23.8	21,17,5	FSW 167	41.3	40.8
9,35,5	SDW 252	6.3	5.3	21,29,5	AIW 60	35.3	34.2
12,14,5	BHW 198	22.0	29.0	21,31,5	AIW 264	26.4	27.7
13,28,5	SDW 33	64.0	63.0	21,36,5	AIW 183	13.2	19.2
13,28,5	SDW 256	64.3	63.0	21,45,5	AIW 301	26.6	22.5
14,19,5	BHW 27	66.0	64.5	21,46,5	AIW 302	19.7	19.1
14,22,5	SDP 4	69.0	72.1	21,46,5	AIW 300	24.3	19.1
15,22,5	SDP 4	69.0	69.8	21,52,5	YAW 89	18.0	11.3
15,29,5	SDW 253	61.4	61.2	22,15,5	FSW 169	32.6	32.0
15,36,5	AIW 315	32.5	29.5	22,29,5	AIW 298	24.3	26.8
16,32,5	AIW 291	50.4	52.7	22,35,5	AIW 255	17.0	14.9
16,42,5	AIW 294	18.1	16.4	22,41,5	AIW 306	27.2	19.0
17,21,5	SDW 154	62.6	63.1	22,46,5	AIW 230	18.4	13.0
17,44,5	AIW 295	26.7	22.2	22,51,5	YAW 104	16.6	11.4
17,46,5	AIW 247	20.3	19.0	23,17,5	FSW 168	35.7	32.4
17,50,5	YAW 98	15.5	14.5	23,25,5	MIW 21	23.2	20.4
17,53,5	YAW 93	9.1	10.2	23,34,5	AIW 260	6.8	9.1
18,12,5	FSW 179	25.3	29.4	23,53,5	YAW 117	7.4	7.4
18,26,5	SDW 258	53.7	58.9	23,54,5	YAW 96	5.2	6.2
18,34,5	AIP 1	44.2	47.3	24,17,5	FSW 173	29.8	27.8
18,55,5	YAW 108	6.3	6.6	24,21,5	MIW 19	26.9	23.8
19,31,5	AIW 263	38.2	43.3	24,50,5	YAW 94	7.7	7.2
19,42,5	AIW 293	34.0	33.2	25, 9,5	FSW 172	7.9	13.2
19,43,5	AIW 292	34.1	31.6	25,18,5	FSW 175	25.7	21.6
19,45,5	AIW 287	30.1	25.0	25,19,5	FSW 176	22.4	21.0
19,48,5	YAW 85	22.7	19.5	25,34,5	AIW 307	5.0	5.4
20,18,5	SDW 262	47.6	47.8	26,18,5	FSW 185	19.7	16.3
20,31,5	AIW 267	33.7	36.8	27,23,5	MIW 29	6.4	7.0
20,31,5	AIW 313	27.5	36.8	28,12,5	FSW 181	5.7	8.9
20,37,5	AIW 254	34.9	31.6	28,17,5	FSW 5	6.2	7.6
20,45,5	AIW 289	29.6	25.3	31,22,5	MIW 18	3.0	3.4
20,46,5	AIW 297	24.8	20.6

Figure 10.-- Calculated and observed average water table for the period of 1963 to 1976, WCAPE model

Figure 11.—(a) Calculated water table, interface between fresh and saline ground water, chloride (Cl) content, in milligrams per liter (mg/L), of water samples collected from wells on June 20, 1979, and (b) resistivity log for well MIW 26. Line of cross section A-A' is shown in figure 3.

Figure 12.—Calculated water table and interface between fresh and saline ground water. Line of cross section B-B' is shown in figure 3.

Figure 13.--Calculated water table and interface between fresh and saline ground water. Line of cross section C-C' is shown in figure 3.

ECAPE Model

For the ECAPE model, agreement between the observed average water levels and the calculated water levels is shown by table 5 and figure 14. Disagreement is generally in the area where the outwash plains overlie moraine deposits. The model was not able to simulate the 40-foot water-level contour in Dennis (fig. 14), nor was it able to simulate the water levels observed deep in the aquifer in the northern part of Dennis. The complex stratigraphy associated with moraine deposits is probably not adequately approximated by the model in this area. Improvement of this portion of the model will require additional hydrogeologic information.

The calculated position of the interface between fresh and saline ground water for a selected cross section (D-D' on fig. 4) is shown in figure 15.

The mass balance calculated for the ECAPE model indicates that the steady-state recharge to the aquifer is 91 ft³/s, withdrawal by pumpage is 7 ft³/s and discharge to streams, marshes, and the ocean is 84 ft³/s.

Table 5.—Comparison of calculated nodal head values and observed average water levels for the period 1963 to 1976 for selected wells, ECAPE model

Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level		Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level	
		observed average	calculated at center of grid block			observed average	calculated at center of grid block
5,31,5	OSW 22	4.2	5.2	11,25,5	BMW 46	27.5	26.2
6,24,5	BMW 22	19.8	12.9	12,10,5	DGW 107	20.6	25.0
6,27,5	OSW 25	15.1	14.0	12,12,5	DGW 157	25.9	30.6
8,27,5	OSP 1	21.7	21.0	12,18,5	HJP 3	31.6	31.1
8,29,5	OSP 3	7.5	15.1	12,19,5	HJP 3	31.6	31.0
9,6,5	DGW 170	6.4	6.5	12,20,5	HJP 3	31.6	31.0
9,16,5	BMW 44	26.4	25.3	13,12,5	DGW 88	25.9	27.7
9,24,5	BMP 3	28.0	27.2	13,18,5	HJP 3	31.6	31.2
9,24,5	BMW 21	27.2	27.2	13,20,5	HJP 3	31.6	31.1
9,25,5	BMP 5	25.8	26.1	13,21,5	HJP 3	31.6	30.8
9,26,5	BMP 5	25.8	24.6	14,10,5	DGW 158	19.2	17.7
9,29,5	OSP 3	7.5	14.8	14,12,5	DGP 7	27.0	26.1
10,8,5	DGW 100	44.7	25.8	14,15,5	HJW 145	31.7	29.0
10,8,5	DGW 114	28.3	25.8	14,25,5	HJW 141	19.2	20.5
10,11,5	DGW 143	30.5	33.7	15,22,5	HJW 150	30.3	28.3
10,12,5	DGW 123	32.8	33.6	15,25,5	HJW 151	11.4	19.6
10,12,5	DGW 144	30.6	33.6	16,12,5	DGW 160	8.2	14.2
10,28,5	OSW 24	18.5	17.8	17,18,5	HJW 148	20.8	22.4
11,8,5	DGW 124	16.9	21.9	17,26,5	CGP 4	10.4	16.3
11,8,5	DGP 4	24.5	21.9	18,25,5	CGW 176	12.5	16.8
11,9,5	DGW 135	16.7	25.6	18,25,5	CGP 5	12.8	16.8
11,10,5	DGP 2	20.3	29.3	18,26,5	CGP 3	12.7	15.6
11,10,5	DGP 3	20.9	29.3	18,28,5	CGW 177	11.9	11.9
11,11,5	DGW 146	25.7	31.9	19,23,5	CGW 138	11.3	12.9
11,11,5	DGP 6	27.6	31.9	19,27,5	CGP 1	14.8	9.7
11,18,5	BMW 45	31.4	30.6

Figure 14.-- Calculated and observed average water table for the period of 1963 to 1976, ECAPE model

Figure 15.—Calculated water table and interface between fresh and saline ground water. Line of cross section D-D' is shown in figure 4.

ESTHM Model

Table 6 and figure 16 show the agreement between the calculated and observed average water levels for the ESTHM model.

The mass balance calculations indicate that the steady-state rate of aquifer recharge is 19 ft³/s. This rate is balanced by an equal rate of discharge to streams, marshes, and the ocean.

Table 6.—Comparison of calculated nodal head values and observed average water levels for the period 1963 to 1976 for selected wells, ESTHM model

Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level		Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level	
		observed average	calculated at center of grid block			observed average	calculated at center of grid block
8,13,7	EGW 37	8.0	8.2	14,19,7	EGW 36	13.5	13.9
12,16,7	EGW 39	13.8	13.5	15,19,7	EGW 32	12.8	13.1
13,31,7	WNW 17	8.7	8.3	16,18,7	EGW 40	8.6	11.7

WLFLT Model

The agreement between the observed average water levels and calculated water levels for the WLFLT model is shown by table 7 and figure 17.

Mass balance calculations indicate that the steady-state recharge rate, 23 ft³/s, is balanced by an equal rate of discharge to streams, marshes, and the ocean.

Table 7.—Comparison of calculated nodal head values and observed average water levels for the period 1963 to 1976 for selected wells, WLFLT model

Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level		Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level	
		observed average	calculated at center of grid block			observed average	calculated at center of grid block
6,16,7	WNW 78	2.7	3.4	16,26,7	TSW 198	7.6	7.1
11,26,7	TSW 216	4.1	5.3	17,22,7	TSP 16	7.6	7.9
15,14,7	WNW 30	6.6	6.7	18,17,7	WNW 34	8.0	8.0
16,14,7	WNW 30	6.6	7.4	21,19,7	TSP 18	6.4	6.5
16,21,7	TSP 17	6.8	7.2

EXPLANATION

-5... Calculated water-table contour, in feet, datum is sea level, contour interval 5 feet
- 5-- Observed average water-table contour, in feet, datum is sea level, contour interval 5 feet
- ⊗ Observation well

Figure 16.-- Calculated and observed average water table for the period of 1963 to 1976, ESTHM model

EXPLANATION

-5... Calculated water-table contour, in feet, datum is sea level, contour interval 5 feet
- 5-- Observed average water-table contour, in feet, datum is sea level, contour interval 5 feet
- ⊗ Observation well
- Δ Pond-level observation site

Figure 17.-- Calculated and observed average water table for the period of 1963 to 1976, WLFLT model

TRURO Model

The agreement between the observed average water levels and calculated water levels for the TRURO model is shown by table 8 and figure 18. Mass balance calculations for the TRURO model indicate a steady-state recharge rate of $12.3 \text{ ft}^3/\text{s}$, withdrawal by pumping of $1.4 \text{ ft}^3/\text{s}$, and discharge to the streams, marshes, and the ocean at a rate of $10.9 \text{ ft}^3/\text{s}$.

Figure 19 shows the calculated position of the interface between fresh and saline ground water along cross section E-E' shown on figure 7. Measured chloride concentrations of water samples collected from a group of wells near that line of section are also included for comparison.

Table 8.—Comparison of calculated nodal head values and observed average water levels for the period 1963 to 1976 for selected wells, TRURO model

Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level		Node (i,j,k)	U.S. Geological Survey well	Water level, in feet above sea level	
		observed average	calculated at center of grid block			observed average	calculated at center of grid block
8,14,7	TSW 157	4.4	3.8	11,5,7	TSW 218	5.2	5.4
10,6,7	TSW 176	5.6	5.6	12,3,7	TSW 181	4.7	3.6
10,8,7	TSW 170	5.9	6.1	12,4,7	TSW 181	4.7	4.9
10,16,7	TSW 89	4.4	5.2	12,18,7	TSW 134	4.9	4.5
10,17,7	TSW 89	4.4	5.0	13,8,7	TSW 203	5.7	6.0
10,19,7	TSW 136	4.3	4.6	14,6,7	TSW 174	5.6	5.0
10,20,7	TSW 126	4.2	4.3				

SUMMARY AND CONCLUSIONS

Cape Cod satisfies its water-supply demands almost entirely from the freshwater contained within the unconsolidated sediments of Pleistocene and Holocene age. Management of this ground-water resource requires an understanding of the behavior of this large complex aquifer system. Three-dimensional finite-difference ground-water-flow models were prepared for five areas of Cape Cod to provide information on the regional behavior of this system.

The models were developed on the basis that the boundary between fresh and saline ground water could be treated as an interface, the saline-water zone is static, and the natural discharge boundaries presently subdivide the aquifer system into individual small aquifers which can be modeled separately.

The models were calibrated for steady-state conditions by comparing calculated and observed water levels, position of the interface between fresh and saline ground water, and ground-water discharge rates at approximately 150, 27, and 2 control points, respectively.

The accuracy of the model results is limited by the accuracy of the input data that describe aquifer properties, boundary conditions, and recharge rates. As additional data become available, the models should be recalibrated to improve model accuracy commensurate with the knowledge available. Continued monitoring of water-level changes, streamflow, and movement of the boundary between fresh and saline ground water in response to natural and man-caused changes in hydrologic stresses will help improve the aquifer models and make them more useful.

The scale of the models precludes detailed analyses of hydrologic conditions for local areas. More detailed smaller-scale models of local areas can be constructed using similar principles provided sufficient data are available.

Mass balance calculations for the five modeled areas indicate a total steady-state natural and artificial recharge rate of $412 \text{ ft}^3/\text{s}$, a total rate of withdrawal by wells of $25 \text{ ft}^3/\text{s}$, and total discharge rate to streams, marshes, and the ocean of $387 \text{ ft}^3/\text{s}$.

EXPLANATION

-2.... Calculated water-table contour, in feet, datum is sea level, contour interval 2 feet
- 2-- Observed average water-table contour, in feet, datum is sea level, contour interval 2 feet
- ⊗ Observation well

Figure 18.-- Calculated and observed average water table for the period of 1963 to 1976, TRURO model.

Figure 19.--Calculated water table and interface between fresh and saline ground water, and chloride (Cl) content, in milligrams per liter (mg/L), of water samples collected from wells on December 5, 1978. Line of cross section E-E' is shown in figure 7.

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SUPPLEMENTAL DATA--MODEL DATA, INPUT DOCUMENTATION, AND SOURCE CODE

Table 9.--Values for transmissivity, average hydraulic conductivity, and ratio between lateral and vertical hydraulic conductivity used in model calibrations

(*Values apply uniformly within the modeled area identified in figs. 3-7 of the report.)

Model	Layer	Transmissivity (T) for each node in layer (ft ² /d)	Average lateral hydraulic conduc- tivity for each node in layer (ft/d)	Ratio between lateral and vertical hydraulic conductivity
WCAPE	1	figure 20	T for node/160	*10
	2	figure 21	T for node/100	figure 25
	3	figure 22	T for node/70	figure 26
	4	figure 23	T for node/50	figure 27
	5	NA	figure 24	figure 28
ECAPE	1	figure 29	T for node/160	*10
	2	figure 30	T for node/100	figure 34
	3	figure 31	T for node/70	figure 35
	4	figure 32	T for node/50	figure 36
	5	NA	figure 33	figure 37
ESTHM	1	*20,250	*135	*10
	2	*20,250	*135	*10
	3	*13,500	*135	*10
	4	*12,150	*135	*10
	5	figure 38	T for node/60	figure 41
	6	figure 39	T for node/40	figure 42
	7	NA	figure 40	figure 43
WLFLT	1	*9,600	*80	*10
	2	*6,400	*80	*10
	3	*4,800	*80	*10
	4	figure 44	T for node/60	*10
	5	figure 45	T for node/40	figure 48
	6	figure 46	T for node/30	figure 49
	7	NA	figure 47	figure 50
TRURO	1	*10,800	*90	*10
	2	*7,200	*90	*10
	3	*5,400	*90	*10
	4	*7,200	*120	*10
	5	figure 51	T for node/40	figure 54
	6	figure 52	T for node/30	figure 55
	7	NA	figure 53	*10

TK arrays, ESTHM, layers 1-2, 2-3, and 3-4 were multiplied by 0.45.
 TK array, WLFLT, layers 3-4 was multiplied by 0.89.
 TK arrays, TRURO, layers 1-2, 2-3, and 3-4 were multiplied by 0.9.

Figure 20.-- Transmissivity, in feet squared per day, WCAPE model, layer 1

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0	50	2500	5000	7500	20,000
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Figure 21.-- Transmissivity, in feet squared per day, WCAPE model, layer 2

0 1 2 3 4 5 MILES

Figure 23.-- Transmissivity, in feet squared per day, WCAPE model, layer 4

Figure 24.-- Hydraulic conductivity, in feet per day, WCAPE model, layer 5

Figure 25.-- Ratio between lateral and vertical hydraulic conductivity, WCAPE model, layer 2

Figure 27.-- Ratio between lateral and vertical hydraulic conductivity, WCAPE model, layer 4

Figure 28.-- Ratio between lateral and vertical hydraulic conductivity, WCAPE model, layer 5

Figure 29.-- Transmissivity, in feet squared per day, ECAPE model, layer 1

Figure 30.-- Transmissivity, in feet squared per day, ECAPE model, layer 2

Figure 31.-- Transmissivity, in feet squared per day, ECAPE model, layer 3

Figure 32.-- Transmissivity, in feet squared per day, ECAPE model, layer 4

Figure 33.-- Hydraulic conductivity, in feet per day, ECAPE model, layer 5

Figure 34.-- Ratio between lateral and vertical hydraulic conductivity, ECAPE model, layer 2

Figure 35.-- Ratio between lateral and vertical hydraulic conductivity, ECAPE model, layer 3

Figure 36.-- Ratio between lateral and vertical hydraulic conductivity, ECAPE model, layer 4

Figure 37.-- Ratio between lateral and vertical hydraulic conductivity, ECAPE model, layer 5

Figure 38.-- Transmissivity, in feet squared per day,
ESTHM model, layer 5

Figure 39.-- Transmissivity, in feet squared per day, ESTHM model, layer 6

EXPLANATION

Figure 40.-- Hydraulic conductivity, in feet per day, ESTHM model, layer 7

Figure 41.-- Ratio between lateral and vertical hydraulic conductivity, ESTHM model, layer 5

Figure 42.-- Ratio between lateral and vertical hydraulic conductivity, ESTHM model, layer 6

Figure 43.-- Ratio between lateral and vertical hydraulic conductivity, ESTHM model, layer 7

Figure 44.-- Transmissivity, in feet squared per day,
WLFLT model, layer 4

Figure 45.-- Transmissivity, in feet squared per day,
WLFLT model, layer 5

Figure 46.-- Transmissivity, in feet squared per day,
WLFLT model, layer 6

Figure 47.-- Hydraulic conductivity, in feet per day, WLFLT model, layer 7

Figure 48.-- Ratio between lateral and vertical hydraulic conductivity, WLFLT model, layer 5

Figure 49.-- Ratio between lateral and vertical hydraulic conductivity, WLFLT model, layer 6

Figure 50.-- Ratio between lateral and vertical hydraulic conductivity, WLFLT model, layer 7

Figure 51.-- Transmissivity, in feet squared per day, TRURO model, layer 5

Figure 52.-- Transmissivity, in feet squared per day,
TRURO model, layer 6

Figure 53.-- Hydraulic conductivity, in feet per day,
TRURO model, layer 7

Figure 54.-- Ratio between lateral and vertical hydraulic conductivity, TRURO model, layer 5

Figure 55.-- Ratio between lateral and vertical hydraulic conductivity, TRURO model, layer 6

Table 10.--Summary of well discharges represented in models

(*Indicates multiple well.)

Node (i,j,k)	U.S. Geological Survey well	Dis- charge (ft ³ /s)	Total node discharge (ft ³ /s)	Node (i,j,k)	U.S. Geological Survey well	Dis- charge (ft ³ /s)	Total node discharge (ft ³ /s)
Model: WCAPE							
3,24,4	BHW 22,232*	0.124	0.124	21,56,4	YAW 53	0.223	
4,26,4	SDW 249,250	.062	.062		YAW 144	.256	
7,28,4	SDW 27	.104	.104		YAW 146	.238	0.717
7,28,5	SDW 37	.320	.320	22,29,5	AlW 369	.113	.113
9,15,4	BHW 233	.079	.079	22,46,4	AlW 377	1.165	
10,14,4	BHW 1-3,136	.336	.336		AlW 385,386	.109	1.274
10,15,5	BHW 199	.239	.239	22,49,4	YAW 128	.125	
15,3,4	BHW 137	.288	.288		YAW 195	--	.125
16,20,5	SDW 155	.433	.433	22,50,4	YAW 193	--	
17,16,5	BHW 23	.507	.507		YAW 194	--	0
17,43,5	AlW 228	.172	.172	22,51,4	YAW 130	--	0
18,52,4	YAW 103*	.223	.223	22,53,4	YAW 64	.345	
18,52,5	YAW 103*	.223	.223		YAW 65	.309	.654
19,35,5	AlW 371	.170	.170	23,17,5	FSW 214	--	0
19,36,5	AlW 372	.156	.156	23,28,4	AlW 251	.112	.112
19,45,5	AlW 370	.269	.269	23,34,5	AlW 159	.133	
19,46,5	AlW 402	.072	.072		AlW 107	.400	.533
19,49,4	YAW 41	--	0	23,34,5	AlW 249	.371	
19,49,5	YAW 42	.248			AlW 158	.133	
	YAW 43	.266	.514		AlW 160	.133	.637
19,55,4	YAW 126	.046		23,41,4	AlW 226	.071	.071
	YAW 127	.027	.073	23,41,5	AlW 227	.048	
20,46,5	AlW 403	.065			AlW 368	.119	.167
	AlW 383	.305		23,42,4	AlW 376	.453	.453
	AlW 387	.173	.543	24,29,5	AlW 224	.046	.046
20,56,4	YAW 54	.467	.467	24,42,4	AlW 229	.210	
21,29,5	AlW 59	.007	.007		AlW 384	.966	1.176
21,36,4	AlW 373	.031	.031	26,9,5	Long Pond	1.04	1.04
21,36,5	AlW 259	.471	.471	26,10,5	Long Pond	1.45	1.45
21,50,4	YAW 58	.310	.310	27,10,5	Long Pond	1.66	1.66
21,52,4	YAW 61	.279		29,24,5	MIW 32	.048	.048
	YAW 63	.208	.487	30,23,4	MIW 35	.150	.150
Model: ECAPE							
8,28,4	OSW 11	0.322		11,11,5	DGW 244	--	0
	OSW 14	.206		11,24,4	BMW 37	0.287	.287
	OSW 15	.277	0.805	12,9,5	DGW 112	.390	.390
9,28,4	OSW 42	.041		12,10,4	DGW 79	.527	.527
	OSW 43	.088	.129	12,11,5	DGW 85	.232	.232
11,9,5	DGW 232	.015		12,12,5	DGW 86	.139	.139
	DGW 67	.059	.074	12,24,4	BMW 41	.231	.231

Table 10.--Summary of well discharges represented in models (Continued)

Node (i,j,k)	U.S. Geological Survey well	Dis- charge (ft ³ /s)	Total node discharge (ft ³ /s)	Node (i,j,k)	U.S. Geological Survey well	Dis- charge (ft ³ /s)	Total node discharge (ft ³ /s)
Model: ECAPE (Continued)							
13,11,5	DGW 56	0.226		18,20,5	HJW 49	0.529	
	DGW 57	.013			HJW 55	.148	
	DGW 58	.123	0.362		HJW 56	.373	
13,12,5	DGW 77	.273			HJW 1-4*	.023	1.073
	DGW 87	.150	.423	18,22,4	HJW 162	.118	
14,9,5	DGW 1-5	.246	.246		HJW 163	.126	.244
14,10,5	DGW 66	.161	.161	18,22,5	HJW 161	.032	.132
16,12,4	DGW 205	--	0	18,26,4	CGW 211	.776	.776
18,20,4	HJW 160	.120	.120	19,22,4	CGW 153	.085	.085
				19,22,5	CGW 1,2	.171	.171
Model: TRURO							
8,21,6	TSW 115*	0.696	0.696	11,14,6	TSW 78*	0.358	0.358
10,14,6	TSW 78*	.358	.358

Figure 56.-- Steady-state recharge, in inches per year, WCAPE model

Figure 57.-- Steady-state recharge, in inches per year,
ECAPE model

Figure 58.-- Steady-state recharge, in inches per year, ESTHM model

Figure 59.-- Steady-state recharge, in inches per year, WLFLT model

Figure 60.-- Steady-state recharge, In inches per year, TRURO model

Table 11.--Input documentation

Group I: Title, Simulation Options, and Problem Dimensions

This group of cards, which are read by the main program, contains 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 the card 4 can be left blank.

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

CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
1	1-80	20A4	HEADING	Any title the user wishes to print on one line at the start of output
2	1-52	13A4	HEADING	
3	1-10	I10	IO	Number of rows
	11-20	I10	JO	Number of columns
	21-30	I10	KO	Number of layers
	31-40	I10	ITMAX	Maximum number of iterations per time step
	41-50	I10	NCH	Number of constant head nodes
	51-60	I10	NKODE	= 1 for interface solution; $\neq 1$ if freshwater/saline water boundary is not to be considered
	61-70	G10.0	BETA1	Parameter to dampen numerical oscillation (usually 0.6 to 1.0)
	71-75	I5	KFLOW	= 1 to print flow rates to individual constant head and leaky nodes
	76-80	I5	NRIV	Number of leaky "river" nodes
	1-4	A4	IDRAW	<u>DRAW</u> to print drawdown
	6-9	A4	IHEAD	<u>HEAD</u> to print hydraulic head
	11-14	A4	IFLOW	<u>MASS</u> to compute a mass balance
	16-18	A3	IDK1	<u>DK1</u> to read initial head, elapsed time, and mass balance parameters from unit 4 on disk
	21-23	A3	IDK2	<u>DK2</u> to write computed head, elapsed time and mass balance parameters on unit 4 (disk)
	26-29	A4	IWATER	<u>WATE</u> if the upper hydrologic unit is unconfined
	31-34	A4	IQRE	<u>RECH</u> for a constant recharge that may be a function of space
4	36-39	A4	IPU1	<u>PUN1</u> to read initial head, elapsed time, and mass balance parameters from cards
	41-44	A4	IPU2	<u>PUN2</u> to punch computed head, elapsed time, and mass balance parameters on cards
	46-49	A4	ITK	<u>ITKR</u> to read the values of $TK(I,J,K)$; for simulations in which confining layers are not represented by layers of nodes, $TK(I,J,K) = K_{zz}/b$; where variation in aquifer anisotropy is to be approximated, $TK(I,J,K) = 2.0 * K_{zz}(K+1) * K_{zz}(K) / (K_{zz}(K+1) * DELZ(K) + K_{zz}(K) * DELZ(K+1))$ (Trescott and Larson, 1976)
	51-54	A4	IEQN	<u>EQN3</u> if equation 3 is being solved; otherwise it is assumed that equation 4 is being solved

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.

CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
1	1-10	G10.0	<u>NPER</u>	Number of pumping periods for the simulation
	11-20	G10.0	<u>KTH</u>	Number of times steps between printouts
	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.			
	21-30	G10.0	<u>ERR</u>	Error criterion for closure (L)
	NOTE: When the head change at all nodes on subsequent iterations is less than this value (for example, 0.01 foot), the program has converged to a solution for the time step.			
2	31-40	G10.0	<u>LENGTH</u>	Number of iteration parameters
	1-10	G10.0	<u>XSCALE</u>	Factor to convert model length unit to unit used in X direction on maps (e.g. to convert from feet to miles, XSCALE = 5280). <u>For no maps, card 2 is blank</u>
	11-20	G10.0	<u>YSCALE</u>	Factor to convert model length unit used in Y direction on maps
	21-30	G10.0	<u>DINCH</u>	Number of map units per inch
	31-40	G10.0	<u>FACT1</u>	Factor to adjust value of drawdown printed*
	41-49	9I1	<u>LEVEL1(I)</u>	Layers for which drawdown maps are to be printed. List layers starting in column 41; the first zero entry terminates the printing of drawdown maps
	51-60	G10.0	<u>FACT2</u>	Factor to adjust value of head printed*
	61-69	9I1	<u>LEVEL2(I)</u>	Layers for which head maps are to be printed. List layers starting in column 61; the first zero entry terminates the printing of head maps.
	71-78	A8	<u>MESUR</u>	Name of map length unit
	1-20	G20.10	<u>SUM</u>	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.
3	21-40	G20.10	<u>SUMP</u>	
	41-60	G20.10	<u>PUMPT</u>	
	61-80	G20.10	<u>CFLUXT</u>	
4	1-20	G20.10	<u>QRET</u>	
	21-40	G20.10	<u>CHST</u>	
	41-60	G20.10	<u>CHDT</u>	
	61-80	G20.10	<u>FLUXT</u>	
5	1-20	G20.10	<u>STORT</u>	
	21-40	G20.10	<u>ETFLXT</u>	
	41-60	G20.10	<u>FLXNT</u>	

* Value of drawdown or head

Value of drawdown or head	FACT 1 FACT 2 or	Printed value
	0.01	1
	0.1	5
52.57	1.0	53
	10.0	526
	100.0	***

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. If the data set requires data for each layer, a parameter card and data cards (for layers with variable data) are required for each layer. Each parameter card contains at least five variables.

CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
Every Parameter Card	1-10	G10.0	FAC	If IVAR = 0, FAC is the value assigned to every element of the matrix for this layer If IVAR = 1, FAC is the multiplication factor for the following sets of data cards for this layer
	11-20	G10.0	IVAR	= 0 if no data cards are to be read for this layer = 1 if data cards for this layer follow
	21-30	G10.0	IPRN	= 0 if input data for this layer are to be printed = 1 if input data for the layer are <u>not</u> to be printed

Transmissivity Parameter Cards also have these Variables:

31-40	G10.0	FACT(K,1)	Multiplication factor for transmissivity in x direction
41-50	G10.0	FACT(K,2)	Multiplication factor for transmissivity in y direction
51-60	G10.0	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)

CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
Every Parameter Card	61-70	G10.0	IRECS	= 0 if the matrix is being read from cards or if each element is being set equal to FAC = 1 if the matrix is to be read from disk (unit 2)
Every Parameter Card	71-80	G10.0	IRECD	= 0 if the matrix is <u>not</u> to be stored on disk = 1 if the matrix being read from cards or set equal to FAC is to be stored on disk (unit 2) for later retrieval

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.

DATA

SET	COLUMNS	FORMAT	VARIABLE	DEFINITION
1	1-80	8F 10.4	PHI(I,J,K)	Head values for continuation of a previous run (L)
NOTE: For a new simulation this data set is omitted. Do not include a parameter card with this data set.				
2	1-80	8F 10.4	STRT(I,J,K)	Starting head matrix (L)
3	1-80	20F 4.0	S (I,J,K)	Storage coefficient (dimensionless). If equation 3 is to be solved, read S_s instead of storage coefficient

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.

DATA SET	COLUMNS	FORMAT	VARIABLE	DEFINITION
4	1-80	8F 10.4	T(I,J,K)	Transmissivity (L^2/T). If equation 3 is to be solved, read hydraulic conductivity instead of transmissivity

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

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

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.

5	1-80	8F 10.4	TK(I,J,K)	K_{zz}/b
---	------	---------	-----------	------------

NOTE: This data set is read only if specified in the options. The number of layers of TK values = K0-1. See the discussion of the treatment of confining layers.

6	1-80	8F 10.4	PERM(I,J)	Hydraulic conductivity (L/T) (see note 1 for data set 4)
7	1-80	20F 4.0	BOTTOM(I,J)	Elevation of bottom of water-table unit (L)

NOTE: Data sets 6 and 7 are required only for simulating unconfined conditions in the upper hydrologic unit.

8	1-80	20F 4.0	QRE(I,J)	Recharge rate (L/T)
---	------	---------	----------	---------------------

NOTE: Omit if not used

9	1-80	8F10.0	DELX(J)	Grid spacing in x direction (L)
10	1-80	8G10.0	DELY(I)	Grid spacing in y direction (L)
11	1-80	8G10.0	DELZ(K)	Grid spacing in z direction (L)
12	1-80	80I1	IDR(I,J,K)	Flag for leaky "river" nodes. = 1 for leaky nodes
13	1-80	G10.0	FAC	Multiplication factor for head on leaky layer
	1-80	20F 4.0	RH(I)	Head on leaky layer
14	1-80	G10.0	FAC	Multiplication factor for elevation of bottom of leaky layer
	1-80	20F 4.0	RB(I)	Elevation of bottom of leaky layer
15	1-80	G10.0	FAC	Multiplication factor for leakance coefficient
	1-80	10F 8.0	RC(I)	Leakance coefficient (Kz/M)

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, 50). The program will compute the exact DELT (which will be $\leq$ DELT coded) and NUMT to arrive exactly at TMAX on the last step.

CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
1	1-10	G10.0	KP	Number of the pumping period
	11-20	G10.0	KPM1	Number of the previous pumping period
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

If NWEL: 0 the following set of cards is omitted

DATA SET 1

(NWEL cards)

COLUMNS	FORMAT	VARIABLE	DEFINITION
1-10	G10.0	K	Layer in which well is located
11-20	G10.0	I	Row location of well
21-30	G10.0	J	Column location of well
31-40	G10.0	WELL (I,J,K)	Pumping rate (L^3/T), negative for a pumping well

For each additional pumping period, another set of group IV cards is required (that is, NPER sets of group IV cards are required).

Group V: Interface and Optional Print Parameters (These data cards follow the first set of Group IV cards)

CARD	COLUMNS	FORMAT	VARIABLE	DEFINITION
1	1-10	I10	NTAD	Transmissivity adjustment code. Specifies frequency of transmissivity adjustment (e.g. = 1 every iteration; = 4 every fourth iteration)
	11-20	G10.0	RF	Density factor
	21-30	I10	KODCHP	= 1 Transmissivity adjustment proceeds across grid from north to south; otherwise adjustment proceeds from both north and south to mid-point of grid
	31-40	I10	KPRNTT	= 1 write to file 9 final PHI, T, PERM and TK matrices

DATA SET

1	1-80	16F 5.0	DBOT(I,J)	Elevation of bottom of aquifer (positive downward). Read similar to array data.
2	1-80	80I1	ISEA(I,J)	Flag for "ocean" nodes. Assign value equal to node layer. Ocean nodes which "leak" into aquifer are treated as saline-water nodes
3	1-80	8G10.0	DTOP(K)	Elevation of top of layers (positive downward)

Group VI: Additional Print Parameters

<u>CARD</u>				
1	1-10	I10	NODKOD	= 1 to print head values at each iteration for selected nodes
	11-20	I10	NMBRND	Number of nodes (10 maximum) for which head values are to be printed
2	1-80	10(I3, I3, I2)	AA(I)	I, J, K location of nodes for which head values are to be printed. If NODKOD not equal to 1 omit this card
3	1-10	I10	IHEDKD	= 1 write to file 8 final head values for selected nodes

<u>DATA</u>				
<u>SET</u>	<u>COLUMNS</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DEFINITION</u>
1	1-80	80I1	IFNLHD	
			(I,J,K)	Index array to identify those nodes for which final head values are to be printed in table form. Two passes are made through the array. The first pass is made only on the top layer and prints head values for those nodes where IFNLHD = 1. The second pass is made through the entire array and prints head values for those nodes where IFNLHD = 2. If IHEDKD is not equal to 1, omit this data set

Table 12.--Computer source code

(*Indicates a change from Trescott, 1975, and Trescott and Larson, 1976.)

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C -----MAN0010
C FINITE-DIFFERENCE MODEL FOR SIMULATION OF GROUND-WATER FLOW IN MAN0020
C THREE DIMENSIONS, SEPTEMBER 1975 BY P.C. TRESCOTT, U. S. G. S. MAN0030
C WITH CONTRIBUTIONS TO MAIN, DATAI AND SOLVE BY S.P. LARSON MAN0040
C AND MODIFICATIONS NOTED BY ASTERISKS BY J.H.GUSWA AND D.R.LEBLANC MAN0045
C -----MAN0050
C SPECIFICATIONS: MAN0060
C REAL *8YSTR MAN0070
C MAN0080
C MAN0090
C DIMENSION Y(177500), L(29), HEADNG(33), NAME(42), INFT(2,2), IOFT(MAN0100*
19,4), DUM(3) MAN0110
C MAN0120
C EQUIVALENCE (YSTR,Y(1)) MAN0130
C MAN0140
C COMMON /INTEGR/ IO,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NMAN0150
1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NCMAN0160
2H,IDK1,IDK2,IWATER,IQRE,IP,JP,I2,J2,IK,JK,K5,IPU1,IPU2,ITK,IEQN MAN0170
3,NKODE,KFLOW MAN0180*
C COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,BETA1 MAN0190*
COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9) MAN0200
C MAN0210
C DATA NAME/2*4H ,4H S,4HTART,4HING ,4HHEAD,4H ,4H STO,4HRAGMAN0220
1E,4H COE,4HFFIC,4HIENT,2*4H ,4H TR,4HANS,4HISSI,4HVITY,5*4H MAN0230
2 ,4H TK,4H HY,4HDRAU,4HLIC ,4HCOND,4HUCTI,4HVITY,2*4H ,4HBTMAN0240
3T,4HOM E,4HLEVA,4HTION,2*4H ,4H R,4HECHA,4HRGE ,4HRAE/ MAN0250
DATA INFT/4H(20F,4H4.0),4H(8F1,4H0.4)/ MAN0260
DATA IOFT/4H(1H0,4H,I2,,4H2X,2,4H0F6.,4H1/(5,4HX,20,4HF6.1,4H)) ,MAN0270
14H ,4H(1H0,4H,I5,,4H14F9,4H.5/(,4H1H ,4H5X,1,4H4F9.,4H5)) ,4H MAN0280
2 ,4H(1H0,4H,I5,,4H10E1,4H2.5/,4H(1H ,4H,5X,,4H10E1,4H2.5),4H) MAN0290
3,4H(1H0,4H,I5,,4H10E1,4H1.3/,4H(1H ,4H,5X,,4H10E1,4H1.3),4H) / MAN0300
C MAN0310
C DEFINE FILE 2(8,1520,U,KKK) MAN0320
C .....MAN0330
C ---READ TITLE, PROGRAM SIZE AND OPTIONS--- MAN0340
C READ (5,200) HEADNG MAN0350
C WRITE (6,190) HEADNG MAN0360
C READ (5,160) IO,J0,K0,ITMAX,NCH,NKODE,BETA1,KFLOW,NRIV MAN0370
C WRITE (6,180) IO,J0,K0,ITMAX,NCH,NKODE,BETA1,KFLOW,NRIV MAN0380*
C READ (5,210) IDRAW,IHEAD,IFLO,IDK1,IDK2,IWATER,IQRE,IPU1,IPU2,ITK MAN0390*
1,IEQN MAN0400
WRITE (6,220) IDRAW,IHEAD,IFLO,IDK1,IDK2,IWATER,IQRE,IPU1,IPU2,ITKMAN0410
1,IEQN MAN0420
IERR=0 MAN0430
C MAN0440
C MAN0450
C ---COMPUTE DIMENSIONS FOR ARRAYS--- MAN0460
C J1=J0-1 MAN0470
C I1=I0-1 MAN0480
C K1=K0-1 MAN0490
C I2=I0-2 MAN0500
C J2=J0-2 MAN0510
C K2=K0-2 MAN0520
C IMAX=MAX0(IO,J0) MAN0530
C NCD=MAX0(1,NCH) MAN0540
C ITMX1=ITMAX+1 MAN0550
C ISIZ=IO*J0*K0 MAN0560
C IK1=IO*J0 MAN0570

```

IK2=MAX0(IK1*K1,1)	MAN0580
ISUM=2*ISIZ+1	MAN0590
L(1)=1	MAN0600
DO 30 I=2,14	MAN0610
IF (I.NE.8) GO TO 20	MAN0620
L(8)=ISUM	MAN0630
ISUM=ISUM+IK2	MAN0640
IF (IK2.EQ.1) GO TO 10	MAN0650
IK=I0	MAN0660
JK=J0	MAN0670
K5=K1	MAN0680
GO TO 30	MAN0690
10 IK=1	MAN0700
JK=1	MAN0710
K5=1	MAN0720
GO TO 30	MAN0730
20 L(I)=ISUM	MAN0740
ISUM=ISUM+ISIZ	MAN0750
30 CONTINUE	MAN0760
L(15)=ISUM	MAN0770
ISUM=ISUM+J0	MAN0780
L(16)=ISUM	MAN0790
ISUM=ISUM+I0	MAN0800
L(17)=ISUM	MAN0810
ISUM=ISUM+K0	MAN0820
L(18)=ISUM	MAN0830
ISUM=ISUM+IMAX	MAN0840
L(19)=ISUM	MAN0850
ISUM=ISUM+K0*3	MAN0860
L(20)=ISUM	MAN0870
ISUM=ISUM+ITMX1	MAN0880
L(21)=ISUM	MAN0890
ISUM=ISUM+3*NCD	MAN0900
L(22)=ISUM	MAN0910
ISUM=ISUM+NCD	MAN0920
L(23)=ISUM	MAN0930
IF (IWATER.NE.ICHK(6)) GO TO 40	MAN0940
ISUM=ISUM+IK1	MAN0950
L(24)=ISUM	MAN0960
ISUM=ISUM+IK1	MAN0970
IP=I0	MAN0980
JP=J0	MAN0990
GO TO 50	MAN1000
40 ISUM=ISUM+1	MAN1010
L(24)=ISUM	MAN1020
ISUM=ISUM+1	MAN1030
IP=1	MAN1040
JP=1	MAN1050
50 L(25)=ISUM	MAN1060
IF (IQRE.NE.ICHK(7)) GO TO 60	MAN1070
ISUM=ISUM+IK1	MAN1080
IQ=I0	MAN1090
JQ=J0	MAN1100
GO TO 70	MAN1110
60 ISUM=ISUM+1	MAN1120
IQ=1	MAN1130
JQ=1	MAN1140

70	IF(NRIV.E2.0) GO TO 75	MAN1150*
	L(26)=ISUM	MAN1160*
	ISUM=ISUM+ISIZ	MAN1170*
	L(27)=ISUM	MAN1180*
	ISUM=ISUM+NRIV	MAN1190*
	L(28)=ISUM	MAN1200*
	ISUM=ISUM+NRIV	MAN1210*
	L(29)=ISUM	MAN1220*
	ISUM=ISUM+NRIV	MAN1230*
	GO TO 79	MAN1240*
75	L(26)=ISUM	MAN1250*
	L(27)=ISUM+1	MAN1260*
	L(28)=ISUM+2	MAN1270*
	L(29)=ISUM+3	MAN1280*
	ISUM=ISUM+4	MAN1290*
79	WRITE (6,170) ISUM	MAN1300*
C		MAN1310
C	---PASS INITIAL ADDRESSES OF ARRAYS TO SUBROUTINES---	MAN1320
	CALL DATAI(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),	MAN1330
	1,Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(23)),Y(L(	MAN1340
	224)),Y(L(25))),	MAN1350
	3Y(L(26)),Y(L(27)),Y(L(28)),Y(L(29)))	MAN1360*
	CALL STEP(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),	MAN1370
	1Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(18)),Y(L(2	MAN1380
	20)))	MAN1390
	CALL SOLVE(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),	MAN1400
	1,Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(10)),Y(L(	MAN1410
	211)),Y(L(12)),Y(L(13)),Y(L(14)),Y(L(20)),Y(L(25)),Y(L(24))),	MAN1420
	3Y(L(23)),Y(L(26)),Y(L(27)),Y(L(28)),Y(L(29)),NRIV)	MAN1430*
	CALL COEF(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),	MAN1440
	1Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(23)),Y(L(2	MAN1450
	24)),Y(L(25)))	MAN1460
	CALL CHECKI(Y(L(1)),Y(L(2)),Y(L(3)),Y(L(4)),Y(L(5)),Y(L(6)),Y(L(7)),	MAN1470
	1),Y(L(8)),Y(L(9)),Y(L(15)),Y(L(16)),Y(L(17)),Y(L(19)),Y(L(21)),Y(L(	MAN1480
	2(22)),Y(L(25))),	MAN1490
	3Y(L(26)),Y(L(27)),Y(L(28)),Y(L(29)),NRIV)	MAN1500*
	CALL PRNTAI(Y(L(1)),Y(L(2)),Y(L(4)),Y(L(5)),Y(L(9)),Y(L(15)),Y(L(1	MAN1510
	16)))	MAN1520
C		MAN1530
C	---START COMPUTATIONS---	MAN1540
C	*****	MAN1550
C	---READ AND WRITE DATA FOR GROUPS II AND III---	MAN1560
	CALL DATAIN	MAN1570
	IRN=1	MAN1580
	NIJ=I0*J0	MAN1590
	DO 80 K=1,K0	MAN1600
	LOC=L(2)+(K-1)*NIJ	MAN1610
80	CALL ARRAY(Y(LOC),INFT(1,2),IOFT(1,1),NAME(1),IRN,DUM)	MAN1620
	DO 90 K=1,K0	MAN1630
	LOC=L(5)+(K-1)*NIJ	MAN1640
90	CALL ARRAY(Y(LOC),INFT(1,1),IOFT(1,2),NAME(7),IRN,DUM)	MAN1650
	DO 100 K=1,K0	MAN1660
	LOC=L(4)+(K-1)*NIJ	MAN1670
	L1=L(19)+K-1	MAN1680
	L2=L(19)+K0+K-1	MAN1690
	L3=L(19)+2*K0+K-1	MAN1700
	CALL ARRAY(Y(LOC),INFT(1,2),IOFT(1,2),NAME(13),IRN,DUM)	MAN1710

Y(L1)=DUM(1)	MAN1720
Y(L2)=DUM(2)	MAN1730
Y(L3)=DUM(3)	MAN1740
100 WRITE (6,230) K,Y(L1),Y(L2),Y(L3)	MAN1750
IF (ITK.NE.ICHK(10)) GO TO 120	MAN1760
DO 110 K=1,K1	MAN1770
LOC=L(8)+(K-1)*NIJ	MAN1780
110 CALL ARRAY(Y(LOC),INFT(1,2),IOFT(1,3),NAME(19),IRN,DUM)	MAN1790
120 IF (IWATER.NE.ICHK(6)) GO TO 130	MAN1800
K = K0	MAN1810
CALL ARRAY(Y(L(23)),INFT(1,2),IOFT(1,4),NAME(25),IRN,DUM)	MAN1820
CALL ARRAY(Y(L(24)),INFT(1,1),IOFT(1,1),NAME(31),IRN,DUM)	MAN1830
130 IF (IQRE.E2.ICHK(7)) CALL ARRAY(Y(L(25)),INFT(1,1),IOFT(1,4),NAME(137),IRN,DUM)	MAN1840
CALL MDAT	MAN1850
IF(NRIV.NE.0) CALL DDAT2(NRIV)	MAN1860
C	MAN1870*
C ---COMPUTE TRANSMISSIVITY FOR UNCONFINED LAYER---	MAN1880
IF (IWATER.E2.ICHK(6)) CALL TRANS(1)	MAN1890
C	MAN1900
C ---COMPUTE T COEFFICIENTS---	MAN1910
CALL TCOF	MAN1920
C	MAN1930
C ---COMPUTE ITERATION PARAMETERS---	MAN1940
CALL ITER	MAN1950
C	MAN1960
C ---READ TIME PARAMETERS AND PUMPING DATA FOR A NEW PUMPING PERIOD---	MAN1970
140 CALL NEWPER	MAN1980
C	MAN1990
KT=0	MAN2000
IFINAL=0	MAN2010
C	MAN2020
C ---START NEW TIME STEP COMPUTATIONS---	MAN2030
150 CALL NEWSTP	MAN2040
C	MAN2050
C ---START NEW ITERATION IF MAXIMUM NO. ITERATIONS NOT EXCEEDED---	MAN2060
CALL NEWITA	MAN2070
C	MAN2080
C ---PRINT OUTPUT AT DESIGNATED TIME STEPS---	MAN2090
CALL OUTPUT	MAN2100
C	MAN2110
C ---LAST TIME STEP IN PUMPING PERIOD ?---	MAN2120
IF (IFINAL.NE.1) GO TO 150	MAN2130
C	MAN2140
C ---CHECK FOR NEW PUMPING PERIOD---	MAN2150
IF (KP.LT.NPER) GO TO 140	MAN2160
C	MAN2170
STOP	MAN2180
C	MAN2190
C ---FORMATS---	MAN2200
C	MAN2210
C	MAN2220
C	MAN2230
C	MAN2240
160 FORMAT (6I10,G10.0,2I5)	MAN2250*
170 FORMAT ('C',54X,'WORDS OF VECTOR Y USED =',I7)	MAN2260
180 FORMAT ('O',62X,'NUMBER OF ROWS =',I5/60X,'NUMBER OF COLUMNS =',I5/61X,'NUMBER OF LAYERS =',I5/39X,'MAXIMUM PERMITTED NUMBER OF ITEM	MAN2270
	MAN2280

2RATIONS =',I5//48X,'NUMBER OF CONSTANT HEAD NODES =',I5//72X,	MAN2290
3'NKODE =',I5//53X,'BETA ITERATION PARAMETER =',F5.2,	MAN2300*
4//72X,'KFLOW =',I5,	MAN2310*
5//56X,'NUMBER OF LEAKY NODES =',I5)	MAN2320*
190 FORMAT ('1',33A4)	MAN2330
200 FORMAT (20A4)	MAN2340
210 FORMAT (16(A4,1X))	MAN2350
220 FORMAT ('-SIMULATION OPTIONS: ',11(A4,4X))	MAN2360
230 FORMAT (1H0,44X,'DIRECTIONAL TRANSMISSIVITY MULTIPLICATION FACTORS	MAN2370
1 FOR LAYER',I3,/,76X,'X =',G15.7/76X,'Y =',G15.7/76X,'Z =',G15.7)	MAN2380
END	MAN2390


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SUBROUTINE STEP(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FACTSTP0010
1,DDN,TEST3) STP0020
-----STP0030
C INITIALIZE DATA FOR A NEW TIME STEP AND PRINT RESULTS STP0040
C -----STP0050
C SPECIFICATIONS: STP0060
C REAL *8PHI STP0070
C REAL *8XLABEL,YLABEL,TITLE,XN1,MESUR STP0080
C STP0090
C STP0100
C DIMENSION PHI(IO,J0,K0), STRT(IO,J0,K0), OLD(IO,J0,K0), T(IO,J0,K0STP0110
1), S(IO,J0,K0), TR(IO,J0,K0), TC(IO,J0,K0), TK(IK,JK,K5), WELL(IO,STP0120
2J0,K0), DELX(J0), DELY(IO), DELZ(K0), FACT(K0,3), DDN(IMAX), TEST3STP0130
3(ITMX1), ITTO(50) STP0140
C STP0150
C COMMON /INTEGR/ IO,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NSTP0160
1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NCSTP0170
2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK,IEQN STP0180
3,NKODE,KFLOW STP0190*
C COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,BETA1 STP0200*
C COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9) STP0210
C COMMON /CK/ RLFLXT,STORT,QRET,CHST,CHDT,FLUXT,PUMPT,CFLUXT,FLXNT STP0220*
C COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANKSTP0230
1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),STP0240
2YN(13),NA(4),N1,N2,N3,YSCALE,FACT1,FACT2 STP0250
C RETURN STP0260
C .....STP0270
C *****STP0280
C ENTRY NEWSTP STP0290
C *****STP0300
C KT=KT+1 STP0310
C IT=0 STP0320
C DO 10 K=1,K0 STP0330
C DO 10 I=1,I0 STP0340
C DO 10 J=1,J0 STP0350
10 OLD(I,J,K)=PHI(I,J,K) STP0360
C DELT=CDLT*DELT STP0370
C SUM=SUM+DELT STP0380
C SUMP=SUMP+DELT STP0390
C DAYSP=SUMP/86400. STP0400
C YRSP=DAYSP/365. STP0410
C HRS=SUM/3600. STP0420
C SMIN=HRS*60. STP0430
C DAYS=HRS/24. STP0440
C YRS=DAYS/365. STP0450
C RETURN STP0460
C STP0470
C ---PRINT OUTPUT AT DESIGNATED TIME STEPS--- STP0480
C *****STP0490
C ENTRY OUTPUT STP0500
C *****STP0510
C IF (KT.EQ.NUMT) IFINAL=1 STP0520
C ITTO(KT)=IT STP0530
C IF (IT.LE.ITMAX) GO TO 20 STP0540
C IT=IT-1 STP0550
C ITTO(KT)=IT STP0560
C IERR=2 STP0570

```

C		STP0580
C	---IF MAXIMUM ITERATIONS EXCEEDED,WRITE RESULTS ON DISK OR CARDS---	STP0590
	IF (IDK2.E2.ICHK(5)) WRITE (4) PHI,SUM,SUMP,PUMPT,CFLUXT,QRET,CHST	STP0600
	1,CHDT,FLUXT,STORT,RLFLXT,FLXNT	STP0610
	IF (IPU2.E2.ICHK(9)) WRITE (7,230) SUM,SUMP,PUMPT,CFLUXT,QRET,CHST	STP0620
	1,CHDT,FLUXT,STORT,RLFLXT,FLXNT	STP0630
C		STP0640
	20 IF (IFLO.E2.ICHK(3)) CALL CHECK	STP0650
	IF (IERR.E2.2) GO TO 30	STP0660
	IF (MOD(KT,KTH).NE.0.AND.IFINAL.NE.1) RETURN	STP0670
	30 WRITE (6,210) KT,DELT,SUM,SMIN,HRS,DAYS,YRS,DAYSP,YRSP	STP0680
	IF (IFLO.E2.ICHK(3)) CALL CWRITE	STP0690
	IT=IT+1	STP0700
	WRITE (6,180) (TEST3(J),J=1,IT)	STP0710
	I3=1	STP0720
	I5=0	STP0730
	352 I5=I5+40	STP0740
	I4=MIN0(KT,I5)	STP0750
	WRITE (6,240) (I,I=I3,I4)	STP0760
	WRITE (6,260)	STP0770
	WRITE (6,250) (ITTO(I),I=I3,I4)	STP0780
	WRITE (6,260)	STP0790
	IF(KT.LE.I5) GO TO 353	STP0800
	I3=I3+40	STP0810
	GO TO 352	STP0820
C		STP0830
C	---PRINT MAPS---	STP0840
	353 IF (XSCALE.E2.0.) GO TO 70	STP0850
	IF (FACT1.E2.0.) GO TO 50	STP0860
	DO 40 IA=1,9	STP0870
	II=LEVEL1(IA)	STP0880
	IF (II.E2.0) GO TO 50	STP0890
	40 CALL PRNTA(1,II)	STP0900
	50 IF (FACT2.E2.0.) GO TO 70	STP0910
	DO 60 IA=1,9	STP0920
	II=LEVEL2(IA)	STP0930
	IF (II.E2.0) GO TO 70	STP0940
	60 CALL PRNTA(2,II)	STP0950
	70 IF (IDRAW.NE.ICHK(1)) GO TO 100	STP0960
C		STP0970
C	---PRINT DRAWDOWN---	STP0980
	DO 90 K=1,K0	STP0990
	WRITE (6,200) K	STP1000
	DO 90 I=1,I0	STP1010
	DO 80 J=1,J0	STP1020
	80 DDN(J)=STRT(I,J,K)-PHI(I,J,K)	STP1030
	90 WRITE (6,170) I,(DDN(J),J=1,J0)	STP1040
	100 IF (IHEAD.NE.ICHK(2)) GO TO 120	STP1050
C		STP1060
C	---PRINT HEAD MATRIX---	STP1070
	DO 110 K=1,K0	STP1080
	WRITE (6,190) K	STP1090
	DO 110 I=1,I0	STP1100
	110 WRITE (6,170) I,(PHI(I,J,K),J=1,J0)	STP1110
C		STP1120
C	---WRITE ON DISK---	STP1130
	120 IF (IERR.E2.2) GO TO 130	STP1140

	IF (KP.LT.NPER.OR.IFIMAL.NE.1) RETURN	STP1150
	IF (IDK2.EQ.1CHK(5)) WRITE (4) PHI,SUM,SUMP,PUMPT,CFLUXT,QRET,CHST	STP1160
	1,CHDT,FLUXT,STORT,RLFLXT,FLXNT	STP1170
C		STP1180
C	---PUNCHED OUTPUT---	STP1190
	130 IF (IPU2.NE.1CHK(9)) GO TO 160	STP1200
	IF (IERR.EQ.2) GO TO 140	STP1210
	WRITE (7,230) SUM,SUMP,PUMPT,CFLUXT,QRET,CHST,CHDT,FLUXT,STORT,ETP	STP1220
	1LXT,FLXNT	STP1230
	140 DO 150 K=1,K0	STP1240
	DO 150 I=1,I0	STP1250
	150 WRITE (7,220) (PHI(I,J,K),J=1,J0)	STP1260
	160 IF (IERR.EQ.2) STOP	STP1270
	RETURN	STP1280
C		STP1290
C	---FORMATS---	STP1300
C		STP1310
C		STP1320
C		STP1330
	170 FORMAT ('0',I4,18F7.2/(5X,18F7.2))	STP1340
	180 FORMAT ('0MAXIMUM HEAD CHANGE FOR EACH ITERATION: '/' ,39('-')/('0	STP1350
	1',10F12.4))	STP1360
	190 FORMAT ('1',55X,'HEAD MATRIX, LAYER',I3/56X,21('-'))	STP1370
	200 FORMAT ('1',55X,' DRAWDOWN, LAYER',I3/59X,18('-'))	STP1380
	210 FORMAT (1H1,44X,57('-')/45X,' ',14X,'TIME STEP NUMBER =',I9,14X,'	STP1390
	1'/45X,57('-')//50X,29HSIZE OF TIME STEP IN SECONDS=,F14.2//55X,'TO	STP1400
	2TAL SIMULATION TIME IN SECONDS=,F14.2/80X,8HMINUTES=,F14.2/82X,6H	STP1410
	3HOURS=,F14.2/83X,5HDAYS=,F14.2/82X,'YEARS=,F14.2///45X,'DURATION	STP1420
	4OF CURRENT PUMPING PERIOD IN DAYS=,F14.2/82X,'YEARS=,F14.2//)	STP1430
	220 FORMAT (10F8.4)	STP1440
	230 FORMAT (4G20.10)	STP1450
	240 FORMAT ('0TIME STEP :',40I3)	STP1460
	250 FORMAT ('0ITERATIONS:',40I3)	STP1470
	260 FORMAT (' ',10('-'))	STP1480
	END	STP1490

	SUBROUTINE SOLVE(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FAC	SP30010
	1T,EL,FL,GL,V,XI,TEST3,QRE,BOTTOM,	SP30020
	2PERM,IDR,RH,RC,RB,IRIV)	SP30030*
C	-----	SP30040
C	SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE	SP30050
C	-----	SP30060
C		SP30070
C	SPECIFICATIONS:	SP30080
	REAL *8PHI,RHO,B,D,F,H,Z,SU,RHOP,W,WMIN,RHO1,RHO2,RHO3,XPART,YPART	SP30090
	1,ZPART,DMIN1,WMAX,XT,YT,ZT,DABS,DMAX1,DEN,TXM,TYM,TDEN	SP30100
	REAL *8E,AL,BL,CL,A,C,G,WU,TU,U,DL,RES,SUPH,GLXI,ZPHI	SP30110
C		SP30120
	DIMENSION PHI(1),STRT(1),OLD(1),T(1),S(1),TR(1),TC(1),TK(1)	SP30130
	1,WELL(1),DELX(1),DELY(1),DELZ(1),FACT(K0,3),RHOP(20),TEST3(	SP30140
	21),EL(1),FL(1),GL(1),V(1),XI(1),QRE(1),BOTTOM(1)	SP30150
	3,PERM(1),IDR(1),RH(1),RC(1),RB(1)	SP30160*
	DIMENSION IN(36,59,7),TT(36,59,6),DBOT(36,59),ISEA(36,59)	SP30170*
	2,DTOP(9),IAA(30),HEDSTR(10),BTM(36,59),KCHOP2(9),IFNLHD(36,59,7),TSP	SP30180*
	3DEN(8)	SP30183*
C		SP30190
	COMMON /INTEGR/ IO,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NSP	SP30200
	1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFL0,IERR,I2,J2,K2,IMAX,ITMX1,NCSP	SP30210
	2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK,IEQN	SP30220
	3,NKODE,KFLOW	SP30230*
	COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,BETA1	SP30240*
	COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)	SP30250
	RETURN	SP30260
C		SP30270
C	*****	SP30280
	ENTRY ITER	SP30290
C	*****	SP30300
C	---COMPUTE AND PRINT ITERATION PARAMETERS---	SP30310
	WRITE (6,240)	SP30320
	WMIN=1.D0	SP30330
	DELT=1.	SP30340
	P2=LENGTH-1	SP30350
	NT=IO*J0*K0	SP30360
	NIJ=IO*J0	SP30370
	XT=3.141593**2/(2.*J2*J2)	SP30380
	YT=3.141593**2/(2.*I2*I2)	SP30390
	ZT=3.141593**2/(2.*K0*K0)	SP30400
	RHO1=0.D0	SP30410
	RHO2=0.D0	SP30420
	RHO3=0.D0	SP30430
	DO 40 K=1,K0	SP30440
	DO 40 I=2,I1	SP30450
	DO 40 J=2,J1	SP30460
	N=I+(J-1)*IO+(K-1)*NIJ	SP30470
	IF (T(N).EQ.0.) GO TO 40	SP30480
	D=TR(N-IO)/DELX(J)	SP30490
	F=TR(N)/DELX(J)	SP30500
	B=TC(N-1)/DELY(I)	SP30510
	H=TC(N)/DELY(I)	SP30520
	SU=0.D0	SP30530
	Z=0.D0	SP30540
	IF (K.NE.1) Z=TK(N-NIJ)/DELZ(K)	SP30550
	IF (K.NE.K0) SU=TK(N)/DELZ(K)	SP30560

10	CONTINUE	SP30570
	TXM=DMAX1(D,F)	SP30580
	TYM=DMAX1(B,H)	SP30590
	TZM=DMAX1(SU,Z)	SP30600
	DEN=DMIN1(D,F)	SP30610
	IF (DEN.EQ.0.D0) DEN=TXM	SP30620
	IF (DEN.EQ.0.D0) GO TO 20	SP30630
	RHO1=DMAX1(RHO1, TYM/DEN)	SP30640
20	DEN=DMIN1(B,H)	SP30650
	IF (DEN.EQ.0.D0) DEN=TYM	SP30660
	IF (DEN.EQ.0.D0) GO TO 30	SP30670
	RHO2=DMAX1(RHO2, TXM/DEN)	SP30680
30	DEN=DMIN1(SU,Z)	SP30690
	IF (DEN.EQ.0.D0) DEN=TZM	SP30700
	IF (DEN.EQ.0.D0) GO TO 40	SP30710
	RHO3=DMAX1(RHO3, TXM/DEN)	SP30720
40	CONTINUE	SP30730
	XPART=XT/(1.D0+RHO1)	SP30740
	YPART=YT/(1.D0+RHO2)	SP30750
	ZPART=ZT/(1.D0+RHO3)	SP30760
	WMIN=DMIN1(WMIN, XPART, YPART, ZPART)	SP30770
	WMAX=1.D0-WMIN	SP30780
	PJ=-1.	SP30790
	DO 50 I=1, LENGTH	SP30800
	PJ=PJ+1.	SP30810
50	RHOP(I)=1.D0-(1.D0-WMAX)**(PJ/P2)	SP30820
	WRITE (6,230) LENGTH, (RHOP(J), J=1, LENGTH)	SP30830
	RETURN	SP30840
C		SP30850
C		SP30860
C	---INITIALIZE DATA FOR A NEW ITERATION---	SP30870
60	IT=IT+1	SP30880
C		SP30890
C	PRINT HEAD VALUES FOR SELECTED NODES	SP30900
C		SP30910
	ITT=IT-1	SP30920
	IF(NODKOD.NE.1) GO TO 68	SP30930*
	IF(ITT.LT.1) WRITE(6,2970) (IAA(I), I=1, MNOD)	SP30940*
	J=1	SP30950*
	DO 64 I=3, MNOD, 3	SP30960*
	N=IAA(I-2)+(IAA(I-1)-1)*I0+(IAA(I)-1)*NIJ	SP30970*
	HEDSTR(J)=PHI(N)	SP30980*
	J=J+1	SP30990*
64	CONTINUE	SP31000*
	WRITE(6,2980) ITT, (HEDSTR(J), J=1, NMBRND)	SP31010*
C		SP31020
68	IF (IT.LE.ITMAX) GO TO 70	SP31030
	WRITE (6,220)	SP31040
	CALL OUTPUT	SP31050
70	IF (MOD(IT, LENGTH)) 80, 80, 90	SP31060
C	*****	SP31070
	ENTRY NEWITA	SP31080
C	*****	SP31090
80	NTH=0	SP31100
90	NTH=NTH+1	SP31110
	W=RHOP(NTH)	SP31120
	TEST3(IT+1)=0.	SP31130

TEST=0.0	SP31140
BIG=0.	SP31150
DO 100 I=1,NT	SP31160
EL(I)=0.	SP31170
FL(I)=0.	SP31180
GL(I)=0.	SP31190
V(I)=0.	SP31200
100 XI(I)=0.	SP31210
C	SP31220
C	SP31230
C	SP31240
---COMPUTE TRANSMISSIVITY AND T COEFFICIENTS FOR UPPER	SP31250
HYDROLOGIC UNIT WHEN IT IS UNCONFINED---	SP31260
IF (IWATER.NE.ICHK(6)) GO TO 110	SP31270
CALL TRANS(0)	SP31280
CALL TCOF	SP31290
C	SP31300
C	SP31310
---CHOOSE SIP NORMAL OR REVERSE ALGORITHM---	SP31320
110 IF (MOD(IT,2)) 120,120,170	SP31330
120 DO 150 K=1,K0	SP31340
DO 150 I=2,I1	SP31350
DO 150 J=2,J1	SP31360
N=I+(J-1)*I0+(K-1)*NIJ	SP31370
NIA=N+1	SP31380
NIB=N-1	SP31390
NJA=N+I0	SP31400
NJB=N-I0	SP31410
NKA=N+NIJ	SP31420
NKB=N-NIJ	SP31430
C	SP31440
C	SP31450
---SKIP COMPUTATIONS IF NODE OUTSIDE MODEL---	SP31460
IF (T(N).EQ.0. .OR.S(N).LT.0.) GO TO 150	SP31470
C	SP31480
C	SP31490
---COMPUTE COEFFICIENTS---	SP31500
D=TR(NJB)/DELX(J)	SP31510
F=TR(N)/DELX(J)	SP31520
B=TC(NIB)/DELY(I)	SP31530
H=TC(N)/DELY(I)	SP31540
SU=0.D0	SP31550
Z=0.D0	SP31560
IF(K.EQ.1) GO TO 124	SP31570
Z=TK(NKB)	SP31580
IF(IEQN.EQ.ICHK(11)) Z=Z/DELZ(K)	SP31590*
124 IF(K.EQ.K0) GO TO 125	SP31600*
SU=TK(N)	SP31610*
IF(IEQN.EQ.ICHK(11))SU=SU/DELZ(K)	SP31620*
125 RHO=S(N)/DELT	SP31630*
QR=0.	SP31640*
UXR=0.	SP31650*
IF (K.NE.K0) GO TO 127	SP31660*
IF (IQRE.EQ.ICHK(7)) QR=QRE(I+(J-1)*I0)	SP31670*
127 IF(IRIV.LE.0) GO TO 130	SP31680*
ND=IDR(N)	SP31690*
IF(ND.EQ.0) GO TO 130	SP31700*
IF(PHI(N).GT.RB(ND)) GO TO 128	
QR=QR+RC(ND)*(RH(ND)-RB(ND))	
GO TO 130	
128 UXR=RC(ND)	
QR=QR+RC(ND)*RH(ND)	

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C      SP31710
C      ---SIP NORMAL ALGORITHM--- SP31720
C      ---FORWARD SUBSTITUTE, COMPUTING INTERMEDIATE VECTOR V--- SP31730
130 E=-B-D-F-H-SU-Z-RHO-UXR SP31740
    BL=B/(1.+W*(EL(NIB)+GL(NIB))) SP31750
    CL=D/(1.+W*(FL(NJB)+GL(NJB))) SP31760
    C=BL*EL(NIB) SP31770
    G=CL*FL(NJB) SP31780
    WU=CL*GL(NJB) SP31790
    U=BL*GL(NIB) SP31800
    IF (K.EQ.1) GO TO 140 SP31810
    AL=Z/(1.+W*(EL(NKB)+FL(NKB))) SP31820
    A=AL*EL(NKB) SP31830
    TU=AL*FL(NKB) SP31840
    DL=E+W*(A+C+G+WU+TU+U)-CL*EL(NJB)-BL*FL(NIB)-AL*GL(NKB) SP31850
    IF (DABS(DL).LT.1.E-10) WRITE(8,8100) I,J,K,DL,E,W,CL,BL,AL SP31860*
    IF (DABS(DL).LT.1.0E-10) WRITE(8,8125) B,D,F,H,SU,Z,RHO,UXR SP31870*
    IF (DABS(DL).LT.1.0E-10) WRITE(8,8130) A,C,G,WU,TU,U SP31880*
    IF (DABS(DL).LT.1.0E-10) WRITE(8,8150) T(N),T(NIB),T(NIA),T(NJB), SP31890*
    T(NJA),T(NKB),T(NKA) SP31900*
    EL(N)=(F-W*(A+C))/DL SP31910
    FL(N)=(H-W*(G+TU))/DL SP31920
    GL(N)=(SU-W*(WU+U))/DL SP31930
    SUPH=0.DO SP31940
    IF (K.NE.K0) SUPH=SU*PHI(NKA) SP31950
    RES=-B*PHI(NIB)-D*PHI(NJB)-E*PHI(N)-F*PHI(NJA)-H*PHI(NIA)-SUPH-Z*P SP31960
    HI(NKB)-WELL(N)-RHO*OLD(N)-QR SP31970
    RES=RES*BETA1 SP31980*
    V(N)=(RES-AL*V(NKB)-BL*V(NIB)-CL*V(NJB))/DL SP31990
    GO TO 150 SP32000
140 DL=E+W*(C+G+WU+U)-CL*EL(NJB)-BL*FL(NIB) SP32010
    EL(N)=(F-W*C)/DL SP32020
    FL(N)=(H-W*G)/DL SP32030
    GL(N)=(SU-W*(WU+U))/DL SP32040
    SUPH=0.DO SP32050
    IF (K.NE.K0) SUPH=SU*PHI(NKA) SP32060
    RES=-B*PHI(NIB)-D*PHI(NJB)-E*PHI(N)-F*PHI(NJA)-H*PHI(NIA)-SUPH-WEL SP32070
    L(N)-RHO*OLD(N)-QR SP32080
    RES=RES*BETA1 SP32090*
    V(N)=(RES-BL*V(NIB)-CL*V(NJB))/DL SP32100
150 CONTINUE SP32110
C      SP32120
C      ---BACK SUBSTITUTE FOR VECTOR XI--- SP32130
    DO 160 K=1,K0 SP32140
    K3=K0-K+1 SP32150
    DO 160 I=1,I2 SP32160
    I3=I0-I SP32170
    DO 160 J=1,J2 SP32180
    J3=J0-J SP32190
    N=I3+(J3-1)*I0+(K3-1)*NIJ+I-I SP32200
    IF (T(N).EQ.0. .OR.S(N).LT.0.) GO TO 160 SP32210
    GLXI=0.DO SP32220
    IF (K3.NE.K0) GLXI=GL(N)*XI(N+NIJ) SP32230
    XI(N)=V(N)-EL(N)*XI(N+I0)-FL(N)*XI(N+1)-GLXI SP32240
    SP32250
C      SP32260
C      ---COMPARE MAGNITUDE OF CHANGE WITH CLOSURE CRITERIA--- SP32270
    TCHK=ABS(XI(N))

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IF (TCHK.GT.BIG) BIG=TCHK	SP32280
PHI(N)=PHI(N)+XI(N)	SP32290
160 CONTINUE	SP32300
IF (BIG.GT.ERR) TEST=1.	SP32310
TEST3(IT+1)=BIG	SP32320
C	SP32330*
C ---GROUP I CARDS---	SP32340*
C	SP32350*
C	SP32360*
C CHECK IF THIS IS FIRST TIME STEP OF FIRST PUMPING PERIOD.	SP32370*
C IF NOT SKIP THIS SECTION.	SP32371*
IF(KP.GT.1) GO TO 2090	SP32380*
IF(KT.GT.1) GO TO 2090	SP32385*
C	SP32390*
C CHECK IF THIS IS FIRST SOLUION. IF IT IS PROCEED WITH INITIAL CHECK	SP32400*
IF(IT.NE.0) GO TO 2090	SP32410*
C	SP32420*
C INTERFACE DEFINITION: DEFINE PARAMETERS, READ DATA, INITIALIZE IN	SP32430*
C ARRAY AND PERFORM FIRST CHOP	SP32440*
C	SP32450*
C	SP32460*
C DEFINITION OF PARAMETERS	SP32470*
C	SP32480*
C NTAD = NUMBER OF ITERATIONS BETWEEN T ADJUSTMENTS	SP32490*
C DBOT(I,J) = BASE OF AQUIFER SYSTEM IN TERMS OF + NUMBERS BECAUSE	SP32500*
C Z IS + DOWNWARD	SP32510*
C RF = COEFFICIENT OF PHI TO GIVE INTERFACE DEPTH BELOW SEA LEVEL	SP32520*
C = ((RHOS-RHOF)/RHOF)	SP32530*
C DTOP(K) = DEPTH BELOW SEA LEVEL TO TOP OF LAYERS IN TERMS OF +	SP32540*
C NUMBERS BECAUSE Z IS + DOWNWARD	SP32550*
C Z2 = DISTANCE TO TOP OF F.D. BLOCK BELOW SEA LEVEL	SP32560*
C IH = IO/2 FOR TWO-SIDED CHOP, = I1 FOR ONE-SIDED CHOP	SP32570*
C (E.G. CROSS SECTIONS)	SP32580*
C Z = DEPTH BELOW S.L. TO INTERFACE	SP32590*
C IN = 4 = BLOCK WITH ADJUSTED T	SP32600*
C = 6 = BLOCK DROPPED DURING CHOP	SP32610*
C = 7 = BLOCK DROPPED BECAUSE OCEAN LEAKAGE INTO AQUIFER	SP32620*
C = 8 = INITIAL T = 0	SP32630*
C KODCHP = CODE TO INDICATE WHETHER CHOPPING SHOULD PROCEED FROM	SP32640*
C TWO SIDES OR ONE (1=ONE-SIDED, NE 1=TWO-SIDED)	SP32650*
C READ AND WRITE INPUT DATA	SP32660*
READ(5,2901) NTAD,RF,KODCHP,KPRNTT	SP32670*
WRITE(6,2902) NTAD,RF,KODCHP,KPRNTT	SP32680*
C	SP32690*
C READ AND PRINT AQUIFER BASE	SP32700*
READ(5,2909) FAC,IVAR,IPRN	SP32710*
IF(IVAR.NE.1) GO TO 2002	SP32720*
DO 2001 I=1,IO	SP32730*
2001 READ(5,2903) (DBOT(I,J),J=1,J0)	SP32740*
2002 DO 2004 I=1,IO	SP32750*
DO 2004 J=1,J0	SP32760*
IF(IVAR.NE.1) GO TO 2003	SP32770*
DBOT(I,J)=DBOT(I,J)*FAC	SP32780*
GO TO 2004	SP32790*
2003 DBOT(I,J)=FAC	SP32800*
2004 CONTINUE	SP32810*
IF(IPRN.EQ.1) GO TO 2006	SP32820*

WRITE(6,2904)	SP32830*
DO 2005 I=1,I0	SP32840*
2005 WRITE(6,2905) I,(DBOT(I,J),J=1,J0)	SP32850*
C	SP32860*
C READ AND PRINT CONSTANT HEAD OCEAN NODES	SP32870*
2006 DO 2007 I=1,I0	SP32880*
2007 READ(5,2906) (ISEA(I,J),J=1,J0)	SP32890*
WRITE(6,2907)	SP32900*
DO 2008 I=1,I0	SP32910*
2008 WRITE(6,2908) I,(ISEA(I,J),J=1,J0)	SP32920*
C	SP32930*
C READ AND PRINT DEPTH TO LAYER TOPS	SP32940*
READ(5,2909) (DTOP(K),K=1,K0)	SP32950*
DO 2010 K=1,K0	SP32960*
2010 WRITE(6,2910) K,DTOP(K)	SP32970*
C READ NODES FOR WHICH HEAD VALUES AT EACH ITERATION ARE TO BE PRINTED	SP32980*
READ(5,2909) NODKOD,NMBRND	SP32990*
IF(NODKOD.NE.1) GO TO 2012	SP33000*
MNOD=3*NMBRND	SP33010*
READ(5,2960) (IAA(I),I=1,MNOD)	SP33020*
C	SP33030*
C READ NODES FOR WHICH FINAL HEADS ARE TO BE PRINTED INDIVIDUALLY	SP33040*
C	SP33050*
2012 READ(5,2909) IHEDKD	SP33060*
IF(IHEDKD.NE.1) GO TO 2014	SP33070*
DO 2013 K=1,K0	SP33080*
DO 2013 I=1,I0	SP33090*
2013 READ(5,2906) (IFNLHD(I,J,K),J=1,J0)	SP33100*
C CHECK IF INTERFACE SOLUTION. IF NOT SKIP THIS SECTION	SP33110*
2014 IF(NKODE.NE.1) GO TO 2095	SP33120*
C	SP33130*
C	SP33140*
C INITIALIZE IN,TT, AND SCALARS	SP33150*
IH=I0/2	SP33160*
IF(KODCHP.EQ.1) IH=I1	SP33170*
NIJ=I0*J0	SP33180*
KCHOP2(K0)=0	SP33190*
DO 2015 K=1,K1	SP33200*
KCHOP2(K)=0	SP33210*
DO 2015 I=1,I0	SP33220*
DO 2015 J=1,J0	SP33230*
N=I+(J-1)*I0+(K-1)*NIJ	SP33240*
IN(I,J,K)=0	SP33250*
2015 TT(I,J,K)=T(N)	SP33260*
C	SP33270*
DO 2017 I=1,I0	SP33280*
DO 2017 J=1,J0	SP33290*
IN(I,J,K0)=0	SP33300*
M=I+(J-1)*I0	SP33310*
2017 BTM(I,J)=BOTTOM(M)	SP33320*
C	SP33330*
C NORTH SIDE CHECK	SP33340*
C	SP33350*
DO 2026 K=1,K0	SP33360*
DO 2025 J=2,J1	SP33370*
DO 2020 I=2,IH	SP33380*
N=I+(J-1)*I0+(K-1)*NIJ	SP33390*

IF(T(N).EQ.0.) IN(I,J,K)=8	SP33400*
2020 CONTINUE	SP33410*
2025 CONTINUE	SP33420*
2026 CONTINUE	SP33430*
C	SP33440*
IF(KODCHP.EQ.1) GO TO 2038	SP33450*
C	SP33460*
C SOUTH SIDE CHECK:	SP33470*
C	SP33480*
DO 2036 K=1,K0	SP33490*
DO 2035 J=2,J1	SP33500*
DO 2030 II=1,IH	SP33510*
I=I0-II	SP33520*
N=I+(J-1)*I0+(K-1)*NIJ	SP33530*
IF(T(N).EQ.0.) IN(I,J,K)=8	SP33540*
2030 CONTINUE	SP33550*
2035 CONTINUE	SP33560*
2036 CONTINUE	SP33570*
C	SP33580*
C PRINT IN ARRAY FOR EACH LAYER	SP33590*
2038 DO 2042 K=1,K0	SP33600*
WRITE(6,2911) K	SP33610*
DO 2040 I=1,I0	SP33620*
2040 WRITE(6,2912) I,(IN(I,J,K),J=1,J0)	SP33630*
2042 CONTINUE	SP33640*
C	SP33650*
C ADJUST T?	SP33660*
2090 IF(NKODE.LT.1) GO TO 2095	SP33670*
IF(TEST.EQ.0.) GO TO 2700	SP33680*
IF(IT.EQ.0) GO TO 60	SP33690*
IF(MOD(IT,NTAD).EQ.0) GO TO 2100	SP33700*
2095 IF(TEST.EQ.0.) RETURN	SP33710
GO TO 60	SP33720
C	SP33730
170 DO 200 KK=1,K0	SP33740
K=K0-KK+1	SP33750
DO 200 II=1,I2	SP33760
I=I0-II	SP33770
DO 200 J=2,J1	SP33780
N=I+(J-1)*I0+(K-1)*NIJ	SP33790
NIA=N+1	SP33800
NIB=N-1	SP33810
NJA=N+I0	SP33820
NJB=N-I0	SP33830
NKA=N+NIJ	SP33840
NKB=N-NIJ	SP33850
C	SP33860
C ---SKIP COMPUTATIONS IF NODE OUTSIDE AQUIFER---	SP33870
IF (T(N).EQ.0. .OR.S(N).LT.0.) GO TO 200	SP33880
C	SP33890
C ---COMPUTE COEFFICIENTS---	SP33900
D=TR(NJB)/DELX(J)	SP33910
F=TR(N)/DELX(J)	SP33920
B=TC(NIB)/DELY(I)	SP33930
H=TC(N)/DELY(I)	SP33940
SU=0.D0	SP33950
Z=0.D0	SP33960

IF(K.EQ.1) GO TO 174	SP33970
Z=TK(NKB)	SP33980
IF(IEQN.EQ.ICHK(11)) Z=Z/DELZ(K)	SP33990
174 IF(K.EQ.K0) GO TO 175	SP34000
SU=TK(N)	SP34010
IF(IEQN.EQ.ICHK(11))SU=SU/DELZ(K)	SP34020
175 RHO=S(N)/DELT	SP34030
QR=0.	SP34040*
UXR=0.	SP34050*
IF (K.NE.K0) GO TO 177	SP34060*
IF (IQRE.EQ.ICHK(7)) QR=QRE(I+(J-1)*I0)	SP34070*
177 IF(IRIV.LE.0) GO TO 180	SP34080*
ND=IDR(N)	SP34090*
IF(ND.EQ.0) GO TO 180	SP34100*
IF(PHI(N).GT.RB(ND)) GO TO 178	SP34110*
QR=QR+RC(ND)*(RH(ND)-RB(ND))	SP34120*
GO TO 180	SP34130*
178 UXR=RC(ND)	SP34140*
QR=QR+RC(ND)*RH(ND)	SP34150*
C	SP34160
---	SP34170
---SIP REVERSE ALGORITHM---	SP34180
C	SP34190
---	SP34200
---FORWARD SUBSTITUTE, COMPUTING INTERMEDIATE VECTOR V---	SP34210
180 E=-B-D-F-H-SU-Z-RHO-UXR	SP34220
BL=H/(1.+W*(EL(NIA)+GL(NIA)))	SP34230
CL=D/(1.+W*(FL(NJB)+GL(NJB)))	SP34240
C=BL*EL(NIA)	SP34250
G=CL*FL(NJB)	SP34260
WU=CL*GL(NJB)	SP34270
U=BL*GL(NIA)	SP34280
IF (K.EQ.K0) GO TO 190	SP34290
AL=SU/(1.+W*(EL(NKA)+FL(NKA)))	SP34300
A=AL*EL(NKA)	SP34310*
TU=AL*FL(NKA)	SP34320*
DL=E+W*(C+G+A+WU+TU)-AL*GL(NKA)-BL*FL(NIA)-CL*EL(NJB)	SP34330*
IF(DABS(DL).LT.1.E-10) WRITE(8,8200) I,J,K,DL,E,W,CL,BL,AL	SP34340*
IF(DABS(DL).LT.1.0E-10) WRITE(8,8125) B,D,F,H,SU,Z,RHO,UXR	SP34350*
IF(DABS(DL).LT.1.0E-10) WRITE(8,8130) A,C,G,WU,TU,U	SP34360
IF(DABS(DL).LT.1.0E-10) WRITE(8,8150) T(N),T(NIB),T(NIA),T(NJB),	SP34370
1T(NJA),T(NKB),T(NKA)	SP34380
EL(N)=(F-W*(C+A))/DL	SP34390
FL(N)=(B-W*(G+TU))/DL	SP34400
GL(N)=(Z-W*(WU+U))/DL	SP34410
ZPHI=0.D0	SP34420
IF (K.NE.1) ZPHI=Z*PHI(NKB)	SP34430*
RES=-B*PHI(NIB)-D*PHI(NJB)-E*PHI(N)-F*PHI(NJA)-H*PHI(NIA)-SU*PHI(NSP34410	SP34440
1KA)-ZPHI-WELL(N)-RHO*OLD(N)-QR	SP34450
RES=RES*BETA1	SP34460
V(N)=(RES-AL*V(NKA)-BL*V(NIA)-CL*V(NJB))/DL	SP34470
GO TO 200	SP34480
190 DL=E+W*(C+G+WU+U)-BL*FL(NIA)-CL*EL(NJB)	SP34490
EL(N)=(F-W*C)/DL	SP34500
FL(N)=(B-W*G)/DL	SP34510
GL(N)=(Z-W*(WU+U))/DL	SP34520
ZPHI=0.D0	SP34530
IF (K.NE.1) ZPHI=Z*PHI(NKB)	
RES=-B*PHI(NIB)-D*PHI(NJB)-E*PHI(N)-F*PHI(NJA)-H*PHI(NIA)-ZPHI-WELSP34520	
1L(N)-RHO*OLD(N)-QR	

RES=RES*BETA1	SP34540*
V(N)=(RES-BL*V(NIA)-CL*V(NJB))/DL	SP34550
200 CONTINUE	SP34560
C	SP34570
C ---BACK SUBSTITUTE FOR VECTOR XI---	SP34580
DO 210 K=1,K0	SP34590
DO 210 I=2,I1	SP34600
DO 210 J=1,J2	SP34610
J3=J0-J	SP34620
N=I+(J3-1)*I0+(K-1)*NIJ	SP34630
IF (T(N).EQ.0. .OR.S(N).LT.0.) GO TO 210	SP34640
GLXI=0.D0	SP34650
IF (K.NE.1) GLXI=GL(N)*XI(N-NIJ)	SP34660
XI(N)=V(N)-EL(N)*XI(N+I0)-FL(N)*XI(N-1)-GLXI	SP34670
C	SP34680
C ---COMPARE MAGNITUDE OF CHANGE WITH CLOSURE CRITERIA---	SP34690
TCHK=ABS(XI(N))	SP34700
IF (TCHK.GT.BIG) BIG=TCHK	SP34710
PHI(N)=PHI(N)+XI(N)	SP34720
210 CONTINUE	SP34730
IF (BIG.GT.ERR) TEST=1.	SP34740
TEST3(IT+1)=BIG	SP34750
C	SP34760
C ---GROUP II CARDS---	SP34770*
C	SP34780*
IF(NKODE.LT.1) GO TO 2900	SP34790*
IF(TEST.EQ.0.) GO TO 2700	SP34800*
IF(MOD(IT,NTAD).GT.0) GO TO 60	SP34810*
C	SP34820*
C ADJUSTMENT OF T:	SP34830*
C NORTH SIDE	SP34840*
C	SP34850*
2100 WRITE(6,2920) IT	SP34860*
DO 2300 K=1,K0	SP34870*
DO 2280 J=2,J1	SP34880*
DO 2260 I=2,IH	SP34890*
N=I+(J-1)*I0+(K-1)*NIJ	SP34900*
M=I+(J-1)*I0	SP34910*
Z2=DTOP(K)	SP34920*
IF(T(N).EQ.0.) GO TO 2260	SP34930*
C	SP34940*
C COMPUTE INTERFACE DEPTH BELOW SEA LEVEL	SP34950*
Z=RF*PHI(N)	SP34960*
C	SP34970*
C DROP A BLOCK IF OCEAN LEAKAGE IS INTO AQUIFER	SP34980*
C	SP34990*
C CHECK LOWER LAYER	SP35000*
IF(IN(I,J,K-1).EQ.0.OR.IN(I,J,K-1).EQ.4) GO TO 2105	SP35010*
ND=IDR(N)	SP35020*
IF(ND.EQ.0) GO TO 2105	SP35030*
IF(ISEA(I,J).EQ.0) GO TO 2105	SP35040*
IF(PHI(N).GE.RH(ND)) GO TO 2105	SP35050*
T(N)=0.	SP35060*
IN(I,J,K)=7	SP35070*
RC(ND)=0.	SP35080*
IF(K.EQ.K0) PERM(M)=0.	SP35090*
C	SP35100*

GO TO 2260	SP35110*
C NEXT FEW STATEMENTS ARE LAYER DEPENDENT	SP35120*
C	SP35130*
2105 IF(K.EQ.1) GO TO 2110	SP35140*
IF(K.EQ.K0) GO TO 2130	SP35150*
GO TO 2120	SP35160*
C	SP35170*
C LAYER 1	SP35180*
C DROP A BLOCK WHERE INTERFACE IS ABOVE THE TOP	SP35190*
2110 IF(Z.LE.Z2) GO TO 2210	SP35200*
C	SP35210*
C INTERFACE BELOW BLOCK BOTTOM IN LAYER 1	SP35220*
IF(Z.GE.DBOT(I,J)) GO TO 2240	SP35230*
C	SP35240*
C ADJUST T IN BLOCK OF LAYER 1	SP35250*
T(N)=TT(I,J,K)*(Z-Z2)/(DBOT(I,J)-Z2)	SP35260*
IF(ND.NE.0) T(N)=TT(I,J,K)	SP35270*
GO TO 2160	SP35280*
C	SP35290*
C	SP35300*
C MIDDLE LAYERS	SP35310*
C	SP35320*
C CHECK LOWER LAYER	SP35330*
2120 IF(IN(I,J,K-1).EQ.0.OR.IN(I,J,K-1).EQ.4) GO TO 2260	SP35340*
C	SP35350*
C DROP A BLOCK WHERE INTERFACE IS ABOVE THE TOP	SP35360*
IF(Z.LE.Z2) GO TO 2210	SP35370*
C	SP35380*
C INTERFACE BELOW BLOCK BOTTOM	SP35390*
IF(Z.GE.DTOP(K-1)) GO TO 2240	SP35400*
C	SP35410*
C ADJUST T FOR LAYER K	SP35420*
T(N)=TT(I,J,K)*(Z-Z2)/(DTOP(K-1)-DTOP(K))	SP35430*
IF(ND.NE.0) T(N)=TT(I,J,K)	SP35440*
GO TO 2160	SP35450*
C	SP35460*
C TOP LAYER	SP35470*
C	SP35480*
C CHECK LOWER LAYER	SP35490*
2130 IF(IN(I,J,K-1).EQ.0.OR.IN(I,J,K-1).EQ.4) GO TO 2260	SP35500*
C	SP35510*
C DROP A BLOCK WHERE INTERFACE IS ABOVE THE TOP	SP35520*
IF(Z.LE.Z2) GO TO 2210	SP35530*
C	SP35540*
C INTERFACE BELOW BLOCK BOTTOM	SP35550*
IF(Z.GE.DTOP(K-1)) GO TO 2240	SP35560*
C	SP35570*
C ADJUST T FOR LAYER K0	SP35580*
BOTTOM(M)=Z*(-1.0)	SP35590*
IF(ND.NE.0) BOTTOM(M)=BTM(I,J)	SP35600*
T(N)=PERM(M)*(PHI(N)-BOTTOM(M))	SP35610*
C CHOP NODES AND NOTE AN ADJUSTED T	SP35620*
C	SP35630*
2160 IN(I,J,K)=4	SP35640*
GO TO 2260	SP35650*
2210 T(N)=0.	SP35660*
IN(I,J,K)=6	SP35670*

GO TO 2260	SP35680*
2240 IF(K.NE.K0) T(N)=TT(I,J,K)	SP35690*
IF(K.EQ.K0) T(N)=PERM(M)*(PHI(N)-BTM(I,J))	SP35700*
IF(K.EQ.K0) BOTTOM(M)=BTM(I,J)	SP35710*
IN(I,J,K)=0	SP35720*
2260 CONTINUE	SP35730*
2280 CONTINUE	SP35740*
2300 CONTINUE	SP35750*
C	SP35760*
IF (KODCHP.EQ.1) GO TO 60	SP35770*
C	SP35780*
C SOUTH SIDE	SP35790*
C	SP35800*
DO 2500 K=1,K0	SP35810*
DO 2480 J=2,J1	SP35820*
DO 2460 II=1,IH	SP35830*
I=I0-II	SP35840*
N=I+(J-1)*I0+(K-1)*NIJ	SP35850*
M=I+(J-1)*I0	SP35860*
Z2=DTOP(K)	SP35870*
IF(T(N).EQ.0.) GO TO 2460	SP35880*
C	SP35890*
C COMPUTE INTERFACE DEPTH BELOW SEA LEVEL	SP35900*
Z=RF*PHI(N)	SP35910*
C	SP35920*
C DROP A BLOCK IF OCEAN LAYER IS LEAKING INTO AQUIFER	SP35930*
C	SP35940*
C CHECK LOWER LAYER	SP35950*
IF(IN(I,J,K-1).EQ.0.OR.IN(I,J,K-1).EQ.4) GO TO 2305	SP35960*
ND=IDR(N)	SP35970*
IF(ND.EQ.0) GO TO 2305	SP35980*
IF(ISEA(I,J).EQ.0) GO TO 2305	SP35990*
IF(PHI(N).GE.RH(ND)) GO TO 2305	SP36000*
T(N)=0.	SP36010*
IN(I,J,K)=7	SP36020*
RC(ND)=0.	SP36030*
IF(K.EQ.K0) PERM(M)=0.	SP36040*
GO TO 2460	SP36050*
C	SP36060*
C THE NEXT FEW STATEMENTS ARE LAYER DEPENDENT	SP36070*
C	SP36080*
2305 IF(K.EQ.1) GO TO 2310	SP36090*
IF(K.EQ.K0) GO TO 2330	SP36100*
GO TO 2320	SP36110*
C	SP36120*
C LAYER 1	SP36130*
C DROP A BLOCK WHERE INTERFACE IS ABOVE THE TOP	SP36140*
2310 IF(Z.LE.Z2) GO TO 2410	SP36150*
C	SP36160*
C INTERFACE BELOW BLOCK BOTTOM IN LAYER 1	SP36170*
IF(Z.GE.DBOT(I,J)) GO TO 2440	SP36180*
C	SP36190*
C ADJUST T IN BLOCK OF LAYER 1	SP36200*
T(N)=TT(I,J,K)*(Z-Z2)/(DBOT(I,J)-Z2)	SP36210*
IF(ND.NE.0) T(N)=TT(I,J,K)	SP36220*
GO TO 2360	SP36230*
C	SP36240*

C MIDDLE LAYERS	SP36250*
C	SP36260*
C CHECK LOWER LAYER	SP36270*
2320 IF(IN(I,J,K-1).E2.0.OR.IN(I,J,K-1).E2.4) GO TO 2460	SP36280*
C	SP36290*
C DROP A BLOCK WHERE INTERFACE IS ABOVE THE TOP	SP36300*
IF(Z.LE.Z2) GO TO 2410	SP36310*
C	SP36320*
C INTERFACE BELOW BLOCK BOTTOM	SP36330*
IF(Z.GE.DTOP(K-1))GO TO 2440	SP36340*
C	SP36350*
C ADJUST T FOR LAYER K	SP36360*
T(N)=TT(I,J,K)*(Z-Z2)/(DTOP(K-1)-DTOP(K))	SP36370*
IF(ND.NE.0) T(N)=TT(I,J,K)	SP36380*
GO TO 2360	SP36390*
C	SP36400*
C TOP LAYER	SP36410*
C	SP36420*
C CHECK LOWER LAYER	SP36430*
2330 IF(IN(I,J,K-1).E2.0.OR.IN(I,J,K-1).E2.4) GO TO 2460	SP36440*
C	SP36450*
C DROP A BLOCK WHERE INTERFACE IS ABOVE THE TOP	SP36460*
IF(Z.LE.Z2) GO TO 2410	SP36470*
C	SP36480*
C INTERFACE BELOW BLOCK BOTTOM	SP36490*
IF(Z.GE.DTOP(K-1)) GO TO 2440	SP36500*
C	SP36510*
C ADJUST T FOR LAYER K0	SP36520*
BOTTOM(M)=Z*(-1.)	SP36530*
IF(ND.NE.0) BOTTOM(M)=BTM(I,J)	SP36540*
T(N)=PERM(M)*(PHI(N)-BOTTOM(M))	SP36550*
C	SP36560*
C CHOP NODES AND NOTE AN ADJUSTED T	SP36570*
C	SP36580*
2360 IN(I,J,K)=4	SP36590*
GO TO 2460	SP36600*
2410 T(N)=0.	SP36610*
IN(I,J,K)=6	SP36620*
GO TO 2460	SP36630*
2440 IF(K.NE.K0) T(N)=TT(I,J,K)	SP36640*
IF(K.E2.K0) T(N)=PERM(M)*(PHI(N)-BTM(I,J))	SP36650*
IF(K.E2.K0) BOTTOM(M)=BTM(I,J)	SP36660*
IN(I,J,K)=0	SP36670*
2460 CONTINUE	SP36680*
2480 CONTINUE	SP36690*
2500 CONTINUE	SP36700*
C	SP36710*
2600 GO TO 60	SP36720*
C	SP36730*
C	SP36740*
C PRINT CONTENTS OF IN ARRAY AND LOCATION OF ADJUSTED T	SP36750*
2700 DO 2710 K=1,K0	SP36760*
DO 2710 I=2,I1	SP36770*
DO 2710 J=2,J1	SP36780*
2710 IF(IN(I,J,K).E2.6) KCHOP2(K)=KCHOP2(K)+1	SP36790*
DO 2740 K=1,K0	SP36800*
WRITE(6,2925) K,KCHOP2(K)	SP36810*

DO 2720 I=1,I0	SP36820*
2720 WRITE(6,2930) I,(IN(I,J,K),J=1,J0)	SP36830*
2740 CONTINUE	SP36840*
C	SP36850*
WRITE(6,2940)	SP36860*
DO 2800 K=1,K0	SP36870*
DO 2800 I=1,I0	SP36880*
DO 2800 J=1,J0	SP36890*
N=I+(J-1)*I0+(K-1)*NIJ	SP36900*
IF(IN(I,J,K).NE.4) GO TO 2800	SP36910*
Z=RF*PHI(N)	SP36920*
WRITE(6,2950) K,I,J,Z,T(N)	SP36930*
2800 CONTINUE	SP36940*
C	SP36950*
C PRINT FINAL HEAD VALUES FOR SELECTED NODES	SP36960*
IF(IHEDKD.NE.1) GO TO 2825	SP36970*
WRITE(8,2985)	SP36980*
C UPPER LAYER ONLY	SP36990*
K=K0	SP37000*
DO 2820 I=2,I1	SP37010*
DO 2820 J=2,J1	SP37020*
IF(IFNLHD(I,J,K).NE.1) GO TO 2820	SP37030*
N=I+(J-1)*I0+(K-1)*NIJ	SP37040*
WRITE(8,2990) I,J,K,PHI(N)	SP37050*
2820 CONTINUE	SP37060*
C ALL LAYERS	SP37070*
DO 2823 K=1,K0	SP37080*
DO 2823 I=2,I1	SP37090*
DO 2823 J=2,J1	SP37100*
IF(IFNLHD(I,J,K).NE.2) GO TO 2823	SP37110*
N=I+(J-1)*I0+(K-1)*NIJ	SP37120*
WRITE(8,2990) I,J,K,PHI(N)	SP37130*
2823 CONTINUE	SP37140*
C	SP37145*
C PRINT FINAL PHI, T, PERM, AND TK MATRICES	SP37150*
2825 IF(KPRNTT.NE.1) GO TO 2895	SP37160*
I0J0=I0*J0	SP37170*
L1=1	SP37175*
DO 2893 N1=1,3	SP37180*
K0A=K0	SP37185*
IF(N1.GT.2) K0A=K0A-1	SP37190*
DO 2890 K=1,K0A	SP37195*
WRITE(9,2830)	SP37200*
2830 FORMAT(9X,'1',9X,'1',9X,'0',9X,'1',9X,'1',9X,'1',9X,'0',9X,'0')	SP37205*
DO 2885 I=1,I0	SP37210*
DO 2880 J=1,J0	SP37215*
N=I+(J-1)*I0+(K-1)*I0J0	SP37220*
GO TO (2835,2840,2845),N1	SP37225*
2835 TDEN(L1)=PHI(N)	SP37230*
GO TO 2850	SP37235*
2840 IF(K.LT.K0A) GO TO 2843	SP37240*
M=I+(J-1)*I0	SP37243*
TDEN(L1)=PERM(M)	SP37246*
GO TO 2850	SP37250*
2843 TDEN(L1)=T(N)	SP37253*
GO TO 2850	SP37256*
2845 TDEN(L1)=TK(N)	SP37260*

2850 IF(L1.LT.8)GO TO 2855	SP37263*
GO TO 2860	SP37266*
2855 IF(J.E2.J0)GO TO 2860	SP37270*
L1=L1+1	SP37273*
GO TO 2880	SP37276*
2860 WRITE(9,2865)(TDEN(N2), N2=1,8)	SP37280*
2865 FORMAT(8E10.4)	SP37283*
DO 2870 N2=1,8	SP37286*
TDEN(N2)=0.0	SP37290*
2870 CONTINUE	SP37293*
L1=1	SP37296*
2880 CONTINUE	SP37300*
2885 CONTINUE	SP37303*
IF(N1.NE.2)GO TO 2888	SP37306*
IF(IWATER NE.ICHK(6))GO TO 2888	SP37310*
K0A1=K0A-1	SP37313*
IF(K.NE.K0A1)GO TO 2888	SP37316*
WRITE(9,2887)	SP37320*
2887 FORMAT(39X,'1',9X,'1',9X,'1'/'ENDOFMEMBER')	SP37323*
GO TO 2890	SP37326*
2888 IF(N1.E2.1.AND.K.NE.K0A)GO TO 2890	SP37330*
WRITE(9,2889)	SP37333*
2889 FORMAT('ENDOFMEMBER')	SP37336*
2890 CONTINUE	SP37340*
2893 CONTINUE	SP37345*
2895 RETURN	SP37350*
2900 CONTINUE	SP37360*
IF(TEST.E2.0.) RETURN	SP37370*
GO TO 60	SP37380
C	SP37390
C	SP37400
C ---FORMATS---	SP37410
C	SP37420
C	SP37430
C	SP37440
220 FORMAT ('OEXCEEDED PERMITTED NUMBER OF ITERATIONS'/' ',39(' '*'))	SP37450
230 FORMAT (///1H0,I5,22H ITERATION PARAMETERS:,6E15.7/(/28X,6E15.7/))	SP37460
240 FORMAT ('-',44X,'SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE'/45X,SP37470	
143(' '))	SP37480
2901 FORMAT(I10,G10.0,2I10)	SP37490*
2902 FORMAT('0','NTAD=' ,I10,/,3X,'RF =' ,F10.2,/,1X,'KODCHP=' ,I10,	SP37500*
1/1X,'KPRNTT =' ,I10)	SP37510*
2903 FORMAT(16F5.0)	SP37520*
2904 FORMAT('1','BOTTOM OF AQUIFER SYSTEM:'//)	SP37530*
2905 FORMAT('0',I4,2X,20F6.1/(7X,20F6.1))	SP37540*
2906 FORMAT(80I1)	SP37550*
2907 FORMAT('1','SPECIFIED-HEAD OCEAN NODES'//5X,'NUMBERS REPRESENT LAYS	SP37560*
1ER CONTAINING THE SPECIFIED HEAD OCEAN NODE'//7X,'0 = NO OCEAN NODES	SP37563*
2 AT THIS LOCATION'//)	SP37566*
2908 FORMAT('0',I4,2X,60(I1,1X)/(7X,60(I1,1X)))	SP37570*
2909 FORMAT(8G10.0)	SP37580*
2910 FORMAT('0',5X,'DEPTH TO TOP OF LAYER',I5,' = ',F6.1)	SP37590*
2911 FORMAT('1','PRELIMINARY IN ARRAY FOR LAYER',I5// ' INITIAL TRANSM	SP37600*
ISSIVITY SET EQUAL TO ZERO ALONG PERIMETER'/' AND WHERE CODE	SP37610*
2 8.'//)	SP37615*
2912 FORMAT('0',I4,2X,60I2/(7X,60I2))	SP37620*
2920 FORMAT('0','T ADJUSTED ON ITERATION ',I4)	SP37630*

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2925 FORMAT('1','IN ARRAY FOR LAYER',I3,5X,I5,' BLOCKS CHOPPED'//') 8=SP37640*
1 INITIAL TRANSMISSIVITY EQUALS ZERO '/' 6= BLOCK DROPPED DURING SP37643*
2CHOP '/' 7= BLOCK DROPPED BECAUSE OF OCEAN LEAKAGE INTO AQUIFER'/SP37646*
3' 4= BLOCK WITH ADJUSTED TRANSMISSIVITY'///) SP37648*
2930 FORMAT('0',6I12/(3X,60I2)) SP37650*
2940 FORMAT('1','SUMMARY OF NODES WITH ADJUSTED TRANSMISSIVITY'/' LASP37660*
1YER ROW COLUMN Z T(I,J,K)') SP37670*
2950 FORMAT('0',5X,I2,2(8X,I2),6X,F6.2,6X,F8.4) SP37680*
2960 FORMAT(10(I3,I3,I2)) SP37690*
2970 FORMAT('1','HEAD VALUES AT SELECTED NODES AFTER EACH ITERATION'//1SP37700*
14X,'NODE(I,J,K):',5X,10('(',I2,',',I2,',',I1,')')) SP37705*
2980 FORMAT('0',' HEAD AT ITERATION',2X,I5,5X,10(2X,F6.2,2X)) SP37710*
2985 FORMAT('1',10X,'FINAL HEAD VALUES FOR SELECTED NODES') SP37720*
2990 FORMAT(' ',3I5,5X,F7.2) SP37730*
8100 FORMAT(' ','I=',I3,2X,'J=',I3,2X,'K=',I3,2X,'DL=',E10.4,' E=', SP37740*
1E10.4,' W=',E10.4,' CL=',E10.4,' BL=',E10.4,' AL=',E10.4,'SIPNORM' SP37750*
2) SP37760*
8125 FORMAT(' ','B,D,F,H,SU,Z,RHO,UXR=',8(E10.4,2X)) SP37770*
8130 FORMAT(' ','A,C,G,WU,TU,U=',6(E10.4,2X)) SP37780*
8150 FORMAT(' ',5X,'T(N)=' ,E10.4,' T(NIB)=' ,E10.4,' T(NIA)=' ,E10.4, SP37790*
1' T(NJB)=' ,E10.4,' T(NJA)=' ,E10.4,' T(NKB)=' ,E10.4,' T(NKA)=' SP37800*
2,E10.4,/) SP37810*
8200 FORMAT(' ','I=',I3,2X,'J=',I3,2X,'K=',I3,2X,'DL=',E10.4,' E=', SP37820*
1E10.4,' W=',E10.4,' CL=',E10.4,' BL=',E10.4,' AL=',E10.4,'SIPREV') SP37830*
8300 FORMAT('1',' I ',' J ',' T(I,J,1) ',' T(I,J,2) ',' T(I,J,3) SP37840*
1',' T(I,J,4) ',' T(I,J,5) ') SP37850*
8400 FORMAT(' ',2I3,5E12.4) SP37860*
8500 FORMAT('1',' I ',' J ',' TK(I,J,1) ',' TK(I,J,2) ',' TK(I,J,3) SP37870*
1',' TK(I,J,4)') SP37880*
8600 FORMAT(' ',2I3,4E12.4) SP37890*
END SP37900

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SUBROUTINE COEF(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FACTCOF0010
1,PERM,BOTTOM,QRE) COF0020
C -----COF0030
C COMPUTE COEFFICIENTS COF0040
C -----COF0050
C COF0060
C SPECIFICATIONS: COF0070
C REAL *8PHI COF0080
C COF0090
C DIMENSION PHI(I0,J0,K0), STRT(I0,J0,K0), OLD(I0,J0,K0), T(I0,J0,K0)COF0100
1), S(I0,J0,K0), TR(I0,J0,K0), TC(I0,J0,K0), TK(IK,JK,K5), WELL(I0,COF0110
2J0,K0), DELX(J0), DELY(I0), DELZ(K0), FACT(K0,3), PERM(IP,JP), BOTCOF0120
3TOM(IP,JP), QRE(I2,J2) COF0130
C COF0140
C COMMON /INTEGR/ I0,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NCOF0150
1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NCCOF0160
2H,IDK1,IDK2,IWATER,IQRE,IP,JP,I2,J2,IK,JK,K5,IPU1,IPU2,ITK,IE2N COF0170
3,NKODE,KFLOW COF0180*
C COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,BETA1 COF0190*
C COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9) COF0200
C N3 = 1 COF0210
C N7=-1 COF0220
C RETURN COF0230
C .....COF0240
C ---COMPUTE TRANSMISSIVITY FOR UPPER HYDROLOGIC UNIT WHEN COF0250
C IT IS UNCONFINED--- COF0260
C ***** COF0270
C ENTRY TRANS(N3) COF0280
C ***** COF0290
C DO 10 I=2,I1 COF0300
C DO 10 J=2,J1 COF0310
C IF (PERM(I,J).E2.0.) GO TO 10 COF0320
C T(I,J,K0)=PERM(I,J)*(PHI(I,J,K0)-BOTTOM(I,J)) COF0330
C IF (T(I,J,K0).GT.0.) GO TO 10 COF0340
C IF (WELL(I,J,K0).LT.0.) WRITE (6,60) I,J,K0 COF0350
C IF (WELL(I,J,K0).GE.0.) WRITE (6,70) I,J,K0 COF0360
C PERM(I,J)=0. COF0370
C T(I,J,K0)=0. COF0380
C TR(I,J-1,K0)=0. COF0390
C TR(I,J,K0)=0. COF0400
C TC(I,J,K0)=0. COF0410
C TC(I-1,J,K0)=0. COF0420
C IF (K0.NE.1) TK(I,J,K1)=0. COF0430
C PHI(I,J,K0)=1.D30 COF0440
10 CONTINUE COF0450
C IF (N3.E2.1) RETURN COF0460
C N1=K0 COF0470
C N2=K0 COF0480
C N4=K1 COF0490
C GO TO 20 COF0500
C ---COMPUTE T COEFFICIENTS--- COF0510
C ***** COF0520
C ENTRY TCOF COF0530
C ***** COF0540
C N7=N7+1 COF0550
C N1=1 COF0560
C N2=K0 COF0570

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IF(N7.GT.0) N2=K1	COF0580
N4=1	COF0590
20 DO 40 K=N1,N2	COF0600
DO 40 I=1,I1	COF0610
DO 40 J=1,J1	COF0620
IF (T(I,J,K).EQ.0.) GO TO 32	COF0630
IF (T(I,J+1,K).EQ.0.) GO TO 30	COF0640
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)*	COF0650
1DELX(J))*FACT(K,1)	COF0660
30 IF (T(I+1,J,K).EQ.0.) GO TO 32	COF0670
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)*	COF0680
1DELY(I))*FACT(K,2)	COF0690
IF(T(I,J+1,K).EQ.0.) GO TO 32	COF0700
GO TO 40	COF0710
32 IF(T(I,J,K).EQ.0.) GO TO 33	COF0720
GO TO 34	COF0730
33 TR(I,J,K)=0.	COF0740
TR(I,J-1,K)=0.	COF0750
TC(I,J,K)=0.	COF0760
TC(I-1,J,K)=0.	COF0770
TK(I,J,K)=0.	COF0780
IF(WELL(I,J,K).LT.0.)GO TO 80	COF0785*
34 IF(T(I+1,J,K).EQ.0.) GO TO 35	COF0790
GO TO 36	COF0800
35 TC(I,J,K)=0.	COF0810
TC(I+1,J,K)=0.	COF0820
TK(I+1,J,K)=0.	COF0830
36 IF(T(I,J+1,K).EQ.0.) GO TO 37	COF0840
GO TO 40	COF0850
37 TR(I,J,K)=0.	COF0860
TR(I,J+1,K)=0.	COF0870
TK(I,J+1,K)=0.	COF0880
40 CONTINUE	COF0890
IF (K0.EQ.1.OR.ITK.EQ.1CHK(10).OR.N3.EQ.0) RETURN	COF0900
DO 50 K=N4,K1	COF0910
DO 50 I=2,I1	COF0920
DO 50 J=2,J1	COF0930
IF (T(I,J,K+1).EQ.0.) GO TO 50	COF0940
T1=T(I,J,K)*FACT(K,3)	COF0950
T2=T(I,J,K+1)*FACT(K+1,3)	COF0960
TK(I,J,K)=(2.*T2*T1)/(T1*DELZ(K+1)+T2*DELZ(K))	COF0970
50 CONTINUE	COF0980
GO TO 100	COF0981
80 WRITE(6,73) I,J,K	COF0982*
WRITE(6,75)	COF0983*
IERR=2	COF0984
CALL OUTPUT	COF0985
100 RETURN	COF0990
	COF1000
	COF1010
60 FORMAT ('-',20('*'),'WELL',2I3,' IN LAYER',I3,' GOES DRY',20('*'))	COF1020
70 FORMAT ('-',20('*'),'NODE',2I3,' IN LAYER',I3,' GOES DRY',20('*'))	COF1030
73 FORMAT ('-',20('*'),' WELL',2I3,' IN LAYER',I3,' GOES DRY--DEWATECOF1031*	
1RED OR SALINE-WATER INTRUSION ',20('*'))	COF1032*
75 FORMAT('-',5X,'*** EXECUTION TERMINATING-DISCHARGING WELL NODE (NOCOF1033*	
1T IN TOP LAYER) GOES DRY--CHECK FOR SW INTRUSION ***'/10X,'THE FOLCOF1034*	
2LOWING OUTPUT REPRESENTS STATE OF SOLUTION WHEN WELL WENT DRY')	COF1035*

END

COF1040

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SUBROUTINE DATAI(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FACDAT0010
1T,PERM,BOTTOM,QRE, DAT0020
2IDR,RH,RC,RB) DAT0030*
-----DAT0040
C READ AND WRITE DATA DAT0050
C -----DAT0060
C SPECIFICATIONS: DAT0070
C REAL *8PHI DAT0080
C REAL *8XLABEL,YLABEL,TITLE,XN1,MESUR DAT0090
C DAT0100
C DAT0110
DIMENSION PHI(I0,J0,K0), STRT(I0,J0,K0), OLD(I0,J0,K0), T(I0,J0,K0)DAT0120
1), S(I0,J0,K0), TR(I0,J0,K0), TC(I0,J0,K0), TK(IK,JK,K5), WELL(I0, DAT0130
2J0,K0), DELX(J0), DELY(I0), DELZ(K0), FACT(K0,3), PERM(IP,JP), BOTDAT0140
3TOM(IP,JP), QRE(IQ,JQ), TF(3), A(I0,J0), IN(6), IOFT(9), INFT(2) DAT0150
4,IDR(I0,J0,K0),RH(1),RC(1),RB(1) DAT0160*
C DAT0170
COMMON /INTEGR/ I0,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NDAT0180
1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IEERR,I2,J2,K2,IMAX,ITMX1,NCDAT0190
2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK,IEQN DAT0200
3,NKODE,KFLOW DAT0210*
COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,BETA1 DAT0220*
COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9) DAT0230
COMMON /CK/ RLFLXT,STORT,QRET,CHST,CHDT,FLUXT,PUMPT,CFLUXT,FLXNT DAT0240*
COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANKDAT0250
1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),DAT0260
2YN(13),NA(4),N1,N2,N3,YSCALE,FACT1,FACT2 DAT0270
RETURN DAT0280
C .....DAT0290
C ***** DAT0300
C ENTRY DATAIN DAT0310
C ***** DAT0320
C DAT0330
C ---READ AND WRITE SCALAR PARAMETERS--- DAT0340
READ (5,330) NPER,KTH,ERR,LENGTH DAT0350
WRITE (6,340) NPER,KTH,ERR DAT0360
READ (5,460) XSCALE,YSCALE,DINCH,FACT1,(LEVEL1(I),I=1,9),FACT2,(LEDAT0370
1VEL2(I),I=1,9),MESUR DAT0380
IF (XSCALE.NE.0.) WRITE (6,470) XSCALE,YSCALE,MESUR,MESUR,DINCH,FADAT0390
1CT1,LEVEL1,FACT2,LEVEL2 DAT0400
C DAT0410
C ---READ CUMULATIVE MASS BALANCE PARAMETERS--- DAT0420
READ (5,450) SUM,SUMP,PUMPT,CFLUXT,QRET,CHST,CHDT,FLUXT,STORT,ETFLDAT0430
1XT,FLXNT DAT0440
IF (IDK1.EQ.ICHK(4)) GO TO 20 DAT0450
IF (IPU1.NE.ICHK(8)) GO TO 50 DAT0460
C DAT0470
C ---READ INITIAL HEAD VALUES FROM CARDS--- DAT0480
DO 10 K=1,K0 DAT0490
DO 10 I=1,I0 DAT0500
10 READ (5,360) (PHI(I,J,K),J=1,J0) DAT0510
GO TO 30 DAT0520
C DAT0530
C ---READ INITIAL HEAD AND MASS BALANCE PARAMETERS FROM DISK--- DAT0540
20 READ (4) PHI,SUM,SUMP,PUMPT,CFLUXT,QRET,CHST,CHDT,FLUXT,STORT,ETFLDAT0550
1XT,FLXNT DAT0560
REWIND 4 DAT0570

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30	WRITE (6,430) SUM	DAT0580
	DO 40 K=1,K0	DAT0590
	WRITE (6,440) K	DAT0600
	DO 40 I=1,I0	DAT0610
40	WRITE (6,350) I,(PHI(I,J,K),J=1,J0)	DAT0620
C		DAT0630
50	DO 60 K=1,K0	DAT0640
	DO 60 I=1,I0	DAT0650
	DO 60 J=1,J0	DAT0660
	WELL(I,J,K)=0.	DAT0670
	TR(I,J,K)=0.	DAT0680
	TC(I,J,K)=0.	DAT0690
	IF (K.NE.K0) TK(I,J,K)=0.	DAT0700
60	CONTINUE	DAT0710
	RETURN	DAT0720
C	*****	DAT0730
	ENTRY ARRAY(A,INFT,IOFT,IN,IRN,TF)	DAT0740
C	*****	DAT0750
	READ (5,330) FAC,IVAR,IPRN,TF,IRECS,IRECD	DAT0760
	IC=4*IRECS+2*IVAR+IPRN+1	DAT0770
	GO TO (70,70,90,90,120,120), IC	DAT0780
70	DO 80 I=1,I0	DAT0790
	DO 80 J=1,J0	DAT0800
80	A(I,J)=FAC	DAT0810
	WRITE (6,280) IN,FAC,K	DAT0820
	GO TO 140	DAT0830
90	IF (IC.EQ.3) WRITE (6,290) IN,K	DAT0840
	DO 110 I=1,I0	DAT0850
	READ (5,INFT) (A(I,J),J=1,J0)	DAT0860
	DO 100 J=1,J0	DAT0870
100	A(I,J)=A(I,J)*FAC	DAT0880
110	IF (IC.EQ.3) WRITE (6,IOFT) I,(A(I,J),J=1,J0)	DAT0890
	GO TO 140	DAT0900
120	READ (2'IRN) A	DAT0910
	IF (IC.EQ.6) GO TO 140	DAT0920
	WRITE (6,290) IN,K	DAT0930
	DO 130 I=1,I0	DAT0940
130	WRITE (6,IOFT) I,(A(I,J),J=1,J0)	DAT0950
140	IF (IRECD.EQ.1) WRITE (2'IRN) A	DAT0960
	IRN=IRN+1	DAT0970
	RETURN	DAT0980
C	*****	DAT0990
	ENTRY MDAT	DAT1000
C	*****	DAT1010
	DO 150 K=1,K0	DAT1020
	DO 150 I=1,I0	DAT1030
	DO 150 J=1,J0	DAT1040
	IF (I.EQ.1.OR.I.EQ.I0.OR.J.EQ.1.OR.J.EQ.J0) T(I,J,K)=0.	DAT1050
	IF (IDK1.NE.ICHK(4).AND.IPU1.NE.ICHK(8)) PHI(I,J,K)=STRT(I,J,K)	DAT1060
	IF (K.NE.K0.OR.IWATER.NE.ICHK(6)) GO TO 150	DAT1070
	IF (I.EQ.1.OR.I.EQ.I0.OR.J.EQ.1.OR.J.EQ.J0) PERM(I,J)=0.	DAT1080
150	CONTINUE	DAT1090
	READ (5,330) FAC,IVAR,IPRN	DAT1100
C	 DELX	DAT1110
	IF (IVAR.EQ.1) READ (5,330) (DELX(J),J=1,J0)	DAT1120
	DO 170 J=1,J0	DAT1130
	IF (IVAR.NE.1) GO TO 160	DAT1140

	DELX(J)=DELX(J)*FAC	DAT1150
	GO TO 170	DAT1160
160	DELX(J)=FAC	DAT1170
170	CONTINUE	DAT1180
	IF (IVAR.EQ.1.AND.IPRN.NE.1) WRITE (6,370) (DELX(J),J=1,J0)	DAT1190
	IF (IVAR.EQ.0) WRITE (6,300) FAC	DAT1200
C	 DELY	DAT1210
	READ (5,330) FAC,IVAR,IPRN	DAT1220
	IF (IVAR.EQ.1) READ (5,330) (DELY(I),I=1,I0)	DAT1230
	DO 190 I=1,I0	DAT1240
	IF (IVAR.NE.1) GO TO 180	DAT1250
	DELY(I)=DELY(I)*FAC	DAT1260
	GO TO 190	DAT1270
180	DELY(I)=FAC	DAT1280
190	CONTINUE	DAT1290
	IF (IVAR.EQ.1.AND.IPRN.NE.1) WRITE (6,380) (DELY(I),I=1,I0)	DAT1300
	IF (IVAR.EQ.0) WRITE (6,310) FAC	DAT1310
C	 DELZ	DAT1320
	READ (5,330) FAC,IVAR,IPRN	DAT1330
	IF (IVAR.EQ.1) READ (5,330) (DELZ(K),K=1,K0)	DAT1340
	DO 210 K=1,K0	DAT1350
	IF (IVAR.NE.1) GO TO 200	DAT1360
	DELZ(K)=DELZ(K)*FAC	DAT1370
	GO TO 210	DAT1380
200	DELZ(K)=FAC	DAT1390
210	CONTINUE	DAT1400
	IF (IVAR.EQ.1.AND.IPRN.NE.1) WRITE (6,390) (DELZ(K),K=1,K0)	DAT1410
	IF (IVAR.EQ.0) WRITE (6,320) FAC	DAT1420
C		DAT1430
C	---INITIALIZE VARIABLES---	DAT1440
	B=0.	DAT1450
	D=0.	DAT1460
	F=0.	DAT1470
	H=0.	DAT1480
	SU=0.	DAT1490
	Z=0.	DAT1500
	IF (XSCALE.NE.0.) CALL MAP	DAT1510
	RETURN	DAT1520
	ENTRY DDAT2(NRIV)	DAT1530*
	NK=1	DAT1540*
	DO 580 K=1,K0	DAT1550*
	DO 580 I=1,I0	DAT1560*
	READ(5,510) (IDR(I,J,K),J=1,J0)	DAT1570*
	DO 580 J=1,J0	DAT1580*
	IF(IDR(I,J,K).EQ.0) GO TO 580	DAT1590*
	IDR(I,J,K)=NK	DAT1600*
	NK=NK+1	DAT1610*
580	CONTINUE	DAT1620*
	NK=NK-1	DAT1630*
	IF(NK.EQ.NRIV) GO TO 600	DAT1640*
	WRITE(6,520) NK,NRIV	DAT1650*
	STOP	DAT1660*
600	READ(5,330) FAC	DAT1670*
	READ(5,560) (RH(I),I=1,NRIV)	DAT1680*
	DO 610 I=1,NRIV	DAT1690*
610	RH(I)=RH(I)*FAC	DAT1700*
	WRITE(6,540) (RH(I),I=1,NRIV)	DAT1710*

	READ(5,330) FAC	DAT1720*
	READ(5,560) (RB(I),I=1,NRIV)	DAT1730*
	DO 620 I=1,NRIV	DAT1740*
620	RB(I)=RB(I)*FAC	DAT1750*
	WRITE(6,545) (RB(I),I=1,NRIV)	DAT1760*
	READ(5,330) FAC	DAT1770*
	READ(5,625) (RC(I),I=1,NRIV)	DAT1780*
	DO 630 I=1,NRIV	DAT1790*
630	RC(I)=RC(I)*FAC	DAT1800*
	WRITE(6,635) (RC(I),I=1,NRIV)	DAT1810*
	RETURN	DAT1820*
C		DAT1830
C	---READ TIME PARAMETERS AND PUMPING DATA FOR A NEW PUMPING PERIOD---	DAT1840
C	*****	DAT1850
	ENTRY NEWPER	DAT1860
C	*****	DAT1870
C		DAT1880
	READ (5,330) KP,KPM1,NWEL,TMAX,NUMT,CDLT,DELT	DAT1890
C		DAT1900
C	---COMPUTE ACTUAL DELT AND NUMT---	DAT1910
	DT=DELT/24.	DAT1920
	TM=0.0	DAT1930
	DO 220 I=1,NUMT	DAT1940
	DT=CDLT*DT	DAT1950
	TM=TM+DT	DAT1960
	IF (TM.GE.TMAX) GO TO 230	DAT1970
220	CONTINUE	DAT1980
	GO TO 240	DAT1990
230	DELT=TMAX/TM*DELT	DAT2000
	NUMT=I	DAT2010
240	WRITE (6,400) KP,TMAX,NUMT,DELT,CDLT	DAT2020
	DELT=DELT*3600.	DAT2030
	TMAX=TMAX*86400.	DAT2040
	SUMP=0.0	DAT2050
C		DAT2060
C	---READ AND WRITE WELL PUMPING RATES---	DAT2070
	WRITE (6,410) NWEL	DAT2080
	IF (NWEL.EQ.0) GO TO 260	DAT2090
	DO 245 K = 1,K0	DAT2100
	DO 245 I = 1,I0	DAT2110
	DO 245 J = 1,J0	DAT2120
245	WELL(I,J,K) = 0.0	DAT2130
	DO 250 II=1,NWEL	DAT2140
	READ (5,330) K,I,J,WELL(I,J,K)	DAT2150
	WRITE (6,420) K,I,J,WELL(I,J,K)	DAT2160
250	WELL(I,J,K)=WELL(I,J,K)/(DELT*(J)*DELY(I))	DAT2170
260	RETURN	DAT2180
C		DAT2190
C	---FORMATS---	DAT2200
C		DAT2210
C		DAT2220
C		DAT2230
280	FORMAT (1H0,52X,6A4,' =',G15.7,' FOR LAYER',I3)	DAT2240
290	FORMAT (1H1,45X,6A4,' MATRIX, LAYER',I3/46X,41('-'))	DAT2250
300	FORMAT ('0',72X,'DELX =',G15.7)	DAT2260
310	FORMAT ('0',72X,'DELY =',G15.7)	DAT2270
320	FORMAT ('0',72X,'DELZ =',G15.7)	DAT2280

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330 FORMAT (8G10.0) DAT2290
340 FORMAT ('0',51X,'NUMBER OF PUMPING PERIODS =',I5/49X,'TIME STEPS B' DAT2300
    1ETWEEN PRINTOUTS =',I5//51X,'ERROR CRITERIA FOR CLOSURE =',G15.7//) DAT2310
350 FORMAT ('0',I2,2X,20F6.1/(5X,20F6.1)) DAT2320
360 FORMAT (8F10.4) DAT2330
370 FORMAT (1H1,46X,40HGRID SPACING IN PROTOTYPE IN X DIRECTION/47X,40) DAT2340
    1(' ')//('0',12F10.0)) DAT2350
380 FORMAT (1H~,46X,40HGRID SPACING IN PROTOTYPE IN Y DIRECTION/47X,40) DAT2360
    1(' ')//('0',12F10.0)) DAT2370
390 FORMAT (1H~,46X,40HGRID SPACING IN PROTOTYPE IN Z DIRECTION/47X,40) DAT2380
    1(' ')//('0',12F10.0)) DAT2390
400 FORMAT ('-',50X,'PUMPING PERIOD NO.',I4,':',F10.2,' DAYS'/51X,38(' DAT2400
    1-')//53X,'NUMBER OF TIME STEPS=',I6//59X,'DELT IN HOURS =',F10.3//) DAT2410
    253X,'MULTIPLIER FOR DELT =',F10.3) DAT2420
410 FORMAT ('-',63X,I4,' WELLS'/65X,9(' ')//50X,'K',9X,'I',9X,'J PUDAT2430
    1MPING RATE'/) DAT2440
420 FORMAT (41X,3I10,2F13.2) DAT2450
430 FORMAT ('-',40X,' CONTINUATION - HEAD AFTER ',G20.7,' SEC PUMPING DAT2460
    1'/42X,58(' ')) DAT2470
440 FORMAT ('1',55X,'INITIAL HEAD MATRIX, LAYER',I3/56X,30(' ')) DAT2480
450 FORMAT (4G20.10) DAT2490
460 FORMAT (3G10.0,2(G10.0,9I1,1X),A8) DAT2500
470 FORMAT ('0',30X,'ON ALPHAMERIC MAP:'//40X,'MULTIPLICATION FACTOR FODAT2510
    1R X DIMENSION =',G15.7/40X,'MULTIPLICATION FACTOR FOR Y DIMENSION DAT2520
    2=',G15.7/55X,'MAP SCALE IN UNITS OF ',A11/50X,'NUMBER OF ',A8,' PDAT2530
    3ER INCH =',G15.7/43X,'MULTIPLICATION FACTOR FOR DRAWDOWN =',G15.7,DAT2540
    4' PRINTED FOR LAYERS',9I2/47X,'MULTIPLICATION FACTOR FOR HEAD =',GDAT2550
    515.7,' PRINTED FOR LAYERS',9I2) DAT2560
510 FORMAT(80I1) DAT2570
520 FORMAT(' ERROR**** NK.NE.NRIV NK=',I5,5X,'NRIV=',I5) DAT2580*
540 FORMAT('1',54X,'RH MATRIX',/'0',54X,9(' '),/( ' ',10(E10.4,2X))) DAT2590*
545 FORMAT('1',54X,'RB MATRIX',/'0',54X,9(' '),/( ' ',10(E10.4,2X))) DAT2600*
560 FORMAT(20F4.0) DAT2610
625 FORMAT(10F8.0) DAT2620
635 FORMAT('1',54X,'RC MATRIX',/'0',54X,9(' '),/( ' ',10(E10.4,2X))) DAT2630*
    END DAT2640

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SUBROUTINE CHECKI(PHI,STRT,OLD,T,S,TR,TC,TK,WELL,DELX,DELY,DELZ,FACHK0010
1CT,JFLO,FLOW,QRE,CHK0020
2IDR,RH,RC,RB,IRIV)CHK0030*
-----CHK0040
C COMPUTE A VOLUMETRIC BALANCECHK0050
-----CHK0060
C SPECIFICATIONS:CHK0070
C REAL *8PHICHK0080
CCHK0090
CCHK0100
C DIMENSION PHI(IO,J0,K0),STRT(IO,J0,K0),OLD(IO,J0,K0),T(IO,J0,K0)CHK0110
1),S(IO,J0,K0),TR(IO,J0,K0),TC(IO,J0,K0),TK(IK,JK,K5),WELL(IO,CHK0120
2J0,K0),DELX(J0),DELY(IO),DELZ(K0),FACT(K0,3),JFLO(NCH,3),FLOCHK0130
3W(NCH),QRE(IQ,JQ)CHK0140
4,IDR(IO,J0,K0),RH(1),RC(1),RB(1)CHK0150*
CCHK0160
C COMMON /INTEGR/ IO,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NCHK0170
1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NCCHK0180
2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK,IEQNCHK0190
3,NKODE,KFLOWCHK0200*
C COMMON /SPARAM/ TMAX,CDLT,DELT,ERR,TEST,SUM,SUMP,QR,BETA1CHK0210*
C COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)CHK0220
C COMMON /CK/ RLFLXT,STORT,QRET,CHST,CHDT,FLUXT,PUMPT,CFLUXT,FLXNTCHK0230*
C RETURNCHK0240
C *****CHK0250
C *****CHK0260
C ENTRY CHECKCHK0270
C *****CHK0280
C ---INITIALIZE VARIABLES---CHK0290
C PUMP=0.CHK0300
C STOR=0.CHK0310
C FLUXS=0.0CHK0320
C CHD1=0.0CHK0330
C CHD2=0.0CHK0340
C QREFLX=0.CHK0350
C CFLUX=0.CHK0360
C FLUX=0.CHK0370
C RLFLUX=0.CHK0380*
C FLXN=0.0CHK0390
C II=0CHK0400
C *****CHK0410
C IF(MOD(KT,KTH).EQ.0.OR.IFINAL.EQ.1) WRITE(6,5900)CHK0425
CCHK0420
C ---COMPUTE RATES,STORAGE AND PUMPAGE FOR THIS STEP---CHK0430
C DO 220 K=1,K0CHK0440
C DO 220 I=2,I1CHK0450
C DO 220 J=2,J1CHK0460
C INDEX=0CHK0470
C IF (T(I,J,K).EQ.0.) GO TO 220CHK0480
C AREA=DELX(J)*DELY(I)CHK0490
C VOLUME=AREA*DELZ(K)CHK0500
C IF (S(I,J,K).GE.0.) GO TO 180CHK0510
CCHK0520
C ---COMPUTE FLOW RATES TO AND FROM CONSTANT HEAD BOUNDARIES---CHK0530
C II=II+1CHK0540
C FLOW(II)=0.CHK0550
C JFLO(II,1)=KCHK0560

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JFLO(II,2)=I	CHK0570
JFLO(II,3)=J	CHK0580
IF (S(I,J-1,K).LT.0..OR.T(I,J-1,K).EQ.0.) GO TO 30	CHK0590
X=(PHI(I,J,K)-PHI(I,J-1,K))*TR(I,J-1,K)*DELY(I)	CHK0600
IF(IEQN.EQ.ICHK(11)) X=X*DELZ(K)	CHK0610
FLOW(II)=FLOW(II)+X	CHK0620
IF(KFLOW.NE.1) GO TO 5	CHK0630*
IF(ABS(X).LT.0.00001) GO TO 5	CHK0640*
M=J-1	CHK0650*
WRITE(6,6000) I,J,K,I,M,K,X	CHK0660*
INDEX=1	CHK0670*
5 IF (X) 10,30,20	CHK0690
10 CHD1=CHD1+X	CHK0700
GO TO 30	CHK0710
20 CHD2=CHD2+X	CHK0720
30 IF (S(I,J+1,K).LT.0..OR.T(I,J+1,K).EQ.0.) GO TO 60	CHK0730
X=(PHI(I,J,K)-PHI(I,J+1,K))*DELY(I)*TR(I,J,K)	CHK0740
IF(IEQN.EQ.ICHK(11)) X=X*DELZ(K)	CHK0750
FLOW(II)=FLOW(II)+X	CHK0760
IF(KFLOW.NE.1) GO TO 35	CHK0770*
IF(ABS(X).LT.0.00001) GO TO 35	CHK0780*
M=J+1	CHK0790*
IF(INDEX.EQ.0) WRITE(6,6000) I,J,K,I,M,K,X	CHK0800*
INDEX=1	CHK0810*
WRITE(6,6100) I,M,K,X	CHK0820*
35 IF (X) 40,60,50	CHK0830
40 CHD1=CHD1+X	CHK0840
GO TO 60	CHK0850
50 CHD2=CHD2+X	CHK0860
60 IF (K.EQ.1) GO TO 90	CHK0870
IF (S(I,J,K-1).LT.0..OR.T(I,J,K-1).EQ.0.) GO TO 90	CHK0880
X=(PHI(I,J,K)-PHI(I,J,K-1))*TK(I,J,K-1)*AREA	CHK0890
FLOW(II)=FLOW(II)+X	CHK0900
IF(KFLOW.NE.1) GO TO 65	CHK0910*
IF(ABS(X).LT.0.00001) GO TO 65	CHK0920*
M=K-1	CHK0930*
IF(INDEX.EQ.0) WRITE(6,6000) I,J,K,I,J,M,X	CHK0940*
INDEX=1	CHK0950*
WRITE(6,6100) I,J,M,X	CHK0960*
65 IF (X) 70,90,80	CHK0970
70 CHD1=CHD1+X	CHK0980
GO TO 90	CHK0990
80 CHD2=CHD2+X	CHK1000
90 IF (K.EQ.K0) GO TO 120	CHK1010
IF (S(I,J,K+1).LT.0..OR.T(I,J,K+1).EQ.0.) GO TO 120	CHK1020
X=(PHI(I,J,K)-PHI(I,J,K+1))*TK(I,J,K)*AREA	CHK1030
FLOW(II)=FLOW(II)+X	CHK1040
IF(KFLOW.NE.1) GO TO 95	CHK1050*
IF(ABS(X).LT.0.00001) GO TO 95	CHK1060*
M=K+1	CHK1070*
IF(INDEX.EQ.0) WRITE(6,6000) I,J,K,I,J,M,X	CHK1080*
INDEX=1	CHK1090*
WRITE(6,6100) I,J,M,X	CHK1100*
95 IF (X) 100,120,110	CHK1110
100 CHD1=CHD1+X	CHK1120
GO TO 120	CHK1130
110 CHD2=CHD2+X	CHK1140

120	IF (S(I-1,J,K).LT.0..OR.T(I-1,J,K).EQ.0.) GO TO 150	CHK1150
	X=(PHI(I,J,K)-PHI(I-1,J,K))*TC(I-1,J,K)*DELX(J)	CHK1160
	IF(IEQN.EQ.1CHK(11)) X=X*DELZ(K)	CHK1170
	FLOW(II)=FLOW(II)+X	CHK1180
	IF(KFLOW.NE.1) GO TO 125	CHK1190
	IF(ABS(X).LT.0.00001) GO TO 125	CHK1200*
	M=I-1	CHK1210*
	IF(INDEX.EQ.0) WRITE(6,6000) I,J,K,M,J,K,X	CHK1220*
	INDEX=1	CHK1230*
	WRITE(6,6100) M,J,K,X	CHK1240*
125	IF (X) 130,150,140	CHK1250
130	CHD1=CHD1+X	CHK1260
	GO TO 150	CHK1270
140	CHD2=CHD2+X	CHK1280
150	IF (S(I+1,J,K).LT.0..OR.T(I+1,J,K).EQ.0.) GO TO 220	CHK1290
	X=(PHI(I,J,K)-PHI(I+1,J,K))*TC(I,J,K)*DELX(J)	CHK1300
	IF(IEQN.EQ.1CHK(11)) X=X*DELZ(K)	CHK1310
	FLOW(II)=FLOW(II)+X	CHK1320
	IF(KFLOW.NE.1) GO TO 155	CHK1330*
	IF(ABS(X).LT.0.00001) GO TO 155	CHK1340*
	M=I+1	CHK1350*
	IF(INDEX.EQ.0) WRITE(6,6000) I,J,K,M,J,K,X	CHK1360*
	INDEX=1	CHK1370*
	WRITE(6,6100) M,J,K,X	CHK1380*
155	IF (X) 160,220,170	CHK1390
160	CHD1=CHD1+X	CHK1400
	GO TO 220	CHK1410
170	CHD2=CHD2+X	CHK1420
	GO TO 220	CHK1430
C		CHK1440
C	---CHECK FOR EQUATION BEING SOLVED---	CHK1450
180	IF(IEQN.EQ.1CHK(11)) GO TO 211	CHK1460
C		CHK1470
C	---EQUATION 4---	CHK1480
C	---RECHARGE AND WELLS---	CHK1490
	IF (K.EQ.K0.AND.IQRE.EQ.1CHK(7)) QREFLX=QREFLX+QRE(I,J)*AREA	CHK1500
	IF (WELL(I,J,K)) 190,210,200	CHK1510
190	PUMP=PUMP+WELL(I,J,K)*AREA	CHK1520
	GO TO 210	CHK1530
200	CFLUX=CFLUX+WELL(I,J,K)*AREA	CHK1540
C		CHK1550
C	---COMPUTE VOLUME FROM STORAGE---	CHK1560
210	STOR=STOR+S(I,J,K)*(OLD(I,J,K)-PHI(I,J,K))*AREA	CHK1570
	IF(IRIV.LE.0) GO TO 220	CHK1580*
C		CHK1585*
C	---COMPUTE 'RIVER' LEAKAGE---	CHK1590*
C		CHK1595*
	ND=IDR(I,J,K)	CHK1600*
	IF(ND.EQ.0) GO TO 220	CHK1610*
	IF(PHI(I,J,K).GT.RB(ND)) GO TO 217	CHK1620*
	FLXRAT=RC(ND)*(RH(ND)-RB(ND))*AREA	CHK1630*
	IF(KFLOW.EQ.1) WRITE(6,6200) I,J,K,FLXRAT	CHK1640*
	RLFLUX=RLFLUX+FLXRAT	CHK1650*
	GO TO 220	CHK1660*
217	FLXRAT=RC(ND)*(RH(ND)-PHI(I,J,K))*AREA	CHK1670*
	IF(KFLOW.EQ.1) WRITE(6,6200) I,J,K,FLXRAT	CHK1680*
	RLFLUX=RLFLUX+FLXRAT	CHK1690*

	GO TO 220	CHK1700
C		CHK1710
C	---EQUATION 3---	CHK1720
C	---RECHARGE AND WELLS---	CHK1730
	211 IF (K.EQ.K0.AND.IQRE.EQ.ICHK(7)) QREFLX=QREFLX+QRE(I,J)*VOLUME	CHK1740
	IF(WELL(I,J,K)) 212,214,213	CHK1750
	212 PUMP=PUMP+WELL(I,J,K)*VOLUME	CHK1760
	GO TO 214	CHK1770
	213 CFLUX=CFLUX+WELL(I,J,K)*VOLUME	CHK1780
C		CHK1790
C	---COMPUTE VOLUME FROM STORAGE---	CHK1800
	214 STOR=STOR+S(I,J,K)*(OLD(I,J,K)-PHI(I,J,K))*VOLUME	CHK1810
	220 CONTINUE	CHK1820
C		CHK1830
C		CHK1840
C	---COMPUTE CUMULATIVE VOLUMES, TOTALS, AND DIFFERENCES---	CHK1850
	FLXPT=0.0	CHK1860
	RLFLXT=RLFLXT-RLFLUX*DELT	CHK1870*
	STORT=STORT+STOR	CHK1880
	STOR=STOR/DELT	CHK1890
	QRET=QRET+QREFLX*DELT	CHK1900
	CHDT=CHDT-CHD1*DELT	CHK1910
	CHST=CHST+CHD2*DELT	CHK1920
	PUMPT=PUMPT-PUMP*DELT	CHK1930
	CFLUXT=CFLUXT+CFLUX*DELT	CHK1940
	TOTL1=STORT+QRET+CFLUXT+CHST+FLXPT	CHK1950
	TOTL2=CHDT+PUMPT+RLFLXT+FLXNT	CHK1960*
	SUMR=QREFLX+CFLUX+CHD2+CHD1+PUMP+RLFLUX+FLUXS+STOR	CHK1970*
	DIFF=TOTL2-TOTL1	CHK1980
	PERCNT=0.0	CHK1990
	IF (TOTL2.EQ.0.) GO TO 230	CHK2000
	PERCNT=DIFF/TOTL2*100.	CHK2010
	230 RETURN	CHK2020
C		CHK2030
C		CHK2040
C	---PRINT RESULTS---	CHK2050
C	*****	CHK2060
	ENTRY CWRITE	CHK2070
C	*****	CHK2080
C		CHK2090
	WRITE (6,260) STOR,QREFLX,STORT,CFLUX,QRET,PUMP,CFLUXT,RLFLUX,CHST	CHK2100*
	1,FLXPT,CHD2,TOTL1,CHD1,FLUX,FLUXS,RLFLXT,CHDT,SUMR,PUMPT,FLXNT,TOTL2,DIFF,PERCNT	CHK2110*
	IF (NCH.EQ.0) GO TO 240	CHK2120
	WRITE (6,270)	CHK2130
	WRITE (6,280) ((JFLO(I,J),J=1,3),FLOW(I),I=1,NCH)	CHK2140
C		CHK2150
C	---COMPUTE VERTICAL FLOW---	CHK2160
	240 X=0.	CHK2170
	Y=0.	CHK2180
	IF (K0.EQ.1) RETURN	CHK2190
	DO 250 I=2,I1	CHK2200
	DO 250 J=2,J1	CHK2210
	X=X+(PHI(I,J,1)-PHI(I,J,2))*TK(I,J,1)*DELX(J)*DELY(I)	CHK2220
	250 Y=Y+(PHI(I,J,K1)-PHI(I,J,K0))*TK(I,J,K1)*DELX(J)*DELY(I)	CHK2230
	WRITE (6,290) Y,X	CHK2240
	RETURN	CHK2250
		CHK2260

C
C
C
C
C
C
C

---FORMATS---

CHK2270
CHK2280
CHK2290
CHK2300
CHK2310
CHK2320
CHK2330

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260 FORMAT ('0',10X,'CUMULATIVE MASS BALANCE:',16X,'L**3',23X,'RATES FCHK2340
1OR THIS TIME STEP:',16X,'L**3/T'/11X,24('-'),43X,25('-'))//20X,'SOUCHK2350
2RCES:',69X,'STORAGE =',F20.4/20X,8('-'),68X,'RECHARGE =',F20.4/27XCHK2360
3,'STORAGE =',F20.2,35X,'CONSTANT FLUX =',F20.4/26X,'RECHARGE =',F2CHK2370
40.2,41X,'PUMPING =',F20.4/21X,'CONSTANT FLUX =',F20.2,30X,' RICHK2380*
5VER LEAKAGE =',F20.4/21X,'CONSTANT HEAD =',F20.2,34X,'CONSTANT HEACHK2390*
6D:',27X,'LEAKAGE =',F20.2,46X,'IN =',F20.4/21X,'TOTAL SOURCES =',FCHK2400
720.2,45X,'OUT =',F20.4/96X,'LEAKAGE:',20X,'DISCHARGES:',45X,'FROM CHK2410
8PREVIOUS PUMPING PERIOD =',F20.4/20X,11('-'),68X,'TOTAL =',F20.4/1CHK2420
96X,' RIVER LEAKAGE =',F20.2/21X,'CONSTANT HEAD =',F20.2,36X,'SCHK2430*
$SUM OF RATES =',F20.4/19X'QUANTITY PUMPED =',F20.2/27X,'LEAKAGE =',CHK2440
$F20.2/19X,'TOTAL DISCHARGE =',F20.2//17X,'DISCHARGE-SOURCES =',F20CHK2450
$.2/15X,'PER CENT DIFFERENCE =',F20.2//) CHK2460
270 FORMAT ('OFLOW RATES TO CONSTANT HEAD NODES:',' ',34('-'))//' ',3(9CHK2470
1X,'K',4X,'I',4X,'J',5X,'RATE (L**3/T)')/' ',3(9X,'-',4X,'-',4X,'-'CHK2480
2,5X,13('-'))//) CHK2490
280 FORMAT (('1X,3(I10,2I5,G18.7))) CHK2500
290 FORMAT ('OFLOW TO TOP LAYER =',G15.7,' FLOW TO BOTTOM LAYER =',GCHK2510
115.7,' POSITIVE UPWARD') CHK2520
5900 FORMAT('1',' I J K FROM I J K CONSTANT HEAD RATE CHK2530*
1 RIVER LEAKAGE'//) CHK2540*
6000 FORMAT(' ',3I4,7X,3I4,8X,G12.4) CHK2550*
6100 FORMAT(' ',19X,3I4,8X,G12.4) CHK2560*
6200 FORMAT(' ',3I4,48X,G12.4) CHK2565*
END CHK2570

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C SUBROUTINE PRNTAI(PHI,STRT,T,S,WELL,DELX,DELY) PRN0010
C ----- PRN0020
C PRINT MAPS OF DRAWDOWN AND HYDRAULIC HEAD PRN0030
C ----- PRN0040
C SPECIFICATIONS: PRN0050
C REAL *8PHI,Z,XLABEL,YLABEL,TITLE,XN1,MESUR PRN0060
C REAL *4K PRN0070
C PRN0080
C PRN0090
C DIMENSION PHI(IO,J0,K0),STRT(IO,J0,K0),S(IO,J0,K0),WELL(IO,J0,KPRN0100
10),DELX(J0),DELY(IO),T(IO,J0,K0) PRN0110
C PRN0120
C COMMON /INTEGR/ IO,J0,K0,I1,J1,K1,I,J,K,NPER,KTH,ITMAX,LENGTH,KP,NPRN0130
1WEL,NUMT,IFINAL,IT,KT,IHEAD,IDRAW,IFLO,IERR,I2,J2,K2,IMAX,ITMX1,NCPRN0140
2H,IDK1,IDK2,IWATER,IQRE,IP,JP,IQ,JQ,IK,JK,K5,IPU1,IPU2,ITK,IEQN PRN0150
3,NKODE,KFLOW PRN0160*
C COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANKPRN0170
1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),PRN0180
2YN(13),NA(4),N1,N2,N3,YSCALE,FACT1,FACT2 PRN0190
C RETURN PRN0200
C ..... PRN0210
C PRN0220
C ---INITIALIZE VARIABLES FOR PLOT--- PRN0230
C ***** PRN0240
C ENTRY MAP PRN0250
C ***** PRN0260
C YDIM=0. PRN0270
C WIDTH=0. PRN0280
C DO 10 J=2,J1 PRN0290
10 WIDTH=WIDTH+DELX(J) PRN0300
C DO 20 I=2,I1 PRN0310
20 YDIM=YDIM+DELY(I) PRN0320
30 XSF=DINCH*XSCALE PRN0330
YSF=DINCH*YSCALE PRN0340
NYD=YDIM/YSF PRN0350
IF (NYD*YSF.LE.YDIM-DELY(I1)/2.) NYD=NYD+1 PRN0360
IF (NYD.LE.12) GO TO 40 PRN0370
DINCH=YDIM/(12.*YSCALE) PRN0380
WRITE (6,330) DINCH PRN0390
IF (YSCALE.LT.1.0) WRITE (6,340) PRN0400
GO TO 30 PRN0410
40 NXD=WIDTH/XSF PRN0420
IF (NXD*XSF.LE.WIDTH-DELX(J1)/2.) NXD=NXD+1 PRN0430
N4=NXD*N1+1 PRN0440
N5=NXD+1 PRN0450
N6=NYD+1 PRN0460
N8=N2*NYD+1 PRN0470
NA(1)=N4/2-1 PRN0480
NA(2)=N4/2 PRN0490
NA(3)=N4/2+3 PRN0500
NC=(N3-N8-10)/2 PRN0510
ND=NC+N8 PRN0520
NE=MAX0(N5,N6) PRN0530
VF1(3)=DIGIT(ND) PRN0540
VF2(3)=DIGIT(ND) PRN0550
VF3(3)=DIGIT(NC) PRN0560
XLABEL(3)=MESUR PRN0570

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	YLABEL(6)=MESUR	PRN0580
	DO 60 I=1,NE	PRN0590
	NNX=N5-I	PRN0600
	NNY=I-1	PRN0610
	IF (NNY.GE.N6) GO TO 50	PRN0620
	YN(I)=YSF*NNY/YSF	PRN0630
50	IF (NNX.LT.0) GO TO 60	PRN0640
	XN(I)=XSF*NNX/YSF	PRN0650
60	CONTINUE	PRN0660
	RETURN	PRN0670
C		PRN0680
C	*****	PRN0690
C	ENTRY PRNTA(NG,LA)	PRN0700
C	*****	PRN0710
C	---VARIABLES INITIALIZED EACH TIME A PLOT IS REQUESTED---	PRN0720
	DIST=WIDTH-DELX(J1)/2.	PRN0730
	JJ=J1	PRN0740
	LL=1	PRN0750
	Z=NXD*XSF	PRN0760
	IF (NG.EQ.1) WRITE (6,300) (TITLE(I),I=1,3),LA	PRN0770
	IF (NG.EQ.2) WRITE (6,300) (TITLE(I),I=4,6),LA	PRN0780
	DO 290 I=1,N4	PRN0790
C		PRN0800
C	---LOCATE X AXES---	PRN0810
	IF (I.EQ.1.OR.I.EQ.N4) GO TO 70	PRN0820
	PRNT(1)=SYM(12)	PRN0830
	PRNT(N8)=SYM(12)	PRN0840
	IF ((I-1)/N1*N1.NE.I-1) GO TO 90	PRN0850
	PRNT(1)=SYM(14)	PRN0860
	PRNT(N8)=SYM(14)	PRN0870
	GO TO 90	PRN0880
C		PRN0890
C	---LOCATE Y AXES---	PRN0900
70	DO 80 J=1,N8	PRN0910
	IF ((J-1)/N2*N2.EQ.J-1) PRNT(J)=SYM(14)	PRN0920
80	IF ((J-1)/N2*N2.NE.J-1) PRNT(J)=SYM(13)	PRN0930
C		PRN0940
C	---COMPUTE LOCATION OF NODES AND DETERMINE APPROPRIATE SYMBOL---	PRN0950
90	IF (DIST.LT.0..OR.DIST.LT.Z-XN1*XSF) GO TO 240	PRN0960
	YLEN=DELY(2)/2.	PRN0970
	DO 220 L=2,I1	PRN0980
	J=YLEN*N2/YSF+1.5	PRN0990
	IF (T(L,JJ,LA).EQ.0.) GO TO 160	PRN1000
	IF (S(L,JJ,LA).LT.0.) GO TO 210	PRN1010
	INDX3=0	PRN1020
	GO TO (100,110), NG	PRN1030
100	K=(STRT(L,JJ,LA)-PHI(L,JJ,LA))*FACT1	PRN1040
C	-TO CYCLE SYMBOLS FOR DRAWDOWN, REMOVE C FROM COL. 1 OF NEXT CARD-	PRN1050
C	K=AMOD(K,10.)	PRN1060
	GO TO 120	PRN1070
110	K=PHI(L,JJ,LA)*FACT2	PRN1080
120	IF (K) 130,160,140	PRN1090
130	IF (J-2.GT.0) PRNT(J-2)=SYM(13)	PRN1100
	N=-K+.5	PRN1110
	IF (N.LT.100) GO TO 150	PRN1120
	GO TO 190	PRN1130
		PRN1140

140	N=K+.5	PRN1150
	IF (N.LT.100) GO TO 150	PRN1160
	IF (N.GT.999) GO TO 190	PRN1170
	INDX3=N/100	PRN1180
	IF (J-2.GT.0) PRNT(J-2)=SYM(INDX3)	PRN1190
	N=N-INDX3*100	PRN1200
150	INDX1=MOD(N,10)	PRN1210
	IF (INDX1.EQ.0) INDX1=10	PRN1220
C	-TO CYCLE SYMBOLS FOR DRAWDOWN, REMOVE C FROM COL. 1 OF NEXT CARD-	PRN1230
C	IF (NG.EQ.1) GO TO 170	PRN1240
	INDX2=N/10	PRN1250
	IF (INDX2.GT.0) GO TO 180	PRN1260
	INDX2=10	PRN1270
	IF (INDX3.EQ.0) INDX2=15	PRN1280
	GO TO 180	PRN1290
160	INDX1=15	PRN1300
170	INDX2=15	PRN1310
180	IF (J-1.GT.0) PRNT(J-1)=SYM(INDX2)	PRN1320
	PRNT(J)=SYM(INDX1)	PRN1330
	GO TO 220	PRN1340
190	DO 200 II=1,3	PRN1350
	JI=J-3+II	PRN1360
200	IF (JI.GT.0) PRNT(JI)=SYM(11)	PRN1370
210	IF (S(L,JJ,LA).LT.0.) PRNT(J)=SYM(16)	PRN1380
220	YLEN=YLEN+(DELY(L)+DELY(L+1))/2.	PRN1390
230	DIST=DIST-(DELX(JJ)+DELX(JJ-1))/2.	PRN1400
	JJ=JJ-1	PRN1410
	IF (JJ.EQ.0) GO TO 240	PRN1420
	IF (DIST.GT.Z-XN1*XSF) GO TO 230	PRN1430
240	CONTINUE	PRN1440
C		PRN1450
C	---PRINT AXES, LABELS, AND SYMBOLS---	PRN1460
	IF (I-NA(LL).EQ.0) GO TO 260	PRN1470
	IF ((I-1)/N1*N1-(I-1)) 270,250,270	PRN1480
250	WRITE (6,VF1) (BLANK(J),J=1,NC),(PRNT(J),J=1,N8),XN(1+(I-1)/6)	PRN1490
	GO TO 280	PRN1500
260	WRITE (6,VF2) (BLANK(J),J=1,NC),(PRNT(J),J=1,N8),XLABEL(LL)	PRN1510
	LL=LL+1	PRN1520
	GO TO 280	PRN1530
270	WRITE (6,VF2) (BLANK(J),J=1,NC),(PRNT(J),J=1,N8)	PRN1540
C		PRN1550
C	---COMPUTE NEW VALUE FOR Z AND INITIALIZE PRNT---	PRN1560
280	Z=Z-2.*XN1*XSF	PRN1570
	DO 290 J=1,N8	PRN1580
290	PRNT(J)=SYM(15)	PRN1590
C		PRN1600
C	---NUMBER AND LABEL Y AXIS AND PRINT LEGEND---	PRN1610
	WRITE (6,VF3) (BLANK(J),J=1,NC),(YN(I),I=1,N6)	PRN1620
	WRITE (6,320) (YLABEL(I),I=1,6)	PRN1630
	IF (NG.EQ.1) WRITE (6,310) FACT1	PRN1640
	IF (NG.EQ.2) WRITE (6,310) FACT2	PRN1650
	RETURN	PRN1660
C		PRN1670
C	---FORMATS---	PRN1680
C		PRN1690
C	-----	PRN1700
C		PRN1710

C

300	FORMAT ('1',49X,3A8,'LAYER',I4//)	PRN1720
310	FORMAT ('0EXPLANATION'/' ',11('-')// ' R = CONSTANT HEAD BOUNDARY'/'	PRN1730
	1' *** = VALUE EXCEEDED 3 FIGURES'/' MULTIPLICATION FACTOR =' ,F8.3)	PRN1740
320	FORMAT ('0',39X,6A8)	PRN1750
330	FORMAT ('0',25X,10('*'),' TO FIT MAP WITHIN 12 INCHES, DINCH REVIS	PRN1760
	1ED TO',G15.7,1X,10('*'))	PRN1770
340	FORMAT ('0',45X,'NOTE: GENERALLY SCALE SHOULD BE > OR = 1.0')	PRN1780
	END	PRN1790
		PRN1800

BLOCK DATA	BLK0010
-----	BLK0020
	BLK0030
SPECIFICATIONS:	BLK0040
REAL *8XLABEL,YLABEL,TITLE,XN1,MESUR	BLK0050
	BLK0060
COMMON /SARRAY/ ICHK(13),LEVEL1(9),LEVEL2(9)	BLK0070
COMMON /PR/ XLABEL(3),YLABEL(6),TITLE(6),XN1,MESUR,PRNT(122),BLANK	BLK0080
1(60),DIGIT(122),VF1(6),VF2(6),VF3(7),XSCALE,DINCH,SYM(17),XN(100),	BLK0090
2YN(13),NA(4),N1,N2,N3,YSCALE,FACT1,FACT2	BLK0100
*****	BLK0110
	BLK0120
DATA ICHK/'DRAW','HEAD','MASS','DK1','DK2','WATE','RECH','PUN1','PBLK	BLK0130
1UN2','ITKR','EQN3',2*0/	BLK0140
DATA SYM/'1','2','3','4','5','6','7','8','9','0','*',' ','-','+',	BLK0150
1','R','W'/	BLK0160
DATA PRNT/122*' '/,N1,N2,N3,XN1/6,10,133,.833333333D-1/,BLANK/60*'BLK	BLK0170
1 '/,NA(4)/1000/	BLK0180
DATA XLABEL/' X DIS- ','TANCE IN',' MILES '/,YLABEL/'DISTANCE','	BLK0190
1FROM OR','IGIN IN ','Y DIRECT','ION, IN ','MILES '/,TITLE/'PLOT	BLK0200
2OF ','DRAWDOWN',' ','PLOT OF ','HYDRAULI','C HEAD'/	BLK0210
DATA DIGIT/'1','2','3','4','5','6','7','8','9','10','11','12','13'BLK	BLK0220
1,'14','15','16','17','18','19','20','21','22','23','24','25','26',	BLK0230
2'27','28','29','30','31','32','33','34','35','36','37','38','39',	BLK0240
340','41','42','43','44','45','46','47','48','49','50','51','52',	BLK0250
43','54','55','56','57','58','59','60','61','62','63','64','65',	BLK0260
5','67','68','69','70','71','72','73','74','75','76','77','78',	BLK0270
6','80','81','82','83','84','85','86','87','88','89','90','91',	BLK0280
7,'93','94','95','96','97','98','99','100','101','102','103',	BLK0290
8,'105','106','107','108','109','110','111','112','113','114',	BLK0300
9,'116','117','118','119','120','121','122'/	BLK0310
DATA VF1/'(1H ',' ',' ','A1,F','10.2',')'/	BLK0320
DATA VF2/'(1H ',' ',' ','A1,1','X,A8',')'/	BLK0330
DATA VF3/'(1H0',' ',' ','A1,F','3.1','12F1','0.2')'/	BLK0340
*****	BLK0350
END	BLK0360