# EVALUATING THE GROUND-WATER RESOURCES OF THE HIGH PLAINS OF TEXAS

## GWSIM-III

## Ground-Water Simulation Program

## Program Documentation and User's Manual

UM-36

Cooperators: TEXAS DEPARTMENT OF WATER RESOURCES
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Program Documentation and User's Manual

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The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies or recommendations of the cooperating entities

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GWSIM-III, documented herein, is a digital modeling technique which is capable of simulating ground-water flow. The solution procedure was developed by T. A. Prickett and C. G. Lonnquist, Illinois State Water Survey, and was later modified by personnel of the Texas Department of Water Resources.

The purpose of the program is to determine water levels at the end of a given time period. The technique is based on the differential equation describing non-steady, two dimensional flow of ground water in a nonhomogeneous, isotropic, water-table aquifer.

A section of the program was developed to predict irrigation pumpage for the High Plains Aquifer Model of Texas. The procedure adjusts initial estimates of irrigation pumpage based on aquifer transmissivity and saturated thickness and on pumping lift.

# GROUND-WATER SIMULATION PROGRAM

# GWSIM-III

## INTRODUCTION

Hydraulic simulation was based on work of T. A. Prickett and C. G. Lonnquist, Illinois State Water Survey (Prickett, 1971). Modifications were made to the program to allow additional types of input and output and to improve the program's ability to simulate different aquifer configurations.

The program is structured to simulate water-table elevations, usually referred to as heads, for a given period of time. It advances through time by major time steps, which are further divided into one or more minor time steps.

Operation of the program is controlled by options. Proper selection of options allows the user to tailor model input, operation, and output to an individual problem.

## DEVELOPMENT OF FINITE DIFFERENCE EQUATION

The partial differential equation describing non-steady flow in a nonhomogeneous aquifer may be written as follows:

$$\frac{\partial}{\partial x}\left(T\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(T\frac{\partial h}{\partial y}\right) = S\frac{\partial h}{\partial t} + W \qquad (1)$$

where

$T$ = aquifer transmissivity ($L^2t^{-1}$)

$h$ = head ($L$)

$S$ = storage coefficient

$t$ = time ($t$)

$W$ = net ground-water flux per unit area ($Lt^{-1}$)

$x,y$ = rectangular coordinates ($L$)
(Prickett, 1971).

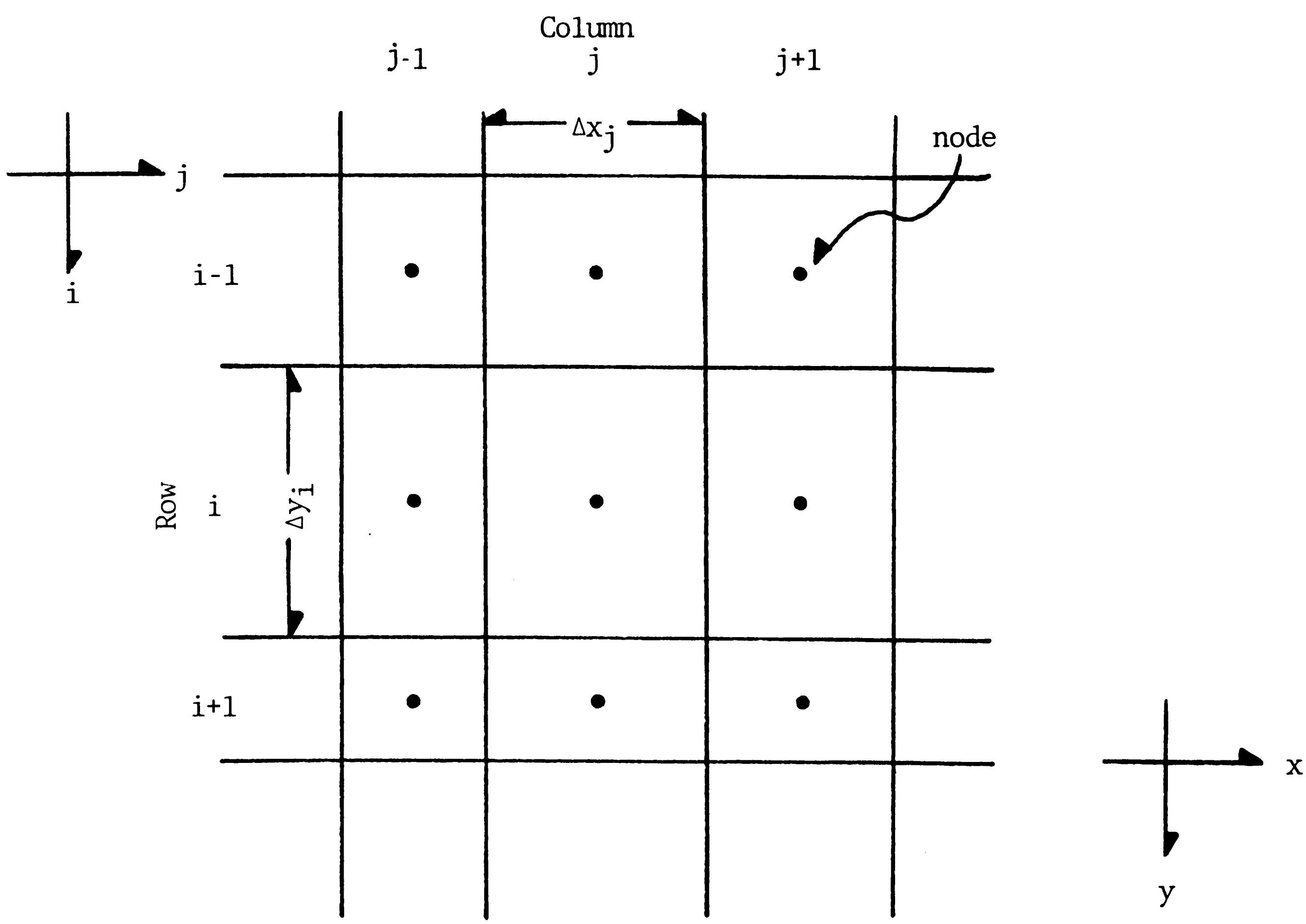
The numerical solution for Equation 1 can be obtained by applying the finite difference approach. The steps in applying the approach are as follows:

(a) a finite difference grid is superimposed upon a map showing the extent of the aquifer, thus allowing the finite difference grid to replace the continuous aquifer with an equivalent set of discrete elements;

(b) the governing partial differential equation is written in finite difference form for each of the discrete elements; and

(c) the resulting set of linear finite difference equations is then solved numerically for the head with the aid of a digital computer.

An example of a portion of a finite difference grid is shown in Figure 1. Each of the discrete elements is a cell, and the center of each cell is a node. Each cell is referenced by its row (i) and column (j) number.




Finite Difference Grid

Figure 1

Equation 1 may be approximated as

$$\frac{1}{\Delta x_j}\left(\{T_{i,j+\frac{1}{2}}(\frac{h_{i,j+1}-h_{i,j}}{\Delta x_{j+\frac{1}{2}}})\} - \{T_{i,j-\frac{1}{2}}(\frac{h_{i,j}-h_{i,j-1}}{\Delta y_{j-\frac{1}{2}}})\}\right)$$

$$+\frac{1}{\Delta y_i}\left(\{T_{i+\frac{1}{2},j}(\frac{h_{i+1,j}-h_{i,j}}{\Delta y_{i+\frac{1}{2}}})\} - \{T_{i-\frac{1}{2},j}(\frac{h_{i,j}-h_{i-1,j}}{\Delta y_{i-\frac{1}{2}}})\}\right)$$

$$= \frac{S_{i,j}}{\Delta t}(h_{i,j} - H_{i,j}) + W_{i,j} \qquad (2)$$

where

$\Delta x_j$ = grid spacing in the x-direction for column j,

$\Delta y_i$ = grid spacing in the y-direction for row i,

$T_{i,j+\frac{1}{2}}$ = transmissivity between node i,j and i,j+1,

$h_{i,j}$ = head at node i,j at end of time step,

$S_{i,j}$ = storage coefficient for cell i,j,

$\Delta t$ = time step increment,

$H_{i,j}$ = head at node i,j at beginning of time step,

$W_{i,j}$ = net withdrawal per unit surface area for cell i,j, and

$\Delta x_{j+\frac{1}{2}}$ = distance between node i,j and node i,j+1

Multiplying Equation 2 by the area of cell i,j, $\Delta x_j\,\Delta y_i$, and rearranging terms results in

$$A_{i,j}(h_{i,j-1} - h_{i,j}) + B_{i,j}(h_{i,j+1} - h_{i,j})$$

$$+C_{i,j}(h_{i-1,j} - h_{i,j}) + D_{i,j}(h_{i+1,j} - h_{i,j})$$

$$= E_{i,j}(h_{i,j} - H_{i,j}) + Q_{i,j} \qquad (3)$$

where

$$A_{i,j} = \frac{2\,T_{i,j}\,T_{i,j-1}}{T_{i,j}\Delta x_{j-1} + T_{i,j-1}\Delta x_j}\quad \Delta y_i \quad ,$$

$$B_{i,j} = \frac{2\ T_{i,j}\ T_{i,j+1}}{T_{i,j}\Delta x_{j+1} + T_{i,j+1}\Delta x_j}\ \Delta y_i \quad ,$$

$$C_{i,j} = \frac{2\ T_{i,j}\ T_{i-1,j}}{T_{i,j}\Delta y_{i-1} + T_{i-1,j}\Delta y_i}\ \Delta x_j \quad ,$$

$$D_{i,j} = \frac{2\ T_{i,j}\ T_{i+1,j}}{T_{i,j}\Delta y_{i+1} + T_{i+1,j}\Delta y_i}\ \Delta x_j \quad ,$$

$$E_{i,j} = \frac{S_{i,j}\Delta x_j \Delta y_i}{\Delta t} \quad \text{, and}$$

$$Q_{i,j} = W_{i,j}\Delta x_j \Delta y_i$$

The first part of $A_{i,j}$ is the harmonic mean of

$$\frac{T_{i,j}}{\Delta x_j} \quad \text{and} \quad \frac{T_{i,j-1}}{\Delta x_{j-1}}$$

which represents the ratio of

$$\frac{T_{i,j-\frac{1}{2}}}{\Delta x_{j-\frac{1}{2}}}$$

Similar representation is used for terms B, C, and D. Use of the harmonic mean ensures zero transmissivity at no-flow boundaries.

An equation of the same form as Equation 3 is written for each cell in the finite difference grid. This results in a large set of linear equations with the water levels (heads) at the end of the time step, h, as unknowns. An iterative alternating direction implicit procedure is used to solve the set of equations.

## SOLUTION TECHNIQUE

The iterative alternating direction implicit (IADI) procedure involves reducing a large set of equations to several smaller sets of equations. One such small set of equations is generated by writing Equation 3 for each node in a column, assuming that the heads for the nodes on the adjacent columns are known. The unknowns in this set of equations are the heads for the nodes along the column. The heads for the nodes along adjoining columns are not considered unknowns. This set of equations is solved by Gauss elimination and the process repeats until each column is treated. The next step is to develop a set of equations along each row, assuming the heads for the nodes along adjoining rows are known. The set of equations for each row is solved, and the process repeats for each row in the finite difference grid.

Once the sets of equations for the columns and the sets of equations for the rows have been solved, one "iteration" has been completed. The iteration process is repeated until the procedure has converged. Upon convergence, the terms $h_{i,j}$ represent the heads at the end of the time step. These heads are used as the beginning heads for the following time step. For a more detailed discussion of the iterative alternating direction implicit procedure, see Peaceman and Rachford (1955) and Prickett and Lonnquist (1971).

The program uses a head predictor algorithm and iteration parameters to speed convergence. The original Prickett program incorporated a head predictor algorithm. This allows the solution procedure to have an improved estimate of the solution before the iterative procedure is started. Without a predictor algorithm, the beginning head values would be the estimates of the ending head values. During each major time step, the external stimuli, pumpage and recharge rate, are constant. It is only natural to assume that, based on constant external stimuli, water levels will continue to change in a consistent manner throughout the time period. The predictor algorithm uses this assumption in that as soon as a consistent pattern of change is established, this pattern is used to improve the initial estimates of the unknown heads. If an inconsistent pattern is established, no prediction is made.

The head prediction algorithm is used during each major time step. After two small time steps have been completed, the algorithm attempts to predict the heads at the end of the next time step. If the direction of the change in head for any one node is different from the direction of the change in head during a previous time step, the head change pattern is assumed to be inconsistent and no prediction is made for that node.

Iteration parameters are also utilized to aid convergence. Development of those parameters is beyond the scope of this manual, but a brief discussion may be in order. Equation 4 is a rearrangement of Equation 3 incorporating the normalized iteration parameter, $G_p$; and, as required in the first phase of the IADI procedure, assumes that the heads along the columns are unknowns.

$$Ah^{n+1}_{i,j-1} + (B+G_p)\, h^{n+1}_{i,j} + Ch^{n+1}_{i,j+1} = (D+G_p)h^{n}_{i,j} + Eh^{n}_{i-1,j} + Fh^{n}_{i+1,j} + G \qquad (4)$$

where

A,B,C,D,E,F,G = collection of terms in Equation 3.

$h^{n+1}_{i,j}$ = head of cell i,j at iteration number n+1, and

$G_p$ = normalized iteration parameter.

Please note that when the solution converges, $h^{n+1}$ becomes approximately equal to $h^{n}$, and the product of head times the normalized iteration parameter appears on each side of the equal sign therefore cancelling out.

The calculation of $G_p$ was adopted from Trescott, 1976, and may be expressed as

$$G_p = \rho_p(A_{i,j} + B_{i,j} + C_{i,j} + D_{i,j}) \quad ,$$

$$\rho_p = \rho_{p-1}\xi \; , \quad p=2,3,\ldots,P \quad ,$$

$$\xi = \exp\,(\ln(1./\rho_1)/P-1) \quad ,$$

$$\rho_1 = \min\,(2,\ fx,\ fy) \quad ,$$

$$fx = \pi^2/(2m^2(1+(\frac{\Delta y}{\Delta x})^2)) \quad , \text{ and}$$

$$fy = \pi^2/(2n^2(1+(\frac{\Delta x}{\Delta y})^2))$$

where

$\rho$ = iteration parameter,

p = iteration index which cycles from one to the number of iteration parameters to be used,

m = number of rows,

n = number of columns, and

P = number of iteration parameters

The value of p changes for each iteration and cycles from one to the number of parameters used. The iteration parameters are printed at the beginning of simulation.

For program GWSIM-III, the solution procedure is assumed to have converged if the sum of the changes in head during an iteration is less than a specified input value, ERROR. As the convergence criterion is reduced (i.e., smaller values for ERROR) the finite difference solution will more closely approximate the theoretical solution. However, as the error criterion is reduced, the number of iterations required for convergence will increase. There is a point of diminishing returns where the increase in accuracy does not justify the increase in the number of iterations and the resulting increase of computer execution time. A few tests should be made with difference values for ERROR to determine the value that yields good results with few iterations. The program performs at least four iterations.

## FEATURES OF THE PROGRAM

In each of the following sections, an important phase of the GWSIM-III program is explained.

## Time Steps

Program GWSIM-III was written to simulate water levels in an aquifer after uniform steps in time. For most regional modeling problems, these uniform time steps would represent yearly time steps. At the beginning of each of these major time steps, the program is designed to accept new values for pumpage and recharge rates. This provides the ability to change the external factors during a long term simulation period. Normally, only yearly values of these parameters are available.

Each of the major time steps is accomplished by completing a number of smaller time steps, called minor time steps. This allows better simulation of the aquifer's response to pumpage and recharge by reducing the shock of sudden changes in these external stimuli. The minor time steps may be nonuniform in size with the first steps small and the later steps large. The size of each time step may be increased over the previous time step, allowing an acceleration of the length of time steps. The program determines the length of the initial minor time step based on the length of the major time step, number of minor steps, and time step acceleration factor.

## Boundary Conditions

The program GWSIM-III is capable of simulating two types of boundary. The first type could be called a barrier or non-flow condition. No ground-water flow is allowed to cross this type of boundary. The exterior sides of the finite difference grid represent no-flow boundaries. Other barriers may be represented by the appropriate location of exterior cells (Flag = 3) which allow no ground-water flow.

The second type of boundary which may be simulated is a constant-head boundary. This type of boundary may be required to simulate a stream or lake. This may be accomplished by designating a cell to be type 0, constant head. Ground-water flow can occur with this type of cell but the water level for the node will not be calculated.

## Type of Cell Declaration

Each cell in the finite difference grid must be assigned a type declaration. A cell's type declaration is based on the conditions existing at the node at the beginning of the simulation period. The entire cell is assumed to exhibit the same characteristics as does the node. These declarations are

1) FLAG = 0 for constant head,
2) FLAG = 1 for water table conditions, and
3) FLAG = 3 for exterior nodes.

These declarations are used to indicate whether the node is active or if it is outside the ground-water system. A FLAG = 0 cell is assumed to be a constant-head cell. Ground water may enter or leave this type of cell, but a new water level will not be simulated. A FLAG = 1 cell is assumed to exhibit water table characteristics. That is, the flow area for ground-water movement will vary as water table elevations change. The FLAG = 3 nodal declaration is for cells which are to be considered exterior to the ground-water system and are therefore considered exterior cells.

The solution procedure of GWSIM-III is programmed to ignore any exterior nodes. Since many ground-water formations are not rectangular in shape, a superimposed rectangular grid would contain cells which are not a portion of the ground-water system. It would be wasteful of computer time to compute a ground-water head elevation for these vacant cells. For this reason, the program only simulates heads for cells which are in the ground-water system and flagged FLAG = 1.

## Program Options

GWSIM-III was constructed to allow the user a large amount of versatility. The input, operation, and output are controlled by a series of options. The General Program Options are set at the beginning of the run, and the Time Step Options are set at the beginning of each major time step. The pumpage prediction procedure developed for the High Plains Aquifer Model also has a set of options. An option is enabled if it is assigned a value greater than zero.

### General Program Options

The following options may be set at the beginning of the simulation. See Data Set 3.

1 PRINT HYDROGRAPHS

Enabling this option causes the reading of Data Set 4 and results in the printing of a hydrograph for specified cells. See description of subroutine HYDRO.

2 PRINT CROSS SECTIONS

Enabling this option causes the reading of Data Set 5 and allows printing a profile view of water levels along columns and/or rows. See descriptions of Time Step Option 23 and subroutine XSECT.

3 READ CONSTANT GRID SPACINGS

Enabling this option causes the program to read a constant grid spacing for each direction; thus individual grid spacings will not be read. See Data Set 6.

4 WRITE GRID SPACINGS

Enabling this option results in a listing of the grid spacings.

5 READ DEFAULT PHYSICAL DATA

Enabling this option causes the program to read a set of physical data which will be assigned to each cell in the system. Values for each cell will not be read. See Data Set 7.

6 PHYSICAL DATA CORRECTIONS

Enabling this option allows replacement of physical data values for specific nodes. Data Set 8 is read.

7 ADJUST PARAMETERS

Enabling this option allows modification of storage coefficient and hydraulic conductivity values. Also, maps of the two parameters may be produced. If the option equals 2, a hydraulic conductivity map is printed; if it equals 3, a storage coefficient map is printed; and if it equals 4, both maps are printed. Data Set 9 is read. See description of subroutine CALIB.

8 WRITE PHYSICAL DATA

Enabling this option results in a cell-by-cell listing of physical data.

9 PLOT INITIAL WATER LEVELS

Enabling this option results in the printing of a map indicating the initial water levels.

10 LIST AND PLOT INITIAL SATURATED THICKNESS

Enabling this option causes the listing of the initial saturated thickness for each cell and the printing of a map indicating the initial saturated thickness. Also listed are the volumes of water in storage and corresponding surface areas by range of saturated thickness.

## Time Step Options

The following options may be set for each major time step. See Data Set 10.

1 CHANGE TIME STEP PARAMETERS

Enabling this option changes the parameters controlling time step lengths for this major time step. The length of this major time step, number of minor time steps, and time step acceleration factor are changed. The original values of these parameters are reset at the end of this major time step. See Data Set 10.

2 READ PUMPAGE FOR EACH CELL

Enabling this option causes the program to read a pumpage rate for each cell in the system. Data Set 11 is read.

3 READ PUMPAGE BY BLOCK

Enabling this option causes the program to read a pumpage rate which is to be assigned to all cells in a specified block or region of the model grid. Data Set 12 is read.

4 PUMPAGE ADJUSTMENTS

Enabling this option causes the program to read an adjustment factor which multiplies the pumpage rate for all cells in a specified block of the model grid. Data Set 13 is read.

5 READ RECHARGE FOR EACH CELL

Enabling this option causes the program to read a recharge rate for each cell in the system. Data Set 14 is read.

6 READ RECHARGE BY BLOCK

Enabling this option causes the program to read a recharge rate which is to be assigned to all cells in a specified block of the grid. Data Set 15 is read.

7 RECHARGE ADJUSTMENTS

Enabling this option causes the program to read an adjustment factor which multiplies the recharge rate for all cells in a specified block of the grid. Data Set 16 is read.

8 CALCULATE HIGH PLAINS PUMPAGE

Enabling this option causes the program to calculate pumpage. This portion of the program was developed especially for the High Plains Aquifer Study. See discussion of subroutine HGHPMP. Data Sets 17 through 27 may be read.

9 STORE PUMPAGE AND RECHARGE RATES

Enabling this option causes the pumpage and recharge rates to be written on unit IN2. These values may be read for a later time step by then enabling Time Step Option 10.

10 RETRIEVE PUMPAGE AND RECHARGE RATES

Enabling this option causes the pumpage and recharge rates to be read from unit IN2. These values must have been stored for a previous time step. This option should not be enabled for the first time step.

11 LIST PUMPAGE AND RECHARGE RATES

Enabling this option causes the printing of the pumpage rates and the recharge rates for each cell.

12 PLOT FLOWS - MINOR

Enabling this option causes the printing of maps indicating ground-water flows at the end of each minor time step during this major step. See discussion of subroutine FLUX.

13 LIST HEADS - MINOR

Enabling this option causes the listing of heads at the end of each minor time step during this major time step.

14 SAVE HEADS

Enabling this option causes the heads at the end of this major time step to be written on unit OUT1.

15 SAVE PHYSICAL DATA

Enabling this option causes the nodal type, bottom of aquifer elevation, head at end of this major time step, hydraulic conductivity, and storage coefficient to be written on unit OUT1. A format card is also written so that these data could be used to re-start the model. A new Data Set 7 is produced.

16 LIST HEADS - MAJOR

Enabling this option causes the listing of heads at the end of this major time step.

17 PLOT FLOWS - MAJOR

Enabling this option causes the printing of maps indicating ground-water flows at the end of this major time step. See discussion of subroutine FLUX.

18 LIST HEAD CHANGES DURING THIS STEP

Enabling this option causes the listing of head changes occurring during this major time step.

19 PLOT HEAD CHANGES DURING THIS STEP

Enabling this option causes the printing of a map indicating head changes occurring during this major time step. See discussion of subroutine PLOTS.

20 LIST HEAD CHANGES THROUGH THIS STEP

Enabling this option causes the listing of head changes occurring from beginning of simulation through this major time step.

21 PLOT HEAD CHANGES THROUGH THIS STEP

Enabling this option causes the printing of a map indicating head changes occurring from beginning of simulation through this major time step.

22 COMPARE MEASURED HEADS

Enabling this option causes comparison of simulated heads with measured heads. A listing of the simulated head, measured head, and simulation error (simulated minus measured) for all cells is printed. A map of simulation errors is also printed. See discussion of subroutine PLOTS. Data Set 30 is read.

23 PLOT CROSS SECTIONS

Enabling this option causes the printing of water-level profiles. General Program Option 2 must have been enabled and Data Set 5 read. See discussion of subroutine XSECT.

24 READ CONSTANT HEADS

Enabling this option allows input of head for constant-head cells (FLAG = 0) at the end of this major time step. Also, a change in head may be read. Heads at the end of minor time steps are interpreted, always maintaining a minimum saturated thickness of 0.1. The option value causes the following to be read:

| Option Value | Action |
|---|---|
| 0 | Nothing |
| 1 | Heads for all cells |
| 2 | Head changes for all cells |
| 3 | Heads for block of cells |
| 4 | Head changes for block of cells |

Data Set 28 is read.

25 LIST AND PLOT SATURATED THICKNESS

Enabling this option causes the listing of saturated thicknesses at the end of this major time step. A printer map of saturated thickness is also produced. See discussion of subroutine PLOTH.

26 PLOT HEADS

Enabling this option causes the printing of a map indicting the elevation of water levels at the end of this major time step. See discussion of subroutine PLOTH.

27 READ LIMITS FOR STATISTICAL BLOCKS

Enabling this option causes the program to compute statistical data for blocks of the grid. The data are printed if plots of water-level change or simulation error are printed, see Time Step Options 19, 21, and 22. Data Set 29 is read. See discussion of Subroutine PLOTS.

## Water-Table Condition Adjustment

The basic solution technique is designed to solve a set of equations based on Equation 3. For water-table conditions, transmissivity is a function of the water-table elevation and is not a constant as assumed in the development of Equation 3. However, Equation 3 may be used if the changes in head and the size of the time step are such that the transmissivity may be assumed to be constant during the time step. For GWSIM-III, it is assumed that during each minor time step, the values for transmissivity are constant. The transmissivity for each cell equals the hydraulic conductivity times the saturated thickness. Saturated thickness equals the distance separating the water table and the base of aquifer. The minimum saturated thickness equals 0.1.

## Units

The program operates using units of length and time. The unit of measure of length may be from either the English or metric system, as long as a consistent set of units is used. The pumpage, recharge, and hydraulic conductivity values are multiplied by conversion factors so that internally, all items measured in length units will be expressed in the same units.

The internal unit of time is days. The pumpage, recharge, and hydraulic conductivity conversion factors may be used to convert input rates so they are expressed in days.

The pumpage and recharge rates are input as volumes per major time step. For example, a cell from which 100 acre-feet of water were pumped annually could be assigned a pumpage value of 100 if the major time step was 365 days long. If the major step was two years in length, the input value would be 200. Assuming a major time step length of one year and the program interval length unit in feet, the factor to convert acre-feet per year to cubic feet per day is 119.34 (43,560 cubic feet per acre-foot/365 days per year).

The conversion factor for hydraulic conductivity converts from the external units into units of length per day. The factor to convert gallons per day per square foot to feet per day is 0.13369 (1/7.48 gallons per cubic foot).

## Temporary Storage of Data

To reduce storage requirements, GWSIM-III only keeps in core the data necessary for each phase of the simulation. Heads at the beginning of simulation and at the beginning and end of each major time step are stored on tape until needed for output routines. If pumpage is calculated for the High Plains aquifer, some hydraulic data are stored and the arrays are used during the pumpage calculations. The hydraulic data are retrieved once the pumpage calculation is completed. The pumpage calculation parameters are likewise stored on tape and read as needed.

## PUMPAGE PREDICTION FOR HIGH PLAINS AQUIFER MODEL

A section of the program, subroutine HGHPMP, was developed to calculate pumpage for the High Plains Aquifer Model. The program calculates pumpage for each cell designated FLAG=1 based on three types of withdrawal.

1) Pumpage assigned to specific cells

   This is pumpage assigned to individual cells and read by subroutine GETPMP (Data Sets 11, 12, or 13). Pumpage assigned by this method is that for which the location and amount are known, such as for municipal and industrial wells. This category is referred to as municipal and industrial (M and I).

2) Pumpage assigned uniformily across a county

   Pumpage for uses such as rural domestic and livestock are usually distributed uniformly across each county. The program distributes this pumpage to cells based on the cell's area and the portion of the associated county that is in the ground-water system.

3) Pumpage for irrigation

   This pumpage is calculated based on the portion of each cell that is irrigated and the application rate per unit area. The portion of each cell that is irrigated may be changed during simulation, and the application rate may be assigned to groups of cells and may vary during the simulation.

Irrigation pumpage for each cell is determined by the following equation.

$$IP_{i,j} = \Delta X_j \, \Delta Y_i \, PI_{i,j} \, R_{i,j} \, FS \, FL \, C$$

where:

$IP_{i,j}$ = Irrigation pumpage for cell i,j (acre-feet per major time step),

$\Delta X_j \, \Delta Y_i$ = Dimensions of cell i,j (feet),

$PI,_{i,j}$ = Fraction of cell i,j under irrigation,

$R_{i,j}$ = Application rate of water (acre-feet per acre or feet),

FS = Reduction factor based on transmissivity,

FL = Reduction factor based on pumping lift, and

C = Constant to ensure proper units

The term $PI_{i,j}$ indicates the percentage of cell i,j that is subject to irrigation. Only land irrigated with water from the High Plains aquifer is considered.

## Transmissivity Constraint

The High Plains aquifer is being mined and as saturated thickness declines, well yields also decline. As this process continues, the amount of water applied will diminish. The program assumes that as long as transmissivity remains larger than a given value, T-one, pumpage is unaffected by well yields. As transmissivity drops below T-one, pumpage is assumed to reduce linearly until the reduction equals 90 percent. The corresponding transmissivity is T-two. FS is set equal to 0.1 for all values of transmissivity less than T-two. The procedure may be expressed as follows:

FS = 1.0
for T equal to or greater than T-one,

= 1-0.9(T-one - T)/(T-one - T-two)
for T less than T-one, but greater than T-two,

= 0.1
for T equal to or less than T-two,

where T equals the transmissivity for cell i,j.

A set of T-one and T-two is read for each cell. The units are similar to the ones used for hydraulic conductivity.

## Pumping Lift Constraint

As the water level in the High Plains continues to decline, the distance that water must be lifted increases. At some point, the cost of lifting the water will exceed its benefit, and pumping will decrease. The program assumes that as long as lifts are less than a given value, PLT, pumpage is unaffected. As lift increases above PLT, pumpage is assumed to reduce linearly until the reduction equals 90 percent. FL will be reduced by a given value, PLS, for each unit increase in lift greater than PLT. FL will always be greater than 0.1, which represents a 90 percent reduction in pumpage. For this work, the pumping lift, PL, equals the distance separating the land surface and the water table. The lift does not consider increased drawdown in the near vicinity of a pumping well. FL is determined as follows:

FL = 1.0 for PL less than PLT,

= 1.0-PLS(PL-PLT) for PL greater than PLT, and

FL = maximum of (FL and 0.1)

A set of PLT and PLS is read for each county. The units for PLT are the same as for water-table elevation.

## Saturated Thickness Contraint

As saturated thickness becomes very thin, well yields will be very small and water will be pumped only when small amounts of water are very important. Water for rural domestic and livestock uses fits into this category. Once saturated thickness reaches five feet, only water for domestic and stock uses will be pumped, and municipal and industrial pumpage and irrigation pumpage reduce to zero. Once saturated thickness reaches two feet, all pumpage is reduced to zero.

The procedure summarizes the pumpage calculations by printing the totals of pumpage assigned to specific cells (M and I), M and I pumpage reduction due to the saturated thickness constraint, pumpage assigned uniformly across counties (D and S), D and S pumpage reduction due to saturated thickness constraint, initial irrigation pumpage, irrigation pumpage reduction due to transmissivity constraint, irrigation pumpage reduction due to pumping lift constraint, irrigation pumpage reduction due to saturated thickness constraint, net irrigation pumpage, and net total pumpage. Also printed is total volume of water in storage, computed as cell dimensions times storage coefficient times saturated thickness. The same summary information may be printed for each county, and the pumpage data may also be printed for each cell. See Pumpage Options 10 and 11.

## Pumpage Options

The pumpage calculation portion of the program is controlled by a series of options. An option is enabled if it is assigned a value greater than zero. The following options are set for each major time step. See Data Set 17.

1 READ DEFAULT COUNTY CODE AND LAND SURFACE ELEVATION

Enabling this option causes the reading of Data Set 18 and the assignment of a county code and a land surface elevation to all cells in the ground-water system. A value for each cell is not read. If this option equals zero, values for each cell are read.

2 ASSIGN COUNTY CODE AND LAND SURFACE ELEVATION BY BLOCK

Enabling this option causes the program to read a county code and/or a land surface elevation to be assigned to all cells in a specified block of the grid. Data Set 19 is read.

3 READ PERCENT IRRIGATED

Enabling this option causes the reading of Data Set 20 and the assignment of a percent irrigated value to all cells in the ground-water system. If the option equals one, a value is read for each cell. If the option equals two, a default value is read and assigned to each cell.

4 LIST BASIC DATA

Enabling this option causes the listing of county code, land surface elevation, and percent irrigated for each cell and the total irrigated area in each county. If the value of the option is two, only the total irrigated area per county is listed.

5 PERCENT IRRIGATED ASSIGNMENTS

Enabling this option causes the program to read a percent irrigated value which is to be assigned to all cells in a specified block of the grid. Data Set 21 is read.

6 READ TRANSMISSIVITY CONSTRAINT PARAMETERS

Enabling this option causes the reading of the transmissivity constraint parameters, T-one and T-two. If the option equals one, a set of values is read for each cell in the grid. If the option equals two, a set of values for each cell is read followed by block assignment/adjustment values. If the option equals three, only assignment/adjustment values are read which are to be applied to all cells in a specific block of the grid. Data Set 23 is read.

7 READ PUMPING LIST CONSTRAINT PARAMETERS

Enabling this option causes the reading of the pumping lift constraint parameters, PLT and PLS, by county. Data Set 24 is read.

8 READ DOMESTIC AND STOCK PUMPAGE

Enabling this option causes the reading of the D and S pumpage rate which is to be uniformly distributed across each county. Data Set 25 is read.

9 READ IRRIGATION RATE ASSIGNMENTS

Enabling this option causes the program to read an irrigation rate which is to be assigned to all cells in a specified block of the grid. Data Set 26 is read.

10 WRITE PUMPAGE DATA BY CELL

Enabling this option causes the listing by cell of various categories of pumpage, any reductions due to constraints, and total pumpage.

11 WRITE PUMPAGE DATA TOTALS BY COUNTY

Enabling this option causes the listing, by county, of the totals of the various categories of pumpage, reductions due to constraints, and total pumpage.

12 WRITE COUNTY AREAS

Enabling this option causes the listing of the modeled area for each county.

13 READ PERCENT IRRIGATED ADJUSTMENTS

Enabling this option causes the reading of an adjustment factor which is applied to the percent irrigated value for all cells in a specified block of the grid. Data Set 22 is read.

14 READ IRRIGATION RATE ADJUSTMENTS

Enabling this option causes the reading of an adjustment factor which is applied to the irrigation application rate value for all cells in a specified block of the grid. Data Set 27 is read.

15 WRITE TRANSMISSIVITY CONSTRAINT PARAMETERS

Enabling this option causes the printing of the transmissivity constraint parameters that are read when Pumpage Option 6 is set equal to 1 or 2. Values of T-one and T-two are listed for each cell.

## INPUT

Program GWSIM-III was written to allow the user great flexibility in the construction of a data deck. The user has the option of choosing formats, the method of assigning the physical parameters of the system, and the form of external stimuli. The input and output may be tailored to fit the user's needs.

The items required for input to hydrologic modeling are as follows:

1) finite difference grid spacings,
2) nodal type,
3) base of aquifer elevation,
4) initial water level elevation,
5) hydraulic conductivity,
6) storage coefficient, and
7) pumpage and recharge rates.

Additional input items required for the High Plains Aquifer Model are as follows:

1) county code,
2) land surface elevation,
3) percent of area irrigated,
4) irrigation rate,
5) domestic and livestock pumpage, and
6) transmissivity and pumping lift constraint parameters.

## Input Unit Numbers

GWSIM-III uses one unit number variable for data input and six unit number variables for internal storage of data. Unit variable 'IN' is used to read all user supplied data and is set equal to 5. Unit Variable 'IN1' is used to store the initial water table elevation and is set equal to 11. Variable 'IN2' is used to store pumpage and recharge rates and is set equal to 12. Unit 'IN3' is used to store water table elevations for the hydrograph routine and is set equal to 13. Unit variable 'IN4' is used to store water table elevations at the beginning of a major time step and is set equal to 14. Variable 'IN5' is used to store hydraulic data during pumpage calculations and is set equal to 15. Variable 'IN6' is used to store pumpage calculation data and is set equal to 16.

## General Description

All user supplied data are read using formatted read statements. Many of the data sets are read using variable, or object time formats. In effect, the format card which describes the data is the first card of the data set. This allows the user maximum flexibility in design of data sets.

Integer input parameters must be punched, right justified, and without a decimal point. It is recommended that a decimal point be included with all real parameters.

## Data Set Descriptions

The sequence of the data sets is shown in Figure 2. Data Sets 1 through 9 may be read only once, whereas the remainder of the sets may be read for each major time step. Many of the data sets are read only if certain options are enabled. Data Sets 17 through 27 may be read only if pumpage is calculated for the High Plains aquifer (Time Step Option 8 enabled). Data Sets 18 through 20 should be read only during the first major time step.

### Data Set 1 - Title

This data set contains one card for input of a title statement. The title should be centered on the card.

### Data Set 2 - Parameters

| Columns | Format | Description |
|---|---|---|
| Card One | | |
| 1-5 | I5 | Number of major time steps |
| 6-10 | I5 | Number of minor time steps |
| 11-15 | I5 | Number of rows in grid |
| 16-20 | I5 | Number of columns in grid |
| 21-25 | I5 | Number of iteration parameters |

DATA SET SEQUENCE

Figure 2

| Data Set Number | Title | Is Data Set Read?* |
|---|---|---|
| 1 | Title | Yes |
| 2 | Parameters | Yes |
| 3 | General program options | Yes |
| 4 | Hydrograph specifications | If GP Option 1 GTO |
| 5 | Cross section specifications | If GP Option 2 GTO |
| 6 | Grid spacings | Yes |
| 7 | Physical data | Yes |
| 8 | Physical data corrections | If GP Option 6 GTO |
| 9 | Physical data adjustments | If GP Option 7 GTO |

The following data sets may be read for each major time step

| Data Set Number | Title | Is Data Set Read?* |
|---|---|---|
| 10 | Time step options | Yes |
| 11 | Pumpage for all cells | If TS Option 2 GTO |
| 12 | Pumpage by block | If TS Option 3 GTO |
| 13 | Pumpage adjustments | If TS Option 4 GTO |
| 14 | Recharge for all cells | If TS Option 5 GTO |
| 15 | Recharge by block | If TS Option 6 GTO |
| 16 | Recharge adjustments | If TS Option 7 GTO |
| 17 | Pumpage options | If TS Option 8 GTO |
| 18 | County and land elevation | If TS Option 8 GTO |
| 19 | County and land elevation by block | If TS Option 8 GTO and P Option 2 GTO |
| 20 | Percent irrigated | If TS Option 8 GTO and PO Option 3 GTO- |
| 21 | Percent irrigated by block | If TS Option 8 GTO and P Option 5 GTO |
| 22 | Percent irrigated adjustments | If TS Option 8 GTO and P Option 13 GTO |
| 23 | Transmissivity constraints | If TS Option 8 GTO and P Option 6 GTO |
| 24 | Pumping lift constraints | If TS Option 8 GTO and P Option 7 GTO |
| 25 | Domestic and stock pumpage | If TS Option 8 GTO and P Option 8 GTO |
| 26 | Irrigation rate assignment | If TS Option 8 GTO and P Option 9 GTO |
| 27 | Irrigation rate adjustment | If TS Option 8 GTO and P Option 14 GTO |
| 28 | Heads for constant head cells | If TS Option 24 GTO |
| 29 | Limits for statistical blocks | If TS Option 27 GTO |
| 30 | Measured heads | If TS Option 22 GTO |

*

GP Option = General Program Option (Data Set 3)
TS Option = Time Step Option (Data Set 10)
P Option = Pumpage Option (Data Set 17)
GTO = greater than zero

| | | |
|---|---|---|
| Card Two | | |
| 1-10 | F10.0 | Length of major time step (days) |
| 11-20 | F10.0 | Convergence criterion |
| 21-30 | F10.0 | Time acceleration factor |
| 31-40 | F10.0 | Units conversion factor for pumpage and recharge |
| 41-46 | A6 | Label to indicate pumpage and recharge units |
| 47-52 | A6 | Label to indicate length units |
| 53-64 | 2A6 | Label to indicate units for ground-water flow maps |
| Card Three | | |
| 1-10 | F10.0 | Units conversion factor for hydraulic conductivity |
| 11-20 | F10.0 | Units conversion factors for ground-water flow maps |

The number of iteration parameters should be between 3 and 7. A suggested value is 4. The convergence criterion is a function of the problem, and various values should be used until an appropriate value is determined; a suggested value is 1.0. A suggested time acceleration factor is 1.20, which allows for 20 percent growth in minor time step length.

The units conversion factor for pumpage and recharge converts the input rates into the internal units, cubic length per day. For example, the factor to convert acre-feet per year to cubic feet per day is 119.34, and the corresponding label could be 'AC-FT.' If the input water table units are in feet, the corresponding length label could be 'FEET.' The units conversion factor for hydraulic conductivity converts the input units into the internal units of length per day. For example, the factor to convert gallons per day per square foot to feet per day is 0.13369. If Time Step Options 12 or 17 are enabled, maps will be produced indicating ground-water flow. The internal units for flow are cubic length per day and the ground-water flow maps units conversion factor converts this rate to a more meaningful value, remembering that only 3 digits may be printed. If the length unit is feet, a factor value of 0.00008379 will result in rates printed in 100's of acre-feet per year. An appropriate label would be '100's AF/YR.'

Data Set 3 - General program options

This one-card data set contains the General Program Options. The value of the option is punched into the column number corresponding to the option number.

Data Set 4 - Hydrograph Specifications

This data set is required if General Program Option 1 is enabled. Up to 25 cells may be so identified.

| Columns | Format | Description |
|---|---|---|
| Card One | | |
| 1-3 | I3 | Number of cells for which hydrographs are to be printed |
| 4-6 | I3 | Row number of first identified cell |
| 7-9 | I3 | Column number of first identified cell |
| 10-12 | I3 | Row number of second identified cell |

The sequence continues through the twelfth identified cell.

| | | |
|---|---|---|
| 76-78 | I3 | Row number of thirteenth identified cell |
| Card Two | | |
| 1-3 | I3 | Column number of thirteenth identified cell |
| 4-6 | I3 | Row number of fourteenth identified cell |

The sequence continues until

| | | |
|---|---|---|
| 72-75 | I3 | Column number of twenty-fifth identified cell. |

The second card is required if more than twelve hydrographs are requested.

Data Set 5 - Cross section specifications

This two card data set is requried if General Program Option 2 is enabled. The first card indicates the number of and the corresponding column numbers for the columns for which profiles are requested. The second card contains similar data for rows. Up to 25 rows and 25 columns may be used.

| Column | Format | Description |
|---|---|---|
| Card One | | |
| 1-3 | I3 | Number of columns for which cross sections are requested |
| 4-6 | I3 | First column to be printed |
| 7-9 | I3 | Second column to be printed |

The sequence continues through the last column

| | | |
|---|---|---|
| 75-78 | I3 | Twenty-fifth column to be printed. |

| Card Two | | |
|---|---|---|
| 1-3 | I3 | Number of rows for which cross sections are requested |
| 4-6 | I3 | First row to be printed |
| 7-9 | I3 | Second row to be printed |

The sequence continues through the last row

| | | |
|---|---|---|
| 75-78 | I3 | Twenty-fifth row to be printed. |

Data Set 6 - Grid spacings

The first card of this data set is the format card. If General Program Option 3 is enabled, constant grid spacings are read on card two. Otherwise, spacings for each row and column are read starting with card two. The constant grid spacings in the x-direction and y-direction are both on card two. For variable grid spacings, the values in the x-direction are read by the command

```
READ (IN,FMT) (DELX(J),J=1,NC)
```

followed by a similar command to read the grid spacings in the y-direction.

The unit for grid spacing is length. Suggested format for constant spacing is (2F10.0) and for variable spacing is (8F10.0).

Data Set 7 - Physical data

This data set contains the data necessary to describe the system. The order in which data must be read is

1) nodal type declaration,
2) base of aquifer elevation,
3) initial water-table elevation,
4) hydraulic conductivity, and
5) storage coefficient.

The unit for the base of aquifer elevation and initial water level is length and it must be the same as that used for grid spacings.

The first card of the data set is the format card. If General Program Option 5 is enabled, default values are read on card two. Otherwise, values for each cell are read. The data are read by cell by rows. A suggested format is (I5,4F10.0).

Data Set 8 - Physical data corrections

This data set is read if General Program Option 6 is enabled. The first card is the format card. The same types of data are read as in Data Set 7 except that the row and column numbers identifying the cell are read prior to the nodal type declaration. A suggested format is (3I5,4F10.0).

The last card must be blank.

Data Set 9 - Physical data adjustments

This data set contains factors to adjust the initial values of hydraulic conductivity and storage coefficient and is read if General Program Option 7 is enabled. One data card is required for each adjustment, and each adjustment is applied to a specified section of the grid. If the adjustment factor is non-negative, the present value of the parameter is multiplied by the value and adjustments are cumulative. If the value is negative, the absolute value of the adjustment factor is assigned to all cells in the grid section.

| Columns | Format | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-25 | I5 | Parameter identifier (1 for hydraulic conductivity and 2 for storage coefficient) |
| 26-35 | F10.0 | Adjustment value |

The last card must be blank.

Data Set 10 - Time step options

This one-card data set contains the Time Step Options plus the parameters needed to adjust time step size (see Time Step Option 1).

| Columns | Format | Description |
|---|---|---|
| 1 | I1 | Value for option 1 |
| 2 | I1 | Value for option 2 |

Sequence continues through option 27.

| | | |
|---|---|---|
| 27 | I1 | Value for option 27 |
| 31-35 | I5 | Number of minor time steps for this step if Time Step Option 1 is enabled. |
| 36-45 | F10.0 | Length of this major time step, in days, if Time Step Option 1 is enabled. |
| 46-55 | F10.0 | Time step acceleration factor for this major time step if Time Step Option 1 is enabled. |

Data Set 11 - Pumpage for all cells

This data set contains a pumpage value for each cell in the system and is read if Time Step Option 2 is enabled. The first card is the variable format card. The pumpage rates are read a row at a time by the following commands:

```
   DO 10 I = 1,NR
10 READ (IN,FMT) (Q(I,J),J=1,NC)
```

The units are volume per major time step, i.e., acre-feet per year. They are converted to cubic length per day by the conversion factor in Data Set 2 (PMPFCT). A suggested format is (10X,10F7.0).

Data Set 12 - Pumpage by block

This data set contains pumpage rates to be assigned to all cells in a specified region of the grid and is read if Time Step Option 3 is enabled.

| Columns | Format | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-30 | F10.0 | Pumpage rate |

The units are the same as those for Data Set 11.

The last card must be blank.

Data Set 13 - Pumpage adjustments

This data set contains pumpage adjustment factors which will multiply the pumpage rates for all cells in a specified region of the grid and is read if Time Step Option 4 is enabled.

| Columns | Format | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-30 | F10.0 | Pumpage adjustment factor. |

The last card must be blank.

Data Set 14 - Recharge for all cells

This data set contains a recharge value for each cell in the system and is read if Time Step Option 5 is enabled. The first card is the variable format card. The recharge rates are read a row at a time as is Data Set 11. The units are the same as those for Data Set 11. A suggested format is (10X,10F7.0).

Data Set 15 - Recharge by block

This data set contains recharge rates to be assigned to all cells in a specified region of the grid and is read if Time

Step Option 6 is enabled. Data are read in the same manner as for Data Set 12 except recharge rate is read instead of pumpage rate. The units are the same as those for Data Set 11.

The last card must be blank.

Data Set 16 - Recharge adjustments

This data set contains recharge adjustment factors which will multiply the recharge rates for all cells in a specified region of the grid and is read if Time Step Option 7 is enabled. Data are read in the same manner as for Data Set 13 except the factor is applied to recharge.

The last card must be blank.

Data Set 17 - Pumpage Options

This data set contains the options controlling the estimation of pumpage for the High Plains Aquifer Model and is read if Time Step Option 8 is enabled. Data are read in the same manner as the Time Step Options in Data Set 10. The value of the option is punched into the column corresponding to the option number.

Data Set 18 - County and land elevation

This data set may be read only for the first major time step and only if Time Step Option 8 is enabled. If Pumpage Option 1 is enabled, the data set contains one card on which a default county number and land surface elevation are punched as follows:

| Columns | Format | Description |
|---|---|---|
| 1-5 | I5 | Default county number |
| 6-15 | F10.0 | Default land surface elevation |

If Pumpage Option 1 is not enabled, a county number and land surface elevation are read for each cell. The first card of the data set is the variable format card to be used to read the county numbers. The county numbers are read a row at a time by commands as follows:

```
      DO 10 I=1,NR
   10 READ (IN,FMT) (ICOUTY(I,J),J=1,NC)
```

After the county numbers are read, a variable format card is read to be used in reading the land surface elevations. These data are read by commands similar to those used to read county numbers. The largest county number cannot exceed 60, and the units on land surface elevation are the same as for initial water-level elevation. Suggested formats are (20I3) and (10X, 10F7.0), respectively.

Data Set 19 - County and land elevation by block

This data set contains county number and land surface elevation to be assigned to all cells in a specified region of the grid and is read if Time Step Option 8 and Pumpage Option 2 are enabled.

| Columns | Format | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-25 | I5 | Variable key |
| 26-35 | F10.0 | Variable value |

The variable key indicates the variable to be assigned. A value of 1 indicates that the county number is the variable to be assigned. A value of 2 indicates the variable is land surface elevation. See Data Set 18 for discussion of units for land surface elevation.

The last card must be blank.

Data Set 20 - Percent irrigated

This data set contains the percent irrigated for each cell and is read if Time Step Option 8 and Pumpage Option 3 are enabled. If Pumpage Option 3 equals two, the data set contains one card on which a default percent irrigated is punched. This value is assigned to all cells. The value is punched into the first 10 columns using a (F10.0) format.

If Pumpage Option 3 equals one, a percent irrigated is read for each cell. The first card is the variable format card. The data are read a row at a time by commands

```
   DO 10 I=1,NR
10 READ (IN,FMT) (PCTIRR(I,J),J=1,NC)
```

A suggested format is (10X,10F7.0).

Data Set 21 - Percent irrigated by block

This data set contains a percent irrigated value to be assigned to all cells in a specified region of the grid and is read if Time Step Option 8 and Pumpage Option 5 are enabled. The first card read is a variable format card. A suggested format is (4I5,F10.0) and, if this format is used, data would be read as follows:

| Columns* | Format* | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-30 | F10.0 | Percent irrigated value |

*Depends on format used.

The last card must be blank.

Data Set 22 - Percent irrigated adjustments

This data set contains percent irrigated adjustment factors which adjust by multiplication the percent irrigated value for all cells in a specified region of the grid and is read if Time Step Option 8 and Pumpage Option 13 are enabled. The first card read is a variable format card. A suggested format is (4I5, F10.0) and, if this format is used, data would be read as follows:

| Columns* | Format* | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-30 | F10.0 | Percent irrigated adjustment |

*Depends on format used.

The last card must be blank.

Data Set 23 - Transmissivity constraints

This data set contains the transmissivity constraint values to be used and is read if Time Step Option 8 and Pumpage Option 6 are enabled. If Pumpage Option 6 equals one or two, a set of values are read for each cell. In each set, the T-one value is followed by the T-two value. The first card of the data set is a variable format. The data are read a row at a time by commands

```
      DO 10 I=1,NR
   10 READ(IN,FMT) (TONE(I,J),TTWO(I,J),J=1,NC)
```

A suggested format is (10X,10F7.0).

If block assignments and/or adjustments are to be made, Pumpage Option 6 must be set equal to two or three. If the option equals two, the block assignments/adjustments are read after values are read for all cells in the grid. Assignment values are assigned to all cells in the grid segment. Adjustment values multiply the existing value of the variables. If a card is to contain adjustment values, the T-one value must have a negative sign. The first card is a variable format card. A suggested format is (4I5,2F10.0) and, if this format is used, data would be read as follows:

| Columns* | Format* | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-30 | F10.0 | Assignment/adjustment value for T-one |
| 31-40 | F10.0 | Assignment/adjustment value for T-two. |

*Depends on format used.

The last card must be blank if Pumpage Option 6 is equal to two or three.

The units for T-one and T-two must agree with the units of hydraulic conductivity used in Data Set 7.

Data Set 24 - Pumping lift constraints
This data set contains the pumping lift constraint values to be used for each county and is read if Time Step Option 8 and Pumpage Option 7 are enabled. Each county must be assigned a set of coefficients during the first major time step.

| Columns | Format | Description |
|---|---|---|
| 1-5 | I5 | County number |
| 6-15 | F10.0 | PLS value |
| 16-25 | F10.0 | PLT value |

The units for PLT agree with those of initial water level in Data Set 7.

The last card must be blank.

Data Set 25 - Domestic and Stock Pumpage
This data set contains the domestic and livestock pumpage values to be assigned to each county and is read if Time Step Option 8 and Pumpage Option 8 are enabled. The first card is a variable format card. A suggested format is (I5,F10.0) and, if this format is used, the data would be read as follows:

| Columns* | Format* | Description |
|---|---|---|
| 1-5 | I5 | County number |
| 6-15 | F10.0 | Pumpage value |

*Depends on format used.

The value represents the total pumpage for the county, and the units must agree with those for Data Set 11.

The last card must be blank.

Data Set 26 - Irrigation rate assignment
This data set contains the irrigation application rates to be assigned to all cells in a specified region of the grid and is read if Time Step Option 8 and Pumpage option 9 are enabled. The first card is a variable format card. A suggested format is (4I5,F10.0) and, if this format is used, the data would be read as follows:

| Columns* | Format* | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-30 | F10.0 | Application rate |

*Depends on format used.

The rate is expressed as volume per time step per unit area. For example, acre-feet per year per acre, or just feet per year.

The last card must be blank.

Data Set 27 - Irrigation rate adjustment
This data set contains adjustment factors which adjust by multiplication the irrigation application rate for all cells in a specified region of the grid and is read if Time Step Option 8 and Pumpage Option 14 are enabled. The first card is a variable format card. A suggested format is (4I5,F10.0) and, if this format is used, the data would be read as follows:

| Columns* | Format* | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-30 | F10.0 | Adjustment factor |

*Depends on format used.

This last card must be blank.

Data Set 28 - Heads for constant-head cells
This data set contains the end-of-major-time heads or changes in head during the major time step for constant-head cells, FLAG=0, and is read if Time Step Option 24 is enabled. The first card is a format card. If data are to be read for all cells, option value of 1 or 2, the data are read a row at a time by commands

```
   DO 10 I=1,NR
10 READ (IN,FMT) (H(I,J),J=1,NC)
```

A suggested format is (10X,10F7.0).

If values are to be read for a specified region of the grid, option value of 3 or 4, and the format used was (4I5,F10.0), the data would be read as follows:

| Columns* | Format* | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |
| 21-30 | F10.0 | Head or change in head |

*Depends on format used

If the option value is 3 or 4, the last card must be blank.

Data Set 29 - Limits of statistical blocks
This data set contains the row and column numbers which delineate a section of the grid for which the statistical data are to be calculated and is read if Time Step Option 27 is enabled. Up

to 60 such blocks may be identified. The first card is a format card. If the format used was (4I5), the data would be read as follows:

| Columns* | Format* | Description |
|---|---|---|
| 1-5 | I5 | First row of grid segment |
| 6-10 | I5 | Last row of grid segment |
| 11-15 | I5 | First column of grid segment |
| 16-20 | I5 | Last column of grid segment |

*Depends on format used.

The last card must be blank.

Data Set 30 - Measured heads

This data set contains measured (observed) heads at the end of the major time step and is read if Time Step Option 22 is enabled. These heads are compared to the simulated heads. The first card is a variable format card. The data are read a row at a time by commands

```
   DO 10 I=1,NR
10 READ (IN,FMT) (H(I,J),J=1,NC)
```

A suggested format is (10X,10F7.0).

## OUTPUT

Program GWSIM-III was written to allow the user the ability to determine the types of output desired. The user selects the types of output produced by the program by the appropriate enabling of certain options. By proper planning, the user can eliminate the printing of unneeded information.

### Output Unit Numbers

Two unit number variables are used for output of information. The unit number associated with the variable "OUT" should be set to the printer's logical unit number. The unit number associated with variable 'OUT1' could be any device for storage of simulated heads and/or physical data. The data may be punched or placed on a mass storage device. The variable 'OUT' is set equal to 6 and 'OUT1' equals 10.

### General Description

The output may be tailored to the user's needs. The program automatically prints the values of many parameters, and through enabling options, almost all data may be printed. Generally, the enabling of an option is required to print any data that require a significant amount of printing. For example, the enabling of Time Step Option 11 is required to list the pumping rate for each cell.

At the end of each minor time step, a message is printed which indicates the number of days simulated and the equivalent number of major time steps completed. The sum of the changes in head during the last iteration of the IADI procedure is printed. The number of iterations needed to complete the minor time step is printed also. If the number of iterations is equal to 51, the IADI procedure may not have converged. This could occur with an exceedingly small error criterion or an error in the physical data.

A listing of the mass balances is printed upon completion of each major time step. Values for this time step and cummulative totals are printed. Values are expressed as rates per day and as total volume. Pumpage and recharge show values titled positive, negative, and net. A positive pumpage represents an outflow, and a positive recharge represents an inflow. The opposite is true for the negative values. Net equals positive minus negative. The reduction in pumpage values represents that amount of water that was not pumped because a cell dewatered, expressed as an average daily rate. The mass balance terms give an indication of the accuracy of the simulation. Flows out of the aquifer are considered positive.

## APPLICATION TO EXAMPLE PROBLEM

As a demonstration of how the program GWSIM-III could be applied, an example problem was constructed. The problem involved simulating a 2-mile by 1-mile section of water table aquifer. The following assumptions were made: (1) no flow is allowed to cross the boundary; (2) the land is irrigated and some domestic and livestock water use occurs; (3) a large municipal well is located approximately one-half mile from the left edge of the grid; (4) a recharge well is located one-half mile from the right side of the grid; (5) the initial head equals 50 feet, and the elevation of base of aquifer is at -50 feet; (6) the hydraulic conductivity equals 400 gallons per day per square foot, and the storage coefficient equals 10 percent; (7) the municipal well pumpage rate is 2,500 acre-feet per year and the recharge well rate is 150 acre-feet per year; and (8) the left 0.4 of the area is in County A, and the remainder is in County B. Values of the various parameters for the two counties are given in the following table.

| | COUNTY | |
|---|---|---|
| | A | B |
| Land surface elevation | 150 feet | 200 feet |
| Percent irrigated | 50 | 50 |
| Domestic and stock pumpage | 0 | 500 ac-ft per year |
| T-one transmissivity constraint | 30,000 gpd/ft$^2$ | 60,000 gpd/ft$^2$ |
| T-two transmissivity constraint | 5,000 gpd/ft$^2$ | 5,000 gpd/ft$^2$ |
| PLS pumplift constraint | 0.01 | 0.01 |
| PLT pumplift constraint | 90 feet | 125 feet |

A uniform irrigation pumpage rate of one foot per year was used, and the system is to be simulated for two years.

A uniform finite difference grid with 10 columns and 5 rows was superimposed over the aquifer. A major time step length of 365 days was selected, with 12 minor steps. The length unit selected was feet, and the external flux unit is acre-feet per year. Figure 3 shows the data cards needed to simulate the aquifer problem. The user should study each card to determine the significance of each number. Figure 4 illustrates a portion of the output which demonstrates many of the output options.

## RESTRICTIONS

The program was written in Fortran V for the Univac 1100 computer series; however, it should be compatible with other systems. Core requirements are large, approximately 30,000 words.

The program has array declarations of 31 rows and 31 columns. If the size of the arrays must be changed, the changes need only be made to the appropriate card in the main segment of the program. The plotting routines have a maximum of 100 rows or columns. The number of hydrographs and cross sections are limited to 25 each.

The user is cautioned to always check the results for potential instabilities in the solution.

```
Data
Set  Column
              1         2         3         4         5         6         7
     1234567890123456789012345678901234567890123456789012345678901234567890
 1                     EXAMPLE PROBLEM  HIGH PLAINS MODEL
 2       2    12    5   10    5
           365.      .1       1.2    119.34 AC-FT  FEET100'S AF/YR
        0.13369  3.379E-5
 3     1 1
 6   (2F10.0)
          1056.     1056.
 7   (I5,4F10.0)
         1      -50.       50.      400.      0.1
10     1  1 1  1    11       11
12       3    3    3    3     2500.
15       3    3    8    8      150.
17   1121 3111111
18       1     150.
19       1    5    5   10    1        2.
         1    5    5   10    2      200.
20          0.5
23   (4I5,2F10.0)
         1    5    1    4   30000.    5000.
         1    5    5   10   60000.    5000.
24       1     0.01      90.
         2     0.01     125.
25     (I5,F10.0)
         1
         2     500.
26   (4I5,F10.0)
         1    5    1   10        1.
10     1  1 1  1    11       11
12       3    3    3    3     2500.
15       3    3    8    8      150.
17            11
     Column
              1         2         3         4         5         6         7
     1234567890123456789012345678901234567890123456789012345678901234567890
```

Input Data for Example Problem

Figure 3

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

```
NUMBER OF MAJOR TIME STEPS                        2
NUMBER OF MINOR TIME STEPS                       12
SIZE OF MAJOR TIME STEPS                    365.000      DAYS
SIZE OF FIRST MINOR TIME STEP                 5.222      DAYS
ERROR CRITERIA                                  .10
NUMBER OF COLUMNS                                10
NUMBER OF ROWS                                    5
NUMBER OF ITERATION PARAMETERS                    5
TIME ACCELERATION FACTOR                      1.200
FLUX CONVERSION FACTOR                 .11934000+03
EXTERNAL FLUX UNITS                           AC-FT
PERMEABILITY CONVERSION UNITS                .13369
PLOTTED FLOWS FACTOR                   .33790000-04
PLOT FLOWS UNITS NAME                   100'S AF/YR
LENGTH UNIT NAME                               FEET

GENERAL PROGRAM OPTION    3 EQUALS    1
GENERAL PROGRAM OPTION    5 EQUALS    1

CONSTANT GRID SPACINGS
DEL X =  1056.000      DEL Y =  1056.000


     DEFAULT VALUES

     NODE TYPE                          1
     BASE OF AQUIFER               -50.00
     WATER LEVEL                    50.00
     PERMEABILITY                  400.00
     STORAGE COEFFICIENT           .10000


ITERATION PARAMETERS

         .02467     .06226     .15708     .39633    1.00000
```

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

```
                                 SIMULATING TIME STEP     1
TIME STEP OPTION     3 EQUALS    1
TIME STEP OPTION     6 EQUALS    1
TIME STEP OPTION     8 EQUALS    1
TIME STEP OPTION    11 EQUALS    1
TIME STEP OPTION    16 EQUALS    1
TIME STEP OPTION    17 EQUALS    1
TIME STEP OPTION    25 EQUALS    1
TIME STEP OPTION    26 EQUALS    1

          BLOCK  PUMPAGE  ASSIGNMENT

 ROW    ROW  COLUMN  COLUMN          VALUE
START   END  START    END

   3     3     3       3         2500.0000

          BLOCK  RECHARGE  ASSIGNMENT

 ROW    ROW  COLUMN  COLUMN          VALUE
START   END  START    END

   3     3     6       8          150.0000
PUMPAGE PREDICTION  OPTION      1 EQUALS    1
PUMPAGE PREDICTION  OPTION      2 EQUALS    1
PUMPAGE PREDICTION  OPTION      3 EQUALS    2
PUMPAGE PREDICTION  OPTION      4 EQUALS    1
PUMPAGE PREDICTION  OPTION      6 EQUALS    3
PUMPAGE PREDICTION  OPTION      7 EQUALS    1
PUMPAGE PREDICTION  OPTION      8 EQUALS    1
PUMPAGE PREDICTION  OPTION      9 EQUALS    1
PUMPAGE PREDICTION  OPTION     10 EQUALS    1
PUMPAGE PREDICTION  OPTION     11 EQUALS    1
PUMPAGE PREDICTION  OPTION     12 EQUALS    1

DEFAULT VALUES

COUNTY CODE                 1
LAND SURFACE ELEV.        150.

          BLOCK ADJUSTMENTS FOR PUMPAGE PREDICTION
 ROW    ROW  COLUMN  COLUMN  KEY      VALUE
START   END  SART     END

   1     5     5      10     1        2.00
   1     5     5      10     2      200.00

DEFAULT PERCENT IRRIGATED      .5000
```

OUTPUT FROM EXAMPLE PROBLEM SIMULATION

FIGURE 4

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

COUNTY CODES

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 4 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 5 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

LAND SURFACE ELEVATION

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 150.0000 | 150.0000 | 150.0000 | 150.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 |
| 2 | 150.0000 | 150.0000 | 150.0000 | 150.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 |
| 3 | 150.0000 | 150.0000 | 150.0000 | 150.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 |
| 4 | 150.0000 | 150.0000 | 150.0000 | 150.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 |
| 5 | 150.0000 | 150.0000 | 150.0000 | 150.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 | 200.0000 |

| COUNTY CODE | AREA |
|---|---|
| 1 | .22302720+08 |
| 2 | .33454080+08 |
| TOTAL | .55756800+08 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

PERCENT IRRIGATED

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 |
| 2 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 |
| 3 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 |
| 4 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 |
| 5 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

| COUNTY | IRRIGATED AREA |
|---|---|
| 1 | .11151360+08 |
| 2 | .16727040+08 |
| TOTAL | .27878400+08 |

TRANSMISSIVITY CONSTRAINTS

FORMAT (4I5,2F10.0)

| ROW START | ROW END | COLUMN START | COLUMN END | VALUE T-ONE | VALUE T-TWO |
|---|---|---|---|---|---|
| 1 | 5 | 1 | 4 | 30000. | 5000. |
| 1 | 5 | 5 | 10 | 60000. | 5000. |

PUMPING LIFT CONSTRAINTS

| COUNTY | PLS | PLT |
|---|---|---|
| 1 | .010 | 90.000 |
| 2 | .010 | 125.000 |

DOMESTIC AND STOCK PUMPAGE

FORMAT (I5,F10.0)

| COUNTY | VALUE |
|---|---|
| 1 | .00000000 |
| 2 | .50000000+03 |

IRRIGATION PUMPAGE RATES

FORMAT (4I5,F10.0)

| ROW START | ROW END | COLUMN START | COLUMN END | VALUE |
|---|---|---|---|---|
| 1 | 5 | 1 | 10 | 1.0000 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

| ROW | COLUMN | M AND I | REDUCE M&I THICKNESS | D AND S | REDUCE D&S THICKNESS | INITIAL IRR | REDUCE IRR TRANS | REDUCE IRR LIFT | REDUCE IRR THICKNESS | NET IRR | TOTAL PUMPAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | .00 | .00 | .00 | .00 | 12.80 | .00 | 1.28 | .00 | 11.52 | 11.52 |
| 1 | 2 | .00 | .00 | .00 | .00 | 12.80 | .00 | 1.28 | .00 | 11.52 | 11.52 |
| 1 | 3 | .00 | .00 | .00 | .00 | 12.80 | .00 | 1.28 | .00 | 11.52 | 11.52 |
| 1 | 4 | .00 | .00 | .00 | .00 | 12.80 | .00 | 1.28 | .00 | 11.52 | 11.52 |
| 1 | 5 | .00 | .00 | 16.67 | .00 | 12.80 | 4.19 | 2.15 | .00 | 6.46 | 23.12 |
| 1 | 6 | .00 | .00 | 16.67 | .00 | 12.80 | 4.19 | 2.15 | .00 | 6.46 | 23.12 |
| 1 | 7 | .00 | .00 | 16.67 | .00 | 12.80 | 4.19 | 2.15 | .00 | 6.46 | 23.12 |
| 1 | 8 | .00 | .00 | 16.67 | .00 | 12.80 | 4.19 | 2.15 | .00 | 6.46 | 23.12 |
| 1 | 9 | .00 | .00 | 16.67 | .00 | 12.80 | 4.19 | 2.15 | .00 | 6.46 | 23.12 |
| 1 | 10 | .00 | .00 | 16.67 | .00 | 12.80 | 4.19 | 2.15 | .00 | 6.46 | 23.12 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

| COUNTY | M AND I | REDUCE M&I THICKNESS | D AND S | REDUCE D&S THICKNESS | INITIAL IRR | REDUCE IRR TRANS | REDUCE IRR LIFT | REDUCE IRR THICKNESS | NET IRR | TOTAL PUMPAGE |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2500.00 | .00 | .00 | .00 | 256.01 | .00 | 25.60 | .00 | 230.40 | 2730.40 |
| 2 | .00 | .00 | 500.00 | .00 | 384.01 | 125.66 | 64.58 | .00 | 193.75 | 693.75 |

| COUNTY | VOLUME FEET**3 |
|---|---|
| 1 | .22302718+09 |
| 2 | .33454074+09 |

| TOTAL AREA | M AND I | REDUCE M&I THICKNESS | D AND S | REDUCE D&S THICKNESS | INITIAL IRR | REDUCE IRR TRANS | REDUCE IRR LIFT | REDUCE IRR THICKNESS | NET IRR | TOTAL PUMPAGE |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2500.00 | .00 | 500.00 | .00 | 640.01 | 125.66 | 90.18 | .00 | 424.15 | 3424.15 |

| COUNTY | VOLUME FEET**3 |
|---|---|
| TOTAL | .55756792+09 |

***TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

PUMPAGE

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.520 | 11.520 | 11.520 | 11.520 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 |
| 2 | 11.520 | 11.520 | 11.520 | 11.520 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 |
| 3 | 11.520 | 11.520 | 2511.520 | 11.520 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 |
| 4 | 11.520 | 11.520 | 11.520 | 11.520 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 |
| 5 | 11.520 | 11.520 | 11.520 | 11.520 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 | 23.125 |

***TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

RECHARGE

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| 2 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| 3 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | 150.000 | .000 | .000 |
| 4 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| 5 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

```
TIME =  .922171+01 DAYS OR   .03 MAJOR TIME STEPS, HEAD CHANGE SUM =   .09 FEET, ITERATIONS =  4
TIME =  .202878+02 DAYS OR   .06 MAJOR TIME STEPS, HEAD CHANGE SUM =   .01 FEET, ITERATIONS =  6
TIME =  .335670+02 DAYS OR   .09 MAJOR TIME STEPS, HEAD CHANGE SUM =   .05 FEET, ITERATIONS =  4
TIME =  .495022+02 DAYS OR   .14 MAJOR TIME STEPS, HEAD CHANGE SUM =   .02 FEET, ITERATIONS =  4
TIME =  .666243+02 DAYS OR   .19 MAJOR TIME STEPS, HEAD CHANGE SUM =   .01 FEET, ITERATIONS =  4
TIME =  .915709+02 DAYS OR   .25 MAJOR TIME STEPS, HEAD CHANGE SUM =   .01 FEET, ITERATIONS =  4
TIME =  .119107+03 DAYS OR   .33 MAJOR TIME STEPS, HEAD CHANGE SUM =   .01 FEET, ITERATIONS =  4
TIME =  .152150+03 DAYS OR   .42 MAJOR TIME STEPS, HEAD CHANGE SUM =   .02 FEET, ITERATIONS =  4
TIME =  .191801+03 DAYS OR   .53 MAJOR TIME STEPS, HEAD CHANGE SUM =   .02 FEET, ITERATIONS =  4
TIME =  .239383+03 DAYS OR   .66 MAJOR TIME STEPS, HEAD CHANGE SUM =   .03 FEET, ITERATIONS =  4
TIME =  .296482+03 DAYS OR   .81 MAJOR TIME STEPS, HEAD CHANGE SUM =   .05 FEET, ITERATIONS =  4
TIME =  .365000+03 DAYS OR  1.00 MAJOR TIME STEPS, HEAD CHANGE SUM =   .08 FEET, ITERATIONS =  4
```

| | FOR TIME STEP 1 | | THROUGH TIME STEP 1 | |
|---|---|---|---|---|
| | FEET**3/DAY | AC-FT/STEP | FEET**3/DAY | AC-FT |
| PUMPAGE | | | | |
| POSITIVE | 408638.5 | 3424.1539 | 408638.5 | 3424.1539 |
| NEGATIVE | .0 | .0000 | .0 | .0000 |
| NET | 408638.5 | 3424.1539 | 408638.5 | 3424.1539 |
| RECHARGE | | | | |
| POSITIVE | 17901.0 | 150.0000 | 17901.0 | 150.0000 |
| NEGATIVE | .0 | .0000 | .0 | .0000 |
| NET | 17901.0 | 150.0000 | 17901.0 | 150.0000 |
| CONSTANT HEAD FLOW | | | | |
| TO CELLS | .0 | .0000 | .0 | .0000 |
| FROM CELLS | .0 | .0000 | .0 | .0000 |
| NET | .0 | .0000 | .0 | .0000 |
| CHANGE IN STORAGE | | | | |
| INCREASE | 124.8 | 1.0455 | 124.8 | 1.0455 |
| DECREASE | 391046.8 | 3276.7450 | 391046.8 | 3276.7450 |
| NET | -390922.0 | -3275.6995 | -390922.0 | -3275.6994 |
| REDUCTION IN PUMPAGE | .0 | .0000 | .0 | .0000 |
| MASS BALANCE | 184.5 | 1.5457 | 184.5 | 1.5457 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

WATER LEVELS FOR END OF TIME STEP 1

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16.492 | 15.793 | 15.916 | 19.857 | 24.490 | 28.674 | 32.003 | 34.399 | 35.805 | 36.452 |
| 2 | 15.006 | 12.735 | 9.645 | 17.392 | 23.519 | 28.399 | 32.040 | 34.661 | 35.939 | 36.519 |
| 3 | 13.474 | 7.809 | -15.441 | 12.618 | 22.476 | 28.179 | 32.186 | 35.537 | 36.153 | 36.569 |
| 4 | 15.006 | 12.735 | 9.644 | 17.391 | 23.518 | 28.399 | 32.040 | 34.661 | 35.940 | 36.520 |
| 5 | 16.492 | 15.792 | 15.916 | 19.857 | 24.490 | 28.674 | 32.003 | 34.399 | 35.805 | 36.453 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

HEADS AT END OF TIME STEP 1

```
          COLUMN   11111111111
          1234567890

R  1      MMMMNOPPQQ
O  2      MLKMNOPPQQ
W  3      LKFLNOPQQQ
   4      MLKMNOPPQQ
   5      MMMMNOPPQQ
```

FREQUENCY DISTRIBUTION

| SYMBOL | RANGE(FT) | FREQUENCY | PER CENT .LE. |
|---|---|---|---|
| A | ******** TO -40.000 | 0 | .0 |
| B | -40.000 TO -35.000 | 0 | .0 |
| C | -35.000 TO -30.000 | 0 | .0 |
| D | -30.000 TO -25.000 | 0 | .0 |
| E | -25.000 TO -20.000 | 0 | .0 |
| F | -20.000 TO -15.000 | 1 | 2.0 |
| G | -15.000 TO -10.000 | 0 | 2.0 |
| H | -10.000 TO -5.000 | 0 | 2.0 |
| I | -5.000 TO .000 | 0 | 2.0 |
| J | .000 TO 5.000 | 0 | 2.0 |
| K | 5.000 TO 10.000 | 3 | 8.0 |
| L | 10.000 TO 15.000 | 4 | 16.0 |
| M | 15.000 TO 20.000 | 12 | 40.0 |
| N | 20.000 TO 25.000 | 5 | 50.0 |
| O | 25.000 TO 30.000 | 5 | 60.0 |
| P | 30.000 TO 35.000 | 9 | 78.0 |
| Q | 35.000 TO 40.000 | 11 | 100.0 |
| R | 40.000 TO 45.000 | 0 | 100.0 |
| S | 45.000 TO 50.000 | 0 | 100.0 |
| T | 50.000 TO 55.000 | 0 | 100.0 |
| U | 55.000 TO 60.000 | 0 | 100.0 |
| V | 60.000 TO 65.000 | 0 | 100.0 |
| W | 65.000 TO 70.000 | 0 | 100.0 |
| X | 70.000 TO 75.000 | 0 | 100.0 |
| Y | 75.000 TO 80.000 | 0 | 100.0 |
| Z | 80.000 TO ******** | 0 | 100.0 |
| * | CONSTANT HEAD | | |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

FLOWS (100'S AF/YR ) IN DIRECTION 1

| ROWS 5 | 4 | 3 | 2 | 1 | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 1 | 0 | 1 |
| 0 | 1 | 5 | 1 | 0 | 2 |
| -1 | -2 | -7 | -2 | -1 | 3 |
| -2 | -2 | -3 | -2 | -2 | 4 |
| -2 | -2 | -2 | -2 | -2 | 5 |
| -1 | -1 | -2 | -1 | -1 | 6 |
| -1 | -1 | -1 | -1 | -1 | 7 |
| -1 | -1 | 0 | -1 | -1 | 8 |
| 0 | 0 | 0 | 0 | 0 | 9 |
| 0 | 0 | 0 | 0 | 0 | 10 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

FLOWS (100'S AF/YR ) IN DIRECTION 2

| ROWS 5 | 4 | 3 | 2 | 1 | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | -1 | -1 | 1 | 1 | 2 |
| 0 | -2 | -6 | 6 | 2 | 3 |
| 0 | -1 | -1 | 1 | 1 | 4 |
| 0 | 0 | 0 | 0 | 0 | 5 |
| 0 | 0 | 0 | 0 | 0 | 6 |
| 0 | 0 | 0 | 0 | 0 | 7 |
| 0 | 0 | 0 | 0 | 0 | 8 |
| 0 | 0 | 0 | 0 | 0 | 9 |
| 0 | 0 | 0 | 0 | 0 | 10 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

SATURATED THICKNESS AT END OF STEP 1

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 66.492 | 65.793 | 65.916 | 69.857 | 74.490 | 78.674 | 82.003 | 84.399 | 85.805 | 86.452 |
| 2 | 65.006 | 62.735 | 59.645 | 67.392 | 73.519 | 78.399 | 82.040 | 84.661 | 85.939 | 86.519 |
| 3 | 63.474 | 57.809 | 34.559 | 62.618 | 72.476 | 78.179 | 82.186 | 85.537 | 86.153 | 86.569 |
| 4 | 65.006 | 62.735 | 59.644 | 67.391 | 73.519 | 78.399 | 82.040 | 84.661 | 85.940 | 86.520 |
| 5 | 66.492 | 65.792 | 65.916 | 69.857 | 74.490 | 78.674 | 82.003 | 84.399 | 85.805 | 86.453 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

SATURATED THICKNESS AT END OF TIME STEP 1

```
        COLUMN   11111111111
        1234567890
R   1   MMMMNOPPQQ
O   2   MLKMNOPPQQ
W   3   LKFLNOPQQQ
    4   MLKMNOPPQQ
    5   MMMMNOPPQQ
```

FREQUENCY DISTRIBUTION

| SYMBOL | RANGE(FT) | FREQUENCY | PER CENT .LE. | VOLUME FEET**3 | AREA FEET**2 |
|---|---|---|---|---|---|
| A | ******** TO 10.000 | 0 | .0 | .00000000 | .00000000 |
| B | 10.000 TO 15.000 | 0 | .0 | .00000000 | .00000000 |
| C | 15.000 TO 20.000 | 0 | .0 | .00000000 | .00000000 |
| D | 20.000 TO 25.000 | 0 | .0 | .00000000 | .00000000 |
| E | 25.000 TO 30.000 | 0 | .0 | .00000000 | .00000000 |
| F | 30.000 TO 35.000 | 1 | 2.0 | .38537576+07 | .11151360+07 |
| G | 35.000 TO 40.000 | 0 | 2.0 | .00000000 | .00000000 |
| H | 40.000 TO 45.000 | 0 | 2.0 | .00000000 | .00000000 |
| I | 45.000 TO 50.000 | 0 | 2.0 | .00000000 | .00000000 |
| J | 50.000 TO 55.000 | 0 | 2.0 | .00000000 | .00000000 |
| K | 55.000 TO 60.000 | 3 | 8.0 | .19748862+08 | .33454080+07 |
| L | 60.000 TO 65.000 | 4 | 16.0 | .28052568+08 | .44605440+07 |
| M | 65.000 TO 70.000 | 12 | 40.0 | .89245468+08 | .13381632+08 |
| N | 70.000 TO 75.000 | 5 | 50.0 | .41091966+08 | .55756800+07 |
| O | 75.000 TO 80.000 | 5 | 60.0 | .43749720+08 | .55756800+07 |
| P | 80.000 TO 85.000 | 9 | 78.0 | .83456029+08 | .10036224+08 |
| Q | 85.000 TO 90.000 | 11 | 100.0 | .10568293+09 | .12266496+08 |
| R | 90.000 TO 95.000 | 0 | 100.0 | .00000000 | .00000000 |
| S | 95.000 TO 100.000 | 0 | 100.0 | .00000000 | .00000000 |
| T | 100.000 TO 105.000 | 0 | 100.0 | .00000000 | .00000000 |
| U | 105.000 TO 110.000 | 0 | 100.0 | .00000000 | .00000000 |
| V | 110.000 TO 115.000 | 0 | 100.0 | .00000000 | .00000000 |
| W | 115.000 TO 120.000 | 0 | 100.0 | .00000000 | .00000000 |
| X | 120.000 TO 125.000 | 0 | 100.0 | .00000000 | .00000000 |
| Y | 125.000 TO 130.000 | 0 | 100.0 | .00000000 | .00000000 |
| Z | 130.000 TO ******** | 0 | 100.0 | .00000000 | .00000000 |
| * | CONSTANT HEAD | | | | |
| | | | TOTAL | .41488129+09 | .55756800+08 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

SIMULATING TIME STEP 2

```
TIME STEP OPTION    3 EQUALS    1
TIME STEP OPTION    6 EQUALS    1
TIME STEP OPTION    8 EQUALS    1
TIME STEP OPTION   11 EQUALS    1
TIME STEP OPTION   16 EQUALS    1
TIME STEP OPTION   17 EQUALS    1
TIME STEP OPTION   25 EQUALS    1
TIME STEP OPTION   26 EQUALS    1
```

BLOCK PUMPAGE ASSIGNMENT

| ROW START | ROW END | COLUMN START | COLUMN END | VALUE |
|---|---|---|---|---|
| 3 | 3 | 3 | 3 | 2500.0000 |

BLOCK RECHARGE ASSIGNMENT

| ROW START | ROW END | COLUMN START | COLUMN END | VALUE |
|---|---|---|---|---|
| 3 | 3 | 6 | 8 | 150.0000 |

```
PUMPAGE PREDICTION OPTION   10 EQUALS   1
PUMPAGE PREDICTION OPTION   11 EQUALS   1
```

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

| ROW | COLUMN | M AND I | REDUCE M&I THICKNESS | D AND S | REDUCE D&S THICKNESS | INITIAL IRR | REDUCE IRR TRANS | REDUCE IRR LIFT | REDUCE IRR THICKNESS | NET IRR | TOTAL PUMPAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | .00 | .00 | .00 | .00 | 12.80 | 1.57 | 4.89 | .00 | 6.35 | 6.35 |
| 1 | 2 | .00 | .00 | .00 | .00 | 12.80 | 1.70 | 4.91 | .00 | 6.19 | 6.19 |
| 1 | 3 | .00 | .00 | .00 | .00 | 12.80 | 1.67 | 4.90 | .00 | 6.22 | 6.22 |
| 1 | 4 | .00 | .00 | .00 | .00 | 12.80 | .95 | 4.76 | .00 | 7.09 | 7.09 |
| 1 | 5 | .00 | .00 | 16.67 | .00 | 12.80 | 6.33 | 3.27 | .00 | 3.20 | 19.87 |
| 1 | 6 | .00 | .00 | 16.67 | .00 | 12.80 | 5.98 | 3.16 | .00 | 3.66 | 20.33 |
| 1 | 7 | .00 | .00 | 16.67 | .00 | 12.80 | 5.70 | 3.05 | .00 | 4.05 | 20.72 |
| 1 | 8 | .00 | .00 | 16.67 | .00 | 12.80 | 5.50 | 2.97 | .00 | 4.34 | 21.01 |
| 1 | 9 | .00 | .00 | 16.67 | .00 | 12.80 | 5.36 | 2.91 | .00 | 4.51 | 21.18 |
| 1 | 10 | .00 | .00 | 16.67 | .00 | 12.80 | 5.32 | 2.88 | .00 | 4.59 | 21.26 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

| COUNTY | M AND I | REDUCE M&I THICKNESS | D AND S | REDUCE D&S THICKNESS | INITIAL IRR | REDUCE IRR TRANS | REDUCE IRR LIFT | REDUCE IRR THICKNESS | NET IRR | TOTAL PUMPAGE |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2500.00 | .00 | .00 | .00 | 256.01 | 43.59 | 97.52 | .00 | 114.89 | 2614.89 |
| 2 | .00 | .00 | 500.00 | .00 | 384.01 | 171.18 | 91.21 | .00 | 121.62 | 621.62 |

| COUNTY | VOLUME FEET**3 |
|---|---|
| 1 | .14090065+09 |
| 2 | .27398063+09 |

| TOTAL AREA | M AND I | REDUCE M&I THICKNESS | D AND S | REDUCE D&S THICKNESS | INITIAL IRR | REDUCE IRR TRANS | REDUCE IRR LIFT | REDUCE IRR THICKNESS | NET IRR | TOTAL PUMPAGE |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2500.00 | .00 | 500.00 | .00 | 640.01 | 214.76 | 188.74 | .00 | 236.51 | 3236.51 |

| COUNTY | VOLUME FEET**3 |
|---|---|
| TOTAL | .41488128+09 |

***TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

PUMPAGE

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.345 | 6.195 | 6.221 | 7.094 | 19.871 | 20.330 | 20.716 | 21.005 | 21.180 | 21.261 |
| 2 | 6.028 | 5.553 | 4.950 | 6.476 | 19.768 | 20.299 | 20.720 | 21.037 | 21.196 | 21.269 |
| 3 | 5.709 | 4.605 | 2501.313 | 5.534 | 19.660 | 20.274 | 20.737 | 21.146 | 21.223 | 21.278 |
| 4 | 6.028 | 5.553 | 4.949 | 6.476 | 19.768 | 20.299 | 20.720 | 21.037 | 21.196 | 21.269 |
| 5 | 6.345 | 6.195 | 6.221 | 7.094 | 19.871 | 20.330 | 20.716 | 21.005 | 21.180 | 21.261 |

***TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

RECHARGE

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| 2 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| 3 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | 150.000 | .000 | .000 |
| 4 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| 5 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

```
TIME =  .374222+03 DAYS OR  1.03 MAJOR TIME STEPS, HEAD CHANGE SUM =      .03 FEET, ITERATIONS =   4
TIME =  .385288+03 DAYS OR  1.06 MAJOR TIME STEPS, HEAD CHANGE SUM =      .05 FEET, ITERATIONS =   4
TIME =  .398567+03 DAYS OR  1.09 MAJOR TIME STEPS, HEAD CHANGE SUM =      .02 FEET, ITERATIONS =   4
TIME =  .414502+03 DAYS OR  1.14 MAJOR TIME STEPS, HEAD CHANGE SUM =      .00 FEET, ITERATIONS =   4
TIME =  .433624+03 DAYS OR  1.19 MAJOR TIME STEPS, HEAD CHANGE SUM =      .00 FEET, ITERATIONS =   4
TIME =  .456571+03 DAYS OR  1.25 MAJOR TIME STEPS, HEAD CHANGE SUM =      .02 FEET, ITERATIONS =   4
TIME =  .484107+03 DAYS OR  1.33 MAJOR TIME STEPS, HEAD CHANGE SUM =      .03 FEET, ITERATIONS =   7
   NODE  3  3 DEWATERED, PUMPAGE REDUCED        .29850666+06  FEET**3/DAY
TIME =  .517150+03 DAYS OR  1.42 MAJOR TIME STEPS, HEAD CHANGE SUM =      .09 FEET, ITERATIONS =   6
TIME =  .556801+03 DAYS OR  1.53 MAJOR TIME STEPS, HEAD CHANGE SUM =      .03 FEET, ITERATIONS =   7
TIME =  .604383+03 DAYS OR  1.66 MAJOR TIME STEPS, HEAD CHANGE SUM =      .04 FEET, ITERATIONS =   8
TIME =  .661482+03 DAYS OR  1.81 MAJOR TIME STEPS, HEAD CHANGE SUM =      .09 FEET, ITERATIONS =   9
TIME =  .730000+03 DAYS OR  2.00 MAJOR TIME STEPS, HEAD CHANGE SUM =      .06 FEET, ITERATIONS =   7
```

| | FOR TIME STEP 2 | | THROUGH TIME STEP 2 | |
|---|---|---|---|---|
| | FEET**3/DAY | AC-FT/STEP | FEET**3/DAY | AC-FT |
| PUMPAGE | | | | |
| POSITIVE | 386245.6 | 3236.5140 | 397442.1 | 6660.6678 |
| NEGATIVE | .0 | .0000 | .0 | .0000 |
| NET | 386245.6 | 3236.5140 | 397442.1 | 6660.6678 |
| RECHARGE | | | | |
| POSITIVE | 17901.0 | 150.0000 | 17901.0 | 300.0000 |
| NEGATIVE | .0 | .0000 | .0 | .0000 |
| NET | 17901.0 | 150.0000 | 17901.0 | 300.0000 |
| CONSTANT HEAD FLOW | | | | |
| TO CELLS | .0 | .0000 | .0 | .0000 |
| FROM CELLS | .0 | .0000 | .0 | .0000 |
| NET | .0 | .0000 | .0 | .0000 |
| CHANGE IN STORAGE | | | | |
| INCREASE | 34240.5 | 286.9159 | 17182.7 | 287.9614 |
| DECREASE | 201411.6 | 1687.7121 | 296229.2 | 4964.4571 |
| NET | -167171.0 | -1400.7963 | -279046.5 | -4676.4957 |
| REDUCTION IN PUMPAGE | 201096.0 | 1665.0848 | 100549.0 | 1685.0848 |
| MASS BALANCE | -75.5 | -.6328 | 54.5 | .9129 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

WATER LEVELS FOR END OF TIME STEP 2

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.391 | 8.966 | 10.161 | 11.925 | 13.817 | 15.887 | 17.840 | 19.420 | 20.359 | 20.796 |
| 2 | 8.249 | 8.754 | 9.882 | 11.790 | 13.783 | 15.936 | 18.013 | 19.784 | 20.539 | 20.864 |
| 3 | 8.127 | 8.520 | 9.426 | 11.652 | 13.757 | 15.996 | 18.265 | 20.885 | 20.811 | 20.974 |
| 4 | 8.249 | 8.754 | 9.883 | 11.790 | 13.783 | 15.937 | 18.013 | 19.784 | 20.539 | 20.864 |
| 5 | 8.391 | 8.966 | 10.161 | 11.925 | 13.817 | 15.687 | 17.840 | 19.420 | 20.359 | 20.795 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

HEADS AT END OF TIME STEP 2

```
        COLUMN  11111111111
        1234567890

R  1    MMNNNOOOPP
O  2    MMMNNOOOPP
W  3    MMMNNOOPPP
   4    MMMNNOOOPP
   5    MMNNNOOOPP
```

FREQUENCY DISTRIBUTION

| SYMBOL | RANGE(FT) | FREQUENCY | PER CENT .LE. |
|---|---|---|---|
| A | ******** TO -50.000 | 0 | .0 |
| B | -50.000 TO -45.000 | 0 | .0 |
| C | -45.000 TO -40.000 | 0 | .0 |
| D | -40.000 TO -35.000 | 0 | .0 |
| E | -35.000 TO -30.000 | 0 | .0 |
| F | -30.000 TO -25.000 | 0 | .0 |
| G | -25.000 TO -20.000 | 0 | .0 |
| H | -20.000 TO -15.000 | 0 | .0 |
| I | -15.000 TO -10.000 | 0 | .0 |
| J | -10.000 TO -5.000 | 0 | .0 |
| K | -5.000 TO .000 | 0 | .0 |
| L | .000 TO 5.000 | 0 | .0 |
| M | 5.000 TO 10.000 | 13 | 26.0 |
| N | 10.000 TO 15.000 | 12 | 50.0 |
| O | 15.000 TO 20.000 | 14 | 78.0 |
| P | 20.000 TO 25.000 | 11 | 100.0 |
| Q | 25.000 TO 30.000 | 0 | 100.0 |
| R | 30.000 TO 35.000 | 0 | 100.0 |
| S | 35.000 TO 40.000 | 0 | 100.0 |
| T | 40.000 TO 45.000 | 0 | 100.0 |
| U | 45.000 TO 50.000 | 0 | 100.0 |
| V | 50.000 TO 55.000 | 0 | 100.0 |
| W | 55.000 TO 60.000 | 0 | 100.0 |
| X | 60.000 TO 65.000 | 0 | 100.0 |
| Y | 65.000 TO 70.000 | 0 | 100.0 |
| Z | 70.000 TO ******** | 0 | 100.0 |
| * | CONSTANT HEAD | | |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

FLOWS (100'S AF/YR ) IN DIRECTION 1

| ROWS 5 | 4 | 3 | 2 | 1 | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 2 |
| 0 | -1 | -1 | -1 | 0 | 3 |
| -1 | -1 | -1 | -1 | -1 | 4 |
| -1 | -1 | -1 | -1 | -1 | 5 |
| -1 | -1 | -1 | -1 | -1 | 6 |
| 0 | -1 | -1 | -1 | 0 | 7 |
| 0 | 0 | 0 | 0 | 0 | 8 |
| 0 | 0 | 0 | 0 | 0 | 9 |
| 0 | 0 | 0 | 0 | 0 | 10 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

FLOWS (100'S AF/YR ) IN DIRECTION 2

| ROWS 5 | 4 | 3 | 2 | 1 | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 2 |
| 0 | 0 | 0 | 0 | 0 | 3 |
| 0 | 0 | 0 | 0 | 0 | 4 |
| 0 | 0 | 0 | 0 | 0 | 5 |
| 0 | 0 | 0 | 0 | 0 | 6 |
| 0 | 0 | 0 | 0 | 0 | 7 |
| 0 | 0 | 0 | 0 | 0 | 8 |
| 0 | 0 | 0 | 0 | 0 | 9 |
| 0 | 0 | 0 | 0 | 0 | 10 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

SATURATED THICKNESS AT END OF STEP 2

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 58.391 | 58.966 | 60.161 | 61.925 | 63.817 | 65.887 | 67.840 | 69.420 | 70.359 | 70.796 |
| 2 | 58.249 | 58.754 | 59.862 | 61.790 | 63.763 | 65.936 | 68.013 | 69.784 | 70.539 | 70.884 |
| 3 | 58.127 | 58.520 | 59.426 | 61.652 | 63.757 | 65.996 | 68.285 | 70.885 | 70.811 | 70.974 |
| 4 | 58.249 | 58.754 | 59.863 | 61.790 | 63.763 | 65.937 | 68.013 | 69.784 | 70.539 | 70.884 |
| 5 | 58.391 | 58.966 | 60.161 | 61.925 | 63.817 | 65.887 | 67.840 | 69.420 | 70.359 | 70.795 |

*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WATER SIMULATION PROGRAM ***

EXAMPLE PROBLEM HIGH PLAINS MODEL

SATURATED THICKNESS AT END OF TIME STEP 2

```
         COLUMN   1111111111
         1234567890

R   1    MMNNNOOOPP
O   2    MMMNNOOOPP
W   3    MMMNNOOPPP
    4    MMMNNOOOPP
    5    MMNNNOOOPP
```

FREQUENCY DISTRIBUTION

| SYMBOL | RANGE(FT) | FREQUENCY | PER CENT .LE. | VOLUME FEET**3 | AREA FEET**2 |
|---|---|---|---|---|---|
| A | ******** TO .000 | 0 | .0 | .00000000 | .00000000 |
| B | .000 TO 5.000 | 0 | .0 | .00000000 | .00000000 |
| C | 5.000 TO 10.000 | 0 | .0 | .00000000 | .00000000 |
| D | 10.000 TO 15.000 | 0 | .0 | .00000000 | .00000000 |
| E | 15.000 TO 20.000 | 0 | .0 | .00000000 | .00000000 |
| F | 20.000 TO 25.000 | 0 | .0 | .00000000 | .00000000 |
| G | 25.000 TO 30.000 | 0 | .0 | .00000000 | .00000000 |
| H | 30.000 TO 35.000 | 0 | .0 | .00000000 | .00000000 |
| I | 35.000 TO 40.000 | 0 | .0 | .00000000 | .00000000 |
| J | 40.000 TO 45.000 | 0 | .0 | .00000000 | .00000000 |
| K | 45.000 TO 50.000 | 0 | .0 | .00000000 | .00000000 |
| L | 50.000 TO 55.000 | 0 | .0 | .00000000 | .00000000 |
| M | 55.000 TO 60.000 | 13 | 26.0 | .85258678+08 | .14496768+08 |
| N | 60.000 TO 65.000 | 12 | 50.0 | .83452563+08 | .13381632+08 |
| O | 65.000 TO 70.000 | 14 | 78.0 | .10571973+09 | .15611904+08 |
| P | 70.000 TO 75.000 | 11 | 100.0 | .86738021+08 | .12266496+08 |
| Q | 75.000 TO 80.000 | 0 | 100.0 | .00000000 | .00000000 |
| R | 80.000 TO 85.000 | 0 | 100.0 | .00000000 | .00000000 |
| S | 85.000 TO 90.000 | 0 | 100.0 | .00000000 | .00000000 |
| T | 90.000 TO 95.000 | 0 | 100.0 | .00000000 | .00000000 |
| U | 95.000 TO 100.000 | 0 | 100.0 | .00000000 | .00000000 |
| V | 100.000 TO 105.000 | 0 | 100.0 | .00000000 | .00000000 |
| W | 105.000 TO 110.000 | 0 | 100.0 | .00000000 | .00000000 |
| X | 110.000 TO 115.000 | 0 | 100.0 | .00000000 | .00000000 |
| Y | 115.000 TO 120.000 | 0 | 100.0 | .00000000 | .00000000 |
| Z | 120.000 TO ******** | 0 | 100.0 | .00000000 | .00000000 |
| * | CONSTANT HEAD | | | | |
| | | | TOTAL | .36116899+09 | .55756800+08 |

*** JOB TERMINATED ***

## REFERENCES

Peaceman, D. W., and Rachford, H. H. Jr. (1955), "The Numerical Solution of Parabolic and Eliptic Differential Equations," "Journal Society of Industrial and Applied Mathematics," V. 3, pp 28 - 41.

Prickett, T. A., and Lonnquist, C. G. (1971), "Selected Digital Computer Techniques for Groundwater Resource Evaluation," Bulletin 55, Illinois State Water Survey, Urbana, Illinois.

Trescott, P. C., Pinder, G. F., and Larson, S. P., (1976) "Finite-Difference Model for Aquifer Simulation in Two-Dimensions with Results of Numerical Experiments," U. S. Geological Survey Techniques of Water-Resources Investigations, Book 7, Chapter C1. p. 20.

## APPENDIX

A. Program Description
B. Flow Chart of Main Program
C. Flow Chart of Pumpage Prediction Program
D. Glossary of Selected Program Variables
E. Listing of Computer Program

## APPENDIX A

### PROGRAM DESCRIPTION

A brief discussion of each segment of GWSIM-III is included in this appendix.

## PROGRAM DESCRIPTION

### MAIN PROGRAM

The main program reads basic data and calls various subroutines. All variables are modified and corrected as required, during each time step, in the main program. The majority of the arrays are dimensioned in the main program. If the finite difference grid contains more than 31 rows or 31 columns, the array declaration will have to be changed only in this segment.

### SUBROUTINE - CALIB

This subroutine adjusts the values of hydraulic conductivity and storage coefficient. Such changes may be necessary during the calibration phase of model construction. The routine may also produce printer maps illustrating the values of the two parameters. Hydraulic conductivity values are divided by 10 prior to printing, and storage coefficients are multiplied by 1000. Data Set 8 is read by the subroutine. The value of General Program Option 7 determines what maps will be printed. If the option is: equal to 1, no maps are printed; equal to 2, the hydraulic conductivity map is produced; equal to 3, the storage coefficient map is printed; and equal to 4, both maps are printed.

### SUBROUTINE - FLUX

This subroutine prints a map indicating the ground-water flows between nodes at the end of a time step. The maps are printed if either Time Step Options 12 or 17 is enabled. Both should not be enabled for the same time step. If maps are to be produced, the appropriate units conversion factor and label must be read in Data Set 2.

Two maps are produced. The first map shows flow between columns and is labeled 'Direction 1.' For cell i,j, the value printed is for flow from cell i,j to cell i,j+1. The second map, labeled 'Direction 2,' shows flow between rows. For cell i,j the flow is from cell i,j to cell i+1,j. A negative number represents a reversal of flow, i.e., from cell i,j+1 to cell i,j.

An example of a map produced by FLUX is shown in Figure 4.

### SUBROUTINE - GETPMP

This subroutine is called for each major time step, and it reads the pumpage and recharge data. The routine to calculate pumpage for the High Plains Model, HGHPMP, is called by this subroutine. The net withdrawal rate in Equation 3, $Q_{i,j}$, is calculated, and the units are cubic length per day.

### SUBROUTINE - HGHPMP

This routine calculates the pumpage for the High Plains Model. Pumpage data and constraint parameters are read, and results of the pumpage calculation are printed. Much of the data are stored on tape for use in later time steps.

SUBROUTINE - HYDRO

This subroutine produces a hydrograph of water levels for specified cells. The program plots water levels at the end of major time steps and measured water levels if available. There is no limit to the number of major time steps. The head at the end of twenty time steps will be plotted per page.

SUBROUTINE - OUTPUT

This subroutine prints most of the model results. The mass balances are also computed in this routine. Many of the plotting routines are called from OUTPUT. Example output is shown in Figure 4.

SUBROUTINE - PHYSDT

This routine reads the physical data describing the aquifer. Subroutine CALIB is called to adjust hydraulic conductivity and storage coefficient. The units of hydraulic conductivity are converted to length per day units, and storage coefficient is multiplied by the cell's dimensions.

SUBROUTINE - PLOTH

The routine produces print plots of head or saturated thickness. A letter will be printed for each active cell in the system to indicate that cell's value of the parameter. The range for each letter is printed with statistics to indicate the distribution of the parameter. An example of such a map is shown in Figure 4.

SUBROUTINE - PLOTS

This routine produces plots similar to those produced by Subroutine PLOTH. A map of simulated errors or head changes may be produced. Simulated error or difference is equal to the simulated head level minus observed head level. Statistics are printed which may be used to compare the head differences. The mean, standard deviation, maximum, and minimum values for the simulated head, observed head (if error map is produced) or beginning head (if head change map is produced), and difference in head are printed. The nodes with the maximum and minimum values are identified by row and column numbers. The mean and standard deviation of the absolute value of the head value is also printed. The covariance and regression coefficient are also printed, but these values have meaning only when an error map is produced. These two values are used to indicate the goodness-of-fit between the simulated and observed water level.

The subroutine only considers cells for which the observed head level is not zero. This allows the possibility of reading a set of observed head levels (Data Set 30) which contains known values only for cells that contain a measured well. Normally, Data Set 30 contains a measured value for all active cells, with most values obtained from a contour map.

SUBROUTINE - SOLVE

This routine solves the system of equations for the head using the iterative alternating direction implicit procedure. A user-supplied error criterion terminates the iteration sequence for each time step. At least four iterations are completed to insure stability.

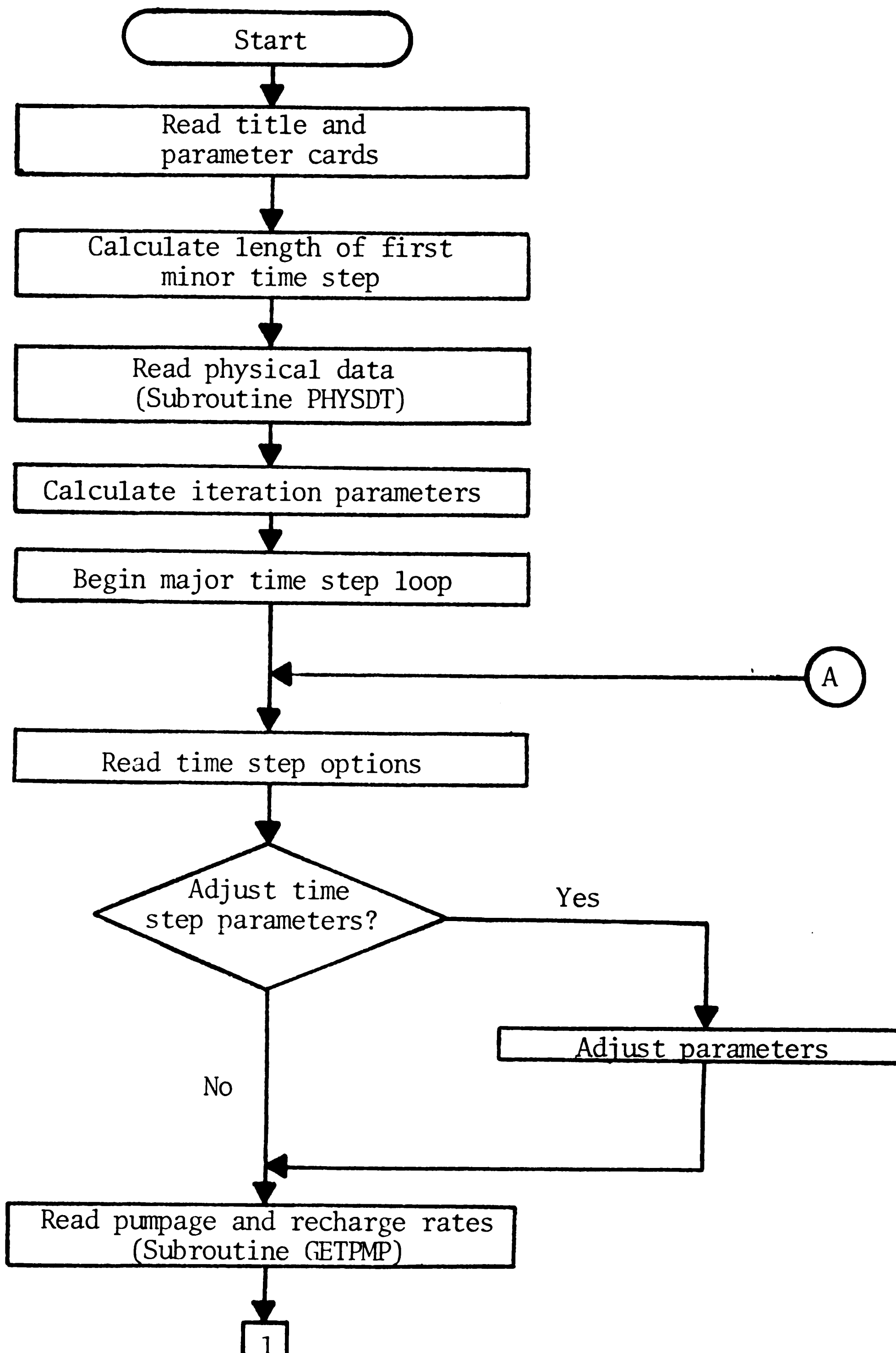
SUBROUTINE - XSECT

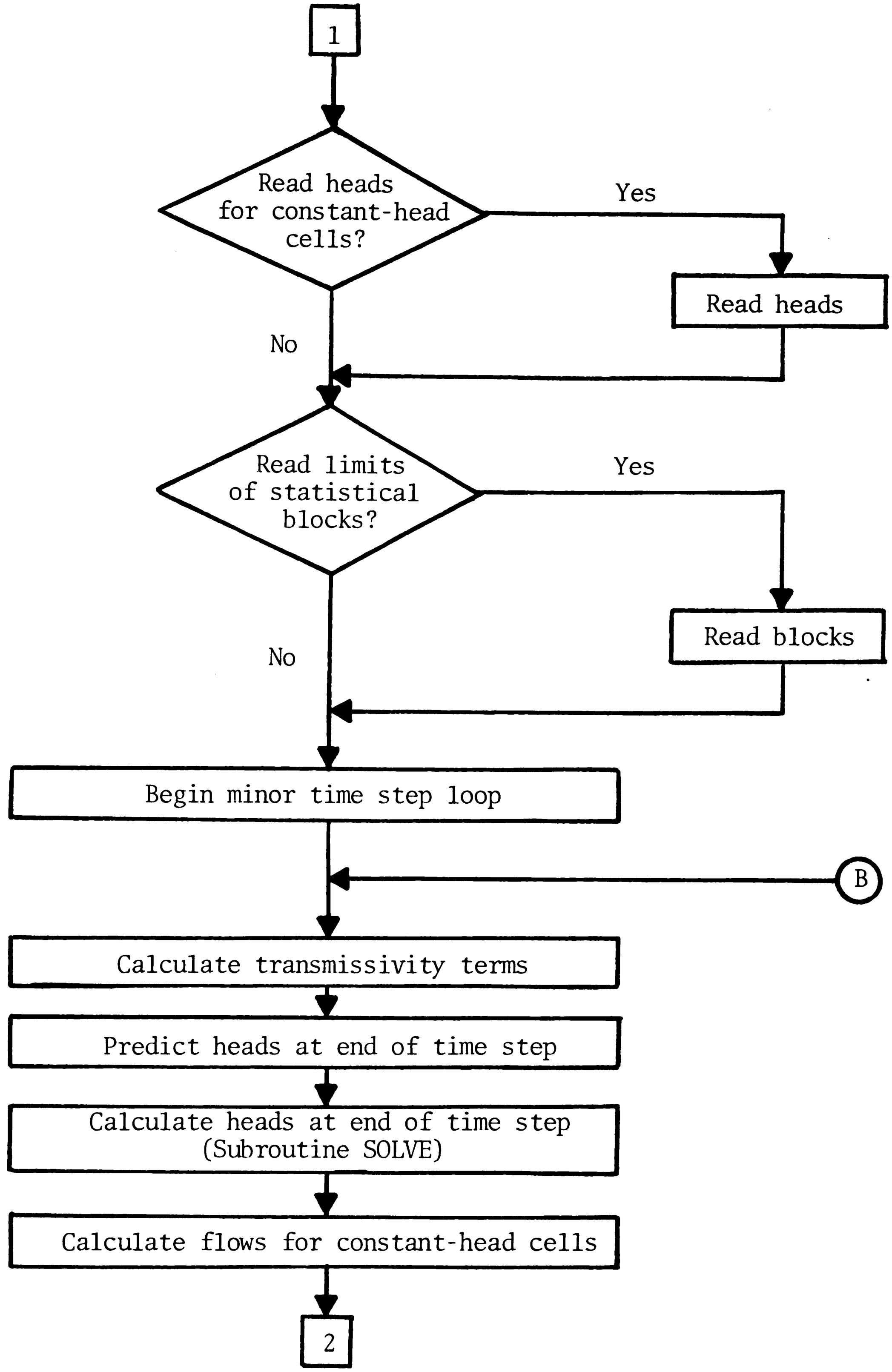
This subroutine produces a printer plot of a profile of the water level and base of aquifer data in the system. If measured water levels are available, these are also plotted. The profiles may be along rows and/or along columns. An example of such a profile is shown in Figure 4.

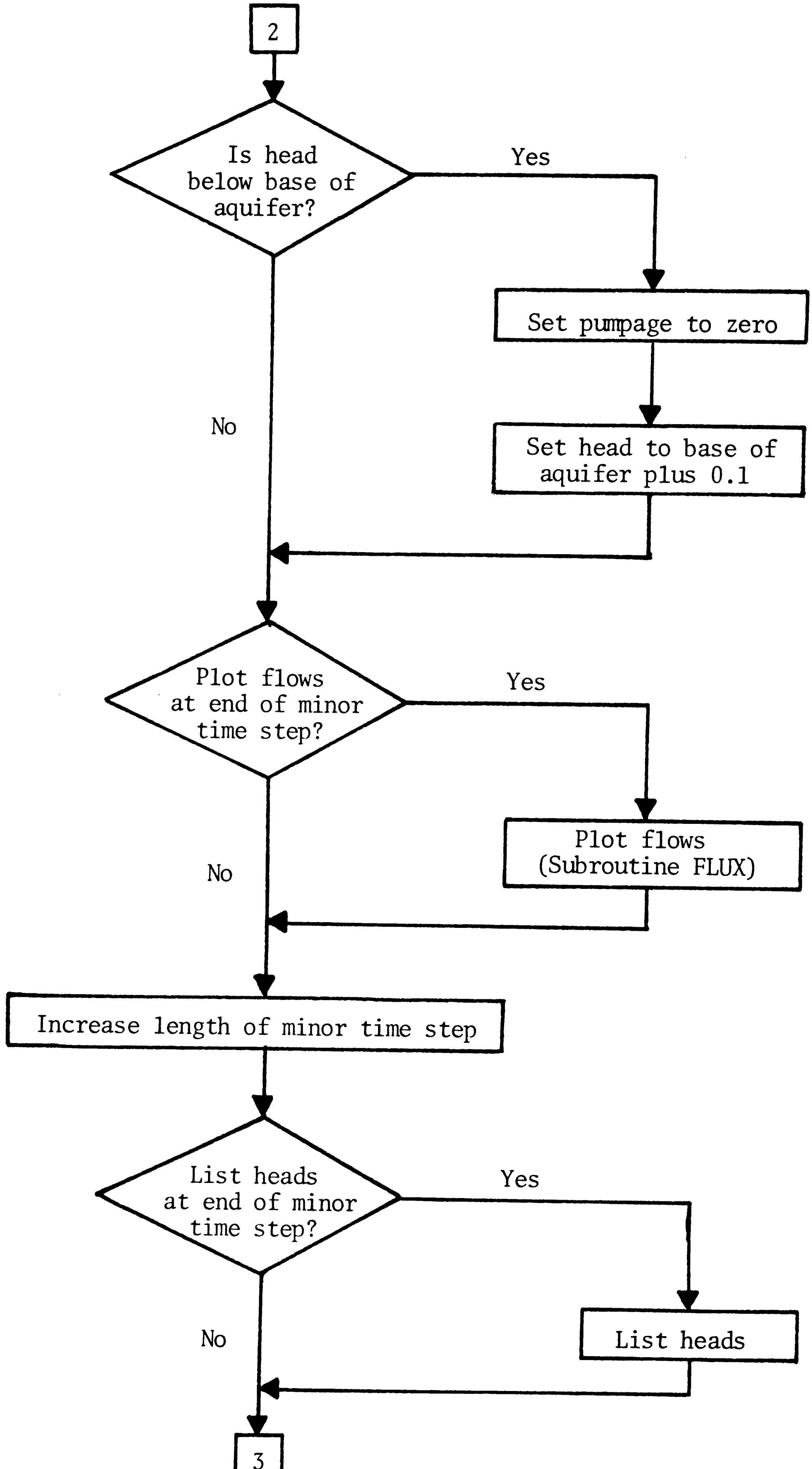
APPENDIX B

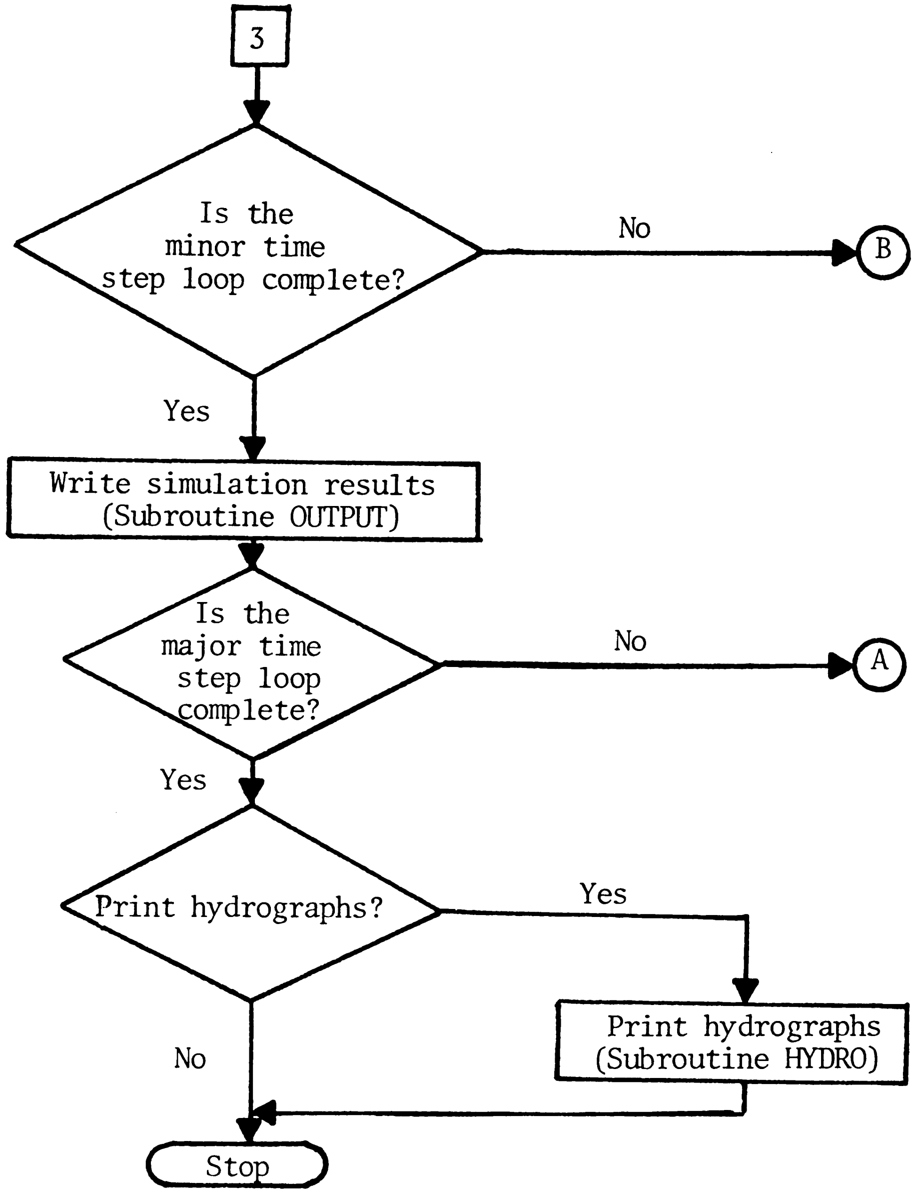
## FLOW CHART OF MAIN PROGRAM

An abbreviated flow chart of the main program of GWSIM-III is included in this appendix.




1
Read heads for constant-head cells?
Yes
Read heads
No
Read limits of statistical blocks?
Yes
Read blocks
No
Begin minor time step loop
B
Calculate transmissivity terms
Predict heads at end of time step
Calculate heads at end of time step (Subroutine SOLVE)
Calculate flows for constant-head cells
2

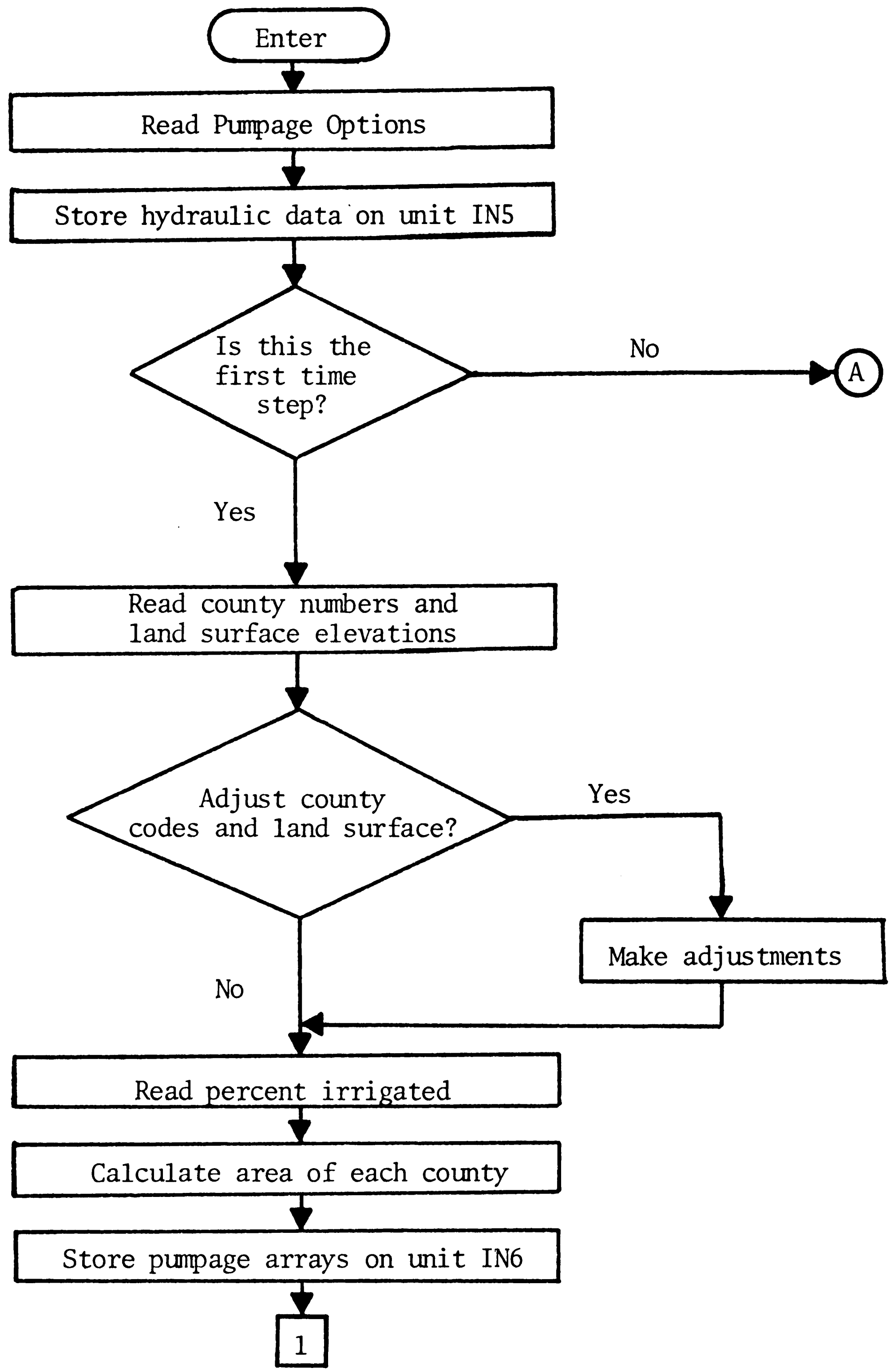

2
Is head below base of aquifer?
Yes
Set pumpage to zero
Set head to base of aquifer plus 0.1
No
Plot flows at end of minor time step?
Yes
Plot flows (Subroutine FLUX)
No
Increase length of minor time step
List heads at end of minor time step?
Yes
List heads
No
3

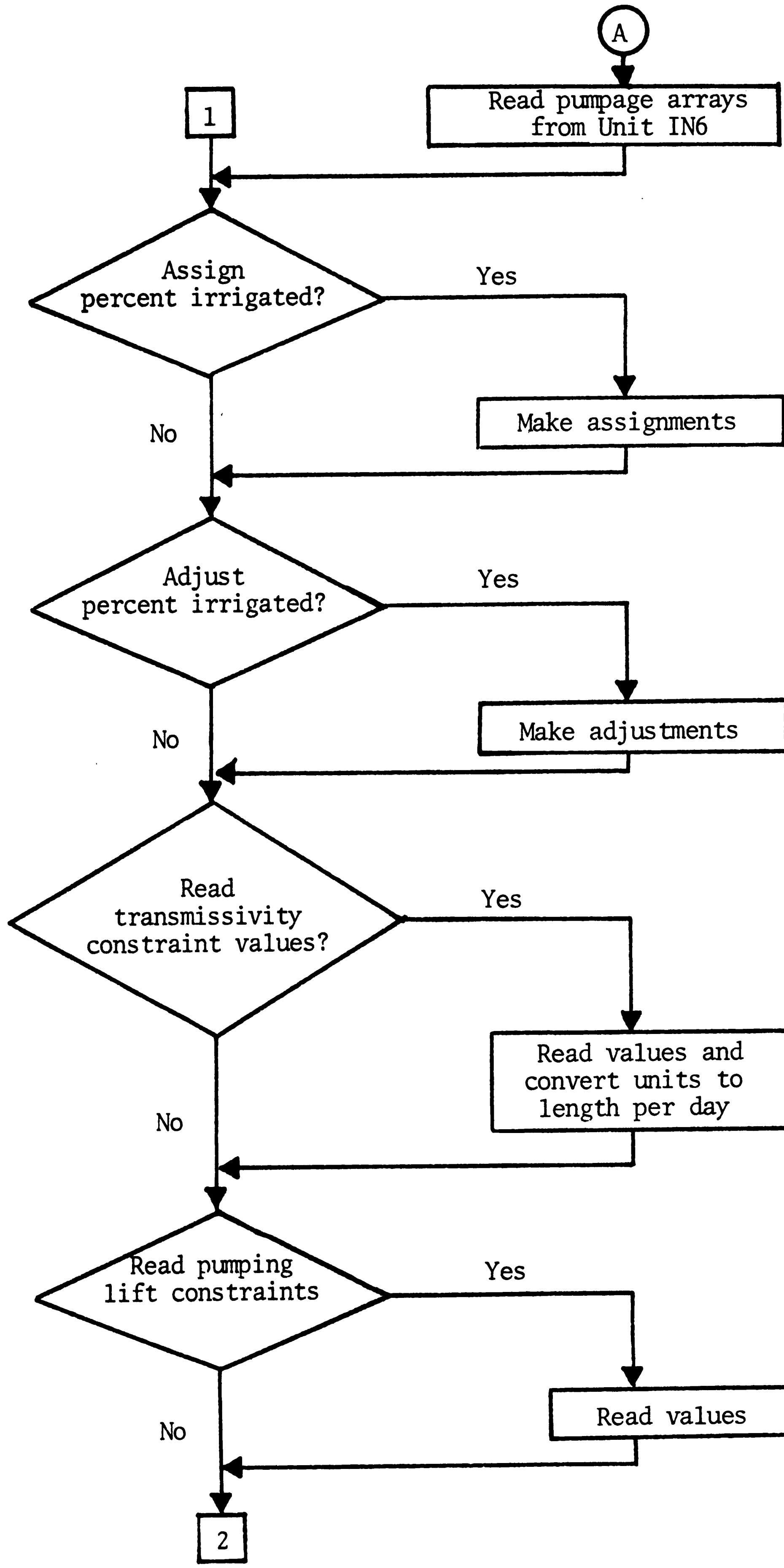

3
Is the minor time step loop complete?
No
B
Yes
Write simulation results (Subroutine OUTPUT)
Is the major time step loop complete?
No
A
Yes
Print hydrographs?
Yes
Print hydrographs (Subroutine HYDRO)
No
Stop

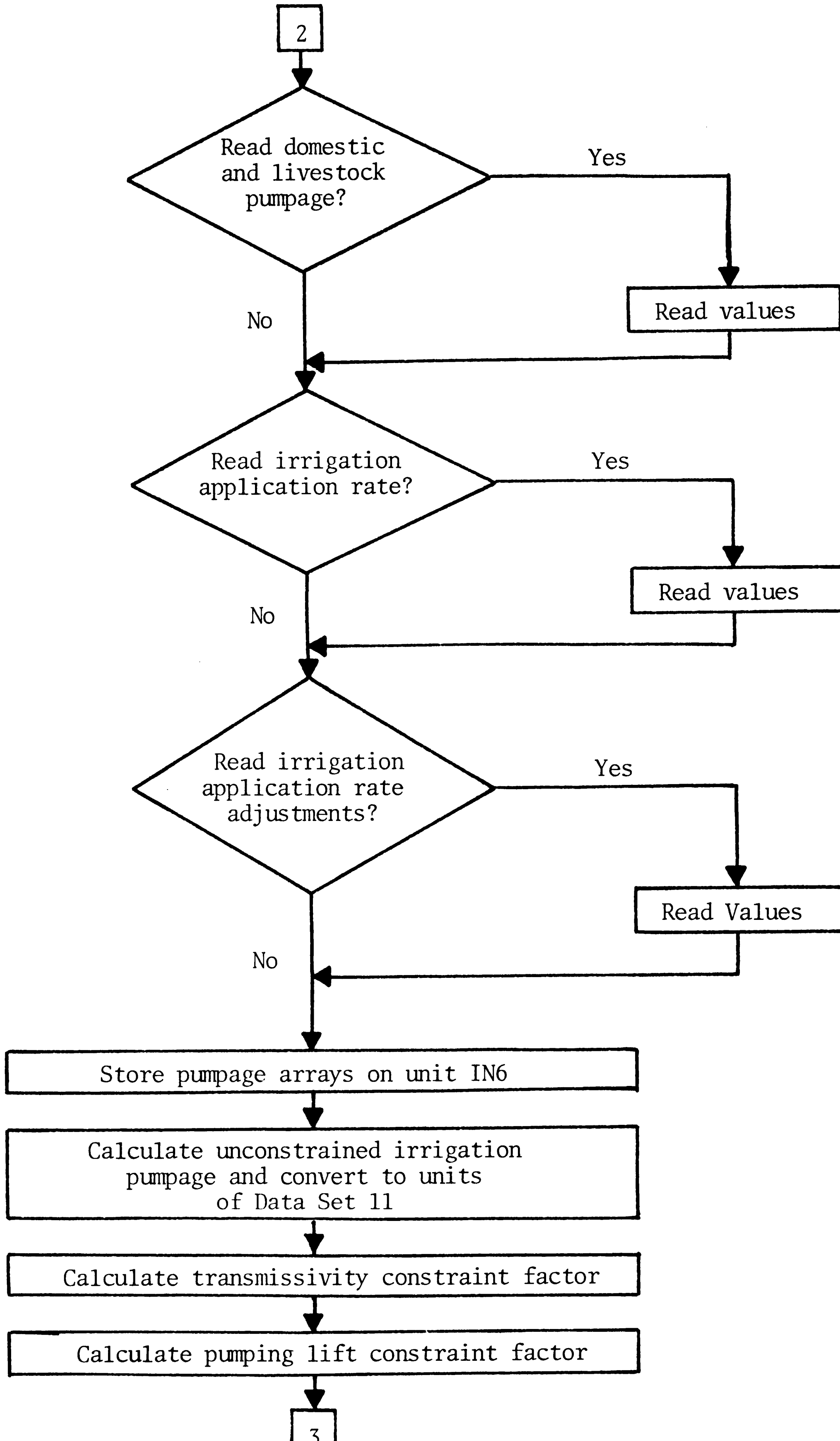
APPENDIX C

FLOW CHART OF PUMPAGE PREDICTION PROGRAM

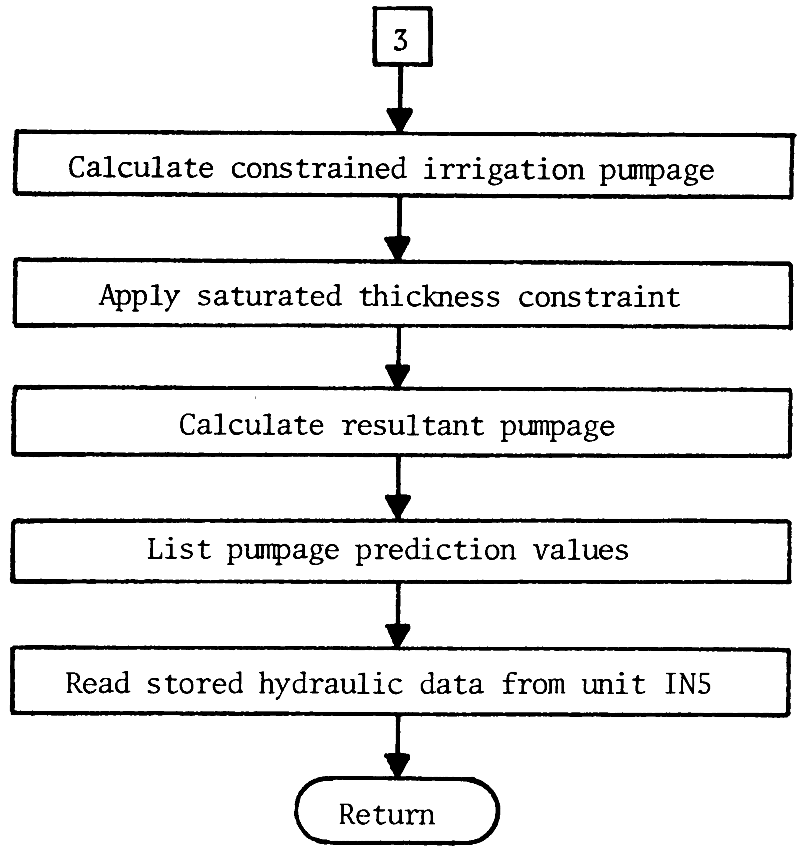
An abbreviated flow chart of the pumpage prediction program for the High Plains Model, HGHPMP, is included in this appendix.




A
Read pumpage arrays from Unit IN6
1
Assign percent irrigated?
Yes
Make assignments
No
Adjust percent irrigated?
Yes
Make adjustments
No
Read transmissivity constraint values?
Yes
Read values and convert units to length per day
No
Read pumping lift constraints
Yes
Read values
No
2



2
Read domestic and livestock pumpage?
Yes
Read values
No
Read irrigation application rate?
Yes
Read values
No
Read irrigation application rate adjustments?
Yes
Read Values
No
Store pumpage arrays on unit IN6
Calculate unconstrained irrigation pumpage and convert to units of Data Set 11
Calculate transmissivity constraint factor
Calculate pumping lift constraint factor
3


3
Calculate constrained irrigation pumpage
Apply saturated thickness constraint
Calculate resultant pumpage
List pumpage prediction values
Read stored hydraulic data from unit IN5
Return

APPENDIX D

## GLOSSARY OF SELECTED PROGRAM VARIABLES

A glossary of selected program variables used in GWSIM-III is included in this appendix.

## GLOSSARY OF SELECTED PROGRAM VARIABLES

| Variable Name | Definition |
|---|---|
| ACTY(K) | Modeled area of county K (L**2) |
| BOTLEL(I,J) | Elevation of bottom of aquifer for cell i,j (L) |
| DANDS(K) | Domestic and livestock pumpage for county K (L**3/step) |
| DELMAJ | Length of major time step in days (T) |
| DELTA | Length of minor time step in days (T) |
| DELX(J) | Grid spacings in x-direction (L) |
| DELY(I) | Grid spacings in y-direction (L) |
| DL(I,J) | Change in head during preceding time step for cell i,j (L) |
| ERROR | Minimum head change allowed for convergence of solution procedure (L) |
| FLAG(I,J) | Type declaration for cell i,j<br>Equal Zero -- Constant head<br>Equal One -- water table<br>Equal Three -- Boundary |
| FLXFCT | Factor to convert ground-water flows prior to printing |
| FLXNAM | Title to indicate units of printed ground-water flows |
| FMT | Variable format array |
| H(I,J) | Head at end of time step for cell i,j (L) |
| HO(I,J) | Head at beginning of time step for cell i,j (L) |
| I | Model row number |
| ICOUTY(K) | Number for County K |
| IN,IN1,IN2,IN3, IN4,IN5,IN6 | Input unit numbers |

| | |
|---|---|
| IOPT | Pumpage option array |
| ISAVE | Storage array for row numbers of hydrograph cells |
| ISTEP | Major time step number |
| ITER | Number of iterations by IADI procedure |
| J | Model column number |
| JSAVE | Storage array for column number of hydrograph cells |
| KHYD | Switch variable to cause printing of hydrographs |
| MCOLS | Storage array for column numbers for cross-section procedure |
| MINOR | Minor time step number |
| MROWS | Storage array for row numbers for cross-section procedure |
| NBLK | Number of statistical blocks |
| NC | Number of columns in model |
| NCOLS | Number of columns for which cross sections are desired |
| NPARM | Number of iteration parameters |
| NR | Number of rows in model |
| NROWS | Number of rows for which cross sections are desired |
| NSAVE | Number of nodes for which hydrographs are desired |
| NSP | Number of minor time steps per major time step |
| NSTEPS | Number of major time steps |
| OPT | General program and time step options array |
| OUT,OUT1 | Output unit numbers |

| | |
|---|---|
| P(I,J) | Hydraulic conductivity for cell i,j (L/T) |
| PCTIRR(I,J) | Percent of cell i,j that is irrigated |
| PERFCT | Factor to convert input values of hydraulic conductivity to interal units of length per day |
| PLS(K) | Pumping lift constraint parameter for county K which indicates the amount of reduction in pumpage per unit increase in lift. |
| PLT(K) | Pumping lift constraint parameter for county K which indicates the smallest lift for which the constraint applies (L) |
| PMPFCT | Factor to convert input values of pumpage and recharge rates to interal units of cubic length per day |
| PMPNAM | Title to indicate units on pumpage and recharge input rates |
| PRMITR | Iteration parameters |
| Q(I,J) | Pumpage rate for cell i,j (L**3/T) |
| R(I,J) | Irrigation application rate for cell i,j (L) |
| RHG(I,J) | Recharge rate for cell i,j (L**3/T) |
| SF1(I,J) | Storage coefficient for cell i,j |
| SURFAC(I,J) | Land surface elevation for cell i,j (L) |
| T(I,J,1) | Transmissivity term between cell i,j and cell i,j+1 (L**2/T) |
| T(I,J,2) | Transmissivity term between cell i,j and cell i+1,j (L**2/T) |
| TIMACL | Time step acceleration factor |
| TONE(I,J) | Transmissivity constraint value for cell i,j which indicates the largest transmissivity value when the constraint applies (L**2/T) |

| | |
|---|---|
| TTWO(I,J) | Transmissivity constraint value for cell i,j which indicates the transmissivity value that results in a 90 percent pumpage reduction (L**2/T) |
| XLGTNM | Title to indicate length unit |

# APPENDIX E

## LISTING OF COMPUTER PROGRAM

A listing of the computer program for GWSIM-III is included in this appendix.

```
C                    PROGRAM GWSIM - III
C               GROUND WATER SIMULATION PROGRAM
C              TEXAS DEPARTMENT OF WATER RESOURCES
C
C                             BY
C                        TOMMY KNOWLES
C              DATA COLLECTION AND EVALUATION SECTION
C              DATA AND ENGINEERING SERVICES DIVISION
C*************************************************************************
      COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
     4,NBLK,IRWC(4,60)
      COMMON /BLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),P
     1(100),G(100),SUMS(10,2),
     2                         ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
      INTEGER OPT,FLAG,OUT,OUT1
C*************************************************************************
C     THE FOLLOWING CARDS MUST BE CHANGED IF THE FINITE DIFFERENCE GRID
C     CONTAINS MORE THAN 31 ROWS OR 31 COLUMNS
C*************************************************************************
      PARAMETER NROW=31,NCOL=31
      DIMENSION FLAG(NROW,NCOL),BOTLEL(NROW,NCOL),H(NROW,NCOL),
     1HO(NROW,NCOL),P(NROW,NCOL),SF1(NROW,NCOL),T(NROW,NCOL,2),
     2(NROW,NCOL),RHE(NROW,NCOL),DL(NROW,NCOL)
C*************************************************************************
      DIMENSION DUM1(2), DUM2(2)
      EQUIVALENCE (DUM1(2),P(1)), (DUM2(2),G(1))
      DUM1(1)=0.0
      DUM2(1)=0.0
C*************************************************************************
C     DEFINE INPUT AND OUTPUT DEVICE NUMBERS
C*************************************************************************
      IN=5
      IN1=11
      IN2=12
      IN3=13
      IN4=14
      IN5=15
      IN6=16
      OUT=6
      OUT1=10
C*************************************************************************
C     READ TITLE CARD AND
C     READ PARAMETER CARD
C*************************************************************************
      READ (IN,530) TITLE
      WRITE (OUT,580) TITLE
      READ (IN,400) NSTEPS,NSP,NR,NC,NPARM
      READ (IN,410) DELMAJ,ERROR,TIMACL,PMPFCT,PMPNAM,XLGTNM,FLXNAM,PERF
     1CT,FLXFCT
C*************************************************************************
C     CALCULATE SIZE OF FIRST MINOR TIME STEP
C*************************************************************************
      DELTA=1.0
      N=NSP
10    N=N-1
      IF (N) 30,30,20
20    DELTA=DELTA+TIMACL**N
      GO TO 10
30    DELTA=DELMAJ/DELTA
      WRITE (OUT,540) NSTEPS,NSP,DELMAJ,DELTA,ERROR,NC,NR,NPARM,TIMACL,P
     1MPFCT,PMPNAM,PERFCT,FLXFCT,FLXNAM,XLGTNM
C*************************************************************************
C      READ PHYSICAL DATA
C*************************************************************************
      CALL PHYSDT (NROW,NCOL,FLAG,BOTLEL,H,HO,P,SF1,T)
40    TIME=0.0
      NBLK=1
      IRWC(1,1)=1
      IRWC(2,1)=NR
      IRWC(3,1)=1
      IRWC(4,1)=NC
      TIMAC2=TIMACL
      DELMJ2=DELMAJ
      DEL=DELTA
C*************************************************************************
C      CALCULATE ITERATION PARAMETERS
C*************************************************************************
      HA=2.
      HC=3.14159*3.14159/(2*NR*NR)
      HE=3.14159*3.14159/(2*NC*NC)
      DO 50 I=1,NR
      DO 50 J=1,NC
      IF (FLAG(I,J).GT.2) GO TO 50
      HF=DELX(J)*DELX(J)/(DELY(I)*DELY(I))
      HD=HE/(1.+HF)
      F=HC/(1.+1./HF)
      HA=AMIN1(HA,HD,F)
50    CONTINUE
      F=EXP(ALOG(1./HA)/(NPARM-1))
      PRMITR(1)=HA
      DO 60 I=2,NPARM
60    PRMITR(I)=PRMITR(I-1)*F
      WRITE (OUT,390) (PRMITR(I),I=1,NPARM)
      TIME1=0.
C*************************************************************************
C     BEGIN MAJOR TIME STEP LOOP
C*************************************************************************
      DO 370 ISTEP=1,NSTEPS
      WRITE (OUT,580) TITLE
      WRITE (OUT,590) ISTEP
      DELTA=DEL
      NSP1=NSP
      DELMAJ=DELMJ2
      TIMACL=TIMAC2
C*************************************************************************
C     READ OPTIONS FOR THIS TIME STEP
C*************************************************************************
      READ (IN,550) OPT,NSP2,DELMJ1,TIMAC1
      DO 70 I=1,30
      IF (OPT(I).GT.0) WRITE (OUT,430) I,OPT(I)
      IF (OPT(I).GT.0.AND.I.EQ.1) WRITE (OUT,560) NSP2,DELMJ1,TIMAC1
70    CONTINUE
80    CONTINUE
      NSP1=NSP
      IF (OPT(1).LT.1) GO TO 120
C*************************************************************************
C      ADJUST TIME STEP PARAMETERS
C*************************************************************************
      TIMACL=TIMAC1
      DELTA=1.
      N=NSP2
90    N=N-1
      IF (N) 110,110,100
100   DELTA=DELTA+TIMACL**N
      GO TO 90
110   DELTA=DELMJ1/DELTA
      NSP1=NSP2
      DELMAJ=DELMJ1
120   CONTINUE
      DO 130 I=1,10
      SUMS(I,1)=0.
      IF(ISTEP.EQ.1)SUMS(I,2)=0.
130   CONTINUE
C*************************************************************************
C       READ EXTERNAL FLUX (PUMPAGE AND RECHARGE)
C*************************************************************************
      CALL GETEMP (NROW,NCOL,FLAG,BOTLEL,H,HO,P,T,DL,Q,RHG,SF1)
```

```
C*************************************************************************
C      READ ENDING HEADS FOR CONSTANT-HEAD CELLS
C*************************************************************************
      IF (OPT(24).LT.1) GO TO 180
      READ (IN,530) FMT
      IF (OPT(24).GT.2) GO TO 160
      DO 150 I=1,NR
      READ (IN,FMT) (B(J),J=1,NC)
      DO 150 J=1,NC
      IF (FLAG(I,J)) 140,140,150
140   DL(I,J)=(B(J)-H(I,J))/DELMAJ
      IF(OPT(24).EQ.2)DL(I,J)=B(J)/DELMAJ
150   CONTINUE
      GO TO 180
160   READ (IN,FMT) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 180
      DO 170 I=II,III
      DO 170 J=JJ,JJJ
      HB=HA-H(I,J)
      IF(OPT(24).EQ.4)HB=HA
170   DL(I,J)=HB/DELMAJ
      GO TO 160
180   CONTINUE
C*************************************************************************
C      READ LIMITS OF STATISTICAL GRID BLOCKS
C*************************************************************************
      IF (OPT(27).LT.1) GO TO 200
      READ (IN,530) FMT
190   NBLK=NBLK+1
      READ (IN,FMT) (IRWC(J,NBLK),J=1,4)
      IF (IRWC(1,NBLK).GT.0) GO TO 190
      NBLK=NBLK-1
200   CONTINUE
C*************************************************************************
C      SAVE HEADS AT BEGINNING OF TIME STEP
C*************************************************************************
      REWIND IN4
      WRITE (IN4) H
C*************************************************************************
C      BEGIN MINOR TIME STEP LOOP
C*************************************************************************
      DO 350 MINOR=1,NSP1
      TIME=TIME+DELTA
C*************************************************************************
C       CALCULATE TRANSMISSIVITIES
C*************************************************************************
      DO 220 I=1,NR
      DO 220 J=1,NC
      T1=P(I,J)*(H(I,J)-BOTLEL(I,J))
      T(I,J,1)=0.
      IF (J.EQ.NC) GO TO 210
      IF (FLAG(I,J).EQ.0.AND.FLAG(I,J+1).EQ.0) GO TO 210
      T2=P(I,J+1)*(H(I,J+1)-BOTLEL(I,J+1))
      IF ((T1+T2).LT.0.001) GO TO 210
      T(I,J,1)=2.*T1*T2*DELY(I)/(T1*DELX(J+1)+T2*DELX(J))
210   T(I,J,2)=0.
      IF (I.EQ.NR) GO TO 220
      IF (FLAG(I,J).EQ.0.AND.FLAG(I+1,J).EQ.0) GO TO 220
      T2=P(I+1,J)*(H(I+1,J)-BOTLEL(I+1,J))
      IF ((T1+T2).LT.0.001) GO TO 220
      T(I,J,2)=2.*T1*T2*DELX(J)/(T1*DELY(I+1)+T2*DELY(I))
220   CONTINUE
230   CONTINUE
C*************************************************************************
C      PREDICT HEAD FOR NEXT TIME STEP
C*************************************************************************
      DO 270 J=1,NC
      DO 270 I=1,NR
      D=H(I,J)-HO(I,J)
      HO(I,J)=H(I,J)
      IF (FLAG(I,J)) 240,240,250
240   H(I,J)=H(I,J)+DELTA*DL(I,J)
      IF(H(I,J).LT.BOTLEL(I,J))H(I,J)=BOTLEL(I,J)+0.1
      GO TO 270
250   CONTINUE
      IF (FLAG(I,J).GT.2) GO TO 270
      F=0.0
      IF (ABS(DL(I,J)).LT.1.E-4) GO TO 260
      IF(MINOR.GT.2)F=D/DL(I,J)
      IF(F.GT.5.0)F=5.0
      IF(F.LT.0.0)F=0.0
260   DL(I,J)=D
      H(I,J)=H(I,J)+D*F
270   CONTINUE
C*************************************************************************
C      REFINE ESTIMATES OF HEADS BY IADI METHOD
C
C       CALL SUBROUTINE SOLVE TO PERFORM THE IADI PROCEDURE
C*************************************************************************
      CALL SOLVE (NROW,NCOL,FLAG,H,HO,T,SF1,Q)
280   CONTINUE
      TIM=TIME/DELMJ2
290   CONTINUE
      WRITE (OUT,440) TIME,TIM,E,ITER
      DO 330 J=1,NC
      DO 330 I=1,NR
      SUMCHD=0.
      IFL=FLAG(I,J)+1
      GO TO (300,310,310,330), IFL
C*************************************************************************
C      DETERMINE FLOWS WITH CONSTANT HEAD CELLS
C*************************************************************************
300   IF(I.GT.1)SUMCHD=SUMCHD-T(I-1,J,2)*(H(I-1,J)-H(I,J))*DELTA
      IF(I.LT.NR)SUMCHD=SUMCHD+T(I,J,2)*(H(I,J)-H(I+1,J))*DELTA
      IF(J.GT.1)SUMCHD=SUMCHD-T(I,J-1,1)*(H(I,J-1)-H(I,J))*DELTA
      IF(J.LT.NC)SUMCHD=SUMCHD+T(I,J,1)*(H(I,J)-H(I,J+1))*DELTA
      IF(SUMCHD.GT.0.)SUMS(6,1)=SUMS(6,1)+SUMCHD
      IF(SUMCHD.LT.0.)SUMS(5,1)=SUMS(5,1)-SUMCHD
      GO TO 330
310   CONTINUE
      HA=(H(I,J)-HO(I,J))*SF1(I,J)
      IF(HA.LT.0.)SUMS(8,1)=SUMS(8,1)-HA
      IF(HA.GT.0.)SUMS(7,1)=SUMS(7,1)+HA
C*************************************************************************
C      IF H IS BELOW BOTTOM ELEVATION, REDUCE PUMPAGE, IF POSSIBLE.
C*************************************************************************
      IF (H(I,J).GT.BOTLEL(I,J)) GO TO 330
      HA=Q(I,J)+RHG(I,J)*PMPFCT
      Q(I,J)=-RHG(I,J)*PMPFCT
      IF(HA.LT.1.)HA=0.
      SUMS(9,1)=SUMS(9,1)+HA*(DELMAJ-TIME+TIME1)
C*************************************************************************
C       SET MINIMUM THICKNESS TO 0.1
C*************************************************************************
      H(I,J)=BOTLEL(I,J)+0.1
      WRITE (OUT,570) I,J,HA,XLCTNM
320   CONTINUE
330   CONTINUE
C*************************************************************************
C      PRINT MAP OF FLOWS - MINOR TIME STEP
C*************************************************************************
      IF (OPT(12).GT.0) CALL FLUX (NROW,NCOL,H,T)
C*************************************************************************
C      INCREASE SIZE OF TIME STEP
C*************************************************************************
      DELTA=DELTA*TIMACL
      IF (OPT(17).LT.1) GO TO 350
C*************************************************************************
C      WRITE WATER LEVELS AT END OF MINOR TIME STEP.
C*************************************************************************
      WRITE (OUT,580) TITLE
      WRITE (OUT,610) TIME
```

```
      DO 340 I=1,NR
340   WRITE (OUT,460) I,(H(I,J),J=1,NC)
C**********************************************************************
C     END MINOR TIME STEP LOOP
C**********************************************************************
350   CONTINUE
      TIME1=TIME
360   CONTINUE
C**********************************************************************
C      WRITE RESULTS
C**********************************************************************
      CALL OUTPUT (NROW,NCOL,FLAG,H,HO,P,BOTLEL,SF1,T)
C**********************************************************************
C     END MAJOR TIME STEP LOOP.
C**********************************************************************
370   CONTINUE
C**********************************************************************
C     PRINT HYDROGRAPHS
C**********************************************************************
      IF (KHYD.GT.0) CALL HYDRO (NROW,NCOL,FLAG,H,HO,T)
380   WRITE (OUT,600)
      STOP
C**********************************************************************
C
C
C
C
390   FORMAT (//T20,'ITERATION PARAMETERS'//(T25,5F10.5))
400   FORMAT (10I5)
410   FORMAT (4F10.0,4A6)
420   FORMAT (20I1)
430   FORMAT (T20,'TIME STEP OPTION',I5,' EQUALS',I5)
440   FORMAT (7H TIME =,E12.6,' DAYS OR ',F5.2,' MAJOR TIME STEPS,',' HE
     1AD CHANGE SUM = ',F8.2,' FEET, ITERATIONS =',I5)
450   FORMAT (1H1)
460   FORMAT (1H0,I4,5X,10F10.3/(10X,10F10.3))
470   FORMAT (20A4)
480   FORMAT (14H1ERROR MESSAGE,I5,/,15H0LAST CARD READ,/,5X,1H/,20A4,1H
     1/)
490   FORMAT (1H0,T4,'NODE',T12,'ROW',T18,'COL',T24,'FLAG',T33,'SURFAC',
     1T45,'TOP',1X,'OF',T54,'BOTTOM',T65,'THIK-',T75,'INIT-',T85,'PERM',
     2T95,'PERM',T103,'STORAGE'/T4,'TYPE',T32,'ELEVATION',T44,'AQUIFER',
     3T53,'ELEVATION',T65,'NESS',T75,'HEAD',T85,'X-DIR',T95,'Y-DIR',T104
     4,'COEF'/1X,28(4H----))
500   FORMAT (1X,2A4,I4,2I6,3X,5F10.2,2F10.0,E10.4)
510   FORMAT (5H NODE,2I3,37H CHANGED TO OUTCROP FOR HEAD EQUAL TOF10.3)
520   FORMAT (26I3)
530   FORMAT (20A4)
540   FORMAT (T20,'NUMBER OF MAJOR TIME STEPS',T65,I5,/T20,'NUMBER OF MI
     1NOR TIME STEPS',T65,I5/T20,'SIZE OF MAJOR TIME STEPS',T60,F10.3,5X
     2,'DAYS'/T20,'SIZE OF FIRST MINOR TIME STEP',T60,F10.3,5X,'DAYS'/T2
     30,'ERROR CRITERIA',T60,F10.2/T20,'NUMBER OF COLUMNS',T65,I5,/T20,'
     4NUMBER OF ROWS',T65,I5/T20,'NUMBER OF ITERATION PARAMETERS',T65,I5
     5/T20,'TIME ACCELERATION FACTOR',T60,F10.3/T20,'FLUX CONVERSION FAC
     6TOR',T50,E20.8/T20,'EXTERNAL FLUX UNITS',T64,A6/T20,'PERMEABILITY
     7CONVERSION UNITS',T60,F10.6/T20,'PLOTTED FLOWS FACTOR',T50,E20.8/T
     820,'PLOT FLOWS UNITS NAME',T58,2A6/T20,'LENGTH UNIT NAME',T64,A6/)
550   FORMAT (30I1,I5,2F10.0)
560   FORMAT (T35,'NUMBER OF MINOR TIME STEPS',T80,I5/T35,'LENGTH OF MAJ
     1OR TIME STEP',T75,F10.2/T35,'TIME ACCELERATION FACTOR',T75,F10.7)
570   FORMAT (T5,' NODE',2I3,' DEWATERED, PUMPAGE REDUCED',E20.8,A6,'**3
     1/DAY')
580   FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
590   FORMAT (1H0,50X,'SIMULATING TIME STEP',I5)
600   FORMAT (1H0,'*** JOB TERMINATED ***')
610   FORMAT (' SIMULATED HEADS AT END OF',F10.3,' DAYS')
      END
```

```
      SUBROUTINE HGHPMP (NROW,NCOL,FLAG,H,BOTLEL,Q,P,SURFAC,ICOUTY,R,PCT
     1IRR,TONE,TTWO)
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
     4,NBLK,IRWC(4,60)
       COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),B
     1(100),G(100),SUPS(10,2),
     2                                  ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION FLAG(NROW,NCOL),H(NROW,NCOL),BOTLEL(NROW,NCOL),
     1Q(NROW,NCOL),SURFAC(NROW,NCOL),ICOUTY(NROW,NCOL),P(NROW,NCOL),
     2R(NROW,NCOL),PCTIRR(NROW,NCOL)
     3,TONE(NROW,NCOL),TTWO(NROW,NCOL),PLT(60),PLS(60),DANDS(60),
     4ACTY(60),SUMP(61,11)
     5,IOPT(20)
C**********************************************************************
C      READ OPTIONS FOR PUMPAGE PREDICTION
C**********************************************************************
      READ (IN,810) IOPT
      DO 10 I=1,20
10    IF (IOPT(I).GT.0) WRITE (OUT,820) I,IOPT(I)
C**********************************************************************
C      SAVE DATA ON UNIT IN5
C**********************************************************************
      REWIND IN5
      WRITE (IN5) ICOUTY,R,SURFAC,PCTIRR,TONE,TTWO
      IF (ISTEP.GT.1) GO TO 110
C**********************************************************************
C      READ COUNTY CODE AND LAND SURFACE ELEVATION
C**********************************************************************
      IF (IOPT(1).LT.1) GO TO 30
      READ (IN,830) K,HA
      WRITE (OUT,840) K,HA
      DO 20 I=1,NR
      DO 20 J=1,NC
      IF (FLAG(I,J).GT.2) GO TO 20
      ICOUTY(I,J)=K
      SURFAC(I,J)=HA
20    CONTINUE
      GO TO 60
30    READ (IN,850) FMT
      DO 40 I=1,NR
40    READ (IN,FMT) (ICOUTY(I,J),J=1,NC)
      READ (IN,850) FMT
      DO 50 I=1,NR
50    READ (IN,FMT) (SURFAC(I,J),J=1,NC)
C**********************************************************************
C      MAKE BLOCK ADJUSTMENTS
C**********************************************************************
60    IF (IOPT(2).LT.1) GO TO 110
      WRITE (OUT,860)
70    READ (IN,1020) II,III,JJ,JJJ,K,HA
      IF (II.LT.1) GO TO 110
      WRITE (OUT,870) II,III,JJ,JJJ,K,HA
      DO 100 I=II,III
      DO 100 J=JJ,JJJ
      IF (FLAG(I,J).GT.2) GO TO 100
      GO TO (80,90), K
80    ICOUTY(I,J)=HA+0.5
      GO TO 100
90    SURFAC(I,J)=HA
100   CONTINUE
      GO TO 70
110   CONTINUE
C**********************************************************************
C      CALCULATE VOLUME IN COUNTY
C**********************************************************************
```

```
      IF (ISTEP.EQ.1) GO TO 120
      REWIND IN6
      READ (IN6) ICOUTY
120   CONTINUE
      DO 130 K=1,60
130   SUMP(K,11)=0.0
      DO 140 I=1,NR
      DO 140 J=1,NC
      K=ICOUTY(I,J)
      IF (FLAG(I,J).NE.1) GO TO 140
      SUMP(K,11)=SUMP(K,11)+(H(I,J)-BOTLEL(I,J))*TONE(I,J)
140   CONTINUE
C**********************************************************************
C       READ PERCENT IRRIGATED
C**********************************************************************
      IF (IOPT(3).LT.1) GO TO 180
      IF (IOPT(3).EQ.1) GO TO 160
      READ (IN,880) HA
      WRITE (OUT,890) HA
      DO 150 I=1,NR
      DO 150 J=1,NC
      IF (FLAG(I,J).GT.2) GO TO 150
      PCTIRR(I,J)=HA
150   CONTINUE
      GO TO 180
160   READ (IN,850) FMT
      DO 170 I=1,NR
170   READ (IN,FMT) (PCTIRR(I,J),J=1,NC)
180   CONTINUE
      IF (ISTEP.GT.1) GO TO 280
C**********************************************************************
C       LIST BASIC DATA
C**********************************************************************
      IF (IOPT(4).NE.1) GO TO 210
      WRITE (OUT,900) TITLE
      WRITE (OUT,910)
      DO 190 I=1,NR
190   WRITE (OUT,920) I,(ICOUTY(I,J),J=1,NC)
      WRITE (OUT,900) TITLE
      WRITE (OUT,930)
      DO 200 I=1,NR
200   WRITE (OUT,940) I,(SURFAC(I,J),J=1,NC)
210   CONTINUE
C**********************************************************************
C       DETERMINE AREAS OF COUNTIES
C**********************************************************************
      DO 220 K=1,60
220   ACTY(K)=0.
      DO 230 I=1,NR
      DO 230 J=1,NC
      IF (FLAG(I,J).GT.2) GO TO 230
      IFL=ICOUTY(I,J)
      IF (IFL.LT.1.OR.IFL.GT.60) WRITE (OUT,960) I,J,IFL
      ACTY(IFL)=DELX(J)*DELY(I)+ACTY(IFL)
230   CONTINUE
      IF (IOPT(12).LT.1) GO TO 250
C**********************************************************************
C       WRITE COUNTY AREAS
C**********************************************************************
      WRITE (OUT,970)
      HA=0.
      DO 240 K=1,60
      HA=HA+ACTY(K)
240   IF (ACTY(K).GT.1.) WRITE (OUT,980) K,ACTY(K)
      WRITE (OUT,770) HA
250   CONTINUE
      DO 260 K=1,60
      PLT(K)=1.E6
      PLS(K)=0.
      DANDS(K)=0.
260   CONTINUE
      DO 270 I=1,NR
      DO 270 J=1,NC
270   TONE(I,J)=0.0
C**********************************************************************
C       WRITE DATA ON TAPE
C**********************************************************************
      REWIND IN6
      WRITE (IN6) ICOUTY,PCTIRR,SURFAC,R,TONE,TTWO,PLT,PLS,DANDS,ACTY
      GO TO 290
C**********************************************************************
C       READ DATA FROM TAPE
C**********************************************************************
280   REWIND IN6
      READ (IN6) ICOUTY,PCTIRR,SURFAC,R,TONE,TTWO,PLT,PLS,DANDS,ACTY
290   CONTINUE
C**********************************************************************
C       BLOCK ASSIGNMENTS OF PERCENT IRRIGATED
C**********************************************************************
      IF (IOPT(5).LT.1) GO TO 320
      WRITE (OUT,1000)
      WRITE (OUT,1010)
      READ (IN,850) FMT
      WRITE (OUT,1170) (FMT(L),L=1,10)
300   READ (IN,FMT) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 320
      WRITE (OUT,1040) II,III,JJ,JJJ,HA
      DO 310 I=II,III
      DO 310 J=JJ,JJJ
      IF (FLAG(I,J).GT.2) GO TO 310
      PCTIRR(I,J)=HA
310   CONTINUE
      GO TO 300
320   IF (IOPT(13).LT.1) GO TO 350
C**********************************************************************
C       READ BLOCK ADJUSTMENTS TO PERCENT IRRIGATED
C**********************************************************************
      WRITE (OUT,990)
      WRITE (OUT,1010)
      READ (IN,850) FMT
      WRITE (OUT,1170) (FMT(L),L=1,10)
330   READ (IN,FMT) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 350
      WRITE (OUT,1040) II,III,JJ,JJJ,HA
      DO 340 I=II,III
      DO 340 J=JJ,JJJ
340   PCTIRR(I,J)=PCTIRR(I,J)*HA
      GO TO 330
350   CONTINUE
      IF (IOPT(4).NE.1) GO TO 370
C**********************************************************************
C       LIST PERCENT IRRIGATED
C**********************************************************************
      WRITE (OUT,900) TITLE
      WRITE (OUT,950)
      DO 360 I=1,NR
360   WRITE (OUT,940) I,(PCTIRR(I,J),J=1,NC)
370   IF (IOPT(4).LT.1) GO TO 420
      WRITE (OUT,900) TITLE
      DO 380 K=1,61
380   SUMP(K,1)=0.0
      DO 390 I=1,NR
      DO 390 J=1,NC
      IF (FLAG(I,J).NE.1) GO TO 390
      K=ICOUTY(I,J)
      SUMP(K,1)=SUMP(K,1)+DELX(J)*DELY(I)*PCTIRR(I,J)
390   CONTINUE
      DO 400 K=1,60
400   SUMP(61,1)=SUMP(61,1)+SUMP(K,1)
      WRITE (OUT,750)
      DO 410 K=1,60
      IF (SUMP(K,1).GT.1.) WRITE (OUT,760) K,SUMP(K,1)
```

```
410   CONTINUE
      WRITE (OUT,770) SUMP(61,1)
420   CONTINUE
C************************************************************************
C       READ TRANSMISSIVITY CONSTRAINTS
C************************************************************************
      IF (IOPT(6).LT.1) GO TO 490
      IF (IOPT(6).GT.2) GO TO 440
      READ (IN,1090) FMT
      IF (IOPT(15).GT.0) WRITE (OUT,1060)
      DO 430 I=1,NR
      READ (IN,FMT) (TONE(I,J),TTWO(I,J),J=1,NC)
      IF (IOPT(15).GT.0) WRITE (OUT,940) I,(TONE(I,J),TTWO(I,J),J=1,NC)
      DO 430 J=1,NC
      TONE(I,J)=TONE(I,J)*PERFCT
430   TTWO(I,J)=TTWO(I,J)*PERFCT
      IF (IOPT(6).LT.2) GO TO 490
440   WRITE (OUT,1060)
      WRITE (OUT,1010)
      WRITE (OUT,780)
      READ (IN,1090) FMT
      WRITE (OUT,1170) (FMT(L),L=1,10)
450   READ (IN,FMT) II,III,JJ,JJJ,HA,HB
      IF (II.LT.1) GO TO 490
      WRITE (OUT,790) II,III,JJ,JJJ,HA,HB
      IF (HA.LT.0.0) GO TO 470
      DO 460 I=II,III
      DO 460 J=JJ,JJJ
      TONE(I,J)=HA*PERFCT
460   TTWO(I,J)=HB*PERFCT
      GO TO 450
470   DO 480 I=II,III
      DO 480 J=JJ,JJJ
      TONE(I,J)=-TONE(I,J)*HA
480   TTWO(I,J)=TTWO(I,J)*HB
      GO TO 450
490   CONTINUE
C************************************************************************
C       READ PUMPAGE LIFT  CONSTRAINTS
C************************************************************************
      IF (IOPT(7).LT.1) GO TO 510
      WRITE (OUT,1070)
500   READ (IN,830) K,HA,HB
      IF (K.LT.1) GO TO 510
      WRITE (OUT,1050) K,HA,HB
      PLS(K)=HA
      PLT(K)=HB
      GO TO 500
510   CONTINUE
C************************************************************************
C       READ DOMESTIC AND STOCK PUMPAGE
C************************************************************************
      IF (IOPT(8).LT.1) GO TO 530
      WRITE (OUT,1080)
      READ (IN,1090) FMT
      WRITE (OUT,1170) (FMT(L),L=1,10)
520   READ (IN,FMT) K,HA
      IF (K.LT.1) GO TO 530
      WRITE (OUT,980) K,HA
      DANDS(K)=HA
      GO TO 520
530   CONTINUE
C************************************************************************
C       READ IRRIGATION PUMPAGE
C************************************************************************
      IF (IOPT(9).LT.1) GO TO 560
      READ (IN,1090) FMT
      WRITE (OUT,1100)
      WRITE (OUT,1010)
      WRITE (OUT,1170) (FMT(L),L=1,10)
540   READ (IN,FMT) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 560
      WRITE (OUT,1040) II,III,JJ,JJJ,HA
      DO 550 I=II,III
      DO 550 J=JJ,JJJ
      IF (FLAG(I,J).GT.2) GO TO 550
      R(I,J)=HA
550   CONTINUE
      GO TO 540
560   CONTINUE
C************************************************************************
C       READ IRRIGATION RATE ADJUSTMENTS
C************************************************************************
      IF (IOPT(14).LT.1) GO TO 590
      READ (IN,1090) FMT
      WRITE (OUT,800)
      WRITE (OUT,1010)
      WRITE (OUT,1170) (FMT(L),L=1,10)
570   READ (IN,FMT) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 590
      WRITE (OUT,1040) II,III,JJ,JJJ,HA
      DO 580 I=II,III
      DO 580 J=JJ,JJJ
580   R(I,J)=R(I,J)*HA
      GO TO 570
590   CONTINUE
C************************************************************************
C       SAVE DATA ON TAPE
C************************************************************************
      REWIND IN6
      WRITE (IN6) ICOUTY,PCTIRR,SURFAC,R,TONE,TTWO,PLT,PLS,DANDS,ACTY
      DO 600 K=1,61
      DO 600 L=1,10
600   SUMP(K,L)=0.
      DO 700 I=1,NR
C************************************************************************
C       CALCULATE PUMPAGE
C************************************************************************
      IF (IOPT(10).LT.1) GO TO 610
      WRITE (OUT,900) TITLE
      WRITE (OUT,1110)
      WRITE (OUT,1120)
610   DO 700 J=1,NC
      IF (FLAG(I,J).EQ.1) GO TO 620
      Q(I,J)=0.
      GO TO 700
620   CONTINUE
      HC=0.
      HD=0.
      K=ICOUTY(I,J)
      HA=DELX(J)*DELY(I)*PCTIRR(I,J)*R(I,J)/(DELMJ2*PMPFCT)
      SAT=H(I,J)-BOTLEL(I,J)
      TRANS=SAT*P(I,J)
C************************************************************************
C       CHECK TRANSMISSIVITY CONSTRAINT
C************************************************************************
      IF (TRANS.GT.TONE(I,J)) GO TO 640
      IF (TRANS.LT.TTWO(I,J)) GO TO 630
      FS=0.9*(TRANS-TONE(I,J))/(TONE(I,J)-TTWO(I,J))+1.0
      GO TO 650
630   FS=0.1
      GO TO 650
640   FS=1.
650   CONTINUE
C************************************************************************
C       CHECK PUMPING LIFT CONSTRAINTS
C************************************************************************
      PL=SURFAC(I,J)-H(I,J)
      IF (PL.GT.PLT(K)) GO TO 660
      FL=1.
      GO TO 670
660   FL=1.-PLS(K)*(PL-PLT(K))
```

```
      FL=AMAX1(0.1,FL)
670   CONTINUE
      HB=HA*FL*FS
      HC=HA*(1.-FS)
      HD=HA-HB-HC
      DS=DANDS(K)*DELX(J)*DELY(I)/ACTY(K)
C***********************************************************************
C       CHECK SATURATED THICKNESS CONSTRAINTS
C***********************************************************************
      HE=0.
      HF=0.
      HG=0.
      IF (SAT.GT.5.) GO TO 680
      HE=HB
      HB=0.
      HF=Q(I,J)
      Q(I,J)=0.
      IF (SAT.GT.2.) GO TO 680
      HG=DS
      DS=0.
680   CONTINUE
      HH=HB+DS+Q(I,J)
      SUMP(K,1)=Q(I,J)+SUMP(K,1)
      SUMP(K,2)=SUMP(K,2)+HF
      SUMP(K,3)=SUMP(K,3)+DS
      SUMP(K,4)=SUMP(K,4)+HG
      SUMP(K,5)=SUMP(K,5)+HA
      SUMP(K,6)=SUMP(K,6)+HC
      SUMP(K,7)=SUMP(K,7)+HD
      SUMP(K,8)=SUMP(K,8)+HE
      SUMP(K,9)=SUMP(K,9)+HB
      SUMP(K,10)=SUMP(K,10)+HH
      IF (IOPT(10).LT.1) GO TO 690
      WRITE (OUT,1140) I,J,C(I,J),HF,DS,HG,HA,HC,HD,HE,HB,HH
690   CONTINUE
      Q(I,J)=HH
700   CONTINUE
C***********************************************************************
C       WRITE COUNTY SUMMARIES
C***********************************************************************
      IF (IOPT(11).LT.1) GO TO 730
      WRITE (OUT,900) TITLE
      WRITE (OUT,1110)
      WRITE (OUT,1130)
      DO 710 K=1,60
      IF (ACTY(K).LT.1) GO TO 710
      WRITE (OUT,1150) K,(SUMP(K,L),L=1,10)
710   CONTINUE
      WRITE (OUT,1180) XLGTHM
      DO 720 K=1,60
      IF (ACTY(K).LT.1.) GO TO 720
      WRITE (OUT,1190) K,SUMP(K,11)
720   CONTINUE
730   DO 740 K=1,60
      DO 740 L=1,11
740   SUMP(61,L)=SUMP(61,L)+SUMP(K,L)
      WRITE (OUT,1110)
      WRITE (OUT,1160) (SUMP(61,L),L=1,10)
      WRITE (OUT,1180) XLGTAM
      WRITE (OUT,1200) SUMP(61,11)
C***********************************************************************
C       REAL STORED DATA
C***********************************************************************
      REWIND INS
      READ (INS) ICOUTY,K,SURFAC,PCTIRR,TONE,TTWO
C***********************************************************************
C       RETURN
C***********************************************************************
      RETURN
C
750   FORMAT (/T20,'COUNTY',T36,'IRRIGATED AREA'/)
760   FORMAT (T20,I5,T30,E20.8)
770   FORMAT (/T20,'TOTAL',T30,E20.8)
780   FORMAT (1H+,T51,'T-ONE',T61,'T-TWO')
790   FORMAT (T21,I3,4X,I3,3X,I3,5X,I3,2F10.0)
800   FORMAT (/T20,'IRRIGATION RATE ADJUSTMENTS'/)
810   FORMAT (20I1)
820   FORMAT (T20,'PUMPAGE PREDICTION  OPTION ',I5,' EQUALS',I5)
830   FORMAT (I5,2F10.0)
840   FORMAT (/T20,'DEFAULT VALUES'//T20,'COUNTY CODE',T45,I5/T20,'LAND
     1SURFACE ELEV.',T40,F10.0)
850   FORMAT (20A4)
860   FORMAT (//T30,'BLOCK ADJUSTMENTS FOR PUMPAGE PREDICTION'/T21,'ROW
     1   ROW  COLUMN  COLUMN  KEY      VALUE'/T21,'START  END  SART    EN
     2D'/)
870   FORMAT (T21,I3,4X,I3,3X,I3,5X,I3,2X,I3,F10.2)
880   FORMAT (F10.0)
890   FORMAT (/T20,'DEFAULT PERCENT IRRIGATED',F10.4)
900   FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
910   FORMAT (/T20,'COUNTY CODES'/)
920   FORMAT (/I5,20I5/(5X,20I5))
930   FORMAT (/T20,'LAND SURFACE ELEVATION'/)
940   FORMAT (/I5,10F12.4/(5X,10F12.4))
950   FORMAT (/T20,'PERCENT IRRIGATED'/)
960   FORMAT (//T20,'COUNTY CODE ERRORS FOR CELL',2I3,' VALUE IS',I5/)
970   FORMAT (/T20,'COUNTY CODE',T45,' AREA'/)
980   FORMAT (T25,I5,E20.8)
990   FORMAT (//T30,'BLOCK ADJUSTMENTS FOR PERCENT IRRIGATED'/)
1000  FORMAT (//T30,'BLOCK ASSIGNMENTS FOR PERCENT IRRIGATED'/)
1010  FORMAT (T21,'ROW    ROW  COLUMN  COLUMN        VALUE'/T21,'START  E
     1ND  START   END'/)
1020  FORMAT (5I5,F10.0)
1030  FORMAT (4I5,F10.0)
1040  FORMAT (T21,I3,4X,I3,3X,I3,5X,I3,F10.4)
1050  FORMAT (T20,I5,T30,F10.3,T45,F10.3)
1060  FORMAT (/T30,'TRANSMISSIVITY CONSTRAINTS'/)
1070  FORMAT (/T30,'PUMPING LIFT CONSTRAINTS'/T20,'COUNTY',T35,'PLS',T50
     1,'PLT'/)
1080  FORMAT (/T30,'DOMESTIC AND STOCK PUMPAGE'/T20,'COUNTY',T35,'VALUE'
     1/)
1090  FORMAT (20A4)
1100  FORMAT (/T30,'IRRIGATION PUMPAGE RATES'/)
1110  FORMAT (/T28,'REDUCE M&I',T50,'REDUCE D&S',T63,'INITIAL  REDUCE IR
     1R REDUCE IRR REDUCE IRR',T108,'NET',T119,'TOTAL'/T18,'M AND I',T29
     2,'THICKNESS  D AND S    THICKNESS    IRR',T74,'TRANS',T86,'LIFT',T
     395,'THICKNESS',T108,'IRR',T118,'PUMPAGE')
1120  FORMAT (1H+,T5,'ROW  COLUMN')
1130  FORMAT (1H+,T8,'COUNTY')
1140  FORMAT (T5,I3,T12,I3,T16,10F11.2)
1150  FORMAT (T9,I3,T16,10F11.2)
1160  FORMAT (1H+,T5,'TOTAL AREA'/T16,10F11.2)
1170  FORMAT (1H+,T80,'FORMAT',2X,10A4)
1180  FORMAT (/T8,'COUNTY',T27,'VOLUME'/T25,A6,'**3'//)
1190  FORMAT (T8,I4,T18,E20.8)
1200  FORMAT (T9,'TOTAL',T18,E20.8/)
      END
```

```
      SUBROUTINE GETPPP (NROW,NCOL,FLAG,BOTLEL,H,HO,P,T,DL,Q,RHG,SF1)
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),NHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
       COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),B
     1(100),G(100),SUMS(10,2),
     2                          ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION FLAG(NROW,NCOL),H(NROW,NCOL),HO(NROW,NCOL),BOTLEL(NROW,
     1NCOL),P(NROW,NCOL),T(NROW,NCOL,2),DL(NROW,NCOL),
     2Q(NROW,NCOL),RHG(NROW,NCOL)
     3,SF1(NROW,NCOL)
      DO 10 I=1,NR
      DO 10 J=1,NC
      RHG(I,J)=0.
10    Q(I,J)=0.
C*********************************************************************
C     READ PUMPAGE FOR ALL CELLS
C*********************************************************************
      IF (OPT(2).LT.1) GO TO 30
      READ (IN,450) FMT
      DO 20 I=1,NR
20    READ (IN,FMT) (Q(I,J),J=1,NC)
C*********************************************************************
C     READ PUMPAGE BY BLOCK
C*********************************************************************
30    IF (OPT(3).LT.1) GO TO 60
      WRITE (OUT,350)
      WRITE (OUT,360)
40    READ (IN,460) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 60
      WRITE (OUT,380) II,III,JJ,JJJ,HA
      DO 50 I=II,III
      DO 50 J=JJ,JJJ
      IF (FLAG(I,J).GT.2) GO TO 50
      Q(I,J)=HA
50    CONTINUE
      GO TO 40
C*********************************************************************
C     READ PUMPAGE ADJUSTMENTS
C*********************************************************************
60    IF (OPT(4).LT.1) GO TO 90
      WRITE (OUT,390)
      WRITE (OUT,360)
70    READ (IN,460) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 90
      WRITE (OUT,380) II,III,JJ,JJJ,HA
      DO 80 I=II,III
      DO 80 J=JJ,JJJ
80    Q(I,J)=Q(I,J)*HA
      GO TO 70
90    CONTINUE
C*********************************************************************
C     READ RECHARGE FOR ALL CELLS
C*********************************************************************
      IF (OPT(5).LT.1) GO TO 110
      READ (IN,450) FMT
      DO 100 I=1,NR
100   READ (IN,FMT) (RHG(I,J),J=1,NC)
C*********************************************************************
C     READ RECHARGE BY BLOCK
C*********************************************************************
110   IF (OPT(6).LT.1) GO TO 140
      WRITE (OUT,370)
      WRITE (OUT,360)
120   READ (IN,460) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 140
      WRITE (OUT,380) II,III,JJ,JJJ,HA
      DO 130 I=II,III
      DO 130 J=JJ,JJJ
      IF (FLAG(I,J).GT.2) GO TO 130
      RHG(I,J)=HA
130   CONTINUE
      GO TO 120
C*********************************************************************
C     READ RECHARGE ADJUSTMENS
C*********************************************************************
140   IF (OPT(7).LT.1) GO TO 170
      WRITE (OUT,400)
      WRITE (OUT,360)
150   READ (IN,460) II,III,JJ,JJJ,HA
      IF (II.LT.1) GO TO 170
      WRITE (OUT,380) II,III,JJ,JJJ,HA
      DO 160 I=II,III
      DO 160 J=JJ,JJJ
160   RHG(I,J)=RHG(I,J)*HA
      GO TO 150
170   CONTINUE
C*********************************************************************
C     CALCULATE PUMPAGE FOR HIGH PLAINS
C*********************************************************************
      IF (OPT(8).LT.1) GO TO 180
      CALL HGHPPP (NROW,NCOL,FLAG,H,BOTLEL,Q,P,DL,T(1,1,1),T(1,1,2),HO,S
     1F1,PHG)
180   CONTINUE
C*********************************************************************
C     STORE PUMPAGE AND RECHARGE
C*********************************************************************
      IF (OPT(9).LT.1) GO TO 190
      REWIND IN2
      WRITE (IN2) Q,RHG
190   IF (OPT(10).LT.1) GO TO 200
      REWIND IN2
      READ (IN2) Q,RHG
C*********************************************************************
C*********************************************************************
C     WRITE PUMPAGE AND RECHARGE
C*********************************************************************
200   IF (OPT(11).LT.1) GO TO 230
      WRITE (OUT,410) TITLE
      WRITE (OUT,420)
      DO 210 I=1,NR
210   WRITE (OUT,430) I,(Q(I,J),J=1,NC)
      WRITE (OUT,410) TITLE
      WRITE (OUT,440)
      DO 220 I=1,NR
220   WRITE (OUT,430) I,(RHG(I,J),J=1,NC)
230   CONTINUE
C*********************************************************************
C     CONVERT PUMPAGE AND RECHARGE UNITS
C*********************************************************************
      DO 340 I=1,NR
      DO 340 J=1,NC
      IF (FLAG(I,J).LT.1.OR.FLAG(I,J).GT.2) GO TO 340
      IF (Q(I,J)) 240,260,250
240   SUMS(2,1)=SUMS(2,1)-Q(I,J)
      GO TO 260
250   SUMS(1,1)=SUMS(1,1)+Q(I,J)
260   IF (RHG(I,J)) 270,290,280
270   SUMS(4,1)=SUMS(4,1)-RHG(I,J)
      GO TO 290
280   SUMS(3,1)=SUMS(3,1)+RHG(I,J)
290   HA=0.
      HB=0.
      IF (Q(I,J)) 300,310,310
300   HA=-Q(I,J)
      Q(I,J)=0.
310   IF (RHG(I,J)) 320,330,330
320   HB=-RHG(I,J)
```

```
      RH6(I,J)=0.
330   RH6(I,J)=RH6(I,J)+HA
      Q(I,J)=(Q(I,J)+HB-RH6(I,J))*PMPFCT
340   CONTINUE
C***********************************************************************
C     RETURN
C***********************************************************************
      RETURN
C
350   FORMAT (//T30,'BLOCK  PUMPAGE  ASSIGNMENT'/)
360   FORMAT (/T21,'ROW    ROW  COLUMN  COLUMN'T56,'VALUE'/T21,'START  E
     1ND  START    END'//)
370   FORMAT (//T30,'BLOCK  RECHARGE  ASSIGNMENT')
380   FORMAT (T21,I3,4X,I3,3X,I3,5X,I3,F19.4)
390   FORMAT (//T30,'BLOCK PUMPAGE ADJUSTMENTS')
400   FORMAT (//T30,'BLOCK RECHARGE ADJUSTMENTS')
410   FORMAT (1H1,29X,'***TEXAS DEPARTMENT OF WATER RESOURCES GROUND WAT
     1ER SIMULATION PROGRAM ***'//25X,20A4/)
420   FORMAT (1H0,T21,'PUMPAGE'/)
430   FORMAT (/I5,10F10.3/(5X,10F10.3))
440   FORMAT (1H0,T21,'RECHARGE'/)
450   FORMAT (20A4)
460   FORMAT (4I5,F10.0)
      END
```

```
      SUBROUTINE CALIE (NROW,NCOL,FLAG,P,S,IOPT7)
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
       COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),B
     1(100),G(100),SUMS(10,2),
     2                                  ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION FLAG(NROW,NCOL),P(NROW,NCOLS),S(NROW,NCOLS)
       DIMENSION NB(100),NP(3)
       EQUIVALENCE (B(1),NB(1))
C      MEANING OF OPTION 7
C***********************************************************************
C      MEANING OF IOPT7
C        1  NO MAPS
C        2  PERM MAP
C        3  S MAP
C        4  BOTH MAPS
C***********************************************************************
      GO TO (10,20,30,40), IOPT7
10    NP(1)=0
      NP(2)=0
      GO TO 50
20    NP(1)=1
      GO TO 50
30    NP(2)=1
      GO TO 50
40    NP(1)=1
      NP(2)=1
50    CONTINUE
      WRITE (OUT,200)
60    READ (IN,210) II,III,JJ,JJJ,K,HA
      IF (II.LT.1) GO TO 90
      WRITE (OUT,220) II,III,JJ,JJJ,K,HA
      DO 80 I=II,III
      DO 80 J=JJ,JJJ
      IF (K.EQ.2) GO TO 70
      P(I,J)=P(I,J)*HA
      IF(HA.LT.0.)P(I,J)=-HA
      GO TO 80
70    S(I,J)=S(I,J)*HA
      IF(HA.LT.0.)S(I,J)=-HA
80    CONTINUE
      GO TO 60
90    DO 190 K=1,2
      IF (NP(K).LT.1) GO TO 190
      IST=1
100   IEND=IST+31
      GO TO (110,120), K
110   WRITE (OUT,230)
      GO TO 130
120   WRITE (OUT,240)
130   CONTINUE
      IF(NR.LT.IEND)IEND=NR
      WRITE (OUT,250)
      DO 140 I=IST,IEND
140   NB(I)=IEND-I+IST
      WRITE (OUT,270) (NB(I),I=IST,IEND)
      DO 180 J=1,NC
      DO 170 I=IST,IEND
      L=IEND-I+IST
      M=K
      GO TO (160,150), M
150   NB(I)=S(L,J)*1000.+0.5
      GO TO 170
160   NB(I)=P(L,J)*0.1+0.5
170   CONTINUE
180   WRITE (OUT,270) (NB(I),I=IST,IEND),J
```

```
      IST=IEND+1
      IF (IST.LT.NR) GO TO 100
190   CONTINUE
      RETURN
C
200   FORMAT (///T20,'CALIBRATION ADJUSTMENTS'/T20,'ROW      ROW   COLUMN
     1COLUMN   PAGE  FACTOR'/T20,'START  END  START       END'/)
210   FORMAT (5I5,F10.0)
220   FORMAT (T20,I3,I7,I6,I8,I7,F10.3)
230   FORMAT (1H1,T30,'PERMEABILITY TIMES 0.1'/)
240   FORMAT (1H1,T30,'STORAGE COEFFICIENT TIMES 1000.'/)
250   FORMAT (5X,'ROWS')
260   FORMAT (1H1,T20,'PAGE',I3/)
270   FORMAT (1X,I3,32I4)
      END
```

```
      SUBROUTINE FLUX (NROW,NCOL,H,T)
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
       COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),P
     1(100),G(100),SUMS(10,2),
     2                            ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION H(NROW,NCOL),T(NROW,NCOL,2)
       DIMENSION NB(100)
       EQUIVALENCE (B(1),NB(1))
      DO 80 M=1,2
      WRITE (OUT,130) TITLE
      WRITE (OUT,120) FLXNAM,M
      WRITE (OUT,90)
      IST=1
10    IEND=IST+31
      IF(NR.LT.IEND)IEND=NR
      DO 20 I=IST,IEND
20    NB(I)=IEND-I+IST
      WRITE (OUT,110) (NB(I),I=IST,IEND)
      WRITE (OUT,110)
      DO 70 J=1,NC
      DO 60 I=IST,IEND
      L=IEND-I+IST
      HA=0.
      IF (L.EQ.NR.AND.M.EQ.2) GO TO 60
      IF (J.EQ.NC.AND.M.EQ.1) GO TO 60
      GO TO (40,30), M
30    HA=T(L,J,M)*(H(L,J)-H(L+1,J))*FLXFCT+0.5
      GO TO 50
40    HA=T(L,J,M)*(H(L,J)-H(L,J+1))*FLXFCT+0.5
50    IF(HA.LT.0.)HA=HA-1.
60    NB(I)=HA
70    WRITE (OUT,110) (NB(I),I=IST,IEND),J
      IST=IEND+1
      IF (IST.GT.NR) GO TO 80
      WRITE (OUT,100)
      GO TO 10
80    CONTINUE
      RETURN
C
90    FORMAT (5X,'ROWS')
100   FORMAT (1H1)
110   FORMAT (1X,I3,32I4)
120   FORMAT (/' FLOWS (',2A6,' ) IN DIRECTION ',I5/)
130   FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
      END
```

```
      SUBROUTINE HYDRO (NROW,NCOL,FLAG,HSIM,H,H1)
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),NHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
       COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),B
     1(100),G(100),SUMS(10,2),
     2                                  ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION FLAG(NROW,NCOL),HSIM(NROW,NCOL),H(NROW,NCOL),H1(NROW,NC
     1OL),IX(21)
C***********************************************************************
C     THIS SUBROUTINE PRODUCES A HYDROGRAPH FOR SPECIFIED NODES.
C     FOR ARRAYS H AND H1, FIRST SUBSCRIPT INDICATES THE NUMBER OF THE
C     SPECIFIED NODE AND THE SECOND SUBSCRIPT INDICATES THE TIME PERIOD
C***********************************************************************
      REAL MAP(21)
      DATA KAT,IX(1),IXX/0,0,1/
      NYR=NSTEPS
      REWIND IN3
      DATA BLANK,SIM,OBS,XINC/1H ,1HS,1HO,5.0/,BOTH/1HB/
      READ (IN3) HSIM
      IX(1)=1
      DO 10 K=1,NSAVE
      I=ISAVE(K)
      J=JSAVE(K)
      H(K,1)=-1.E5
10    H1(K,1)=HSIM(I,J)
20    NYRS=NYR-20
C***********************************************************************
      IF (KAT.GT.0.AND.NYRS.LE.-20) RETURN
C***********************************************************************
      IF(NYRS.LE.0)NYRS=NYR
      NSTOP=0
      IF(KAT.LT.1)NSTOP=1
      IF (NYRS.EQ.NYR) GO TO 30
      NYRS=20
30    CONTINUE
      NYR=NYR-NYRS
      DO 60 N=1,NYRS
      IK=IXX+N
      READ (IN3) HSIM
      NSTOP=NSTOP+1
      READ (IN3) IOPT
      IX(IK)=IOPT
      DO 40 K=1,NSAVE
      I=ISAVE(K)
      J=JSAVE(K)
40    H(K,IK)=HSIM(I,J)
      IF (IOPT.LT.1) GO TO 60
      NSTOP=NSTOP+1
      READ (IN3) HSIM
      DO 50 K=1,NSAVE
      I=ISAVE(K)
      J=JSAVE(K)
50    H1(K,IK)=HSIM(I,J)
60    CONTINUE
      KAT=KAT+1
      IF (KAT.GT.1) GO TO 70
      IXY=0
      NYRS=NYRS+1
70    DO 140 N=1,NSAVE
      II=ISAVE(N)
      WRITE (OUT,170) TITLE
      JJ=JSAVE(N)
      IYX=NYRS-IXX+(KAT-1)*20
      WRITE (OUT,150) II,JJ,(J,J=IXY,IYX)
      HMAX=-1.E10
      DO 80 K=1,NYRS
      IOPT=IX(K)
      IF(IOPT.GT.0)HMAX=AMAX1(HMAX,H1(N,K))
80    HMAX=AMAX1(HMAX,H(N,K))
      HMAX=HMAX+2.0*XINC
      KOUNT=0
      JOUNT=0
90    DO 100 J=1,21
100   MAP(J)=BLANK
      JOUNT=JOUNT+1
      HMAX=HMAX-XINC
      DO 120 L=1,NYRS
      IOPT=IX(L)
      IF (ABS(H(N,L)-HMAX).GE.(XINC*0.5)) GO TO 110
      KOUNT=KOUNT+1
      MAP(L)=SIM
      IF (IOPT.LT.1) GO TO 120
      IF (ABS(H1(N,L)-HMAX).GE.(XINC*0.5)) GO TO 110
      KOUNT=KOUNT+1
      MAP(L)=BOTH
      GO TO 120
110   CONTINUE
      IF (IOPT.LT.1) GO TO 120
      IF (ABS(H1(N,L)-HMAX).GE.(XINC*0.5)) GO TO 120
      KOUNT=KOUNT+1
      MAP(L)=OBS
120   CONTINUE
130   CONTINUE
      WRITE (OUT,160) HMAX,MAP
      IF (KOUNT.GE.NSTOP.OR.JOUNT.GT.50) GO TO 140
      GO TO 90
140   CONTINUE
      IXX=0
      IXY=KAT*20+1
      GO TO 20
C
C
C
C
150   FORMAT (1H0,10X,'HYDROGRAPH FOR NODE (',I3,1H,,I3,1H),10X,'S=SIMUL
     1ATED',5X,'O=OBSERVED',5X,'B=OBSERVED=SIMULATED'//5X,'HEAD',11X,21I
     25/)
160   FORMAT (1H ,F10.3,17X,21(1X,A4))
170   FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
      END
```

```
      SUBROUTINE OUTPUT (NROW,NCOL,FLAG,H,HO,P,BOTLEL,SF1,T)
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVF,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
       COMMON /RLCOM/ FMI(20),TITLE(20),DELX(100),DELY(100),PPMITR(10),B
     1(100),G(100),SUMS(10,2),
     2                               ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLETNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION FLAG(NROW,NCOL),H(NROW,NCOL),HO(NROW,NCOL)
     1,P(NROW,NCOL),BOTLEL(NROW,NCOL),SF1(NROW,NCOL)
     2,T(NROW,NCOL,2)
C***********************************************************************
C       SAVE HEADS FOR HYDROGRAPH ROUTINE
C***********************************************************************
      IF (KHYD.LT.1) GO TO 10
C***********************************************************************
C     SAVE SIMULATED HEAD FOR HYDROGRAPH ROUTINE
C***********************************************************************
      WRITE (IN3) H
      WRITE (IN3) OPT(22)
10    CONTINUE
C***********************************************************************
C     PREFORM MASS BALANCE COMPUTATIONS.
C***********************************************************************
      WRITE (OUT,330) ISTEP,ISTEP,XLGTNM,PMPNAM,XLGTNM,PMPNAM
      SUMS(10,1)=SUMS(8,1)-SUMS(7,1)+PMPFCT*DELMAJ*(SUMS(2,1)-SUMS(1,1)+
     1SUMS(3,1)-SUMS(4,1))+SUMS(6,1)-SUMS(5,1)+SUMS(9,1)
      DLT2J=DELMAJ/DELMJ2
      DO 20 K=1,4
20    SUMS(K,1)=SUMS(K,1)*DLT2J
      DO 30 K=1,10
30    SUMS(K,2)=SUMS(K,2)+SUMS(K,1)
      DO 40 K=5,10
40    SUMS(K,1)=SUMS(K,1)/DELMAJ
      DO 50 K=1,3,2
      B(1)=SUMS(K,1)*PMPFCT/DLT2J
      B(2)=SUMS(K,2)*PMPFCT*DELMJ2/TIME
      B(3)=SUMS(K+1,1)*PMPFCT/DLT2J
      B(4)=SUMS(K+1,2)*PMPFCT*DELMJ2/TIME
      B(6)=SUMS(K,1)-SUMS(K+1,1)
      B(5)=B(1)-B(3)
      B(8)=SUMS(K,2)-SUMS(K+1,2)
      B(7)=B(2)-B(4)
      IF (K.EQ.1) WRITE (OUT,340)
      IF (K.EQ.3) WRITE (OUT,350)
      WRITE (OUT,360) (B(L),SUMS(K,L),L=1,2),(B(L+2),SUMS(K+1,L),L=1,2),
     1(B(L),L=5,8)
50    CONTINUE
      DO 60 K=5,7,2
      B(1)=SUMS(K,1)/PMPFCT*DLT2J
      HA=SUMS(K,2)/TIME
      B(2)=HA/PMPFCT*TIME/DELMJ2
      B(3)=SUMS(K+1,1)/PMPFCT*DLT2J
      HB=SUMS(K+1,2)/TIME
      B(4)=HB/PMPFCT*TIME/DELMJ2
      B(5)=SUMS(K,1)-SUMS(K+1,1)
      B(6)=B(1)-B(3)
      B(7)=HA-HB
      B(8)=B(2)-B(4)
      IF (K.EQ.5) WRITE (OUT,370) SUMS(K,1),B(1),HA,B(2),SUMS(K+1,1),P(3
     1),HB,B(4),(P(L),L=5,8)
      IF (K.EQ.7) WRITE (OUT,380) SUMS(K,1),B(1),HA,B(2),SUMS(K+1,1),P(3
     1),HB,B(4),(P(L),L=5,8)
60    CONTINUE
      B(1)=SUMS(9,1)/PMPFCT*DLT2J
      HA=SUMS(9,2)/TIME
      B(2)=HA/PMPFCT*TIME/DELMJ2
      B(3)=SUMS(10,1)/PMPFCT*DLT2J
      HB=SUMS(10,2)/TIME
      B(4)=HB/PMPFCT*TIME/DELMJ2
      WRITE (OUT,390) SUMS(9,1),B(1),HA,B(2),SUMS(10,1),B(3),HB,B(4)
      IF (OPT(14).LT.1) GO TO 90
C***********************************************************************
C     SAVE HEAD DATA ON UNIT OUT1
C***********************************************************************
      WRITE (OUT1,500) ISTEP
      DO 70 I=1,NR
70    WRITE (OUT1,490) I,(H(I,J),J=1,NC)
80    CONTINUE
90    IF (OPT(15).LT.1) GO TO 110
C***********************************************************************
C     WRITE PHYSICAL DATA
C***********************************************************************
      WRITE (OUT1,640)
      DO 100 I=1,NR
      DO 100 J=1,NC
      HA=SF1(I,J)/(DELX(J)*DELY(I))
      HB=P(I,J)/PERFCT
      WRITE (OUT1,650) I,J,FLAG(I,J),BOTLEL(I,J),H(I,J),HA,HA
100   CONTINUE
110   CONTINUE
      IF (OPT(16).LT.1) GO TO 130
C***********************************************************************
C     PRINT WATER LEVELS AT END OF MAJOR TIME STEP
C***********************************************************************
      WRITE (OUT,590) TITLE
      WRITE (OUT,460) ISTEP
      DO 120 I=1,NR
120   WRITE (OUT,410) I,(H(I,J),J=1,NC)
130   CONTINUE
C***********************************************************************
C      PLOT WATER LEVELS
C***********************************************************************
      IF (OPT(26).GT.0) CALL PLOTH (NROW,NCOL,FLAG,H,SF1,1)
C***********************************************************************
C      READ HEAD AT START OF TIME STEP
C***********************************************************************
      IF (OPT(18).LT.1.AND.OPT(19).LT.1) GO TO 170
      REWIND IN4
      READ (IN4) HO
C***********************************************************************
C         PRINT MAP OF WATER LEVEL CHANGES DURING THIS TIME STEP
C***********************************************************************
      IF (OPT(19).LT.1) GO TO 140
      CALL PLOTS (NROW,NCOL,FLAG,H,HO,2)
140   CONTINUE
C***********************************************************************
C      LIST HEAD CHANGES DURING TIME STEP
C***********************************************************************
      IF (OPT(18).LT.1) GO TO 170
      WRITE (OUT,590) TITLE
      WRITE (OUT,480) ISTEP
      DO 160 I=1,NR
      DO 150 J=1,NC
150   B(J)=H(I,J)-HO(I,J)
160   WRITE (OUT,410) I,(B(J),J=1,NC)
170   CONTINUE
C***********************************************************************
C      PLOT GROUND WATER FLOWS
C***********************************************************************
      IF (OPT(17).GT.0) CALL FLUX (NROW,NCOL,H,T)
      IF (OPT(20).LT.1.AND.OPT(21).LT.1) GO TO 210
C***********************************************************************
C      READ INITIAL WATER LEVELS
C***********************************************************************
      REWIND IN1
      READ (IN1) HC
      IF (OPT(20).LT.1) GO TO 200
C***********************************************************************
```

```
C     PRINT HEAD CHANGES THROUGH THIS TIME STEP
C***********************************************************************
      WRITE (OUT,590) TITLE
      WRITE (OUT,470) ISTEP
      DO 190 I=1,NR
      DO 180 J=1,NC
180   E(J)=H(I,J)-HO(I,J)
190   WRITE (OUT,410) I,(E(J),J=1,NC)
200   CONTINUE
C***********************************************************************
C      PLOT WATER LEVEL  CHANGES THROUGH THIS TIME STEP
C***********************************************************************
      IF (OPT(21).GT.0) CALL PLOTS (NROW,NCOL,FLAG,H,HO,3)
210   CONTINUE
      IF (OPT(22).LT.1) GO TO 280
220   CONTINUE
C***********************************************************************
C     READ MEASURED WATER LEVEL DATA
C***********************************************************************
      READ (IN,450) FMT
      DO 230 I=1,NR
      READ (IN,FMT) (HO(I,J),J=1,NC)
      IF (OPT(16).LT.2) GO TO 230
C***********************************************************************
C     LIST SIMULATED AND MEASURED WATER LEVELS
C     AND SIMULATION ERRORS
C***********************************************************************
230   CONTINUE
      WRITE (OUT,590) TITLE
      WRITE (OUT,600) ISTEP
      DO 270 I=1,NR
      DO 250 J=1,NC
      B(J)=0.
      IFL=FLAG(I,J)+1
      GO TO (250,240,240,250), IFL
240   E(J)=H(I,J)-HO(I,J)
250   CONTINUE
      JST=1
260   JEND=JST+9
      JEND=MINO(JEND,NC)
      WRITE (OUT,410)
      WRITE (OUT,420) I,(H(I,J),J=JST,JEND)
      WRITE (OUT,430) (HO(I,J),J=JST,JEND)
      WRITE (OUT,430) (E(J),J=JST,JEND)
      JST=JEND+1
      IF (JST.GT.NC) GO TO 270
      GO TO 260
270   CONTINUE
C***********************************************************************
C     PRINT MAP OF SIMULATION ERRORS
C***********************************************************************
      CALL PLOTS (NROW,NCOL,FLAG,H,HO,1)
C***********************************************************************
C     SAVE HEADS FOR HYDROGRAPH ROUTINE.
C***********************************************************************
      WRITE (IN3) HO
280   CONTINUE
C***********************************************************************
C     PRINT CROSS-SECTIONS
C***********************************************************************
      IF (OPT(23).LT.1) GO TO 290
      CALL XSECT (NROW,NCOL,FLAG,H,HO,BOTLEL)
290   CONTINUE
C***********************************************************************
C      LIST AND PLOT SATURATED THICKNESS
C***********************************************************************
      IF (OPT(25).LT.1) GO TO 320
      WRITE (OUT,590) TITLE
      WRITE (OUT,610) ISTEP
      DO 310 I=1,NR
      DO 300 J=1,NC
      HO(I,J)=0.
300   IF(FLAG(I,J).LT.3)HO(I,J)=H(I,J)-BOTLEL(I,J)
310   WRITE (OUT,410) I,(HO(I,J),J=1,NC)
      CALL PLOTH (NROW,NCOL,FLAG,HO,SF1,2)
320   CONTINUE
C***********************************************************************
C      RETURN
C***********************************************************************
       RETURN
C***********************************************************************
C
C
C
C
330   FORMAT (//1H1,'FOR TIME STEP',I6,T80,'THROUGH TIME STEP',I6/T34,A6
     1,'**3/DAY',T55,A6,'/STEP',T74,A6,'**3/DAY',T99,A6/)
340   FORMAT (/T6,'PUMPAGE')
350   FORMAT (/T6,'RECHARGE')
360   FORMAT (T10,'POSITIVE',T26,2(F20.1,F20.4)/T10,'NEGATIVE',T26,2(F20
     1.1,F20.4)/T10,'NET',T26,2(F20.1,F20.4))
370   FORMAT (/T6,'CONSTANT HEAD FLOW',/T10,'TO CELLS',T26,2(F20.1,F20.4
     1)/T10,'FROM CELLS',T26,2(F20.1,F20.4)/T10,'NET',T26,2(F20.1,F20.4)
     2)
380   FORMAT (/T6,'CHANGE IN STORAGE',/T10,'INCREASE',T26,2(F20.1,F20.4)
     1/T10,'DECREASE',T26,2(F20.1,F20.4)/T10,'NET',T26,2(F20.1,F20.4))
390   FORMAT (/T6,'REDUCTION IN PUMPAGE',T26,2(F20.1,F20.4)/T6,/T6,'MASS
     1 BALANCE',T26,2(F20.1,F20.4))
400   FORMAT (1H1)
410   FORMAT (1H0,I4,5X,10F10.3/(10X,10F10.3))
420   FORMAT (1H0,I4,5X,10F10.3)
430   FORMAT (10X,10F10.3)
440   FORMAT (20A4)
450   FORMAT (20A4)
460   FORMAT (T20,'WATER LEVELS FOR END OF TIME STEP',I5//)
470   FORMAT (1H0,T10,'WATER LEVEL CHANGES THROUGH TIME STEP',I5//)
480   FORMAT (1H0,T10,'WATER LEVEL CHANGES DURING TIME STEP',I5//)
490   FORMAT (I5,5X,10F7.1/(10X,10F7.1))
500   FORMAT (30H SIMULATED HEADS FOR TIME STEP,T40,I5)
510   FORMAT (1H+,T55,'PFACT =',F10.2)
520   FORMAT (1H+,T55,'RFACT =',F10.2)
530   FORMAT (1H+,T55,'NOOPT -',I10)
540   FORMAT (1H+,T55,'NSP2 =',I5,' DELMJ2 =',F10.1)
550   FORMAT (1H1,T20,'PUMPAGE VALUES (AC-FT) FOR TIME STEP',I5//)
560   FORMAT (1H1,T20,'RECHARGE VALUES (AC-FT) FOR TIME STEP',I5//)
570   FORMAT (' FOR NODE',2I3,' PUMPAGE REDUCED BY',F10.2,' AC-FT/TIME S
     1TEP')
580   FORMAT (1H1,T20,'NET PUMPAGE-RECHARGE VALUES (AC-FT) FOR TIME'1X,'
     1STEP',I5//)
590   FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
600   FORMAT (T10,'FOR TIME STEP ',I5,T35,'SIMULATED WATER LEVELS'/T35,'
     1MEASURED WATER LEVELS'/T35,'SIMULATION ERRORS'/)
610   FORMAT (T5,'SATURATED THICKNESS AT END OF STEP',I5//)
620   FORMAT (1H0,'*** JOB TERMINATED ***')
630   FORMAT (' SIMULATED HEADS AT END OF',F10.3,' DAYS')
640   FORMAT ('(6X,I3,4F15.0)')
650   FORMAT (3I3,4F15.5)
      END
```

```
      SUBROUTINE PHYSCT (NROW,NCOL,FLAG,BOTLEL,H,HO,P,SF1,T)
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
       COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),B
     1(100),G(100),SUMS(10,2),
     2                          ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION FLAG(NROW,NCOL),H(NROW,NCOL),BOTLEL(NROW,NCOL),HO(NROW,
     1NCOL),P(NROW,NCOL),SF1(NROW,NCOL),T(NROW,NCOL,2)
      DIMENSION TYPE(2,4)
      DATA TYPE/4HOUTC,4HROP ,4HARTE,4HSIAN,4HBOUN,
     14HDARY,4HCONS,4HT HD/
C***********************************************************************
C     READ OPTIONS WHICH CONTROL GENERAL EXECUTION OF PROGRAM
C***********************************************************************
      READ (IN,270) OPT
      DO 10 I=1,10
      IF (OPT(I).GT.0) WRITE (OUT,240) I,OPT(I)
10    CONTINUE
C***********************************************************************
C     IF HYDROGRAPHS ARE REQUIRED, READ NUMBER OF AND COORDINATES OF
C     THE SPECIFIC NODES.
C***********************************************************************
      IF (OPT(1).LT.1) GO TO 20
      KHYD=OPT(1)
      READ (IN,300) NSAVE,(ISAVE(I),JSAVE(I),I=1,NSAVE)
20    CONTINUE
C***********************************************************************
C     IF CROSS-SECTIONS ARE REQUESTED, READ NUMBER OF AND INDEX FOR THE
C     REQUESTED COLUMNS AND ROWS, RESPECTIVELY.
C***********************************************************************
      IF (OPT(2).LT.1) GO TO 30
      READ (IN,300) NCOLS,(MCOLS(I),I=1,NCOLS)
      READ (IN,300) NROWS,(MROWS(I),I=1,NROWS)
30    CONTINUE
C***********************************************************************
C     READ GRID SPACINGS IN THE X AND Y DIMENSIONS, RESPECTIVELY.
C***********************************************************************
      READ (IN,310) FMT
      HA=4H
      IF (OPT(3).LT.1) GO TO 60
C***********************************************************************
C     READ AND WRITE CONSTANT GRID SPACINGS
C***********************************************************************
      READ (IN,FMT) HA,HB
      DO 40 I=1,NR
40    DELY(I)=HB
      DO 50 J=1,NC
50    DELX(J)=HA
      WRITE (OUT,370) HA,HB
      GO TO 70
60    CONTINUE
      READ (IN,FMT) (DELX(J),J=1,NC)
      READ (IN,FMT) (DELY(I),I=1,NR)
      IF (OPT(4).LT.1) GO TO 70
      WRITE (OUT,330)
      WRITE (OUT,250) (DELX(J),J=1,NC)
      WRITE (OUT,340)
      WRITE (OUT,250) (DELY(I),I=1,NR)
70    CONTINUE
C***********************************************************************
C     READ PHYSICAL DATA FORMAT CARD
C***********************************************************************
      READ (IN,310) FMT
      IF (OPT(5).LT.1) GO TO 90
C***********************************************************************
C     READ AND WRITE DEFAULT VALUES TO BE ASSIGNED TO ALL NODES
C***********************************************************************
      READ (IN,FMT) K,(B(N),N=1,4)
      WRITE (OUT,360) K,(B(N),N=1,4)
      DO 80 J=1,NC
      DO 80 I=1,NR
      FLAG(I,J)=K
      BOTLEL(I,J)=B(1)
      H(I,J)=B(2)
      P(I,J)=B(3)
80    SF1(I,J)=B(4)
      GO TO 110
90    CONTINUE
C***********************************************************************
C     READ NODE CARDS
C***********************************************************************
      DO 100 I=1,NR
      DO 100 J=1,NC
      READ (IN,FMT) FLAG(I,J),BOTLEL(I,J),H(I,J),P(I,J),SF1(I,J)
100   CONTINUE
110   CONTINUE
      IF (OPT(6).LT.1) GO TO 130
      READ (IN,310) FMT
C***********************************************************************
C      READ CORRECTIONS TO NODE CARDS
C***********************************************************************
      WRITE (OUT,350)
      WRITE (OUT,280)
120   READ (IN,FMT) I,J,K,(B(N),N=1,4)
      IF (I.LT.1) GO TO 130
      FLAG(I,J)=K
      IF(K.EQ.0)K=4
      WRITE (OUT,290) TYPE(1,K),TYPE(2,K),I,J,FLAG(I,J),(B(N),N=1,4)
      BOTLEL(I,J)=B(1)
      H(I,J)=B(2)
      P(I,J)=B(3)
      SF1(I,J)=B(4)
      GO TO 120
130   CONTINUE
C***********************************************************************
C      READ PARAMETER ADJUSTMENT DATA
C***********************************************************************
      IF (OPT(7).GT.0) CALL CALIB (NROW,NCOL,FLAG,P,SF1,OPT(7))
      IF (KHYD.LT.1) GO TO 140
C***********************************************************************
C     SAVE ORIGINAL HEADS FOR HYDROGRAPH ROUTINE
C***********************************************************************
      REWIND IN3
      WRITE (IN3) H
140   CONTINUE
C***********************************************************************
C      SAVE INITIAL WATER LEVELS
C***********************************************************************
      REWIND IN1
      WRITE (IN1) H
C***********************************************************************
C      ZERO PERMEABILITIES FOR BOUNDARY CELLS
C***********************************************************************
      DO 150 I=1,NR
      DO 150 J=1,NC
      IF(FLAG(I,J).EQ.3)P(I,J)=0.
150   CONTINUE
C***********************************************************************
C     WRITE PHYSICAL PARAMETERS
C***********************************************************************
      IF (OPT(8).LT.1) GO TO 170
      DO 160 I=1,NR
      WRITE (OUT,320) TITLE
      WRITE (OUT,280)
      DO 160 J=1,NC
      IFLG=FLAG(I,J)
      IF(IFLG.EQ.0)IFLG=4
```

```
      WRITE (OUT,290) TYPE(1,IFLG),TYPE(2,IFLG),I,J,FLAG(I,J),BOTLEL(I,J
     1),H(I,J),P(I,J),SF1(I,J)
160   CONTINUE
170   CONTINUE
C***********************************************************************
C       CONVERT UNITS
C***********************************************************************
      DO 180 I=1,NR
      DO 180 J=1,NC
      P(I,J)=P(I,J)*PERFCT
180   SF1(I,J)=SF1(I,J)*DELX(J)*DELY(I)
C***********************************************************************
C       PLOT INITIAL WATER LEVELS
C***********************************************************************
      IF (OPT(9).GT.0) CALL PLOTH (NROW,NCOL,FLAG,H,SF1,1)
C***********************************************************************
C       LIST AND PLOT INITIAL SATURATED THICKNESS
C***********************************************************************
      IF (OPT(10).LT.1) GO TO 210
      WRITE (OUT,320) TITLE
      WRITE (OUT,230)
      DO 200 I=1,NR
      DO 190 J=1,NC
      HO(I,J)=0.
190   IF(FLAG(I,J).LT.3)HO(I,J)=H(I,J)-BOTLEL(I,J)
200   WRITE (OUT,220) I,(HO(I,J),J=1,NC)
      CALL PLOTH (NROW,NCOL,FLAG,HO,SF1,2)
210   CONTINUE
C***********************************************************************
C       RETURN
C***********************************************************************
      RETURN
C***********************************************************************
C
C
C
C
220   FORMAT (/I5,10F10.3/(5X,10F10.3))
230   FORMAT (I5,'INITIAL SATURATED THICKNESS'/)
240   FORMAT (120,'GENERAL PROGRAM OPTION',I5,' EQUALS',I5)
250   FORMAT (5X,10F10.1)
260   FORMAT (1H1)
270   FORMAT (35I1)
280   FORMAT (1H0,T24,'TYPE',T32,'ROW',T38,'COL',T44,'FLAG',T54,'BASE',T
     163,'HEAD',T73,'PERM',T82,'STORAGE'/21X,18(4H----))
290   FORMAT (21X,2A4,I4,2I6,3X,3F10.2,F10.5)
300   FORMAT (26I3)
310   FORMAT (20A4)
320   FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
330   FORMAT (1H0,'DISTANCE SPACINGS IN X-DIRECTION')
340   FORMAT (1H0,'DISTANCE SPACINGS IN Y-DIRECTION')
350   FORMAT (1H0,T30,'NODE CORRECTIONS',//)
360   FORMAT (1H0,T25,'DEFAULT VALUES'//T25,'NODE TYPE',T55,I5/T25,'BASE
     1 OF AQUIFER',T50,F10.2/T25,'WATER LEVEL',T50,F10.2/T25,'PERMEABILI
     2TY',T50,F10.2/T25,'STORAGE COEFFICIENT',T50,F10.5//)
370   FORMAT (1H0,T20,'CONSTANT GRID SPACINGS'/T20,'DEL X =',F10.3,5X,'D
     1EL Y =',F10.3/)
      END
```

```
      SUBROUTINE PLOTH (NROW,NCOL,FLAG,H,SF1,ICD)
C***********************************************************************
C       MAXIMUM NUMBER OF COLUMNS IS 100.
C***********************************************************************
        COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
        COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRNITR(10),B
     1(100),G(100),SUMS(10,2),
     2                                  ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
        INTEGER OPT,FLAG,OUT,OUT1
        DIMENSION SYMBOL(26),XRANGE(27),PLOTS(100),PERCT(26),H(NROW,NCOL)
     1,FLAG(NROW,NCOL),IFREQ(26)
     2,SF1(NROW,NCOL),TOT(26)     ,TOT1(26)
        EQUIVALENCE (PLOTS(1),B(1))
C***********************************************************************
C       XINCRE EQUALS THE RANGE FOR EACH PRINTER SYMBOL
C***********************************************************************
        DATA BLANK/4H    /
          DATA SYMBOL/1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HI,1HJ,1HK,1HL,
     11HM,1HN,1HO,1HP,1HQ,1HR,1HS,1HT,1HU,1HV,1HW,1HX,1HY,1HZ/
      DIMENSION IDUM(10)
      DATA IDUM/1,2,3,4,5,6,7,8,9,0/
      DIMENSION XROW(3), XCOL(2)
      DATA XROW/1HP,1HO,1HW/,XCOL/4HCOLU,4HMN  /
      M=0
      HA=0.
      HB=-1.E-6
      HC=1.E6
      DO 10 I=1,NR
      DO 10 J=1,NC
      IF (FLAG(I,J).GT.2) GO TO 10
      IF (FLAG(I,J).EQ.0) GO TO 10
      M=M+1
      HA=HA+H(I,J)
      HB=AMAX1(HB,H(I,J))
      HC=AMIN1(HC,H(I,J))
10    CONTINUE
      HA=HA/M
      HF=(HB-HC)/26.
      HC=5.
      IF(HB.GT.5.)HC=10.
      IF(HF.GT.10.)HC=25.
      IF(HF.GT.25.)HC=50.
      IF(HF.GT.50.)HC=100.
      HA=IFIX(HA/HC)*HC
      XRANGE(1)=-1000.
      XRANGE(27)=1.E6
      DO 20 I=2,26
20    XRANGE(I)=HA-HC*(14-I)
30    CONTINUE
      WRITE (OUT,250) TITLE
      IF (ICD.EQ.1) WRITE (OUT,180) ISTEP
      IF (ICD.EQ.2) WRITE (OUT,190) ISTEP
40    CONTINUE
      M=NC/10
      M=M-1
      IF(MOD(NC,10).GT.0)M=M+1
      MP1=M+1
      WRITE (OUT,230) ((J,I=1,10),J=1,M),MP1
      WRITE (OUT,270) XCOL
      M=M+1
      WRITE (OUT,240) (IDUM,J=1,M)
      WRITE (OUT,220)
      DO 50 I=1,26
      TOT(I)=0.
      TOT1(I)=0.
50    IFREQ(I)=0.0
```

```
      SUBROUTINE PLOTS (NROW,NCOL,FLAG,HSIM,HOBS,N)
C*************************************************************************
C     THIS SUBROUTINE PRODUCES A SYMBOLIC MAP OF VARIOUS PARAMETERS.
C     MAXIMUM NUMBER OF COLUMNS IS 100.
C     N=1  SIMULATION ERROR MAP
C     N=2 HEAD CHANGE DURING THIS TIME STEP
C     N=3 HEAD CHANGE THROUGH THIS TIME STEP
C*************************************************************************
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
     4,NBLK,IPWC(4,60)
       COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),B
     1(100),G(100),SUMSS(10,2),
     2                                  ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       INTEGER IFREQ(13)
       DIMENSION SYMBOL(13),XRANGE(14),PLOTS(100), PERCT(13),HSIM(NROW,N
     1COL),HOBS(NROW,NCOL)
     2,FLAG(NROW,NCOL)
       EQUIVALENCE (PLOTS(1),P(1))
C*************************************************************************
C     XINCRE EQUALS THE RANGE FOR EACH PRINTER SYMBOL
C*************************************************************************
      DATA XINCRE,BLANK,IFIRST/10.0,4H    ,0/
      DATA SYMBOL/1HI,1HJ,1HK,1HL,1HM,1HN,1HO,1HP,1HQ,1HR,1HS,1HT,1HU/
      DIMENSION IDUM(10)
      DATA IDUM/1,2,3,4,5,6,7,8,9,0/
      DIMENSION XROW(3), XCOL(2)
      DATA XROW/1HR,1HO,1HW/,XCOL/4HCOLU,4HMN  /
       DIMENSION SUMS(10),IMAXS(4,3),HMAXS(2,3)
      IF (IFIRST) 30,10,30
10    IFIRST=1
      XRANGE(1)=-1000.
      XRANGE(14)=10000.
      DO 20 I=2,13
20    XRANGE(I)=(FLOAT(I)-7.5)*XINCRE
30    CONTINUE
      DO 300 NBLKN=1,NBLK
      HMAX=-1.E6
      HMIN=1.E6
      DO 40 K=1,10
40    SUMS(K)=0.
      DO 50 K=1,3
      HMAXS(1,K)=-1.E6
50    HMAXS(2,K)=1.E6
      IF (NBLKN.GT.1) GO TO 110
      WRITE (OUT,490) TITLE
      GO TO (60,70,80), N
60    PRINT 420, ISTEP
      GO TO 90
70    PRINT 430, ISTEP
      GO TO 90
80    PRINT 440, ISTEP
90    CONTINUE
      M=NC/10
      M=M-1
      IF(MOD(NC,10).GT.0)M=M+1
      MP1=M+1
      WRITE (OUT,470) ((J,I=1,10),J=1,M),MP1
      WRITE (OUT,510) XCOL
      M=M+1
      WRITE (OUT,480) (IDUM,J=1,M)
      WRITE (OUT,460)
      DO 100 I=1,13
100   IFREQ(I)=0.0
110   CONTINUE
      XNODE=0.0
```

```
      XNODE=0.0
      DO 130 I=1,NR
      DO 120 J=1,NC
      PLOTS(J)=BLANK
      IFL=FLAG(I,J)+1
      GO TO (60,70,70,120), IFL
60    PLOTS(J)=1H*
      GO TO 120
70    ERR=H(I,J)
      XNODE=XNODE+1.
      DO 80 K=2,26
      IF (ERR.LT.XRANGE(K)) GO TO 90
80    CONTINUE
      IERR=26
      GO TO 100
90    IERR=K-1
100   CONTINUE
110   IFREQ(IERR)=IFREQ(IERR)+1
      TOT1(IERR)=TOT1(IERR)+DELX(J)*DELY(I)
      TOT(IERR)=TOT(IERR)+SF1(I,J)*H(I,J)
      PLOTS(J)=SYMBOL(IERR)
120   CONTINUE
      WRITE (OUT,170) I,(PLOTS(J),J=1,NC)
      IF (I.LT.4) WRITE (OUT,260) XROW(I)
130   CONTINUE
      PERCT(1)=FLOAT(IFREQ(1))/XNODE*100.
      DO 140 I=2,26
140   PERCT(I)=FLOAT(IFREQ(I))/XNODE*100.+PERCT(I-1)
      WRITE (OUT,200)
      TOT2=0.
      TOT3=0.
      IF (ICD.EQ.2) WRITE (OUT,310) XLGTNM,XLGTNM
      WRITE (OUT,300)
      DO 150 I=1,26
      WRITE (OUT,220) SYMBOL(I),XRANGE(I),XRANGE(I+1),IFREQ(I),PERCT(I)
      IF (ICD.EQ.2) WRITE (OUT,280) TOT(I),TOT1(I)
      TOT3=TOT3+TOT1(I)
150   TOT2=TOT2+TOT(I)
      WRITE (OUT,160)
      IF (ICD.EQ.2) WRITE (OUT,290) TOT2,TOT3
C*************************************************************************
      RETURN
C
C
C
C
160   FORMAT (4X,'*',8X,'CONSTANT HEAD'/)
170   FORMAT (1H ,I5,5X,100A1)
180   FORMAT (T5,'HEADS AT END OF TIME STEP',I5)
190   FORMAT (T5,'SATURATED THICKNESS AT END OF TIME STEP',I5)
200   FORMAT (1H0,T25,'FREQUENCY DISTRIBUTION',//,' SYMBOL',12X,9HRANGE(
     1FT),12X,'FREQUENCY',5X,' PER CENT .LE.')
210   FORMAT (5H MEAN,19X,F10.5,/19H STANDARD DEVIATION,5X,F10.5)
220   FORMAT (1H ,3X,A1,6X,F8.3,4H TO ,F8.3,9X,I4,6X,F10.1)
230   FORMAT (1H0,19X,10UI1)
240   FORMAT (11X,100I1)
250   FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
260   FORMAT (1H+,A1)
270   FORMAT (1H+,10X,2A4)
280   FORMAT (1H+,T70,2E20.8)
290   FORMAT (/T65,'TOTAL',2E20.8)
300   FORMAT (//)
310   FORMAT (1H+,T75,'VOLUME',1X,A6,'**3',T95,'AREA',2X,A6,'**2')
      END
```

```
      IST=IRWC(1,NBLKN)
      IEND=IRWC(2,NBLKN)
      JST=IRWC(3,NBLKN)
      JEND=IRWC(4,NBLKN)
      DO 250 I=IST,IEND
      DO 240 J=JST,JEND
      PLOTS(J)=BLANK
      IFL=FLAG(I,J)+1
      GO TO (120,130,130,240), IFL
120   PLOTS(J)=1H*
      GO TO 240
130   ERR=HSIM(I,J)-HOBS(I,J)
      IF (ABS(HOBS(I,J)).LT.1.E-3) GO TO 240
      XNODE=XNODE+1.
      IERR=ERR/XINCRE+7.5
      IF (IERR) 140,140,150
140   IERR=1
      GO TO 170
150   IF (IERR-13) 170,170,160
160   IERR=13
170   IFREQ(IERR)=IFREQ(IERR)+1
      PLOTS(J)=SYMBOL(IERR)
      DO 230 K=1,3
      GO TO (180,190,200), K
180   HA=HSIM(I,J)
      GO TO 210
190   HA=HOBS(I,J)
      GO TO 210
200   HA=ERR
210   HDUM=HMAXS(1,K)
      HMAX=AMAX1(HA,HMAXS(1,K))
      IF (HDUM.GE.HMAX) GO TO 220
      HMAXS(1,K)=HMAX
      IMAXS(1,K)=I
      IMAXS(2,K)=J
220   HDUM=HMAXS(2,K)
      HMIN=AMIN1(HA,HMAXS(2,K))
      IF (HDUM.LE.HMIN) GO TO 230
      HMAXS(2,K)=HMIN
      IMAXS(3,K)=I
      IMAXS(4,K)=J
230   CONTINUE
      SUMS(1)=SUMS(1)+1.
      SUMS(2)=SUMS(2)+HSIM(I,J)*HOBS(I,J)
      SUMS(3)=SUMS(3)+HSIM(I,J)*HSIM(I,J)
      SUMS(4)=SUMS(4)+HSIM(I,J)
      SUMS(5)=SUMS(5)+HOBS(I,J)*HOBS(I,J)
      SUMS(6)=SUMS(6)+HOBS(I,J)
      SUMS(7)=SUMS(7)+ERR*ERR
      SUMS(8)=SUMS(8)+ERR
      ERR=ABS(ERR)
      SUMS(9)=SUMS(9)+ERR*ERR
      SUMS(10)=SUMS(10)+ERR
240   CONTINUE
      IF (NBLKN.GT.1) GO TO 250
      WRITE (OUT,400) I,(PLOTS(J),J=1,NC)
      IF (I.LT.4) WRITE (OUT,500) XROW(I)
250   CONTINUE
      IF (NBLKN.GT.1) GO TO 270
      PERCT(1)=FLOAT(IFREQ(1))/XNODE*100.
      DO 260 I=2,13
260   PERCT(I)=FLOAT(IFREQ(I))/XNODE*100.+PERCT(I-1)
      WRITE (OUT,450)
      WRITE (OUT,460) (SYMBOL(I),XRANGE(I),XRANGE(I+1),IFREQ(I),PERCT(I)
     1,I=1,13)
      WRITE (OUT,380)
270   WRITE (OUT,310) NBLKN,IST,IEND,JST,JEND
      WRITE (OUT,330)
      DO 280 K=4,10,2
280   SUMS(K)=SUMS(K)/SUMS(1)
      WRITE (OUT,320) (SUMS(K),K=4,10,2)
      SS=SUMS(7)
      DO 290 K=3,9,2
290   SUMS(K)=SQRT((SUMS(1)*SUMS(K)-(SUMS(1)*SUMS(K+1))**2)/(SUMS(1)*(SU
     1MS(1)-1.)))
      WRITE (OUT,350) (SUMS(K),K=3,9,2)
      WRITE (OUT,360) (HMAXS(1,K),K=1,3),((IMAXS(L,K),K=1,3),L=1,2)
      WRITE (OUT,370) (HMAXS(2,K),K=1,3),((IMAXS(L,K),K=1,3),L=3,4)
      WRITE (OUT,340) SUMS(1)
      COV=(SUMS(2)-SUMS(1)*SUMS(4)*SUMS(6))/(SUMS(1)-1.)
      REG=COV/(SUMS(3)*SUMS(5))
      WRITE (OUT,390) SS,COV,REG
300   CONTINUE
C*************************************************************************
      RETURN
C
C
C
C
310   FORMAT (/T42,'FOR BLOCK',I3,' FROM ROW',I3,' TO',I3,' AND FROM',' 
     1COLUMN',I3,' TO',I3)
320   FORMAT (T5,'MEAN',T31,4F20.4)
330   FORMAT (/T42,'SIMULATED',T63,'OBS/INIT',T81,'DIFFERENCE',T103,'ABS
     1 DIFF'/)
340   FORMAT (T5,'NUMBER OF CELLS',T31,F20.4)
350   FORMAT (T5,'STANDARD DEVIATION',T31,4F20.4)
360   FORMAT (T5,'MAXIMUM-VALUE',T31,3F20.4/T13,'ROW',T31,3I20/T13,'COLU
     1MN',T31,3I20)
370   FORMAT (T5,'MINIMUM-VALUE',T31,3F20.4/T13,'ROW',T31,3I20/T13,'COLU
     1MN',T31,3I20)
380   FORMAT (4X,'*',8X,'CONSTANT HEAD'/)
390   FORMAT (T5,'SUM OF SQUARED DIFFERENCES',T31,F20.4/T5,'COVARIANCE',
     1T31,F20.4/T5,'REGRESSION COEFFICIENT',T31,F20.4)
400   FORMAT (1H ,I5,5X,100A1)
410   FORMAT (22H0SUM OF ERRORS SQUARED,2X,F10.1)
420   FORMAT (39H0ERROR MAP FOR SIMULATION FOR TIME STEP,I4)
430   FORMAT (28H0HEAD CHANGES FOR TIME STEP ,I4)
440   FORMAT ('0HEAD CHANGES FROM BEGINNING OF SIMULATION',' THROUGH TIM
     1E STEP',I4)
450   FORMAT (1H0,T25,'FREQUENCY DISTRIBUTION',//,' SYMBOL',12X,9HRANGE(
     1FT),12X,9HFREQUENCY,5X,'PER CENT .LE.'//)
460   FORMAT (1H ,3X,A1,6X,F8.3,4H TO ,F8.3,9X,I4,6X,F10.1)
470   FORMAT (1H0,19X,100I1)
480   FORMAT (11X,100I1)
490   FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
500   FORMAT (1H+,A1)
510   FORMAT (1H+,10X,2A4)
      END
```

```
      SUBROUTINE SOLVE (NROW,NCOL,FLAG,H,HO,T,SF1,Q)
C**********************************************************************SOLV0210
C     THIS ROUTINE SOLVES FOR HEADS USING THE IADI PROCEDURE
C**********************************************************************SOLV0410
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVE,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
       COMMON /RLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),  PARM(10),B
     1(100),G(100),SUMS(10,2),
     2                               ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLETNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION H(NROW,NCOL),HO(NROW,NCOL),T(NROW,NCOL,2),SF1(NROW,NCOL
     1),G(NROW,NCOL) ,FLAG(NROW,NCOL)
        DOUBLE PRECISION BB,CC,W
      ITER=0
10    CONTINUE
      ITER=ITER+1
      IF (ITER.GT.50) GO TO 380
      K=MOD(ITER,NPARM)+1
      PK=PARM(K)
      E=0.0
C**********************************************************************SOLV1410
C     ROW CALCULATIONS                                                  SOLV1510
C**********************************************************************SOLV1610
      DO 190 II=1,NR
      I=II
      IF(MOD(ISTEP+ITER,2).EQ.1)I=NR-I+1
      EE=1.
      IF(I.EQ.1)EE=0.0
      JSTRT=1
20    DO 30 JJ=JSTRT,NC
      IFL=FLAG(I,JJ)+1
      GO TO (30,40,40,30), IFL
30    CONTINUE
      GO TO 190
40    CONTINUE
      JJP1=JJ+1
50    DO 60 JJJ=JJP1,NC
      IFL=FLAG(I,JJJ)+1
      GO TO (70,60,60,70), IFL
60    CONTINUE
      JJJ=NC
      JSTRT=NC
      GO TO 80
70    JJJ=JJJ-1
      JSTRT=JJJ+1
80    CONTINUE
      AA=0.
      DD=0.
      BB=0.
      IF (JJ.EQ.1) GO TO 90
      IF (FLAG(I,JJ-1).GT.0) GO TO 90
      BB=T(I,JJ-1,1)
      DD=BB*H(I,JJ-1)
90    CONTINUE
      DO 150 J=JJ,JJJ
      TT=-AA
      BB=BB+TT
100   TT=T(I,J,1)
      CC=-TT
      BB=BB+TT
      IF(FLAG(I,J+1).EQ.0)DD=DD+TT*H(I,J+1)
110   TT=T(I-1,J,2)*EE
      BB=BB+TT
      DD=DD+TT*H(I-1,J)
120   TT=T(I,J,2)
      BB=BB+TT
      DD=DD+TT*H(I+1,J)
```

```
      DD=DD+BB*PK*H(I,J)
      BB=BB*(1.+PK)
130   DD=DD+HO(I,J)*SF1(I,J)/DELTA-Q(I,J)
      BB=BB+SF1(I,J)/DELTA
140   W=BB-AA*B(J-1)
      B(J)=CC/W
      G(J)=(DD-AA*G(J-1))/W
      DD=0.
      BB=0.
150   AA=-T(I,J,1)
C**********************************************************************SOLV6710
C     RE-ESTIMATE HEADS                                                 SOLV6810
C**********************************************************************SOLV6910
      E=E+ABS(H(I,JJJ)-G(JJJ))
      H(I,JJJ)=G(JJJ)
      N=JJJ
160   N=N-1
      IF (N-JJ+1) 180,180,170
170   HA=G(N)-B(N)*H(I,N+1)
      E=E+ABS(HA-H(I,N))
      H(I,N)=HA
      GO TO 160
180   IF (JSTRT-NC) 20,190,190
190   CONTINUE
C**********************************************************************SOLV8110
C     COLUMN CALCULATIONS                                               SOLV8210
C**********************************************************************SOLV8310
      DO 370 JJ=1,NC
      J=JJ
      IF(MOD(ISTEP+ITER,2).EQ.1)J=NC-J+1
      EE=1.
      IF(J.EQ.1)EE=0.
      ISTRT=1
200   DO 210 II=ISTRT,NR
      IFL=FLAG(II,J)+1
      GO TO (210,220,220,210), IFL
210   CONTINUE
      GO TO 370
220   CONTINUE
      IIP1=II+1
230   DO 240 III=IIP1,NR
      IFL=FLAG(III,J)+1
      GO TO (250,240,240,250), IFL
240   CONTINUE
      III=NR
      ISTRT=NR
      GO TO 260
250   III=III-1
      ISTRT=III+1
260   CONTINUE
      AA=0.
      DD=0.
      BB=0.
      IF (II.EQ.1) GO TO 270
      IF (FLAG(II-1,J).GT.0) GO TO 270
      BB=T(II-1,J,2)
      DD=BB*H(II-1,J)
270   CONTINUE
      DO 330 I=II,III
280   TT=T(I,J-1,1)*EE
      BB=BB+TT
      DD=DD+TT*H(I,J-1)
290   TT=T(I,J,1)
      BB=BB+TT
      DD=DD+TT*H(I,J+1)
      TT=-AA
      BB=BB+TT
300   TT=T(I,J,2)
      BB=BB+TT
      CC=-TT
      IF(FLAG(I+1,J).EQ.0)DD=DD+TT*H(I+1,J)
```

```
      DD=DD+BB*PK*H(I,J)
      BB=BB*(1.+PK)
310   DD=DD+HO(I,J)*SF1(I,J)/DELTA-Q(I,J)
      BB=BB+SF1(I,J)/DELTA
320   W=BB-AA*B(I-1)
      B(I)=CC/W
      G(I)=(DD-AA*G(I-1))/W
      DD=0.
      BB=0.
330   AA=-T(I,J,2)
C*************************************************************************SOL13410
C     RE-ESTIMATE HEADS                                                   SOL13510
C*************************************************************************SOL13610
      E=E+ABS(H(III,J)-G(III))
      H(III,J)=G(III)
      N=III
340   N=N-1
      IF (N-II+1) 360,360,350
350   HA=G(N)-B(N)*H(N+1,J)
      E=E+ABS(H(N,J)-HA)
      H(N,J)=HA
      GO TO 340
360   IF (ISTRT-NR) 200,370,370
370   CONTINUE
      IF (E.GT.ERROR) GO TO 10
      IF (ITER.LT.4) GO TO 10
380   RETURN
      END
```

```
      SUBROUTINE XSECT (NROW,NCOL,FLAG,HSIM,HOBS,POTLEL)
C***********************************************************************
C     THIS SUBROUTINE PRODUCES A PRINTER PLOT OF CROSS-SECTIONS ALONG
C     ROWS OR COLUMNS.  MAXIMUM NUMBER OF ROWS OR COLUMNS IS 100.
C***********************************************************************
      INTEGER IDUM(10)
      DATA IDUM/1,2,3,4,5,6,7,8,9,0/
       COMMON /ITCOM/ NR,NC,ISTEP,NPARM,IN,OUT,OUT1,OPT(30),ITER,NSAVF,
     1ISAVE(25),JSAVE(25),KHYD,NCOLS,MCOLS(25),NROWS,MROWS(25)
     2,IN1,IN2,IN3,IN4,IN5,IN6
     3,NSTEPS
       COMMON /PLCOM/ FMT(20),TITLE(20),DELX(100),DELY(100),PRMITR(10),B
     1(100),G(100),SUMS(10,2),
     2                               ERROR,PMPFCT,PMPNAM,PERFCT,DELTA,
     3DELMAJ,E,XLGTNM,FLXNAM(2),FLXFCT
     4,DELMJ2,TIME
       INTEGER OPT,FLAG,OUT,OUT1
       DIMENSION HSIM(NROW,NCOL),HOBS(NROW,NCOL),PLOT(100),
     1FLAG(NROW,NCOL)
     2,BOTLEL(NROW,NCOL)
       EQUIVALENCE (PLOT(1),P(1))
      DATA SIM,OBS,BLANK,BOTH/1HS,1HO,1H ,1HB/
      DIMENSION XCOL(2)
      DATA XROW/3HROW/,XCOL/4HCOLU,2HMN/
      IOPT=OPT(22)
      DO 80 L=1,NCOLS
      IF (NCOLS.LT.1) GO TO 80
      WRITE (OUT,220) TITLE
      J=MCOLS(L)
      WRITE (OUT,160) J
      WRITE (OUT,230)
      M=NR/10
      IF(MOD(NR,10).GT.0)M=M+1
      M=M-1
      N=M+1
      WRITE (OUT,170) ((K,I=1,10),K=1,M),N
      WRITE (OUT,240) XROW
      M=M+1
      WRITE (OUT,190) (IDUM,K=1,M)
      HMAX=-1.E5
      HMIN=1.E5
      DO 10 I=1,NR
      IF (FLAG(I,J).GT.2) GO TO 10
      IF(IOPT.LT.1)HOBS(I,J)=HSIM(I,J)
      HMAX=AMAX1(HMAX,HSIM(I,J),HOBS(I,J))
      HMIN=AMIN1(HSIM(I,J),HOBS(I,J),HMIN)
10    CONTINUE
      HMAX=IFIX(HMAX+1.)
      HMIN=IFIX(HMIN-1.)
      XINC=(HMAX-HMIN)/40.
      XINC=FLOAT(IFIX((XINC+0.5)*2.))/2.0
      XXINC=XINC*0.5
      DO 70 LL=1,41
      DO 20 I=1,NR
20    PLOT(I)=BLANK
      DO 50 I=1,NR
      IF (FLAG(I,J).GT.2) GO TO 50
      IF(ABS(BOTLEL(I,J)-HMAX).LE.XXINC)PLOT(I)=1H*
      IF(ABS(HSIM(I,J)-HMAX).LE.XXINC)PLOT(I)=SIM
      IF (IOPT.LT.1) GO TO 50
      IF (ABS(HOBS(I,J)-HMAX).LE.XXINC) GO TO 30
      GO TO 50
30    IF (PLOT(I).EQ.SIM) GO TO 40
      PLOT(I)=OBS
      GO TO 50
40    PLOT(I)=BOTH
50    CONTINUE
60    WRITE (OUT,200) HMAX,(PLOT(I),I=1,NR)
      HMAX=HMAX-XINC
70    CONTINUE
      WRITE (OUT,180) (IDUM,I=1,M)
```

```
80    CONTINUE
      DO 150 L=1,NROWS
      IF (NROWS.LT.1) GO TO 150
      WRITE (OUT,220) TITLE
      I=NROWS(L)
      WRITE (OUT,210) I
      WRITE (OUT,230)
      M=NC/10
      IF(MOD(NC,10).GT.0)M=M+1
      M=M-1
      N=M+1
      WRITE (OUT,170) ((K,J=1,10),K=1,M),N
      WRITE (OUT,240) XCOL
      M=M+1
      WRITE (OUT,190) (IDUM,K=1,M)
      HMAX=-1.E5
      HMIN=1.E5
      DO 90 J=1,NC
      IF (FLAG(I,J).GT.2) GO TO 90
      IF(IOPT.LT.1)HOBS(I,J)=HSIM(I,J)
      HMAX=AMAX1(HMAX,HSIM(I,J),HOBS(I,J))
      HMIN=AMIN1(HSIM(I,J),HOBS(I,J),HMIN)
90    CONTINUE
      HMAX=IFIX(HMAX+1.)
      HMIN=IFIX(HMIN-1.)
      XINC=(HMAX-HMIN)/40.
      XINC=FLOAT(IFIX((XINC+0.5)*2.))/2.0
      XXINC=XINC*0.5
      DO 140 LL=1,41
      DO 100 J=1,NC
100   PLOT(J)=BLANK
      DO 130 J=1,NC
      IF (FLAG(I,J).GT.2) GO TO 130
      IF(ABS(BOTLEL(I,J)-HMAX).LE.XXINC)PLOT(J)=1H+
      IF(ABS(HSIM(I,J)-HMAX).LE.XXINC)PLOT(J)=SIM
      IF (IOPT.LT.1) GO TO 130
      IF (ABS(HOBS(I,J)-HMAX).LE.XXINC) GO TO 110
      GO TO 130
110   IF (PLOT(J).EQ.SIM) GO TO 120
      PLOT(J)=OBS
      GO TO 130
120   PLOT(J)=BOTH
130   CONTINUE
      WRITE (OUT,200) HMAX,(PLOT(J),J=1,NC)
      HMAX=HMAX-XINC
140   CONTINUE
      WRITE (OUT,180) (IDUM,J=1,M)
150   CONTINUE
      RETURN
C**********************************************************************
C
C
C
C
160    FORMAT (25H0CROSS-SECTION FOR COLUMN,I3)
170    FORMAT (1H0,24X,100I1)
180    FORMAT (16X,100I1)
190    FORMAT (7X,'HEAD',5X,100I1)
200    FORMAT (1X,F10.2,5X,100A1)
210    FORMAT (22H0CROSS-SECTION FOR ROW,I3)
220    FORMAT (1H1,29X,'*** TEXAS DEPARTMENT OF WATER RESOURCES GROUND WA
     1TER SIMULATION PROGRAM ***'//25X,20A4/)
230    FORMAT (1H+,T40,'S=SIMULATED',5X,'O=OBSERVED',5X,'B=OBSERVED=SIMUL
     1ATED',5X,'+=BASE')
240    FORMAT (1H+,15X,2A4)
       END
```

GWSIM-II
Corrections and Additions

On page 15, under Program Options, add the following after the discussion of Option 6 USE STEADY STATE HEADS

Option 7 ADJUST PARAMETERS

The enabling of this option allows input of changes in permeability and storage coefficient values. Such changes are often needed during model calibration. The enabling of this option may also cause the printing of a map(s) indicating the parameter values. The map(s) may be printed even though no adjustments are made. See Data Set 7a

Data Set 7a is read if the value of Option 7 in Data Set 3 is greater than zero. The maps to be plotted may be selected by setting the value Option 7 as shown below.

| Option 7 | Maps Produced |
| --- | --- |
| 1 | None |
| 2 | Permeability-x |
| 3 | Permeability-y |
| 4 | Storage Coefficient |
| 5 | Permeability-x and Permeability-y |
| 6 | Permeability-x and Storage coefficient |
| 7 | Permeability-y and Storage coefficient |
| 8 | Permeability-x, Permeability-y, and Storage coefficient. |

On page 15, under Program Options, add the following before the discussion of Option 3 READ CONSTANT HEAD ENDING VALUES

Option 2 PRINT MAPS OF FLOWS

The enabling of this option causes the printing of a map indicating ground-water flows at the end of the major time step. If option 2 equals two (2), the maps are produced at the end of each minor time step.

Two maps are produced, one for flows in the x-direction (direction 1) and the other for flows in the y-direction (direction 2). For flows in the x-direction, the value shown is for flow to the right; or from cell I,J to cell I,J+1. A negative sign indicates flow from cell I,J+1 to cell I,J.

Flows from row I to row I+1 are shown on the y-direction map as a positive number. A negative number represents flow in the opposite direction. Flows are printed in 1000's of acre-feet per year.

On page 15, under Program Options, add the following after the discussion of Option 3 READ CONSTANT HEAD ENDING VALUES

Option 4 CHANGE TIME STEP SIZE

The enabling of this option allows for the change of the length of this major time step and of the number of minor time steps. See Data Set 11. The new time step parameters will be in effect for this time step.

On page 17, the discussion of Option 17 OUTPUT WATER LEVELS ON UNIT 'OUT1' should read:

Option 17 SAVE DATA ON UNIT OUT1

The enabling of this option will cause a listing of heads for the end of the time set. The data are written on unit OUT1. Data suitable for Data Set 7 (Physical Data) may also be written which would allow the starting of a future run where the run terminated. If option 17 equals one (1), the heads are listed by rows with the row number preceeding the heads. the format used is

(I5, 5X, 10F7.1/(10X, 10F7.1))

If option 17 equals two (2), the head data are followed by physical data. A format to be used to read the physical data precedes the listing of the physical data. If option 17 equals three (3), only the physical data is written.

On page 24, under Data Set 3, the second sentence should read "Only the first seven options..."

The figure on page 27 is in error.

Format for Data Set 2.

Data Set 2 is read as follows.

| Columns | Variable | Meaning |
|---|---|---|
| 1-5 | NSTEPS | Number of Major Time Steps |
| 6-10 | NSP | Number of Minor Time Steps |
| 11-15 | NC | Number of Columns |
| 16-20 | NR | Number of Rows |
| 21-25 | NSPRNG | Number of Springs |
| 26-35 | DELMAJ | Length of Major Time Step, in days |
| 36-45 | ERROR | Conveyance Criterian, in feet |

Format for Data Set 3

The column number is equivalent to the option number. An option is enabled if an integer greater than zero is punched into the appropriate column.

On page 30, add the following after the discussion of the Data Set 7.

Data Set 7a - This data set will be required if Option 7 was enabled in Data Set 3. This data set contains the values used to adjust permeabilities and storage coefficient. One data card is required for each adjustment and each adjustment is applied to a specified section of the grid.

The information is read by a command in the form

```
READ (IN,100) II, III, JJ, JJJ, K, KK, HA
```

and the values are adjusted by command such as

```
    DO 10 I = II, III
    DO 10 J = JJ, JJJ
    IF (K,.GT.2) GO TO 5
    DO 4 L = K, KK
 4  P(I, J, L) = P(I, J, L)*HA
    GO TO 10
 5  SF1(I, J) = SF1(I, J)*HA
10  CONTINUE
```

The data are read as follows

| Columns | Variable | Meaning |
|---|---|---|
| 1-3 | II | First row of grid segment |
| 4-6 | III | Last row of grid segment |
| 7-9 | JJ | First column of grid segment |
| 10-12 | JJJ | Last column of grid segment |
| 13-15 | K | First parameter identifier |
| 16-18 | KK | Second parameter identifier |
| 19-29 | HA | Parameter adjustment |

Set K equal 1 if permeability x-direction is to be adjusted cr equal 2 if only permeability y-direction is to be changed. Set KK equal to 1 if only permeability x-direction is to be changed or equal 2 if permeability y-direction is to be changed. Set K equal 3 if storage coefficient is to be changed.

If Data Set 7a is read, the last card must be blank.

On page 32, under Data Set 11, the second sentence should read "Only options 2-20 may be enabled at this time."

On page 33, the format for Data Set 11 must be expanded for the time step parameters.

The data are read as follows:

| Columns | Variable | Meaning |
|---|---|---|
| 1-20 | OPT | Options 1-20 |
| 21-25 | NOOPT | Maintain these options for the next NOOPT time steps. See Option 11 |
| 26-35 | PFACT | Pumpage adjustment factor. See Option 9 |
| 36-45 | RFACT | Recharge adjustment factor. See Option 10 |
| 46-50 | NSP1 | Number of minor time steps. See Option 4 |
| 51-60 | DELMJ2 | Length of major time step, in days. See Option 4. |

On page 38, under output Unit Numbers, the last sentence should read "The output unit variable OUT equals 6 and OUT1 equals 10."