

**USERS MANUAL FOR
THE UNIVERSITY OF IDAHO
GROUND-WATER FLOW MODEL AND
RECHARGE PROGRAM**

by

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and

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TABLE OF CONTENTS

	Page
Abstract	v
Introduction	1
University of Idaho Ground-Water Flow Model description . .	3
Purpose	4
Capabilities	4
Derivation of the head computation	6
Description of transient and steady-state modes	12
Parameter calibration	14
Calibration of hydraulic conductivity.	19
Calibration of leakage parameters	22
Calibration of storage coefficient	22
Application to confined and unconfined aquifers.	25
Boundary conditions	25
Hydraulically connected rivers	28
Modeling of surface drains or intermittent springs . . .	29
Incorporation of recharge and discharge from land surface sources	30
Program output	32
University of Idaho Ground-Water Flow Model input description	33
RECHARGE program description	43
Purpose	44
Capabilities	44
Algorithm description.	45
Calculation of irrigation percolation.	46
Determination of canal seepage	51

Calculation of evapotranspiration	53
Application of precipitation data	58
Calculation of the moisture balance	58
Ground-water pumping	61
Application of river gains and losses.	62
Application of ground-water underflow.	62
Limitations and assumptions.	62
Data requirements	63
Program output	65
Program description.	66
RECHARGE program input description	68
References	78
Appendices	
A. Example input for the University of Idaho Ground-Water Flow Model	80
B. Example input for the RECHARGE program	84
C. University of Idaho Ground-Water Flow Model listing . .	88
D. RECHARGE program listing	108

ILLUSTRATIONS

Figure	Page
1 Schematic illustrating iterative application of the alternating-direction procedure to the backward difference equation	9
2 Flow diagram of the general procedure of multiple parameter calibration	16
3 Relationship among factors affecting the magnitude of calibration adjustments	20
4 Leakage calibration ratios for combinations of reference and simulated head, with leakage discharging the modeled aquifer . . .	23
5 Leakage calibration ratios for combinations of reference and simulated head, with leakage recharging the modeled aquifer . . .	23
6 Storage coefficient calibration ratio for combinations of reference and simulated head.	24
7 Boundary and hydraulically connected river diagram	27
8 Illustration of changes in head (DELH) of fixed-head nodes . . .	27
9 Effect of drain-flow on a typical hydrograph	31
10 Generalized flow diagram of the RECHARGE program	47
11 Illustration of determination of irrigation application	50
12 Illustration of the calculation of evapotranspiration	54
13 Variations of alfalfa based crop coefficients over the growing season	57
14 Illustration of the calculation of water balances	59
15 Boundary and node specifications of model data set	81
16 Conditions of RECHARGE program example data set	85

TABLES

Table	Page
1 Definition of input and output unit variables	34
2 Recharge and discharge (Q) input formats	34

ABSTRACT

This manual documents two computer programs. The first is a finite difference ground-water flow model which has been applied to several areas in southern Idaho since its conception in 1970. The second program, titled RECHARGE, calculates and sums several factors contributing to aquifer recharge and discharge, for each cell of a rectangular model grid.

The model simulates two-dimensional flow under anisotropic and heterogeneous aquifer conditions. Head values are calculated by application of the alternating-direction procedure to the backward-difference form of the finite-difference equation. The model is capable of calculating flow to or from a single overlying or underlying aquifer under transient or steady-state conditions, for confined and unconfined aquifers. The model includes an automatic calibration routine which can be used to improve estimates of hydraulic conductivity, leakage parameters, and storage coefficient at each grid point. The adjustment is based on a comparison of simulated and measured head values. Boundaries may be either fixed head or fixed flux. The model is capable of calculating recharge and discharge to rivers and discharge to drains.

The RECHARGE program calculates aquifer recharge and discharge from precipitation, ground-water and surface-water irrigation, canal seepage, river gains and losses, ground-water pumping, and boundary underflow. These factors are summed for each grid cell and timestep for input to a ground-water model. Evapotranspiration, calculated by a modified Blaney-Criddle method, is used along with precipitation, irrigation, and soil moisture to maintain a water balance in which the excess recharges

ground water. Pumping in ground-water irrigated areas is assumed equal to crop consumptive use and is automatically withdrawn from the aquifer.

INTRODUCTION

A finite difference ground-water flow model was developed by J. de Sonneville of the University of Idaho in 1970 (de Sonneville, 1972). The model has been applied several times by the University of Idaho and the Idaho Department of Water Resources to aquifers in southern Idaho. Ground-water flow of the Rigby-Ririe area and the eastern Snake River Plain was modeled by de Sonneville (1974). Newton (1978) updated the eastern Snake River Plain model. The model was also applied to the Silver Creek aquifer in Blaine County, Idaho (Brockway and Grover, 1978), the Henry's Fork area (Wytzes, 1980), the Boise Valley aquifer (Lindgren, 1982), and to the Mud Lake area (Johnson, Brockway, and Luttrell, 1982). During the years of use calibration and management versions of the model have evolved, and have been modified by the users. This project combined features of both programs into a single model which is documented in this manual.

A second program, originally named the "Input Program," was developed by de Sonneville to determine aquifer recharge and discharge from land surface for each cell (area represented by a model node) of a model grid (de Sonneville, 1974). The purpose of this program was to minimize input to the model and simplify calculations within the model. The program has been revised to the present "RECHARGE program" and is also documented in this manual. The program accounts for aquifer discharge and recharge resulting from canal seepage, irrigation percolation, precipitation, evapotranspiration, well pumping, river gains and losses, and known values of boundary underflow.

These two programs were developed and used in southern Idaho but can

be applied equally well to other areas. The ground-water model has no characteristics which restrict the area of application. The RECHARGE program can also be applied in most areas, but is especially well suited to irrigated areas.

The computer programs are written in Fortran IV language with a minimum of machine specific code and tested on IBM 360 and HP 1000 computers.

This manual was prepared to provide the user with sufficient information to apply the programs and make modifications in the programs for specific situations. The first section discusses ground-water model application and computer code. The second section describes the RECHARGE program and its use.

The assistance of Garth Newton of the U.S. Geological Survey, and John Lindgren of the Idaho Department of Water Resources was essential to this project and is greatly appreciated. The authors would also like to acknowledge the the technical assistance of Stuart Luttrell and Richard Allen of the University of Idaho.

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GROUND-WATER FLOW MODEL

DESCRIPTION

PURPOSE

The model is designed to operate either for the purpose of calibrating hydrogeologic parameters or for using calibrated parameters to predict aquifer response to imposed stress situations. The model is general enough to apply to many situations and is written in an easily understood form.

Input and output are kept as simple as possible. Situations requiring special output may require program modifications.

CAPABILITIES

The model simulates two-dimensional ground-water flow in an anisotropic, nonhomogeneous media. The modeled aquifer may be confined or unconfined, or may be confined only in portions of the area. The model will calculate leakage to or from a single overlying or underlying water-bearing unit. The head in the adjacent unit may vary areally but must remain constant in time.

The model uses a block-centered, finite-difference grid, employing a cartesian coordinate system with grid spacing in the x and y directions constant and equal. The time increment (timestep length) is selected by the user and can be doubled at any point within a simulation.

The model can simulate flow under steady-state or transient conditions. Steady-state simulation requires the assumption that the aquifer head, recharge, discharge, leakage, and boundary conditions remain constant in time. Transient simulation permits temporal variation of the above factors but requires knowledge of the variation in time.

Model boundaries must be either fixed-head or fixed-flux.

Fixed-head boundaries are applied when the head varies both with time and location, however, head values must be known for each location and timestep. This condition applies to situations where the water table along a boundary is controlled by river elevation, or when estimates of aquifer head at a boundary are more accurate than estimates of underflow across the boundary. Fixed-flux boundaries may be applied when underflow across a boundary can be accurately estimated for each location and time. The simplest example of fixed flux is an impermeable boundary.

Rivers which are hydraulically connected to the aquifer, that is the river elevation corresponds to the water table, may be included as points of fixed aquifer head. Flux between the river and aquifer is calculated in the simulation and may be compared to actual river gains and losses to evaluate accuracy of the simulation. Drains or intermittent springs which discharge only when the aquifer potential exceeds the elevation of the drain may be used to establish a maximum aquifer elevation at the drain. Simulated flow out of the drain may also be compared to known drain flows.

The model contains an automatic parameter calibration routine which can be used to improve estimates of hydraulic conductivity, storage coefficient, and/or leakage parameters. Calibration is based on a comparison of simulated to measured (reference) aquifer heads at each grid node. The routine can be used to adjust any or all of the above parameters based on comparison at one or more reference timesteps.

DERIVATION OF THE HYDRAULIC HEAD COMPUTATION

The original program written by de Sonnevile calculated head values by an implicit alternating direction procedure. The procedure was modified by Garth Newton of the Idaho Department of Water Resources to an iterative alternating direction solution to the backward difference equation. The original methodology is described by de Sonnevile (1972) and de Sonnevile (1974). An excellent explanation of both procedures is given by Bennett (1976).

The purpose of this discussion is to explain the derivation of the equations currently used for head calculations within the model. The explanation will include involvement of the storage coefficient, leakage, and recharge and discharge in the calculation.

Ground-water flow in two dimensions is expressed mathematically in the following partial differential equation:

$$\frac{\partial(T_a \frac{\partial h}{\partial x})}{\partial x} + \frac{\partial(T_b \frac{\partial h}{\partial x})}{\partial x} + \frac{\partial(T_c \frac{\partial h}{\partial y})}{\partial y} + \frac{\partial(T_d \frac{\partial h}{\partial y})}{\partial y} = S \frac{\partial h}{\partial t} + W \quad (1)$$

where

T_a, T_b, T_c, T_d = transmissivity components in the +x, -x, +y,
and -y directions (ft^2/day),

S = storage coefficient,

h = hydraulic head (ft),

t = time (days),

W = volume of recharge or discharge per unit of

surface area including leakage from an overlying or
underlying aquifer ($\text{ft}^3/\text{ft}^2\text{-day}$).

Expressing equation 1 in finite difference form it becomes

$$\begin{aligned}
 & T_1 \frac{(h_{i-1,j,k} - h_{i,j,k})}{\Delta x^2} + T_2 \frac{(h_{i+1,j,k} - h_{i,j,k})}{\Delta x^2} + T_3 \frac{(h_{i,j-1,k} - h_{i,j,k})}{\Delta y^2} + \\
 & T_4 \frac{(h_{i,j+1,k} - h_{i,j,k})}{\Delta y^2} = \frac{S}{\Delta t} (h_{i,j,k} - h_{i,j,k-1}) + W
 \end{aligned} \quad (2)$$

where

i, j, k = indexes in the x direction, y direction, and in time (fig. 1),

T_1, T_2, T_3, T_4 = transmissivities between nodes (i, j) and $(i-1, j)$, $(i+1, j)$, $(i, j-1)$, and $(i, j+1)$, respectively (ft^2/day),

Δt = length of time interval (days),

$\Delta x, \Delta y$ = node spacing in the x and y directions (ft).

The recharge and discharge term, W , must be split into surface flux and leakage fractions because leakage is head dependent,

$$W = W' + (1/2) (K_v / b_c) ((h_{i,j,k-1} + h_{i,j,k}) - 2h_c) \quad (3)$$

where

W' = volume of recharge and discharge per unit area and time resulting from surface components ($\text{ft}^3/\text{ft}^2\text{-day}$),

K_v = vertical hydraulic conductivity of the confining layer (ft/day),

b_c = thickness of the confining layer (ft), and

h_c = constant head of the overlying or underlying aquifer (ft).

According to the sign conventions used, the above terms representing aquifer recharge have a negative sign, and terms representing discharge

have a positive sign.

Allowing

$$\text{FAC} = (1/2) * (K_v / b_c) \quad (1/\text{day}) \quad (4)$$

substituting and rearranging equation 3 to a convenient form for application of the alternating direction technique,

$$\begin{aligned} \frac{T_1 * h_{i-1,j,k}^{m+1}}{\Delta x^2} + \frac{T_2 * h_{i+1,j,k}^{m+1}}{\Delta x^2} - \left[\frac{(T_1 + T_2)}{\Delta x^2} + \frac{\text{FAC} + S}{\Delta t} \right] h_{i,j,k}^{m+1} = - \frac{T_3 * h_{i,j-1,k}^m}{\Delta y^2} \\ - \frac{T_4 * h_{i,j+1,k}^m}{\Delta y^2} + \frac{(T_3 + T_4)}{\Delta y^2} * h_{i,j,k}^m - \left(\frac{S}{\Delta t} - \text{FAC} \right) h_{i,j,k-1} - 2 * \text{FAC} * h_c + W \quad (5) \end{aligned}$$

where

m = the iteration level.

The alternating-direction procedure is applied in an iterative manner using equation 5. Terms on the right side of the equation are considered known and are taken from the iteration prior to the unknowns on the left side of the equation. Equation 5 is written to perform calculations along a grid row. Alternate iterations perform the same calculations along the columns. In the first iteration of each timestep the values of the previous iteration are assumed to be the resulting values of the previous timestep. The iterations are normally continued until convergence, that is, until the head change between iterations is insignificant (fig. 1).

The University of Idaho Ground-Water Flow Model uses two iterations to arrive at the solution for each timestep, as shown in figure 1. The first iteration uses heads resulting from the previous timestep as initial values, and performs calculations along rows. The second

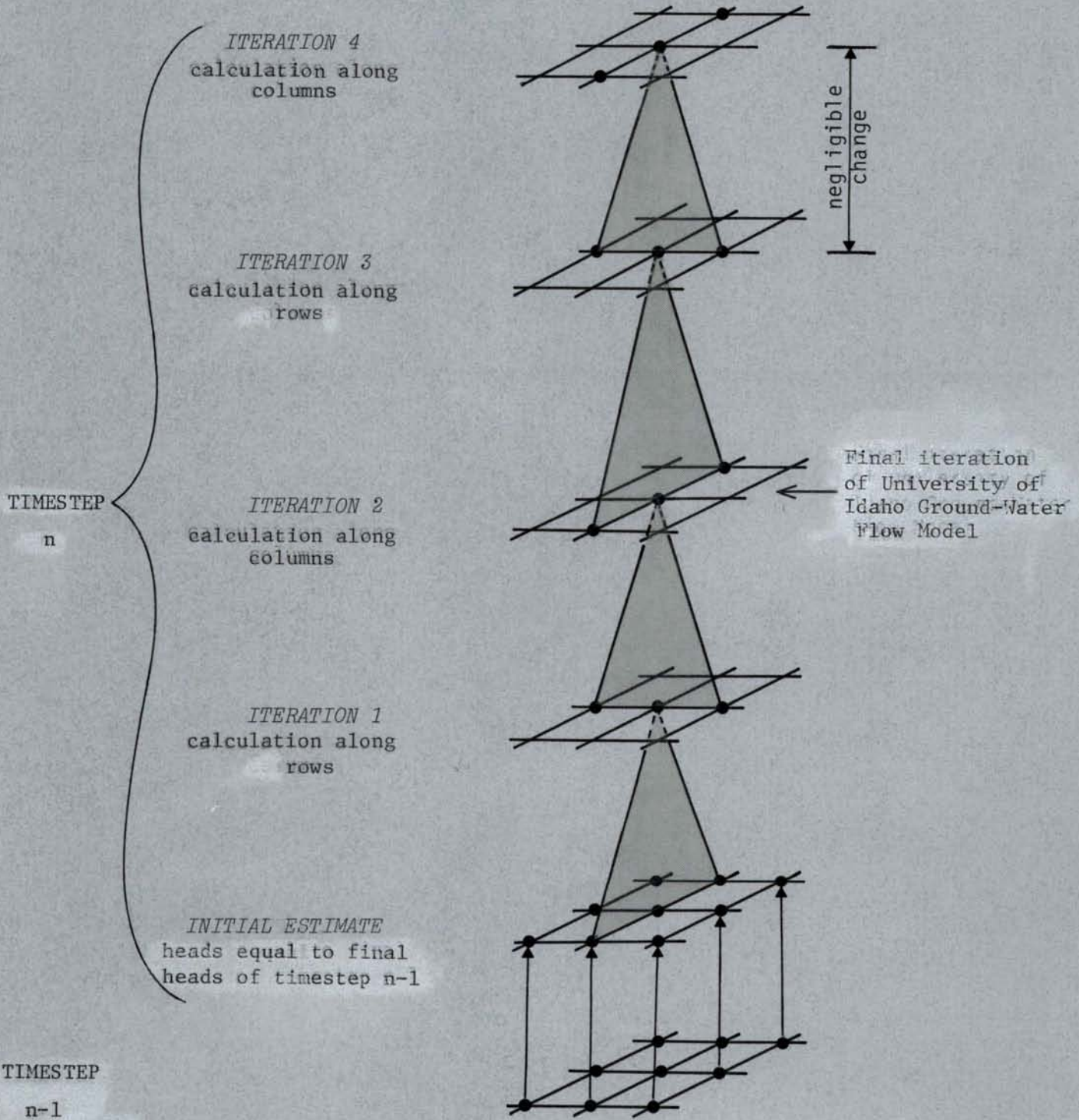


FIGURE 1. Schematic illustrating iterative application of the alternating direction procedure to the backward difference equation.

iteration proceeds along columns using values calculated in the first iteration. Experience has indicated that in most situations two iterations are sufficient for convergence. In special situations, such as rapidly changing head with time, or where extreme accuracy is necessary, it may be desirable to modify the program to execute more iterations.

Equation 5 was written for calculations along rows. A similar equation can be written for calculation along columns. For convenience, however, all equations presented in this section will represent calculations along the rows.

Equation 5 can be simplified by substituting the following identities:

$$\Delta x = \Delta y, \quad (6)$$

$$GA1 = (FAC + S / \Delta t) \Delta x^2, \quad (7)$$

$$GA2 = (FAC - S / \Delta t) \Delta x^2, \quad (8)$$

$$QC = 2 * FAC * h_c * \Delta x^2, \quad (9)$$

and dividing by Δx^2 . This results in the following equation:

$$T_1 * h_{i-1,j,k}^{m+1} + T_2 * h_{i+1,j,k}^{m+1} - \left[GA1 - (T_1 + T_2) \right] h_{i,j,k}^{m+1} = - T_3 * h_{i,j-1,k}^m \quad (10)$$

$$- T_4 * h_{i,j+1,k}^m + (T_3 + T_4) h_{i,j,k}^m + GA2 * h_{i,j,k-1} - QC + W * \Delta x^2$$

Using the following additional identities:

$$Q = W' \Delta x^2 \text{ (surface recharge or discharge volume per node per day, ft}^3\text{/day) ,} \quad (11)$$

$$A = T_1, \quad (12)$$

$$B = -(T_1 + T_2 + GA1), \quad (13)$$

$$C = T_2, \quad (14)$$

$$D = (T_3 + T_4) * h_{i,j,k}^m - T_3 * h_{i,j-1,k} - T_4 * h_{i,j+1,k} + GA2 * h_{i,j,k-1} + (Q - QC), \quad (15)$$

equation 10 then becomes,

$$A * h_{i-1,j,k} + B * h_{i,j,k} + C * h_{i+1,j,k} = D. \quad (16)$$

When equation 16 is written in matrix form the coefficients form the following tridiagonal matrix:

$$\begin{bmatrix} B_1 & C_1 & \emptyset & \emptyset & \dots \\ A_2 & B_2 & C_2 & \emptyset & \dots \\ \emptyset & A_3 & B_3 & C_3 & \dots \\ \vdots & \vdots & \vdots & \vdots & \\ & & & A_n & B_n \end{bmatrix} \begin{bmatrix} h_{1,j} \\ h_{2,j} \\ h_{3,j} \\ \vdots \\ h_{n,j} \end{bmatrix} = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \\ \vdots \\ D_n \end{bmatrix} \quad (17)$$

where the time index k is omitted and subscripts of the coefficients A , B , and C refer to the location along a row. The A and C coefficients have been eliminated from the first and last equations by application of boundary conditions at the beginning and end of each row.

The Thomas algorithm is used to solve the head matrix in equation 17. The head at each node is obtained by rearranging equation 16 to

$$h_i = (D_i - A_i * h_{i-1} - C_i * h_{i+1}) / B_i, \quad (18)$$

where indexes relating to iteration level (m), row (j), and timestep (k) are no longer necessary and have been omitted. Through a series of substitutions explained by Bennett (1976), the following equation is developed which expresses the head of each node in terms of two coefficients and the head at the succeeding node:

$$h_i = G_i - BE_i * h_{i+1}, \quad (19)$$

where

$$G_i = (D_i - A_i * G_{i-1}) / (B_i - A_i * BE_{i-1}), \quad (20)$$

and

$$BE_i = C_i / (B_i - A_i * BE_{i-1}) . \quad (21)$$

Calculations begin at the first node of each row ($i=1$) and progress to the right along the row calculating values of G_i and BE_i at each node. At the end of each row the head of the last node (h_n) is determined from G_n , BE_n , and the boundary condition. Head calculations then proceed back down the row to the left calculating each head from the previous value and from the values of G_i and BE_i .

When all heads have been calculated for a given row the procedure is started again on the next row using head values of the previous iteration. The process continues until a head value has been calculated for each grid point. The next iteration, using the new head values, is then started with calculations progressing along the columns. The University of Idaho Ground-Water Flow Model uses two iterations in each timestep, one along rows and one along columns. Head values calculated after the first iteration are merely intermediate values and should not be considered representative of an intermediate time level. The procedure bears strong resemblance to the standard (non-iterative) implicit alternating-direction procedure but the resulting equations differ. The method is stable, and combines advantages of alternating-direction and backward-difference techniques.

DESCRIPTION OF TRANSIENT AND STEADY-STATE MODES

The model can be used to simulate either transient or steady-state conditions. Transient simulation provides for changes in head and ground-water flow with time. Steady-state simulation requires that the

head, surface flux, leakage, and boundary underflow remain constant in time. Estimates of the storage coefficient need not be calibrated in steady-state simulations since no change in storage is intended.

The transient simulation period is divided into a series of timesteps of length DELT (consisting of one iteration along rows and one along columns). The length of timestep selected by the user is dependent upon the rate of change of head and flux with time, and on the overall length of the simulation period. The simulation progresses through the designated number of timesteps using head values calculated at the end of each timestep as the initial heads of the following timestep. The beginning and final timestep numbers are input as the variables BTS and NTS (all input variables and formats are listed in "University of Idaho Ground-Water Flow Model Description"). Transient simulations require input of the surface flux for each node (Q), and head changes at fixed head nodes (DELH), for each timestep.

The timestep length within a simulation can be doubled through the use of the input variable LTS. The variable LTS represents the last timestep of length DELT. The length of all timesteps after LTS is equal to 2*DELT. Specifying LTS greater than or equal to NTS maintains all timesteps at a length of DELT.

The objective of the steady-state simulation is to obtain a set of head values which remain constant in time under constant recharge and discharge conditions. This is accomplished by repetitive simulation, substituting the resulting heads of each simulation for the initial heads of the following simulation. The calculated heads converge to the steady-state solution when the difference between heads of consecutive

simulations becomes negligible. This may be considered an iterative procedure, or may be thought of as progressing through time, until the heads reach a steady-state condition.

Steady-state repetitions in the model are accomplished using the timestep loop. Each timestep is a complete simulation of length DELT. The simulation is repeated the desired number of times by appropriate specification of the input variables BTS and NTS. Steady state is reached when an insignificant change occurs between simulations (timesteps). Calibration of hydraulic conductivity or leakage in steady state is based on comparison of the final simulated heads to the reference heads, which must be identical to the initial heads.

PARAMETER CALIBRATION

The automatic calibration routine is designed to adjust estimated parameter values at each node. The procedure can be applied to calibrate the hydraulic conductivity (KX), the leakage factor (FAC), the initial head difference between the modeled aquifer and the underlying or overlying aquifer (LKDIFF), or the storage coefficient (S). Calibration is based on a comparison of simulated to reference head values at one or more timesteps. The procedure can be applied in steady-state or transient simulations. The success of the calibration is measured by the reduction of the total sum of squares of the differences between simulated and reference head values at each node summed for each reference timestep.

The calibration technique is an iterative procedure in which the user supplies initial estimates of the parameter(s) to be calibrated.

Parameter adjustments are made at each node at the completion of all timesteps (one calibration iteration). Only one parameter (at all nodes) is adjusted at a time regardless of the number of parameters being calibrated. The series of timesteps is again executed using the newly calibrated parameter values. After all timesteps have been completed the calculated heads are again compared to the reference heads and adjustments are made in the same parameter. The procedure is repeated until no reduction in the sum of squares occurs or until the number of calibration iterations reaches the maximum designated by the user (SIMUL).

When more than one parameter is calibrated in a single program run (multiple parameter calibration) each parameter is calibrated for the designated number of calibration iterations before proceeding to the next parameter. That is, the first parameter is calibrated independently until no reduction in the sum of squares occurs or until the designated number of calibration iterations is complete. The optimum values (those producing the minimum sum of squares) are then used in calibration of the next parameter. The second parameter is adjusted similar to the first, until no improvement occurs or the designated maximum number of calibration iterations is reached. The procedure is repeated for the third and fourth parameters if desired, each time using the values of the previous parameter which resulted in the minimum sum of squares.

The entire process can be repeated using the optimum values of all parameters to again calibrate new values for each parameter. This loop is referred to as the calibration cycle. The number of calibration cycles is input in the variable NSTOP. The multiple parameter calibration procedure is illustrated in figure 2.

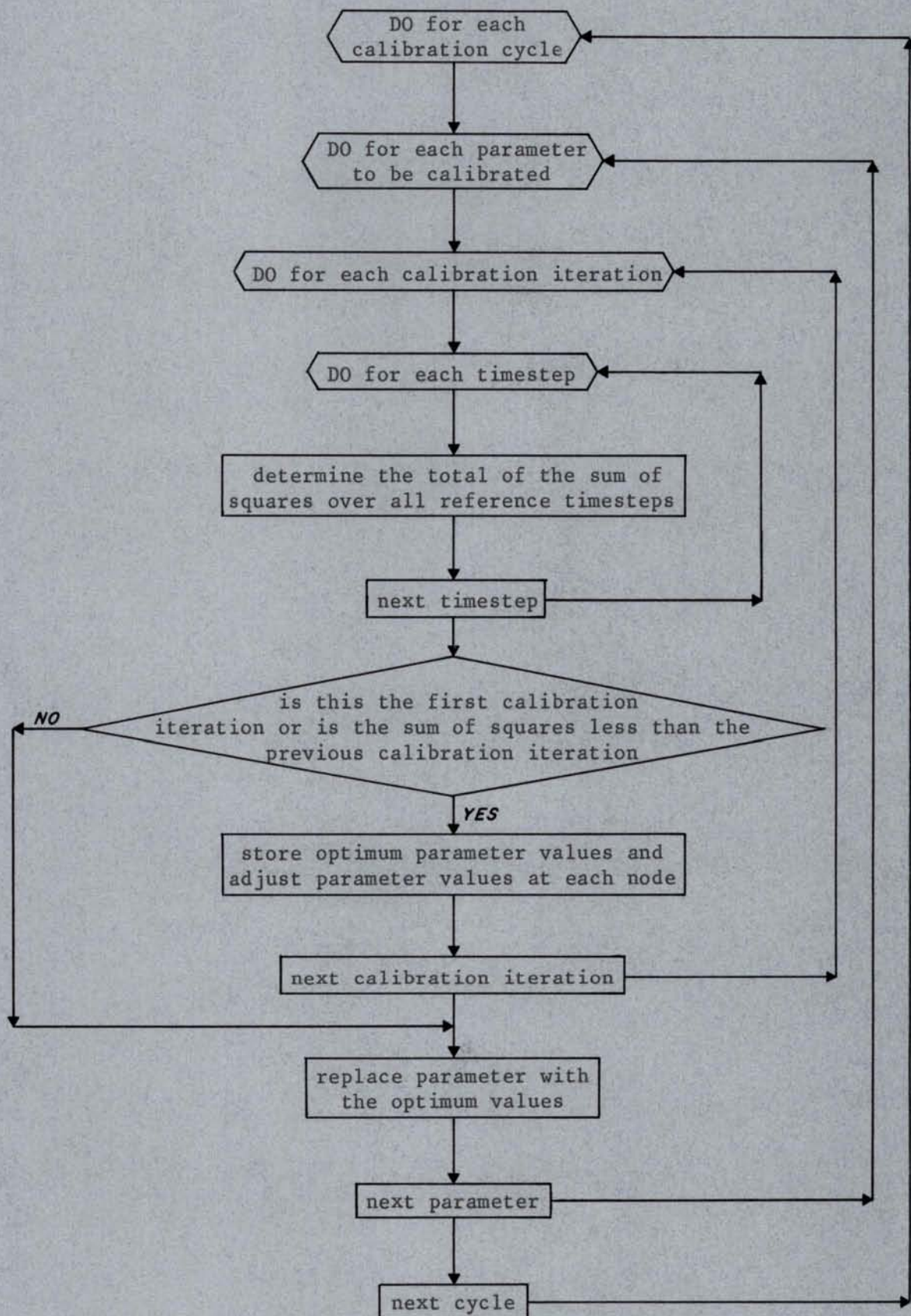


FIGURE 2. Generalized flow chart for multiple parameter calibration.

The parameters to be calibrated are specified by the input variables NVA1, NVA2, and NVA3 which are applied in the program by the following DO LOOP:

$$\text{NVAR}=\text{NVA1},\text{NVA2},\text{NVA3} \quad (22)$$

where NVAR is the variable specifying the parameter being calibrated according to the following definition:

- NVAR=1, hydraulic conductivity (KX) is calibrated,
- =2, leakage factor (FAC) is calibrated,
- =3, leakage head difference (LKDIFF) is calibrated,
- =4, storage coefficient (S) is calibrated,

NVA1 = starting limit of the loop,

NVA2 = ending limit of the loop,

NVA3 = the step of the loop.

For example, if it were necessary to calibrate hydraulic conductivity and leakage head difference, then NVA1=1, NVA2=3, and NVA3=2. If only the leakage factor were to be calibrated, then NVA1=2, NVA2=2, and NVA3=1. It should be noted that all combinations are possible except two: 1) calibrating hydraulic conductivity, leakage factor, and storage coefficient in a single run; and 2) calibrating hydraulic conductivity, leakage head difference, and storage coefficient. The order in which the parameters of a multiple parameter calibration run are calibrated is set by their corresponding value of NVAR; that is, hydraulic conductivity is first, leakage factor is second, leakage head difference is third, and the storage coefficient is last. The user will normally calibrate only one parameter in a program run. Single parameter

calibration permits interpretation of intermediate results and may influence judgement of future changes.

The values of the calibrated parameter are individually adjusted at each node according to the following equation:

$$\text{parm}_{\text{new}} = \text{parm}_{\text{old}} * (1 + VV * (R - 1)) \quad (23)$$

where

parm_{new} = adjusted value of the calibration parameter
to be used in the next calibration iteration,

parm_{old} = value of the calibration parameter used in
the last calibration iteration,

VV = a factor based on the reduction in the sum of squares
in the last calibration iteration and on the
input dampening factor, VP, and

R = ratio of the appropriate head difference
or hydraulic gradient at the calibration
timestep (TCALB) depending upon the parameter
being calibrated.

The magnitude of the calibration adjustments is partially based on improvement in the sum of squares of all reference timesteps, but is based primarily on comparison of heads or gradients at the calibration timestep (TCALB). Any of the reference timesteps may be selected as the calibration timestep, but the calibration timestep cannot be changed within a program run.

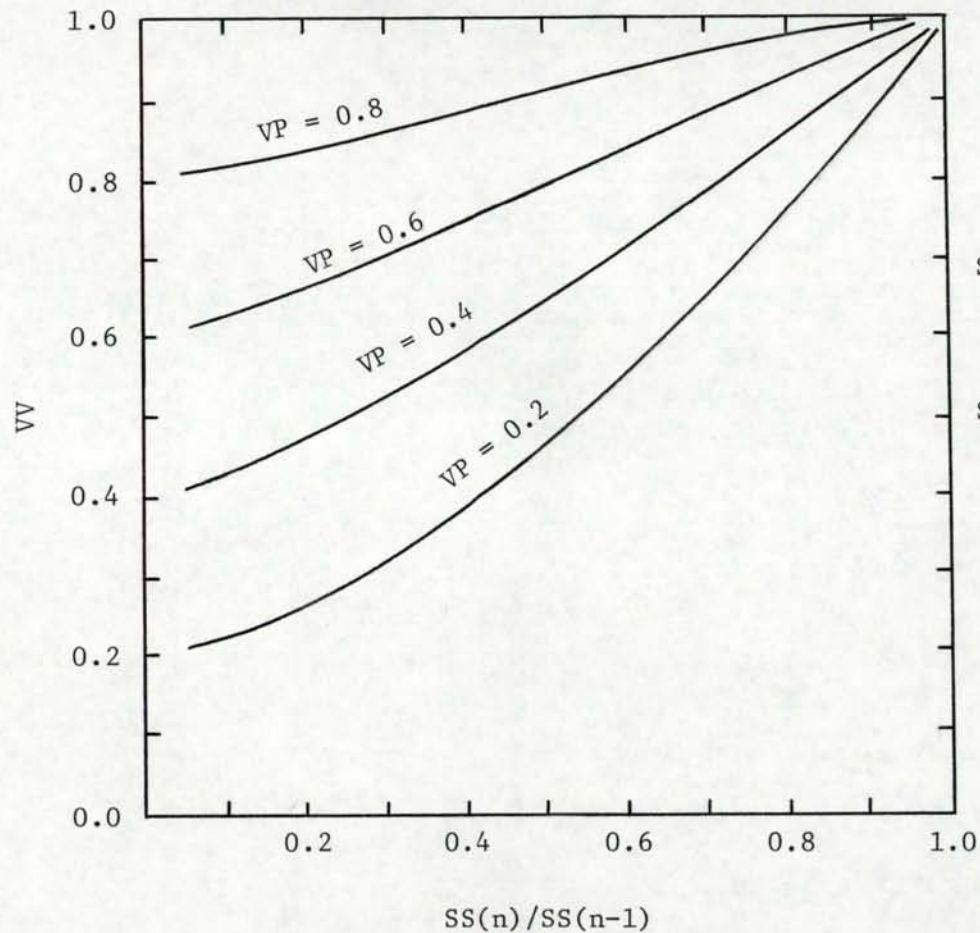
Limits are set on the amount of adjustment of a parameter and on the

resulting parameter values at each node. The adjustment is based on the quantity $(1+VV*(R-1))$ and is limited to 35% of the previous parameter value. The resulting value must also fall within a range input by the user. The input variables are described in the section "University of Idaho Ground-Water Flow Model Input Description."

The value of VV in equation 23 ranges from 0 to 1 and is based on the reduction of the sum of squares between calibration iterations and the user specified value of the dampening factor, VP. The approximate relationship between the ratio of the sum of squares of two calibration iterations, the dampening factor VP, and the variable VV is illustrated in figure 3. In the first calibration iteration $VV = VP$. When a large improvement (reduction) in the sum of squares occurs between calibration iterations the value of VV will be small, preventing overshooting the optimum values. Conversely, when small reductions in the sum of squares occur between consecutive calibration iterations the value of VV is larger, resulting in more drastic changes in parameter values. Large values input for the dampening factor VP tend to cause a more rapid reduction in the sum of squares than smaller values, that is, fewer calibration iterations are required to achieve convergence. When allowed to continue until no improvement is obtained however, a smaller value of VP will generally produce a lower final sum of squares.

Calibration of Hydraulic Conductivity

Hydraulic conductivity is the only parameter for which calibration is based on hydraulic gradients. When calibrating hydraulic conductivity the ratio R in equation 23 is the ratio of the absolute values of the magnitudes of the simulated and reference hydraulic gradients. The ratio



EXPLANATION

VP = Input calibration dampening factor.

SS(n) = Sum of squares of deviations between simulated and reference heads for all reference timesteps of the current simulation.

SS(n-1) = Sum of squares of deviations between simulated and reference heads for all reference timesteps of the previous simulation.

VV = Program calculated dampening factor incorporating effects of VP and the sum of squares.

FIGURE 3. Relationship among factors affecting the magnitude of calibration adjustments.

is expressed mathmatically as follows:

$$R=TT/TS, \quad (24)$$

where

$$TT = \sqrt{s_x^2 + s_y^2}$$

$$TS = \sqrt{sr_x^2 + sr_y^2}$$

and

s_x = simulated hydraulic gradient in the x direction,

s_y = simulated hydraulic gradient in the y direction,

sr_x = reference hydraulic gradient in the x direction,

sr_y = reference hydraulic gradient in the y direction.

The variables TT and TS can be considered the resultants of the components of the hydraulic gradients in the x and y directions. The ratio R will be greater than 1 when the simulated hydraulic gradient is steeper than the reference gradient. This would result in an increase in the hydraulic conductivity at the node and a subsequent flattening of the hydraulic gradient in the next calibration iteration. If the ratio R were less than 1 the reverse would be true. Although the magnitude of the hydraulic gradients in both the x and y directions are considered, the direction of the resultant is not. That is, the ratio R would be the same whether the simulated and reference hydraulic gradients were in the same direction or in opposite directions. In situations where the simulated water table greatly deviates from the reference water table, the automatic calibration of hydraulic conductivity may not be successful.

Hydraulic gradients used in equation 24 are actually the average gradients within a radius of one node of the node being calibrated.

Calibration of Leakage Parameters

The leakage parameters, FAC and LKDIFF, are adjusted by identical procedures. The ratio R, of equation 23 in both cases is based on simulated and reference head differences with respect to the initial head. The exact definition of the ratio is dependent upon the situation, as shown in figures 4 and 5. Leakage out of the modeled aquifer is illustrated in figure 4, and leakage into the aquifer in figure 5. When the simulated head change at a node is in the opposite direction of the reference head change at the calibration timestep (figs. 4 e&f and 5 e&f), the ratio is set equal to the maximum or the minimum, depending upon the situation.

The ratios described in figures 4 and 5 are applied in equation 23 to calibrate either of the two leakage parameters. For example, in the situation depicted by figure 4, the simulated head is higher than the reference. In this situation the ratio $R=D1/D2$ is greater than 1, resulting in an increase in the leakage factor, FAC, or the head difference, LKDIFF. An increase in either parameter will result in an increase in leakage and lower the simulated head in the next calibration iteration.

Calibration of Storage Coefficient

Calibration of storage coefficient is also based on simulated and reference head with respect to the initial head. The ratio R in equation 23 however, is not calculated the same as in calibration of the leakage parameters. The storage coefficient is calibrated using a ratio defined in figure 6. For example, figure 6a illustrates the situation when the simulated head increases from the initial head, but does not increase as

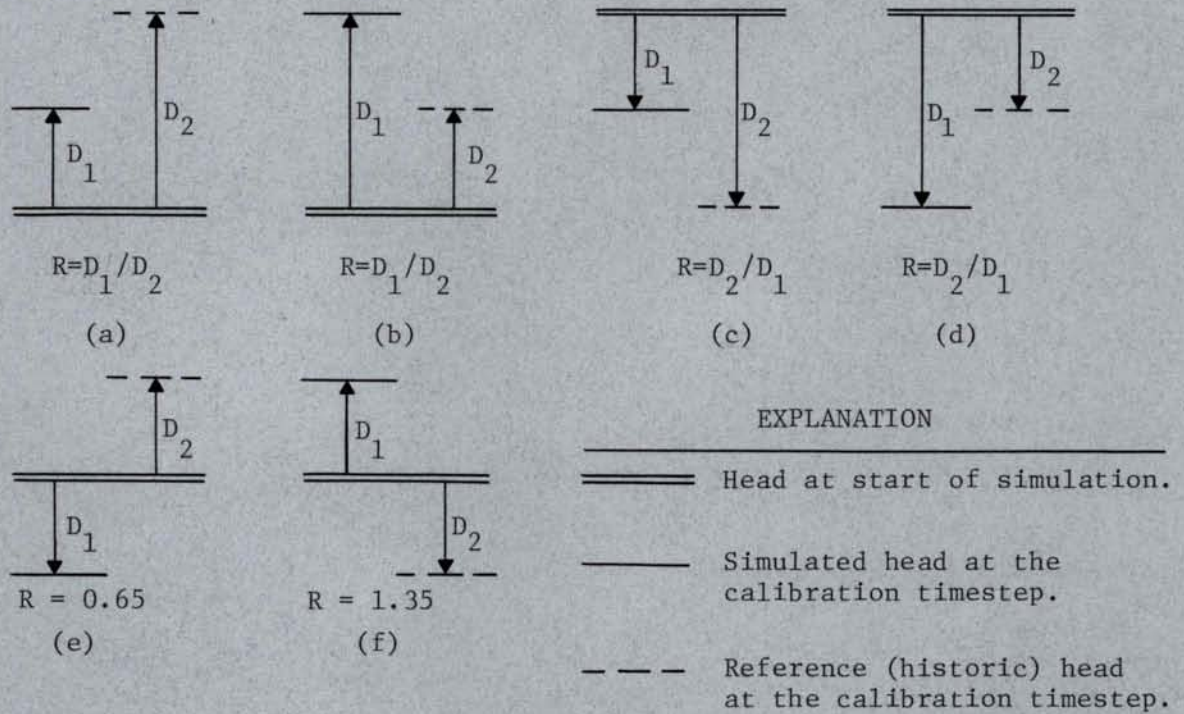


FIGURE 4. Leakage calibration ratios for combinations of reference and simulated head, with leakage discharging the modelled aquifer (after deSonneville, 1974).

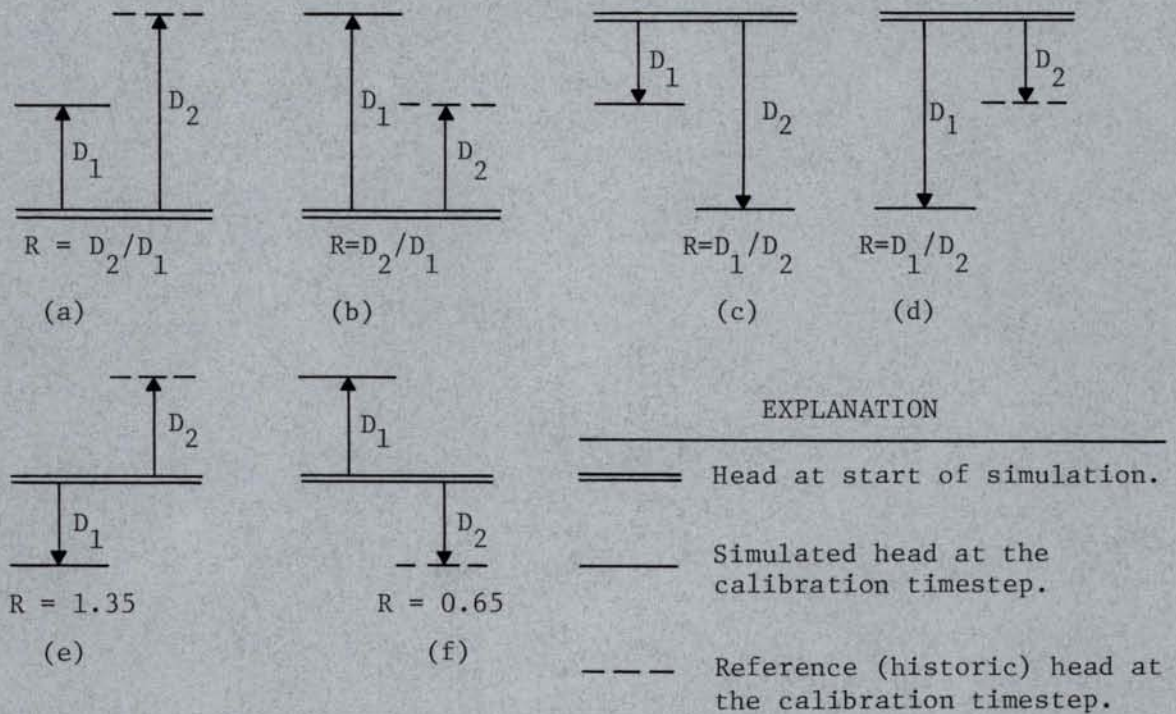


FIGURE 5. Leakage calibration ratios for combinations of reference and simulated head, with leakage recharging the modelled aquifer (after deSonneville, 1974).

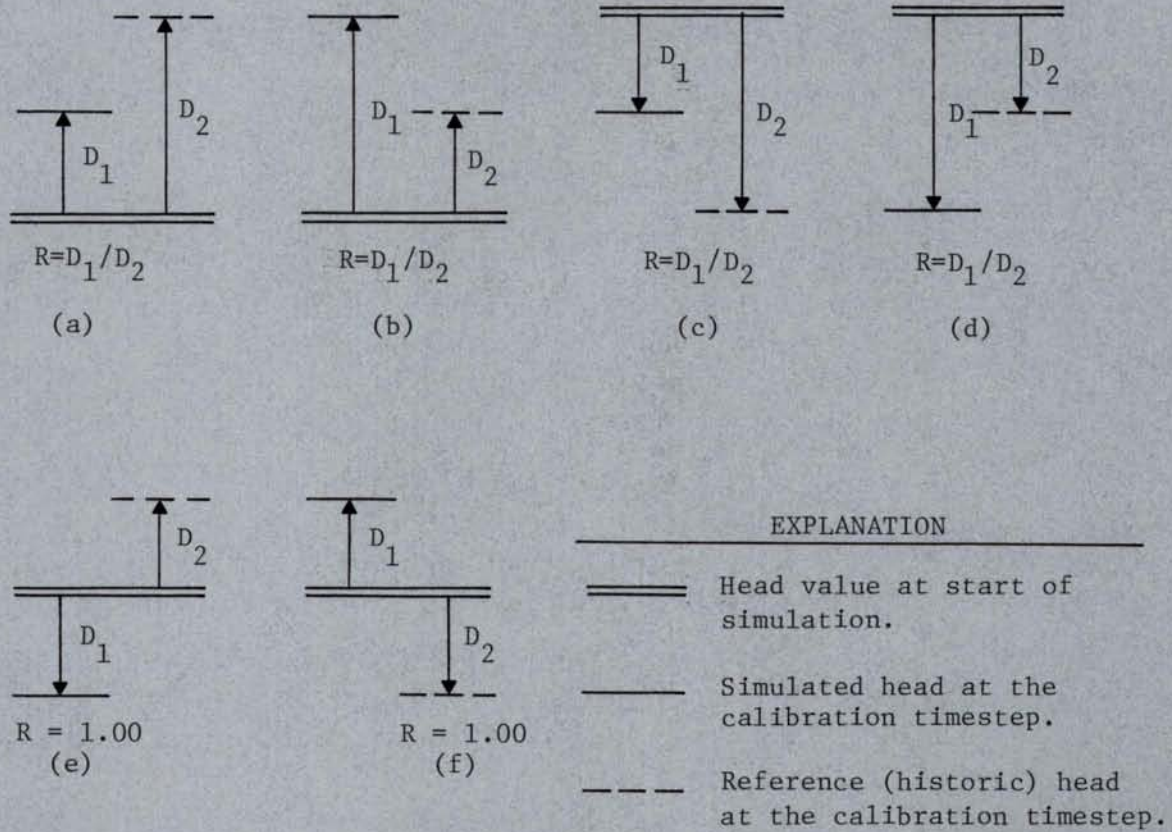


FIGURE 6. Storage coefficient calibration ratios for combinations of reference and simulated head (after deSonneville, 1974).

much as the reference water level. In this case the ratio $R=D1/D2$ is less than 1, resulting in a decrease in the storage coefficient at the particular node. A smaller storage coefficient will have the effect of increasing the simulated head in the next calibration iteration. When the simulated head change from initial is in the opposite direction of the reference head change (fig. 6e&f), the storage coefficient is ineffective and therefore is not adjusted ($R=1$).

APPLICATION TO CONFINED AND UNCONFINED AQUIFERS

The modeled aquifer may be either confined, unconfined, or a combination of the two conditions. The saturated thickness and transmissivity of unconfined aquifers is calculated from the simulated head in each timestep. Nodes in which the aquifer is confined maintain a constant saturated thickness and transmissivity throughout the simulation. When part or all of the modeled aquifer is confined, the value of the variable ICON is input as 1, and the saturated thickness of the confined nodes is input to the array THICK for each node in which the aquifer is confined. A value of 0 for the variable THICK causes the model to treat the aquifer as unconfined at that node. When the aquifer is unconfined at all nodes, the value of ICON is input as 0 and the confined aquifer thickness (THICK) is input as 0 at all nodes.

BOUNDARY CONDITIONS

Two types of boundary conditions are permitted: 1) fixed head, and 2) fixed flux. Fixed-head boundaries include those in which the head is controlled by a river or in which heads are known at all timesteps. Fixed-flux boundaries include situations where underflow is known or

where an impermeable boundary exists. One of the two conditions must be specified for each boundary node according to the following definition of the input variable NOD:

- NOD=0, node is outside model boundaries;
- NOD=1, node is fixed head;
- NOD=2, node is not fixed head and is inside boundaries;
- NOD=3, node is fixed flux.

Fixed-head nodes may be either a boundary, or an interior node in which the head is controlled by hydraulic connection to a river or stream. An example application of the variable NOD to a situation including both types of boundaries and a hydraulically connected river is shown in figure 7. This discussion will pertain exclusively to boundaries; hydraulically connected rivers will be discussed in a following section.

Fixed-head boundaries can be either constant head or have a head which varies in time. Fixed-head boundary nodes are organized into reaches of similar temporal characteristics identified by the input variable NREACH. That is, each reach is composed of nodes which exhibit similar head changes with time. Each fixed-head node must have a value input for NREACH unless the node has constant head. The head change between each timestep is input for each reach in the array DELH. The head of a fixed-head node at any given timestep is the sum of the head at the previous timestep and the DELH of the appropriate reach and timestep (fig. 8).

Use of the fixed-flux boundary requires knowledge of the underflow rates or a no flow condition. Underflow, if it occurs, is externally

(not within the model) added to the surface flux term Q . The boundary is simulated as impermeable, that is, having a transmissivity of zero, one half grid spacing outside of the specified fixed-flux node (NOD=3). Head at fixed-flux boundaries is allowed to vary as calculated in the simulation.

Model boundaries should ideally be established at locations where a natural impermeable boundary exists, or where the head is controlled by an outside influence such as a river. When these conditions cannot be satisfied a calibrated model may not accurately simulate stress conditions which affect head or underflow at the boundaries.

The study area must be surrounded entirely by at least one row or column of inactive nodes (NOD=0).

HYDRAULICALLY CONNECTED RIVERS

Rivers or streams which locally control the water table by gaining and/or losing water are referred to as hydraulically connected and can be modeled as fixed-head nodes. The river surface in these cases is considered to reflect the altitude of the water table.

Hydraulically connected rivers are treated identically to fixed-head boundaries. The river surface may be constant or vary with time. Nodes along the river are identified in the array NOD with a value of 1 (fig. 7). Hydraulically connected nodes with similar temporal changes in water level between timesteps are grouped into reaches (NREACH). Changes in water level with each timestep (DELH) are input for each reach (fig. 8). River gains or losses are calculated for each node and can be output for comparison to actual gains or losses.

Hydraulically connected rivers fix the aquifer head at a series of nodes sometimes extending across the interior of a modeled area. This situation divides the model into two or more pieces where one side is totally independent of the other. The hydraulically connected river nodes provide an unlimited source or sink of water to the aquifer, controlled only by the aquifer heads and hydraulic conductivities of the surrounding nodes.

River head is modeled at the center of a model cell. The elevation of hydraulically connected rivers may therefore need to be adjusted to represent the water table at the center of the cell. For example, if a hydraulically connected river passes 1/2 mile from the center of a cell (grid point), and the water table has an average gradient of 20 ft./mi. perpendicular to the river; then the fixed head of the hydraulically connected node must be adjusted 10 ft. from the river elevation.

MODELING OF SURFACE DRAINS OR INTERMITTENT SPRINGS

The altitude of springs or drains in some cases may be used to establish a maximum ground-water level at the spring or drain location. The water level may drop below the drain altitude during periods of no flow. The model provides a method of establishing a maximum head and calculating the drain discharge. The routine will function for either springs or drains and the term "spring" has been omitted from the following discussion for convenience.

When drains are used in the model to fix the head at one or more nodes the variable IDRAIN is specified as 1 (0 if not used). The

altitude and location of drain-flow nodes, if used, are input in the array DRAIN(I,J). Heads are calculated for drain-flow nodes until the simulated heads exceed the altitude of the respective drains (DRAIN). The head at that node is then reset to the altitude of the drain. The head remains fixed at that level until the simulated heads in the surrounding nodes cause the drain to act as a source of aquifer recharge rather than discharge. At this point the head at the node is no longer fixed, and the drain acts neither as a source of recharge or discharge. Heads are then calculated until they once again exceed the altitude of the drains.

A hydrograph at a drain-flow node is illustrated in figure 9. The hydrograph peaks above the drain altitude since simulated heads must exceed the drain altitude in order to initiate the fixed head. The drain altitude is maintained until the actual head drops below the fixed level resulting in a lag in termination of the fixed head.

INCORPORATION OF RECHARGE AND DISCHARGE FROM LAND SURFACE SOURCES

Aquifer recharge and discharge are input as the array Q, in cubic feet per day, for each node. Negative values represent recharge, positive values represent aquifer discharge. The values may be input in a variety of formats depending upon the situation and specification of the control variable NQ.

When the model is used to simulate steady-state conditions, recharge and discharge remain constant in time, and NQ is input between 1 and 4. When NQ=2 the recharge and discharge are constant for all model nodes and equal to the rate input for variable FLUX. Specifying NQ = 1, 3, or 4 varies the format and input unit from which Q is read. The format and

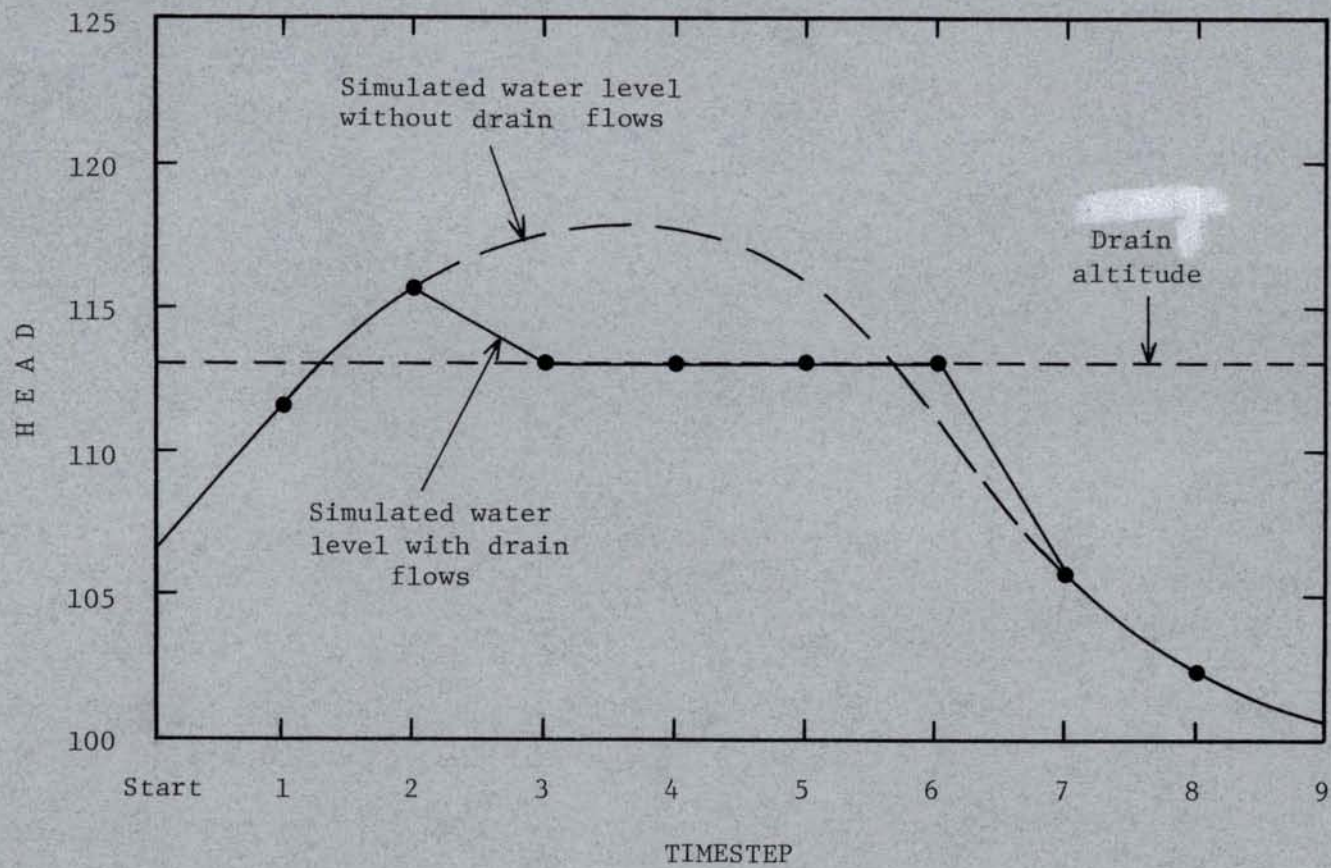


FIGURE 9. Effect of drain-flow on a typical hydrograph.

unit descriptions are given in "University of Idaho Ground-Water Flow Model Input Description."

Transient simulations (NQ=5) require recharge and discharge input for each node and for each timestep. Recharge and discharge (Q) is then input, unformatted, from a separate unit as outlined in "University of Idaho Ground-Water Flow Model Input Description."

PROGRAM OUTPUT

Input data are optionally returned to the primary output unit (M6) by specifying the input variable IPRINT greater than or equal to 1. Entering IPRINT as 0 prevents output of all input arrays and of calculated arrays of aquifer thickness and saturated aquifer thickness. Surface flux (Q), leakage volume (RLEAK), and gains or losses in fixed-head nodes (FL00) are optionally output to unit M6 for each node and timestep by specifying IPRINT as 2. Total volumes of leakage, gains and losses from fixed-head and drain-flow nodes (outflows), surface flux, and change in storage are output as a mass balance for each timestep.

Head values (H) for each grid point are output to unit M6 at a selected number of timesteps (NHEAD). The timesteps of output are input to the THEAD array corresponding in number to the value of NHEAD. NHEAD has a maximum value of 10 and a minimum of 1. If head arrays are not to be output, then NHEAD=1 and THEAD=0.

Head data for the preparation of hydrographs may be output for all timesteps to unit M5 for as many as 9 nodes. The altitudes of the water surface are output in tabular form with the grid coordinates labeled on each column and the timestep labeled on each row.

Depth to water at each node can be output for as many as 3 timesteps, input as TDEP1, TDEP2, and TDEP3. Depth to water will not be output when TDEP1, TDEP2, and TDEP3 are all equal to 0.

When the model is used for parameter calibration several additional items may be output. When IPRINT = 1, reference heads and the difference between reference and initial heads at each node are output in grid format following the rest of the input data (unit M6). The accuracy of the simulated heads with respect to the reference heads is summarized in a table at the end of each calibration iteration. The table includes the "mean error," the "sum of squares," and the "standard deviation" for each reference timestep. The "mean error" is the average of the absolute value of the difference between simulated and reference heads at each node. The "sum of squares" is the sum of the squares of the differences at each node. The "standard deviation" is the square root of the total variance of the difference between the mean error and the absolute value of the error (measured minus simulated head) at each node. The "sum of squares" is totalled for all reference timesteps of a simulation and is used as a measure of calibration accuracy. New parameter values calculated at the end of each calibration simulation are output to unit M6. The optimum values of all calibration parameters are output to unit M6 at the end of a complete run and can be routed to unit M8 for later use.

UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL INPUT DESCRIPTION

Input and output units are represented as variables in the model. Unit numbers are assigned to the variables in the beginning of the main program and may need to be changed when the program is brought up at a

new facility. The input and output variables are defined in table 1.

Table 1. Definition of input and output unit variables.

Variable	Definition
M5	output unit for hydrograph data
M6	primary output unit, usually printer
M7	unit of primary input
M8	output unit of optimum values of calibrated parameters
M9	input unit of recharge and discharge, Q, when NQ=3, 4, or 5

Under the user specified condition of NQ=3, 4, or 5 the unit M9 is used for input of recharge and discharge, Q. The input formats for each of these conditions is given in table 2.

Table 2. Recharge and discharge (Q) input formats.

NQ	Format	Read
3	8F10.0	READ ((Q(I,J),I=1,NCOL),J=1,NROW)
4	unformatted	DO 10 J=1,NROW 10 READ (Q(I,J),I=1,NCOL)
5	unformatted	DO 20 K=BTS,NTS DO 10 J=1,NROW 10 READ (Q(I,J),I=1,NCOL) 20 CONTINUE

Description of the input from unit M6 is presented in the following pages. Some of the input may be omitted as indicated by the "Inpt.

Cond." column. A "mand." condition indicates that the record is required in the data set. Read statements enclosed in loops are surrounded by a box of "+" symbols.

UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL INPUT DESCRIPTION

<u>Record</u>	<u>Inpt. Cond.</u>	<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Definition</u>
1	mand.	1-80	20A4	TITLE	simulation title
2	mand.	1-80	20A4	TITLE	simulation title continued
3	mand.	1-5	I5	NCOL	number of grid columns
		6-10	I5	NROW	number of grid rows
		11-15	F5.2	DELT	initial time interval (days)
		16-25	F10.2	DELX	grid interval (ft)
4	mand.	1-5	I5	IPRINT	output specification: =0, minimum output =1, outputs most important data, including all input =2, detailed output including recharge/discharge and outflows at each timestep
					6-10
		11-15	I5	ICON	specifies use of confined aquifer: =0, no confined areas present within model =1, all or part of the area is confined
		16-20	I5	IDRAIN	specifies use of drains =0, no drain nodes present =1, drains are present
					21-25
		26-30	I5	TDEP2	timestep number of second depth to water output, 0 if not used
		31-35	I5	TDEP3	timestep number of third depth to water output, 0 if not used
		36-40	I5	IFPNCH	specifies output of optimum values of calibration parameters: =0, no values are output =1, values of all calibrated parameters are output to unit M8

UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL INPUT DESCRIPTION

<u>Record</u>	<u>Inpt. Cond.</u>	<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Definition</u>
		41-45	I5	ICALB	specifies use of calibration routines =0, calibration is not performed =1, calibration is executed
		46-50	I5	NHYDRO	specifies the number of nodes in which heads are output for hydrographs, NHYDRO=0 if not used
5	mand.	1-5	I5	NHEAD	number of timesteps in which head is output at each node, value must be 1,2, or 3
		6-10	I5	BTS	beginning timestep number
		11-15	I5	LTS	last timestep before doubling timestep length (>NTS if not used)
		16-20	I5	NTS	final timestep number
		21-25	I5	NRIVER	number of hydraulically connected river reaches (=0 if not used)
6	mand.	1-5	I5	NQ	specifies transient or steady state simulation and type of input for aquifer recharge or discharge, Q =1, steady state, reads I,J,Q(I,J) from unit M7 =2, steady state, constant flux, Q(I,J)=FLUX for all I,J =3, steady state, reads formatted Q(I,J) for each node from unit M9 =4, steady state, reads unformatted Q(I,J) for each node from unit M9 =5, transient state, reads Q(I,J) for each node and timestep from unit M9
		6-15	F10.0	FLUX	value of constant aquifer recharge (-) or discharge (+) to or from the surface at each node when NQ=2 (ft ³ /day)
		16-20	F5.2	MU	multiplier used to change all recharge or discharge to the surface by a constant factor, MU=1 if not used
7	mand.	1-15	3I5	THEAD(K) (K=1,NHEAD)	timesteps in which head distributions are output

UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL INPUT DESCRIPTION

<u>Record</u>	<u>Inpt. Cond.</u>	<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Definition</u>
8	NHYDRO>0	1-72	9(I3, I3,2X)	IH(K),JH(K), (K=1,NHYDRO)	grid locations of hydrograph data to be output to unit M5
9	ICALB=1	1-5	F5.2	VP	calibration dampening factor ranging from 0 to 1, small values of VP result in a more refined calibration but require a greater number of iterations to achieve convergence
		6-10	I5	NVA1	NVA1 and NVA2 are limits and NVA3 is the step in a DO LOOP used to specify the parameters to be calibrated in which NVAR is the index variable: NVAR=NVA1,NVA2,NVA3 where NVAR=1, hydraulic conductivity (KX) is calibrated NVAR=2, leakage factor (FAC) is calibrated NVAR=3, initial head difference (LKDIFF) for leakage is calibrated NVAR=4, storage coefficient (S) is calibrated
		11-15	I5	NVA2	
		16-20	I5	NVA3	
		21-25	I5	NSTOP	
		26-30	I5	ITE	number of calibration iterations of each parameter
		31-35	I5	TCALIB	reference timestep used for calibration (TCALIB=3 refers to the third reference timestep)
		36-40	I5	NREF	number of reference timesteps
		41-75	7I5	TREF(K) (K=1,NREF)	timestep numbers of reference timesteps
10	ICALB=1	1-10	F10.2	SMIN	minimum value of storage coefficient permitted in calibration
		11-20	F10.2	SMAX	maximum value of storage coefficient permitted in calibration
		21-30	F10.2	KMIN	minimum value of hydraulic conductivity permitted in calibration (ft/day)
		31-40	F10.2	KMAX	maximum value of hydraulic conductivity permitted in calibration (ft/day)

UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL INPUT DESCRIPTION

<u>Record</u>	<u>Inpt. Cond.</u>	<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Definition</u>
		41-50	F10.2	FMIN	minimum value of leakage factor (FAC) permitted in calibration (1/day)
		51-60	F10.2	FMAX	maximum value of leakage factor (FAC) permitted in calibration (1/day)
		61-70	F10.2	LKMIN	minimum value of initial leakage head difference permitted in calibration (ft)
		71-80	F10.2	LKMAX	maximum value of initial leakage head difference permitted in calibration (ft)

```

+++++++REPEAT record 11 for each fixed head (hydraulically connected) node ++++++
+11 NRIVER>0 1-2 I2 I column +
+ 3-5 I3 J row +
+ 6-8 I3 NREACH(I,J) reach identification number assigned to each fixed head +
+ (hydraulically connected) node +
+ 9-11 I3 LAST flag indicating end of NREACH data (LAST=99) +
+++++++

```

```

+++++++REPEAT record 12 for each fixed head reach (K=1,NRIVER) ++++++
+ 12 NRIVER>0 1-75 15F5.0 DELH(K,I) change in head of each fixed head reach (hydraulically +
+ (I=BTS,NTS) connected) for each timestep (ft) +
+++++++

```

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+++++++REPEAT record 13 for each drain flow node ++++++
+ 13 IDRAIN>0 1-2 I2 I column +
+ 3-5 I3 J row +
+ 6-10 I5 DRAIN(I,J) elevation of drain in given node (ft) +
+ 11-13 I3 LAST flag indicating end of file (LAST=99) +
+++++++

```

UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL INPUT DESCRIPTION

Inpt. Record	Cond.	Columns	Format	Variable Name	Definition
+++++REPEAT record 14 for each node with surface flux when NQ=1 +++++					
+ 14	NQ=1	1-2	I2	I	column
+		3-5	I3	J	row
+		6-15	F10.0	Q(I,J)	aquifer recharge (-) or discharge (+) from or to the surface in steady state (ft ³ /day)
+		16-17	I2	LAST	flag indicating end of flux data (LAST=99)
+++++					
+++++REPEAT record 15 for each grid row beginning with the top row (J=NROW,1) +++++					
+ 15	mand.	1-78	13F6.1	KX(I,J)	hydraulic conductivity of each node along a row (ft/day)
+				(I=1,NCOL)	
+++++					
+++++REPEAT record 16 for each grid row beginning with the top row (J=NROW,1) +++++					
+ 16	IFAC=1	1-80	10F8.6	FAC(I,J)	leakage factor for each node along a row, equal to the vertical hydraulic conductivity of the impeding layer divided by twice the thickness of the impeding layer, if no leakage FAC=0 (1/day)
+				(I=1,NCOL)	
+++++					
+++++REPEAT record 17 for each grid row beginning with the top row (J=NROW,1) +++++					
+ 17	IFAC=1	1-72	18F4.0	LKDIFF(I,J)	initial head difference between the modelled aquifer and the overlying or underlying aquifer, modelled aquifer minus the adjacent system (ft)
+				I=1,NCOL	
+++++					
+++++REPEAT record 18 for each grid row beginning with the top row (J=NROW,1) +++++					
+ 18	mand.	1-75	15F5.4	S(I,J)	storage coefficient for each node along a row
+				(I=1,NCOL)	
+++++					

UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL INPUT DESCRIPTION

Record	Inpt. Cond.	Columns	Format	Variable Name	Definition
+++++REPEAT record 19 for each node where temporary changes in the hydraulic conductivity are desired+					
+ 19	mand.	1-2	I2	I	column
+		3-5	I3	J	row
+		6-10	F5.0	KX(I,J)	trial value of hydraulic conductivity (ft/day)
+		11-13	I3	LAST	flag indicating end of trial values of hydraulic conductivity (LAST=99)
+++++					
+++++REPEAT record 20 for each active node within the study boundaries +++++					
+ 20	ICALB=1	1-3	I3	LAST	flag indicating end of data (LAST=99)
+		4-6	I3	I	column
+		7-9	I3	J	row
+		10-12	I3	NOD(I,J)	identifier of node type
+					=0, node is outside model boundaries
+					=1, node is fixed head (hydraulically connected)
+					=2, just your plain, old, basic node inside model boundaries
+					=3, fixed flux boundary is located one half grid spacing outside this node
+		13-17	I5	THICK(I,J)	thickness of <u>confined</u> aquifer:
+					=0, aquifer at this node is unconfined
+					=1, aquifer at this node is confined with a thickness equal to THICK(I,J) (ft)
+		18-22	I5	SURF(I,J)	elevation of land surface (ft)
+		23-27	I5	BOTTM(I,J)	elevation of the bottom of the aquifer (ft)
+		28-33	F6.1	HINITL(I,J)	elevation of the potentiometric surface at the beginning of the simulation (ft)
+		34-51	3F6.1	HREF(I,J,K)	known elevations of the potentiometric surface corresponding to (K=1,NREF) reference timesteps (TREF(1-3)) (ft)
+++++					

UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL INPUT DESCRIPTION

Record	Inpt. Cond.	Columns	Format	Variable Name	Definition
+++++REPEAT record 21 for each active node within study boundaries +++++					
+ 21	ICALB=0	1-3	I3	LAST	flag indicating end of data (LAST=99)
+		4-6	I3	I	column
+		7-9	I3	J	row
+		10-12	I3	NOD(I,J)	identifier of node type
+					=0, node is outside model boundaries
+					=1, node is fixed head (hydraulically connected)
+					=2, just your plain, old, basic node inside model boundaries
+					=3, fixed flux boundary is located one half grid spacing
+					outside this node
+		13-17	I5	THICK(I,J)	thickness of <u>confined</u> aquifer:
+					=0, aquifer at this node is unconfined
+					=1, aquifer at this node is confined and the thickness is
+					equal to THICK(I,J) (ft)
+		18-22	I5	SURF(I,J)	elevation of land surface (ft)
+		23-27	I5	BOTTM(I,J)	elevation of the bottom of the aquifer (ft)
+		28-33	F6.1	HINITL(I,J)	elevation of the potentiometric surface at the beginning of
+					the simulation (ft)
+++++					

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STAPLES BOND

RECHARGE PROGRAM

DESCRIPTION

PURPOSE

Input to numerical ground-water flow models usually includes an array or arrays representing aquifer recharge and discharge. Recharge and discharge must be determined for each grid cell and for each timestep of a transient simulation. The purpose of the RECHARGE program is to calculate and sum recharge and discharge from several factors into a single term for each cell and timestep. All factors included in the calculations must be independent of aquifer head.

CAPABILITIES

The program calculates aquifer recharge and discharge resulting from the following sources:

- 1) seepage from irrigation canals,
- 2) percolation from surface-water supplied irrigation,
- 3) withdrawals for irrigation pumping,
- 4) percolation from precipitation,
- 5) gains and losses in rivers and lakes,
- 6) ground-water pumping other than irrigation, and
- 7) underflow across study boundaries.

Evapotranspiration is calculated and used in the determination of percolation from irrigation and precipitation, and also in determination of ground-water pumping for irrigation. Soil moisture retention is included in calculation of recharge resulting from irrigation and precipitation.

Recharge and discharge are determined for each cell of a rectangular grid. When data are needed for multiple timesteps (for a transient model application) the program will generate a recharge or discharge value for

each timestep and grid cell. The recharge and discharge at each timestep may also be summed to produce a total for input to a longer term steady-state simulation.

ALGORITHM DESCRIPTION

This section describes the calculation of aquifer recharge and discharge resulting from each of the factors listed above. Capital letters are used to identify variable and subroutine names used in the computer program (except ET used as an abbreviation for evapotranspiration). Variables written in lower case letters are created to simplify the discussion and do not refer to specific variables within the program. Variable subscripts indicating grid location and timestep have been omitted for simplicity.

The total recharge and discharge, Q, for any given cell, is the sum of the eight basic factors in the following equation:

$$Q = \text{SEEP} + (\text{irr} + \text{rain} - \text{ET} - \text{soil}) + \text{WELL} + \text{RIVER} + \text{UNDER} \quad (25)$$

where

SEEP = canal seepage,

irr = surface water irrigation,

rain = precipitation,

ET = evapotranspiration,

soil = change in soil water content,

WELL = pumping withdrawals,

RIVER = river gains or losses,

UNDER = ground-water underflow.

The program main routine calls subroutines once each timestep to calculate factors on the right hand side of equation (25) for each grid cell. The factors enclosed in parentheses are used in a water balance in which excess is assumed to be aquifer recharge. The remaining factors, not enclosed in parenthesis, act independently of all other factors in the equation. A schematic of the basic calculations is shown in figure 10.

Factors of equation (25) which represent aquifer recharge are considered positive, those representing discharge are negative. The sign convention of the output values of the total flux, Q , is specified by the user in the variable ISIGN, as outlined in "RECHARGE Program Input Description."

Calculation of Irrigation Percolation

The method of calculation of aquifer recharge and discharge resulting from irrigation depends upon the source of the irrigation water. Irrigation based on a surface water supply exerts no demand on the ground water, and application in excess of crop consumptive use (evapotranspiration) contributes to aquifer recharge. Irrigation supplied by ground-water pumping results in net ground-water withdrawals equal to the crop consumptive use. Surface and ground-water irrigation are treated differently within the RECHARGE program.

A water balance is maintained for ground-water irrigated areas within each cell. The consumptive use of the crop is balanced against precipitation, irrigation application, and changes in soil moisture. The irrigation season begins and ends on dates input by the user (IMSTRT, IDSTRT, IMEND, IDEND). Crop consumptive use is balanced only by

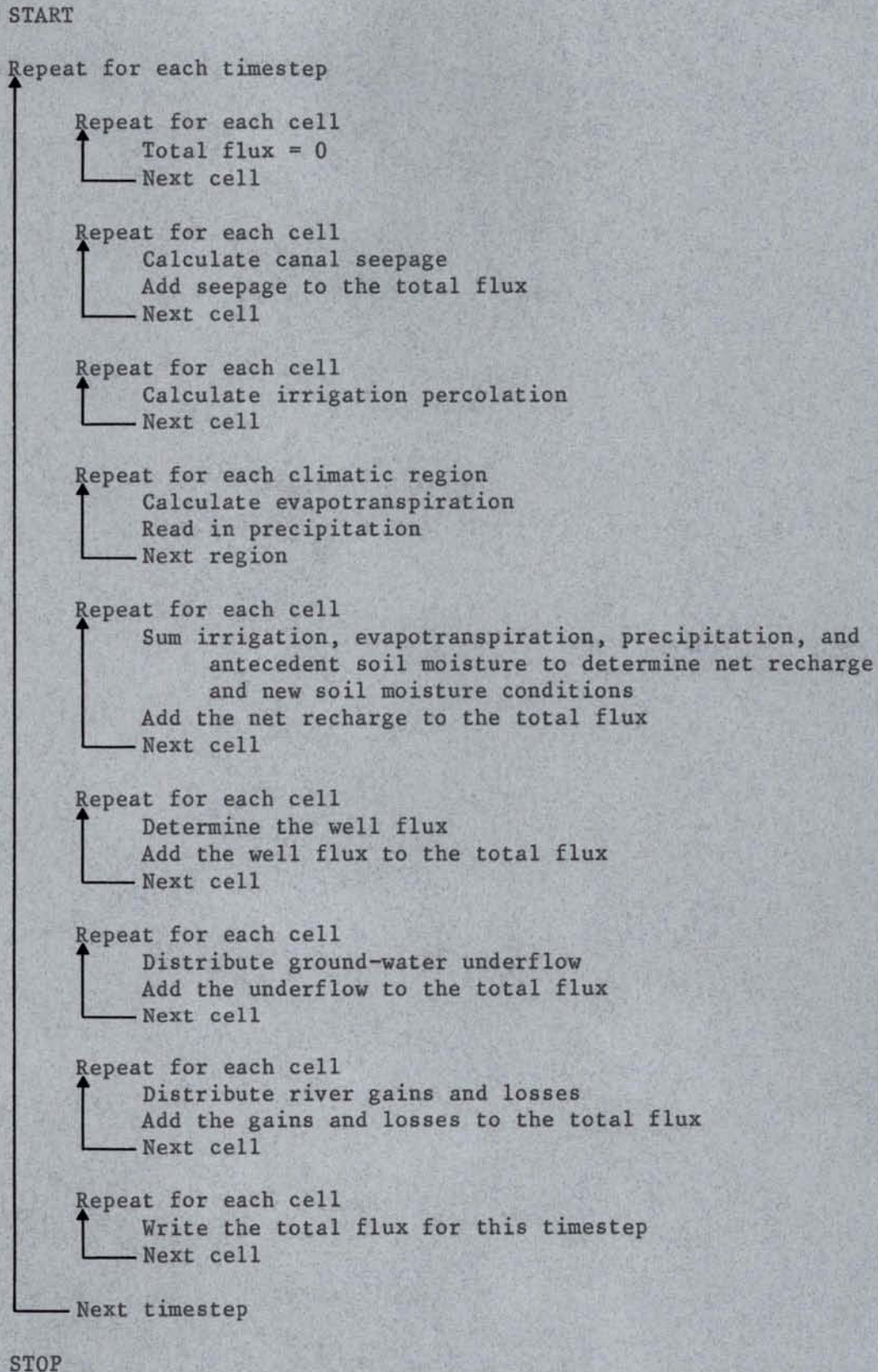


FIGURE 10. Generalized flow diagram of the RECHARGE program.

precipitation and depletion of available soil moisture during the non-irrigation season. As soon as the irrigation season begins, ground-water withdrawals are created to replenish the soil moisture deficit (return to field capacity), and together with precipitation, meet the crop consumptive use. Crop consumptive use is balanced throughout the specified irrigation season by ground-water withdrawals and precipitation.

Local ground-water pumping for irrigation is calculated within the program and should not be input as the WELL term. These calculations require input data on the ground-water irrigated area in each cell, GWIRAC, and related weather data described later in this section. Calculations are performed in SUBROUTINE RCHRG. The subject is discussed further in "Calculation of the Moisture Balance."

A water balance within each node is also maintained for surface-water irrigated areas. In this case, crop consumptive use is balanced against precipitation, calculated irrigation applications, and changes in soil moisture. When the last three factors exceed crop consumptive use aquifer recharge occurs.

The irrigation application rate on surface-water irrigated areas is calculated for designated irrigation projects. Projects refer to either irrigation companies or districts. The application rate is calculated by evenly distributing net diversions over the total irrigated area of the project. Net diversions are calculated within the program as the project diversions minus canal seepage and return flow. This results in a uniform application rate for all irrigated lands associated with a given project. Surface-water irrigated areas (ACRES) must be input for each

cell and identified by project (PROJ).

Diversions and return flows of each project (DIVERS, RETFLO) must be input for each timestep. The procedure for calculation of the surface-water irrigation application in each cell is illustrated by figure 11. The resulting water volume, IRR, is used in the water balance for surface-water irrigated areas in that cell. The calculation of irrigation applications is performed in SUBROUTINE IRRIG and the water balance and resulting aquifer recharge are determined in SUBROUTINE RCHRG.

If irrigation diversions or return flows are not known for a project or projects, they may be grouped together as a single project having an unknown irrigation application rate. The application rate for this "unknown" project will not be uniform over the entire study area, but will vary from one cell to the next. The unknown rate within a given cell is calculated as the average application rate of other surface-water irrigated areas within the cell. If no other surface-water irrigated areas are present within the cell, the average rate of the entire study area is applied. The project number associated with unknown diversions and return flows is input as the variable NONAME.

Changes in the size of irrigated areas during a simulation are permitted to a limited extent. One change in ground-water irrigated area and one change in surface-water irrigated area are allowed in each cell. The new areas are input in the variables GWACNW and ACRENW. The timestep in which the areas become effective are input in GWSTNW and STPNW. The project in which the change in surface-water irrigation occurs is identified in the input variable PROJNW. If no changes occur in the

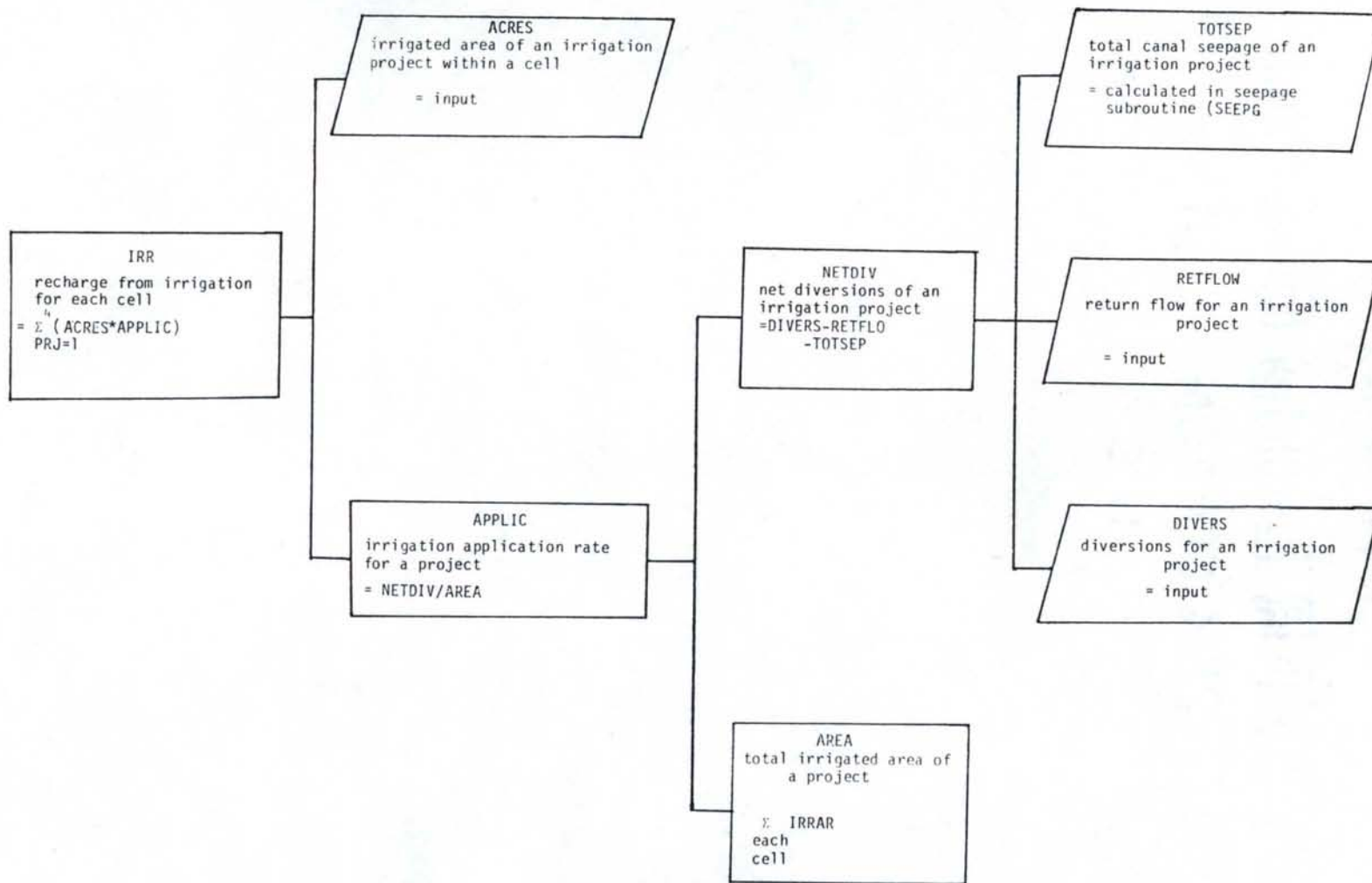


FIGURE 11. Illustration of determination of irrigation application.

node, no input for the associated variables is required.

If no irrigation is present within the study area input and calculations relative to irrigation can be omitted by specifying OIRRIG = 0. This will also omit all input and calculations related to canal seepage.

Determination of Canal Seepage

Canal seepage is determined as the product of three factors: 1) wetted canal area, 2) infiltration rate of the canal bottom, and 3) a factor representing changes in the infiltration rate resulting from either a change in canal operation or in the condition of the canal bottom. The product is calculated for canals of each irrigation project present within a cell. The products determined for each project are summed to yield the canal seepage for the entire cell. The basic procedure for calculation of the seepage for a single cell and timestep is represented by the following equation:

$$SEEP = (WETAR * RATE * ADJST) \quad (26)$$

where

WETAR= wetted canal area of an irrigation project within a cell,

RATE= infiltration rate of the seepage zone containing the cell,

ADJST= factor accounting for changes in canal operation with time for each irrigation project.

The wetted canal area is input for each irrigation project operating canals within a cell. A maximum of four projects are permitted within a cell. If the irrigation diversions are equal to zero for any timestep

and project, then the seepage for all canals associated with that project is equal to zero for that timestep.

The infiltration rate of the canal bottom is not constant, but changes with location and time. Values input for the infiltration rate (RATE) adjust for changes due to location. A seepage zone is assigned to cells having similar soil and bottom characteristics. A seepage rate is specified for each zone based on measurements or estimates of soil properties. A maximum of ten seepage zones are allowed.

The adjustment factor, ADJST, accounts for changes with respect to time. The adjustment factors should be based on changes in infiltration rate resulting from changes in bottom conditions, water depth in the canal, and the percentage of time the canal remains full during any given timestep. The adjustment factor is input for each irrigation project and timestep.

Canal wetted areas and adjustment factors must also be input for the irrigation project with unknown diversions and return flows (NONAME).

A change in the canal wetted area can be implemented for one irrigation project within each cell. The project code (PRJNEW), new wetted area (NEWAR), and the timestep in which it becomes effective (STPNEW), are specified in the input if changes are to be effected.

Calculations of recharge from canal seepage are performed in SUBROUTINE SEEPG. Calculation of canal seepage can be omitted by specifying OIRRIG=0, which also omits irrigation calculation.

Calculation of Evapotranspiration

Ground-water models may include a large area with a variety of weather conditions and agricultural practices. The program therefore allows the breakdown of the study area into climatic regions. Within any region it is assumed that the weather and crop management is uniform. Each cell must be assigned to a climatic region. A maximum of 20 regions is permitted.

Evapotranspiration (ET), or consumptive use, is determined individually for irrigated (ETIRR) and non-irrigated (ETDRY) areas of each region for each timestep. The actual ET for either of these conditions is the product of a calculated reference ET and an empirical crop or vegetation coefficient. The calculation of the ET is illustrated in figure 12. The diagram shows calculations for a single climatic region and timestep.

A modification of the Blaney-Criddle method is used to calculate reference ET (equation 27). The method, taken from Doorenbos and Pruitt (1977), determines ET from grass (grass-based reference ET) under ideal management and the specified weather conditions. The grass-based reference ET is then multiplied by 1.15 to convert to an alfalfa-based ET for use with crop coefficients based on an alfalfa reference. Actual alfalfa ET is usually less than calculated due to effects of disease, windrowing, and other management factors. The calculated alfalfa reference ET is therefore multiplied by the ratio of typical alfalfa yields to potential yield, resulting in the actual alfalfa ET. Typical and potential yield may be assumed to be the average and maximum yields in the area.

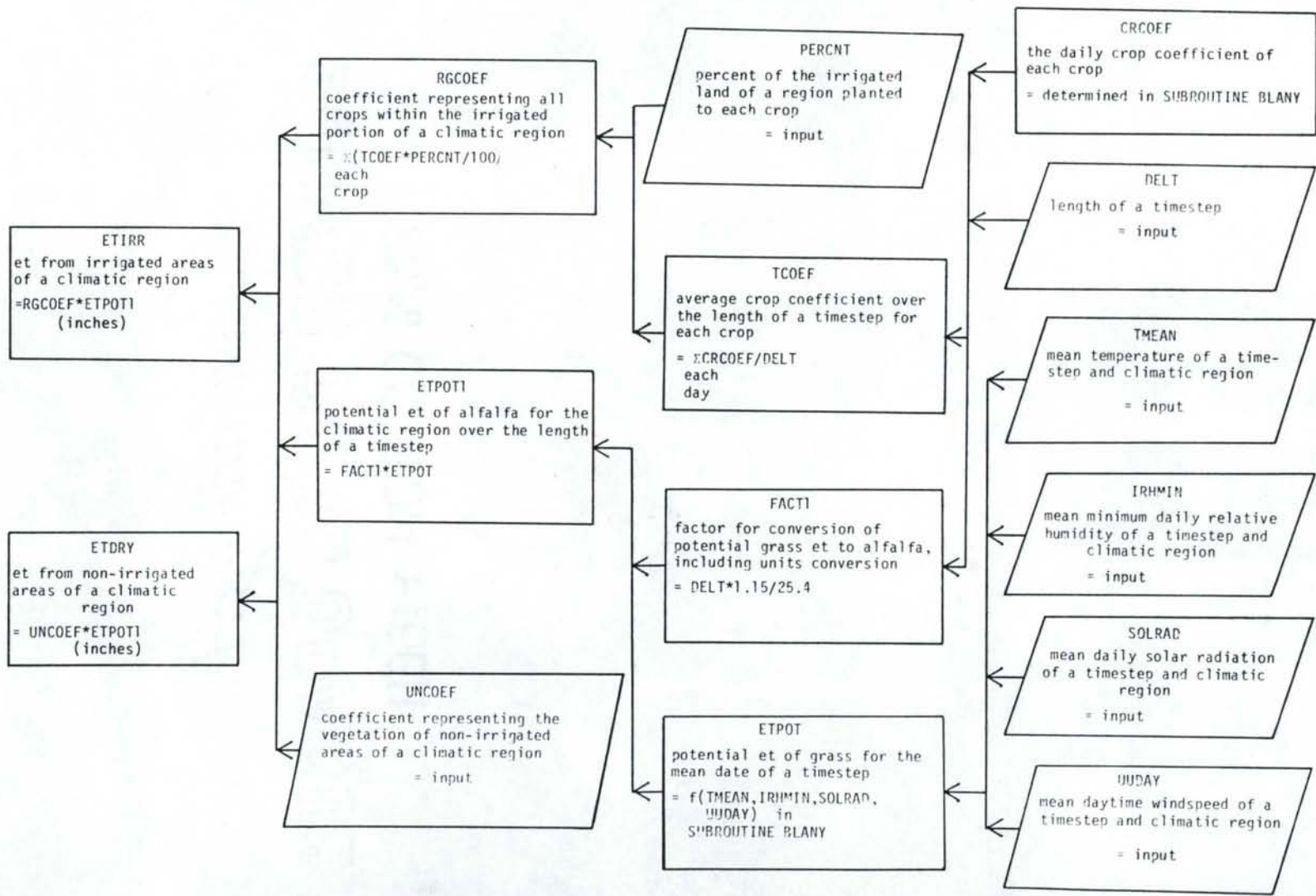


FIGURE 12. Illustration of the calculation of evapotranspiration.

$$ET = a + b * p * (0.46 * t + 8.13) \quad (\text{mm/day}) \quad (27)$$

where

ET= reference crop ET (grass),

t= mean daily temperature in °C,

p= mean daily percentage of total annual daytime
hours for a given month and latitude,

a,b= adjustment factors based on minimum relative
humidity, sunshine hours, and daytime wind
estimates.

The above equation is reduced to its simplest form, and therefore the variable names and equation do not match those used in the program. The equation requires a mean temperature for each timestep based on actual temperature measurements, not estimates or long-term averages. Measured values of minimum humidity, solar data, and daytime wind (7 am to 7 pm) should be used if available, otherwise the best available estimates should be applied. Solar radiation, incident to a flat surface, is input in langleys/day and converted within the program to sunshine hours for use in the equation.

The reference ET is calculated for the mean date of each timestep. This imposes restrictions on the length of the timestep. Timesteps longer than one month may produce a reference ET that does not yield an accurate estimate of actual ET for the period when multiplied by an average crop coefficient. If estimates of the three secondary parameters (wind, solar, and humidity) are used, a timestep may also be too small. That is, actual short-term conditions may greatly deviate from long-term averages used to produce the original estimates. Doorenbos and Pruitt (1977) state that periods should not be less than one month when

estimates are used. If all parameters are measured on a daily basis the minimum length of timestep is reduced to one day.

The crop, or vegetation coefficient is used to adjust the actual alfalfa reference ET to represent the average ET for the area. Coefficients for non-irrigated areas (UNCOEF) must be estimated and input for each climatic region and timestep. Crop coefficients for irrigated areas (RGCOEF) are calculated within the program. They are calculated for each climatic region as the average of the coefficients for all crops within the region, weighted according to the percent of irrigated area they occupy. Any of the following nine crops may be specified: 1) alfalfa, 2) beans, 3) corn, 4) pasture, 5) peas, 6) potatoes, 7) sugar beets, 8) spring grain, and 9) winter grain. The coefficient of an individual crop for a timestep is the average of the daily values over the length of the timestep. The daily values are determined in SUBROUTINE CROPC, written by R.G. Allen of the University of Idaho, using crop coefficients reported by Wright (1982). The coefficients are illustrated in figure 13, which shows the variation of the coefficients of several crops over the growing season. The coefficients were obtained from data collected at the Snake River Conservation Research Center, SEA, USDA, at Kimberly, Idaho. Coefficients obtained from other sources or for other crops could be substituted into the program.

The ET determined for both irrigated and non-irrigated parts of each region is used later with irrigation and precipitation in the determination of a water balance (SUBROUTINE RCHRG).

Calculation of ET and the corresponding input can be bypassed by appropriate specification of the input variable OEVAP. An input value of

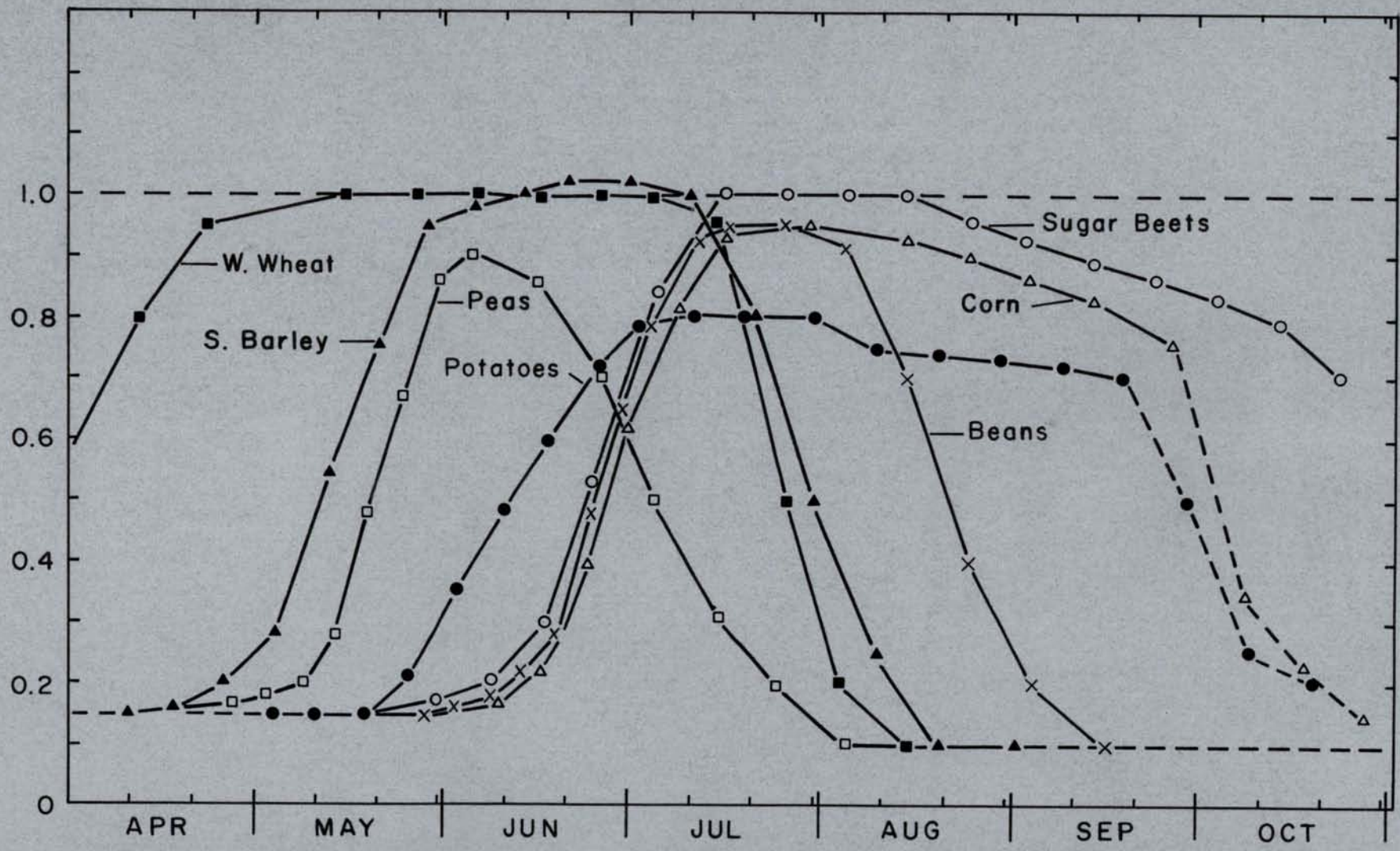


FIGURE 13. Variations of alfalfa based crop coefficients over the growing season (from Wright, 1982).

0 bypasses all calculations and causes ET to be 0 in all cells. A value of 1 results in calculation according to the above description. A value of 2 requires input of ET for each cell and timestep according to the format given in "RECHARGE Program Input Description."

Application of Precipitation Data

Precipitation is input for each climatic region and timestep. If precipitation is in the form of snow, it may be more desirable to input snowmelt rather than snowfall water equivalent. This term is used along with irrigation and ET in SUBROUTINE RCHRG to determine a moisture balance.

Calculation of the Moisture Balance

The unsaturated soil profile may act as a temporary water storage unit. Changes in soil moisture affect the amount of recharge reaching the aquifer from precipitation, ET, and irrigation. The purpose of SUBROUTINE RCHRG is to account for changes in soil moisture in determination of the actual recharge to the aquifer from these sources.

A moisture balance is maintained separately for three types of areas: 1) non-irrigated, 2) surface-water irrigated, and 3) ground-water irrigated. All three types may be present within a single cell. The recharge or discharge within a cell resulting from precipitation, irrigation, and ET is the sum of the flux from all three areas within the cell. The calculation of the net recharge for each area is illustrated by figure 14 for a single cell and timestep.

A water balance of surface-water irrigated areas is kept between irrigation (IRR), precipitation (RAIN), and evapotranspiration (ETIRR).

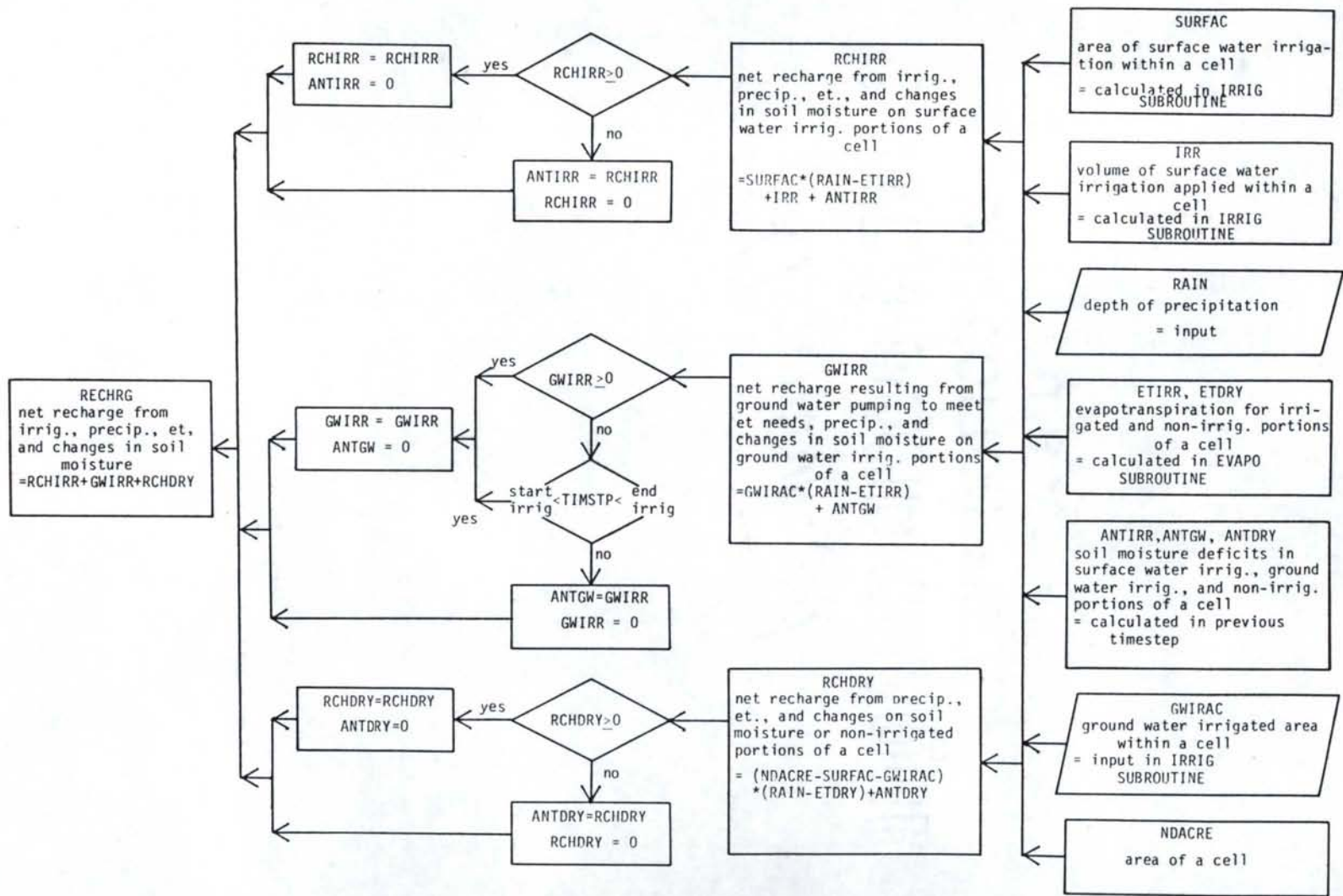


FIGURE 14. Illustration of the calculation of water balances.

If ET exceeds the sum of irrigation and precipitation then the soil moisture deficit is increased by an equivalent amount. The program calculates the soil moisture deficit, not content, therefore a value of zero represents soil at field capacity. If precipitation plus irrigation exceed evapotranspiration, the excess replenishes the soil moisture and reduces the deficit. When a deficit no longer exists the excess recharges the ground water. The soil moisture deficit calculated in a timestep is maintained as the antecedent condition of the soil in the succeeding timestep.

A similar balance is kept for non-irrigated areas. The difference being that irrigation is not included in the balance, and the ET from non-irrigated areas (ETDRY) is used in place of ET for irrigated areas. Again recharge is determined as the excess once the soil profile has reached field capacity. The soil moisture deficit for non-irrigated areas is also determined on a cell by cell basis and carried into the next timestep.

A moisture balance is also kept on ground-water irrigated areas although the procedure is somewhat different. A balance is maintained between precipitation and irrigated ET (ETIRR). If the precipitation exceeds ET, the excess replenishes the soil moisture deficit. When no deficit exists the remainder recharges ground water. If the evapotranspiration exceeds precipitation, one of two things may occur. During the winter, when no irrigation occurs, the soil moisture deficit is increased an equivalent amount. If, however, the situation occurs during the specified ground-water irrigation season, the excess, along with any soil moisture deficit, is withdrawn from ground water. This applies the assumption that ground-water irrigation will be sufficient to

supply crop demands, and any excess application will be immediately returned to the ground water by means of percolation.

Any moisture deficit created within the soil will have to be filled before recharge can take place in that area. The maximum moisture deficit is considered to be the available water-holding capacity of the root zone. Evapotranspiration which would dry a soil beyond the available water holding capacity is not considered effective. The total available water-holding capacity of the root zone is input for each climatic region (CAPCTY).

The calculation of the moisture balance can be bypassed by specifying ORECH=0. This results in elimination of all recharge and discharge from irrigation and precipitation.

Ground-Water Pumping

A ground-water pumping term is included to represent any known point withdrawals or recharge sources by specifying OWELL=1. Most commonly it is used to represent pumping withdrawals other than those determined automatically for ground-water irrigated areas. It may, however, be applied to situations such as irrigation pumping from beneath a confining layer, known seepage losses from a lake, or other circumstances where recharge and discharge are known on a cell by cell basis. Negative values represent withdrawals from the the ground water, and positive values represent recharge. Values for WELL are input for every timestep for each cell in which they occur.

Application of River Gains and Losses

Gains or losses from rivers or creeks (RIVER) are included by specifying the input variable ORIVER=1. Streams are divided into reaches based on the assumption of equal gains or losses in each cell along the reach. The total gains or losses along each reach must be input for each timestep. A river reach value must be assigned to every cell. Cells not containing rivers are assigned a value of zero. The gains or losses within a cell are equal to the total gains or losses for the reach divided by the number of cells in the reach. A maximum of 20 reaches are allowed. Calculations are performed in SUBROUTINE FLOWS.

Application of Ground-Water Underflow

Ground-water underflow (UNDER) may be included in the total flux by specifying the input variable OUNDER=1. The situation is handled identically to the river gains and losses. Boundary cells with equal amounts of underflow are grouped into reaches. A reach must be assigned to every cell. Cells not using the underflow calculation are assigned a reach number of zero. The underflow for a given cell is equal to that of the entire reach divided by the number of cells in the reach. A maximum of 20 reaches is allowed. Underflow calculations are performed in SUBROUTINE FLOWS.

LIMITATIONS AND ASSUMPTIONS

The program, although general, is limited by physical conditions and assumptions. A list of the major limitations and assumptions follows.

- 1) Recharge occurs in the same timestep as application, that is, no time is provided for movement through the unsaturated zone.

- 2) No significant lateral flow occurs above the water table in the unsaturated region.
- 3) The aquifer is unconfined (unless inputs are adjusted accordingly).
- 4) Ground-water irrigation occurs at rates sufficient to meet crop demands.
- 5) Ground-water irrigation occurs only between the dates specified by the user.
- 6) Irrigation supplies sufficient water to allow crops to transpire at their potential.
- 7) Irrigation application rates within a project are uniform.
- 8) Weather, agricultural practices, and soil properties are constant within a climatic region.
- 9) No significant amount of crops other than alfalfa, winter and spring grain, sugar beets, beans, peas, corn, potatoes, or pasture is grown.
- 10) The crop coefficients determined at Kimberly, Idaho are representative of the study area.
- 11) Evapotranspiration from alfalfa is proportional to yield.
- 12) The length of a timestep is neither too long nor too short to cause errors in the calculation of ET, according to the criteria described in "Algorithm Description."
- 13) Precipitation does not result in runoff.
- 14) River or creek gains or losses are uniform along a specified reach.
- 15) Underflow is uniform along a specified reach.

Deviations from the above assumptions require appropriate changes within the program.

DATA REQUIREMENTS

A list of data required for calculation of each component of the flux term is as follows:

<u>Factor</u>	<u>Input Condition</u>	<u>Data Required</u>
Seepage	OIRRIG =1	<ol style="list-style-type: none"> 1) Determine canal area (length*width*curvature factor) and ownership of all canals in each cell. 2) Determine seepage zones, and seepage rates associated with each zone, based on canal bottoms and soil descriptions. 3) Determine changes in seepage with time based on canal operation and bottom conditions.
Irrig.	OIRRIG =1	<ol style="list-style-type: none"> 1) For irrigation with surface-water sources: <ol style="list-style-type: none"> a) Determine diversions and return flows for each irrigation project. b) Determine irrigated area of each project within each cell. 2) For ground-water irrigated areas <ol style="list-style-type: none"> a) determine the total ground-water irrigated area within each cell. b) Determine the average beginning and ending dates of ground-water irrigation for the season.
ET	OEVAP =1	<ol style="list-style-type: none"> 1) Outline climatic regions based on uniformity of climate, agricultural practices, and soil properties. 2) Estimate coefficients relating ET from non-irrigated areas to alfalfa for each region. 3) Determine the major crops in each region and the percentage of agricultural area planted to each crop. 4) Determine typical values for dates of planting, cover, and harvest of each crop. 5) Determine number and dates of alfalfa cuttings, maximum potential yield, and typical yield. 6) Determine the mean latitude of the modeled area. 7) Determine the mean temperature for each timestep, based on daily measurements. 8) Determine the average minimum daytime humidity, the average daily solar radiation, and the average daytime windspeed, for each region and timestep. If possible, the determinations should be based on measurements, otherwise use historic averages. 9) If a different method of ET calculation is preferred, ET can be input directly by specifying OEVAP=2.
Precip.	ORECH	<ol style="list-style-type: none"> 1) Determine the average total precipitaton for each region and timestep. Snowmelt should be used during winter periods.
Soil	ORECH	<ol style="list-style-type: none"> 1) Determine the average available water-holding capacity of the root zone for each climatic region. 2) Determine the initial moisture deficit (field capacity minus actual moisture content) of the

entire root zone for each climatic region for both irrigated and non-irrigated areas.

- | | | |
|------------|--------|---|
| Wells | OWELL | <ol style="list-style-type: none"> 1) Determine the location of all point sources of ground-water withdrawals or recharge other than those supplying water for local ground-water irrigation. 2) Determine the volume of water added or withdrawn by these sources in each timestep. |
| Under Flow | OUNDER | <ol style="list-style-type: none"> 1) Determine boundary reaches along which the underflow is known and uniform within each reach. 2) Assign a numerical code to all cells identifying the reaches. Cells not within an underflow reach are assigned a value of 0. 3) Determine the total flow across each reach in each timestep. |
| River Flux | ORIVER | <ol style="list-style-type: none"> 1) Determine river or creek reaches such that gains or losses are known and can be assumed to be uniform within each reach. 2) Assign a numerical code to all cells identifying the reaches. Cells not within a reach are assigned a value of 0. 3) Determine the gains or losses from each reach, usually based on streamflow data, for each timestep. |

Formats for data input and the units of the data are given in the section "RECHARGE Program Input Description."

PROGRAM OUTPUT

The primary output of the program is the recharge and discharge rate for each cell and timestep, Q . The units and sign convention (+ or -) of this array are dependent upon specification of the options ORATE and OSIGN. The array can be written to printer, and/or in an unformatted form to a file specified by the user (IFILE).

A mass balance of the terms comprising the total flux summarizes results for all timesteps. A description of each of the terms in the mass balance is as follows:

SEEP= total canal seepage for over all cells,

IRRIG= total irrigation volume applied from surface-water sources,

PRECIP= volume of precipitation over the entire study area,

ET= the sum of ET for irrigated and non-irrigated areas not adjusted for soil reaching the maximum moisture deficit,

CALCULATED= soil moisture change prior to adjustment to maintain the SOIL deficit less than the maximum, MOISTURE CHANGE

ADJUSTED= soil moisture change adjusted such that the deficit never SOIL exceeds the maximum available water holding capacity of MOISTURE the root zone; lack of available water results in a CHANGE reduction in ET which is not shown in the balance, but which is compensated by the adjustment of this term.

WELL FLUX= total of the WELL term for the given timestep,

UNDERFLOW= total volume of underflow for the given timestep,

RIVER FLUX= total river gains and losses for the given timestep,

TOTAL FLUX= sum of all the above factors except ADJUSTED SOIL MOISTURE CHANGE, equal to the total recharge or discharge for a given timestep.

The above terms are all in units of acre-feet. The mass balance can be output on printer, and/or can be written in an identical format on a file specified by the user (MASSB) for later application to a graphics routine. It must be remembered that in order to have IRR, PRECIP, ET, and SOIL MOISTURE CHANGE included in the TOTAL FLUX and in the Q array the option ORECH must be equal to 1.

Detailed results and a reflection of the input data can be output by specification of OPRINT as outlined in "RECHARGE Program Input Description."

PROGRAM DESCRIPTION

The input data for all timesteps are read in the first timestep.

Data pertaining to each particular term (IRR,SEEP,etc.) are read in the subroutine performing the calculations. In the first timestep all data required in subsequent timesteps are written onto a temporary storage file, SCRTCH. The file is then read back in each of the following timesteps. This procedure helps minimize the memory requirement of the program. Two large arrays ISPACE (integers), and RSPACE (reals) have been established to provide temporary memory space for all variables when read from SCRTCH. Once the calculations relative to a term have been completed the memory space of ISPACE and RSPACE is reassigned to new variables by means of EQUIVALENCE statements.

A single, labeled COMMON block contains the arrays ISPACE, RSPACE, and several other arrays. This COMMON was established for use on an HP 1000 computer for transfer to an extended memory area. The single COMMON block is operational on computers with larger memory, although several smaller COMMON blocks may be more convenient.

Some ground-water models may require a larger grid, more river reaches, or other variables than are currently allowed by the program. The array size can be increased by increasing the dimensions of the appropriate variables. It must be remembered however, that increasing the size of arrays written onto SCRTCH will require corresponding changes in the EQUIVALENCE statements and possibly the dimensions of ISPACE and RSPACE.

Two subroutines, PRINT and INTEGER, have been included to output all arrays with dimensions equal to the number of rows and columns of the study.

RECHARGE PROGRAM INPUT DESCRIPTION

Five variables are assigned to input/output units within the program. A numerical value is assigned to the variables in the input data set except for the unit of primary input, M1, which is assigned in the beginning of the main program. A description of all inputs from unit M1 is given in the following list. The "Inpt. Cond." specifies the condition required for input of each record.

RECHARGE PROGRAM INPUT DESCRIPTION

Record	Inpt. Cond.	Columns	Format	Variable Name	Definition
1	mand.	1-5	I5	IFILE	output unit of recharge and discharge at each node, Q(I,J)
		6-10	I5	SCRTCH	unit of input and output of temporary data set
		11-15	I5	M2	unit of detailed output, usually printer
		16-20	I5	MASSB	unit of output of mass balance when OMASS=1
		21-25	I5	ETFILE	unit of input of evapotranspiration (ETIRR, ETDRY), when OEVAP=2
2	mand.	1-5	I5	OPRINT	output option: =0, outputs only Q(I,J) to IFILE =1, outputs Q(I,J) and mass balance to M2 =2, outputs all major terms to M2 =3, detailed output to unit M2
		6-10	I5	OIRRIG	irrigation option: =0, calculations and input for irrigation and canal seepage are bypassed =1, irrigation and seepage calculations are executed
		11-15	I5	ORECH	moisture balance option: =0, moisture balance is not calculated, recharge and discharge from irrigation, precipitation, and et is not included in the total =1, moisture balance is calculated
		16-20	I5	OEVAP	evapotranspiration option: =0, et is not calculated and is set equal to 0 at all cells =1, et is calculated =2, et is not calculated and is input directly from ETFILE
		21-25	I5	OWELL	well pumping option (not ground-water irrigation) =0, no wells used =1, well recharge and discharge to be input

RECHARGE PROGRAM INPUT DESCRIPTION

Record	Inpt. Cond.	Columns	Format	Variable Name	Definition
		26-30	I5	OUNDER	underflow option: =0, underflow calculations and input are bypassed =1, underflow is calculated
		31-35	I5	ORIVER	river gains and losses option: =0, river gain and loss calculations and input are bypassed =1, river gains and losses are calculated
		36-40	I5	ORATE	designates units of Q(I,J) output to IFILE =0, output is in af/timestep =1, output is in ft ³ /day
		41-45	I5	OMASS	mass balance output option: =0, mass balance not output to MASSB =1, mass balance output to MASSB
		46-50	I5	OSIGN	specifies sign (+ or -) of surface flux output to IFILE =-1, aquifer recharge is negative, discharge is positive =1, aquifer recharge is positive, discharge is negative
3	mand.	1-5	I5	NCOL	number of grid columns
		6-10	I5	NROW	number of grid rows
		11-20	F10.0	DELX	grid spacing in the x-direction (ft.)
		21-30	F10.0	DELY	grid spacing in the y-direction (ft.)
4	mand.	1-5	I5	NTS	number of timesteps
		6-10	I5	LTS	last timestep in which length is DELT1, LTS>NTS if not used
		11-20	F10.0	DELT1	initial timestep length (days)
		21-30	F10.0	DELT2	final timestep length (days)
5	OIRRIG =1	1-5	I5	NONAME	identification number of irrigation projects with unknown diversions or return flows, NONAME=0 if not used

RECHARGE PROGRAM INPUT DESCRIPTION

Record	Inpt. Cond.	Columns	Format	Variable Name	Definition
+++++REPEAT records 6 through 8 for each irrigation project (K), except NONAME+++++					
+ 6	OIRRIG	1-5	I5	PROJCT	irrigation project number for which data follows
+	=1				
+ 7	OIRRIG	1-75	15F5.0	DIVERS(K,T)	diversions for the given project for each timestep
+	=1			(T=1,NTS)	(af/timestep)
+ 8	OIRRIG	1-75	15F5.0	RETFLO(K,T)	return flows for the given project for each timestep
+	=1			(T=1,NTS)	(af/timestep)
+++++					
9	OIRRIG=1	blank record indicating end of diversion data			
10	OIRRIG	1-5	I5	NZONE	number of seepage zones (maximum=10)
	=1	6-65	10F6.0	RATE(K)	seepage rate for each zone (ft ³ /ft ² -day), zones must
				(K=1,NZONE)	be numbered consecutively from 1 to NZONE
+++++REPEAT records 11 and 12 for each irrigation project (K) including NONAME+++++					
+ 11	OIRRIG	1-5	I5	KPROJ(K)	irrigation project number associated with the following
+	=1				adjustment factors
+ 12	OIRRIG	1-78	26F3.1	ADJST(KPROJ,T)	seepage adjustment factors for each timestep for the above
+	=1			(T=1,NTS)	irrigation project
+++++					
+++++REPEAT record 13 for each cell containing canals (K)+++++					
+ 13	OIRRIG	1-5	I5	II(K)	column of cell
+	=1				
+		6-10	I5	JJ(K)	row of cell

RECHARGE PROGRAM INPUT DESCRIPTION

Record	Inpt. Cond.	Columns	Format	Variable Name	Definition
+		11-15	I5	SPZONE(K)	seepage zone containing the cell
+		16-35	4I5	PRJ(K,K1) (K1=1,4)	irrigation projects with canals located within the cell
+		36-59	4F6.0	WETAR(K,K1) (K1=1,4)	canal wetted area of the respective projects (ft ²)
+		60-64	I5	STPNEW(K)	timestep in which wetted area within the cell changes, STPNEW=0 if no change
+		65-70	F6.0	NEWAR(K)	new wetted area for the specified project (ft ²)
+		71-75	I5	PRJNEW(K)	project to which new wetted area is assigned

14 OIRRIG=1 blank record indicating end of seepage data

+++++REPEAT record 15 for each cell (K) containing irrigation+++++

+	15 OIRRIG	1-5	I5	II(K)	column of cell
+	=1	6-10	I5	JJ(K)	row of cell
+		11-30	4I5	PROJ(K,K1) (K1=1,4)	projects with irrigated areas present within the specified cell
+		31-50	4F5.0	ACRES(K,K1) (K1=1,4)	irrigated areas of the respective projects (acres)
+		51-55	F5.0	GWACRE	ground-water irrigated area within the cell (acres)
+		56-60	I5	STPNW(K)	timestep in which irrigated area of a project within the cell changes, STPNW=0 if no change
+		61-65	I5	PROJNW(K)	project to which the new area is applied
+		66-70	F5.0	ACRENW(K)	new area (total) for the specied project within the cell (acres)
+		71-75	I5	GWSTNW(K)	timestep in which ground water irrigated area changes, GWSTNW=0 if no change
+		76-80	F5.0	GWACNW(K)	new ground-water irrigated area (total) within the cell (acres)

+++++

RECHARGE PROGRAM INPUT DESCRIPTION

Inpt. Record	Cond.	Columns	Format	Variable Name	Definition
16	OIRRIG=1	blank record			indicating end of irrigation data
17	OEVAP =1	1-5	I5	NREG	number of climatic regions
+++++++REPEAT records 18 through 21 for each climatic region (K)+++++++					
+ 18	OEVAP	1-5	I5	REGION(K)	climatic region identification code
+ =1		6-10	I5	NCROPS(K)	number of crops within the climatic region
+ 19	OEVAP	1-75	15F5.2	UNCOEF(K,T)	vegetation coefficients assigned to non-irrigated areas of
+ =1				(T=1,NTS)	the specified region for each timestep
+++++++REPEAT record 20 for each crop within the region+++++++					
++20	OEVAP	1-5	I5	CRCODE	identification code of the crop:
++ =1				1 = alfalfa	
++				2 = beans	
++				3 = corn	
++				4 = pasture	
++				5 = peas	
++				6 = potatoes	
++				7 = sugar beets	
++				8 = spring grain	
++				9 = winter grain	
++		6-10	I5	MOPLNT	month of planting or green-up of the specified crop
++		11-15	I5	DYPLNT	day of planting or green-up
++		16-20	I5	MOCOVR	month of vegetative cover
++		21-25	I5	DYCOVR	day of vegetative cover
++		26-30	I5	MOHARV	month of harvest
++		31-35	I5	DYHARV	day of harvest
++		36-40	I5	PERCNT	percentage of irrigated area in the region planted to
++					the specified crop
+++++++					

RECHARGE PROGRAM INPUT DESCRIPTION

Record	Inpt. Cond.	Columns	Format	Variable Name	Definition
+++++REPEAT record 26 for every timestep (T)+++++					
+ 26	OEVAP	1-75	15F5.0	SOLRAD(K,T)	average solar radiation for each region for a
+ =1				(K=1,NREG)	timestep (Ly/day)
+++++					
27	OEVAP	1-5	I5	NREG	number of climatic regions
	=0				
28	ORECH	1-5	I5	IMSTRT	month in which ground-water irrigation begins
	=1	6-10	I5	IDSTRT	day of month in which ground-water irrigation begins
		11-15	I5	IMEND	month in which ground-water irrigation ends
		16-20	I5	IDEND	day of month in which ground-water irrigation ends
+++++REPEAT record 29 for each grid row (J) beginning with the top row+++++					
+ 29	ORECH	1-80	80I1	REGION(I,J)	climatic region of each cell along the row
+ =1				(I=1,NCOL)	
+++++					
+++++REPEAT records 30 and 31 for each climatic region (K)+++++					
+ 30	ORECH	1-5	I5	REG(K)	climatic region for which data follows
+ =1					
+ 31	ORECH	1-75	15F5.2	RAIN(REG(K),T)	precipitation for the specified region for every
+ =1				(T=1,NTS)	timestep (in./timestep)
+++++					

RECHARGE PROGRAM INPUT DESCRIPTION

Inpt. Record	Cond.	Columns	Format	Variable Name	Definition
+++++REPEAT record 32 for each climatic region (K)+++++					
+ 32	ORECH	1-5	I5	REG(K)	climatic region for which data follows
+ =1		6-10	F5.2	CAPCTY(REG(K))	available water holding capacity of the root zone of the specified region (in.)
+ =1		11-15	F5.2	STRTDY(REG(K))	initial soil moisture deficit of the root zone of non-irrigated areas of the specified region (in.)
+ =1		16-20	F5.2	STRTIR(REG(K))	initial soil moisture deficit of the root zone of irrigated areas of the specified region (in.)
+++++REPEAT records 33 and 34 for each cell having well data (K)+++++					
+ 33	OWELL	1-5	I5	II(K)	column of cell
+ =1		6-10	I5	JJ(K)	row of cell
+ 34	OWELL	1-77	11F7.0	FLO(K,T)	recharge (+) or discharge (-) from the aquifer by direct means such as pumping, for each timestep (af/timestep)
+ =1				T=1,NTS	
35 OWELL=1 blank record indicating end of well data					
36	OUNDER	1-5	I5	NZONES	number of ground water underflow zones
=1					
+++++REPEAT record 37 for each timestep (T)+++++					
+ 37	OUNDER	1-75	15F5.0	FLOW(K,T)	total underflow of each zone for the specified timestep
+ =1				(K=1,NZONES)	(af/timestep)
+++++REPEAT record 38 for each row (J) beginning with the top row+++++					
+ 38	OUNDER	1-80	80I1	ZONE(I,J)	underflow zone of each cell, cells without underflow are
+ =1				(I=1,NROW)	zone 0

RECHARGE PROGRAM INPUT DESCRIPTION

<u>Record</u>	<u>Inpt. Cond.</u>	<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Definition</u>
39	ORIVER =1	1-5	I5	NZONES	number of river reaches
+++++REPEAT record 40 for each timestep (T)+++++					
+ 40	ORIVER	1-75	15F5.0	FLOW(K,T)	total river gains or losses for each reach for the
+ =1				(K=1,NZONES)	specified timestep (af/timestep)
+++++					
+++++REPEAT record 41 for each row (J) beginning with the top row+++++					
+ 41	ORIVER	1-80	80I1	ZONE(I,J)	river reach of each cell, cells without river gains or
+ =1				(I=1,NROW)	losses are assigned to reach 0
+++++					

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Department of
Interior

Public Lands Administration

Section of Reclamation

Washington, D.C.

APPENDICES

APPENDIX A

Example Input for the University of Idaho Ground-Water Flow Model

An example data set for the model is presented in this appendix and is based on the situation illustrated by figure 15. The transient simulation is comprised of 4 timesteps of 15 days duration. Hydraulic conductivity and storage coefficient are calibrated using 3 calibration iterations. The aquifer is unconfined and is initially assumed to have uniform hydraulic conductivity, storage coefficient, and outward leakage at every node. Timesteps 2 and 4 are reference timesteps and timestep 4 is the calibration timestep. The left boundary is variable, fixed head, the right boundary is constant head, and the top and bottom boundaries are impermeable. One row and column of inactive nodes (NOD=0) is established outside the study perimeter as required by the model.

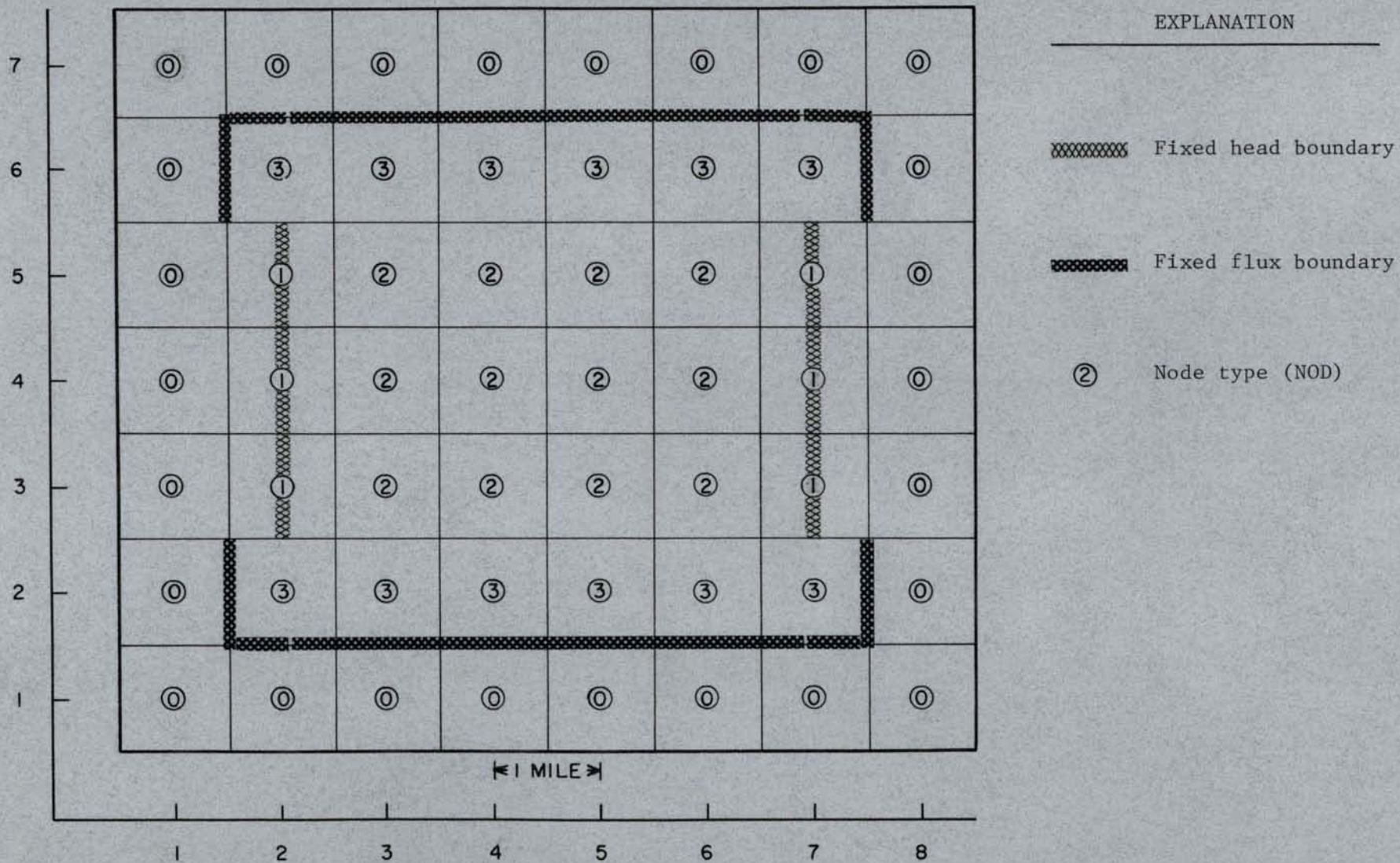


Figure 15. Boundary and node specifications of model data set.

University of Idaho Ground-Water Flow Model Example Input

Record¹

```

(1)          UNIVERSITY OF IDAHO GROUND-WATER FLOW MODEL
(2)                EXAMPLE DATA SET
(3)          8      7  15.      5280.
(4)          1      1      0      0      0      0      0      1      1
(5)          2      1      5      4      1
(6)          5              0.0      1.
(7)          2      4
(8)          3  4      6  3
(9)          0.4      1      4      3      1      3      2      2      2      4
(10)         0.10      0.20      400.0      800.0      0.0      0.0      0.0      0.0
(11)         2  3  1
(11)         2  4  1
(11)         2  5  1 99
(12)         2.0  2.0  2.0  2.0
(15)         600.  600.  600.  600.  600.  600.  600.  600.
(15)         600.  600.  600.  600.  600.  600.  600.  600.
(15)         600.  600.  600.  600.  600.  600.  600.  600.
(15)         600.  600.  600.  600.  600.  600.  600.  600.
(15)         600.  600.  600.  600.  600.  600.  600.  600.
(15)         600.  600.  600.  600.  600.  600.  600.  600.
(15)         600.  600.  600.  600.  600.  600.  600.  600.
(16)         .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001
(16)         .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001
(16)         .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001
(16)         .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001
(16)         .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001
(16)         .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001
(16)         .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001
(17)         20. 20. 20. 20. 20. 20. 20. 20.
(17)         20. 20. 20. 20. 20. 20. 20. 20.
(17)         20. 20. 20. 20. 20. 20. 20. 20.
(17)         20. 20. 20. 20. 20. 20. 20. 20.
(17)         20. 20. 20. 20. 20. 20. 20. 20.
(17)         20. 20. 20. 20. 20. 20. 20. 20.
(17)         20. 20. 20. 20. 20. 20. 20. 20.
(18)         .15 .15 .15 .15 .15 .15 .15 .15
(18)         .15 .15 .15 .15 .15 .15 .15 .15
(18)         .15 .15 .15 .15 .15 .15 .15 .15
(18)         .15 .15 .15 .15 .15 .15 .15 .15
(18)         .15 .15 .15 .15 .15 .15 .15 .15
(18)         .15 .15 .15 .15 .15 .15 .15 .15
(18)         .15 .15 .15 .15 .15 .15 .15 .15
(19)         1  1 600. 99
(20)         2  2  3      0  500  100  200.  204.  208.
(20)         2  3  1      0  500  100  200.  204.  208.
(20)         2  4  1      0  500  100  200.  204.  208.
(20)         2  5  1      0  500  100  200.  204.  208.
(20)         2  6  3      0  500  100  200.  204.  208.
(20)         3  2  3      0  500  100  205.  208.  212.
(20)         3  3  2      0  500  100  205.  208.  212.
(20)         3  4  2      0  500  100  205.  208.  212.

```

(20)	3	5	2	0	500	100	205.	208.	212.	
(20)	3	6	3	0	500	100	205.	208.	212.	
(20)	4	2	3	0	500	100	210.	212.	215.	
(20)	4	3	2	0	500	100	210.	212.	215.	
(20)	4	4	2	0	500	100	210.	212.	215.	
(20)	4	5	2	0	500	100	210.	212.	215.	
(20)	4	6	3	0	500	100	210.	212.	215.	
(20)	5	2	3	0	500	100	215.	216.	219.	
(20)	5	3	2	0	500	100	215.	216.	219.	
(20)	5	4	2	0	500	100	215.	216.	219.	
(20)	5	5	2	0	500	100	215.	216.	219.	
(20)	5	6	3	0	500	100	215.	216.	219.	
(20)	6	2	3	0	500	100	220.	221.	222.	
(20)	6	3	2	0	500	100	220.	221.	222.	
(20)	6	4	2	0	500	100	220.	221.	222.	
(20)	6	5	2	0	500	100	220.	221.	222.	
(20)	6	6	3	0	500	100	220.	221.	222.	
(20)	7	2	3	0	500	100	225.	225.	225.	
(20)	7	3	1	0	500	100	225.	225.	225.	
(20)	7	4	1	0	500	100	225.	225.	225.	
(20)	7	5	1	0	500	100	225.	225.	225.	
(20)	99	7	6	3	0	500	100	225.	225.	225.

¹ refers to record number from "University of Idaho Ground-Water Flow Model Input Description".

APPENDIX B

Example Input for the RECHARGE Program

A sample data set representing a simple, rectangular study area is presented in this appendix. The data are for simulation of 4 timesteps of 15 days duration for the physical situation illustrated in figure 16. The conditions are fictional, intended to serve only as an example of data set preparation.

The study area defined in figure 16 is divided into two climatic regions differentiated by climate and agricultural practices. Alfalfa and spring grain are the two principle crops in region #1 and alfalfa, spring grain, and corn are the major crops in climatic region #2. Four organized irrigation projects exist within the study area. Project #3 has unknown rates of diversion and return flow. Ground-water irrigation (pumping within the same cell) also occurs. A river passes through the area and is divided into two reaches of uniform gains and losses.

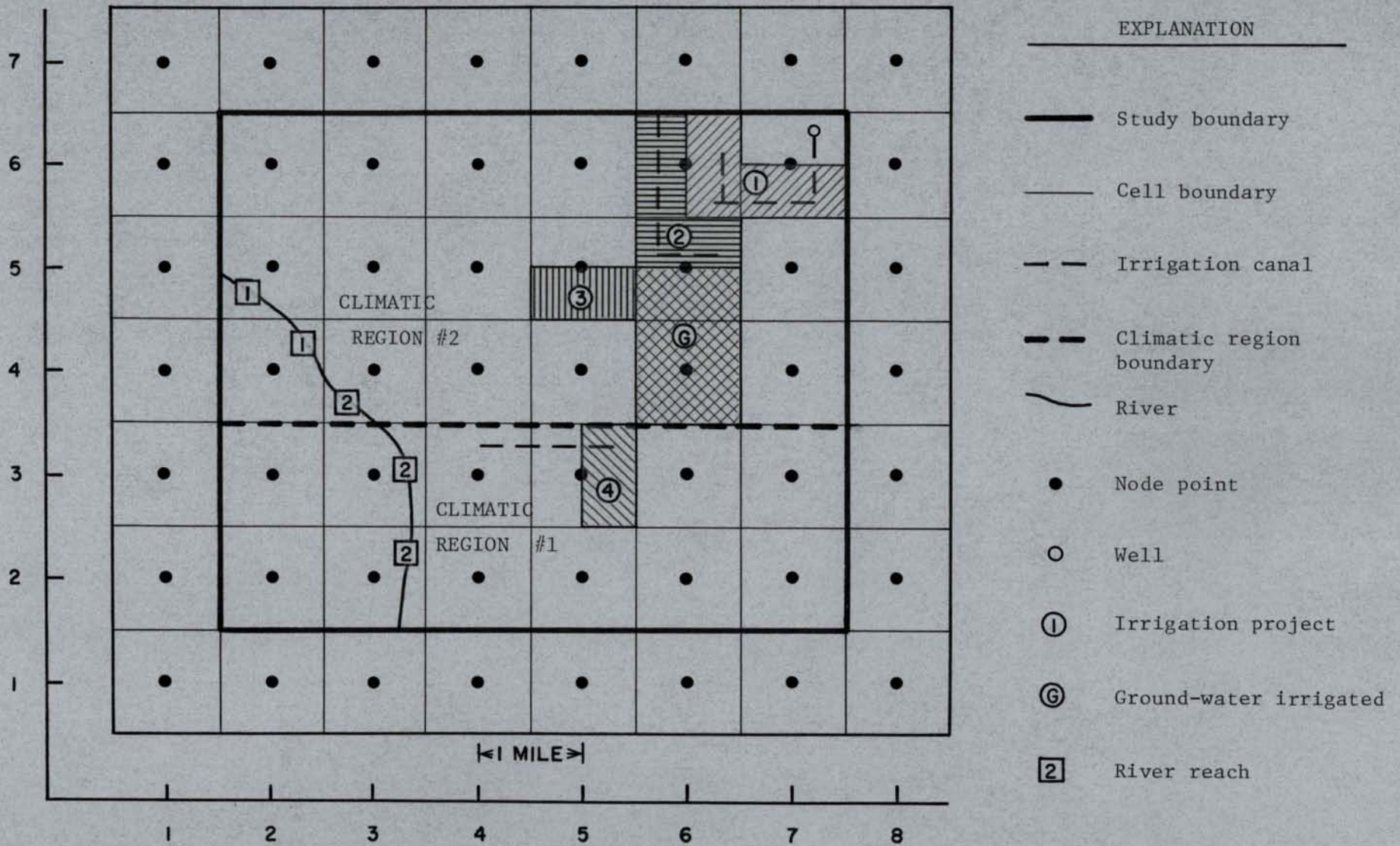


Figure 16. Conditions of RECHARGE program example data set.

(23)	45	50		
(23)	48	51		
(23)	53	60		
(24)	20	20		
(24)	20	20		
(24)	25	30		
(24)	30	30		
(25)	4.0	4.0		
(25)	4.8	4.8		
(25)	5.1	4.9		
(25)	5.7	5.8		
(26)	400.	400.		
(26)	450.	450.		
(26)	500.	500.		
(26)	400.	400.		
(28)	6	1	9	1
(29)	22222222			
(29)	22222222			
(29)	22222222			
(29)	22222222			
(29)	11111111			
(29)	11111111			
(29)	11111111			
(30)	1			
(31)	1.4	2.1	1.1	0.9
(30)	2			
(31)	1.5	2.0	1.8	0.7
(32)	1	10.0	2.0	0.0
(32)	2	10.0	1.0	0.0
(33)	7	6		
(34)	100.	200.	400.	100.
(33)	4	3		
(34)	400.	400.	320.	100.
(35)				
(39)	2			
(40)	40.0	60.0		
(40)	50.0	50.0		
(40)	40.0	45.0		
(40)	30.0	40.0		
(41)	00000000			
(41)	00000000			
(41)	01000000			
(41)	01100000			
(41)	00200000			
(41)	00200000			
(41)	00000000			

¹ refers to record number in "RECHARGE Program Input Description".

APPENDIX C
University of Idaho Ground-Water Flow Model Listing

```

C*****
C*
C*      UNIVERSITY OF IDAHO
C*      GROUND-WATER CALIBRATION MODEL
C*
C* THIS PROGRAM WAS ORIGINALLY WRITTEN BY J. DE SONNEVILLE, UNIV. OF
C* IDAHO, IT HAS BEEN REVISED TO ITS PRESENT FORM AND IS DOCUMENTED
C* IN "USERS MANUAL FOR THE UNIVERSITY OF IDAHO GROUND-WATER FLOW
C* MODEL AND RECHARGE PROGRAM", BY JOHNSON AND BROCKWAY, UNIV. OF
C* IDAHO FOR THE BUREAU OF RECLAMATION (1982).
C*
C*****
C
C
C
C*****
C*      MAIN ROUTINE
C* THIS ROUTINE CONTROLS THE PROGRAM INPUT AND A MAJORITY OF THE
C* OUTPUT. IT ALSO PROVIDES THE BASIC FLOW OF THE PROGRAM BY
C* CALLING SUBROUTINES TO PERFORM SPECIFIC FUNCTIONS.
C*****
C
C*****VARIABLES IN THE DECLARATION STATEMENTS ARE SEPARATED
C*****BETWEEN THOSE REQUIRED FOR MANAGEMENT AND CALIBRATION
C*****SIMULATIONS
C
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
REAL KX,MU,LKDIFF
INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTM,TDEP1,
& TDEP2,TDEP3
DOUBLE PRECISION BE,G,GA1,GA2,TX,T1,T2,T3,T4
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
REAL KMAX,KMIN,LKMAX,LKMIN
INTEGER SIM,TREF,TCALIB
C
C      COMMON/EXTND/
C*****INTEGERS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
& NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
& BOTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
& IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
& TCALIB,
C*****REALS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
& AFLOT(41,37),AQTHCK(41,37),H(41,37),H1(41,37),
& H2(41,37),HINITL(41,37),Q(41,37);QC(41,37),

```

```

& QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
& DELH(42,110),BE(55),G(55),TITLE(40),ADELS,ALEAK,AREA,ATELS,
& ATLEAK,DELT,GA1,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
& SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SS1(3,40),
& FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SFMIN,SMIN,SMAX,VP

```

```

C
COMMON M5,M6,M7,M8,M9
C
C***** INITIALIZE NECESSARY VARIABLES
C
CALL INITL
C
SIM=0
SUMQ1=0.0
SUMQ2=0.0
SUMQT=0.0
MODE=0
A=0.0
HMEAN=0.0
TDELS=0.0
TLEAK=0.0
N=1

```

```

C
C      LOGICAL UNIT ASSIGNMENTS
C
C
C      UNIT          DESCRIPTION
C
C
C      M5          UNIT FOR OUTPUT OF HYDROGRAPH DATA
C      M6          UNIT FOR PRIMARY OUTPUT
C      M7          UNIT OF PRIMARY INPUT
C      M8          UNIT OF OUTPUT OF CALIBRATION
C                  PARAMETERS (IFPNCH=1)
C      M9          UNIT FOR INPUT OF SURFACE FLUX,
C                  Q(I,J) (NQ=3,4,OR 5)
C
C
C      M5=58
C      M6=6
C      M7=56
C      M8=57
C      M9=54
C
C      READ(M7,10) TITLE
C      WRITE (M6,35)TITLE
C
C      READ(M7,25) NCOL,NROW,DELT,DELX
C      WRITE (M6,40)NCOL,NROW,DELT,DELX
C
C      READ(M7,15) IPRINT,IFAC,ICON,IDRAIN,TDEP1,TDEP2,TDEP3,
&IFPNCH,ICALB,NHYDRO
C      WRITE(M6,45)IPRINT,IFAC,ICON,IDRAIN,TDEP1,TDEP2,TDEP3,
&IFPNCH,ICALB,NHYDRO

```

```

C
READ(M7,15) NHEAD,BTS,LTS,NTS,NRIVER
WRITE (M6,50) NHEAD,BTS,LTS,NTS,NRIVER

C
READ(M7,20) NQ,FLUX,MU
WRITE (M6,55)NQ,FLUX,MU

C
READ (M7,15) (THEAD(1),I=1,NHEAD)
WRITE (M6,70) (THEAD(1),I=1,NHEAD)

C
IF (NHYDRO.GT.0) READ (M7,8) (IH(K),JH(K),K=1,NHYDRO)
IF (NHYDRO.GT.0) WRITE (M6,72) (IH(K),JH(K),K=1,NHYDRO)

C
IF (ICALB.EQ.0) GO TO 5

C
READ(M7,30) VP,NVA1,NVA2,NVA3,NSTOP,ITE,TCALIB,NREF,
& (TREF(K),K=1,NREF)
WRITE (M6,65) VP,NVA1,NVA2,NVA3,NSTOP,ITE,TCALIB,NREF,
& (TREF(K),K=1,NREF)

C
READ (M7,32) SMIN,SMAX,KMIN,KMAX,FMIN,FMAX,LKMIN,LKMAX
WRITE (M6,67) SMIN,SMAX,KMIN,KMAX,FMIN,FMAX,LKMIN,LKMAX

C
5 CONTINUE

C
8 FORMAT (10(I3,I3,2X))
10 FORMAT(20A4)
15 FORMAT(15I5)
20 FORMAT(15,F10.0,F5.2)
25 FORMAT(2I5,F5.2,2F10.2)
30 FORMAT(F5.2,14I5)
32 FORMAT(8F10.2)

C
35 FORMAT(1H1,19X,20A4/20X,20A4)
40 FORMAT(1H ,49X, ' NCOL =',I3/50X, ' NROW =',I3/50X, ' DELT =',F7.2
&/50X, ' DELX =',F7.1/)
45 FORMAT(1H ,49X, ' IPRINT =',I3/50X,
& ' IFAC =',I3/50X, ' ICON =',I3/50X, ' IDRAIN =',I3/50X,
& ' TDEP1 =',I3/50X, ' TDEP2 =',I3/50X, ' TDEP3 =',I3/50X,
& ' IFPNCH =',I3/50X, ' ICALB =',I3/50X, ' NHYDRO =',I3/)
50 FORMAT(1H ,49X, ' NHEAD =',I3/
& 50X, ' BTS =',I3/50X, ' LTS =',I3/50X, ' NTS =',I3/50X,
& ' NRIVER =',I3/)
55 FORMAT(1H ,49X, ' NQ =',I3/50X, ' FLUX =',F10.0/50X, ' MU =',F
&5.2/)
65 FORMAT(1H ,49X, ' VP =',F3.2/50X, ' NVA1 =',I3/50X, ' NVA2 =',I3
&/50X, ' NVA3 =',I3/50X, ' NSTOP =',I3/50X, ' ITE =',I3/50X,
& ' TCALIB =',I3/50X, ' NREF =',F6.2,
& 10(/50X, ' TREF =',I3))
67 FORMAT (50X, 'SMIN =',F10.5/50X, 'SMAX =',F10.5/50X,
& 'KMIN =',F10.1/50X, 'KMAX =',F10.1/50X, 'FACMIN =',
& F10.4/50X, 'FACMAX =',F10.4/50X, 'LKMIN =',F10.1/
& 50X, 'LKMAX =',F10.1/)
70 FORMAT(1H ,49X, 'THEAD =',I3/(50X, 'THEAD =',I3))
72 FORMAT(1H ,49X, 'HYDROGRAPH AT: (',I2,',',I2,')'

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C
C*****NREACH SPECIFIES HYDRAULICALLY CONNECTED RIVER OR BOUNDARY NODES
C
IF(NRIVER.EQ.0)GO TO 100
DO 75 K=1,100
READ(M7,85)I,J,NREACH(I,J),LAST
IF(LAST.EQ.99)GO TO 80
75 CONTINUE
80 CONTINUE
85 FORMAT(12,3I3)

C
C*****DELH IS THE CHANGE IN ALTITUDE OF EACH HYDRAULICALLY CONNECTED
C*****REACH BETWEEN EACH TIMESTEP
C
DO 90 K=1,NRIVER
90 READ(M7,95)(DELH(K,I),I=BTS,NTS)
95 FORMAT(15F5.0)
100 CONTINUE

C
C*** DRAIN(I,J) DENOTES THE SPRING ELEVATION AT NODE (I,J)
C
IF(IDRAIN.EQ.0) GO TO 115
DO 110 K=1,100
READ(M7,105)I,J,DRAIN(I,J),LAST
105 FORMAT(12,I3,I5,I3)
IF(LAST.EQ.99)GO TO 115
110 CONTINUE
115 CONTINUE

C
C*** CALCULATE NECESSARY CONSTANTS
C
XX1=DELT/43560.0
XXX=XX1*MU
AREA=DELX*DELX

C
C*****READ IN THE SURFACE FLUX (Q(I,J) FOR THE STEADY-STATE
C*****CALIBRATION ACCORDING TO A FORMAT SPECIFIED BY NQ (NQ.LT.5)
C
GO TO (120,145,165,155,175) NQ
120 WRITE (M6,125)
125 FORMAT(1H1,10X, 'STEADY STATE SIMULATION : THE SOURCE TERM Q(I,J,K)
& IS READ IN FOR SPECIFIC NODE POINTS'////)
DO 140 K=1,100
READ(M7,130)I,J,Q(I,J),LAST
130 FORMAT(12,I3,F10.0,I2)
WRITE (M6,135)I,J,Q(I,J)
135 FORMAT(1H ,10X, 'I =',I3,3X, 'J =',I3,3X, 'Q =',F10.0)
IF(LAST.EQ.99)GO TO 175
140 CONTINUE
GO TO 175
145 DO 150 J=1,NROW
DO 150 I=1,NCOL
150 Q(I,J)=FLUX
GO TO 175
155 DO 160 J=1,NROW

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      READ(M9)(Q(I,J),I=1,NCOL)
160 CONTINUE
      GO TO 175
165 CONTINUE
      READ(M9,170)((Q(I,J),I=1,NCOL),J=1,NROW)
170 FORMAT(8F10.0)
175 CONTINUE
C
C**** READ IN HYDRAULIC CONDUCTIVITY (KX)
C
      NRUW=NROW+1
      DO 180 J=1,NROW
      READ(M7,215)(KX(I,NRUW-J),I=1,NCOL)
180 CONTINUE
C
C****READ LEAKAGE FACTOR (FAC) AND INITIAL HEAD DIFFERENCE (LKDIFF)
C
      IF(IFAC.EQ.0) GO TO 205
      DO 195 J=1,NROW
      READ(M7,230)(FAC(I,NRUW-J),I=1,NCOL)
195 CONTINUE
C
C****READ INITIAL HEAD DIFFERENCE (LKDIFF) FOR THE LEAKY AQUIFER
C****WHEN IFAC=1
C
      DO 200 J=1,NROW
      READ(M7,235)(LKDIFF(I,NRUW-J),I=1,NCOL)
200 CONTINUE
205 CONTINUE
C
C****READ STORAGE COEFFICIENT (S)
C
      DO 210 J=1,NROW
      READ(M7,225)(S(I,NRUW-J),I=1,NCOL)
210 CONTINUE
C
215 FORMAT(13F6.1)
220 FORMAT(I2,I3,I5,I3)
225 FORMAT(15F5.4)
230 FORMAT(10F8.6)
235 FORMAT(18F4.0)
C
C
C
C****READ IN CHANGES TO HYDRAULIC CONDUCTIVITY ARRAY (KX(I,J))
C
      DO 255 L=1,100
      READ(M7,265)I,J,KX(I,J),LAST
      IF(LAST.EQ.99)GO TO 260
255 CONTINUE
260 CONTINUE
265 FORMAT(I2,I3,F5.0,I3)
C
C****READ ARRAYS DENOTING THE NODE TYPE (NOD),CONFINED
C****THICKNESS (THICK), SURFACE ELEVATION (SURF), AQUIFER BOTTOM

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C****ELEVATION (BOTTH), INITIAL HYDRAULIC HEAD (HINITL), AND
C****REFERENCE HEAD VALUES COMPARED IN CALIBRATION (HREF)
C
      IF (ICALB.EQ.0) GO TO 272
      DO 270 L=1,2000
      READ(M7,275) LAST,I,J,NOD(I,J),THICK(I,J),SURF(I,J),
& BOTTH(I,J),HINITL(I,J),(HREF(I,J,K),K=1,NREF)
      IF (LAST.EQ.99)GO TO 276
270 CONTINUE
272 CONTINUE
      DO 273 L=1,2000
      READ (M7,275) LAST,I,J,NOD(I,J),THICK(I,J),SURF(I,J),
& BOTTH(I,J),HINITL(I,J)
      IF (LAST.EQ.99) GO TO 276
273 CONTINUE
275 FORMAT(4I3,3I5,4F6.1)
276 CONTINUE
C
C****DETERMINE THE NODE STATUS FOR CALCULATIONS IN THE X AND Y DIRECTIONS
C
      DO 280 I=1,NCOL
      DO 280 J=1,NROW
C
C****FOR NODES OUTSIDE BOUNDARIES
C
      IF (NOD(I,J).NE.0) GO TO 277
      NCX(I,J)=0
      NCY(I,J)=0
      GO TO 280
277 CONTINUE
C
C****FOR HYDRAULICALLY CONNECTED NODES
C
      IF (NOD(I,J).NE.1) GO TO 278
      NCX(I,J)=1
      NCY(I,J)=1
      GO TO 280
278 CONTINUE
      NCX(I,J)=2
      NCY(I,J)=2
C
C****FOR NODES ADJACENT TO HYDRAULICALLY CONNECTED NODES
C
      IF (NOD(I-1,J).EQ.1) NCX(I,J)=5
      IF (NOD(I,J-1).EQ.1) NCY(I,J)=5
      IF (NOD(I+1,J).EQ.1) NCX(I,J)=6
      IF (NOD(I,J+1).EQ.1) NCY(I,J)=6
      IF (NOD(I-1,J).EQ.1 .AND. NOD(I+1,J).EQ.1) NCX(I,J)=7
      IF (NOD(I,J-1).EQ.1 .AND. NOD(I,J+1).EQ.1) NCY(I,J)=7
      IF (NOD(I,J).NE.3) GO TO 280
C
C****FOR NODES WITH AN IMPERMIABLE BOUNDARY 1/2 NODE AWAY
C
      IF (NOD(I-1,J).EQ.0) NCX(I,J)=3
      IF (NOD(I,J-1).EQ.0) NCY(I,J)=3

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      IF (NOD(I+1,J).EQ.0) NCX(I,J)=4
      IF (NOD(I,J+1).EQ.0) NCY(I,J)=4
280 CONTINUE
C
C*****SET VALUES OUTSIDE BOUNDARIES TO ZERO
C
      DO 281 I=1,NCOL
      DO 281 J=1,NROW
      IF (NCX(I,J).GT.0) GO TO 281
      HINITL(I,J)=0.0
      BOTTM(I,J)=0
      THICK(I,J)=0
      IF (ICALB.EQ.0) GO TO 281
      DO 281 K=1,NREF
      HREF(I,J,K)=0.0
281 CONTINUE
C
C*****SUM THE SURFACE FLUX TO THE MODEL (STEADY STATE ONLY)
C*****IN ACRE FEET
C
      IF(NQ.EQ.5) GO TO 290
      DO 285 J=1,NROW
      DO 285 I=1,NCOL
      IF(NCX(I,J).GE.1)SUMQ1=SUMQ1+MU*Q(I,J)*XX1
285 CONTINUE
290 CONTINUE
C
C*****LIST OUT INPUT DATA BASED ON THE VALUE OF IPRINT
C***** IPRINT=0, MINIMAL RESULTS OUTPUT
C***** IPRINT=1, DETAILED OUTPUT INCLUDING INPUT ARRAYS
C
      IF(IPRINT.EQ.0) GO TO 520
      IF(NRIVER.EQ.0) GO TO 310
      N8=1
291 CONTINUE
      MM=N8+15
      IF (NRIVER.LE.MM) MM=NRIVER
      WRITE (M6,292) (K,K=N8,MM)
      WRITE (M6,293)
292 FORMAT (1H1,30X,"CHANGES IN ELEVATION OF HYDRAULICALLY CONNECTED",
      & "NODES (DELH)"/74X,"TIMESTEP"/1X,"REACH",16(5X,12))
293 FORMAT (/1X,5(1H-),16(6X,1H-)/)
      DO 296 I=BTS,NTS
      WRITE (M6,295) I,(DELH(K,I),K=N8,MM)
295 FORMAT (3X,13,3X,16(F5.2,2X))
296 CONTINUE
      N8=N8+16
      IF (MM.LT.NRIVER) GO TO 291
310 CONTINUE
C
      IF(IDRAIN.EQ.0) GO TO 330
      WRITE (M6,315)
315 FORMAT(1H1,20X,"SPRING ALT. FOR SPRINGS IN THE MODEL AREA"/)
      DO 320 J=1,NROW
      DO 320 I=1,NCOL

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      IF(DRAIN(I,J).LE.1)GO TO 320
      WRITE (M6,325)I,J,DRAIN(I,J)
320 CONTINUE
325 FORMAT(1H ,10X,"I= ",12,3X,"J= ",12,5X,"SPRING LEVEL=",16)
330 CONTINUE
C
      DO 390 JP=1,5
      IF(IFAC.EQ.0.AND.(JP.EQ.2.OR.JP.EQ.3)) GO TO 390
      NSEC=0
      DO 385 LJ=1,NROW,50
      DO 380 LI=1,NCOL,25
      NSEC=NSEC+1
      GO TO (335,340,345,350,352),JP
335 WRITE (M6,460)NSEC
      GO TO 355
340 WRITE (M6,465)NSEC
      GO TO 355
345 WRITE (M6,470)NSEC
      GO TO 355
350 WRITE (M6,475)NSEC
      GO TO 355
352 WRITE (M6,490)NSEC
355 CONTINUE
      GO TO (360,365,370,375,377),JP
360 CALL PRNT1(NCOL,NROW,LI,LJ,KX,4H0) ,1)
      GO TO 380
365 CALL PRNT1(NCOL,NROW,LI,LJ,FAC,4H4) ,1)
      GO TO 380
370 CALL PRNT1(NCOL,NROW,LI,LJ,LKDIFF,4H1) ,1)
      GO TO 380
375 CALL PRNT1(NCOL,NROW,LI,LJ,S,4H2) ,1)
      GO TO 380
377 CALL PRNT2(NCOL,NROW,LI,LJ,THICK,4H25I4,24)
380 CONTINUE
385 CONTINUE
390 CONTINUE
C
      DO 450 JP=1,2
      IF(NRIVER.EQ.0.AND.JP.EQ.2) GO TO 450
      NSEC=0
      DO 445 LJ=1,NROW,50
      DO 440 LI=1,NCOL,40
      NSEC=NSEC+1
      GO TO (395,410),JP
395 WRITE (M6,480)NSEC
      GO TO 415
410 WRITE (M6,455)NSEC
415 CONTINUE
      GO TO (420,435),JP
420 CALL PRNT2(NCOL,NROW,LI,LJ,NOD,4H43I3,39)
      GO TO 440
435 CALL PRNT2(NCOL,NROW,LI,LJ,NREACH,4H40I3,39)
440 CONTINUE
445 CONTINUE
450 CONTINUE

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C
455 FORMAT(1H1,15X,"TABLE DENOTING RIVER REACHES WITH CHANGING WATER L
&LEVELS FOR SECTOR",I3//10X,"IF NREACH(1,J)=0,THE RIVER LEVEL AT (I,
&J) IS CONSTANT OR THERE IS NO RIVER PRESENT"//)
460 FORMAT(1H1,30X,"TABLE OF HYDR. CONDUCTIVITY KX(1,J) FOR SECTOR",I3
&//)
465 FORMAT(1H1,30X,"TABLE OF LEAKANCE OF LEAKY AQUIFER FAC(I,J) FOR S
&ECTOR",I3//)
470 FORMAT(1H1,30X,"TABLE OF HYDRAULIC HEAD DIFFERENCE LKDIFF(1,J) IN
&THE LEAKY AQUIFER FOR SECTOR",I3//)
475 FORMAT(1H1,30X,"TABLE OF STORAGE COEFFICIENT S(1,J) FOR SECTOR",I3
&//)
480 FORMAT(1H1,30X,"TABLE DENOTING LOCATION AND TYPE OF NODE POINT (NO
&D(I,J)) FOR SECTOR",I3//)
490 FORMAT(1H1,30X,"TABLE DENOTING THICKNESS OF CONFINED AQUIFER (THIC
& K) FOR SECTOR",I3//)
C
520 CONTINUE
C
C*****CALCULATE AQUIFER THICKNESS (AQTHCK), SATURATED
C*****THICKNESS (SAQTHC), AND CALIBRATION HEAD DIFFERENCE
C***** (HCHANG) WITH RESPECT TO STARTING HEADVALUE (HINITL)
C
DO 531 J=1,NROW
DO 530 I=1,NCOL
IF (NCX(I,J).EQ.0) GO TO 530
AQTHCK(I,J)=SURF(I,J)-BOTTM(I,J)
SAQTHC(I,J)=HINITL(I,J)-BOTTM(I,J)
IF(THICK(I,J).GT.1) AQTHCK(I,J)=THICK(I,J)
IF(THICK(I,J).GT.1) SAQTHC(I,J)=THICK(I,J)
IF (ICALB.EQ.0) GO TO 530
DO 525 K=1,NREF
HCHANG(I,J,K)=HREF(I,J,K)-HINITL(I,J)
525 CONTINUE
530 CONTINUE
531 CONTINUE
C
C*****PRINT AQUIFER BOTTOM (BOTTM), STARTING HEADVALUE (HINITL),
C*****CALIBRATION HEAD VALUES (HREF(1,2,3)), SATURATED AQUIFER
C*****THICKNESS (AQTHCK) AND THE RISE AND FALL OF THE WATERLEVELS
C*****WITH RESPECT TO HINITL (HCHANG).
C
535 FORMAT(1H1,30X,"TABLE OF BOTTOM OF AQUIFER BOTTM(I,J) FOR PAGE",
&I3,/)
540 FORMAT(1H1,30X,"TABLE OF STARTING HEADVALUES HINITL(I,J) FOR PAGE"
&,I3//)
545 FORMAT(1H1,30X,"TABLE OF AQUIFER THICKNESS AQTHCK(I,J)",
&" (SURF-BOTTM)",30X,"PAGE",I3/)
550 FORMAT(1H1,30X,"TABLE OF SATURATED THICKNESS SAQTHC(I,J)",
&" (HINITL-BOTTM)",30X,"PAGE",I3/)
555 FORMAT(1H1,30X,"TABLE OF HEAD VALUES TIMEPERIOD TREF(1)=",I2,
&" HREF(I,J,1)",30X,"PAGE",I3/)
560 FORMAT(1H1,30X,"TABLE OF HEAD DIFFERENCES HCHANG(I,J,1)",
&" (HREF(1)-HINITL)",30X,"PAGE",I3/)
565 FORMAT(1H1,30X,"TABLE OF HEAD VALUES TIMEPERIOD TREF(2)=",I2,

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&" HREF(I,J,2)",30X,"PAGE",I3/)
570 FORMAT(1H1,30X,"TABLE OF HEAD DIFFERENCES HCHANG(I,J,2)",
&" (HREF(2)-HINITL)",30X,"PAGE",I3/)
575 FORMAT(1H1,30X,"TABLE OF HEAD VALUES TIMEPERIOD TREF(3)=",I2,
&" HREF(I,J,3)",30X,"PAGE",I3/)
580 FORMAT(1H1,30X,"TABLE OF HEAD DIFFERENCES HCHANG(I,J,3)",
&" (HREF(3)-HINITL)",30X,"PAGE",I3/)
C
IF (IPRINT.EQ.0) GO TO 701
IF (ICALB.EQ.1) LIMT=4+2*NREF
IF (ICALB.EQ.0) LIMT=4
DO 700 JP=1,LIMT
NSEC=0
DO 695 LJ=1,NROW,50
DO 690 LI=1,NCOL,25
NSEC=NSEC+1
GO TO (585,590,595,600,605,610,615,620,625,630),JP
585 WRITE (M6,535)NSEC
GO TO 635
590 WRITE (M6,540)NSEC
GO TO 635
595 WRITE (M6,545)NSEC
GO TO 635
600 WRITE (M6,550)NSEC
GO TO 635
605 WRITE (M6,555)TREF(1),NSEC
GO TO 635
610 WRITE (M6,560)NSEC
GO TO 635
615 WRITE (M6,565)TREF(2),NSEC
GO TO 635
620 WRITE (M6,570)NSEC
GO TO 635
625 WRITE (M6,575)TREF(3),NSEC
GO TO 635
630 WRITE (M6,580)NSEC
635 CONTINUE
C
GO TO (640,645,650,655,660,665,670,675,680,685),JP
640 CALL PRNT2(NCOL,NROW,LI,LJ,BOTTM,4H2515,24)
GO TO 690
645 CALL PRNT1(NCOL,NROW,LI,LJ,HINITL,4H0) ,1)
GO TO 690
650 CALL PRNT1(NCOL,NROW,LI,LJ,AQTHCK,4H0) ,1)
GO TO 690
655 CALL PRNT1(NCOL,NROW,LI,LJ,SAQTHC,4H0) ,1)
GO TO 690
660 CALL PRNT1(NCOL,NROW,LI,LJ,HREF,4H0) ,1)
GO TO 690
665 CALL PRNT1(NCOL,NROW,LI,LJ,HCHANG,4H0) ,1)
GO TO 690
670 CALL PRNT1(NCOL,NROW,LI,LJ,HREF,4H0) ,2)
GO TO 690
675 CALL PRNT1(NCOL,NROW,LI,LJ,HCHANG,4H0) ,2)
GO TO 690

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680 CALL PRNT1(NCOL,NROW,L1,LJ,HREF,4H0) ,3)
GO TO 690
685 CALL PRNT1(NCOL,NROW,L1,LJ,HCHANG,4H0) ,3)
690 CONTINUE
695 CONTINUE
700 CONTINUE
701 CONTINUE
C
C*****COUNT AND IDENTIFY THE LOCATIONS OF NODES WITH DRAINS,
C*****AND HYDRAULICALLY CONNECTED FOR LATER USE
C*****IN CALCULATION OF FLOW VOLUMES
C
IC=0
DO 710 J=1,NROW
DO 705 I=1,NCOL
IF(DRAIN(I,J).EQ.0.AND.NCX(I,J).NE.1) GO TO 705
IC=IC+1
IX(IC)=I
IY(IC)=J
705 CONTINUE
710 CONTINUE
725 CONTINUE
C
C*****IF CALIBRATION IS NOT USED GO TO 732
C
IF (ICALB.EQ.0) GO TO 732
A=0.0
DO 730 J=2,NROW-1
DO 730 I=2,NCOL-1
C
C*****CALCULATE THE HYDRAULIC GRADIENT AT EACH NODE FOR THE
C*****CALIBRATION TIMESTEP FOR LATER USE IN PARAMETER CALIBRATION
C
IF (NCX(I,J).EQ.0) GO TO 730
L1=1
L2=1
L3=1
L4=1
IF (NCX(I-1,J).EQ.0) L1=0
IF (NCX(I+1,J).EQ.0) L2=0
IF (NCX(I,J-1).EQ.0) L3=0
IF (NCX(I,J+1).EQ.0) L4=0
TS(I,J)= SQRT(((HREF(I+L2,J,TCALIB)-HREF(I-L1,J,TCALIB)))/
&(L1+L2))*2+((HREF(I,J+L4,TCALIB)-HREF(I,J-L3,TCALIB)))/
&(L3+L4))*2)
C
C*****CALCULATE THE MEAN CHANGE IN THE POTENTIOMETRIC SURFACE BETWEEN
C*****THE CALIBRATION TIMESTEP AND INITIAL VALUES
C
HMEAN=HMEAN+(ABS(HCHANG(I,J,TCALIB)))
A = A + 1.0
730 CONTINUE
HMEAN=HMEAN/A
732 CONTINUE
N=1

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ITER=1
C *****
C *
C * ENTER THE CALIBRATION CYCLE LOOP. EACH CALIBRATION CYCLE *
C * USES THE BEST VALUES CALCULATED IN THE PREVIOUS CYCLE *
C *
C *****
C
C
IF (ICALB.EQ.0) NSTOP=1
IF (ICALB.EQ.0) ITE=1
DO 1020 NCYCLE=1,NSTOP
C
C*****ANY OR ALL OF FOUR PARAMETERS MAY BE CALIBRATED DEPENDING UPON THE
C*****VALUE OF CONTROL VARIABLE NVA1,NVA2,NVA3. THE CONTROL VARIABLES ARE
C*****USED AS LIMITS OF A LOOP TO PROVIDE ANY COMBINATION OF PARAMETERS.
C***** IF NVAR=1, THE HYDRAULIC CONDUCTIVITY (KX) IS ADJUSTED
C***** IF NVAR=2, THE LEAKANCE (FAC) OF THE LEAKY AQUIFER IS CHANGED
C***** IF NVAR=3, THE HEAD DIFF. (LKDIF) OF THE LEAKY AQUIFER IS
C***** CHANGED
C***** IF NVAR=4, THE STORAGE COEFFICIENT (S) IS CHANGED
C
C
DO 1010 NVAR=NVA1,NVA2,NVA3
C
SIM=0
C
C*****
C* EACH PARAMETER IS ADJUSTED ITE-1 TIMES IN THE FOLLOWING *
C* ITERATION LOOP *
C*****
C
DO 985 ITER=1,ITE
SSS(ITER)=0.0
734 CONTINUE
C
C**** SET STARTING HEAD VALUES FOR BEGINNING A SIMULATION
C
DO 740 J=1,NROW
DO 735 I=1,NCOL
H(I,J)=HINITL(I,J)
735 CONTINUE
740 CONTINUE
C
C**** COMPUTE TRANSMISSIVITY TX FOR A CONFINED AQUIFER,
C**** (ICON=1, THICK(I,J).GT.1)
C
IF(ICON.EQ.0) GO TO 755
DO 750 J=1,NROW
DO 745 I=1,NCOL
IF(NCX(I,J).EQ.0) GO TO 745
IF(THICK(I,J).GT.1) TX(I,J)=KX(I,J)*THICK(I,J)
745 CONTINUE
750 CONTINUE
755 CONTINUE

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C
C*****COMPUTE AN ARRAY OF CONSTANTS USED IN CALCULATION OF
C***** LEAKAGE
C
  IF(IFAC.EQ.0) GO TO 770
  D=2.0*AREA
  DO 765 J=1,NROW
  DO 760 I=1,NCOL
  IF(NCX(I,J).EQ.0) GO TO 760
  QC(I,J)=FAC(I,J)*(HINITL(I,J)-LKDIFF(I,J))*D
760 CONTINUE
765 CONTINUE
770 CONTINUE
  IF (NHYDRO.GT.0) REWIND M5
C
C*****
C* ENTER TIMESTEP LOOP, IF STEADY STATE, NTS IS THE NUMBER OF *
C* TIMES THE SIMULATION IS REPEATED. ONE SET OF CALCULATIONS *
C* ALONG THE ROWS AND ONE SET ALONG THE COLUMNS ARE PERFORMED *
C* FOR EACH TIMESTEP OF LENGTH DELT. *
C*****
C
  DO 975 ISTEP=BTS,NTS
C
C*****LTS IS THE LAST TIMESTEP WITH DELT = ORIGINAL # OF DAYS IN
C*****EACH TIMESTEP. AFTER LTS THE TIMESTEP LENGTH IS DOUBLED
C
  IF(ISTEP.EQ.LTS+1) DELT=2.0*DELT
C
  IF(ISTEP.EQ.LTS+1)XX1=2.0*XX1
C
C**** READ IN SOURCE TERM Q(I,J) FOR THE NON STEADY STATE FROM UNIT M9
C
  IF(NQ.NE.5) GO TO 811
  SUMQ1=0.0
  DO 780 J=1,NROW
  READ (M9) (Q(I,J),I=1,NCOL)
780 CONTINUE
  DO 795 J=1,NROW
  DO 795 I=1,NCOL
  IF (NCX(I,J).EQ.0) GO TO 795
  QACFT(I,J)=Q(I,J)*DELT/43560.*MU
  SUMQ1=SUMQ1+QACFT(I,J)
795 CONTINUE
C
C**** IF SPECIFIED (IPRINT=2) OUTPUT THE VALUES OF SURFACE FLUX ****
C
  IF (IPRINT.LE.1) GO TO 811
  IF (NQ.LT.5 .AND. ISTEP.GT.1) GO TO 811
  NSEC=0
  DO 810 LJ=1,NROW,50
  DO 800 LI=1,NCOL,25
  NSEC=NSEC+1
  WRITE (M6,797) NSEC

```

```

797 FORMAT(1H1,30X,'TABLE OF SURFACE FLUX Q(I,J) IN AF/TIMESTEP',
&30X,'PAGE',I3,/)
  CALL PRNT1(NCOL,NROW,LI,LJ,QACFT,4H0) ,1)
800 CONTINUE
810 CONTINUE
811 CONTINUE
C
  SUMQ2=SUMQ2+SUMQ1
C
C*****DETERMINE IF ANY DRAIN NODES ARE ACTIVE
C
  IF (IDRAIN.GT.0) CALL DRA
C
C**** 1) SET THE INITIAL HEADVALUE FOR THIS TIME INCREMENT (H1)
C**** 2) SET THE INITIAL VALUE FOR THE ROW CALCULATION (H2)
C**** 3) CALCULATE TRANSMISSIVITY (TX) FOR UNCONFINED NODES
C**** 4) CALCULATE HEAD VALUES IN HYDRAULICALLY CONNECTED NODES
C**** AS THE SUM OF THE HEAD IN THE PREVIOUS TIMESTEP AND THE
C**** DELH FOR THE PARTICULAR REACH
C
  DO 820 J=1,NROW
  DO 815 I=1,NCOL
  H1(I,J)=H(I,J)
  H2(I,J)=H(I,J)
  IF(THICK(I,J).EQ.0) TX(I,J)=KX(I,J)*(H(I,J)-BOTTM(I,J))
  IF(NCX(I,J).NE.1) GO TO 815
  IF(NREACH(I,J).NE.0) H(I,J)=DELH(NREACH(I,J),ISTEP) + H(I,J)
815 CONTINUE
820 CONTINUE
C
C****FOR EACH NODE ALONG A ROW CALCULATE THE AVERAGE
C****TRANSMISSIVITY ON EACH SIDE AND EXECUTE THE
C****NECESSARY CALCULATIONS IN SUBROUTINE THOMS.
C
  DO 830 J=1,NROW
  DO 825 I=1,NCOL
  K4=NCX(I,J)
  IF(K4.LE.1) GO TO 825
  IF(NC(I,J).EQ.1) GO TO 825
C
  T1=(TX(I-1,J)+TX(I,J))/2.0
  T2=(TX(I+1,J)+TX(I,J))/2.0
  T3=(TX(I,J-1)+TX(I,J))/2.0
  T4=(TX(I,J+1)+TX(I,J))/2.0
C
  IF(NCY(I,J).EQ.3) T3=0.0
  IF(NCY(I,J).EQ.4) T4=0.0
C
  CALL THOMS (0,1,2,1,J)
C
825 CONTINUE
C
C****GO TO NEXT ROW
C
830 CONTINUE

```

```

C
C*****FOR EACH NODE ALONG A COLUMN CALCULATE THE
C*****AVERAGE TRANSMISSIVITIES ON EACH SIDE AND PERFORM
C*****THE NECESSARY CALCULATIONS IN SUBROUTINE THOMS
      DO 840 I=1,NCOL
      DO 835 J=1,NROW
      H2(I,J)=H(I,J)
      IF (THICK(I,J).EQ.0) TX(I,J)=KX(I,J)*(H(I,J)-BOTTM(I,J))
835 CONTINUE
840 CONTINUE
C
      DO 850 I=1,NCOL
      DO 845 J=1,NROW
C
      K4=NCY(I,J)
C
      IF(K4.LE.1) GO TO 845
      IF(NC(I,J).EQ.1) GO TO 845
C
      T1=(TX(I,J-1)+TX(I,J))/2.0
      T2=(TX(I,J+1)+TX(I,J))/2.0
      T3=(TX(I-1,J)+TX(I,J))/2.0
      T4=(TX(I+1,J)+TX(I,J))/2.0
C
      IF(NCX(I,J).EQ.3) T3=0.0
      IF(NCX(I,J).EQ.4) T4=0.0
C
      CALL THOMS      (1,0,3,I,J)
C
845 CONTINUE
C
C***** GO TO NEXT COLUMN
C
850 CONTINUE
C
C*****THE HEAD CALCULATION FOR THIS TIME INCREMENT IS COMPLETED
C*****HEADS AT SELECTED TIMESTEPS ARE PRINTED
C
      IF(ISTEP.NE.THEAD(N)) GO TO 870
      N=N+1
855 NSEC=0
      DO 865 LJ=1,NROW,50
      DO 860 LI=1,NCOL,25
      NSEC=NSEC+1
      WRITE (M6,875)NSEC,ISTEP,DELT
      CALL PRNT1(NCOL,NROW,LI,LJ,H,4H1) ,1)
860 CONTINUE
865 CONTINUE
870 CONTINUE
875 FORMAT(1H1,41X,'TABLE OF CALCULATED HYDRAULIC HEAD (H) FOR SECTO
&R ',I3//35X,' Timestep NO ',I3,' : ',F6.2,' DAY Timestep'//)
C
C*****OUTPUT HYDROGRAPH DATA TO UNIT M5 IF SPECIFIED
C
      IF (NHYDRO.EQ.0) GO TO 879

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      IF (ISTEP.EQ.BTS) WRITE (M5,876) (IH(K),JH(K),K=1,NHYDRO)
      WRITE (M5,877) ISTEP,(H(IH(K),JH(K)),K=1,NHYDRO)
876 FORMAT (1X,'ISTEP',3X,9('(',I2,',',I2,',',I2,',',I2,',',I2,',',I2,',',I2),1X))
877 FORMAT (2X,I3,3X,9F8.2)
879 CONTINUE
C
C*****LEAKAGE AND STORAGE VOLUMES ARE CALCULATED HERE FOR THE
C*****PURPOSE OF OUTPUT ONLY
C
      LEAK=0.0
      DELS=0.0
      DO 890 J=1,NROW
      DO 890 I=1,NCOL
      RLEAK(I,J)=0.0
      IF(NCX(I,J).LE.1) GO TO 880
      IF(IFAC.EQ.0) GO TO 885
      RLEAK(I,J)=DELT*(AREA*FAC(I,J)*(H(I,J)+H1(I,J))-QC(I,J))
      LEAK=LEAK+RLEAK(I,J)
880 IF(NCX(I,J).EQ.0) GO TO 890
      RLEAK(I,J)=RLEAK(I,J)/43560.
885 DELS=DELS+S(I,J)*AREA*(H(I,J)-H1(I,J))
C
C**** OUTPUT LEAKAGE IF SPECIFIED (IPRINT=2)
C
890 CONTINUE
895 CONTINUE
      IF (IPRINT.LE.1) GO TO 897
      IF (NQ.LT.5 .AND. ISTEP.GT.1) GO TO 897
      NSEC=0
      DO 896 LJ=1,NCOL,50
      DO 896 LI=1,NROW,25
      NSEC=NSEC+1
      WRITE (M6,898) NSEC,ISTEP
      CALL PRNT1 (NCOL,NROW,LI,LJ,RLEAK,4H0) ,1)
896 CONTINUE
897 CONTINUE
898 FORMAT (1H1,41X,'TABLE OF LEAKAGE (RLEAK) IN ACRE-FEET PER TIMESTE
&P, FOR SECTOR',I3//35X,' Timestep NO.',I3//)
C
      ALEAK=LEAK/43560.0
      ATLEAK=ATLEAK+ALEASEAK
      TLEAK=TLEAK+LEAK
      ADELS=DELS/43560.0
      ATDELS=ATDELS+ALEASELS
      TDELS=TDELS+DELS
C
C*****CALL INOUT ROUTINE TO COMPUTE THE DISCHARGE
C*****AT HYDRAULICALLY CONNECTED NODES
C
      IF(ITER.EQ.1 .AND. IPRINT.GE.1) CALL INOUT
C
      IF (ICALB.EQ.0) GO TO 942
C
C*****DETERMINE SIMULATION STATISTICS BASED ON A COMPARISON OF
C*****SIMULATED (H) TO MEASURED (HREF) HEAD VALUES AT THREE REFERENCE

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C*****TIMESTEPS (TREF) IN SUBROUTINE STAT
C
900 IF(ISTEP.EQ.TREF(1).OR.ISTEP.EQ.TREF(2).OR.ISTEP.EQ.TREF(3))
& CALL STAT(HMEAN)
C
C*****HEADS CALCULATED THE DESIGNATED
C*****CALIBRATION TIMESTEP (TCALIB) ARE SAVED FOR CALIBRATION
C*****ADJUSTMENTS
C
IF(ISTEP.NE.TREF(TCALIB)) GO TO 940
DO 910 J=1,NROW
DO 905 I=1,NCOL
CALH(I,J)=H(I,J)
905 CONTINUE
910 CONTINUE
C
940 CONTINUE
942 CONTINUE
C
C**** FOR THREE TIMESTEPS (TDEP1,TDEP2,TDEP3) THE DEPTH TO WATER IS
C**** PRINTED OUT
C
IF(ISTEP.NE.TDEP1.AND.ISTEP.NE.TDEP2.AND.ISTEP.NE.TDEP3)
& GO TO 970
DO 950 J=1,NROW
DO 945 I=1,NCOL
IF(NCX(I,J).EQ.0) GO TO 945
DEPTH(I,J)=SURF(I,J)-H(I,J)
945 CONTINUE
950 CONTINUE
C
NSEC=0
DO 965 LJ=1,NROW,50
DO 960 LI=1,NCOL,25
NSEC=NSEC+1
WRITE (M6,955)NSEC,ISTEP,DELT
955 FORMAT(1H1,35X,"TABLE OF DEPTH TO WATER FOR PAGE ",I3//35X,"HALF
&TIMESTEP NO ",I3," DURATION ",F5.2," DAYS"//)
CALL PRNT2(NCOL,NROW,LI,LJ,DEPTH,4H25I5,24)
960 CONTINUE
965 CONTINUE
C
970 CONTINUE
C
C*****
C* PROCEED TO THE NEXT TIMESTEP *
C*****
C
975 CONTINUE
C
C*****RETURN DELT TO THE ORIGINAL NUMBER OF DAYS
C*****AND REWIND THE Q FILE
C
IF(LTS.LT.NTS) DELT=0.5*DELT
IF (NQ.EQ.5) REWIND M9

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```

C
IF (ICALB.EQ.0) GO TO 1040
C
C*****ADJUST THE CALIBRATION PARAMETER IN SUBROUTINE COMPA
C
980 CALL COMPA(SIM,HMEAN)
C
C*****WHEN NO IMPROVEMENT IN THE SIMULATION IS ACHIEVED BY
C*****FURTHER ITERATION PROCEED TO THE NEXT PARAMETER
C
IT=ITER
IF (SIM .EQ. 1) GO TO 987
C
C*****
C* CHANGE THE SAME PARAMETER FOR ANOTHER ITERATION *
C*****
C
985 CONTINUE
987 CONTINUE
C
C*****PRINT A SUMMARY FOR EACH PARAMETER
C
WRITE (M6,990)
990 FORMAT(1H0,///50X,"SUMMARY OF THE CALIBRATION RESULTS",
$/48X,"SUM OF THE SQUARES OF THE DEVIATIONS"//)
WRITE (M6,995)NCYCLE,NSTOP,IT,ITE
995 FORMAT(1H ,55X,"CALIBRATION CYCLE ",I2," OF ",I2,
$/57X,"ITERATIONS TERMINATED AFTER",I2," OF ",I2//)
DO 1005 J=1,IT
WRITE (M6,1000)J,SSS(J)
1000 FORMAT(1H ,56X,"SSS",I3," = ",E10.4)
1005 CONTINUE
C
PMIN(NVAR)=SFMIN
C
C*****
C* PROCEED TO NEXT PARAMETER *
C*****
C
1010 CONTINUE
C
C*****
C* PROCEED TO NEXT CALIBRATION CYCLE *
C*****
C
1020 CONTINUE
C
C*****PRINT THE FINAL PARAMETERS AND THE SUM OF SQUARES
C*****OF THE DEVIATIONS OF THE BEST SIMULATION.
C
1025 CALL FINAL
1035 CONTINUE
1040 STOP
END
C*****

```

```

C+++++SUBROUTINE THOMS
C+++++
C
C          THOMAS ALGORITHM
C          THE FINITE DIFFERENCE EQUATION
C
C*****
C *
C * THIS SUBROUTINE IS APPLIED TWICE EACH TIMESTEP, ONCE ALONG THE*
C * ROWS AND ONCE ALONG COLUMNS. IT IS BASED ON APPLICATION OF *
C * THE ALTERNATING DIRECTION TECHNIQUE TO THE BACKWARD DIFFERENCE*
C * APPROXIMATION. IT IS NOT THE STANDARD ALTERNATING DIRECTION *
C * IMPLICIT PROCEEDURE.
C *
C*****
C
C          SUBROUTINE THOMS (L,M,K,I,J)
C          DOUBLE PRECISION A,B,C,D,W
C
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
REAL KX,MU,LKDIFF
INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTTM,TDEP1,
& TDEP2,TDEP3
DOUBLE PRECISION BE,G,GA1,GA2,TX,T1,T2,T3,T4
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
REAL KMAX,KMIN,LKMAX,LKMIN
INTEGER SIM,TREF,TCALIB
C
C          COMMON/EXTND/
C*****REALS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
& NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
& BOTTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
& IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
& TCALIB,
C*****REALS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
& AFLOT(41,37),AQTHCK(41,37),H(41,37),H1(41,37),
& H2(41,37),HINITL(41,37),Q(41,37),QC(41,37),
& QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
& DELH(42,110),BE(55),C(55),TITLE(40),ADELS,ALEAK,AREA,ATDELS,
& ATLEAK,DELT,GA1,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
& SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SS1(3,40),
& FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SFMIN,SMIN,SMAX,VP
C
C          COMMON M5,M6,M7,M8,M9

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C
C*****ESTABLISH EQUATION COEFFICIENTS FOR EACH NODE
C
C          N=I*M+J*L
C          GA1=((FAC(I,J) + S(I,J)/DELT))*AREA
C          GA2=((FAC(I,J) - S(I,J)/DELT))*AREA
C          IF(K4.EQ.3) T1=0.0
C          IF(K4.EQ.4) T2=0.0
C          A=T1
C          B=-T1-T2-GA1
C          C=T2
C          D=((T3+T4)*H2(I,J) - T3*H2(I-L,J-M) + GA2*H1(I,J) -
& T4*H2(I+L,J+M)) + (MU*Q(I,J)-QC(I,J))
C
C*****NODES ADJACENT TO AN ACTIVE DRAIN (SPRINGS), ARE
C*****TREATED SIMILAR TO THE CASE OF HYDRAULICALLY CONNECTED
C
C          IF (NC(I,J).EQ.0 .AND. NC(I-M,J-L).EQ.1 .AND. NC(I+M,J+L).EQ.1)
& GO TO 25
C          IF(NC(I+M,J+L).EQ.1) GO TO 10
C          IF(NC(I-M,J-L).EQ.1) GO TO 20
C
C          C*** METHOD OF HEAD CALCULATION IS DETERMINED BY NODE TYPE (K4)
C
C          GO TO (50,30,15,5,20,10,25),K4
C
C          C*** FOR NODES WITH AN IMPERMIABLE BOUNDRY 1/2 GRID SPACING TO THE
C          C*** RIGHT, OR ABOVE.
C
C          5 T2=0.0D00
C
C          C*** FOR NODES WITH A HYDRAULICALLY CONNECTED NODE TO THE RIGHT,
C          C*** OR ABOVE.
C
C          10 D=D-T2*H(I+M,J+L)
C          NR4=N
C          NR6=1
C          C=0.0D00
C          GO TO 30
C
C          C*** FOR NODES WITH AN IMPERMIABLE BOUNDRY 1/2 GRID SPACING TO THE
C          C*** LEFT, OR BELOW.
C
C          15 T1=0.0D00
C
C          C*****FOR NODES WHERE A HYDRAULICALLY CONNECTED NODE LIES TO
C          C*****THE LEFT OR BELOW
C
C          20 D=D-T1*H(I-M,J-L)
C          BE(N-1)=0.0D00
C          G(N-1)=0.0D00
C          NR1=N
C          NR6=0
C          A=0.0D00
C          GO TO 30

```



```

C
C*** FOR NODES WITH A HYDRAULICALLY CONNECTED NODE ON BOTH SIDES.
C
25 H(I,J)= (D-T1*(I-M,J-L)-T2*(I+M,J+L))/B
C
RETURN
C
C*** FOR INTERIOR NODES
C
30 W=B-A*BE(N-1)
BE(N)=C/W
G(N)=(D-A*G(N-1))/W
C
C*** RETURN UNLESS AT THE END OF A ROW OR COLUMN
C
IF(NR6.EQ.0) RETURN
C
IF(L.EQ.0) GO TO 40
C
C*** HEAD VALUES ARE CALCULATED FOR EACH COLUMN
C
H(I,NR4)=G(NR4)
LAST=NR4-NR1
DO 35 KK=1, LAST
JJ=NR4-KK
H(I,JJ)=G(JJ)-BE(JJ)*H(I,JJ+1)
C
IF (H(I,JJ).LT.6000 .AND. H(I,JJ).GT.3000) GO TO 35
C
WRITE (1,7777) I,JJ,H(I,JJ),KX(I,JJ),S(I,JJ),Q(I,JJ),QC(I,JJ),
C
& FAC(I,JJ),H2(I+1,JJ),H2(I-1,JJ),G(JJ),BE(JJ),H(I,JJ+1),ISTEP,
C
& L,G(JJ-1),BE(JJ-1)
C
IF (H(I,JJ).LT.3000. .OR. H(I,JJ).GT.6000.) STOP
C7777 FORMAT (5X,'I=',I3,'J=',I3,'H=',F6.0,'KX=',F4.0,'S=',F4.3/
C
& 5X,'Q=',F12.0,'QC=',F12.0,'FAC=',F5.4/
C
& 5X,'H2+=',F6.0,'H2-=',F6.0,'G=',F6.1/
C
& 5X,'BE=',F4.2,'H+1=',F6.0,'ISTEP=',I3,'L=',I2,
C
& 5X,'G-1=',F6.1,'BE-1=',F4.2)
C
35 CONTINUE
RETURN
C
C*** HEAD VALUES ARE CALCULATED FOR EACH ROW
C
40 H(NR4,J)=G(NR4)
LAST=NR4-NR1
DO 45 KK=1, LAST
II=NR4-KK
H(II,J)=G(II)-BE(II)*H(II+1,J)
C
IF (H(II,J).GT.3000. .AND. H(II,J).LT.6000.) GO TO 45
C
WRITE (1,7777) II,J,H(II,J),KX(II,J),S(II,J),Q(II,J),
C
& QC(II,J),FAC(II,J),H2(II,J+1),H2(II,J-1),G(II),
C
& BE(II),H(II+1,J),ISTEP,L,G(II-1),BE(II-1)
C
IF (H(II,J).LT.3000. .OR. H(II,J).GT.6000.) STOP
45 CONTINUE
C
50 RETURN

```

```

C
END
C+++++
C+++++SUBROUTINE INOUT
C+++++
SUBROUTINE INOUT
C
C
C *****
C *
C * THIS SUBROUTINE CALCULATES FLOWS OUT OF HYDRAULICALLY CONNECTED *
C * NODES AND SPRINGS. IT ALSO CALCULATES AND OUTPUTS THE MASS *
C * BALANCE. *
C * *
C *****
C
C
DOUBLE PRECISION F1,F2,F3,F4,FLOO
C
C
C****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
REAL KX,MU,LKDIFF
INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTTM,TDEP1,
& TDEP2,TDEP3
DOUBLE PRECISION BE,G,GAI,GA2,TX,T1,T2,T3,T4
C****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
REAL KMAX,KMIN,LKMAX,LKMIN
INTEGER SIM,TREF,TCALIB
C
C
COMMON/EXTND/
C****INTEGERS*****
C****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
& NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
& BOTTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
& IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
& TCALIB,
C****REALS*****
C****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
& AFLOT(41,37),AQTHCK(41,37),H(41,37),H1(41,37),
& H2(41,37),HINITL(41,37),Q(41,37),QC(41,37),
& QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
& DELH(42,110),BE(55),G(55),TITLE(40),ADELS,ALEAK,AREA,ATDELS,
& ATLEAK,DELT,GAI,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
& SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SSI(3,40),
& FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SFMIN,SMIN,SMAX,VP
COMMON M5,M6,M7,M8,M9
C
DIMENSION FLOTO(200),FLOSTE(200)

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```

DATA FLOTO/200*0.0/,FLOSTE/200*0.0/
C
C*** INITIALIZE SUMFLO
SUMFLO=0.0
C
DO 40 K=1,IC
I=IX(K)
J=IY(K)
F1=0.0
F2=0.0
F3=0.0
F4=0.0
C
HIJ=H(I,J)+H1(I,J)
IF(NCX(I-1,J).GT.0)
&F1=(H(I-1,J)+H1(I-1,J)-HIJ)/2.*(TX(I,J)+TX(I-1,J))
C
IF(NCX(I+1,J).GT.0)
&F2=(H(I+1,J)+H1(I+1,J)-HIJ)/2.*(TX(I,J)+TX(I+1,J))
C
IF(NCX(I,J-1).GT.0)
&F3=(H(I,J-1)+H1(I,J-1)-HIJ)/2.*(TX(I,J)+TX(I,J-1))
C
IF(NCX(I,J+1).GT.0)
&F4=(H(I,J+1)+H1(I,J+1)-HIJ)/2.*(TX(I,J)+TX(I,J+1))
C
30 CONTINUE
C
C*** THE OUTFLOWS FROM A NODE ARE THE NET DIFFERENCE OF GROUND-WATER
C*** FLOW ON ALL SIDES MINUS THE CHANGE IN STORAGE,
C***LEAKAGE, AND SURFACE FLUX
C
FLOO=(F1+F2+F3+F4)/2.0*DELT-S*(H(I,J)-H1(I,J))*AREA-
& Q(I,J)*DELT-RLEAK(I,J)*43560.
C
C*****SPRINGS ARE TERMINATED WHEN THEY ACT AS A SOURCE OF
C*****RECHARGE RATHER THAN DISCHARGE
C
IF(DRAIN(I,J).GT.0.AND.FLOO.LT.0) NC(I,J)=0
IF(DRAIN(I,J).GT.0.AND.FLOO.LT.0) FLOO=0.0
FLOTO(K)=FLOTO(K)+FLOO
AFLOW=FLOO/43560.
FLOSTE(K)=FLOO
SUMFLO=SUMFLO+AFLOW
C
*****
C *
C * COMPUTE AND OUTPUT FLOW RATE IN CUBIC FEET PER DAY FOR *
C * FLOW BOUNDARIES AND HYDRAULICALLY CONNECTED NODES *
C *
C *****
35 FORMAT(I2,I3,F15.0)
40 CONTINUE
IF (IPRINT.GE.2) CALL AROUT(FLOSTE,100,0)

```

```

45 CONTINUE
C
C*** COMPUTE AND OUTPUT MASS BALANCE ***
C
BLNCE=ALEAK+ADELS+SUMFLO+SUMQ1
WRITE (M6,50)ALEAK,ADELS,ISTEP,SUMFLO,SUMQ1,BLNCE
50 FORMAT(' '//
150X'TOTAL LEAKAGE (ALEAK) 'F10.0/20X'MASS BALANCE SUMMARY',
210X'TOTAL STORAGE (ADELS) 'F10.0/20X' Timestep # '13,
313X'TOTAL OUTFLOW (SUMFLO) 'F10.0/20X' (ACRE FEET)',
514X'TOTAL INPUT (SUMQ1) 'F10.0/
650X'MASS BALANCE (BLNCE) 'F10.0)
IF(ISTEP.NE.NTS) RETURN
C
*****
C *
C * COMPUTE AND PRINT OUTFLOWS FOR THE TOTAL CALIBRATION PERIOD, *
C * ALSO COMPUTE AND PRINT MASS BALANCE FOR THE TOTAL CALIBRATION *
C * PERIOD *
C *
C *****
SUMFLO=0.0
WRITE (M6,55)ITER
55 FORMAT(IH1,47X,'SIMULATION NUMBER (ITER)',I3/41X,'TOTAL FLOW FOR T
&THE SIMULATION PERIOD')
WRITE (M6,75)
DO 60 K=1,IC
I=IX(K)
J=IY(K)
ATOT=FLOTO(K)/43560.
SUMFLO=SUMFLO+ATOT
WRITE (M6,80)I,J,FLOTO(K),I,J,ATOT
60 CONTINUE
CALL AROUT(FLOTO,1000,1)
65 CONTINUE
DO 70 K=1,IC
70 FLOTO(K)=0.0
BLNCE=ATLEAK+ATDELS+SUMFLO+SUMQ2
WRITE (M6,85)ATLEAK,ATDELS,SUMFLO,SUMQ2,BLNCE
75 FORMAT(IH0,42X,'NODE FLOW NODE FLOW'//42X,
1'(I,J) (FLOTO) (I,J) (ATOT) '/49X,
2'(CUBIC FEET) ',6X,'(ACRE FEET)')//
80 FORMAT(IH ,40X,'('',12,',',12,',')=',E12.4,' ('',12,',',12,',')=',
&F12.0)
85 FORMAT(' '//
150X'TOTAL LEAKAGE (ATLEAK) 'F10.0/18X'MASS BALANCE SUMMARY FOR',
28X'TOTAL STORAGE (ATDELS) 'F10.0/19X'THE SIMULATION PERIOD',
38X'TOTAL OUTFLOW (SUMFLO) 'F10.0/17X' (ACRE FEET)',
514X'TOTAL INPUT (SUMQ2) 'F10.0/
650X'MASS BALANCE (BLNCE) 'F10.0)
RETURN
END
C*****
C*****SUBROUTINE AROUT

```

```

C+++++
C
C
C      SUBROUTINE AROUT(FLOTOT,N,IT)
C
C *****
C *
C * THIS SUBROUTINE WRITES OUTFLOW VALUES IN ARRAY FORM FOR EACH *
C * INDIVIDUAL NODE *
C *
C *****
C
C
C      DOUBLE PRECISION F1,F2,F3,F4,FLOO,ACRFT
C
C *****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
C      REAL KX,MU,LKDIFF
C      INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTTM,TDEP1,
C      & TDEP2,TDEP3
C      DOUBLE PRECISION BE,G,GA1,GA2,TX,T1,T2,T3,T4
C *****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
C      REAL KMAX,KMIN,LKMAX,LKMIN
C      INTEGER SIM,TREF,TCALIB
C
C
C      COMMON/EXTND/
C *****INTEGERS*****
C *****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
C      & DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
C      & NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
C      & BOTTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
C      & IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C *****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
C      & TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
C      & TCALIB,
C *****REALS*****
C *****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
C      & KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
C      & AFLOT(41,37),AQTHCK(41,37),H(41,37),H1(41,37),
C      & H2(41,37),HINITL(41,37),Q(41,37),QC(41,37),
C      & QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
C      & DELH(42,110),BE(55),G(55),TITLE(40),ADELS,ALEAK,AREA,ATDELS,
C      & ATLEAK,DELT,GA1,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C *****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
C      & CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
C      & SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SS1(3,40),
C      & FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SFMIN,SMIN,SMAX,VP
C
C
C      COMMON M5,M6,M7,M8,M9
C
C      DIMENSION FLOTOT(200)
C
C      ACRFT=43560.*N
C
C *****CONVERT FLOTOT TO APPROPRIATE UNITS IN I,J COORDINATES

```

```

C
C      DO 10 J=1,NROW
C      DO 10 I=1,NCOL
C      AFLOT(I,J)=0.0
C
C      10 CONTINUE
C      DO 15 K=1,IC
C      I=IX(K)
C      J=IY(K)
C      AFLOT(I,J)=FLOTOT(K)/ACRFT
C
C      15 CONTINUE
C
C *****WRITE OUT IN APPROPRIATE FORMAT
C
C      IF(IT.EQ.1) GOTO 35
C
C      NSEC=0
C      DO 30 LJ=1,NROW,50
C      DO 25 LI=1,NCOL,25
C      NSEC=NSEC+1
C      WRITE (M6,20)ISTEP,NSEC
C      20 FORMAT(1H1,20X,'OUTFLOWS IN 100 ACRE-FEET FOR TIMESTEP',I3,50X,'PA
C      &GE',I2//)
C      CALL PRNT1(NCOL,NROW,LI,LJ,AFLOT,4H1) ,1)
C
C      25 CONTINUE
C      30 CONTINUE
C      GOTO 55
C
C
C      35 CONTINUE
C      NSEC=0
C      DO 50 LJ=1,NROW,50
C      DO 45 LI=1,NCOL,25
C      NSEC=NSEC+1
C      WRITE (M6,40)NSEC
C      40 FORMAT(1H1,20X,'OUTFLOWS IN 1000 ACRE-FEET FOR THE OVERALL CALIBRA
C      &TION PERIOD ',I30X,'PAGE',I2//)
C      CALL PRNT1(NCOL,NROW,LI,LJ,AFLOT,4H1) ,1)
C
C      45 CONTINUE
C      50 CONTINUE
C
C
C      55 CONTINUE
C      RETURN
C      END
C+++++
C*****SUBROUTINE DRA
C*****
C
C      SUBROUTINE DRA
C
C *****
C *
C * THIS SUBROUTINE DETERMINES IF DRAIN NODES ARE ACTIVE, THAT IS *
C * IF THE CALCULATED HEAD IS ABOVE THE DRAIN ELEVATION *
C *
C *****
C
C

```

```

C
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
REAL KX,MU,LKDIFF
INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTTM,TDEP1,
& TDEP2,TDEP3
DOUBLE PRECISION BE,G,GA1,GA2,TX,T1,T2,T3,T4
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
REAL KMAX,KMIN,LKMAX,LKMIN
INTEGER SIM,TREF,TCALIB

C
C
COMMON/EXTND/
C*****INTEGERS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
& NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
& BOTTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
& IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
& TCALIB,
C*****REALS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
& AFLOT(41,37),AQTHCK(41,37),H(41,37),H1(41,37),
& H2(41,37),HINITL(41,37),Q(41,37),QC(41,37),
& QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
& DELH(42,110),BE(55),G(55),TITLE(40),ADELS,ALEAK,AREA,ATDELS,
& ATLEAK,DELT,GA1,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
& SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SS1(3,40),
& FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SFMIN,SMIN,SMAX,VP

C
COMMON M5,M6,M7,M8,M9

C
MODE=0
DO 10 K=1,IC
I=IX(K)
J=IY(K)

C
C*** CHECK FOR POSSIBLE DRAIN AT NODE (I,J) ***
C
IF(DRAIN(I,J).LT.1)GO TO 10

C
C**** COMPARE DRAIN ALTITUDE TO SIMULATED HEAD
C
IF(H(I,J).LE.DRAIN(I,J)) GO TO 10
5 NC(I,J)=1
MODE=1
H(I,J)=DRAIN(I,J)
10 CONTINUE

C
20 CONTINUE
RETURN

```

```

END
C*****
C*****SUBROUTINE COMPA
C*****
C
SUBROUTINE COMPA(SIM,HMEAN)
C
C *****
C *
C * THIS SUBROUTINE AUTOMATICALLY ADJUSTS THE DESIGNATED
C * CALIBRATION PARAMETERS BASED ON DIFFERENCES BETWEEN GRADIENTS *
C * OR CALCULATED HEADS (HI) AND THE MEASURED HEADS (HREF) AT THE *
C * DESIGNATED CALIBRATION TIMESTEP (TCALIB).
C *****
C
C
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
REAL KX,MU,LKDIFF
INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTTM,TDEP1,
& TDEP2,TDEP3
DOUBLE PRECISION BE,G,GA1,GA2,TX,T1,T2,T3,T4
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
REAL KMAX,KMIN,LKMAX,LKMIN
INTEGER SIM,TREF,TCALIB

C
C
COMMON/EXTND/
C*****INTEGERS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
& NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
& BOTTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
& IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
& TCALIB,
C*****REALS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
& AFLOT(41,37),AQTHCK(41,37),H(41,37),H1(41,37),
& H2(41,37),HINITL(41,37),Q(41,37),QC(41,37),
& QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
& DELH(42,110),BE(55),G(55),TITLE(40),ADELS,ALEAK,AREA,ATDELS,
& ATLEAK,DELT,GA1,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
& SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SS1(3,40),
& FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SFMIN,SMIN,SMAX,VP

C
COMMON M5,M6,M7,M8,M9

C
DIMENSION PARM(41,37,4),SLOPE(41,37),PAR(7,4),XMEAN(3),SDEV(3)
EQUIVALENCE (PARM(1,1,1),KX(1,1))
EQUIVALENCE (SLOPE(1,1),TX(1,1))
C

```

```

DATA PAR/4HHYDR,4HAULI,4HC CO,4HN Duc,4HTIVI,4HTY ,4H(KX),4HLEAK,
&4HAGE ,4HFACT,4HOR ,4H(FAC,4H) ,4H ,4HHEAD,4H DIF,4HFERE,4HN
&CE ,4H(LKD,4HIFF),4H ,4HSTOR,4HAGE ,4HCOEF,4HFICI,4HENT ,
&4H(S) ,4H /
C
C
C *****
C * THE NEXT SECTION DETERMINES THE STATUS OF THE *
C * CURRENT ITERATION AND PRINTS A SUMMARY OF THE *
C * PREVIOUS ITERATIONS. *
C *****
C
IF(ITER.EQ.1) GO TO 30
IF(SSS(ITER).LT.SFMIN) GO TO 30
DO 15 J=1,NROW
DO 10 I=1,NCOL
PARM(I,J,NVAR)=SAVE(I,J)
10 CONTINUE
15 CONTINUE
20 SIM=1
25 CONTINUE
C
RETURN
C
30 SFMIN=SSS(ITER)
35 SIM=0
DO 45 J=1,NROW
DO 40 I=1,NCOL
SAVE(I,J)=PARM(I,J,NVAR)
40 CONTINUE
45 CONTINUE
IF(ITER.EQ.ITE) GO TO 25
C
C *****
C * BEGIN CALIBRATION *
C *****
C**** CALCULATE VV BASED ON THE SUM OF SQUARES OF PREVIOUS SIMULATIONS
C
VV=VP
IF(ITER.EQ.1)GO TO 50
VA=VP+(1.0-VP)*VP*SSS(ITER)/SSS(ITER-1)
VB=(1.0-VA)*((SSS(ITER)/SSS(ITER-1))**2)
VV=VA+VB
C
50 CONTINUE
A1=1.35
A2=0.65
C
C**** THE PARAMETER TO BE ADJUSTED DEPENDS UPON THE VALUE OF NVAR
C
GO TO (55,80,130,180),NVAR
C
55 CONTINUE
C

```

```

C****ADJUST THE HYDRAULIC CONDUCTIVITIES
C
NNCOL=NCOL-1
NNROW=NROW-1
DO 65 J=2,NNROW
DO 60 I=2,NNCOL
IF(NCX(I,J).EQ.0)GO TO 60
L1=1
L2=1
L3=1
L4=1
IF (NCX(I-1,J).EQ.0) L1=0
IF (NCX(I+1,J).EQ.0) L2=0
IF (NCX(I,J-1).EQ.0) L3=0
IF (NCX(I,J+1).EQ.0) L4=0
TT=SQRT(((CALH(I+L2,J)-CALH(I-L1,J))/(L1+L2))**2+((CALH(I,J+L4) -
&CALH(I,J-L3))/(L3+L4))**2)
C
C**** DETERMINE THE RATIO OF CALCULATED TO MEASURED GRADIENT
C
SLOPE(I,J)=TT/TS(I,J)
60 CONTINUE
65 CONTINUE
C
C**** CALCULATE NEW CONDUCTIVITY VALUES
C
DO 75 J=2,NNROW
DO 70 I=2,NNCOL
IF(NCX(I,J).EQ.0)GO TO 70
AB=1.0+(SLOPE(I,J)-1.0)*VV
IF(AB.GT.1.35)AB=1.35
IF(AB.LT.0.65)AB=0.65
KX(I,J) = AB*KX(I,J)
IF(KX(I,J).GT.KMAX) KX(I,J) = KMAX
IF(KX(I,J).LT.KMIN) KX(I,J) = KMIN
70 CONTINUE
75 CONTINUE
GO TO 200.
C
C**** CHANGE THE LEAKANCE
C
80 CONTINUE
DO 125 J=1,NROW
DO 120 I=1,NCOL
IF(NCX(I,J).EQ.0) GO TO 120
D1=CALH(I,J)-HINITL(I,J)
D2=HREF(I,J,TCALIB)-HINITL(I,J)
IF(D1*D2.LE.0.0) GO TO 100
IF(D1.EQ.D2) GO TO 120
C
C****WHEN THE CALCULATED HEAD CHANGE FROM INITIAL CONDITIONS IS
C****IN THE SAME DIRECTION AS THE ACTUAL CHANGE, ADJUST FAC
C****BASED OF THE RATE OF CHANGE AND THE SUM OF SQUARES
C
IF(D1*LKDIFF(I,J)) 85,120,90

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```

85 AB=(1.0+((D2/D1)-1.0)*VV)
   GO TO 95
90 AB=(1.0+((D1/D2)-1.0)*VV)
95 IF(AB.GT.A1)AB=A1
   IF(AB.LT.A2)AB=A2
   FAC(I,J)=AB*FAC(I,J)
   GO TO 115
C
C*****WHEN THE CALCULATED HEAD CHANGE FROM THE INITIAL CONDITIONS
C*****IS OPPOSITE THE ACTUAL CHANGE ADJUST FAC BY THE MAXIMUM OR
C*****MINIMUM DEPENDING UPON THE DIRECTION OF FLOW
C
100 IF(D1*LKDIFF(I,J))105,120,110
105 FAC(I,J)=A2*FAC(I,J)
   GO TO 115
110 FAC(I,J)=A1*FAC(I,J)
115 IF(FAC(I,J).LT.FMIN)FAC(I,J)=FMIN
   IF(FAC(I,J).GT.FMAX)FAC(I,J)=FMAX
120 CONTINUE
125 CONTINUE
   GO TO 200
C
C**** CHANGE THE INITIAL HEAD DIFFERENCE (LKDIFF)
C
130 CONTINUE
   DO 175 J=1,NROW
   DO 170 I=1,NCOL
   IF(NCX(I,J).EQ.0)GO TO 170
   D1=CALH(I,J)-HINITL(I,J)
   D2=HREF(I,J,TCALIB)-HINITL(I,J)
   IF(D1*D2.LE.0.0) GO TO 150
   IF(D1.EQ.D2) GO TO 170
C
C*****WHEN THE CALCULATED HEAD CHANGE FROM THE INITIAL CONDITIONS
C*****IS IN THE SAME DIRECTION AS THE ACTUAL CHANGE ADJUST LKDIFF
C*****BASED ON THE RATE OF CHANGE AND THE SUM OF SQUARES
C
   IF(D1*LKDIFF(I,J)) 135,170,140
135 AB=(1.0+((D2/D1)-1.0)*VV)
   GO TO 145
140 AB=(1.0+((D1/D2)-1.0)*VV)
145 IF(AB.GT.A1)AB=A1
   IF(AB.LT.A2)AB=A2
   LKDIFF(I,J)=AB*LKDIFF(I,J)
   GO TO 165
C
C*****WHEN THE CALCULATED HEAD CHANGE FROM INITIAL CONDITIONS IS
C*****IN THE OPPOSITE DIRECTION OF THE ACTUAL CHANGE ADJUST LKDIFF
C*****BY THE MAXIMUM OR MINIMUM DEPENDING UPON DIRECTION OF FLOW
C
150 IF(D1*LKDIFF(I,J)) 155,170,160
155 LKDIFF(I,J)=A2*LKDIFF(I,J)
   GO TO 165
160 LKDIFF(I,J)=A1*LKDIFF(I,J)
165 IF(LKDIFF(I,J).LT.LKMIN)LKDIFF(I,J)=LKMIN

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```

   IF(LKDIFF(I,J).GT.LKMAX)LKDIFF(I,J)=LKMAX
170 CONTINUE
175 CONTINUE
   GO TO 200
C
C**** CHANGE THE STORAGE COEFFICIENT
C
180 CONTINUE
   DO 195 J=1,NROW
   DO 190 I=1,NCOL
   AB=1.0
   IF(NCX(I,J).EQ.0)GO TO 190
   D1=CALH(I,J)-HINITL(I,J)
   D2=HREF(I,J,TCALIB)-HINITL(I,J)
C
C*****WHEN THE CALCULATED HEAD CHANGE FROM INITIAL CONDITIONS
C*****IS IN THE SAME DIRECTION AS THE ACTUAL CHANGE ADJUST S
C*****BASED ON THE RATE OF CHANGE AND THE SUM OF SQUARES,
C*****OTHERWISE DO NOT CHANGE S
C
   IF(D1*D2.LE.0.0) GO TO 190
   AB=(1.0+((D1/D2)-1.0)*VV)
185 S(I,J)=AB*S(I,J)
   IF(S(I,J).LT.SMIN) S(I,J)=SMIN
   IF(S(I,J).GT.SMAX) S(I,J)=SMAX
190 CONTINUE
195 CONTINUE
C
C**** WRITE HEADINGS FOR NEW PARAMETER VALUES AND WRITE OUT THE VALUES
C
200 CONTINUE
   NSEC=0
   DO 235 LJ=1,NROW,50
   DO 230 LI=1,NCOL,25
   NSEC=NSEC+1
   WRITE (M6,205)ITER,(PAR(NNN,NVAR),NNN=1,7),NSEC
205 FORMAT(1H1,10X,"CALIBRATION BASED ON SIMULATION",I2,/11X,"THE PARA
&METER CHANGED WAS THE ",7A4,/11X,"THE NEW VALUE OF THE PARAMETER
&IS PRINTED BELOW AND USED IN THE NEXT SIMULATION",32X,"PAGE",I2/)
   GO TO (210,215,220,225),NVAR
210 CALL PRNT1(NCOL,NROW,LI,LJ,KX,4H0) ,1)
   GO TO 230
215 CALL PRNT1(NCOL,NROW,LI,LJ,FAC,4H4) ,1)
   GO TO 230
220 CALL PRNT1(NCOL,NROW,LI,LJ,LKDIFF,4H0) ,1)
   GO TO 230
225 CALL PRNT1(NCOL,NROW,LI,LJ,S,4H4) ,1)
230 CONTINUE
235 CONTINUE
   RETURN
   END
C+++++
C+++++SUBROUTINE STAT
C+++++
C

```

```

C *****
C * THIS SUBROUTINE DETERMINES THE ERROR (RESIDUAL) AT EACH NODE, *
C * THE STANDARD DEVIATION OF THAT ERROR FROM THE MEAN ERROR, AND *
C * THE SUM OF SQUARES OF THE ERRORS. THESE STATISTICS ARE
C * COMPUTED AT EACH REFERENCE TIMESTEP BASED ON MEASURED
C * (REFERENCE) HEAD VALUES.
C *
C *****
C
C SUBROUTINE STAT(HMEAN)
C
C *****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
REAL KX,MU,LKDIFF
INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTTM,TDEP1,
& TDEP2,TDEP3
DOUBLE PRECISION BE,G,GA1,GA2,TX,T1,T2,T3,T4
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
REAL KMAX,KMIN,LKMAX,LKMIN
INTEGER SIM,TREF,TCALIB
C
C
C COMMON/EXTND/
C*****INTEGERS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
& NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
& BOTTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
& IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
& TCALIB,
C*****REALS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
& AFLOT(41,37),AQTHCK(41,37),H(41,37),H1(41,37),
& H2(41,37),HINITL(41,37),Q(41,37),QC(41,37),
& QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
& DELH(42,110),BE(55),G(55),TITLE(40),ADELS,ALEAK,AREA,ATDELS,
& ATLEAK,DELT,GA1,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
& SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SS1(3,40),
& FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SFMIN,SMIN,SMAX,VP
C
C COMMON M5,M6,M7,M8,M9
C
C DIMENSION PAR(7,4),XMEAN(3),SDEV(3)
C
C DATA PAR/4HHYDR,4HAULI,4HC CO,4HNDUC,4HTIVI,4HTY ,4HXX =,4HLEAK,
&4HAGE ,4HFACT,4HOR ,4H FA,4HC IS,4H THE,4HHEAD,4H DIF,4HFERE,4HN
&CE ,4HLKDI,4HF IS,4H THE,4HSTOR,4HAGE ,4HCOEF,4HFIFI,4HENT ,4HS IS
&,4H THE/
C
C DO 5 K=1,4

```

```

IF(ISTEP.EQ.TREF(K)) GO TO 10
5 CONTINUE
10 CONTINUE
C
C*****CALCULATE THE ERRORS (DEV), THE SUM OF SQUARES FOR THIS TIMESTEP
C***** (SS1), AND THE MEAN ERROR (XMEAN)
C
A=0.0
XMEAN(K)=0.0
SS1(K,ITER)=0.0
DO 20 J=1,NROW
DO 15 I=1,NCOL
IF(NCX(I,J).EQ.0) GO TO 15
A = A + 1.0
DEV(I,J)=H(I,J)-HREF(I,J,K)
SS1(K,ITER)=SS1(K,ITER)+DEV(I,J)*DEV(I,J)
XMEAN(K)=XMEAN(K)+ABS(DEV(I,J))
15 CONTINUE
20 CONTINUE
C
C**** COMPUTE MEAN (XMEAN) AND STANDARD DEVIATION (SDEV) OF THE
C**** INDIVIDUAL ERRORS FROM THE MEAN ERROR
C
SSS(ITER)=SSS(ITER)+SS1(K,ITER)
E=(SS1(K,ITER)-(XMEAN(K)*XMEAN(K))/A)/(A-1)
SDEV(K)=SQRT(E)
XMEAN(K)=XMEAN(K)/A
C
C**** PRINT OUT THE DEVIATIONS OF ALL NODE POINTS FOR NREF TIMESTEPS
C
NSEC=0
DO 35 LJ=1,NROW,50
DO 30 LI=1,NCOL,25
NSEC=NSEC+1
WRITE (M6,25)NSEC,TREF(K),ITER,(PAR(NNN,NVAR),NNN=1,7)
25 FORMAT(1H1,2X,"PAGE #",I3," : DEVIATIONS OF THE GENERATED HEADVAL
&UES FROM THE MEASURED VALUES FOR TIMESTEP",I3," AFTER",I3," SIMULA
&TIONS"/15X,"WHILE CHANGING THE ",7A4," PARAMETER")
CALL PRNT1(NCOL,NROW,LI,LJ,DEV,4H1) ,1)
30 CONTINUE
35 CONTINUE
IF(ISTEP.LT.TREF(NREF)) RETURN
C**** WRITE THE SUM OF SQUARES OF THE DEVIATIONS (SS1) AND SUMTOTAL (SSS)
WRITE (M6,45)
45 FORMAT(1H1,/,55X,"PRINTOUT SUBROUTINE STAT")
WRITE (M6,50)ITER,TREF(TCALIB),(PAR(NNN,NVAR),NNN=1,7)
50 FORMAT(1H ,/,47X,"STATISTICAL SUMMARY FOR SIMULATION#",I4/
&53X,"CALIBRATION TIMESTEP #",I4//
&38X,7A4," GEOHYDROLOGICAL PARAMETER CHANGED"/)
WRITE (M6,55)
55 FORMAT(1H ,56X,"SUM OF MEAN STANDARD"/44X,
& "TIMESTEP SQUARES ERROR DEVIATION"/44X,
& "TREF(1,2,3) SS1, SSS XMEAN SDEV '/')
C
C DO 65 K=1,NREF

```

```

WRITE(M6,60)TREF(K),SS1(K,ITER),XMEAN(K),SDEV(K)
60 FORMAT (1H0,46X,I3,6X,E10.4,4X,F4.1,7X,F4.1)
65 CONTINUE
C
C*****PRINT TOTALED SUM OF SQUARES
C
WRITE (M6,70) SSS(ITER)
70 FORMAT(1H0,56X,'-----'/56X,E10.4)
WRITE (M6,75) A,HMEAN
75 FORMAT (1H ,///12X,'THE MEAN HISTORICAL CHANGE (HMEAN=HREF(TCALIB)
&-HINITL) IN THE WATERTABLE OVER ',F4.0,'NODES IS', F8.2)
C
C
C
RETURN
END
C+++++
C+++++SUBROUTINE PRNT1
C+++++
C *****
C *
C * THIS SUBROUTINE PRINTS AN ARRAY TABLE FOR SINGLE PRECISION *
C * REAL NUMBERS *
C *
C *****
C
SUBROUTINE PRNT1(NCOL,NROW,LI,LJ,X,A,K)
EMA X(41,37,3),NCOL,NROW
C
DIMENSION F(5)
COMMON M5,M6,M7,M8,M9
DATA F/4H(1H ,4H,I3,,4H1X,2,4H5F5.,4H0) /
C
F(5)=A
NRUW=NROW+1
NEND=NCOL
NUP=NROW
IF((LI+24).LT.NEND) NEND=LI+24
WRITE (M6,5)(I,I=LI,NEND)
5 FORMAT(1H0,'J/I',3X,I2,24(3X,I2))
IF((LJ+49).LT.NUP) NUP=LJ+49
DO 10 J=LJ,NUP
NJ=NRUW-J
WRITE(M6,F) NJ,(X(I,NJ,K),I=LI,NEND)
10 CONTINUE
RETURN
END
C+++++
C+++++SUBROUTINE PRNT2
C+++++
C *****
C *
C * THIS SUBROUTINE PRINTS AN ARRAY TABLE FOR SINGLE PRECISION *
C *
C *****

```

```

C * INTEGER NUMBERS *
C *
C *****
C
SUBROUTINE PRNT2(NCOL,NROW,LI,LJ,N,A,L)
EMA N(41,37),NCOL,NROW
C
DIMENSION F(5),G(4)
COMMON M5,M6,M7,M8,M9
DATA G/4H(1H0,4H,5X,,4H2515,4H) /
DATA F/4H (1H,4H ,I3,4H,2X,,4H2515,4H) /
C
F(4)=A
G(3)=A
NRUW=NROW+1
NUP=NROW
NEND=NCOL
IF((LI+L).LT.NEND) NEND=LI+L
WRITE(M6,G) (I,I=LI,NEND)
IF((LJ+49).LT.NUP) NUP=LJ+49
DO 5 J=LJ,NUP
NJ=NRUW-J
WRITE(M6,F) NJ,(N(I,NJ),I=LI,NEND)
5 CONTINUE
RETURN
END
C+++++
C+++++SUBROUTINE PRNT3
C+++++
C *****
C *
C * THIS SUBROUTINE PRINTS AN ARRAY TABLE FOR DOUBLE PRECISION *
C * REAL NUMBERS *
C *
C *****
C
SUBROUTINE PRNT3(NCOL,NROW,LI,LJ,X,A,K)
EMA X(41,37),NCOL,NROW
DOUBLE PRECISION X
C
DIMENSION F(5)
COMMON M5,M6,M7,M8,M9
DATA F/4H(1H ,4H,I3,,4H3X,2,4H5F5.,4H0) /
C
F(5)=A
NRUW=NROW+1
NEND=NCOL
NUP=NROW
IF((LI+24).LT.NEND) NEND=LI+24
WRITE (M6,5)(I,I=LI,NEND)
5 FORMAT(1H0,' J/I',25I5)
IF((LJ+49).LT.NUP) NUP=LJ+49
DO 10 J=LJ,NUP

```



```

NJ=NRUW-J
WRITE(M6,F) NJ,(X(1,NJ),I=LI,NEND)
10 CONTINUE
RETURN
END
C+++++
C+++++SUBROUTINE PNCH
C+++++
C *****
C *
C * THIS SUBROUTINE OUTPUTS CALIBRATED PARAMETERS TO UNIT M8 *
C * IN A FORMAT IDENTICAL TO THE INPUT *
C *
C *****
C
SUBROUTINE PNCH(NCOL,NROW,SAVE,AA,BB,K)
EMA SAVE(41,37,4),NCOL,NROW
DIMENSION F(2)
COMMON M5,M6,M7,M8,M9
C
F(1)=AA
F(2)=BB
N=NRUW+1
DO 10 J=1,NROW
WRITE(M8,F) (SAVE(I,N-J,K),I=1,NCOL)
10 CONTINUE
RETURN
END
C+++++
C+++++SUBROUTINE FINAL
C+++++
C *****
C *
C * THIS SUBROUTINE SUMMARIZES CALIBRATION RESULTS AND OUTPUTS *
C * CALIBRATED PARAMETERS WHEN IFPNCH=1 *
C *
C *****
C
SUBROUTINE FINAL
C
C
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
REAL KX,MU,LKDIFF
INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTTM,TDEP1,
& TDEP2,TDEP3
DOUBLE PRECISION BE,G,GA1,GA2,TX,T1,T2,T3,T4
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
REAL KMAX,KMIN,LKMAX,LKMIN
INTEGER SIM,TREF,TCALIB
C
COMMON/EXTND/
C*****INTEGERS*****

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```

C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
& NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
& BOTTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
& IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
& TCALIB,
C*****REALS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
& AFLOT(41,37),AQTHCK(41,37),H(41,37),H1(41,37),
& H2(41,37),HINITL(41,37),Q(41,37),QC(41,37),
& QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
& DELH(42,110),BE(55),G(55),TITLE(40),ADELS,ALEAK,AREA,ATDELS,
& ATLEAK,DELT,GA1,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
& SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SS1(3,40),
& FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SFMIN,SMIN,SMAX,VP
C
COMMON M5,M6,M7,M8,M9
DIMENSION PAR(7,4),PARM(41,37,4)
EQUIVALENCE (PARM(1,1,1),KX(1,1))
C
DATA PAR/4HHYDR,4HAULI,4HC CO,4HNDUC,4HTIVI,4HTY ,4H(KX),4HLEAK,
& 4HAGE ,4HFACT,4HOR ,4H (FA,4HC) ,4H THE,4HHEAD,4H DIF,4HFERE,4HN
& CE ,4H(LKD,4HIF) ,4H ,4HSTOR,4HAGE ,4HCOEF,4HFIFI,4HENT ,4H(S)
& ,4H /
C
C*****WRITE OUT FINAL CALIBRATION STATISTICS
C
WRITE (M6,5)
5 FORMAT(1H0,/63X,'SUBROUTINE FINAL'//)
WRITE (M6,10)TITLE
10 FORMAT(20A4/20A4)
WRITE (M6,15)SSS(ITER),NCYCLE,ITE
15 FORMAT(1H0,48X,'SUMMARY OF THE CALIBRATION RESULTS'
&/48X,'OVERALL SUM OF SQUARES OF DEVIATIONS (SSS(ITER)) ',E10.4,
&/48X,'NUMBER OF CALIBRATIONS (NCYCLE) ',I2,
&/48X,'NUMBER OF SIMULATIONS (ITE) ',I2,/)
C
C*****WRITE OUT CALIBRATED PARAMETER VALUES FOR FUTURE USE ON
C*****OUTPUT UNIT M8
C
DO 20 NVAR=NVA1,NVA2,NVA3
WRITE (M6,25)(PAR(I,NVAR),I=1,7),PMIN(NVAR)
20 CONTINUE
25 FORMAT(1H ,44X,7A4,' = ',E10.4)
C
IF (IFPNCH.EQ.0) GO TO 55
DO 50 NVNN=NVA1,NVA2,NVA3
GO TO (30,35,40,45),NVNN
30 CALL PNCH(NCOL,NROW,PARM,4H(13F,4H6.1),1)
GO TO 50

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35 CALL PNCH(NCOL,NROW,PARM,4H(10F,4H8.6),2)
GO TO 50
40 CALL PNCH(NCOL,NROW,PARM,4H(18F,4H4.0),3)
GO TO 50
45 CALL PNCH(NCOL,NROW,PARM,4H(15F,4H5.4),4)
50 CONTINUE
55 CONTINUE
C
C*****WRITE OUT CALIBRATED PARAMETER VALUES TO PRIMARY OUTPUT UNIT (M6)
C
DO 95 NVAR=NVA1,NVA2,NVA3
NSEC=0
DO 90 LJ=1,NROW,50
DO 85 LI=1,NCOL,25
NSEC=NSEC+1
MVAR=NVAR
WRITE (M6,60)(PAR(N,NVAR),N=1,7),NSEC,TREF(TCALIB),NCYCLE
60 FORMAT(1H1,44X,"FINAL PARAMETER VALUES FOR THE ",7A4,15X,"PAGE",I2
&/45X,"BEST FIT PRIORITY TIMESTEP NUMBER IS (TREF(TCALIB))",I3
&/45X,"CALIBRATION CYCLE NUMBER (NCYCLE)",I3)
GO TO (65,70,75,80),NVAR
65 CALL PRNT1(NCOL,NROW,LI,LJ,PARM,4H0) ,MVAR)
GO TO 85
70 CALL PRNT1(NCOL,NROW,LI,LJ,PARM,4H4) ,MVAR)
GO TO 85
75 CALL PRNT1(NCOL,NROW,LI,LJ,PARM,4H0) ,MVAR)
GO TO 85
80 CALL PRNT1(NCOL,NROW,LI,LJ,PARM,4H2) ,MVAR)
85 CONTINUE
90 CONTINUE
95 CONTINUE
RETURN
END
SUBROUTINE INITL
C+++++
C+++++SUBROUTINE INITL
C+++++
C
C *****
C *
C * THIS SUBROUTINE INITIALIZES ALL VARIRIABLES PRESENT IN THE *
C * COMMON "EXTND" *
C *
C *****
C
C
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
REAL KX,MU,LKDIFF
INTEGER BTS,DEPTH,DRAIN,THEAD,SURF,THICK,BOTTM,TDEP1,
& TDEP2,TDEP3
DOUBLE PRECISION BE,G,GA1,GA2,TX,T1,T2,T3,T4
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
REAL KMAX,KMIN,LKMAX,LKMIN
INTEGER SIM,TREF,TCALIB
C
C

```

```

COMMON/EXTND/
C*****INTEGERS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& DEPTH(41,37),DRAIN(41,37),NC(41,37),NCX(41,37),NCY(41,37),
& NOD(41,37),NREACH(41,37),SURF(41,37),THICK(41,37),
& BOTTM(41,37),THEAD(9),IH(9),JH(9),IX(200),IY(200),
& IC,IFPNCH,IPRINT,ISTEP,K4,MODE,MU,NROW,NCOL,NRUW,NTS,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& TREF(3),ITE,ITER,NCYCLE,NREF,NSTOP,NVAR,NVA1,NVA2,NVA3,
& TCALIB,
C*****REALS*****
C*****MUTUAL TO CALIBRATION AND MANAGEMENT VERSIONS
& KX(41,37),FAC(41,37),LKDIFF(41,37),S(41,37),
& AFLOT(41,37),AQTHCK(41,37),H(41,37),HI(41,37),
& H2(41,37),HINITL(41,37),Q(41,37),QC(41,37),
& QACFT(41,37),SAQTHC(41,37),RLEAK(41,37),TX(41,37),
& DELH(42,110),BE(55),G(55),TITLE(40),ADELS,ALEAK,AREA,ATDELS,
& ATLEAK,DELT,GA1,GA2,SUMQ,SUMQ1,SUMQ2,T1,T2,T3,T4,
C*****USED EXCLUSIVELY BY THE CALIBRATION ROUTINES
& CALH(41,37),DEV(41,37),HCHANG(41,37,3),HREF(41,37,3),
& SAVE(41,37),TS(41,37),PMIN(4),SSS(40),SS(3,40),SS1(3,40),
& FMIN,FMAX,KMIN,KMAX,LKMIN,LKMAX,SPMIN,SMIN,SMAX,VP
C
COMMON M5,M6,M7,M8,M9
C
DIMENSION ISP(14104),RSP(19988,2)
EQUIVALENCE (ISP(1),DEPTH(1,1)),(RSP(1,1),KX(1,1))
C
DO 10 K=1,14104
ISP(K)=0
10 CONTINUE
DO 20 K=1,19988
DO 20 M=1,2
RSP(K,M)=0.0
20 CONTINUE
RETURN
END

```

APPENDIX D
RECHARGE Program Listing

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C*****RECHARGE PROGRAM
C*****WRITTEN BY: GARY S. JOHNSON, UNIVERSITY OF IDAHO
C*****THIS PROGRAM PREPARES HYDROLOGIC DATA FOR INPUT TO A GROUND WATER
C*****MODEL. THE PROGRAM WAS DEVELOPED BY THE UNIVERSITY OF IDAHO UNDER
C*****CONTRACT WITH THE US BUREAU OF RECLAMATION. A USERS MANUAL
C*****ACCOMPANIES THE PROGRAM AND IS AVAILABLE THROUGH THE BUREAU.
C*****
C
C*****DECLARATIONS*****
C
COMMON/EXTND/SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
&
RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
&
Q(41,35),ANTGW(41,35)
COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRATCH,OPRINT,M1,M2,IMEAN,
&
SUMSP(30),SUMIRR(30),SUMPRE(30),SUMET(30),DELANT(30),
&
DELACT(30)
INTEGER SCRATCH,OIRRIG,ORECH,OEVP,OWELL,OUNDER,ORIVER,
&
OPRINT,TIMSTP,OMASS,OSIGN,ETFILE
REAL IRR,ISIGN
DIMENSION SEEP(41,35),RECHRG(41,35),ETDRY(20),ETDRY(20),
&
RIVER(41,35),UNDER(41,35),WELL(41,35),TIRR(20),IARRAY(5),
&
TRCH(20),TEVP(20),TWELL(20),TRIV(20),TUND(20),TFLUX(20),
&
QPRT(41,35),SUMPT(41,35),TSUM(20),LCK(4),GWIRAC(41,35),
&
IRR(41,35),IREG(20),SUMWEL(30),SUMUND(30),SUMRIV(30),SUMQ(30)
EQUIVALENCE(TERM(1,1),SEEP(1,1),UNDER(1,1),RIVER(1,1),RECHRG(1,1),
&
WELL(1,1),QPRT(1,1),SUMPT(1,1),IRR(1,1)),
&
(RSPACE(4800),GWIRAC(1,1))
DATA TIRR/9*4H ,4HIRRI,4HGATI,4HON ,8*4H /,
&
TRCH/9*4H ,4HRECH,4HARGE,9*4H /,
&
TEVP/8*4H ,4HEVP,4HOTRA,4HNSPI,4HRATI,4HON ,9*4H /,
&
TWELL/9*4H ,4HWELL,4HS ,9*4H /,
&
TUND/9*4H ,4HUNDE,4HRFLO,4HW ,8*4H /,
&
TRIV/8*4H ,4HRIVE,4HR GA,4HINS ,4H& LO,4HSSES,7*4H /,
&
TFLUX/9*4H ,4HTOTA,4HL FL,4HUX ,8*4H /,
&
TSUM/7*4H ,4HTOTA,4HL FL,4HUX F,4HOR A,4HLL T,4HIMES,
&
4HTEPS,6*4H /,
C
C*****SPECIFY THE UNIT CODES FOR THE PRINTER,OUTPUTFILE,AND THE SCRATCH DISC
C
C*****M1 IS THE UNIT CODE FOR THE DATA FILE
C
M1=61
C
READ (M1,10) IFILE,SCRATCH,M2,MASSB,ETFILE
10 FORMAT (515)
C
C*****REWIND THE SCRATCH FILE
C
REWIND SCRATCH
C

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C*****SPECIFY THE DESIRED OPTIONS
C
READ (M1,20) OPRINT,OIRRIG,ORECH,OEVP,OWELL,OUNDER,ORIVER,ORATE,
&
OMASS,OSIGN
20 FORMAT (1015)
C
C*****SPECIFY THE GRID AND TIME VARIABLES
C
READ (M1,30) NCOL,NROW,DELX,DELY
30 FORMAT (215,2F10.0)
READ (M1,40) NTS,LTS,DELTI,DELTI2
40 FORMAT (215,2F10.0)
C
C*****PRINT THE DATA JUST INPUT, IF SO SPECIFIED
C
IF (OPRINT.EQ.0) GO TO 100
WRITE (M2,50) OPRINT
50 FORMAT (1H1//5X,120(1H*)//5X,120(1H*)//
&
50X,30HR E C H A R G E P R O G R A M/
&
57X,14HPRINT OPTION #,I3//)
IF (ORATE.EQ.0) WRITE (M2,52)
IF (ORATE.EQ.1) WRITE (M2,53)
52 FORMAT (///40X,'FLUX OUTPUT TO UNIT IFILE IN ACRE-FEET'///)
53 FORMAT (///40X,'FLUX OUTPUT TO UNIT IFILE IN CU.FT./DAY'///)
IF (OSIGN.LT.0) WRITE (M2,54)
IF (OSIGN.GT.0) WRITE (M2,55)
54 FORMAT (///40X,'AQUIFER RECHARGE ON IFILE= (-)'/
&
40X,'AQUIFER DISCHARGE ON IFILE= (+)'/)
55 FORMAT (///40X,'AQUIFER RECHARGE ON IFILE= (+)'/
&
40X,'AQUIFER DISCHARGE ON IFILE= (-)'/)
IF (OPRINT.LT.2) GO TO 100
WRITE (M2,60)
60 FORMAT (5X,120(1H*)/55X,17HOPTIONS SPECIFIED/55X,17(1H*)//
&
49X,29HTERM NOT USED: 0,/
&
49X,29HVALUES TO BE CALCULATED: 1,/
&
49X,29HVALUES TO BE READ IN: 2//)
WRITE (M2,70) OIRRIG,ORECH,OEVP,OWELL,OUNDER,ORIVER
70 FORMAT (49X,27HIRRIGATION OPTION= ,I2/
&
49X,27HRECHARGE OPTION= ,I2/
&
49X,27HEVAPOTRANSPIRATION OPTION= ,I2/
&
49X,27HWELL OPTION= ,I2/
&
49X,27HUNDERFLOW OPTION= ,I2/
&
49X,27HRIVER OPTION= ,I2//5X,120(1H*)//)
C
C*****WRITE THE PHYSICAL SPECIFICATIONS OF THE MODEL
C
WRITE (M2,80) NROW,NCOL,DELX,DELY
80 FORMAT (53X,23HPHYSICAL SPECIFICATIONS/53X,23(1H*)//
&
46X,15HNUMBER OF ROWS=,I3/
&
46X,18HNUMBER OF COLUMNS=,I3/
&
46X,31HGRID INTERVAL-X DIRECTION (FT)=,I6/
&
46X,31HGRID INTERVAL-Y DIRECTION (FT)=,I6//)
WRITE (M2,90) NTS,LTS,DELTI,DELTI2
90 FORMAT (46X,20HNUMBER OF TIMESTEPS=,I3/
&
46X,32HSTEP OF CHANGE IN TIME INTERVAL=,I3/

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&      46X,24HBEGINNING TIME INTERVAL=,F7.2/
&      46X,21HSECOND TIME INTERVAL=,F7.2/)
100 CONTINUE
C
C*****INITIALIZE VARIABLES
C
  TOSP=0.0
  TOIRR=0.0
  TOPRE=0.0
  TOET=0.0
  TODELC=0.0
  TODELA=0.0
  TOWEL=0.0
  TOUND=0.0
  TORIV=0.0
  TOQ=0.0
  DO 110 I=1,NCOL
  DO 110 J=1,NROW
  SUM(I,J)=0.0
  Q(I,J)=0.0
  SEEP(I,J)=0.0
110 CONTINUE
  DO 120 K=1,20
  ETIRR(K)=0.0
  ETDY(K)=0.0
120 CONTINUE
  DELT=DELTI
C
C*****ENTER THE TIMESTEP LOOP, DO ONCE FOR EACH TIMESTEP
C*****
C
  DO 1000 TIMSTP=1,NTS
C
C*****INITIALIZE NECESSARY VARIABLES
C
  SUMWEL(TIMSTP)=0.0
  SUMUND(TIMSTP)=0.0
  SUMRIV(TIMSTP)=0.0
  SUMQ(TIMSTP)=0.0
  SUMET(TIMSTP)=0.0
  SUMPRE(TIMSTP)=0.0
  SUMIRR(TIMSTP)=0.0
  SUMSP(TIMSTP)=0.0
C
C*****WRITE OUT TIMESTEP
C
  IF (OPRINT.GE.2) WRITE (M2,125) TIMSTP
125 FORMAT (1H1//////////)
&      25X,80(“”) /2(25X,“”,78X,“”),25X,“”,31X,
&      “T I M E S T E P”,31X,“”/25X,“”,78X,“”/25X,“”,37X,I2,
&      39X,“”/2(25X,“”,78X,“”),25X,80(“”)
C
C*****CREATE THE APPROPRIATE LENGTH OF TIMESTEP
C

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130 IF (TIMSTP.GE.LTS) DELT=DELT2
C
C*****CALCULATE THE IRRIGATION AND SEEPAGE TERMS, IF SO SPECIFIED
C
  IF (OIRRIG.EQ.0) GO TO 150
  CALL IRRIG(NROW,NCOL)
C
C*****PRINT THE IRRIGATION TERM, IF SO SPECIFIED
C
  IF (OPRINT.LT.2) GO TO 150
  CALL PRINT (TIRR,NROW,NCOL)
C
C*****THE IRRIGATION TERM IS NOT ADDED TO THE TOTAL FLUX UNTIL THE
C*****RECHRG SUBROUTINE
C
150 CONTINUE
C
C*****CALCULATE THE EVAPOTRANSPIRATION TERM, IF SO SPECIFIED
C
  IF (OEVAP.EQ.0) GO TO 170
  IF (OEVAP.EQ.2) GO TO 160
  CALL EVAPO (ETIRR,ETDRY,NREG)
  GO TO 170
160 CONTINUE
  IF (TIMSTP.EQ.1) READ (ETFILE,165) NREG,(IREG(K),K=1,NREG)
  READ (ETFILE,167) (ETIRR(IREG(K)),ETDRY(IREG(K)),K=1,NREG)
165 FORMAT (16I5)
167 FORMAT(16F5.0)
  DO 168 K=1,NREG
  IF (OPRINT.GT.1) WRITE (M2,169) IREG(K),ETIRR(IREG(K)),
& ETDY(IREG(K))
168 CONTINUE
169 FORMAT (//50X,“ET INPUT DATA”/30X,“REG”,5X,“ETIRR”,5X,“ETDRY”/
&      31X,I2,5X,F5.2,5X,F5.2/)
170 CONTINUE
C
C*****CALCULATE THE NET RECHARGE FROM PRECIP, ET, AND IRRIGATION,
C*****IF SO SPECIFIED
C
  IF (ORECH.EQ.0) GO TO 250
  IF (OEVAP.EQ.0.AND.TIMSTP.EQ.1) READ (M1,180) NREG
180 FORMAT (I5)
  IF (OIRRIG.GT.0) GO TO 190
  DO 190 I=1,NCOL
  DO 190 J=1,NROW
  SURFAC(I,J)=0.0
  GWIRAC(I,J)=0.0
190 CONTINUE
  CALL RCHRG (ETIRR,ETDRY,NROW,NCOL,NREG)
C
C*****PRINT THE NET RECHARGE, IF SO SPECIFIED
C
  IF (OPRINT.LT.2) GO TO 240
  CALL PRINT (TRCH,NROW,NCOL)
240 CONTINUE

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```

C
C*****ADD THE NET RECHARGE TO THE TOTAL FLUX, AND RESET THE ARRAY TO ZERO
C
  DO 250 I=1,NCOL
  DO 250 J=1,NROW
  Q(I,J)=Q(I,J)+RECHRG(I,J)
  RECHRG(I,J)=0.0
250 CONTINUE
C
C*****CALCULATE THE WELL TERM, IF SO SPECIFIED
C
  IF (OWELL.EQ.0) GO TO 270
  CALL WELLO (NROW,NCOL)
C
C*****PRINT THE WELL TERM, IF SO SPECIFIED
C
  IF (OPRINT.LT.2) GO TO 260
  CALL PRINT (TWELL,NROW,NCOL)
260 CONTINUE
C
C*****ADD THE WELL TERM TO THE TOTAL FLUX, SUM THE ARRAY FOR THE ENTIRE
C*****AREA, AND RESET TO ZERO
C
  DO 270 I=1,NCOL
  DO 270 J=1,NROW
  Q(I,J)=Q(I,J)+WELL(I,J)
  SUMWEL(TIMSTP)=SUMWEL(TIMSTP)+WELL(I,J)
  WELL(I,J)=0.0
270 CONTINUE
C
C*****CALCULATE THE BOUNDRY UNDERFLOW, IF SO SPECIFIED
C
  IF (OUNDER.EQ.0) GO TO 350
  CALL FLOWS (NROW,NCOL,TUND)
C
C*****PRINT THE UNDERFLOW, IF SO SPECIFIED
C
  IF (OPRINT.LT.2) GO TO 320
  CALL PRINT (TUND,NROW,NCOL)
320 CONTINUE
C
C*****ADD THE UNDERFLOW TERM TO THE TOTAL FLUX, SUM FOR THE ENTIRE AREA,
C*****AND RESET TO ZERO
C
  DO 350 I=1,NCOL
  DO 350 J=1,NROW
  Q(I,J)=Q(I,J)+UNDER(I,J)
  SUMUND(TIMSTP)=SUMUND(TIMSTP)+UNDER(I,J)
  UNDER(I,J)=0.0
350 CONTINUE
C
C*****CALCULATE THE RIVER GAINS AND LOSSES, IF SO SPECIFIED
C
  IF (ORIVER.EQ.0) GO TO 400
  CALL FLOWS (NROW,NCOL,TRIV)

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C
C*****PRINT THE RIVER GAINS AND LOSSES, IF SO SPECIFIED
C
  IF (OPRINT.LT.2) GO TO 380
  CALL PRINT (TRIV,NROW,NCOL)
380 CONTINUE
C
C*****ADD THE RIVER GAINS AND LOSSES TO THE TOTAL FLUX, SUM FOR THE
C*****ENTIRE AREA, AND RESET TO ZERO
C
  DO 400 I=1,NCOL
  DO 400 J=1,NROW
  Q(I,J)=Q(I,J)+RIVER(I,J)
  SUMRIV(TIMSTP)=SUMRIV(TIMSTP)+RIVER(I,J)
  RIVER(I,J)=0.0
400 CONTINUE
C
C*****WRITE THE TOTAL AS SPECIFIED
C
  IF (OPRINT.EQ.0) GO TO 600
  DO 500 I=1,NCOL
  DO 500 J=1,NROW
  QPRT(I,J)=Q(I,J)
  SUMQ(TIMSTP)=SUMQ(TIMSTP)+Q(I,J)
500 CONTINUE
  CALL PRINT (TFLUX,NROW,NCOL)
600 CONTINUE
C
C*****SUM THE TOTAL FLUX IN EACH NODE OVER ALL TIMESTEPS
C
  DO 800 I=1,NCOL
  DO 800 J=1,NROW
  SUM(I,J)=SUM(I,J)+Q(I,J)
800 CONTINUE
C
C*****WRITE THE TOTAL FLUX ON DISCFILE AS SPECIFIED
C*****RESET THE FLUX AT ALL NODES TO ZERO
C
  RATE=1.
  IF(ORATE.EQ.1) RATE=43560./DELT
  DO 850 I=1,NCOL
  DO 850 J=1,NROW
  Q(I,J)=Q(I,J)*RATE*OSIGN
850 CONTINUE
  DO 853 J=1,NROW
  WRITE (IFILE,852) (Q(I,J),I=1,NCOL)
852 FORMAT (10F8.0)
853 CONTINUE
900 CONTINUE
  DO 920 I=1,NCOL
  DO 920 J=1,NROW
  Q(I,J)=0.0
  QPRT(I,J)=0.0
920 CONTINUE
C*****MARK THE END OF FILE FOR THE SCRATCH FILE

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      ENDFILE SCRATCH
C*****REWIND THE SCRATCH FILE
      REWIND SCRATCH
C*****BEGIN NEXT TIMESTEP
C*****
      1000 CONTINUE
C
C*****WRITE THE SUM OVER ALL TIMESTEPS, IF SPECIFIED
C
      TIMSTP=99
      IF (OPRINT.EQ.0) GO TO 1300
C
C*****SET SUMPT EQUAL TO SUM
C
      DO 1050 I=1,NCOL
      DO 1050 J=1,NROW
      SUMPT(I,J)=SUM(I,J)
      1050 CONTINUE
      CALL PRINT (TSUM,NROW,NCOL)
      IF (OPRINT.NE.0) WRITE(M2,1055)
      1055 FORMAT(1H1,47X,37(1H*))//
      &58X,'MASS BALANCE (AF) '//
      &48X,37(1H*)////
      &56X,'SOIL MOISTURE CHANGE'/
      &'+' ,55X,20(' '),/
      &1X,'TIMESTEP',7X,'SEEP',6X,'IRRIG',6X,
      &'PRECIP',7X,'ET',30X,
      &'WELL FLUX',4X,'UNDERFLOW',4X,'RIVER FLUX',
      &4X,'TOTAL FLUX',/'+' ,8(' '),7X,4(' '),
      &6X,5(' '),6X,6(' '),7X,2(' '),30X,
      &9(' '),4X,9(' '),4X,
      &10(' '),4X,10(' '),/
      &56X,'CALCULATED ADJUSTED',/'+' ,55X,10(' '),2X,8(' '),//
      DO 1200 KTIME=1,NTS
      IF (OPRINT.NE.0) WRITE(M2,700)KTIME,SUMSP(KTIME),SUMIRR(KTIME),
      &SUMPRE(KTIME),SUMET(KTIME),DELACTION(KTIME),DELANT(KTIME),
      &SUMWEL(KTIME),SUMUND(KTIME),SUMRIV(KTIME),SUMQ(KTIME)
      IF (OMASS.EQ.1) WRITE (MASSB,700) KTIME,SUMSP(KTIME),
      & SUMIRR(KTIME),SUMPRE(KTIME),SUMET(KTIME),DELACTION(KTIME),
      & DELANT(KTIME),SUMWEL(KTIME),SUMUND(KTIME),SUMRIV(KTIME),
      & SUMQ(KTIME)
      700 FORMAT(3X,I4,7X,F7.0,4X,F7.0,4X,F7.0,4X,F7.0,4X,F7.0,4X,
      &F7.0,7X,F7.0,6X,F7.0,7X,F7.0,7X,F7.0)
      TOSP=TOSP+SUMSP(KTIME)
      TOIRR=TOIRR+SUMIRR(KTIME)
      TOPRE=TOPRE+SUMPRE(KTIME)
      TOET=TOET+SUMET(KTIME)
      TODELC=TODELC+DELACTION(KTIME)
      TODELA=TODELA+DELANT(KTIME)
      TOWEL=TOWEL+SUMWEL(KTIME)
      TOUND=TOUND+SUMUND(KTIME)
      TORIV=TORIV+SUMRIV(KTIME)
      TOQ=TOQ+SUMQ(KTIME)
      1200 CONTINUE

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      IF (OPRINT.NE.0) WRITE(M2,1210)TOSP,TOIRR,TOPRE,TOET,TODELC,
      &TODELA,TOWEL,TOUND,TORIV,TOQ
      1210 FORMAT(/,1X,'TOTAL',8X,F7.0,4X,F7.0,4X,F7.0,2X,F9.0,4X,F7.0,
      &4X,F7.0,7X,F7.0,6X,F7.0,7X,F7.0,7X,F7.0)
      1300 CONTINUE
C
      CALL LURQ(OB,LCK,4)
      STOP
      END
      SUBROUTINE SEEPG (NROW,NCOL,TOTSEP,NPRO1,NONAME)
C*****
C
C*****THIS SUBROUTINE CALCULATES CANAL OR CREEK SEEPAGE VOLUMES FOR
C*****EACH NODE AND RETURNS THE RESULTS TO THE IRRIGATION SUBROUTINE.
C*****SEEPAGE IS ALSO TOTALED FOR EACH IRRIGATION PROJECT.
C
C*****DECLARATIONS*****
      COMMON/EXTND/SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
      & RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
      & Q(41,35),ANTGW(41,35)
      COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRATCH,OPRINT,M1,M2,IMEAN,
      &SUMSP(30),SUMIRR(30),SUMPRE(30),SUMET(30),DELACTION(30),DELACTION(30)
      INTEGER SCRATCH,OPRINT,TIMSTP,SPZONE(500),STPNEW(500),
      & PRJ(500,4),PRJNEW(500)
      REAL IRR,NEWAR
      DIMENSION SEEP(41,35),II(500),JJ(500),ADJUST(20,25),RATE(10),
      & WETAR(500,4),NEWAR(500),TOTSEP(20),TITL(20),KPROJ(20),
      & DIVERS(20,30),RETFLO(20,30),IRR(41,35)
      EQUIVALENCE (ISPACE(1),II(1)),(ISPACE(501),JJ(1)),(ISPACE(1001),
      & SPZONE(1)),(ISPACE(1501),STPNEW(1)),(ISPACE(2001),PRJ(1,1)),
      & (ISPACE(4001),PRJNEW(1)),(TERM(1,1),SEEP(1,1),IRR(1,1)),
      & (RSPACE(1),RATE(1)),(RSPACE(11),WETAR(1,1)),
      & (RSPACE(2011),NEWAR(1)),(RSPACE(2511),ADJUST(1,1)),
      & (RSPACE(3600),DIVERS(1,1)),(RSPACE(4200),RETFLO(1,1))
C
C*****READ IN THE VARIABLES FROM THE APPROPRIATE UNIT
C*****IN THE FIRST TIMESTEP, VARIABLES MUST BE READ IN FROM THE INPUT
C*****UNIT AND WRITTEN ONTO SCRATCH DISC.
C
      IF (TIMSTP.GT.1) GO TO 180
C
C*****INITIALIZE THE COUNTER
C
      K=0
C
C*****READ DATA FROM DATA FILE
C
      READ (M1,10) NZONE,(RATE(KZNE),KZNE=1,NZONE)
      10 FORMAT (15,10F6.0)
      DO 25 K9=1,NPRO1
      READ (M1,18) KPROJ(K9)
      18 FORMAT (15)
      READ (M1,20) (ADJUST(KPROJ(K9),KSTEP),KSTEP=1,NTS)
      20 FORMAT (26F3.1)
      25 CONTINUE
      30 K=K+1

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      READ (M1,40)II(K),JJ(K),SPZONE(K),(PRJ(K,KO),K0=1,4),(WETAR(K,KO),
      &      KO=1,4),STPNEW(K),NEWAR(K),PRJNEW(K)
40 FORMAT (7I5,4F6.0,15,F6.0,15)
C
C*****CHECK FOR VARIABLES APPROACHING THE MAXIMUM DIMENSION
C
      IF (K.GT.490) WRITE (M2,1150)
C
C*****CHECK THAT SPZONE IS WITHIN BOUNDS
C
      IF(SPZONE(K).LT.0.OR.SPZONE(K).GT.NZONE) WRITE (M2,1200) SPZONE(K)
C
C*****UNLESS END OF DATA IS FOUND READ THE NEXT DATA LINE
C
      IF (II(K).GT.0) GO TO 30
C
C*****DECREASE THE COUNTER BY 1 TO ELIMINATE THE BLANK RECORD
C
      NSEEP=K-1
C
C*****WRITE THE ARRAYS ON SCRATCH DISC
C
      WRITE(SCRATCH) (II(K1),JJ(K1),SPZONE(K1),(PRJ(K1,K2),WETAR(K1,K2),
      &      K2=1,4),STPNEW(K1),NEWAR(K1),PRJNEW(K1),K1=1,NSEEP)
      WRITE (SCRATCH) NZONE,(RATE(KZONE),KZONE=1,NZONE)
      WRITE (SCRATCH) ((ADJST(KPROJ(K9),KSTEP),K9=1,NPRO1),KSTEP=1,NTS)
C
C*****PRINT OUT THE DATA JUST READ IN, IF SPECIFIED IN THE PRINT OPTION
C
      IF (OPRINT.LT.3) GO TO 200
      WRITE (M2,80)
80 FORMAT (1H1,5X,54(1H*),13HSEEPAGE INPUT,53(1H*))//
      &      49X,26HSEEPAGE RATES IN EACH ZONE/
      &      41X,4HZONE,31X,12HSEEPAGE RATE/
      &      1H*,72X,17H(CU FT/SQ FT/DAY)/
      &      41X,4H____,28X,17(1H_)
      WRITE (M2,90) (KZNE,RATE(KZNE),KZNE=1,NZONE)
90 FORMAT (41X,13,34X,F6.2)
      WRITE (M2,100) (KPROJ(K9),K9=1,NPRO1)
100 FORMAT (///1H*,44X,36HADJUSTMENT FACTORS FOR SEEPAGE RATES/
      &      45X,36(____)/60X,'PROJECTS'/5X,'TIMESTEP',2X,20I5)
      DO 107 KSTEP=1,NTS
      WRITE (M2,105) KSTEP,(ADJST(KPROJ(K9),KSTEP),K9=1,NPRO1)
105 FORMAT (8X,12,6X,20F5.1)
107 CONTINUE
      WRITE (M2,120)
120 FORMAT (1H1//1H*,57X,13HSEEPAGE INPUT/58X,13(____)
      &      //11X,'SEEPAGE',4(2X,'PROJECT'),5X,'WETTED AREAS (SQ. F
      &      T.)',4X,'TIMESTEP OF',4X,'NEW WETTED',4X,'PROJECT OF'/1H*,1X,'1',
      &      4X,'J',5X,'ZONE',4X,'NO. 1',4X,'NO. 2',4X,'NO. 3',4X,'NO. 4',
      &      5X,'(1)',4X,'(2)',4X,'(3)',4X,'(4)',3X,'AREA CHANGE',2X,
      &      'AREA (SQ. FT.)',4X,'CHANGE'/1X,3(____),2X,3(____),
      &      5(2X,7(____)),1X,4(2X,5(____)),2X,11(____),2X,14(____),2X,
      &      10(____)/)
      DO 150 K1=1,NSEEP

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      WRITE (M2,130) II(K1),JJ(K1),SPZONE(K1),(PRJ(K1,K2),K2=1,4),
      &      (WETAR(K1,K2),K2=1,4),STPNEW(K1),NEWAR(K1),PRJNEW(K1)
130 FORMAT (1X,12,3X,12,4X,13,4(6X,13),4X,4F7.0,6X,13,8X,F8.1,8X,13)
150 CONTINUE
180 CONTINUE
C
C*****FOR ALL TIMESTEPS EXCEPT THE FIRST, READ ARRAYS FROM SCRATCH DISC
C
      IF (TIMSTP.EQ.1) GO TO 200
      READ (SCRATCH) (II(K1),JJ(K1),SPZONE(K1),(PRJ(K1,K2),WETAR(K1,K2),
      &      K2=1,4),STPNEW(K1),NEWAR(K1),PRJNEW(K1),K1=1,NSEEP)
      READ (SCRATCH) NZONE,(RATE(KZONE),KZONE=1,NZONE)
      READ (SCRATCH) ((ADJST(KPROJ(K9),KSTEP),K9=1,NPRO1),KSTEP=1,NTS)
200 CONTINUE
C
C*****CALCULATE THE SEEPAGE FOR THOSE NODES WHICH CONTAIN CANALS
C
      DO 400 K1=1,20
      TOTSEP(K1)=0.0
400 CONTINUE
      DO 600 K0=1,NSEEP
      DO 600 K1=1,4
C
C*****CHECK THAT ALL DISTRICTS ARE OPERATING
C
      IF (PRJ(K0,K1).LE.0) GO TO 600
      IF (PRJ(K0,K1).NE.NONAME .AND. DIVERS(PRJ(K0,K1),TIMSTP).LE.0.0)
      & GO TO 600
C
C*****SELECT THE APPROPRIATE WETTED AREA
C
      SPAREA=WETAR(K0,K1)
      IF (TIMSTP.GE.STPNEW(K0).AND.STPNEW(K0).GT.0.AND.PRJNEW(K0).EQ.
      & PRJ(K0,K1)) SPAREA=NEWAR(K0)
C
C*****CALCULATE THE SEEPAGE TERM FOR THIS NODE IN ACRE FEET
C
      FACT1=SPAREA*RATE(SPZONE(K0))*ADJST(PRJ(K0,K1),TIMSTP)*DELT/43560.
      SEEP(II(K0),JJ(K0))=SEEP(II(K0),JJ(K0))+FACT1
      TOTSEP(PRJ(K0,K1))=TOTSEP(PRJ(K0,K1))+FACT1
600 CONTINUE
C
C*****AFTER ALL NODES HAVE BEEN COMPLETED, RETURN THE VALUES TO THE
C*****MAIN PROGRAM. NODES NOT USED WERE ASSIGNED A SEEPAGE EQUAL TO ZERO
C*****IN THE MAIN PROGRAM.
C
C*****THE ERROR MESSAGE PRINTOUTS FOLLOW
C
1150 FORMAT (1H1,5X,120(1H*))//
      &63HWARNING!! MORE THAN 1000 NODES HAVE SEEPAGE. THE SEEPAGE TERM/
      &55HIS NOT INCLUDED IN THE TOTAL FLUX FOR NODES AFTER 1000/5X,
      &120(1H*))
1200 FORMAT (1H1,5X,'WARNING: SEEPAGE ZONE NO.',I5,'OUT OF BOUNDS')
      RETURN
      END

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C
C*****
C*****
SUBROUTINE IRRIG (NROW,NCOL)
C*****THIS SUBROUTINE CALCULATES IRRIGATED AREAS, AND THE VOLUME OF
C*****SURFACE SUPPLIED IRRIGATION WATER. THE SEPAC SUBROUTINE IS CALLED
C*****FROM THIS SUBROUTINE.
C*****
C
C*****DECLARATIONS*****
REAL IRR,IRRAR,NETDIV(20)
INTEGER SCRATCH,TIMSTP,PROJ(500,4),PROJNW(500),STPNW(500),
& GWSTNW(500),PROJECT(20),OPRINT
COMMON/EXTND/SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
& RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
& Q(41,35),ANTGW(41,35)
COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRATCH,OPRINT,M1,M2,IMEAN,
&SUMSP(30),SUMIRR(30),SUMPRES(30),SUMET(30),DELANT(30),DELACT(30)
DIMENSION II(500),JJ(500),ACRES(500,4),TSEEP(20),
& GWACNW(500),AREA(20),TOTSEP(20),
& APPLIC(20),ACRENW(500),SEEP(41,35),IRRAR(500),
& DIVERS(20,30),RETFLO(20,30),GWIRAC(41,35),IRR(41,35)
EQUIVALENCE (RSPACE(1),ACRES(1,1)),
& (RSPACE(2001),ACRENW(1)),(RSPACE(2501),GWACNW(1)),
& (RSPACE(3001),AREA(1)),(RSPACE(3021),IRRAR(1)),
& (RSPACE(3521),NETDIV(1)),(RSPACE(3541),APPLIC(1)),
& (RSPACE(3600),DIVERS(1,1)),(RSPACE(4200),RETFLO(1,1)),
& (RSPACE(4800),GWIRAC(1,1)),
& (ISPACE(1),II(1)),(ISPACE(501),JJ(1)),
& (ISPACE(1001),PROJ(1,1)),(ISPACE(3001),PROJNW(1)),
& (ISPACE(3501),STPNW(1)),(ISPACE(4001),GWSTNW(1)),
& (ISPACE(4501),PROJECT(1)),(TERM(1,1),SEEP(1,1),IRR(1,1))
DATA TSEEP/9*4H ,4HSEEP,4HAGE ,9*4H /
C
C*****INITIALIZE THE NECESSARY VARIABLES
C
VOLNO=0
SUMIRR(TIMSTP)=0.0
SUMSP(TIMSTP)=0.0
DO 10 J=1,NROW
DO 10 I=1,NCOL
SURFAC(I,J)=0.0
GWIRAC(I,J)=0.0
10 CONTINUE
DO 20 NPRO=1,20
AREA(NPRO)=0.0
NETDIV(NPRO)=0.0
20 CONTINUE
TOTIRR=0.0
TOTNET=0.0
TOTAR=0.0
SEPSUM=0.0
DO 30 NODE=1,500
IRRAR(NODE)=0.0

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30 CONTINUE
C
C*****READ IN INPUT DATA IN THE FIRST TIMESTEP ONLY
C
IF(TIMSTP.GT.1) GO TO 500
READ (M1,35) NONAME
35 FORMAT (15)
C
C*****INITIALIZE COUNTERS USED TO READ DATA
C
K1=0
K2=0
K3=0
C
C*****READ IN FLOWS FOR EACH IRRIGATION PROJECT AND EACH TIMESTEP,
C*****AND COUNT THE NUMBER OF PROJECTS
C
40 K1=K1+1
READ (M1,45) PROJECT(K1)
45 FORMAT(15)
C
C*****CHECK FOR END OF DATA
C
IF (PROJECT(K1).EQ.0) GO TO 60
READ (M1,50) (DIVERS(PROJECT(K1),KSTEP),KSTEP=1,NTS)
READ (M1,50) (RETFLO(PROJECT(K1),KSTEP),KSTEP=1,NTS)
50 FORMAT(15F5.0)
IF (K1.GT.95) WRITE (M2,1000)
GO TO 40
60 CONTINUE
NOPRJT=K1-1
NPRO1=NOPRJT
IF (NONAME.NE.0) NPRO1=K1
C
C*****WRITE THE DIVERSIONS AND RETURN FLOWS TO SCRATCH DISK
C
WRITE(SCRATCH)(PROJECT(K3),(DIVERS(PROJECT(K3),KSTEP),
& RETFLO(PROJECT(K3),KSTEP), KSTEP=1,NTS),K3=1,NOPRJT)
C
C*****FOR FIRST TIMESTEP, DETERMINE SEEPAGE BY NODE
C
CALL SEEPG (NROW,NCOL,TOTSEP,NPRO1,NONAME)
C
C*****READ IN IRRIGATED AREA FOR EACH NODE WHERE IRRIGATION IS PRESENT,
C*****AND COUNT THE NUMBER OF NODES
C
70 K2=K2+1
READ (M1,80) II(K2),JJ(K2),(PROJ(K2,K),K=1,4),(ACRES(K2,K),K=1,4),
& GWACRE,STPNW(K2),PROJNW(K2),ACRENW(K2),
& GWSTNW(K2),GWACNW(K2)
80 FORMAT (6I5,5F5.0,2I5,F5.0,I5,F5.0)
IF (K2.GT.1000) WRITE (M2,1000)
C
C*****READ IN NEXT DATA LINE UNLESS END HAS BEEN REACHED
IF (II(K2).NE.0) GWIRAC(II(K2),JJ(K2))=GWACRE

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C
  IF (I1(K2).GT.0) GO TO 70
C
C*****OMIT LAST RECORD READ (BLANK)
C
  NNODES=K2-1
  90 CONTINUE
C
C*****PRINT OUT THE IRRIGATED AREAS, IF SO SPECIFIED
C
  IF (OPRINT.LT.3) GO TO 450
  WRITE (M2,400) (I1(K),JJ(K),(PROJ(K,KO),KO=1,4),
& (ACRES(K,KO),KO=1,4),GWIRAC(I1(K),JJ(K)),
& K=1,NNODES)
400 FORMAT (I1//45(' '),1 R R I G A T I O N   I N P U T   D A T A',
& 45(' ')//58X,'IRRIGATED AREAS'/62X,'(ACRES)'/
& 29X,4(3X,'PROJECT'),4X,3('AREA',6X),'AREA',4X,'GRNDWATER'/
& 1H*,13X,'I',9X,'J',7X,'NO. (1)',3X,'NO. (2)',3X,'NO. (3)',3X,
& 'NO. (4)',4X,'(1)',7X,'(2)',7X,'(3)',7X,'(4)',7X,'AREA'/
& 13X,' ',7X,' ',3X,4(3X,7(' ')),4X,3(4(' '),6X),' ',
& 4X,9(' ')/(12X,13,7X,13,8X,3(13,7X),13,6X,F5.0,4(5X,F5.0)))
C
C*****PRINT THE TIMESTEPS OF AREA CHANGES
C
  WRITE(M2,410)
410 FORMAT (I1//1H*,52X,'TIMESTEPS OF AREA CHANGES'/53X,25(' ')/1H*,
& 42X,'SURFACE WATER', 50X,'GROUND WATER'/23X,57(' ')/10X,
& 40(' ')/26X,'TIMESTEP',11X,'PROJECT OF',9X,'NEW IRRIGATED',
& 19X,'TIMESTEP',9X,'NEW IRRIGATED'/1H*,5X,'I',7X,'J',11X,
& 'OF CHANGE',12X,'CHANGE',11X,'AREA (ACRES)',20X,'OF CHANGE',8X,
& 'AREA (ACRES)'/2(5X,' '),9X,11(' '),8X,12(' '),7X,15(' '),17X,
& 11(' '),6X,15(' ')/
  DO 418 K=1,NNODES
  WRITE (M2,415) I1(K),JJ(K),STPNW(K),PROJNW(K),ACRENW(K),
& GWSTNW(K),GWACNW(K)
415 FORMAT (2(5X,I3),11X,I5,14X,I5,16X,F5.0,24X,I5,15X,F5.0)
418 CONTINUE
C
C*****PRINT DIVERSIONS AND RETURN FLOWS OF IRRIGATION PROJECTS
C
  WRITE (M2,420)
420 FORMAT (I1//40X,
& DIVERSIONS AND RETURN FLOWS OF IRRIGATION PROJECTS'
& //36X,'PROJECT',24X,'IRRIGATION',10X,'RETURN'/1H*,37X,
& 'NO.',10X,'TIMESTEP',6X,'DIVERSION (AF)',7X,'FLOW (AF)'/
& 36X,7(' '),8X,8(' '),6X,14(' '),7X,9(' ')/
  DO 440 K=1,NOPRJT
  WRITE (M2,430) PROJECT(K)
430 FORMAT(35X,I5)
  DO 440 KSTEP=1,NTS
  WRITE (M2,435) KSTEP,DIVERS(PROJECT(K),KSTEP),RETFL0(PROJECT(K),
& KSTEP)
435 FORMAT (54X,I2,13X,F5.0,13X,F5.0)
440 CONTINUE
450 CONTINUE

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```

C
C*****WRITE THE DATA ON SCRATCH DISK
C
  WRITE (SCRATCH) (I1(K),JJ(K),(PROJ(K,KO),KO=1,4),(ACRES(K,KO),
& KO=1,4),GWIRAC(I1(K),JJ(K)),STPNW(K),PROJNW(K),
& ACRENW(K),GWSTNW(K),GWACNW(K),K=1,NNODES)
  GO TO 600
500 CONTINUE
C
C*****READ DIVERSIONS AND RETURN FLOWS FROM SCRATCH DISC IN ALL TIMESTEPS
C*****EXCEPT THE FIRST
C
  READ(SCRATCH) (PROJECT(K3),(DIVERS(PROJECT(K3),KSTEP),
& RETFL0(PROJECT(K3),KSTEP),KSTEP=1,NTS),K3=1,NOPRJT)
C
C*****FOR ALL TIMESTEPS EXCEPT THE FIRST, CALL SEEPG
C
  CALL SEEPG (NROW,NCOL,TOTSEP,NPRO1,NONAME)
C
C*****READ DATA FROM SCRATCH DISK FOR ALL TIMESTEPS EXCEPT THE FIRST
C
  READ (SCRATCH) (I1(K),JJ(K),(PROJ(K,KO),KO=1,4),(ACRES(K,KO),
& KO=1,4),GWIRAC(I1(K),JJ(K)),STPNW(K),PROJNW(K),
& ACRENW(K),GWSTNW(K),GWACNW(K),K=1,NNODES)
  600 CONTINUE
C
C*****FOR ALL TIMESTEPS
C
C*****PRINT THE SEEPAGE IF SO SPECIFIED
C
  IF (OPRINT.LT.2) GO TO 602
  CALL PRINT (TSEEP,NROW,NCOL)
602 CONTINUE
C
C*****ADD THE SEEPAGE TO THE TOTAL FLUX AND RESET THE ARRAY TO ZERO
C
  DO 605 I=1,NCOL
  DO 605 J=1,NROW
  Q(I,J)=Q(I,J)+SEEP(I,J)
  SUMSP(TIMSTP)=SUMSP(TIMSTP)+SEEP(I,J)
  SEEP(I,J)=0.0
605 CONTINUE
C
C*****FOR ALL TIMESTEPS, CALCULATE THE IRRIGATED AREAS FOR EACH NODE
C
  DO 630 K=1,NNODES
C
C*****CHANGE THE GROUND WATER IRRIGATED AREAS IN THE APPROPRIATE TIMESTEP
C
  IF (TIMSTP.GE.GWSTNW(K).AND.GWSTNW(K).GT.0) GWIRAC(I1(K),JJ(K))=
& GWACNW(K)
  DO 610 KO=1,4
  IF (PROJ(K,KO).LE.0) GO TO 610
C
C*****CHANGE THE PROJECT IRRIGATED AREA IN THE APPROPRIATE TIMESTEP

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C      IF (TIMSTP.GE.STPNW(K).AND.STPNW(K).GT.0.AND.PROJNW(K).EQ.PROJ(K,
&K0)) ACRES(K,K0)=ACRENW(K)
C
C*****SUM THE IRRIGATED AREAS BY NODE AND PROJECT
C
SURFAC(II(K),JJ(K))=SURFAC(II(K),JJ(K))+ACRES(K,K0)
AREA(PROJ(K,K0))=AREA(PROJ(K,K0))+ACRES(K,K0)
IF (PROJ(K,K0).EQ.NONAME) GO TO 610
TOTAR=TOTAR+ACRES(K,K0)
610 CONTINUE
IRRAR(K)=SURFAC(II(K),JJ(K))+GWIRAC(II(K),JJ(K))
TOTIRR=TOTIRR+IRRAR(K)
630 CONTINUE
C
C*****CALCULATE THE TOTALS FOR THE PROJECTS
C
DO 660 K=1,NOPRJT
IF (PROJECT(K).LE.0) GO TO 660
NETDIV(PROJ(K))=DIVERS(PROJ(K),TIMSTP)-TOTSEP(PROJ(K))-
& RETFLO(PROJ(K),TIMSTP)
TOTNET=TOTNET+NETDIV(PROJ(K))
SEPSUM=TOTSEP(PROJ(K))+SEPSUM
APPLIC(PROJ(K))=NETDIV(PROJ(K))/AREA(PROJ(K))
C
C*****CHECK FOR POSSIBLE DIVISION BY ZERO
C
IF (AREA(PROJ(K)).EQ.0.0) APPLIC(PROJ(K))=0.0
660 CONTINUE
C
C*****CALCULATE A FACTOR FOR USE WHEN THERE ARE NO KNOWN
C*****APPLICATION RATES WITHIN A NODE
C
DO 700 K=1,NNODES
ISUM=0
DO 675 K0=1,4
ISUM=PROJ(K,K0)+ISUM
675 CONTINUE
DO 690 K0=1,4
IF (PROJ(K,K0).LE.0) GO TO 690
IF (PROJ(K,K0).NE.NONAME) GO TO 680
APPLIC(NONAME)=TOTNET/TOTAR
IF(ISUM.EQ.NONAME) GO TO 680
C
C*****THE AVERAGE SURFACE IRRIGATION RATE FOR THIS NODE IS CALCULATED AS
C*****VOLUME/AREA
C
VOLUME=0.
SIZE=0.
DO 678 K1=1,4
IF (PROJ(K,K1).LE.0 .OR. PROJ(K,K1).EQ.NONAME) GO TO 678
VOLUME=VOLUME+APPLIC(PROJ(K,K1))*ACRES(K,K1)
SIZE=SIZE+ACRES(K,K1)
678 CONTINUE
IF (SIZE.EQ.0.0) WRITE (M2,1300) K

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IF (SIZE.EQ.0.0) SIZE=1.0
APPLIC(NONAME)=VOLUME/SIZE
680 CONTINUE
IF (PROJ(K,K0).EQ.NONAME) VOLNO=VOLNO+APPLIC(NONAME)*ACRES(K,K0)
C
C*****CALCULATE THE IRRIGATION VOLUME IN EACH NODE
C
IRR(II(K),JJ(K))=IRR(II(K),JJ(K))+APPLIC(PROJ(K,K0))*ACRES(K,K0)
690 CONTINUE
SUMIRR(TIMSTP)=SUMIRR(TIMSTP)+IRR(II(K),JJ(K))
700 CONTINUE
IF (NONAME.NE.0) APPNO=VOLNO/AREA(NONAME)
IF (NONAME.NE.0) NODIV=VOLNO
C
C*****WRITE OUT THE INTERMEDIATE RESULTS, IF SO SPECIFIED
C
IF (OPRINT.LE.3) GO TO 712
C
C*****WRITE OUT SURFACE AND TOTAL IRRIGATED AREA FOR EACH NODE
C
WRITE (M2,710) (II(K),JJ(K),SURFAC(II(K),JJ(K)),IRRAR(K),
& K=1,NNODES)
710 FORMAT (1H1//42X,"INTERMEDIATE RESULTS FOR IRRIGATION SUBROUTINE"
& //58X,"IRRIGATED AREAS"/62X,"(ACRES)"
& /1H*,29X,"I",10X,"J",10X,"SURFACE IRRIG. AREA",10X,
& "TOTAL IRRIG. AREA"/30X,"_",10X,"_",10X,19(" _"),10X,
& 17(" _")//29X,13,9X,13,17X,F5.0,23X,F5.0)
712 CONTINUE
IF (OPRINT.LT.2) GO TO 732
C
C*****WRITE PROJECT RESULTS
C
WRITE (M2,720) (PROJECT(K),NETDIV(PROJ(K)),AREA(PROJ(K)),
& TOTSEP(PROJ(K)),APPLIC(PROJ(K)),K=1,NOPRJT)
IF (NONAME.GT.0) WRITE (M2,725) NONAME,NODIV,AREA(NONAME),
& TOTSEP(NONAME),APPNO
720 FORMAT (///58X,"PROJECT RESULTS"/25X,"PROJECT",10X,"NET DIVERSION"
& ,10X,"AREA",10X,"SEEPAGE",10X,"APPLICATION RATE"/1H*,26X,
& "NO.",17X,"(AF)",12X,"(ACRES)",11X,"(AF)",15X,"(AF/ACRE)"
& 25X,7(" _"),10X,13(" _"),8X,7(" _"),9X,7(" _"),10X,16(" _")
& (26X,13,15X,F8.4,12X,F6.2,9X,F6.4,16X,F6.4))
725 FORMAT (18X,"NONAME",13,15X,F8.4,12X,F6.2,9X,F6.4,16X,F6.4)
IF (NONAME.GT.0) TOTNET=TOTNET+NODIV
IF (NONAME.GT.0) SEPSUM=SEPSUM+TOTSEP(NONAME)
C
C*****WRITE OUT TOTALS
C
WRITE (M2,730) TOTAR,TOTIRR,TOTNET,SEPSUM
730 FORMAT (///1H*,61X,"TOTALS"/62X,6(" _")//
& 40X,"TOTAL SURFACE IRRIGATED AREA (ACRES)",F10.4/
& 40X,"TOTAL IRRIGATED AREA (ACRES)",F10.4/
& 40X,"TOTAL APPLICATION (AF)",F10.4/
& 40X,"TOTAL SEEPAGE (AF)",F10.4/
732 CONTINUE
C

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C*****WARNING FORMATS

C
1000 FORMAT (1H1,5X,'WARNING: IRRIGATION DATA APPROACHING MAXIMUM DIMEN
&SION')
1300 FORMAT (1H1,5X,'WARNING: SIZE OF KNOWN PROJECTS IN DATA LINE',I5,
& ^, IS EQUAL TO ZERO')
RETURN
END

C
C*****
C*****
SUBROUTINE EVAPO (ETIRR,ETDRY,NREG)
C*****
C*****THIS SUBROUTINE CALLS THE CROPC AND BLANY SUBROUTINES. TOGETHER
C*****THEY CALCULATE THE POTENTIAL ET FOR IRRIGATED AND NON-IRRIGATED
C*****LAND IN EACH CLIMATIC REGION.
C*****
C
C*****DECLARATIONS*****

REAL MEANJD,LAT,NRATIO
INTEGER REGION,STEP,CRCODE,DYPLNT,DYCOVR,DYHARV,DAY1,TEMP,
& RHMIN,CUTDAT,TIMSTP,OPRINT,SCRCH,DATE1,DCUT
COMMON/EXTND/SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
& RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
& Q(41,35),ANTGW(41,35)
COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRCH,OPRINT,M1,M2,IMEAN,
&SUMSP(30),SUMIRR(30),SUMPRES(30),SUMET(30),DELANT(30),DELACT(30)
DIMENSION SOLRAD(20,50),REGION(20),NRCROPS(20),CRCODE(9,20),
& JDPLNT(9,20),JDCOVR(9,20),JDHARV(9,20),
& NCUT(20),MOCUT(6),DYCUT(6),JDCUT(6,20),TEMP(20,50),
& RHMIN(20,50),UDAY(20,50),CUTDAT(6),UNCOEF(20,50),
& RGCDEF(20),ETIRR(20),ETDRY(20),PERCNT(9,20),RRAN(11,12),
& ADJ(20)
EQUIVALENCE (ISPACE(1),REGION(1)),(ISPACE(21),NRCROPS(1)),
& (ISPACE(41),CRCODE(1,1)),(ISPACE(221),JDPLNT(1,1)),
& (ISPACE(401),JDCOVR(1,1)),
& (ISPACE(581),JDHARV(1,1)),(ISPACE(761),NCUT(1)),
& (ISPACE(781),MOCUT(1)),(ISPACE(787),DYCUT(1)),
& (ISPACE(793),JDCUT(1,1)),(ISPACE(913),TEMP(1,1)),
& (ISPACE(1913),RHMIN(1,1)),
& (ISPACE(2919),JD1),
& (RSPACE(1),UNCOEF(1,1)),(RSPACE(1001),SOLRAD(1,1)),
& (RSPACE(2001),RGCDEF(1)),(RSPACE(2021),UDAY(1,1)),
& (RSPACE(3021),PERCNT(1,1))

DATA RRAN
1 / 15.0,14.1,13.2,12.2,11.2,10.1, 8.9, 7.6, 6.4, 5.1, 3.8,
2 15.5,14.9,14.3,13.5,12.7,11.7,10.7, 9.6, 8.5, 7.3, 6.1,
3 15.5,14.9,14.3,13.5,12.7,11.7,10.7, 9.6, 8.5, 7.3, 6.1,
4 15.3,15.5,15.6,15.7,15.6,15.5,15.2,14.7,14.2,13.5,12.7,
5 14.4,15.0,15.5,16.0,16.3,16.4,16.5,16.4,16.3,16.1,15.7,
6 13.9,14.6,15.2,15.8,16.3,16.7,17.0,17.2,17.3,17.3,17.2,
7 14.1,14.7,15.3,15.8,16.3,16.6,16.7,16.8,16.7,16.6,16.4,
8 14.8,15.2,15.5,15.8,15.9,15.8,15.7,15.5,15.1,14.6,14.0,
9 15.3,15.3,15.3,15.1,14.8,14.5,13.9,13.2,12.5,11.7,10.9,
A 15.4,15.1,14.6,14.1,13.4,12.6,11.7,10.7, 9.6, 8.5, 7.2,

B 15.1,14.4,13.6,12.7,11.7,10.6, 9.5, 8.2, 7.0, 5.6, 4.3,
C 14.8,13.9,13.0,11.9,10.8, 9.5, 8.3, 7.0, 5.7, 4.3, 3.9 /

C
C*****INITIALIZE THE NECESSARY VARIABLES
C
DO 5 NP=1,20
RGCDEF(NP)=0.0
NCUT(NP)=1
DO 5 IC=1,6
JDCUT(IC,NP)=0
5 CONTINUE
DO 10 K=1,20
DO 10 L=1,50
TEMP(K,L)=0
RHMIN(K,L)=0
UDAY(K,L)=0.
SOLRAD(K,L)=0.
10 CONTINUE
KOUNT=1
C
C*****READ IN DATA IN THE FIRST TIMESTEP ONLY
C
IF (TIMSTP.GT.1) GO TO 400
C
C*****READ IN THE NUMBER OF CLIMATIC REGIONS AND THE NON-IRRIGATED
C*****CROP COEFFICIENT FOR EACH TIMESTEP
C
READ (M1,20) NREG
20 FORMAT (I5)
C
C*****READ IN THE CROP DATA ASSOCIATED WITH EACH CLIMATIC REGION
C
DO 70 K=1,NREG
READ (M1,40) REGION(K),NRCROPS(K)
40 FORMAT (2I5)
READ (M1,45) (UNCOEF(REGION(K),KSTEP),KSTEP=1,NTS)
45 FORMAT (15F5.0)
DO 70 KO=1,NRCROPS(K)
READ (M1,50) CRCODE(KO,K),MOPLNT,DYPLNT,MOCOVR,
& DYCOVR,MOHARV,DYHARV,PERCNT(KO,K)
50 FORMAT (7I5,F5.0)
C
C*****CONVERT TO JULIAN DATES
C
CALL DAY (MOPLNT,DYPLNT,JDPLNT(KO,K))
CALL DAY (MOCOVR,DYCOVR,JDCOVR(KO,K))
CALL DAY (MOHARV,DYHARV,JDHARV(KO,K))
C
C*****FOR ALFALFA (CRCODE=1) READ THE DATA ON THE CUTTINGS
C
IF (CRCODE(KO,K).GT.1) GO TO 70
READ (M1,60) YIELDP,YIELDA,NCUT(K),(MOCUT(K1),DYCUT(K1),
& K1=1,NCUT(K))
60 FORMAT (2F5.0,13I5)
C

C*****CALCULATE AN ALFALFA ET ADJUSTMENT FACTOR BASED ON ALFALFA YIELDS

C
ADJ((REGION(K)))=YIELDA/YIELDP

C
C*****CONVERT TO JULIAN DATES

C
DO 65 K2=1,NCUT(K)
MCUT=MOCUT(K2)
DCUT=DYCUR(K2)
CALL DAY (MCUT,DCUT,JDCUT(K2,K))
65 CONTINUE
70 CONTINUE

C
C*****READ IN DATA FOR CALCULATION OF POTENTIAL ET

C
READ (M1,80) MONTH1,DAY1,LAT
80 FORMAT (215,F5.0)

C
C*****CALCULATE JULIAN DATE FOR BEGINNING OF SIMULATION

C
CALL DAY (MONTH1,DAY1,JD1)
MEANJD=JD1-DELT/2.0
RJD1=JD1
DO 81 KSTEP=1,NTS
READ (M1,90) (TEMP(REGION(K),KSTEP),K=1,NREG)
81 CONTINUE
DO 82 KSTEP=1,NTS
READ (M1,90) (RHMIN(REGION(K),KSTEP),K=1,NREG)
82 CONTINUE
DO 83 KSTEP=1,NTS
READ (M1,95) (UDAY(REGION(K),KSTEP),K=1,NREG)
83 CONTINUE
DO 84 KSTEP=1,NTS
READ (M1,95) (SOLRAD(REGION(K),KSTEP),K=1,NREG)
84 CONTINUE
90 FORMAT (15I5)
95 FORMAT (15F5.0)

C
C*****WRITE OUT THE INPUT DATA IF SO SPECIFIED

C
IF (OPRINT.LT.3) GO TO 200
WRITE (M2,170) NREG,((KSTEP),KSTEP=1,NTS)
170 FORMAT (1H1//1X,35('*'),'E V A P O T R A N S P I R A T I O N I N
& P U T D A T A',35('*'))//51X,'NUMBER OF CLIMATIC REGIONS=',12//
& 45X,'CROP COEFFICIENTS OF NON-IRRIGATED AREAS'/1H*,60X,
& 'TIMESTEP'/61X,8('_')/3X,'REGION',1X,2415)
DO 172 K=1,NREG
WRITE (M2,171) REGION(K),(UNCOEF(REGION(K),KSTEP),KSTEP=1,NTS)
171 FORMAT (/3X,16,1X,24F5.2)
172 CONTINUE
WRITE (M2,175)
DO 179 K=1,NREG
WRITE (M2,176) REGION(K)
176 FORMAT (125)
DO 179 K0=1,NCROPS(K)

WRITE(M2,177) CRCODE(K0,K),JDPLNT(K0,K),JDCOVR(K0,K),
& JDHARV(K0,K),PERCNT(K0,K)
177 FORMAT (25X,4I15,F15.1)
IF (CRCODE(K0,K).EQ.1) WRITE (M2,178) (JDCUT(K1,K),K1=1,NCUT(K))
178 FORMAT (T34,'HAY CUTTING',T53,'(1)',T68,'(2)',T83,'(3)',T98,'(4)',
& T113,'(5)'/40X,5115//)
175 FORMAT (//50X,'CROP DATA FOR CLIMATIC REGIONS'/1H*,59X,
& 'JULIAN DATE'/60X,11('_')/T38,'CROP',T96,'% OF'/1H*,T22,'REGION',
& T38,'CODE',T52,'PLANT',T66,'COVER',T82,'HARVEST',T96,'AREA',
& /T22,6('_'),T38,4('_'),T52,5('_'),T66,6('_'),T82,
& 7('_'),T96,4('_'),/)
179 CONTINUE
WRITE (M2,120) (REGION(K),ADJ((REGION(K))),K=1,NREG)
120 FORMAT (//50X,'ALFALFA YIELD ADJUSTMENT FACTORS'/
& 40X,'REGION',8X,'ADJ',20X,'REGION',8X,'ADJ'/
& 40X,'-----',8X,'----',20X,'-----',8X,'----'/
& 10(42X,12,9X,F4.2,22X,12,9X,F4.2//))
WRITE (M2,180) JD1,LAT
180 FORMAT (///T22,'SIMULATION STARTING DATE=',I3/
& T22,'STUDY LATITUDE=',F5.0)
WRITE (M2,185)
185 FORMAT(1H1//1H*,51X,'MEAN TEMPERATURES (DEG. F)'/52X,27('_'))
WRITE (M2,199)
DO 187 KSTEP=1,NTS
WRITE (M2,201) KSTEP,(TEMP(K,KSTEP),K=1,8)
187 CONTINUE
WRITE (M2,190)
190 FORMAT(//1H*,49X,'MINIMUM RELATIVE HUMIDITY (Z)'/50X,29('_'))
WRITE (M2,199)
DO 192 KSTEP=1,NTS
WRITE (M2,201) KSTEP,(RHMIN(K,KSTEP),K=1,8)
192 CONTINUE
WRITE (M2,195)
195 FORMAT (//1H*,52X,'MEAN DAYTIME WIND (MPH)'/53X,23('_'))
WRITE (M2,199)
DO 196 KSTEP=1,NTS
WRITE (M2,202) KSTEP,(UDAY(K,KSTEP),K=1,8)
196 CONTINUE
WRITE (M2,197)
197 FORMAT (//1H*,52X,'SOLAR RADIATION (LY/DAY)'/53X,24('_'))
WRITE (M2,199)
DO 198 KSTEP=1,NTS
WRITE (M2,202) KSTEP,(SOLRAD(K,KSTEP),K=1,8)
198 CONTINUE
199 FORMAT (1H*,61X,'REGION'/62X,6('_')/T20,'TIMESTEP',T33,'(1)',T43,
& '(2)',T53,'(3)',T63,'(4)',T73,'(5)',T83,'(6)',T93,'(7)',
& T103,'(8)'/)
201 FORMAT (124,8I10)
202 FORMAT (124,2X,8F10.2)
200 CONTINUE

C
C*****WRITE THE DATA ON SCRATCH DISK

C
WRITE (SCRATCH) (REGION(K),NCROPS(K),K=1,NREG)
WRITE (SCRATCH) ((UNCOEF(REGION(K),KSTEP),K=1,NREG),KSTEP=1,NTS)

```

DO 220 K=1,NREG
DO 220 K0=1,NCROPS(K)
WRITE (SCRATCH)CRCODE(K0,K),JDPLNT(K0,K),JDCOVR(K0,K),
&
&      JDHARV(K0,K),PERCNT(K0,K)
IF (CRCODE(K0,K).NE.1) GO TO 220
WRITE (SCRATCH) NCUT(K),(JDCUT(K1,K),K1=1,NCUT(K))
220 CONTINUE
WRITE (SCRATCH) ((TEMP(REGION(K2),KSTEP),RHMIN(REGION(K2),KSTEP),
&
&      UDAY(REGION(K2),KSTEP),SOLRAD(REGION(K2),KSTEP),
&
&      K2=1,NREG),KSTEP=1,NTS)
GO TO 500
400 CONTINUE
C
C*****FOR ALL TIMESTEPS EXCEPT THE FIRST READ DATA FROM SCRATCH DISK
C
READ (SCRATCH) (REGION(K),NCROPS(K),K=1,NREG)
READ (SCRATCH) ((UNCOEF(REGION(K),KSTEP),K=1,NREG),KSTEP=1,NTS)
DO 420 K=1,NREG
DO 420 K0=1,NCROPS(K)
READ (SCRATCH) CRCODE(K0,K),JDPLNT(K0,K),JDCOVR(K0,K),
&
&      JDHARV(K0,K),PERCNT(K0,K)
IF (CRCODE(K0,K).NE.1) GO TO 420
READ (SCRATCH) NCUT(K),(JDCUT(K1,K),K1=1,NCUT(K))
420 CONTINUE
READ (SCRATCH) ((TEMP(REGION(K2),KSTEP),RHMIN(REGION(K2),KSTEP),
&
&      UDAY(REGION(K2),KSTEP),SOLRAD(REGION(K2),KSTEP),
&
&      K2=1,NREG),KSTEP=1,NTS)
C
C*****FOR ALL TIMESTEPS
C
500 CONTINUE
C
C*****CALCULATE A FACTOR FOR CONVERTING POTENTIAL ET IN MM/DAY,
C*****TO ACTUAL ET IN INCHES/TIMESTEP
C
FACT1=DELT*1.15/25.4
C
C*****CALCULATE THE AVERAGE CROP COEFFICIENT FOR A REGION BY AVERAGING
C*****THE COEFFICIENTS FOR EACH DAY AND TAKING A WEIGHTED
C*****AVERAGE OF ALL THE CROPS IN THE REGION
C
RJD2=RJD1+DELT
JDIFF=RJD2-RJD1
IF (RJD2.GT.365.) RJD2=RJD2-365.
DO 540 K=1,NREG
TPRCNT=0.0
DO 510 K1=1,6
CUTDAT(K1)=JDCUT(K1,K)
510 CONTINUE
DO 530 K0=1,NCROPS(K)
SMCOEF=0.0
DO 520 K1=1,JDIFF
DATE1=RJD1+K1-1
IF (DATE1.GT.365) DATE1=DATE1-365

```

```

C*****CALL CROPC SUBROUTINE
C
JDP=JDPLNT(K0,K)
JDC=JDCOVR(K0,K)
JDH=JDHARV(K0,K)
ICRC=CRCODE(K0,K)
NCU=NCUT(K)
CALL CROPC (CRCOEF,JDP,JDC,JDH,ICRC,DATE1,NCU,CUTDAT)
C
C*****ADJUST ALFALFA ET BASED ON YIELD
C
IF (CRCODE(K0,K).EQ.1) CRCOEF=CRCOEF*ADJ((REGION(K)))
SMCOEF=SMCOEF+CRCOEF
520 CONTINUE
TCOEF=SMCOEF/JDIFF
IF (OPRINT.GE.3.AND.KOUNT.EQ.1) WRITE (M2,1090)
IF (OPRINT.GE.3) WRITE (M2,1100) REGION(K),CRCODE(K0,K),TCOEF
KOUNT=KOUNT+1
RGCOEF(REGION(K))=RGCOEF(REGION(K))+TCOEF*PERCNT(K0,K)/100.
TPRCNT=TPRCNT+PERCNT(K0,K)
530 CONTINUE
IF (TPRCNT.NE.100) WRITE (M2,1200) K
540 CONTINUE
RJD1=RJD2
C
C*****CALCULATE THE POTENTIAL ET FOR EACH REGION
C
MEANJD=MEANJD+DELT
IF (MEANJD.GT.365) MEANJD=MEANJD-365
IMEAN=MEANJD
C
C*****CALL DATE SUBROUTINE
C
CALL DATE (IMEAN,MMONTH,MDAY)
RDAY=MDAY
C
C*****CALCULATE NRATIO FROM SOLAR RADIATION
C
LL=INT(LAT/5)*5
IF (LAT.GT.50.0) LL=50
L1=LL/5+1
L2=L1+1
IF (L2.GT.11) L2=11
FAC1=(LAT-LL)/5.0
MONTH1=MMONTH
MONTH2=MMONTH
IF (MDAY.LT.15.AND.MDAY.NE.0) MONTH1=MOD(MMONTH+10,12)+1
IF (MDAY.GT.15) MONTH2=MOD(MMONTH,12)+1
RA1=RRAN(L1,MONTH1)+FAC1*(RRAN(L2,MONTH1)-RRAN(L1,MONTH1))
RA2=RRAN(L1,MONTH2)+FAC1*(RRAN(L2,MONTH2)-RRAN(L1,MONTH2))
FAC=MDAY-15
IF (FAC.LT.0.0) FAC=FAC+30.0
FAC2=FAC/30.0
RA=RA1+FAC2*(RA2-RA1)
DO 600 K=1,NREG

```

```

TEMP1=TEMP(REGION(K),TIMSTP)
TMEAN=(TEMP1-32.)*5./9.
RS=SOLRAD(REGION(K),TIMSTP)*.017
NRATIO=2.0*RS/RA-0.5
IF (NRATIO.GT.1.0) WRITE (M2,1500) NRATIO
IF (NRATIO.GT.1.0) NRATIO=.999
IF (NRATIO.LT.0.0) WRITE (M2,1600) NRATIO
IF (NRATIO.LT.0.0) NRATIO=0.0
IRHMIN=RHMIN(REGION(K),TIMSTP)
C
C*****USE A FACTOR OF 0.447 TO CONVERT WIND DATA FROM MPH TO M/SEC
C
      UUDAY=UDAY(REGION(K),TIMSTP)*0.447
C
C*****CALL BLANY SUBROUTINE
C
      CALL BLANY (LAT,MMONTH,MDAY,TMEAN,IRHMIN,NRATIO,UUDAY,ETPOT)
C
C*****CALCULATE ACTUAL ET AS THE PRODUCT OF THE POTENTIAL ET AND
C*****THE REGIONAL CROP COEFFICIENT
C
      ETPOT1=ETPOT*FACT1
      ETIRR(REGION(K))=ETPOT1*RGCOEF(REGION(K))
      ETDY(REGION(K))=ETPOT1*UNCOEF(REGION(K),TIMSTP)
      IF (ETIRR(REGION(K)).LT.0.0) ETIRR(REGION(K))=0.0
      IF (ETDY(REGION(K)).LT.0.0) ETDY(REGION(K))=0.0
      IF (OPRINT.GE.3.AND.K.EQ.1) WRITE (M2,1300) MMONTH,MDAY
      IF (OPRINT.GE.3) WRITE (M2,1400) REGION(K),TMEAN,IRHMIN,
&
      UDAY(REGION(K),TIMSTP),NRATIO,ETPOT1
600 CONTINUE
C
C*****WRITE INTERMEDIATE RESULTS IF SO SPECIFIED
C
      IF (OPRINT.LT.2) GO TO 900
      WRITE (M2,800)
800 FORMAT (1H1///47X,'EVAPOTRANSPIRATION INTERMEDIATE DATA'/47X,
&
      36('*')//1H*,49X,'CROP COEFFICIENTS AND ET DATA'/50X,
&29('_')//2X,'REGION',5X,'REGIONAL CROP COEFFICIENT',5X,
&'ET FOR IRRIGATED AREA',5X,'NON-IRRIGATED COEFFICIENT',5X,
&'ET FOR NON-IRRIGATED AREA',/45X,'(INCHES/TIMESTEP)',T104,
&'(INCHES/TIMESTEP)',/2X,6('_'),5X,25('_'),5X,21('_'),5X,
&25('_'),5X,25('_')//
      DO 880 K=1,NREG
      WRITE (M2,810) REGION(K),RGCOEF(REGION(K)),ETIRR(REGION(K)),
&UNCOEF(REGION(K),TIMSTP),ETDY(REGION(K))
810 FORMAT (T5,I2,T23,F6.3,22X,F6.3,22X,F6.3,24X,F6.3)
880 CONTINUE
900 CONTINUE
C
C*****WARNING FORMATS AND INTERMEDIATE DATA FORMATS
C
1090 FORMAT (1H1///41X,'REGIONAL CROP COEFFICIENTS FOR INDIVIDUAL CROPS
&',/41X,47('*')//1H*,44X,'REGION',7X,'CROP CODE',7X,'COEFFICIENT'/
&
      45X,6('_'),7X,9('_'),7X,11('_')//)
1100 FORMAT (47X,I2,I2X,I2,I2,13X,F6.4)

```

```

1200 FORMAT (1H1,5X,'WARNING! TOTAL CROP PERCENTAGES FOR REGION',I3,
&
      'ARE NOT EQUAL TO 100')
1300 FORMAT(///58X,'ET CALCULATION'/58X,14('*')//63X,'MEAN'/1H*,58X,
&
      'MONTH DAY'/59X,'_'//60X,I2,6X,I2//
&
      25X,'MEAN TEMP.',6X,'RELATIVE',8X,'MEAN DAYTIME',7X,
&
      'ACT.SUN.HRS./',4X,'REFERENCE ET, ALFALFA'/1H*,13X,'REGION'
&
      ,6X,'(DEG. C)',5X,'HUMIDITY (%)',5X,'WINDSPEED (MPH)',5X,
&
      'TOTAL SUN.HRS.',5X,'(INCHES/TIMESTEP)'/14X,6('_'),5X,
&
      10('_'),4X,12('_'),5X,15('_'),5X,14('_'),5X,17('_')//)
1400 FORMAT (16X,I2,9X,F5.2,I2X,I2,15X,F5.2,14X,F5.3,16X,F5.2)
1500 FORMAT(1H1//5X,'WARNING! NRATIO IS GREATER THAN 1!--NRATIO=',F5.3)
1600 FORMAT (1H1//5X,'WARNING! NRATIO IS LESS THAN 0!--NRATIO=',F5.3)
      RETURN
      END
C
C*****
C*****SUBROUTINE RCHRG (ETIRR,ETDRY,NROW,NCOL,NREG)
C*****THIS SUBROUTINE MAINTAINS A BALANCE BETWEEN IRRIGATION,
C*****PRECIPITATION, EVAPOTRANSPIRATION,AND SOIL MOISTURE, WITH ANY
C*****REMAINDER RESULTING IN RECHARGE. THE BALANCE IS KEPT FOR THREE
C*****CONDITIONS: 1) SURFACE WATER IRRIGATED, 2) GROUND WATER IRRIGATED,
C*****AND 3) NON-IRRIGATED AREAS. NEGATIVE VALUES MAY BE HELD INTO THE
C*****NEXT TIMESTEP AS A SOIL MOISTURE DEFICIT.
C*****
C
C*****DECLARATIONS*****
REAL NDACRE,MAXDRY,MAXIRR,MAXGW,IRR
INTEGER TIMSTP,REGION,REGN,REG,OPRINT,SCRCH
COMMON/EXTND/ SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
&
      RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
&
      Q(41,35),ANTGW(41,35)
COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRCH,OPRINT,M1,M2,IMEAN,
&SUMSP(30),SUMIRR(30),SUMPRE(30),SUMET(30),DELANT(30),DELACT(30)
DIMENSION REGION(41,35),RAIN(20,30),REG(20),CAPCTY(20),
&
      STRTDY(20),RECHRG(41,35),ETIRR(20),ETDRY(20),
&
      TITLE1(20),TITLE2(20),TITLE3(20),STRTRIR(20),
&
      GWIRAC(41,35),IRR(41,35),COND(20)
EQUIVALENCE (RSPACE(1),CAPCTY(1)),(RSPACE(21),STRTRIR(1)),
&
      (RSPACE(41),STRTDY(1)),(RSPACE(61),RAIN(1,1)),
&
      (RSPACE(4800),GWIRAC(1,1)),(RSPACE(6500),COND(1)),
&
      (TERM(1,1),RECHRG(1,1),IRR(1,1)),
&
      (ISPACE(1),REGION(1,1)),(ISPACE(2026),REG(1)),
&
      (ISPACE(4598),ISTART),(ISPACE(4599),IEND)
DATA TITLE2/4*4H ,4HNET,4HRECH,4HARGE,4H FRO,4HM PR,4HECIP,
&4H AND,4H ET ,4HON N,4HON-1,4HRRIG,4HATED,4H LAN,4HD ,2*4H /,
&
      TITLE3/6*4H ,4HCLIM,4HATIC,4H REG,4HION ,4HIDEN,4HTIFI,
&
      4HCATI,4HON ,6*4H /
C
C*****INITIALIZE THE SUM OF THE ANTECEDENT MOISTURE DEFICIT
C
      IF (TIMSTP.GT.1) SUMAT1=SUMAT2
C*****READ IN THE INPUT DATA IN THE FIRST TIMESTEP ONLY
C

```

```

IF (TIMSTP.GT.1) GO TO 300
C
C*****CALCULATE THE AREA OF A NODE, AND INITIALIZE THE SUM OF THE
C*****ANTECEDENT MOISTURE DEFICIT
C
NDACRE=DELX*DELY/43560.
SUMAT1=0.0
C
C*****READ IN THE MONTH AND DAY OF THE START AND END OF G.W. IRRIGATION
C
READ (M1,5) IMSTRT,IDSTRT,IMEND,IDEND
5 FORMAT (4I5)
C
C*****CONVERT TO JULIAN DATES
C
CALL DAY(IMSTRT,IDSTRT,ISTART)
CALL DAY(IMEND,IDEND,IEND)
C
C*****READ IN THE CLIMATIC REGION OF EACH NODE
C
DO 20 J=1,NROW
J1=NROW+1-J
READ (M1,10) (REGION(I,J1),I=1,NCOL)
10 FORMAT (80I1)
20 CONTINUE
C
C*****READ THE PRECIPITATION DATA FOR EACH CLIMATIC REGION,
C*****AND EACH TIMESTEP
C
DO 50 K=1,NREG
READ (M1,30) REG(K)
30 FORMAT(I5)
READ (M1,40) (RAIN(REG(K),KSTEP),KSTEP=1,NTS)
40 FORMAT (15F5.2)
50 CONTINUE
C
C*****READ IN THE MAXIMUM AVAILABLE WATER AND ANTECEDENT MOISTURE
C*****DEPLETION OF THE SOIL FOR EACH REGION
C
DO 70 K=1,NREG
READ (M1,60) REG(K),CAPCTY(REG(K)),STRTDY(REG(K)),STRTRIR(REG(K))
60 FORMAT (I5,3F5.2)
COND(REG(K))=-STRTDY(REG(K))
70 CONTINUE
C
C*****CONVERT THE MAXIMUM AVAILABLE WATER AND ANTECEDENT MOISTURE VALUES
C*****TO ACRE-FEET PER NODE
C
DO 90 J=1,NROW
DO 90 I=1,NCOL
IF (REGION(I,J).EQ.0) GO TO 90
ANTDRY(I,J)=(-STRTDY(REGION(I,J)))/12.*(NDACRE-SURFAC(I,J)-
& GWIRAC(I,J))
ANTIRR(I,J)=(-STRTRIR(REGION(I,J)))/12.*SURFAC(I,J)
ANTGW(I,J)=(-STRTRIR(REGION(I,J)))/12.*GWIRAC(I,J)

```

```

SUMAT1=SUMAT1+ANTDRY(I,J)+ANTIRR(I,J)+ANTGW(I,J)
90 CONTINUE
C
C*****WRITE THE INPUT DATA ON THE PRINTER IF SO SPECIFIED
C
IF (OPRINT.LT.3) GO TO 200
C
C*****WRITE CLIMATIC REGION IDENTIFICATION TABLE
C
WRITE (M2,100)
100 FORMAT (1H1//5X,20('*'),'PRECIPITATION AND WA
& TER BALANCE INPUT DATA',20('*'))
CALL INTGR (TITLE3,NROW,NCOL)
C
C*****PRINT PRECIPITATION REGIONS
C
WRITE (M2,105) IMSTRT,IDSTRT,IMEND,IDEND
105 FORMAT (1H1,30X,'GROUND WATER IRRIGATION DATES'/
& 30X,'-----'/'/'
& 25X,'FROM' 'TO'/'
& 20X,'MONTH DAY',22X,'MONTH DAY'/'
& 20X,'-----',22X,'-----'/'/'
& 22X,I2,5X,I2,24X,I2,6X,I2//)
WRITE (M2,110) (REG(K),K=1,NREG)
110 FORMAT (/1H*,54X,'PRECIPITATION (INCHES)'/55X,22('_')/63X,
& 'REGION'/5X,'TIMESTEP',2X,20I5//)
DO 125 KSTEP=1,NTS
WRITE (M2,120) KSTEP,(RAIN(REG(K),KSTEP),K=1,NREG)
120 FORMAT (8X,I2,6X,20F5.2)
125 CONTINUE
C
C*****WRITE SOIL CONDITIONS
C
WRITE (M2,140) (REG(K),K=1,NREG)
140 FORMAT(/1H*,57X,'SOIL CONDITIONS'/58X,15('_')/63X,'REGION'/22X,
& 10I8)
WRITE (M2,150) (CAPCTY(REG(K)),K=1,NREG)
150 FORMAT (2X,'MAX. AVAIL. WATER'/2X,'DEFICIT (INCHES)',5X,10F8.2)
WRITE (M2,170) (STRTDY(REG(K)),K=1,NREG)
170 FORMAT (2X,'START MOISTURE'/2X,'DEFICIT (INCHES)'/
& 5X,'NON-IRRIGATED',5X,10F8.2)
WRITE (M2,175) (STRTRIR(REG(K)),K=1,NREG)
175 FORMAT (2X,'START MOISTURE'/2X,'DEFICIT (INCHES)'/
& 5X,'IRRIGATED',9X,10F8.2)
200 CONTINUE
C
C*****WRITE THE INPUT DATA ON SCRATCH DISK
C
DO 210 K=1,NREG
WRITE (SCRATCH) REG(K),CAPCTY(REG(K))
WRITE (SCRATCH) (RAIN(REG(K),KSTEP),KSTEP=1,NTS)
210 CONTINUE
WRITE (SCRATCH) ((REGION(I,J),I=1,NCOL),J=1,NROW)
GO TO 400
C

```

C*****READ DATA FROM SCRATCH DISK IN ALL TIMESTEPS EXCEPT THE FIRST
C*****AND INITIALIZE THE NECESSARY VARIABLES

```
C
300 CONTINUE
SUMAT1=SUMAT2
DO 410 K=1,NREG
  READ (SCRATCH) REG(K),CAPCTY(REG(K))
  READ (SCRATCH) (RAIN(REG(K),KSTEP),KSTEP=1,NTS)
410 CONTINUE
  READ (SCRATCH) ((REGION(I,J),I=1,NCOL),J=1,NROW)
400 CONTINUE
C
  DO 450 K=1,NREG
  COND(REG(K))=COND(REG(K))+RAIN(REG(K),TIMSTP)-ETDRY(REG(K))
  IF (-COND(REG(K)).GT.CAPCTY(REG(K))) COND(REG(K))=
& -CAPCTY(REG(K))
  IF (COND(REG(K)).GT.0.0) WRITE (M2,460) COND(REG(K))
  IF (COND(REG(K)).GT.0.0) COND(REG(K))=0.0
460 FORMAT (////////10X,"DRYLAND RECHARGE THIS TIMESTEP=",F5.2)
450 CONTINUE
C*****FOR ALL TIMESTEPS
C
  SUMAT2=0.0
  S2=0.0
  IF (OPRINT.GT.3) WRITE (M2,510)
510 FORMAT (1H1///1H*,49X,"RECHARGE INTERMEDIATE DATA"/50X,26(' ')///
& 1H*,5X,"I",3X,"J",5X,"REGION",8X,"SURFAC",6X,"GWACRE",
& 7X,"ETIRR",7X,"ETDRY",6X,"PRECIP",4X,"ANTDRY",
& 4X,"ANTIRR",4X,"ANTGW",5X,"IRR"/
& 5X,"",1X,"",4X,6(''),8X,6(''),6X,6(''),
& 2(7X,5('')),6X,6(''),4X,6(''),2(4X,6('')),
& 4X,3(''))
```

C
C*****FOR EACH CELL

```
C
DO 800 I=1,NCOL
DO 800 J=1,NROW
IF (REGION(I,J).EQ.0) GO TO 800
IF (OPRINT.GT.2) WRITE (M2,520) I,J,REGION(I,J),SURFAC(I,J),
& GWIRAC(I,J),ETIRR(REGION(I,J)),ETDRY(REGION(I,J)),
& RAIN(REGION(I,J),TIMSTP),ANTDRY(I,J),
& ANTIRR(I,J),ANTGW(I,J),IRR(I,J)
520 FORMAT (5X,12,2X,12,5X,14,5X,F10.2,3(2X,F10.2),2X,5F10.2)
```

C
C*****CALCULATE THE NET PRECIPITATION ON THE IRRIGATED PORTION
C*****OF EACH NODE IN ACRE-FEET

C
C*****SURFACE SUPPLIED IRRIGATION

```
C
EFFCTI=(RAIN(REGION(I,J),TIMSTP)-ETIRR(REGION(I,J)))/12.
RCHIRR=IRR(I,J)+EFFCTI*SURFAC(I,J)+ANTIRR(I,J)
RECHRG(I,J)=0.0
IF (RCHIRR.LE.0.0) GO TO 530
RECHRG(I,J)=RCHIRR
ANTIRR(I,J)=0.0
```

```
GO TO 540
530 CONTINUE
  ANTIRR(I,J)=RCHIRR
540 CONTINUE
```

C
C*****GROUND WATER SUPPLIED IRRIGATION

```
C
  GWIRR=EFFCTI*GWIRAC(I,J)+ANTGW(I,J)
  IF (GWIRR.GT.0.0) GO TO 560
  IF (IMEAN.GE.ISTART .AND. IMEAN.LE.IEND) GO TO 560
  ANTGW(I,J)=GWIRR
  GO TO 570
560 CONTINUE
  RECHRG(I,J)=RECHRG(I,J)+GWIRR
  ANTGW(I,J)=0.0
570 CONTINUE
```

C
C*****CALCULATE THE NET PRECIP FOR NON-IRRIGATED LAND IN THE SAME NODE

```
C
  EFFCTD=(RAIN(REGION(I,J),TIMSTP)-ETDRY(REGION(I,J)))/12.
  RCHDRY=EFFCTD*(NDACRE-SURFAC(I,J)-GWIRAC(I,J))+ANTDRY(I,J)
```

C
C*****IF RCHDRY IS (+) IT BECOMES RECHARGE AND IS RESET TO ZERO

```
C
  IF (RCHDRY.LE.0.0) GO TO 580
  RECHRG(I,J)=RECHRG(I,J)+RCHDRY
  ANTDRY(I,J)=0.0
  GO TO 590
```

```
580 CONTINUE
  ANTDRY(I,J)=RCHDRY
590 CONTINUE
```

C
C*****SUM THE VOLUMES OF PRECIPITATION AND EVAPOTRANSPIRATION

```
C
  IRACR=SURFAC(I,J)+GWIRAC(I,J)
  DRYAC=NDACRE-IRACR
  SUMPRE(TIMSTP)=SUMPRE(TIMSTP)+NDACRE*RAIN(REGION(I,J),TIMSTP)/12.
  SUMET(TIMSTP)=SUMET(TIMSTP)-(IRACR*ETIRR(REGION(I,J)))/12.-
& (DRYAC*ETDRY(REGION(I,J)))/12.
  S2=S2+ANTDRY(I,J)+ANTIRR(I,J)+ANTGW(I,J)
```

C
C*****THE MOISTURE DEFICIENCY OF THE SOIL AND RCHDRY MUST
C*****ALWAYS BE LESS THAN OR EQUAL TO THE MAXIMUM AVAILABLE
C*****WATER HOLDING CAPACITY OF THE SOIL

```
C
  MAXDRY=CAPCTY(REGION(I,J))/12.*(NDACRE-SURFAC(I,J)-GWIRAC(I,J))
  MAXIRR=CAPCTY(REGION(I,J))/12.*SURFAC(I,J)
  MAXGW=CAPCTY(REGION(I,J))/12.*GWIRAC(I,J)
  IF (-ANTDRY(I,J).GT.MAXDRY) ANTDRY(I,J)=-MAXDRY
  IF (-ANTIRR(I,J).GT.MAXIRR) ANTIRR(I,J)=-MAXIRR
  IF (-ANTGW(I,J).GT.MAXGW) ANTGW(I,J)=-MAXGW
```

C
C*****DETERMINE THE CHANGE IN SOIL MOISTURE FOR THE ENTIRE AREA

```
C
  SUMAT2=SUMAT2+ANTDRY(I,J)+ANTIRR(I,J)+ANTGW(I,J)
```



```

800 CONTINUE
C
C*****WRITE OUT MESSAGE IF GROUND WATER IRRIGATION IS ACTIVE
C
      IF (OPRINT.GE.3 .AND. IMEAN.GE.ISTART .AND. IMEAN.LE.IEND)
        & WRITE (M2,810)
810 FORMAT (///5X,120(1H*)/20X,'GROUND WATER IRRIGATION ACTIVE'/
        & 5X,120(1H*)//)
      DELANT(TIMSTP)=- (SUMAT2-SUMAT1)
      DELACT(TIMSTP)=- (S2-SUMAT1)
      RETURN
      END
C
C*****
C*****
C*****SUBROUTINE WELLO (NROW,NCOL)
C*****
C*****THIS SUBROUTINE SELECTS THE WELL INPUTS FOR THE APPROPRIATE
C*****TIMESTEP FOR ADDITION TO THE TOTAL FLUX TERM
C*****
C*****DECLARATIONS*****
      INTEGER TIMSTP,OPRINT,SCRATCH
      COMMON/EXTND/SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
      & RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
      & Q(41,35),ANTGW(41,35)
      COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRATCH,OPRINT,M1,M2,IMEAN,
      &SUMSP(30),SUMIRR(30),SUMPRES(30),SUMET(30),DELANT(30),DELACT(30)
      DIMENSION FLO(134,25),II(200),JJ(200),WELL(41,35)
      EQUIVALENCE (RSPACE(1),FLO(1,1)),(ISPACE(1),II(1)),
      & (ISPACE(201),JJ(1)),(TERM(1,1),WELL(1,1))
C
C*****READ IN DATA IN THE FIRST TIMESTEP ONLY
C
      IF (TIMSTP.GT.1) GO TO 200
C
C*****INITIALIZE NECESSARY VARIABLES
C
      K=0
C
C*****READ IN DATA
C
10 CONTINUE
      K=K+1
      READ (M1,20) II(K),JJ(K)
20 FORMAT (215)
      IF (II(K).LE.0) GO TO 35
      READ (M1,25) (FLO(K,KSTEP),KSTEP=1,NTS)
25 FORMAT (11F7.0)
      IF (K.EQ.190) WRITE (M2,1000)
      GO TO 10
35 CONTINUE
C
C*****OMIT THE BLANK RECORD LAST READ
C

```

```

      NWEEL=K-1
C
C*****WRITE OUT THE DATA, IF SO SPECIFIED
      IF (OPRINT.LT.3) GO TO 100
      WRITE (M2,50) ((KSTEP),KSTEP=1,NTS)
50 FORMAT (1H1///1H*,49X,'WELL INPUT DATA'/50X,30( '-' )/
      & /60X,'WELL FLOWS'/63X,'(AF)'/1H*,60X,'TIMESTEP'/61X,
      & 8( '-' )/1H*,2X,'I',4X,'J',2415)
      WRITE (M2,53)
53 FORMAT (26(2X, '-' ))
      DO 60 K=1,NWEEL
      WRITE (M2,55) II(K),JJ(K),(FLO(K,KSTEP),KSTEP=1,NTS)
55 FORMAT (2X,I2,I5,2X,24F5.0)
60 CONTINUE
100 CONTINUE
C
C*****WRITE THE DATA TO THE SCRATCH DISK
C
      WRITE(SCRATCH) (II(K),JJ(K),(FLO(K,KSTEP),KSTEP=1,NTS),K=1,NWEEL)
      GO TO 300
C
C*****FOR ALL TIMESTEPS EXCEPT THE FIRST READ THE DATA FROM THE SCRATCH DISK
C
200 CONTINUE
      READ(SCRATCH) (II(K),JJ(K),(FLO(K,KSTEP),KSTEP=1,NTS),K=1,NWEEL)
300 CONTINUE
C
C*****FOR ALL TIMESTEPS
C
      DO 400 K=1,NWEEL
      WELL(II(K),JJ(K))=FLO(K,TIMSTP)
400 CONTINUE
C
C*****WRITE OUT WARNING STATEMENT
C
1000 FORMAT (1H1,5X,'WARNING: WELL INPUTS EXCEED 190')
      RETURN
      END
C
C*****
C*****
C*****SUBROUTINE FLOWS (NROW,NCOL,NAME)
C*****
C*****THIS SUBROUTINE DIVIDES FLUX FOR A REACH INTO INDIVIDUAL CELLS. IT
C*****MAY BE USED FOR THE DETERMINATION OF UNDERFLOW OR RIVER FLUX.
C*****
C*****DECLARATIONS*****
      REAL NAME(20)
      INTEGER TIMSTP,SCRATCH,OPRINT,ZONE(41,35)
      COMMON/EXTND/SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
      & RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
      & Q(41,35),ANTGW(41,35)
      COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRATCH,OPRINT,M1,M2,IMEAN,

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&SUMSP(30),SUMIRR(30),SUMPRE(30),SUMET(30),DELANT(30),DELACT(30)
DIMENSION FLOW(100,30),NNODES(20),FLUX(41,35),TNAME(20)
EQUIVALENCE (ISPACE(1),ZONE(1,1)),(ISPACE(206),NNODES(1)),
& (RSPACE(1),FLOW(1,1)),(TERM(1,1),FLUX(1,1))
DATA TNAME/9*4H ,4HFLOW,4H ZON,4HES ,8*4H /
C
C*****INITIALIZE NECESSARY VARIABLES
C
DO 5 I=1,20
  NNODES(I)=0
5 CONTINUE
C
C*****READ IN DATA IN THE FIRST TIMESTEP ONLY
C
IF (TIMSTP.GT.1) GO TO 200
READ (M1,15) NZONES
15 FORMAT (I5)
DO 30 ISTEP=1,NTS
  READ (M1,20) (FLOW(KZONE,ISTEP),KZONE=1,NZONES)
20 FORMAT (15F5.0)
30 CONTINUE
DO 50 J=1,NROW
  J0=NROW+1-J
  READ (M1,40) (ZONE(I,J0),I=1,NCOL)
40 FORMAT (80I1)
DO 50 I=1,NCOL
  IF (ZONE(I,J0).LE.0) GO TO 50
  NNODES(ZONE(I,J0))=NNODES(ZONE(I,J0))+1
50 CONTINUE
C
C*****WRITE OUT THE INPUT DATA IF SO SPECIFIED
C
IF (OPRINT.LT.3) GO TO 100
WRITE (M2,120) (NAME(I),I=1,20),NZONES
120 FORMAT(1H1///1H*,23X,20A4/55X,21(____)/60X,'INPUT DATA'
& //53X,'NUMBER OF FLOW ZONES=',I2//
& 53X,'TOTAL FLOW IN EACH ZONE'/63X,'(AF)')
  NZON1=1
  NZON2=NZON1+9
  IF (NZONES.LT.NZON2) NZON2=NZONES
125 CONTINUE
WRITE (M2,130) ((KZONE),KZONE=NZON1,NZON2)
130 FORMAT (/1H*,62X,'ZONE'/63X,'____'/1H*,25X,10I8)
WRITE (M2,133) (NNODES(KZONE),KZONE=1,NZONES)
133 FORMAT (31X,10(____',4X)/15X,'NNODES',6X,10F8.1)
WRITE (M2,134)
134 FORMAT (15X,'TIMESTEP')
DO 140 ISTEP=1,NTS
  WRITE (M2,135) ISTEP,(FLOW(KZONE,ISTEP),KZONE=NZON1,NZON2)
135 FORMAT (17X,I2,T28,10F8.1)
140 CONTINUE
IF (NZON2.EQ.NZONES) GO TO 150
NZON1=NZON2+1
NZON2=NZON1+9
GO TO 125

```

```

150 CONTINUE
WRITE (M2,160)
160 FORMAT(1H1///)
C
C*****WRITE OUT LOCATION OF FLOW ZONES ON THE PRINTER
C
CALL INTGR (TNAME,NROW,NCOL)
100 CONTINUE
C
C*****WRITE THE DATA ON THE SCRATCH FILE
C
WRITE (SCRATCH) NZONES,((FLOW(KZONE,ISTEP),KZONE=1,NZONES),
& ISTEP=1,NTS)
WRITE (SCRATCH) ((ZONE(I,J),I=1,NCOL),J=1,NROW)
WRITE (SCRATCH) (NNODES(KZONE),KZONE=1,NZONES)
GO TO 300
200 CONTINUE
C
C*****READ DATA FROM SCRATCH DISK FOR ALL TIMESTEPS EXCEPT THE FIRST
C
READ (SCRATCH) NZONES,((FLOW(KZONE,ISTEP),KZONE=1,NZONES),
& ISTEP=1,NTS)
READ (SCRATCH) ((ZONE(I,J),I=1,NCOL),J=1,NROW)
READ (SCRATCH) (NNODES(KZONE),KZONE=1,NZONES)
300 CONTINUE
C
C*****FOR ALL TIMESTEPS CALCULATE THE FLUX IN EACH NODE
C
DO 400 I=1,NCOL
  DO 400 J=1,NROW
  IF (ZONE(I,J).LE.0) GO TO 400
  IF (NNODES(ZONE(I,J)).LE.0) WRITE(M2,1000) ZONE(I,J)
  FLUX(I,J)=FLOW(ZONE(I,J),TIMSTP)/NNODES(ZONE(I,J))
400 CONTINUE
C
C*****WRITE OUT WARNING STATEMENTS
C
1000 FORMAT (1H1,5X,'WARNING: NNODES LE 0 IN ZONE',I3)
RETURN
END
C
C*****
C*****
C*****SUBROUTINE CROPC(CK,JPL,JEC,JHV,ICRP,I2,NCUT,JCUT)
C*****THIS SUBROUTINE CALCULATES THE CROP COEFFICIENT FO A SPECIFIED
C*****CROP AND DATE. THE COEFFICIENTS ARE BASED OF ALFALFA, AND WERE
C*****TAKEN FROM J. L. WRIGHT (19 ). THIS SUBROUTINE WAS WRITTEN BY
C*****R.G. ALLEN, UNIV. OF IDAHO. IT IS CALLED FROM THE EVAPO SUBROUTINE
C*****
C
C*****DECLARATIONS*****
DIMENSION C(20,9),JCUT(6)
C
DATA G/

```

```

C****ALFALFA (1)
  Z0.50,0.58,0.67,0.75,0.80,0.85,0.90,0.95,0.98,1.00,
  Z0.50,0.25,0.25,0.40,0.55,0.79,0.80,0.90,0.98,1.00,
C****BEANS (2)
  Z0.15,0.17,0.18,0.22,0.38,0.48,0.65,0.78,0.93,0.95,
  D0.95,0.94,0.65,0.36,0.18,0.15,0.10,0.10,0.10,0.10,
C****CORN (3)
  Z0.15,0.15,0.16,0.17,0.18,0.25,0.40,0.62,0.80,0.95,
  D0.95,0.95,0.93,0.91,0.89,0.83,0.76,0.30,0.20,0.15,
C****PASTURE (4)
  Z0.34,0.43,0.52,0.59,0.66,0.73,0.78,0.82,0.85,0.87,
  D0.87,0.87,0.87,0.87,0.87,0.87,0.87,0.87,0.87,0.87,
C****PEAS (5)
  Z0.20,0.17,0.16,0.18,0.20,0.28,0.48,0.67,0.86,0.95,
  D0.93,0.82,0.50,0.37,0.20,0.10,0.10,0.10,0.10,0.10,
C****POTATOES (6)
  Z0.15,0.15,0.15,0.21,0.35,0.45,0.60,0.72,0.78,0.80,
  D0.80,0.80,0.75,0.74,0.73,0.72,0.70,0.50,0.25,0.20,
C****SUGAR BEETS (7)
  Z0.20,0.17,0.15,0.15,0.16,0.20,0.30,0.50,0.80,1.00,
  D1.00,1.00,1.00,0.96,0.93,0.89,0.86,0.83,0.80,0.75,
C****SPRING GRAIN(8)
  Z0.15,0.16,0.20,0.28,0.55,0.75,0.90,0.98,1.00,1.02,
  D1.02,1.00,0.80,0.50,0.25,0.10,0.10,0.10,0.10,0.10,
C****WINTER GRAIN(9)
  Z0.65,0.70,0.75,0.80,0.85,0.90,0.95,0.98,1.00,1.02,
  D1.02,1.00,0.96,0.50,0.20,0.10,0.10,0.10,0.10,0.10/
C
C
C****CROP COEFFICIENTS
  J=ICRP
  I=I2
  REC=JEC-JPL
C
C****LINEARLY INTERPOLATE BETWEEN COEFFICIENTS
C
  IF(I.GE.JEC)GO TO 100
C****BEFORE EFFECTIVE COVER
  80 P1=(I-JPL)/REC*100
  IF(P1.LT.10.)P1=10.01
  IP1=INT(P1/10.)
  DIFF=AMOD(P1,10.)/10.
  90 CK=G(IP1,J)+(G(IP1+1,J)-G(IP1,J))*DIFF
  IF (J.EQ.1 .AND. I.LE.JPL) CK=.20
  GO TO 200
C
C****AFTER EFFECTIVE COVER
  100 DI=I-JEC
  DIFF=AMOD(DI,10.)/10.
  ID1=INT(DI/10.)+10
  IF(ID1.LT.11)DIFF=0.
  IF(ID1.LT.11)ID1=11
  IF(ID1.GT.19) DIFF=1
  IF(ID1.GT.19) ID1=19
  110 CK=G(ID1,J)+(G(ID1+1,J)-G(ID1,J))*DIFF

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  IF(I.GT.JHV) CK=G(20,5)
C
C****CHECK FOR ALFALFA
  IF(J.GT.1) GO TO 200
  IF(I.GT.JHV) GO TO 190
C****CUTTINGS
  D9=I
  DO 120 NQ1=1,NCUT
  DI=D9-JCUT(NQ1)
  IF(DI.LT.20..AND.DI.GT.0.) GO TO 180
  120 CONTINUE
  CK=1.00
  GO TO 200
C****USE SECOND SET OF COEFFICIENTS TO DESCRIBE ET DURING REGROWTH
C****ASSUME 20 DAYS FOR REGROWTH PERIOD
  180 DI=D1/20.*100.
  DIFF=AMOD(DI,10.)/10.
  ID1=INT(DI/10.)+10
  IF(ID1.LT.11) DIFF=0.
  IF(ID1.LT.11)ID1=11
  CK=G(ID1,J)+(G(ID1+1,J)-G(ID1,J))*DIFF
  GO TO 200
C****DECREASE OF ALFALFA ET AFTER HARVEST (KILLING FROST)
  190 CK=0.80-(I-JHV)*0.01833
  IF(CK.LT.0.25) CK=0.25
  200 CONTINUE
  210 RETURN
  END
C
C*****
C*****
  SUBROUTINE DAY(M, ID, JD)
C*****
C..THE SUBROUTINE DAY CHANGES MONTH AND DAY TO JULIAN DAY
C*****
  DIMENSION MD(12)
  DATA MD/31,28,31,30,31,30,31,31,30,31,30,31/
  ISUM=0
  DO 5 J=1,12
  IF(M.EQ.J)GOTO10
  ISUM=ISUM+MD(J)
  5 CONTINUE
  10 JD=ID+ISUM
  RETURN
  END
C
C*****
C*****
  SUBROUTINE DATE(JD,M, ID)
C*****
C****THE SUBROUTINE DATE CHANGES JULIAN DAY TO MONTH AND DAY
C*****
  DIMENSION MD(12)

```

```

DATA MD/31,28,31,30,31,30,31,31,30,31,30,31/
ISUM=0
DO 5 M=1,12
ISUM=ISUM+MD(M)
IF(JD.LE.ISUM)GOTO10
5 CONTINUE
10 ID=JD-ISUM+MD(M)
RETURN
END

C
C*****
C*****
SUBROUTINE PRINT (TITLE,MROW,MCOL)
C*****THIS SUBROUTINE WRITES REAL ARRAYS TO THE PRINTER
C*****
C*****DECLARATIONS*****
INTEGER TIMSTP,OPRINT,SCRATCH
REAL IRR
COMMON/EXTND/SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
& RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
& Q(41,35),ANTGW(41,35)
COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRATCH,OPRINT,M1,M2,IMEAN,
&SUMSP(30),SUMIRR(30),SUMPRES(30),SUMET(30),DELANT(30),DELACT(30)
DIMENSION TITLE(20)

C
C*****SUM UP TERMS OF THE ARRAY
C
TRMSUM=0.0
DO 460 I=1,MCOL
DO 460 J=1,MROW
TRMSUM=TERM(I,J)+TRMSUM
460 CONTINUE
IF (TRMSUM.EQ.0.0) GO TO 560

C
C*****INITIALIZE COLUMNS
C
KCOL0=1
KCOL1=KCOL0+14

C
C*****PRINT OUT TITLE AND TIMESTEP
C
500 WRITE (M2,510) (TITLE(I),I=1,20),TIMSTP
510 FORMAT (1H1///20X,20A4/10X,"TIMESTEP=",I2,37X,"(AF)")

C
C*****INITIALIZE J AS NROW AND I AS NCOL
C
520 J=MROW
IF (MCOL.LE.KCOL1) KCOL1=MCOL

C
C*****WRITE OUT COLUMN LABELS
C
WRITE(M2,530) ((I),I=KCOL0,KCOL1)
530 FORMAT (//2X,"J/I",1518//)

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C
C*****WRITE OUT ARRAY
C
540 CONTINUE
WRITE (M2,550) J,(TERM(I,J),I=KCOL0,KCOL1)
550 FORMAT (2X,I2,2X,15F8.2)
J=J-1
IF (J.GE.1) GO TO 540
IF(MCOL.EQ.KCOL1) GO TO 560
KCOL0=KCOL1+1
KCOL1=KCOL0+14
GO TO 520

560 CONTINUE
WRITE (M2,570) (TITLE(I),I=1,20),TIMSTP,TRMSUM
570 FORMAT (//20X,80(" ")/53X,"THE SUM OF THE"/20X,20A4/1H*,46X,
& "FOR TIMESTEP ",I2," IS ",F10.3/66X,10("_")/20X,80(" "))
RETURN
END

C
C*****
C*****
SUBROUTINE INTGR (TITLE,MROW,MCOL)
C*****
C*****THIS SUBROUTINE WRITES INTEGER ARRAYS OUT TO THE PRINTER
C*****
C*****DECLARATIONS
COMMON TIMSTP,DELT,DELX,DELY,NTS,SCRATCH,OPRINT,M1,M2,IMEAN,
&SUMSP(30),SUMIRR(30),SUMPRES(30),SUMET(30),DELANT(30),DELACT(30)
COMMON/EXTND/SURFAC(41,35),ANTDRY(41,35),ANTIRR(41,35),
& RSPACE(6700),ISPACE(4600),TERM(41,35),SUM(41,35),
& Q(41,35),ANTGW(41,35)
INTEGER TIMSTP,OPRINT,SCRATCH,ARRAY
DIMENSION TITLE(20),ARRAY(41,35)
EQUIVALENCE (ISPACE(1),ARRAY(1,1))

C
C*****WRITE TITLE AND LABELS
C
WRITE (M2,100) (TITLE(I),I=1,20),((K),K=1,MCOL)
100 FORMAT (///25X,20A4//2X,"J/I",2X,41I3)
WRITE (M2,101)
101 FORMAT (5X)

C
C*****WRITE OUT ARRAY
C
DO 115 J=1,MROW
J1=MROW+1-J
WRITE (M2,110) J1,(ARRAY(I,J1),I=1,MCOL)
110 FORMAT (1X,I3,3X,41I3)
115 CONTINUE
RETURN
END

C
C*****
C*****

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SUBROUTINE BLANY (LAT,MONTH,DAY,TMEAN,RHMIN,NRATIO,UDAY,ET1)
C*****
C*****THIS SUBROUTINE USES A MODIFIED VERSION OF THE BLANEY-CRIDDLE
C*****EQUATION TO CALCULATE THE POTENTIAL ET OF GRASS. THE SUBROUTINE
C*****IS TAKEN FROM AND PRUITT (19 ). THIS SUBROUTINE IS CALLED
C*****FROM THE EVAPO SUBROUTINE.
C*****DECLARATIONS*****
DIMENSION AA(3,3), BB(6,6), C(2,2), D(2), PP(11,12)
REAL NRATIO, LAT
INTEGER MONTH, DAY, RHMIN
C*****
C THIS SECTION INTERPOLATES "F".
C*****
DATA PP
1 / .267, .264, .261, .257, .252, .246, .239, .231, .220, .209, .195,
2 .269, .268, .266, .264, .261, .257, .253, .248, .243, .236, .228,
3 .269, .269, .269, .269, .269, .268, .268, .268, .267, .266,
4 .269, .270, .272, .275, .278, .282, .286, .291, .297, .303, .310,
5 .271, .273, .276, .281, .287, .294, .303, .312, .322, .334, .346,
6 .274, .280, .285, .291, .298, .307, .316, .328, .341, .355, .371,
7 .275, .281, .287, .293, .299, .305, .313, .321, .330, .341, .354,
8 .274, .278, .282, .287, .291, .295, .300, .304, .309, .315, .322,
9 .271, .277, .280, .281, .281, .281, .281, .281, .281, .281, .281,
A .270, .269, .268, .267, .264, .261, .258, .254, .250, .245, .240,
B .269, .267, .264, .260, .254, .247, .240, .231, .222, .211, .200,
C .268, .266, .262, .257, .250, .242, .232, .221, .209, .195, .180 /
LL=INT(LAT/5) * 5
IF (LAT.GT.50) LL=50
L1=LL/5 + 1
L2 = L1 + 1
IF (L2.GT.11) L2=11
FAC=(LAT-LL)/5.0
MONTH1=MONTH
MONTH2=MONTH
IF (DAY.GT.15 ) MONTH2=MOD(MONTH,12) + 1
IF (DAY.LT.15.AND.DAY.NE.0) MONTH1=MOD(MONTH+10,12) + 1
P1=PP(L1,MONTH1) + FAC * (PP(L2,MONTH1)-PP(L1,MONTH1))
P2=PP(L1,MONTH2) + FAC * (PP(L2,MONTH2)-PP(L1,MONTH2))
FAC=DAY - 15
IF (FAC.LT.0.0) FAC=FAC+30.0
FAC2=FAC/30.0
P=P1 + FAC2 * (P2-P1)
F=P*(0.46*TMEAN + 8.13)
C*****
C THIS SECTION INTERPOLATES ET1 USING A, B, AND F.
C*****
DATA BB/.84, .8, .74, .64, .52, .38, 1.03, .95, .87, .76, .63, .48, 1.22,
21.10, 1.01, .88, .74, .57, 1.38, 1.24, 1.13, .99, .85, .66, 1.54, 1.37, 1.25,
31.09, .94, .75, 1.68, 1.5, 1.36, 1.18, 1.04, .84, .97, .9, .81, .68, .54, .4,
41.19, 1.08, .96, .84, .66, .5, 1.41, 1.26, 1.11, .97, .77, .6, 1.6, 1.42, 1.25,
51.09, .89, .7, 1.79, 1.59, 1.39, 1.21, 1.01, .79, 1.98, 1.74, 1.52, 1.31, 1.11,
6.89, 1.08, .98, .87, .72, .56, .42, 1.33, 1.18, 1.03, .87, .69, .52, 1.56, 1.38,
71.19, 1.02, .82, .62, 1.78, 1.56, 1.34, 1.15, .94, .73, 2., 1.74, 1.5, 1.28,
81.05, .83, 2.19, 1.9, 1.64, 1.39, 1.16, .92, 1.18, 1.06, .92, .74, .58, .43,

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91.44, 1.27, 1.1, .91, .72, .54, 1.7, 1.48, 1.27, 1.06, .85, .64, 1.94, 1.67,
A1.44, 1.21, .97, .75, 2.18, 1.86, 1.59, 1.34, 1.09, .85, 2.39, 2.03, 1.74,
B1.46, 1.2, .95, 1.26, 1.11, .96, .76, .6, .44, 1.52, 1.34, 1.14, .93, .74, .55,
C1.79, 1.56, 1.32, 1.1, .87, .66, 2.05, 1.76, 1.49, 1.25, 1., .77, 2.3, 1.96,
D1.66, 1.39, 1.12, .87, 2.54, 2.14, 1.82, 1.52, 1.24, .98, 1.29, 1.15, .98, .78,
E.61, .45, 1.58, 1.38, 1.17, .96, .75, .56, 1.86, 1.61, 1.36, 1.13, .89, .68,
F2.13, 1.83, 1.54, 1.28, 1.03, .79, 2.39, 2.03, 1.71, 1.43, 1.15, .89, 2.63,
G2.22, 1.86, 1.56, 1.27, 1./
X=RHMIN
Y=NRATIO
Z=UDAY
I1=INT(X/20.) + 1
I2=I1 + 1
IF (I2.GT.6) I2=6
J1=INT(Y/0.2) + 1
J2=J1 + 1
IF (J2.GT.6) J2=6
K1=INT(Z/2) + 1
K2=K1 + 1
IF(K2.GT.6) K2=6
IF(K1.GT.6) K1 =6
X1=(I1-1) * 20
X2=(I2-1) * 20
Y1=(J1-1) * 0.2
Y2=(J2-1) * 0.2
Z1=(K1-1) * 2
Z2 = (K2-1) * 2
FACX=0.0
FACY = 0.0
FACZ = 0.0
IF (K1.NE.K2) FACZ=(Z-Z1)/(Z2-Z1)
C(1,1)=BB(I1,J1,K1) + FACZ * (BB(I1,J1,K2)-BB(I1,J1,K1))
C(1,2)=BB(I1,J2,K1) + FACZ * (BB(I1,J2,K2)-BB(I1,J2,K1))
C(2,1)=BB(I2,J1,K1) + FACZ * (BB(I2,J1,K2)-BB(I2,J1,K1))
C(2,2)=BB(I2,J2,K1) + FACZ * (BB(I2,J2,K2)-BB(I2,J2,K1))
IF (J1.NE.J2) FACY=(Y-Y1)/(Y2-Y1)
IF (I1.NE.I2) FACX=(X-X1)/(X2-X1)
D(1)=C(1,1) + FACY * (C(1,2)-C(1,1))
D(2)=C(2,1) + FACX * (C(2,2)-C(2,1))
BP=D(1)+FACX*(D(2)-D(1))
AP=0.0043*X-Y-1.41
ET1=AP+BP*F
RETURN
END

```