Computer Program for Simulation of Variable Recharge with the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model (MODFLOW)

By Angelo L. Kontis

U.S. GEOLOGICAL SURVEY

Open-File Report 00-173

Troy, New York
2001

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

The use of firm, trade, and brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey

---

For additional information write to:

U.S. Geological Survey
425 Jordan Road
Troy, New York 12180-8349

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver Federal Center
Denver, CO 80286

FOREWORD/PREFACE

This report presents a computer program (Package), to be used in conjunction with the Modular Finite-Difference Ground-Water Flow Model (MODFLOW) developed by the U.S. Geological Survey, to simulate areal recharge and the upland contribution of recharge to a valley-fill aquifer. The performance of this computer program has been empirically tested in several ground-water flow models. Because future applications of the program could reveal errors that were not detected in the simulations, users of the report are encouraged to notify the originating office of any errors found in the report or in the computer program. Updates may be made occasionally to both the report and to the program. Users who wish to be added to the mailing list to receive updates, if any, may send a request to:

U.S. Geological Survey
425 Jordan Road
Troy. NY 12180-8349

Although this program has been used by the USGS, no warranty, expressed or implied, is made by the USGS or the United States Government as to accuracy and functioning of the program and related program material, nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the USGS in connection therewith.

Files containing the programs, data for an example model, and instructions to run the model and accessory programs (VIZGEN and VARRGEN) discussed in this report are in a tar file (varech.tar.gz) and may be accessed by anonymous ftp by the following commands:

```
ftp ny.usgs.gov
anonymous
cd /outgoing/progs/varech
get varech.tar.gz
bye
```

The tar file can be uncompressed and files extracted by the command:

```
gzcat varech.tar.gz | tar xvof -
```

CONTENTS

APPENDIXES

FIGURES

TABLE

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch per year (in/yr)	25.40	millimeter per year
foot (ft)	.3048	meter
foot per day (ft/d)	.3048	meter per day
foot per second (ft/s)	.3048	meter per second
foot per day per foot [(ft/d)/ft]	1	meter per day per meter
foot per second per foot [(ft/s)/ft]	1	meter per second per meter
foot squared per second (ft^2/s)	0.09290	meter squared per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Computer Program for Simulation of Variable Recharge with the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model (MODFLOW)

By Angelo L. Kontis

Abstract

The Variable-Recharge Package is a computerized method designed for use with the U.S. Geological Survey three-dimensional finite-difference ground-water flow model (MODFLOW-88) to simulate areal recharge to an aquifer. It is suitable for simulations of aquifers in which the relation between ground-water levels and land surface can affect the amount and distribution of recharge. The method is based on the premise that recharge to an aquifer cannot occur where the water level is at or above land surface. Consequently, recharge will vary spatially in simulations in which the Variable-Recharge Package is applied, if the water levels are sufficiently high. The input data required by the program for each model cell that can potentially receive recharge includes the average land-surface elevation and a quantity termed "water available for recharge," which is equal to precipitation minus evapotranspiration.

The Variable-Recharge Package also can be used to simulate recharge to a valley-fill aquifer in which the valley fill and the adjoining uplands are explicitly simulated. Valley-fill aquifers, which are the most common type of aquifer in the glaciated northeastern United States, receive much of their recharge from upland sources as channeled and(or) unchanneled surface runoff and as lateral ground-water flow. Surface runoff in the uplands is generated in the model when the applied water available for recharge is rejected because simulated water levels are at or above land surface. The surface runoff can be distributed to other parts of the model by (1) applying the amount of the surface runoff that flows to upland streams (channeled runoff) to explicitly simulated streams that flow onto the valley floor, and(or) (2) applying the amount that flows downslope toward the valley-fill aquifer (unchanneled runoff) to specified model cells, typically those near the valley wall.

An example model of an idealized valley-fill aquifer is presented to demonstrate application of the method and the type of information that can be derived from its use. Documentation of the Variable-Recharge Package is provided in the appendixes and includes listings of model code and of program variables. Comment statements in the program listings provide a narrative of the code. Input-data instructions and printed model output for the package are included.

INTRODUCTION

The relation between ground-water levels and land surface in many aquifer systems can affect the amount and distribution of aquifer recharge from precipitation (Theis, 1940). For example, rainfall in areas where the water table is at or near land surface cannot penetrate the aquifer and will be rejected as recharge. The uplands that border valley-fill aquifers are inherently part of the aquifers' flow systems, and runoff from these uplands provide significant recharge to such aquifers (Babcock and Cushing, 1942; Morrissey and others, 1988; Williams and Morrissey, 1996; Kontis and others (in press)). In particular, water originating in the uplands can be a source of recharge to the valley fill through the mechanisms of (1) unchanneled ground-water or surface-water runoff and (2) channeled runoff in tributaries that cross the aquifer. The general characteristics of an idealized valley-fill aquifer and the various sources of recharge to stratified-drift deposits within the valley are depicted in figure 1. Of the five sources of recharge to the stratified drift, three originate in the uplands, and two originate within the valley.

A modeling technique for simulating areal recharge to an aquifer was developed by the U.S. Geological Survey (USGS) as part of its Northeast Glacial Aquifers Regional Aquifer-System Analysis project (Lyford, 1986; Randall and Johnson, 1988; Sun and Weeks, 1991; Sun and Johnston, 1994; Sun and others, 1997). The technique is intended for use with the USGS finite-difference ground-water flow model code, MODFLOW-88 (McDonald and Harbaugh, 1988). It is designed to simulate recharge from precipitation on the aquifer and adjacent uplands (sources A and B of fig. 1) as a function of aquifer head relative to land surface, and can also simulate recharge to the valley-fill aquifer from runoff from explicitly simulated uplands (sources C, D and E of fig. 1).

MODFLOW contains groups of modules (subroutines) termed “packages”, which perform a particular aspect of a simulation; thus, the technique described herein is termed the Variable-Recharge (V-R) Package. It consists of four modules, the first of which allocates computer storage required by the package, the second reads input data and prepares the data for further processing, the third places V-R values in their appropriate locations in the model finite-difference equations, and the fourth calculates flows and parts of the model water budget related to the V-R Package. Application of the V-R package has been demonstrated in ground-water flow models of the Killbuck Creek valley near Wooster, Ohio (Breen and others, 1995) and the Rockaway River valley near Dover, N. J. (Kontis, 1999).

Purpose and Scope

This report documents the V-R Package and presents sufficient information that interested readers can implement the method.The report also describes conceptual development and formulation of the method and presents (1) a general description of the model code and of model input and output, (2) an example of model input and output for a simple one-layer model, and (3) a listing of the V-R Package computer code and description of program variables.

Program Design

The V-R Package is designed to be compatible with the version of MODFLOW termed MODFLOW-88 as documented by McDonald and Harbaugh (1988). The V-R Package modules are incorporated into MODFLOW by modifying the MAIN program to include appropriate subroutine calls to the four modules described above which are named the Allocation module (VAR1AL), the Read and Prepare module (VAR1RP), the Formulation module (VAR1FM) and the Budget module (VAR1BD). FORTRAN code given in this report conforms to the FORTRAN 77 language used in McDonald and Harbaugh (1988).

Invoking the Variable-Recharge Package

The V-R Package is invoked by inserting a nonzero input unit number in the 21st element of the Basic Package’s IUNIT array (McDonald and Harbaugh, 1988, Chap.4, p. 9).

Additions to MODFLOW MAIN program

The FORTRAN listing of the MAIN program of MODFLOW (appendix 1) contains the additional statements (denoted by *VAR*) required for the V-R Package. These statements call the Variable-Recharge Package modules VAR1AL, VAR1RP, VAR1FM, and VAR1BD. This version of MAIN contains calls to packages that have been documented in various USGS reports since August 1993. In addition to the packages BAS1, RIV1,

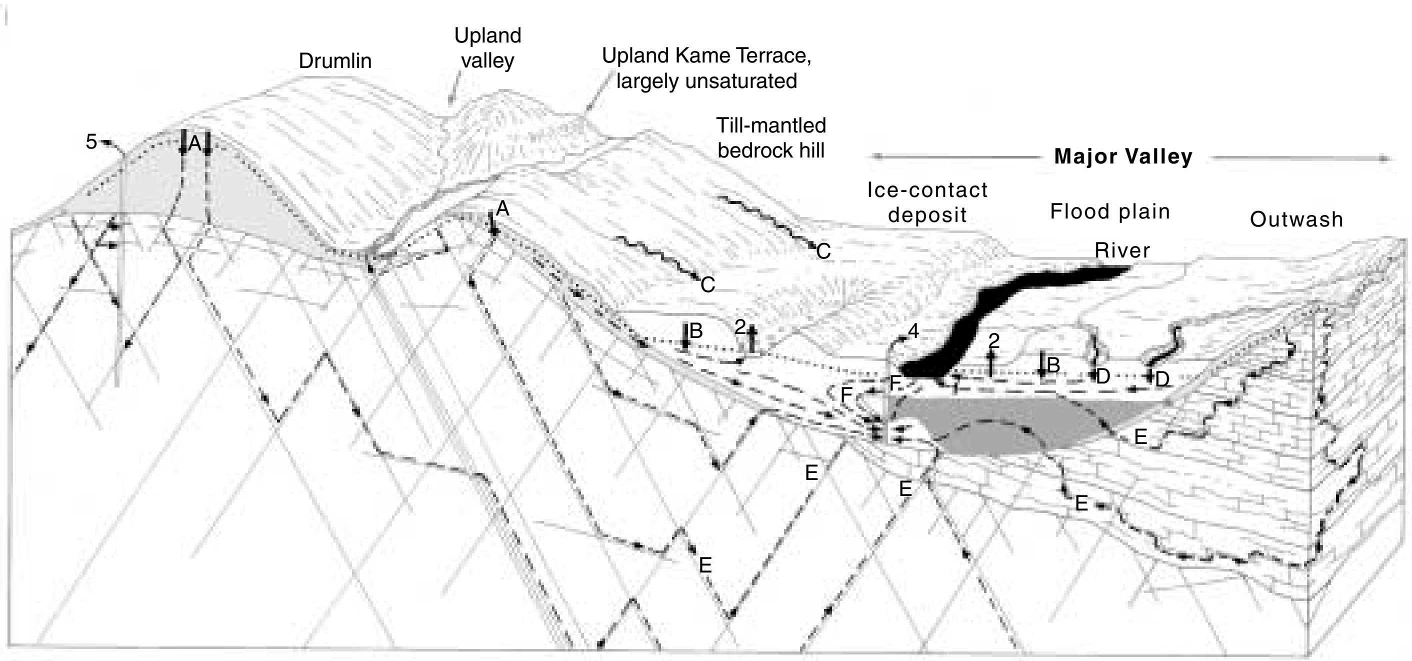


Figure 1. Distribution of geologic units and ground-water flow in an idealized valley-fill aquifer system. (From Randall and others, 1988, fig. 1)

DRN1, WEL1, GHB1, RCH1, EVT1, SIP1, SOR1and UTL1, documented in McDonald and Harbaugh (1988), this version provides calls to the following packages: IBS1 and CHD1 (Leake and Prudic, 1988), STR1 (Prudic, 1989), PCG2 (Hill, 1990), GFD1 (Harbaugh,1992), BCF3 (McDonald and others,1992; Goode and Appel,1992); and HFB1 (Hsieh and Freckleton, 1993). Some of these calls are noted in columns 73-80 of the code in appendix 1. A narrative of the MAIN program, corresponding to numbered comment statements C1-C8 in the code, is given in McDonald and Harbaugh (1988, p. 3-29 to 3-31).

Additions to BLock-Centered Flow Package

If the Variable-Recharge package is invoked, one line of code should be added to subroutine SBCF1F of the Block-Centered Flow package. Subroutine SBCF1F computes flow to and from constant head cells. These flows are accumulated and included in the overall volumetric budget of the model, and the individual cell-by-cell flows are available for eventual output. In the Variable-Recharge Package, active cells (1) in which the simulated water level is at or above land surface, and (2) that receive a net inflow (eq. 3c, 3d) are converted to constant-head cells and given an IBOUND array value of -99. The cell-by-cell-flows for these cells, and their contribution to the volumetric budget, are calculated in the budget module (VAR1BD) of the Variable-Recharge code and are incorporated in Variable-Recharge Leakage budget terms. Consequently, flow calculations for seepage cells are bypassed in subroutine SBCF1F to avoid double counting of these flows. The code between C4 and C5 of Subroutine SBCF1F (page 5-89 of McDonald and Harbaugh, 1988) should read as follows (the new code contains *VAR* in columns 73-77):

```
C4----IF CELL IS NOT CONSTANT HEAD SKIP IT & GO ON TO NEXT CELL.
      IF (IBOUND(J,I,K).GE.0)GO TO 200
C4A---IF CELL IS A VARIABLE-RECHARGE SEEPAGE CELL (IBOUND=-99), BYPASS *VAR*
C     FLOW CALCULATION. FLOW TO THESE CELLS IS CALCULATED IN VAR1BD.   *VAR*
       IF(IBOUND(J,I,K).EQ.-99) GO TO 200                               *VAR*
C
C5-----CLEAR FIELDS FOR SIX FLOW RATES
```

VARABLE-RECHARGE PACKAGE

Simulation of recharge in MODFLOW with the Recharge Package (McDonald and Harbaugh, 1988, chap. 7) entails specifying the *areal distribution of recharge* and applying it to specified active model cells, irrespective of the model head distrbution, whereas simulation of recharge with the V-R Package entails specifying the *amount of water available for recharge from precipitation* (WAFR, defined in eq. 1) and applying it to specified active model cells. Whether the water becomes recharge depends, in part, on the model-head distribution. The basic premise of the technique is that precipitation cannot be accepted as recharge where the water table is at or above land surface. Where the head is above land surface, discharge (outward seepage) from the aquifer may occur. Thus, the method is conceptually similar to (1) the "variable-source area" overland-flow concept of Dunne and Black (1970), which postulates that overland flow occurs where soils are saturated by a rising water table, and (2) the ground-water model code of Potter and Gburek (1987), wherein outward seepage is calculated once the water level reaches land surface. Where recharge is rejected or where outward seepage occurs in upland areas, the rejected recharge and seepage become surface runoff that may eventually become recharge to a valley-fill aquifer at the base of the upland hillsides, either as channeled flow in tributaries that cross the valley fill or as unchanneled runoff that infiltrates when it reaches the valley fill. The land surface areas within which recharge, rejected recharge, and outward seepage occur may vary spatially as a function of temporal variations in WAFR. Applications in which the V-R Package can be useful include (1) simulations in which the spatial distribution and magnitude of recharge and surface runoff can vary widely in response to seasonal or annual variations in precipitation and evapotranspiration, (2) simulations of the migration of contaminants originating in uplands, (3) simulations of recharge to wetlands and/or aquifer response to pumping near wetlands and ephemeral streams, and (4) simulations of valley-fill aquifers bordered by uplands composed of poorly permeable bedrock or till.

Conceptualization and Formulation

The V-R Package requires the following information for simulations in which the uplands are explicitly represented and upland channeled and unchanneled runoff is distributed to specified parts of the modeled area. If the uplands are not explicitly simulated, or if upland surface runoff is not distributed to other parts of the model, only items 1 and 6 (listed below) are required. Each item is illustrated in figures 2 and 3 for the example model of an idealized valley-fill aquifer and described in detail in the "Example Model" section further on.

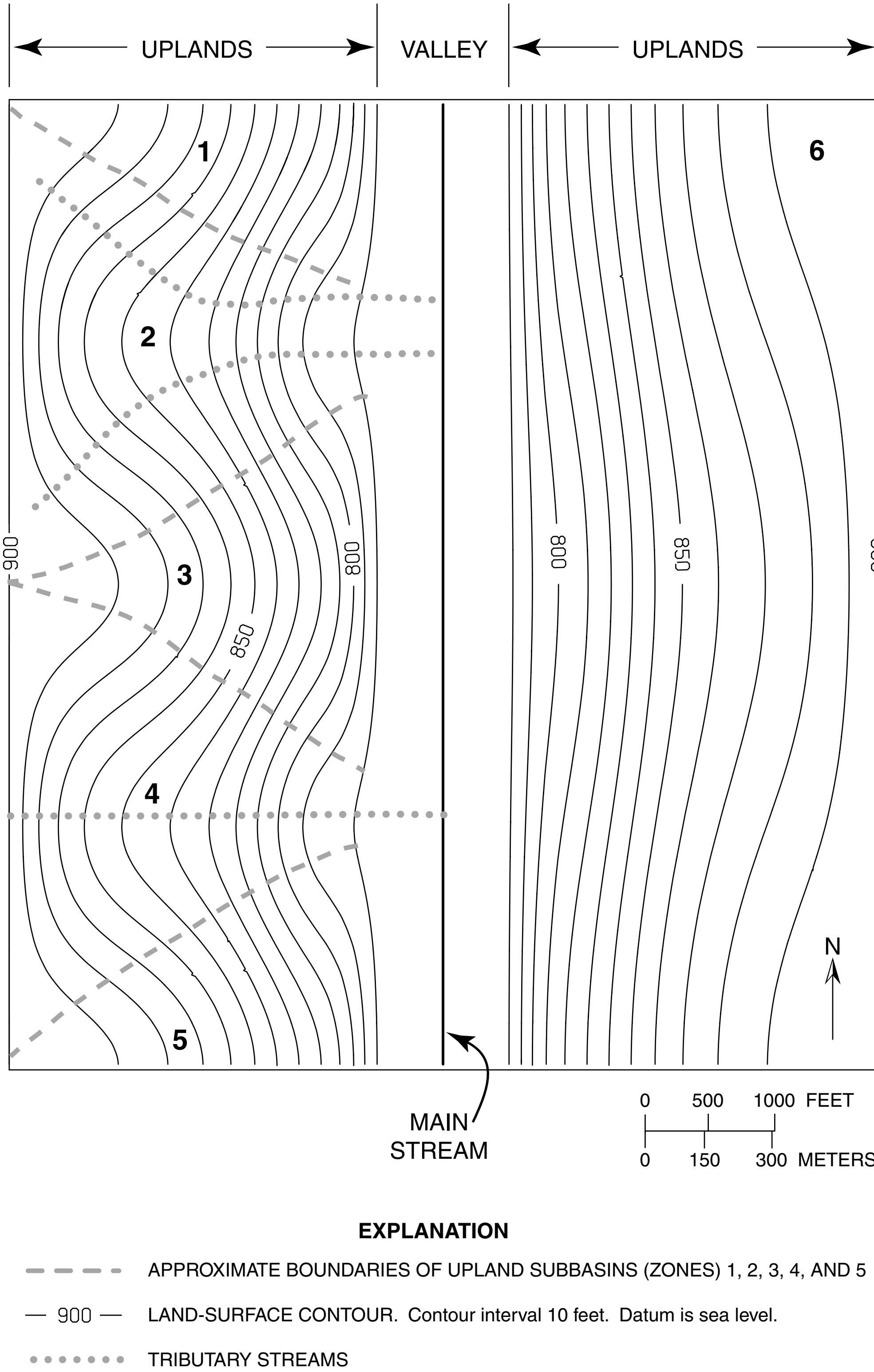


Figure 2. Plan view of an idealized valley-fill aquifer and adjacent uplands showing land-surface elevation, division of uplands into six subbasins (zones), and locations of tributaries and main valley stream. The four corners of the map coincide with the centers of the corresponding finite-difference cells of figure 3.

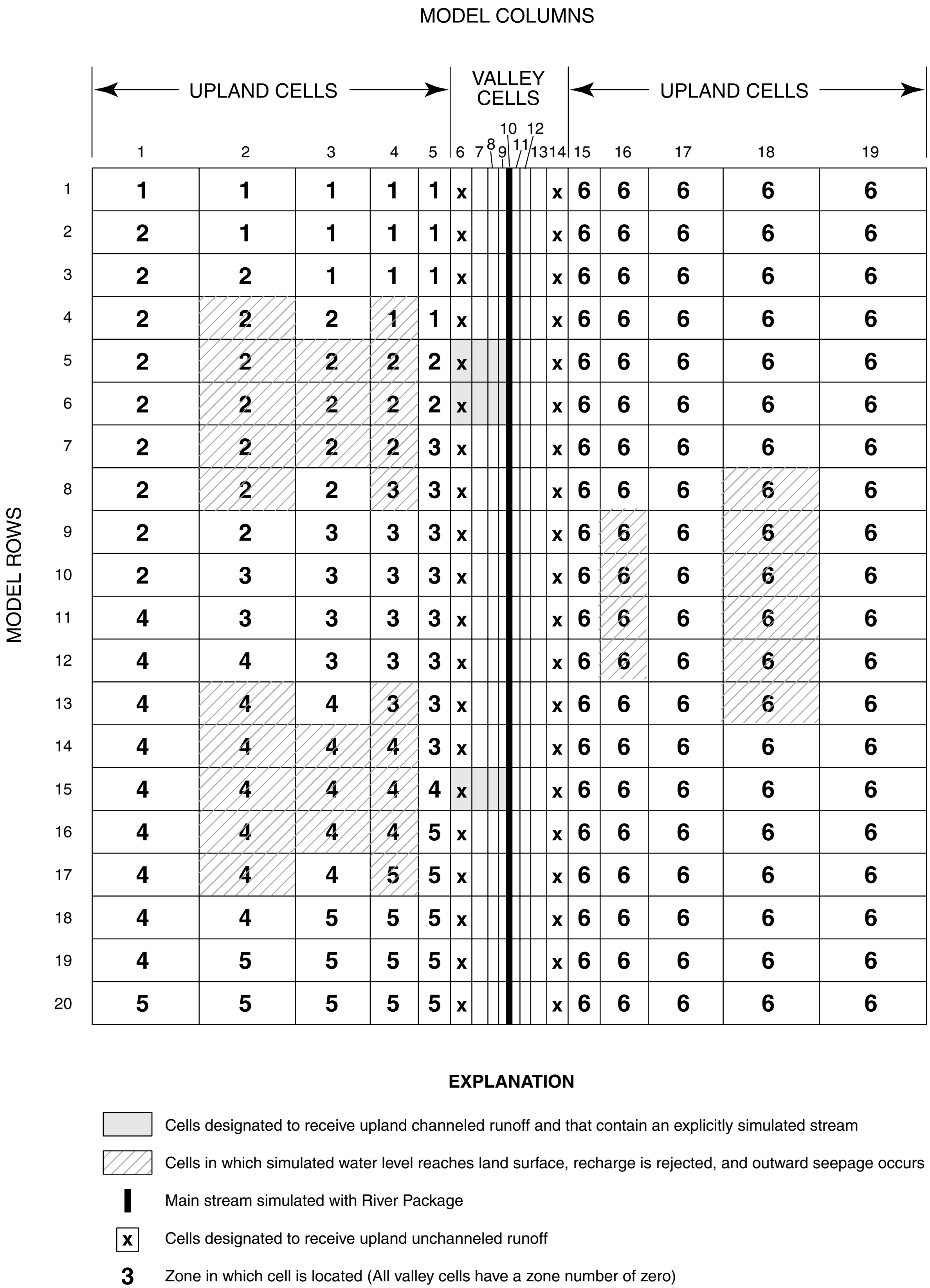


Figure 3. Example model grid showing zone number of each cell, locations of main stream, and of cells designated to receive upland channeled and unchanneled runoff, and locations of upland cells in which simulated water level reaches land surface causing outward seepage.

(1) Average land-surface elevation of each active model cell that receives WAFR (fig. 2).

(2) Division of the entire model area into a V-R zone array (figs. 2 and 3). The zones differentiate (a) upland topographic subbasins for which surface runoff is calculated and redistributed to other parts of the model, and (b) topographically low areas in which surface runoff is not redistributed. The topographically low areas will usually include the main valley-fill aquifer being evaluated but may also include some upland valleys in which surface runoff enters streams whose flow does not cross the aquifer being evaluated. These lowland areas, if specified in items 4 and 5, may receive water from the uplands. Each upland subbasin is assigned a unique non-zero zone number whereas all topographically low areas are collectively designated zone zero.

(3) The proportion of upland runoff (rejected recharge plus outward seepage) that reaches the valley floor as channeled flow in each upland subbasin. This quantity can be estimated from the topographic configuration of the subbasin, as the percentage of the subbasin area that slopes toward channels whose valley-floor reaches are explicitly simulated (as described in item 4). For example, a reasonable estimate for subbasin 4 of figure 2, is that most of the upland surface runoff in the subbasin flows toward and into the upland stream. If no explicitly simulated streams emanate from an upland subbasin the value for that subbasin is zero.

(4) The location of each model cell that contains a channel in which upland channeled runoff simulated by the V-R Package reaches the valley floor, if interaction of that channeled runoff with an aquifer is to be simulated (fig.3); also the streambed conductance, stream stage, and elevation of the top and bottom of the streambed in that cell. The interaction between stream and aquifer is simulated by incorporating pertinent parts of the Stream Package of Prudic (1989) in the V-R Package; code dealing with the calculation of stream stage as a function of stream discharge and streambed geometry from the Manning formula is excluded. Most of the input data required by the Stream Package also are required by the V-R Package. One exception is data pertaining to the Manning Formula; another is streamflow in the upstream cell of each simulated stream. In the V-R Package, this streamflow is calculated from simulated surface runoff generated in the uplands. A stream that is simulated with the V-R Package cannot also be simulated with the Stream Package, although the Stream (or River) Package can be applied to other streams in the model.

(5) The location of each valley-floor model cell, along the valley wall, that receives unchanneled runoff from the uplands (fig. 3).

(6) The estimated quantity of water available for recharge (WAFR) for each time period simulated. This quantity can be computed from

$$WAFR = P - ET + SN_m - SN_s \pm SM \qquad \text{(L)}, \qquad (1)$$

where P = precipitation,
ET = evapotranspiration of moisture above the water table,
SN_m = snowmelt,
SN_s = water equivalent of snow held in storage, and
SM = change in soil moisture content.

A method by which equation 1 can be applied to aquifers in the glaciated northeastern United States is given in Lyford and Cohen (1988). If evapotranspiration of soil moisture (*ET*) exceeds precipitation (*P*), WAFR is zero, and soil moisture (*SM*) is depleted. If precipitation exceeds evapotranspiration, then soil moisture can be replenished. WAFR is zero until any soil-moisture deficits accumulated over time have been replenished. Calculations of WAFR for two ground-water flow models is described in Breen and others (1995) and Kontis (1999).

Input to the model consists of WAFR, expressed as a flow rate. The flow rate, *Rwa*, for any finite-difference cell i, j, k is defined as

$$Rwa_{i,j,k} = \left(\frac{WAFR}{t}\Delta r \Delta c\right)_{i,j,k} \qquad (L^3/T), \qquad (2)$$

where Δr and Δc = cell dimensions in the row and column directions, respectively,
$\Delta r \Delta c$ = area of cell i, j, k, and
t = length of time period for which WAFR is computed.

In the MODFLOW indexing system for finite difference cells, if I, J, K are the total number of model rows, columns, and layers, respectively, then i = 1, 2, ...I; j = 1, 2,...J and k = 1, 2,...K. In the V-R Package, the layer index (k) is the model layer of the cell to which R_{wa} is applied.

The V-R Package is implemented in MODFLOW each time the finite-difference equation for ground-water flow is formulated (that is, at each iteration). At each iteration, the simulated hydraulic head in each cell receiving WAFR is compared with land-surface elevation. The WAFR value is partitioned into recharge, rejected recharge, or both, depending on the elevation of the simulated hydraulic head (H_a) relative to land surface (H_s) or to a pseudo- land surface H'_s defined to be H_s - df, where df is a specified depth factor (fig. 4). The pseudo-land surface and depth factors, as explained below, are computational devices used to minimize numerical instabilities. Three alternative recharge conditions are simulated by the V-R package (fig. 4). For each condition, the amount of recharge (R), rejected recharge (REJ), outward seepage (OS), and surface runoff (SR) of each finite-difference cell i, j, k receiving WAFR is described in equations 3a, 3b, and 3c. In these equations, the cell location i, j, k is implicit.

Condition 1 (full recharge, no rejected recharge, no surface runoff, no outward seepage)

$$\left.\begin{aligned} R &= Rwa \\ REJ &= 0 \\ SR &= 0 \\ OS &= 0 \end{aligned}\right\} \quad \text{if } H_a \le H'_s \qquad (L^3/T) \qquad (3a)$$

Condition 2 (partial recharge, partial rejected recharge, surface runoff, no outward seepage)

$$\left.\begin{aligned} R &= Rwa\frac{H_s - H_a}{df} \\ SR = REJ &= Rwa - R \\ OS &= 0 \end{aligned}\right\} \quad \text{if } H'_s < H_a < H_s \text{ and } df > 0 \quad (L^3/T) \qquad (3b)$$

Condition 3 (no recharge, full rejected recharge, surface runoff, and possible outward seepage)

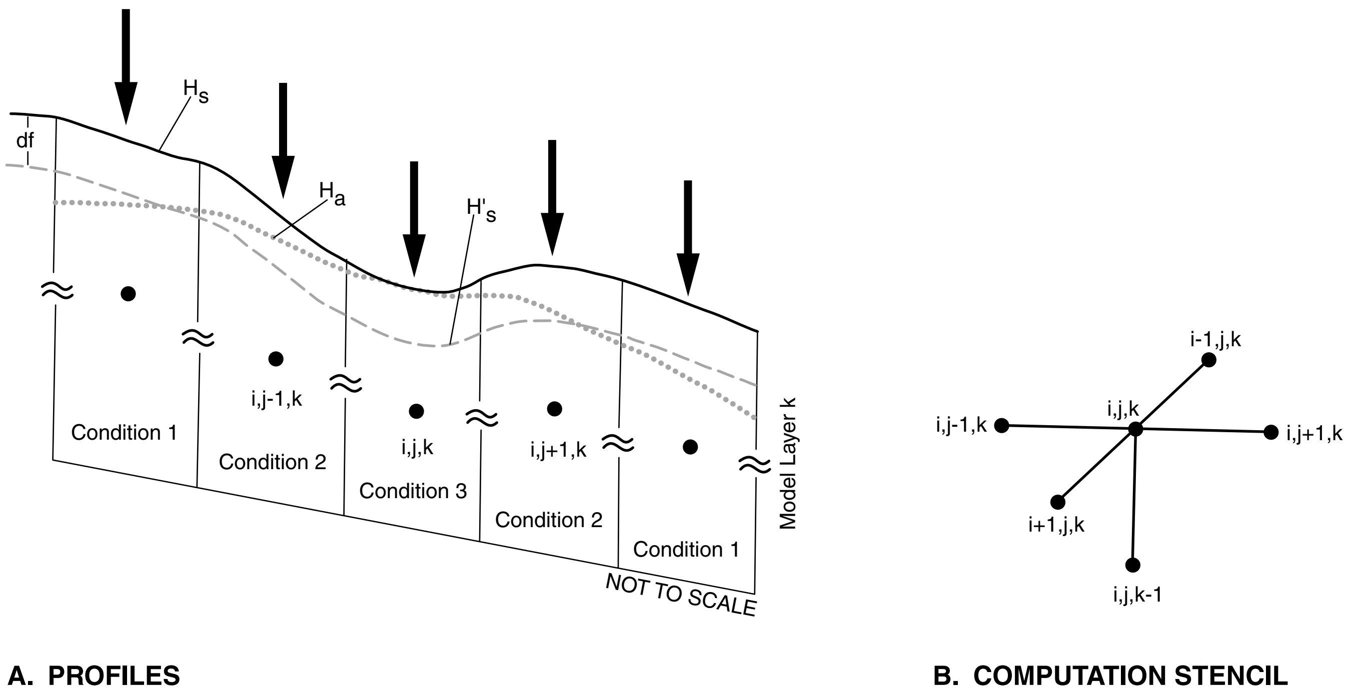
$$\left.\begin{aligned} R &= 0 \\ REJ &= Rwa \\ SR &= REJ + OS = Rwa + OS \end{aligned}\right\} \quad \textit{if } H_a \ge H_s \quad (L^3/T) \qquad (3c)$$

The V-R Package occasionally gives rise, during the iteration process, to numerical instabilities that prevent convergence to a suitable solution for head; therefore, the pseudo land surface (H'_s) and depth factor (df) are introduced to minimize such instability. These terms have no physical meaning, but the manner in which the depth factor affects recharge is related to a physical process in some hydrologic settings. For example, if the actual land surface represented by a model cell contains small scale topographic relief (microtopography) with relief similar to the depth factor, a water-level rise to the elevation of the low places will prevent further recharge in these places and will result in rejected recharge, outward seepage and formation of surface rills. Recharge can still occur in the areas between the low places, but will tend to be less than if the microtopography were absent and the total recharge will decrease as the water table rises. Similarly, where the water level rises to or above the pseudo-land surface, as described by equation 3b, the amount of recharge is reduced. In general, the partition of WAFR into recharge and surface runoff will vary as a function of the depth factor. During the testing of the V-R Package, use of a nonzero depth factor of 1 ft or less in equations 3a and 3b generally minimized numerical instabilities, and variations in recharge and runoff over this range were relatively small. If the depth factor is zero, then $H_s = H'_s$, and only conditions 1 and 3 (eqs. 3a and 3c) apply.

Outward seepage, OS in equation 3c, is assumed to occur if the sum of the ground-water flows between the cell i, j, k and the five adjacent cells depicted in fig. 4B is positive. This is determined from the provisional quantity OS* for cell i, j, k, defined as

$$OS^* = q_{i,\,j-1/2,\,k} + q_{i,\,j+1/2,\,k} + q_{i-1/2,\,j,\,k} + q_{i+1/2,\,j,\,k} + q_{i,\,j,\,k+1/2} \qquad (L^3/T), \qquad (3d)$$

in which the q terms represent ground-water flows between cell i, j, k and the 5 adjacent cells (eqs. 10-13 and eq. 15 of McDonald and Harbaugh, 1988). If OS* is positive, the net ground-water flow from adjacent areas is into the cell, and this net inflow is designated as outward seepage by setting OS equal to OS^*. In addition, the cell in question is set to a constant head, equal to land-surface elevation; that is, $H_a = H_s$ if $OS^* > 0$. If the net ground-water flow between the cell i, j, k, and adjacent cells is zero or away from the cell ($OS^* \le 0$) outward seepage does not occur, and the cell continues to be active and the provisional term OS^* is not used.



EXPLANATION

Rate of water available for recharge (Rwa) applied to each uppermost active model cell

Land surface

df — Depth of pseudo land surface below land surface, usually 1 foot or less

Pseudo-land surface (H_s - df)

Water level

Center of cell

i,j,k — Indices of finite-difference model cell located at ith row, jth column, kth layer

Condition:

1	$H_a \leq H'_s$	(Full recharge)
2	$H'_s < H_a < H_s$	(Partial recharge)
3	$H_a \geq H_s$	(No recharge)

Figure 4. (A) Idealized profiles showing land surface (H_s), pseudo-land surface (H'_s), and simulated head (H_a) along ground-water flow model finite-difference model row i, and the three conditions of equation 3 that provide for full, partial, and zero recharge. (B) Finite-difference computation stencil used to compute flow between model cell i, j, k and five adjacent cells (eq. 3d).

If a cell converts to a constant-head seepage cell, it becomes a constant-head cell in all MODFLOW packages in which the cell had been active. If the effect of a particular MODFLOW package in a simulation is to induce a lowering of head in one or more cells (as may result from a discharging well), those cells will probably always be active. But if the effect of a package is to cause head in one or more cells to rise (as may result from a recharging well) and the value of equation 3d is positive, the effect of that package could change in unintended ways when head reaches land surface and the cells become constant head. If the flow between a seepage cell and adjacent cells is reversed (from positive to negative) in response to changing hydraulic conditions, the constant-head condition is removed, and the cell becomes active.

The total amount of surface runoff from each upland subbasin is calculated at each iteration as the sum of the rejected recharge and the outward seepage for all cells within that upland subbasin (Variable-Recharge zone), and is distributed to the adjacent valley floor according to the information specified in items (3), (4) and (5) above. The unchanneled runoff from each subbasin is divided equally among all valley cells designated to receive runoff from that subbasin and is applied as additional WAFR to these cells. The channeled runoff from each subbasin is divided equally among all streams draining that subbasin that are explicitly simulated in the V-R Package and is applied as the initial streamflow in the upstream cell of each stream at the edge of the valley floor (See comment C14 of Subroutine VAR1FM code in appendix 5.) The streams may gain or lose water as they flow across the valley floor, depending on the relation between stream-surface altitude and the hydraulic head in the aquifer beneath the stream.

Budget Terms

In the V-R Package, some or all of the WAFR to the uplands eventually becomes recharge to the valley fill. The processes by which this occurs can be described and summarized by an upland water budget, each component of which is calculated in the V-R Package. Budget terms are calculated for each upland subbasin, for the entire upland area modeled, and for the upland contributions to valley recharge. The V-R Package budget components, all of which have units of volume per unit time, are defined as follows; most of them are printed in the model output.

Upland Subbasins

The relative amounts of recharge and surface runoff for each cell are characterized by the WAFR flow rate (Rwa), rejected recharge (REJ), and outward seepage (OS). When these terms are summed over cells within each upland subbasin (Variable-Recharge zone), the zonal sums WAFRZ(i), REJZ(i), and OSZ(i) are generated for each upland zone i, i = 1,2,...NZ, (NZ is the total number of subbasins) as follows:

$$\mathrm{WAFRZ(i)} = \omega(\mathrm{i}) \sum_{u} \mathrm{Rwa}, \tag{4a}$$

$$\mathrm{REJZ(i)} = \sum_{u} \mathrm{REJ}\big|_{H_a \geq H_s} + \sum_{u} \mathrm{REJ}\big|_{H'_s < H_a < H_s}, \tag{4b}$$

$$\mathrm{OSZ(i)} = \sum_{u} \mathrm{OS}. \tag{4c}$$

The factor $\omega(i)$ $(0 \leq \omega(i) \leq 1)$ in equation 4a allows the modeler to modify the calculated rate of WAFR for each zone if the rate of WAFR is postulated to vary spatially and/or for sensitivity analysis. The ω factor for each zone i is read in as part of the input data and applied to each of the cells in zone i. The summations are carried out over all upland cells (u) within zone i, and Rwa, REJ, H_a, H_s, H'_s and OS are as defined in equations 2 and 3.

Surface runoff is the sum of rejected recharge and outward seepage, direct recharge is the flow rate of WAFR minus rejected recharge, and net recharge is the flow rate of WAFR minus surface runoff. The surface runoff (SRZ(i)), direct recharge (DRZ(i)), and net recharge (NRZ(i)) for upland zone i are defined as:

$$SRZ(i) = REJZ(i) + OSZ(i), \quad (4d)$$

$$DRZ(i) = WAFRZ(i) - REJZ(i), \quad (4e)$$

$$NRZ(i) = WAFRZ(i) - SRZ(i). \quad (4f)$$

In some locations, part of the surface runoff from an upland basin may be unavailable to recharge the adjacent valley fill because it is diverted; for example, it could be intercepted by storm drains that discharge to surface water. Consequently, the amount of surface runoff that is available to recharge the valley could be less than the amount indicated by equation 4d. The available surface runoff (ASRZ(i)) to the valley from zone i, for some estimated proportion ρ(i), $(0 \le \rho(i) \le 1)$ is denoted by

$$ASRZ(i) = \rho(i)\, SRZ(i). \quad (4g)$$

If ε(i), $(0 \le \varepsilon(i) \le 1)$ is the estimated proportion of available surface runoff that becomes channeled runoff in zone i, then the channeled-runoff (ACRZ(i)) and unchanneled-runoff (AURZ(i)) available to recharge the valley from zone i are

$$ACRZ(i) = \varepsilon(i)\, ASRZ(i), \text{ and} \quad (4h)$$

$$AURZ(i) = (1-\varepsilon(i))\, ASRZ(i). \quad (4i)$$

The proportion terms ω, ρ, and ε in equations 4a, 4g, 4h and 4i are part of the V-R Package input as discussed in the “Input” section for the Variable-Recharge Package.

Entire Upland Area Modeled

The zonal values explained above when summed over all upland zones, constitute the upland water budget for the entire model. Budget values calculated by the V-R Package are illustrated in figure 5, further on, and are defined as follows.

Total WAFR flow rate, $$TWAFR = \sum_i WAFRZ(i) \quad (4j)$$

Total Rejected Recharge, $$TREJ = \sum_i REJZ(i) \quad (4k)$$

Total Outward Seepage, $$TOS = \sum_i OSZ(i) \quad (4l)$$

Total Surface Runoff, $$TSR = TREJ + TOS = \sum_i SRZ(i) \quad (4m)$$

Total Direct Recharge, $$TDR = \sum_i DRZ(i), \quad (4n)$$

Total Net Recharge, $$TNR = TDR - TOS = \sum_i NRZ(i) \quad (4o)$$

Total Available Surface Runoff, $$TASR = \sum_i ASRZ(i) \quad (4p)$$

Total Available Channeled Runoff, $$TACR = \sum_i ACRZ(i) \text{ and} \quad (4q)$$

Total Available Unchanneled Runoff, $$TAUR = \sum_i AURZ(i), \quad (4r)$$

where $\sum_i$ denotes summation over all uplands zones i, i = 1, 2,.....NZ.

Upland Contribution to Valley Recharge

The WAFR applied to the uplands eventually recharges the valley fill in three forms: (1) subsurface flow, (2) recharge from unchanneled runoff, and (3) recharge from channeled runoff. The budget terms that pertain to these sources of recharge are illustrated in figure 5, further on, and are defined as follows.

Subsurface flow, that is the total lateral ground-water flow (*TLF*) from the uplands to the valley, at the valley wall, between upland and valley cells, is

$$TLF = TNR + \sum_U (St + Q) \quad (4s)$$

where St represents upland flow in or out of storage and Q represents any other additional upland sources and sinks, and $\sum_U$ denotes summation over all upland cells . The total lateral flow, under steady-state conditions, is equivalent to the total net recharge (TNR) if no upland sources or sinks are present.

The amount of available channeled and unchanneled runoff that actually recharges the valley depends on (1) the relation between aquifer head and stream-surface elevation in cells containing streams, and (2) the relation between aquifer head and land-surface elevation in cells designated to receive unchanneled runoff. The total channeled recharge (TCR) and total unchanneled recharge (TUR) are defined as

$$TCR = \sum_{i} \delta(i)ACRZ(i), \text{ and} \quad (4t)$$

$$TUR = \sum_{i} \gamma(i)AURZ(i) \quad (4u)$$

where $\delta(i)$ ($0 \leq \delta(i) \leq 1$) symbolizes the proportion of total available channeled runoff from zone i that actually recharges the valley from zone i in the form of stream losses, and $\gamma(i)$ ($0 \leq \gamma(i) \leq 1$) symbolizes the proportion of available unchanneled runoff from zone i that recharges valley cells adjacent to the uplands.
The δ and γ factors are neither specified as input nor calculated in the V-R Package, but are included in equations 4t and 4u to emphasize that only a part of the available runoff may recharge the valley. The amount of recharge from these sources will depend on the simulated hydraulic-head distribution in the aquifer relative to the corresponding stream-surface and land-surface elevations. All streamflow that does not become recharge is discharged to the main stream of the entire modeled area, and is calculated in the V-R Package as TSF, where

$$TSF = TACR - TCR. \quad (4v)$$

The total recharge to the valley from all upland sources ($TR_{u\text{-}v}$) is the sum of total lateral flow (eq. 4s), total channeled recharge (eq. 4t), and total unchanneled recharge (eq. 4u); that is

$$TR_{u\text{-}v} = TLF + TCR + TUR. \quad (4w)$$

The terms of equation 4a-4w and how they can be used to analyze the valley recharge components originating in the uplands are discussed in detail in the section “Example Model Output” further on.

Limitations

Some of the conceptual and programming limitations of the V-R package are as follows:

1. The V-R Package code has no provision to transfer flow from the downstream end of a stream explicitly simulated with the V-R Package to a receiving stream that is simulated with the Stream Package.
2. If the ET estimate that was used to calculate WAFR (eq. 1) includes ground-water evapotranspiration (gwet), and if gwet is explicitly simulated by the Evapotranspiration Package, gwet will be overestimated, and flow in the aquifer will be underestimated. One way to minimize this potential overestimation of gwet would be to include code in MODFLOW to calculate gwet at each iteration, then convert gwet to an average gwet rate over the model area, and subtract this average rate from the WAFR rate.
3. Channeled and unchanneled upland surface runoff calculated by the V-R Package is instantaneously applied to the valley, that is, the travel time of surface-water from areas of runoff generation to cells along the valley wall is not accounted for.

Modules

The four Variable-Recharge Package modules (VAR1AL,VAR1RP, VAR1FM, and VAR1BD) are called from the MAIN program (appendix 1). A program listing of the FORTRAN code and a list and description of the variables of each module (subroutine) are given in appendix 5. A narrative of each module is provided by the comment statements C1, C2,.........etc., within the program listings.

Input

The general input information required by the V-R Package is discussed in the earlier section, “Conceptualization and Formulation.” The V-R Package output is extensive and includes zonal and overall model flows for the upland runoff and recharge components and the upland contribution to the valley-fill recharge, as described in equations 4a-4w. Input and output for the example model are given in appendixes. The specific input-data items, numbered from 1 to 12, are listed in the box on page 15, along with the format(s) required for each item when the uplands and valley fill are explicitly simulated and upland surface runoff is distributed to the valley. Input data for the Allocation module (VAR1AL) and all items for the Read and Prepare module (VAR1RP), with exception of the VARR array can be read only once per simulation. The VARR array entries can be changed each stress period, if a simulation has more than one stress period.

The fields used in the input instruction (in box) are defined as follows:

MXVARR--maximum number of VARR records. Equivalently, it is the maximum number of cells receiving WAFR.

MXCHN--maximum number of channels (tributaries) explicitly simulated per upland subbasin.

IVARCB--if positive, is the output unit number on which Variable-Recharge flow will be written. If negative, flow will be printed whenever ICBCFL is set. If zero, Variable-Recharge flow will not be printed or recorded.

NZ--number of upland subbasins (zones).

NUMCH--number of cells designated to receive upland channeled runoff (explicitly simulated stream cells).

NUMU--number of cells designated to receive upland unchanneled runoff.

IMOD--number of iterations between distribution of upland runoff to specified cells. The value of IMOD can be varied if convergence problems arise but otherwise is set to unity.

IDRY--a factor that governs the disposition of WAFR when a cell goes dry. If IDRY is nonzero, the WAFR is applied to the uppermost active cell beneath the cell that goes dry; if IDRY is zero, recharge to the cells beneath the dry cell is cut off.

RFACT--depth below land surface that defines the recharge conditions described in equations 3a, 3b, and 3c.

SPLM--a minimum flow value that must be exceeded before a constant head seepage cell is converted to an active cell. A seepage cell is made active if the sum of flows between the seepage cell and the five adjacent cells is negative and exceeds SPLM; SPLM is usually zero or some small number (such as $1x10^{-5}$).

RPZ--a one-dimensional array containing a multiplicative factor (between 0 and 1) for each upland zone; RPZ can be used to modify the rate of WAFR of all cells within that zone, as calculated by equation 2. If the rate of WAFR for a particular zone is not to be modified, a value of unity is specified. RPZ is the ω factor in equation 4a.

NCH--a one-dimensional array containing the number of channels (upland tributaries that flow onto the valley floor) explicitly simulated for each upland subbasin (zone).

NCHN--a two-dimensional array containing data pertaining to the number of explicitly simulated stream cells for each subbasin with at least one simulated stream (a nonzero value of NCH). NCHN is the number of model cells containing a stream reach for each simulated stream originating within the zone. A record is read for each zone that contains an explicitly simulated stream; a record is not needed if a zone has no stream (NCH = 0).

NMUCHN--a one-dimensional array containing the number of cells that are to receive the unchanneled upland surface runoff emanating from each upland zone.

FMX--a one-dimensional array containing a multiplicative factor (between 0 and 1) that allows the modeler to modify the simulated surface runoff of each upland zone. For example, if a particular subbasin contains storm drains that collect runoff, the modeler may reduce the surface runoff available to recharge the valley by specifying FMX for that subbasin to be less than unity. If the surface runoff for a particular zone is not to be modified, specify a value of unity. FMX is the ρ factor in equation 4g, which when applied to a zone i's surface runoff (SRZ(i)) produces the available surface runoff (ASRZ(i)) for the zone .

VMX--a one-dimensional array containing an upper bound for the magnitude of unchanneled surface runoff applied to individual cells specified to receive unchanneled runoff from each upland zone. Placement of an upper bound on the applied runoff may be useful in sensitivity analysis, or if the rate of WAFR for a particular stress period is anomalously high. If the VMX value for each zone is set to an arbitrarily high value that is larger than the applied simulated runoff to each cell as calculated by the model, the simulation will be unaffected. Consequentially, in most simulations VMX should be set to a high flow value.

PER--a one-dimensional array containing a multiplicative factor (between 0 and 1), that governs the proportion of upland surface runoff (after application of the FMX factor) to be applied as streamflow to upstream cells of valley channels (tributaries) that are explicitly simulated in the V-R Package. PER is the ε factor of equation 4h, which produces the available channeled runoff (ACRZ(i)) for zone i, when applied to the available surface runoff (ASRZ(i)).

VIZ--a two-dimensional array of data pertaining to cells designated to receive upland surface runoff. The first NUMCH records contain seven elements of data for each explicitly simulated stream cell in which the water in the stream is derived from channeled upland surface runoff. The nth record contains the following information for each cell:

VIZ(1,n)-- the VARR record sequence number (ISEQ)
VIZ(2,n)-- the row number (IROW) of the cell.
VIZ(3,n)-- the column number (ICOL) of the cell.
VIZ(4,n)-- the depth to stream surface (relative to land surface)
VIZ(5,n)-- the depth to top of streambed (relative to land surface).
VIZ(6,n)-- the depth to bottom of streambed (relative to land surface), and
VIZ(7,n) = SBC-- the conductance of the streambed.

The first element of a VIZ record (the VARR record sequence number) can be generated from a FORTRAN program preprocessor termed VIZGEN. The program code and instructions for its use are available as described in the Preface. The next NUMU records contain data for the cells that receive unchanneled upland runoff. Only the first three fields are required for each record; namely ISEQ, IROW, AND ICOL. All other fields (VIZ(4,n) to VIZ(7,n)) are blank.

IZONE-- a two-dimensional array containing a zone number for each active model cell of the top layer. The uplands are divided into a series of subbasins (zones) that are numbered 1,2,...NZ. The zone number of an upland cell designates the subbasin in which the cell is located. The cells in the valley are designated by a zone number of zero.

ITMP-- a flag and a counter
If ITMP < 0, Variable Recharge data (VARR records) from the last stress period will be used.
If ITMP > 0, ITMP will be the number of cells that receive WAFR.

NPRINT-- a flag
If NPRINT is zero, Variable-Recharge input data (VARR records) will be printed in model output.
If NPRINT is nonzero, none of the Variable-Recharge input data (VARR records) will be printed.

VARR-- a two-dimensional array containing data for cells that are to receive WAFR. The data for each cell is contained in a record consisting of five elements. For the nth record:

VARR(1,n)-- the layer number of the cell
VARR(2,n)-- the row number of the cell
VARR(3,n)-- the column number of the cell
VARR(4,n)-- the land surface elevation of the cell
VARR(5,n)-- the WAFR (rate of WAFR times area of model cell).

The VARR records should be ordered by column, within rows, starting with the first model row. The sequence number of a particular VARR record is the value of m in the sequence 1,2,........m.......ITMP. The VARR records can be generated from a FORTRAN program preprocessor termed VARRGEN. The program code and instructions for its use are available as described in the Preface.

Input Instructions

Input to the Variable-Recharge Package version 1 (VAR1) is read from the unit specified in IUNIT(21) of the Basic Package Dimension of input arrays are given in parenthesis :

```
(FOR EACH SIMULATION)
                                  VAR1AL (Allocation Module)

1. Data:  MXVARR  MXCHN   IVARCB     NZ    NUMCH     NUMU    IMOD    IDRY     RFACT    SPLM
   Format  I5      I5       I5       I5     I5        I5      I5      I5      F10.0    E10.0

                              VAR1RP (Read and Prepare Module)
2. DATA:   RPZ (NZ)
   Format  16F5.0

3. DATA:   NCH(NZ)
   FORMAT  16I5

4. DATA:   NCHN(NZ,MXCNN)
   FORMAT  16F5.0

5. DATA:   NMUCHN(NZ)
   FORMAT  16I5

6. DATA:   FMX(NZ)
   FORMAT  16F5.0

7. DATA:   VMX(NZ)
   FORMAT   8F10.0

8. DATA:   PER(NZ)
   FORMAT  16F5.0

                    Repeat the following record NUMCH times
9. DATA:   VIZ(1,1)   VIZ(2,1)   VIZ(3,1)  VIZ(4,1)    VIZ(5,1)   VIZ(6,1)   VIZ(7,1)
   FORMAT    I10        I10        I10      F10.0       F10.0      F10.0      F10.0
            .          .           .           .           .          .          .
            .          .           .           .           .          .          .

              Repeat the folowing record NUMU times
         DATA:   VIZ(1,1)    VIZ(2,1)    VIZ(3,1
         FORMAT    I10         I10         I10
                   .            .           .
                   .            .           .

            (A total of NUTOT (NUTOT = NUMCH + NUMU) VIZ records are read)

10. DATA:  IZONE(NROW,NCOLS)
    FORMAT     20I4

    (FOR EACH STRESS PERIOD)

11. DATA:   ITMP NPRINT
    FORMAT   10   I10


       Repeat the following record ITMP times (except for negative ITMP)
12. DATA:       VARR1,1   VARR2,1   VARR3,1   VARR4,1   VARR5,1
    FORMAT        I10       I10       I10       F10.0     F10.0
                   .         .         .           .         .
                   .         .         .           .         .
```

Data Requirements when Upland Surface Runoff is not Redistributed

Use of the V-R Package in its simplest form—to simulate areal recharge to the specified cells of a model—requires only data items 1, 11 and 12 (in “Input Instructions”). For simulations in which uplands are not explicitly simulated or in which the uplands are explicitly simulated, but upland surface runoff is not distributed to the valley fill, the number of upland zones (NZ) in data item 1 is set to zero. In addition, MXCHN, NUMCH, and NUMU of data item 1 are set to zero, and the arrays: RPZ, NCH, NCHN, NMUCHN, FMX, VMZ, PER, VIZ and IZONE (data items 2-10) are not required. Required items are the number of cells receiving WAFR (ITMP), the print flag (NPRINT) of data item 11, and the ITMP-VARR records for each stress period of data item 12, as described above.

Example Model

This section presents a steady-state example model of an idealized valley-fill aquifer in which (1) the uplands are explicitly simulated, (2) recharge is simulated by the V-R Package, and (3) channeled and unchanneled runoff generated in the uplands are distributed to the valley. This section illustrates (1) how the V-R Package functions in its entirety, (2) how input data are developed, and (3) what kinds of hydrologic information can be derived from model application. The idealized valley-fill aquifer is depicted in figure 2. The valley is bounded on the east and west by uplands, and a main stream runs north-south through the center of the valley. The western uplands are divided into five subbasins (zones), whereas the eastern upland is treated as a single basin. Two tributaries originating in subbasin 2 and one tributary originating in subbasin 4 flow onto the valley floor and to the main stream. The model represents this aquifer system as a single unconfined layer, discretized as shown in figure 3. The thickness of the till and bedrock in the eastern uplands ranges from 90 to 100 ft, and that in the western uplands ranges from 60 to 100 ft. The thickness of the valley fill is 75 ft. The hydraulic conductivity of the uplands and the valley fill are taken to be 0.25 and 100 ft/d, respectively. The boundary conditions consist of the water table at the top and zero-flow boundaries along (1) the eastern and western edges of the model, which coincide with upland topographic divides, (2) the northern and southern edges of the model, which parallel ground-water flow lines, and (3) the bottom of the aquifer (bedrock). The model contains 20 rows and 19 columns. Model-grid spacing along columns is a uniform 400 feet, whereas spacing along rows is unequal, ranging from 1,000 feet at the west and east edges of the uplands to 50 feet in the center of the valley. The values of the V-R zone array for the western uplands (zones 1, 2, 3, 4, and 5) indicate the upland subbasin (fig. 3) in which any particular model cell resides. All cells of the eastern uplands have a zone number of 6, and cells within the valley fill have a zone number of zero. Cells containing the main stream, are indicated, as are cells in the valley that are designated to receive channeled and/or unchanneled runoff from the adjoining uplands. The cells that receive channeled runoff represent three tributaries that are explicitly simulated with the V-R Package. The streambed leakance of all streams is 1 (ft/d)/ft or 0.1157×10^{-4} (ft/s)/ft.

Input Data for MODFLOW

Input data for the sample model is given in appendixes 2 and 3. Appendix 2 contains input data for the Basic, Block-Centered Flow (BCF), River, Strongly-Implicit (SIP), and Output-Control Packages and appendix 3 contains the input data for the V-R Package. With the exception of the V-R Package, documentation of the packages and their input data is given in McDonald and Harbaugh (1988).

Basic Package

The input data for the Basic Package are given in lines 1-68 of appendix 2. Line 3 contains the record that designates the number of model layers (1), rows (20), columns (19), number of stress periods (1) and the unit-of-time flag (1), which indicates that the model time is in seconds. The IUNIT array (line 4) indicates which MODFLOW Packages are to be used in a simulation; the V-R Package is invoked by inserting a nonzero Fortran unit number (unit 20) in the 21st element of the IUNIT array. The V-R Package data is read from this unit number. Line 5 indicates that the starting heads are not to be saved. All elements of the IBOUND array (lines 7-26) are positive, therefore all model cells are active. The starting-head array (lines 29-67) in this example is the land surface (fig. 2); consequently, when the starting heads are compared with the land surface at the first iteration (see comment C6A of Subroutine VAR1FM), condition 3 (eq. 3c) will be satisfied for all cells receiving WAFR, and all these cells may convert to constant-head seepage cells. To avoid this, all starting heads are multiplied by a factor (0.999999) as indicated in the control record for starting heads (line 28) so that the starting heads will be slightly below land surface. Line 68 indicates that the length of the simulation stress period (PERLEN) is 86,400 seconds, that only one time step is used (NSTP = 1), and that the time-step multiplier (TSMULT) is 1.

Block-Centered Flow Package (BCF)

The input data for the BCF Package are given in lines 80-168 of appendix 2. The values in line 80 indicate that the simulation is steady state and that cell-by-cell flows are to be recorded on FORTRAN unit 35. Line 81 indicates that the LAYCON value for the single model layer is 1, which indicates that the layer is unconfined. Line 82 indicates that the system is isotropic, in that the ratio of hydraulic conductivity along model rows to hydraulic conductivity along model columns is unity. Lines 84-86 indicate the model-grid spacing in feet, lines 88-127 give the horizontal hydraulic conductivity in feet per second, and lines 129-168 give the model layer's, bottom altitude which was obtained by subtracting 100 ft from the upland land-surface elevation and 75 ft from the valley-fill land-surface elevation (fig. 2).

River Package

The River Package input data for the 20 stream reaches along column 10 (figure 3) are shown in lines 180-201. The altitude of the stream surface and of the top of the streambed is 765 and 760 ft, respectively, in all reaches. Vertical conductance of the streambed is 0.09 ft^2/s, which is equivalent (1) to a streambed thickness of 1 ft, (2) a streambed vertical hydraulic conductivity of 1 ft/d (0.11574×10^{-4} ft/s), (3) a stream width of 19.4 ft, and (4) a stream length of 400 ft (see eq. 63a of McDonald and Harbaugh, 1988).

Strongly-Implicit Package (SIP)

The SIP Package input data in lines 212 and 213 indicate that the maximum number of iterations allowed in solving the finite-difference equations is 250 and that five SIP iteration parameters are to be used. The acceleration parameter and initial seed for the five SIP parameters are 0.8 and 0.04, and the closure criterion for determining when a solution for head has been achieved is 0.0001 ft.

Output-Control Package

The Output-Control Package input data (lines 223-225) indicate that (1) model heads will be saved on Fortran unit 9, (2) the model water budget will be printed, and that (3) cell-by-cell flows will also be saved (on FORTRAN unit 35 as specified on line 80 of the BCF Package input).

Variable-Recharge Package

Input data are required for Subroutine VAR1AL, the module in which the computer storage used by the V-R Package is determined dynamically, and for Subroutine VAR1RP, the module that reads the V-R input data, including information that governs how upland runoff is to be allocated in the simulation. A complete list of the input data required by the V-R Package is given with the input instructions in the earlier sections "Input", and "Input Instructions."

The specific input values for the example model are given in appendix 3. Line 1 of appendix 3 contains the data record for the Allocation module (VAR1AL); the record indicates that (1) 360 model cells are to receive WAFR (MVARR), (2) at least one upland subbasin contains two explicitly simulated tributaries (channels) (MXCHN), (3) flows from the V-R Package are to be recorded on FORTRAN unit 33 (IVARCB), (4) six upland zones (NZ) are used, (5) 12 model cells are to receive channeled runoff (NUMCH); that is, a total of 12 cells are explicitly simulated as stream cells, and (6) 40 cells are to receive unchanneled runoff from the uplands (NUMU). IMOD is set to 1 so that surface runoff will be distributed after each iteration. Because the model has only one layer, the value of IDRY is not used and is set to an arbitrary value of unity. The depth RFACT (df of eq. 3b) to the pseudo land surface (H_s' of eqs. 3a and 3b) that defines the head for full recharge is 1ft. SPLM is an arbitrarily small number (0.1×10^{-6}); if the net flow (OS*) between a constant-head seepage cell and adjacent cells, as calculated by equation 3d, changes from positive to negative and its absolute value exceeds SPLM, the cell in question is made active.

The values of arrays RPZ (ω of eq. 4a) and NCH for each of the six upland subbasins are given in lines 2 and 3. The value of RPZ for each subbasin is set to unity so that the input WAFR flow rate applied to cells within each subbasin will not be modified. The values of NCH indicate that two tributary streams within upland subbasin 2 and one within subbasin 4 will be explicitly simulated, whereas subbasins 1, 3, 5, and 6 have no tributaries to be simulated. The values of the NCHN array are given in lines 4 and 5; line 4 indicates that each of the two explicitly simulated tributaries in upland zone 2 (figs. 2 and 3) crosses four model cells, and line 5 indicates that the single tributary in upland zone 4 also crosses four model cells. The sum of the values in the NCHN array (in this case 12) should equal the value of NUMCH. Line 6 indicates the number of cells receiving unchanneled runoff (the NMUCHN array) from each of the six upland subbasins, and lines 7, 8 and 9 indicate the values of FMX (ρ of eq. 4g), VMX and PER (ε of eq. 4h), respectively. Given that the values of FMX are unity for each subbasin, the simulated surface runoff in each zone will not be modified. Unrealistically high unchanneled-runoff values are not expected for this model, therefore each of the VMX-array values are set to an extremely large flow, arbitrarily chosen to be 5 ft^3/s in this example. The VMX values will have no effect on the simulation because no simulated unchanneled runoff that is applied to a cell will exceed this value. The values specified for the PER array for zones 1, 3, 5, and 6 indicate that none of the surface runoff in these zones is to be treated as channeled runoff, whereas those for zones 2 and 4 specify that 90 and 95 percent, respectively of the simulated upland surface-runoff is to be treated as channeled runoff and will determine the streamflow at the upstream valley cell of each of the three explicitly simulated streams.

Lines 10 through 21 contain the 12 (NUMCH) records (VIZ array values) for the explicitly simulated stream cells. For example, the first record indicates that a stream resides in the model cell in row 5, column 6. The value of 78 (VARR array sequence-number) indicates that the land-surface elevation of the cell (775 ft) can be found in the 78th VARR record (line 160). The 4th, 5th and 6th fields of line 10 indicate that the depth to the top of the stream surface, streambed, and stream bottom are 2, 3, and 4 ft, respectively; thus the corresponding elevations are 773, 772, and 771 ft, respectively. The streambed conductance (0.03 ft^2/s) is given in the 7th field. Lines 10 through 21 contain all the information required to simulate the flow interchange between the streams and the valley fill, except for the streamflow in the upstream cell of each stream. This information is generated in the V-R Package, which divides the available channeled runoff from each subbasin by the number of simulated streams emanating from the subbasin and applying the result to the upstream cell of each stream. The stream reach in row 5, column 6, is the upstream cell, at the valley wall, of one of the two streams originating in upland subbasin 2 (figs. 2 and 3). The streamflow applied to the upstream reach of this stream, according to the PER array value for zone 2 (line 9) will be 45 percent (90 divided by 2 streams) of the upland surface runoff simulated for upland subbasin 2.

Lines 22 through 61 contain the 40 records that give information (location and land-surface elevation) for the 40 model cells designated to receive unchanneled surface runoff (fig. 3). For example, the record on line 23 indicates that the 24th VARR record (line 106) contains the land-surface elevation (775 ft) of the model cell located at row 2, column 6.

Lines 62 through 81 contain the IZONE array showing the model cells corresponding to the six upland subbasins (zones 1-6) and the valley fill (zone 0) (figs. 2 and 3).

The VARR array is specified for each stress period. The first record (line 82) indicates that there are 360 VARR records in the stress period and that the records are not to be printed in the model output. The value of 360 is derived from the 380 model cells, 20 rows x 19 columns minus the 20 cells to which WAFR was not applied, —those containing a river reach (as simulated by the River Package). Each VARR record contains the layer, row, and column of each cell that receives WAFR, the land-surface elevation of the cell, and the value of the flow rate of WAFR. For example, the record on line 150 indicates that the model cell in layer 1, row 4, and column 15 has a land-surface elevation of 797.73 ft and a WAFR flow rate of 0.007927 ft^3/s. The flow rate was calculated according to equation 2, by multiplying the area of the cell (300 ft x 400 ft) by a WAFR rate of 25 in/yr (after conversion to feet per second).

Example Model Output

The printed output for the example model is given in appendix 4. Information regarding computer storage used by the V-R Package and other input data read by the Allocation module are given in lines 36-49. Next come several input data arrays or values printed from other MODFLOW packages (boundary, initial heads, column to row anisotropy, grid spacing, hydraulic conductivity, bottom elevation of layer, SIP parameters and river cells) that together occupy lines 51 through 387. The V-R Package input-data arrays (RPZ, NCH, NCHN, NMUCHN, NCHN, NMUCHN, FMX, VMX, and PER, see section "Input Instructions") read in the "Read and Prepare" module are then printed (lines 393-406), as are the VIZ array values for cells receiving channeled runoff (lines 412-423) and for cells receiving unchanneled runoff (lines 429-468). Lines 475 through 494 contain the IZONE array. Line 498 contains the number of cells receiving WAFR for the stress period. Because NPRINT was nonzero, the 360 VARR records (appendix 3) are not printed here. The sum of the WAFR rates (eq. 4a) applied to the 360 upland cells and valley cells and their areas prior to execution of the Formulation module (VAR1FM) are printed (lines 501, 504, and 507).

Lines 579 through 880 give model output pertaining to the V-R Package budget, most of which is calculated in Subroutine VAR1BD after convergence is achieved. This part of the output will be printed only if the budget print-flag, IBUDF, for a particular time step as specified in the Output-Control Package, is nonzero. Lines 586 and 588 give the total area of active cells and the corresponding total rates of WAFR for the uplands (eq. 4a) and for the valley. These values are the same as in lines 504 and 507 because no cells "dried up" during the simulation. Lines 596 through 601 contain rates of rejected recharge (eq. 4b), outward seepage (eq. 4c), surface runoff (eq. 4d), available surface runoff (eq. 4g), and the channeled (eq.4h) and unchanneled (eq. 4i) components of available surface runoff for each of the six upland subbasins. The number of valley cells receiving unchanneled runoff from each subbasin is also given. Line 603 gives the totals of the above values for the entire model. Thus, of the total WAFR rate (3.54 ft^3/s) applied to the uplands, 2.90 ft^3/s (0.66 + 2.24) was rejected (eq. 4k); this, together with about 0.08 ft^3/s of outward seepage (eq. 4l), resulted in 2.97 ft^3/s of upland surface runoff (eq.4m). All values of the FMX array are unity; hence, all of the surface runoff in each zone is available (eq. 4g). The values of the PER array for zones 2 and 4 are 90 and 95 percent, respectively; hence, 0.48 and 0.51 ft^3/s of the surface runoff in these zones is channeled runoff (eq. 4h) and the remainder (0.05 and 0.03 ft^3/s) is unchanneled runoff (eq. 4i), as shown in lines 597 and 599. The PER values for zones 1, 3, 5 and 6 are all zero; hence, surface runoff in these zones is entirely unchanneled. The values printed in this section (lines 596-603) are calculated in subroutine VAR1FM from heads prevailing in the iteration immediately prior to convergence. Consequently, these zonal budget values may differ slightly from corresponding budget terms that follow.

The output under the heading RECHARGE SUMMARY (lines 607-616) contains the area of active cells, the total rate of WAFR, and the simulated direct recharge (eq. 4e) and net recharge (eq. 4f) in each upland subbasin. For example, the total rate of WAFR in zone 6 is 1.77 ft^3/s (line 616). The rejected recharge (line 601) is 1.46 ft^3/s (0.19 + 1.27 ft^3/s); hence, the direct recharge (line 616) is 0.31 ft^3/s. Outward seepage is negligible (0.004 ft^3/s, line 601); hence, net recharge to zone 6 is also 0.31 ft^3/s. Recharge rates are commonly given in units of in/yr; therefore, the simulated direct and net recharge are converted to in/yr for purposes of comparison. This calculation is valid only if model distance units are in feet.

The output under the heading DISTRIBUTION OF UPLAND WAFR (lines 626-657) is a reformulation of the components of WAFR and how the WAFR is distributed for the entire model. This information can be used to summarize the upland water budget, as illustrated in figure 5A. Thus, the simulated water levels in the uplands, and their relation to land surface, is such that, of the 3.54 ft^3/s of applied WAFR (eq. 4j), 2.90 ft^3/s is rejected (eq. 4k) so that a total of 0.65 ft^3/s (line 644) enters the uplands as direct recharge (eq. 4n). Outward seepage (eq. 4l) is

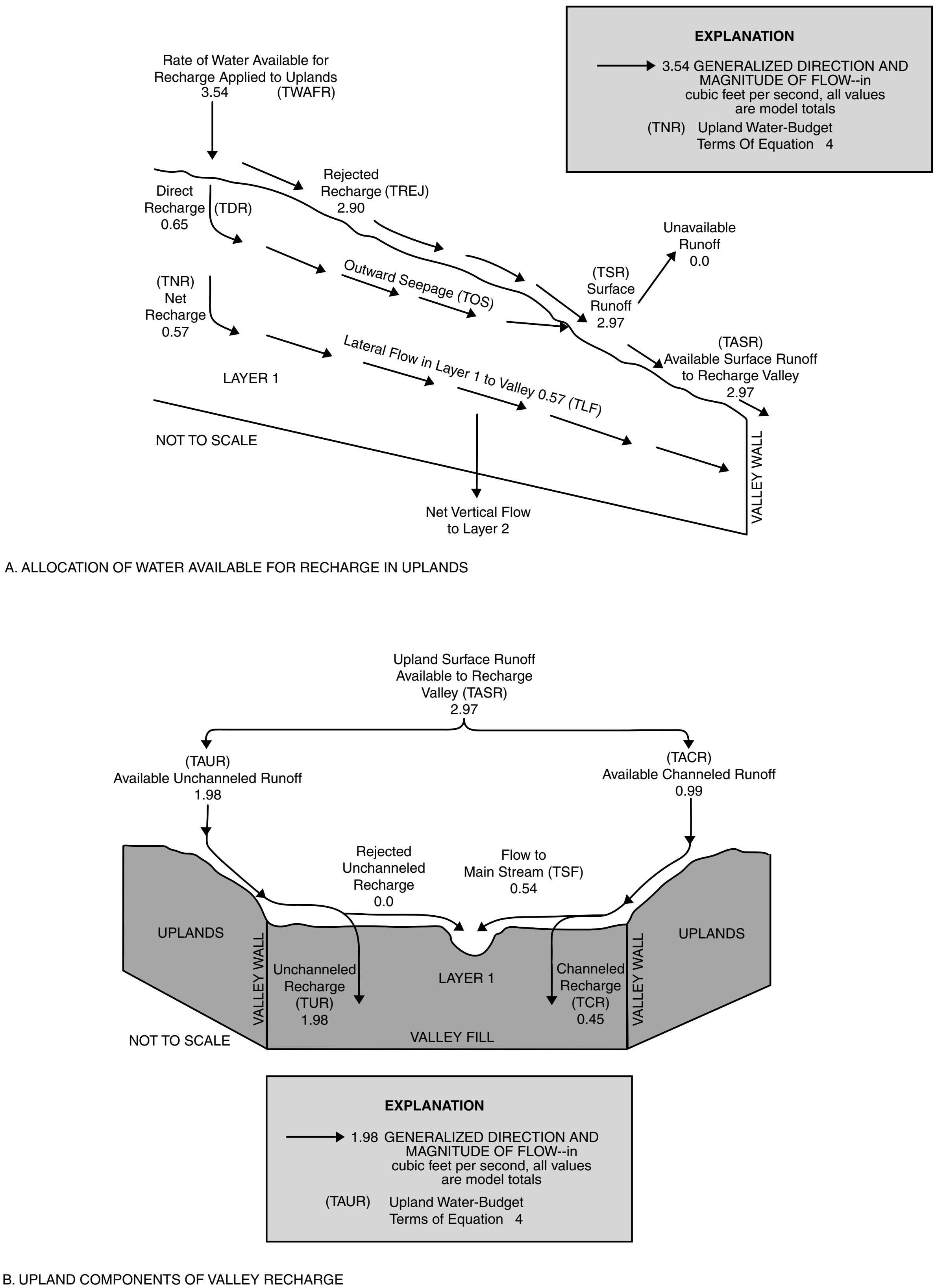


Figure 5. (A) Allocation of water available for recharge applied to uplands in example model. (B) Components of valley recharge from upland sources and direct recharge

0.08 ft^3/s (line 645); thus, the total net recharge to the uplands (eq. 4o) is 0.57 ft^3/s (line 647), which moves to the valley in the form of subsurface flow. The remainder of the applied WAFR, 2.97 ft^3/s, becomes surface runoff (line 650). The total surface runoff can also be obtained through equation 4m; that is, by summing the total rejected recharge (line 637) and outward seepage (line 639). Because all elements of the FMX array were specified to be unity (line 7 of appendix 3), all of the surface runoff (line 653) of 2.97 ft^3/s (eq. 4p) is available to recharge the valley (fig. 5A), either as channeled or unchanneled runoff.

A summary of the distribution of the WAFR applied to the valley in the example model is presented under the heading DISTRIBUTION OF VALLEY WAFR (lines 665-678). Because no recharge is rejected in the valley (line 675), all of the applied WAFR of 0.55 ft^3/s recharges the valley fill. The distribution of the channeled component of surface runoff to the valley is given in lines 691 through 731, whereas the distribution of the unchanneled component is given in lines 739-807. The following two sections describe recharge from these components.

Recharge From Channeled Runoff

Lines 702 through 704 list (1) the upland subbasin (zone) from which each simulated tributary stream channel originates, (2) the simulated streamflow crossing the valley wall into the upstream cell in each explicitly simulated stream, (3) the streamflow at the downstream cell, and (4) the gain or loss of flow along the length of the stream. For example, zone 4 generates about 0.53 ft^3/s of available surface runoff, of which 95 percent or 0.51 ft^3/s is channeled runoff (line 599). Only one stream emanates from zone 4; therefore, the entire available channeled runoff is applied as streamflow to the cell at row 15, column 6 (fig. 3). The streamflow remaining in this tributary at row 15, column 9, is 0.35 ft^3/s, which flows into the main stream. Thus, the tributary contributes 0.16 ft^3/s (0.51ft^3/s - 0.35 ft^3/s) to the valley fill. Lines 707 through 711 and figure 5B summarize the fate of the 0.99 ft^3/s of total channeled runoff available to recharge the valley. Altogether, 0.45 ft^3/s recharges the valley fill (eq. 4t) and 0.54 ft^3/s flows to the main stream. Lines 720 through 731 indicate for each of the 12 simulated reaches of the three streams, stream and aquifer heads, streamflows in and out of each cell and flow between stream and aquifer. This output is similar to that generated by the Stream Package (Prudic, 1989). In each stream reach, the head in the aquifer is below the stream-surface elevation (head in reach); thus, all stream reaches are losing water.

Recharge From Unchanneled Runoff

Lines 747 through 799 indicate the following values for each cell designated to receive the unchanneled component of surface runoff (fig. 3): (1) the zone from which the unchanneled runoff originates, (2) cell location, (3) land-surface elevation, (4) simulated head, and (5) rate of recharge. For example, the unchanneled runoff available from zone 3 is about 0.15 ft^3/s (line 598, also line 771). Each of the 8 cells adjacent to zone 3 (lines 763-770) receive 1/8th of this runoff as additional WAFR. All of the simulated heads are below land surface (and below the pseudo land surface); thus, all additional WAFR recharges the cells. In particular, each cell is recharged at a rate of 0.0184 ft^3/s, and $\gamma(3)$ of equation 4u is unity. Also indicated are the total available unchanneled runoff, simulated recharge, and rejected recharge for all cells adjacent to each of the subbasins (the right side of lines 753 through 800). Lines 803 through 807 and figure 5B summarize the allocation of the unchanneled runoff for the entire model. None of the total available unchanneled runoff of 1.98 ft^3/s is rejected; hence, the valley fill receives 1.98 ft^3/s of recharge from this source (eq. 4u).

Lines 817 through 828 indicate the sources of recharge that make up the Variable-Recharge leakage terms in the overall model Volumetric Budget (lines 963-981). Thus, the VAR-RECH LEAKAGE IN (line 966) of 3.63 ft^3/s is the sum of recharge components given in lines 817 through 820, and the VAR-RECH LEAKAGE OUT (line 975) of 0.08 ft^3/s is the sum of discharge components given in lines 824 through 826. The total recharge of 3.0 ft^3/s to the valley from upland sources (eq. 4w and fig. 5) consists of (1) lateral subsurface flow from the uplands (0.65 - 0.08 = 0.57 ft^3/s), (2) recharge from unchanneled upland sources (1.98 ft^3/s), and (3) recharge from channeled upland sources (0.45 ft^3/s). Direct recharge to the valley is 0.55 ft^3/s (line 678); thus, the total simulated recharge to the valley is 3.55 ft^3/s, of which 85 percent originates in the uplands.

Table 1. Variable-Recharge Package water-budget components for example model when upland surface runoff is applied, or not applied, to valley fill.

[NZ, number of upland subbasins. A dash denotes entry is unavailable or is not applicable]

Component	Flow rate. in cubic feet per second	
	Applied to valley (NZ = 6)	Not applied (NZ = 0)
WAFR (total)	4.096	4.096
MODEL RECHARGE		
Direct upland recharge	0.65*	---
Valley recharge from unchanneled runoff	1.98*	---
Valley recharge from channeled runoff	0.45*	---
Direct valley recharge	0.55*	---
Variable-Recharge Leakage -- (In)	3.63	1.22
MODEL DISCHARGE		
River Leakage	3.56	1.14
Variable-Recharge Leakage --(Out)	0.08	0.08

* Denotes flow components that are summed to obtain Variable-Recharge Leakage-In

The MBOUND array is printed in lines 850 through 869 and shows the status of each topmost model cell at the end of the time step in question. In particular, (1) MBOUND is unity if the cell receives recharge only from WAFR, (2) MBOUND is zero if the cell is inactive or is a conventional constant-head cell, (3) MBOUND = -99 if there is outward seepage from the cell, (4) MBOUND = 77 if the cell receives unchanneled runoff, (5) MBOUND = 88 if the cell receives channeled runoff, and (6) MBOUND = 66 if the cell receives channeled and unchanneled runoff. Line 876 indicates the total number of seepage cells in the MBOUND array and line 878 gives the number of seepage cells (36) and the percentage of the active upland area in which seepage occurred (18.6 percent). Line 880 contains the corresponding results for the valley. As shown in the MBOUND array and figure 3, the upland regions in which outward seepage occurs coincide with topographically low areas (fig. 2).

In addition to the printed output, the recharge to each cell or discharge from each cell of the uppermost cells can be recorded on unit IVARCB, if cell-by-cell flow output has been specified for the V-R Package (that is, if the flag IVARCB of VAR1AL is greater than zero and the flag ICBCFL in Output Control for the time step is nonzero).

Effect of Upland Surface Runoff on Heads in the Valley

As discussed in the earlier section “Data Requirements when Upland Surface Runoff is not Redistributed,” the V-R Package can be used to simulate recharge to an aquifer without the distribution of surface runoff. The example model was run a second time with the uplands and valley fill explicitly simulated but with NZ = 0, to demonstrate the use of the V-R Package in this manner and to show the effects of neglecting recharge from upland sources. When a model is run with NZ = 0, WAFR is applied to the specified active cells, and the criteria for recharge, rejected recharge, and seepage (eq. 3) still apply. Where simulated water level is below land surface, recharge occurs; but if, WAFR is rejected, or if outward seepage occurs, the resulting surface runoff is not distributed to other parts of the model.

When upland surface runoff of the example model was not distributed to the valley, simulated heads in the valley were 1 to 3 ft lower than when upland runoff was distributed to the valley. The largest differences were in cells along the valley wall, which previously received unchanneled runoff, and in cells along stream reaches which previously received channeled runoff (fig. 3). Except for upland cells adjacent to the valley wall, upland heads were about the same for both models and differed by a few hundredths of a foot, at most. As shown in table 1, the total recharge to the model when upland runoff was distributed to the valley is 3.63 ft^3/s. This value is the sum of direct recharge to the uplands (0.65 ft^3/s), direct recharge to the valley (0.55 ft^3/s), recharge from unchanneled runoff (1.98 ft^3/s), and recharge from channeled runoff (0.45 ft^3/s). The total recharge when upland runoff was not distributed is 1.22 ft^3/s or 2.4 ft^3/s less than when runoff was distributed. Thus, relative to the model in which upland runoff was applied to the valley, simulated valley heads were generally lower and discharge to the river was decreased by 2.4 ft^3/s.

The V-R Package does not differentiate between uplands and valley cells when NZ = 0; therefore, direct-recharge components to the uplands and valley are unavailable in the model output. The "Leakage -- In" term of 1.22 ft^3/s is nearly the same as the sum of the direct recharge to uplands and valley in the distributed model, indicating that direct recharge was virtually the same in both models

REFERENCES CITED

Babcock, H.M., and Cushing, E.M., 1942, Recharge to groundwater from floods in a typical desert wash, Pinal County, Arizona: Transactions of the American Geophysical Union, v. 23, p. 49-55.

Breen, K.J., Kontis, A.L., Rowe, G.L. and Haefner, R.J., 1995, Simulated ground-water flow and sources of water in the Killbuck Creek Valley near Wooster, Wayne County, Ohio: U.S. Geological Survey Water-Resources Investigations Report 94-4131, 104 p.

Dunne, T., and Black, R.D., 1970, Partial area contributions to storm runoff in a small New England watershed: Water Resources Research, v. 6, no. 5, p. 1296-1311.

Goode, D.J., and Appel, C.A., 1992, Finite-difference interblock transmissivity for unconfined aquifers and for aquifers having smoothly varying transmissivity: U.S. Geological Survey Water-Resources Investigations Report 92-4124, 79 p.

Harbaugh, A.W., 1992, A generalized finite-difference formulation for the U.S. Geological Survey modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 91-494, 60 p.

Hill, M.C., 1990, Preconditioned conjugate-gradient 2 (PCG2), a computer program for solving ground-water flow equations: U.S. Geological Survey Water Resources Investigations Report 90-4048, 43 p.

Hsieh, P.A., and Freckleton, J.R., 1993, Documentation of a computer program to simulate horizontal-flow barriers using the U.S. Geological Survey's modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 92-477, 32 p.

Kontis, A.L., 1999, Modeling ground-water flow in the Rockaway River Valley, *in* Dysart, J.E. and Rheaume, S.J., Induced infiltration from the Rockaway River and water chemistry in a stratified-drift aquifer at Dover, New Jersey: U.S. Geological Survey Water-Resources Investigations Report 96-4068, 112 p.

Kontis, A.L., Randall, A.D., and Mazzaferro, D.L., (in press). Regional hydrology and simulation of flow of stratified-drift aquifers in the glaciated northeastern United States, U.S. Geological Survey Professional Paper 1415-C.

Leake, S.A., and Prudic, D.E., 1988, Documentation of a computer program to simulate aquifer-system compaction using the modular finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A2, 68 p.

Lyford, F.P., 1986, Northeast glacial regional aquifer-system study, in Sun, R.J., ed., Regional Aquifer-System Analysis Program of the U.S. Geological survey--summary of projects, 1978-84: U.S. Geological Survey Circular 1002, p 162-167.

Lyford, F.P., and Cohen, A.J., 1988, Estimation of water-available-for-recharge to sand and gravel aquifers in the glaciated Northeastern United States, *in* Randall, A.D., and Johnson, A.I.,(eds.), Regional Aquifer Systems of the United States, Northeast Glacial Aquifers: American Water Resources Association Monograph series, no. 11, p.37-61.

McDonald, M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A1.1v.

McDonald, M.G., Harbaugh, A.W., Orr, B.R., and Ackerman, D.J., 1992, A method of converting no-flow cells to variable-head cells for the U.S. Geological Survey modular finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 91-536, 99 p.

Morrissey, J.D., Randall, A.D., and Williams, J.H., 1988, Upland runoff as a major source of recharge to stratified drift in the glaciated Northeast, *in* Randall, A.D., and Johnson, A.I., eds., Regional Aquifer Systems of the United States, Northeast Glacial Aquifers: American Water Resources Association Monograph Series, no. 11, p. 17-36.

Potter, S.T., and Gburek, W.J., 1987, Seepage face simulation using PLASM: Ground Water, v. 25, no. 6, p. 722-732.

Prudic, P.E., 1989, Documentation of a computer program to simulate stream-aquifer relations using a modular, finite difference, ground-water flow model: U.S. Geological Survey Open-File Report 88-729, 113 p.

Randall, A.D., Francis, R.M., Frimpter, M.H., and Emery, J.M.,1988, Region 19, Northeastern Appalachians, *in* Back, William, Rosenshein, J.S., and Seaber, P.R., eds. Hydrogeology: Boulder, Colo., Geological Society of America, The Geology of North America, v. 0-2, p. 177-187.

Randall, A.D., and Johnson, I.A., 1988, The northeast glacial aquifers RASA project—an overview of results through 1987, *in* Randall, A.D., and Johnson, A.I., eds., Regional Aquifer Systems of the United States, Northeast Glacial Aquifers: American Water Well Association Monograph Series, no. 11, p. 1-15.

Sun, Ren Jen and Weeks, J.B., 1991, Bibliography of Regional Aquifer-System Analysis Program of the U.S. Geological Survey, 1978-1992: U.S. Geological Survey Circular 1099, 126 p.

Sun, Ren Jen and Johnston, R.B., 1994, Regional Aquifer-System Analysis Program of the U.S. Geological Survey, 1978-1992: U.S. Geological Survey Circular 1099, 126 p.

Sun, Ren Jen, Weeks, J.B., and Grubb, H.F., 1997, Bibliography of Regional Aquifer-System Analysis Program of the U.S. Geological Survey, 1978-96: U.S. Geological Survey Water-Resources Investigations Report 97-4074, 63 p.

Theis, C.V., 1940, The source of water derived from wells--essential factors controlling the response of an aquifer to development: Civil Engineering, v. 10, no. 5, p. 277-280.

Williams, J.H., and Morrissey, D.J., 1996, Recharge of valley-fill aquifers in the glaciated Northeast from upland runoff, *in* Ritchie, J.D. and Rumbaugh, J.O. eds., Subsurface fluid flow (ground-water and vadose zone) modeling: Philadelphia, American Society for Testing and Materials, STP 1288, p. 97-113.

APPENDIXES

1. Program listing for modified MAIN program of MODFLOW
2. Listing of example model input data for Basic, BCF, River, SIP, and Output-Control Packages
3. Listing of example model input data for the Variable-Recharge Package
4. Listing of example model printed output
5. List of program and variables for Variable-Recharge Package for U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW

Subroutine A. Program listing and list of variables for Allocation Module (VAR1AL)
Program listing
List of variables

Subroutine B. Program listing and list of variables for Read and Prepare Module (VAR1RP)
Program listing
List of variables

Subroutine C. Program listing and list of variables for Formulation Module (VAR1FM)
Program listing
List of variables

Subroutine D. Program listing and list of variables for Budget Module (VAR1BD)
Program listing
List of variables

Appendix 1. Program Listing for Modified MAIN Program of MODFLOW

```
C     ******************************************************************
C     MAIN CODE FOR MODULAR MODEL --    9/1/87
C          BY MICHAEL G. MCDONALD AND ARLEN W. HARBAUGH
C-----VERSION 1638 24JUL1987 MAIN1
C-----VERSION 1323 21FEB1992 -- added BCF2, PCG2, STR1, IBS1, CHD1, and
C-----  GFD1 as documented in USGS reports
C-----VERSION 1515 30AUG1993 -- added BCF3 and HFB1 as documented in
C-----  USGS reports
C-----VERSION JAN2000 -- Documented by A.L. Kontis
C-----Modified AUG1999 to incorporate MBOUND array
C-----                INBAS set to unit 5
C     ******************************************************************
C
C        SPECIFICATIONS:
C     ------------------------------------------------------------------
      COMMON X(1000000)
      COMMON /FLWCOM/LAYCON(80)
      COMMON /FLWAVG/LAYAVG(80)
      CHARACTER*4 HEADNG,VBNM
      DIMENSION HEADNG(32),VBNM(4,20),VBVL(4,20),IUNIT(24)
      DOUBLE PRECISION DUMMY
      EQUIVALENCE (DUMMY,X(1))
C     ------------------------------------------------------------------
C
C1------SET SIZE OF X ARRAY. REMEMBER TO REDIMENSION X.
      LENX=1000000
C
C2------ASSIGN BASIC INPUT UNIT AND PRINTER UNIT.
      INBAS=5
      IOUT=6
C
C3------DEFINE PROBLEM__ROWS,COLUMNS,LAYERS,STRESS PERIODS,PACKAGES
      CALL BAS1DF(ISUM,HEADNG,NPER,ITMUNI,TOTIM,NCOL,NROW,NLAY,
     1             NODES,INBAS,IOUT,IUNIT)
C
C4------ALLOCATE SPACE IN "X" ARRAY.
      CALL BAS1AL(ISUM,LENX,LCHNEW,LCHOLD,LCIBOU,LCCR,LCCC,LCCV,
     1              LCHCOF,LCRHS,LCDELR,LCDELC,LCSTRT,LCBUFF,LCIOFL,
     2              INBAS,ISTRT,NCOL,NROW,NLAY,IOUT)
      IF(IUNIT(1).GT.0) CALL BCF3AL(ISUM,LENX,LCSC1,LCHY,
     1     LCBOT,LCTOP,LCSC2,LCTRPY,IUNIT(1),ISS,
     2     NCOL,NROW,NLAY,IOUT,IBCFCB,LCWETD,IWDFLG,LCCVWD,
     3     WETFCT,IWETIT,IHDWET,HDRY,LCRHS,LCBUFF)
      IF(IUNIT(2).GT.0) CALL WEL1AL(ISUM,LENX,LCWELL,MXWELL,NWELLS,
     1                 IUNIT(2),IOUT,IWELCB)
      IF(IUNIT(3).GT.0) CALL DRN1AL(ISUM,LENX,LCDRAI,NDRAIN,MXDRN,
     1                 IUNIT(3),IOUT,IDRNCB)
      IF(IUNIT(8).GT.0) CALL RCH1AL(ISUM,LENX,LCIRCH,LCRECH,NRCHOP,
     1            NCOL,NROW,IUNIT(8),IOUT,IRCHCB)
      IF(IUNIT(5).GT.0) CALL EVT1AL(ISUM,LENX,LCIEVT,LCEVTR,LCEXDP,
     1            LCSURF,NCOL,NROW,NEVTOP,IUNIT(5),IOUT,IEVTCB)
      IF(IUNIT(4).GT.0) CALL RIV1AL(ISUM,LENX,LCRIVR,MXRIVR,NRIVER,
     1            IUNIT(4),IOUT,IRIVCB)
      IF(IUNIT(7).GT.0) CALL GHB1AL(ISUM,LENX,LCBNDS,NBOUND,MXBND,
     1            IUNIT(7),IOUT,IGHBCB)
           IF(IUNIT(13).GT.0) CALL PCG2AL(ISUM,LENX,LCV,LCSS,LCP,LCCD,
     1       LCHCHG,LCLHCH,LCRCHG,LCLRCH,MXITER,ITER1,NCOL,NROW,NLAY,
     2       IUNIT(13),IOUT,NPCOND)
      IF(IUNIT(11).GT.0) CALL SOR1AL(ISUM,LENX,LCA,LCRES,LCHDCG,LCLRCH,
     1          LCIEQP,MXITER,NCOL,NLAY,NSLICE,MBW,IUNIT(11),IOUT)
      IF (IUNIT(19).GT.0) CALL IBS1AL(ISUM,LENX,LCHC,LCSCE,LCSCV,       IBS
     1          LCSUB,NCOL,NROW,NLAY,IIBSCB,IIBSOC,ISS,IUNIT(19),IOUT) IBS
      IF(IUNIT(20).GT.0) CALL CHD1AL(ISUM,LENX,LCCHDS,NCHDS,MXCHD,      CHD
     1          IUNIT(20),IOUT)                                        CHD
      IF(IUNIT(14).GT.0) CALL GFD1AL(ISUM,LENX,LCSC1,LCCDTR,LCCDTC,
     1     LCBOT,LCTOP,LCSC2,IUNIT(14),ISS,NCOL,NROW,NLAY,IOUT,IGFDCB)
      IF(IUNIT(16).GT.0) CALL HFB1AL(ISUM,LENX,LCHFBR,NHFB,IUNIT(16),      *HFB*
```

```
     1           IOUT)                                                      *HFB*
      IF(IUNIT(21).GT.0) CALL VAR1AL(ISUM,LENX,LCVARR,MXVARR,NVARCH,        *VAR*
     1 IUNIT(21),IOUT,MXCHN,IVARCB,LCVIZ,LCIZON,NCOL,NROW,NZ,NUTOT,         *VAR*
     2 LCRPZ,LCFMX,IMOD,LCVMX,LCSUMR,LCSUMD,LCTSUM,LCPER,RFACT,             *VAR*
     3 LCRES,LCNCHN,LCNCH,LCNUCH,LCIUZ,NUMCH,NUMU,IDRY,LCRUP,LCARZ,         *VAR*
     4 LCRIPY,LCRIPN,LCWAFR,LCMBND,SPLM)                                    *VAR*
      IF(IUNIT(18).GT.0) CALL STR1AL(ISUM,LENX,LCSTRM,ICSTRM,MXSTRM,     STR1
     1                NSTREM,IUNIT(18),IOUT,ISTCB1,ISTCB2,NSS,NTRIB,     STR1
     2                 NDIV,ICALC,CONST,LCTBAR,LCTRIB,LCIVAR,LCFGAR)
      IF(IUNIT(9).GT.0) CALL SIP1AL(ISUM,LENX,LCEL,LCFL,LCGL,LCV,
     1          LCHDCG,LCLRCH,LCW,MXITER,NPARM,NCOL,NROW,NLAY,
     2          IUNIT(9),IOUT)
C5------IF THE "X" ARRAY IS NOT BIG ENOUGH THEN STOP.
      IF(ISUM-1.GT.LENX) STOP
C
C6------READ AND PREPARE INFORMATION FOR ENTIRE SIMULATION.
      CALL BAS1RP(X(LCIBOU),X(LCHNEW),X(LCSTRT),X(LCHOLD),
     1       ISTRT,INBAS,HEADNG,NCOL,NROW,NLAY,NODES,VBVL,X(LCIOFL),
     2       IUNIT(12),IHEDFM,IDDNFM,IHEDUN,IDDNUN,IOUT)
      IF(IUNIT(1).GT.0) CALL BCF3RP(X(LCIBOU),X(LCHNEW),X(LCSC1),
     1          X(LCHY),X(LCCR),X(LCCC),X(LCCV),X(LCDELR),
     2     X(LCDELC),X(LCBOT),X(LCTOP),X(LCSC2),X(LCTRPY),IUNIT(1),
     3     ISS,NCOL,NROW,NLAY,NODES,IOUT,X(LCWETD),IWDFLG,X(LCCVWD))
      IF(IUNIT(9).GT.0) CALL SIP1RP(NPARM,MXITER,ACCL,HCLOSE,X(LCW),
     1          IUNIT(9),IPCALC,IPRSIP,IOUT)
C    MODIFICATIONS FROM HILL(1990):
C    01SEPT1090 OMITTED IPCGCD; ADDED NITER
      IF(IUNIT(13).GT.0) CALL PCG2RP(MXITER,ITER1,HCLOSE,RCLOSE,
     1         NPCOND,NBPOL,RELAX,IPRPCG,IUNIT(13),IOUT,MUTPCG,
     2         NITER)
      IF(IUNIT(11).GT.0) CALL SOR1RP(MXITER,ACCL,HCLOSE,IUNIT(11),
     1         IPRSOR,IOUT)
      IF(IUNIT(19).GT.0) CALL IBS1RP(X(LCDELR),X(LCDELC),X(LCHNEW),      IBS
     1      X(LCHC),X(LCSCE),X(LCSCV),X(LCSUB),NCOL,NROW,NLAY,           IBS
     2      NODES,IIBSOC,ISUBFM,ICOMFM,IHCFM,ISUBUN,ICOMUN,IHCUN,        IBS
     3      IUNIT(19),IOUT)                                              IBS
      IF(IUNIT(14).GT.0) CALL GFD1RP(X(LCIBOU),X(LCHNEW),X(LCSC1),
     1          X(LCCDTR),X(LCCDTC),X(LCCR),X(LCCC),X(LCCV),X(LCDELR),
     2          X(LCDELC),X(LCBOT),X(LCTOP),X(LCSC2),
     3          IUNIT(14),ISS,NCOL,NROW,NLAY,NODES,IOUT)
      IF(IUNIT(16).GT.0) CALL HFB1RP(X(LCCR),X(LCCC),X(LCDELR),             HFB
     1         X(LCDELC),X(LCHFBR),IUNIT(16),NCOL,NROW,NLAY,NODES,          HFB
     1         NHFB,IOUT)                                                   HFB
C
C7------SIMULATE EACH STRESS PERIOD.
      DO 300 KPER=1,NPER
      KKPER=KPER
C
C7A-----READ STRESS PERIOD TIMING INFORMATION.
      CALL BAS1ST(NSTP,DELT,TSMULT,PERTIM,KKPER,INBAS,IOUT)
C
C7B-----READ AND PREPARE INFORMATION FOR STRESS PERIOD.
      IF(IUNIT(2).GT.0) CALL WEL1RP(X(LCWELL),NWELLS,MXWELL,IUNIT(2),
     1            IOUT)
      IF(IUNIT(3).GT.0) CALL DRN1RP(X(LCDRAI),NDRAIN,MXDRN,IUNIT(3),
     1                IOUT)
      IF(IUNIT(8).GT.0) CALL RCH1RP(NRCHOP,X(LCIRCH),X(LCRECH),
     1           X(LCDELR),X(LCDELC),NROW,NCOL,IUNIT(8),IOUT)
      IF(IUNIT(5).GT.0) CALL EVT1RP(NEVTOP,X(LCIEVT),X(LCEVTR),
     1           X(LCEXDP),X(LCSURF),X(LCDELR),X(LCDELC),NCOL,NROW,
     1           IUNIT(5),IOUT)
      IF(IUNIT(4).GT.0) CALL RIV1RP(X(LCRIVR),NRIVER,MXRIVR,IUNIT(4),
     1           IOUT)
      IF(IUNIT(7).GT.0) CALL GHB1RP(X(LCBNDS),NBOUND,MXBND,IUNIT(7),
     1             IOUT)
      IF(IUNIT(18).GT.0) CALL STR1RP(X(LCSTRM),X(ICSTRM),NSTREM,         STR1
     1                    MXSTRM,IUNIT(18),IOUT,X(LCTBAR),NDIV,NSS,      STR1
     2                    NTRIB,X(LCIVAR),ICALC,IPTFLG)                  STR1
      IF(IUNIT(20).GT.0) CALL CHD1RP(X(LCCHDS),NCHDS,MXCHD,X(LCIBOU),   CHD
```

```
     1            NCOL,NROW,NLAY,PERLEN,DELT,NSTP,TSMULT,IUNIT(20),IOUT)CHD
      IF(IUNIT(21).GT.0) CALL VAR1RP(X(LCVARR),X(LCVIZ),X(LCIZON),NVARCH   *VAR*
     1,MXVARR,IUNIT(21),IOUT,NCOL,NROW,NZ,KPER,NUTOT,X(LCRPZ),             *VAR*
     2 X(LCFMX),X(LCVMX),X(LCPER),MXCHN,X(LCNCH),X(LCNCHN),X(LCNUCH),SUM   *VAR*
     3RCH,NLAY,X(LCIBOU),X(LCDELC),X(LCDELR),ITMUNI,UCONV,VCONV,AREAU,     *VAR*
     4AREAV,SMURCH,SMVRCH,X(LCIUZ),X(LCMBND),NUMCH,NUMU)                   *VAR*
C
C7C-----SIMULATE EACH TIME STEP.
      DO 200 KSTP=1,NSTP
      KKSTP=KSTP
C
C7C1----CALCULATE TIME STEP LENGTH. SET HOLD=HNEW.
      CALL BAS1AD(DELT,TSMULT,TOTIM,PERTIM,X(LCHNEW),X(LCHOLD),KKSTP,
     1             NCOL,NROW,NLAY)
      IF(IUNIT(20).GT.0) CALL CHD1FM(NCHDS,MXCHD,X(LCCHDS),X(LCIBOU),   CHD
     1          X(LCHNEW),X(LCHOLD),PERLEN,PERTIM,DELT,NCOL,NROW,NLAY)  CHD
      IF(IUNIT(1).GT.0) CALL BCF2AD(X(LCIBOU),X(LCHOLD),X(LCBOT),
     1             X(LCWETD),IWDFLG,ISS,NCOL,NROW,NLAY)
C
C7C2----ITERATIVELY FORMULATE AND SOLVE THE EQUATIONS.
      DO 100 KITER=1,MXITER
      KKITER=KITER
C
C7C2A---FORMULATE THE FINITE DIFFERENCE EQUATIONS.
      CALL BAS1FM(X(LCHCOF),X(LCRHS),NODES)
      IF(KITER.GT.1.AND.IUNIT(21).GT.0) THEN                               *VAR*
      CALL VAR1FM(NVARCH,MXVARR,X(LCVARR),X(LCHNEW),                       *VAR*
     1             X(LCHCOF),X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY,            *VAR*
     2       NZ,X(LCVIZ),X(LCIZON),IOUT,NUTOT,X(LCRPZ),                    *VAR*
     3       X(LCFMX),IMOD,KITER,X(LCVMX),X(LCPER),                        *VAR*
     4       X(LCSUMR),X(LCSUMD),X(LCTSUM),RFACT,X(LCRES)                  *VAR*
     5       ,MXCHN,X(LCNCH),X(LCNCHN),X(LCNUCH),X(LCCR),X(LCCC)           *VAR*
     6       ,X(LCCV),X(LCMBND),IDRY,SPLM)                                 *VAR*
      END IF                                                               *VAR*
      IF(IUNIT(1).GT.0) CALL BCF3FM(X(LCHCOF),X(LCRHS),X(LCHOLD),
     1          X(LCSC1),X(LCHNEW),X(LCIBOU),X(LCCR),X(LCCC),X(LCCV),
     2          X(LCHY),X(LCTRPY),X(LCBOT),X(LCTOP),X(LCSC2),
     3          X(LCDELR),X(LCDELC),DELT,ISS,KKITER,KKSTP,KKPER,NCOL,
     4          NROW,NLAY,IOUT,X(LCWETD),IWDFLG,X(LCCVWD),WETFCT,
     5          IWETIT,IHDWET,HDRY,X(LCBUFF))
      IF(IUNIT(2).GT.0) CALL WEL1FM(NWELLS,MXWELL,X(LCRHS),X(LCWELL),
     1           X(LCIBOU),NCOL,NROW,NLAY)
      IF(IUNIT(3).GT.0) CALL DRN1FM(NDRAIN,MXDRN,X(LCDRAI),X(LCHNEW),
     1         X(LCHCOF),X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY)
      IF(IUNIT(8).GT.0) CALL RCH1FM(NRCHOP,X(LCIRCH),X(LCRECH),
     1            X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY)
      IF(IUNIT(5).GT.0) CALL EVT1FM(NEVTOP,X(LCIEVT),X(LCEVTR),
     1            X(LCEXDP),X(LCSURF),X(LCRHS),X(LCHCOF),X(LCIBOU),
     1            X(LCHNEW),NCOL,NROW,NLAY)
      IF(IUNIT(4).GT.0) CALL RIV1FM(NRIVER,MXRIVR,X(LCRIVR),X(LCHNEW),
     1            X(LCHCOF),X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY)
      IF(IUNIT(7).GT.0) CALL GHB1FM(NBOUND,MXBND,X(LCBNDS),X(LCHCOF),
     1            X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY)
      IF(KITER.EQ.1.AND.IUNIT(21).GT.0) THEN                               *VAR*
      CALL VAR1FM(NVARCH,MXVARR,X(LCVARR),X(LCHNEW),                       *VAR*
     1             X(LCHCOF),X(LCRHS),X(LCIBOU),NCOL,NROW,NLAY,            *VAR*
     2       NZ,X(LCVIZ),X(LCIZON),IOUT,NUTOT,X(LCRPZ),                    *VAR*
     3       X(LCFMX),IMOD,KITER,X(LCVMX),X(LCPER),                        *VAR*
     4       X(LCSUMR),X(LCSUMD),X(LCTSUM),RFACT,X(LCRES)                  *VAR*
     5       ,MXCHN,X(LCNCH),X(LCNCHN),X(LCNUCH),X(LCCR),X(LCCC)           *VAR*
     6       ,X(LCCV),X(LCMBND),IDRY,SPLM)                                 *VAR*
      END IF                                                               *VAR*
      IF(IUNIT(18).GT.0) CALL STR1FM(NSTREM,X(LCSTRM),X(ICSTRM),        STR1
     1                     X(LCHNEW),X(LCHCOF),X(LCRHS),X(LCIBOU),      STR1
     2              MXSTRM,NCOL,NROW,NLAY,IOUT,NSS,X(LCTBAR),           STR1
     3              NTRIB,X(LCTRIB),X(LCIVAR),X(LCFGAR),ICALC,CONST)    STR1
      IF(IUNIT(19).GT.0) CALL IBS1FM(X(LCRHS),X(LCHCOF),X(LCHNEW),      IBS
     1       X(LCHOLD),X(LCHC),X(LCSCE),X(LCSCV),X(LCIBOU),             IBS
     2       NCOL,NROW,NLAY,DELT)                                       IBS
```

```
      IF(IUNIT(14).GT.0) CALL GFD1FM(X(LCHCOF),X(LCRHS),X(LCHOLD),
     1          X(LCSC1),X(LCHNEW),X(LCIBOU),X(LCCR),X(LCCC),X(LCCV),
     2          X(LCCDTR),X(LCCDTC),X(LCBOT),X(LCTOP),X(LCSC2),
     3          DELT,ISS,KKITER,KKSTP,KKPER,NCOL,NROW,NLAY,IOUT)
      IF(IUNIT(16).GT.0) CALL HFB1FM(X(LCHNEW),X(LCCR),X(LCCC),            HFB
     1          X(LCBOT),X(LCTOP),X(LCDELR),X(LCDELC),X(LCHFBR),           HFB
     2          NCOL,NROW,NLAY,NHFB)                                       HFB
C
C7C2B---MAKE ONE CUT AT AN APPROXIMATE SOLUTION.
      IF(IUNIT(9).GT.0) CALL SIP1AP(X(LCHNEW),X(LCIBOU),X(LCCR),X(LCCC),
     1     X(LCCV),X(LCHCOF),X(LCRHS),X(LCEL),X(LCFL),X(LCGL),X(LCV),
     2     X(LCW),X(LCHDCG),X(LCLRCH),NPARM,KKITER,HCLOSE,ACCL,ICNVG,
     3     KKSTP,KKPER,IPCALC,IPRSIP,MXITER,NSTP,NCOL,NROW,NLAY,NODES,
     4     IOUT)
C    MODIFICATIONS FROM HILL(1990):
C    01JULY1990 OMITTED TWO OCCURRENCES OF ICD=0
C    01SEPT1990 OMITTED IPCGCD, STEPL, DELT, IUNIT(15), AND IP
C    01SEPT1991 ADDED 0,IP,SN,SP,SR
      IF(IUNIT(13).GT.0) CALL PCG2AP(X(LCHNEW),X(LCIBOU),X(LCCR),
     1      X(LCCC),X(LCCV),X(LCHCOF),X(LCRHS),X(LCV),X(LCSS),X(LCP),
     2      X(LCCD),X(LCHCHG),X(LCLHCH),X(LCRCHG),X(LCLRCH),KKITER,
     3      NITER,HCLOSE,RCLOSE,ICNVG,KKSTP,KKPER,IPRPCG,MXITER,ITER1,
     4      NPCOND,NBPOL,NSTP,NCOL,NROW,NLAY,NODES,RELAX,IOUT,MUTPCG,
     5      0,IP,SN,SP,SR)
      IF(IUNIT(11).GT.0) CALL SOR1AP(X(LCHNEW),X(LCIBOU),X(LCCR),
     1     X(LCCC),X(LCCV),X(LCHCOF),X(LCRHS),X(LCA),X(LCRES),X(LCIEQP),
     2     X(LCHDCG),X(LCLRCH),KKITER,HCLOSE,ACCL,ICNVG,KKSTP,KKPER,
     3     IPRSOR,MXITER,NSTP,NCOL,NROW,NLAY,NSLICE,MBW,IOUT)
C
C7C2C---IF CONVERGENCE CRITERION HAS BEEN MET STOP ITERATING.
      IF(ICNVG.EQ.1) GO TO 110
  100 CONTINUE
      KITER=MXITER
  110 CONTINUE
C
C7C3----DETERMINE WHICH OUTPUT IS NEEDED.
      CALL BAS1OC(NSTP,KKSTP,ICNVG,X(LCIOFL),NLAY,
     1  IBUDFL,ICBCFL,IHDDFL,IUNIT(12),IOUT)
C
C7C4----CALCULATE BUDGET TERMS. SAVE CELL-BY-CELL FLOW TERMS.
      MSUM=1
           IF(IUNIT(1).GT.0) CALL BCF1BD(VBNM,VBVL,MSUM,X(LCHNEW),
     1     X(LCIBOU),X(LCHOLD),X(LCSC1),X(LCCR),X(LCCC),X(LCCV),
     2     X(LCTOP),X(LCSC2),DELT,ISS,NCOL,NROW,NLAY,KKSTP,KKPER,
     3     IBCFCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(2).GT.0) CALL WEL1BD(NWELLS,MXWELL,VBNM,VBVL,MSUM,
     1     X(LCWELL),X(LCIBOU),DELT,NCOL,NROW,NLAY,KKSTP,KKPER,IWELCB,
     1     ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(3).GT.0) CALL DRN1BD(NDRAIN,MXDRN,VBNM,VBVL,MSUM,
     1     X(LCDRAI),DELT,X(LCHNEW),NCOL,NROW,NLAY,X(LCIBOU),KKSTP,
     2     KKPER,IDRNCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(8).GT.0) CALL RCH1BD(NRCHOP,X(LCIRCH),X(LCRECH),
     1     X(LCIBOU),NROW,NCOL,NLAY,DELT,VBVL,VBNM,MSUM,KKSTP,KKPER,
     2     IRCHCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(5).GT.0) CALL EVT1BD(NEVTOP,X(LCIEVT),X(LCEVTR),
     1     X(LCEXDP),X(LCSURF),X(LCIBOU),X(LCHNEW),NCOL,NROW,NLAY,
     2     DELT,VBVL,VBNM,MSUM,KKSTP,KKPER,IEVTCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(4).GT.0) CALL RIV1BD(NRIVER,MXRIVR,X(LCRIVR),X(LCIBOU),
     1     X(LCHNEW),NCOL,NROW,NLAY,DELT,VBVL,VBNM,MSUM,
     2     KKSTP,KKPER,IRIVCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(7).GT.0) CALL GHB1BD(NBOUND,MXBND,VBNM,VBVL,MSUM,
     1     X(LCBNDS),DELT,X(LCHNEW),NCOL,NROW,NLAY,X(LCIBOU),KKSTP,
     2     KKPER,IGHBCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(18).GT.0) CALL STR1BD(NSTREM,X(LCSTRM),X(ICSTRM),        STR1
     1   X(LCIBOU),MXSTRM,X(LCHNEW),NCOL,NROW,NLAY,DELT,VBVL,VBNM,MSUM, STR1
     2   KKSTP,KKPER,ISTCB1,ISTCB2,ICBCFL,X(LCBUFF),IOUT,NTRIB,NSS,     STR1
     3   X(LCTRIB),X(LCTBAR),X(LCIVAR),X(LCFGAR),ICALC,CONST,IPTFLG)    STR1
      IF(IUNIT(19).GT.0) CALL IBS1BD(X(LCIBOU),X(LCHNEW),X(LCHOLD),     IBS
     1      X(LCHC),X(LCSCE),X(LCSCV),X(LCSUB),X(LCDELR),X(LCDELC),     IBS
```

```
     2      NCOL,NROW,NLAY,DELT,VBVL,VBNM,MSUM,KSTP,KPER,IIBSCB,        IBS
     3      ICBCFL,X(LCBUFF),IOUT)                                      IBS
      IF(IUNIT(14).GT.0) CALL GFD1BD(VBNM,VBVL,MSUM,X(LCHNEW),
     1     X(LCIBOU),X(LCHOLD),X(LCSC1),X(LCCR),X(LCCC),X(LCCV),
     2     X(LCTOP),X(LCSC2),DELT,ISS,NCOL,NROW,NLAY,KKSTP,KKPER,
     3     IGFDCB,ICBCFL,X(LCBUFF),IOUT)
      IF(IUNIT(21).GT.0) CALL VAR1BD(NVARCH,MXVARR,X(LCVARR),X(LCIBOU),    *VAR*
     1     X(LCHNEW),NCOL,NROW,NLAY,DELT,VBVL,VBNM,MSUM,IBUDFL,            *VAR*
     2     KSTP,KPER,IVARCB,ICBCFL,X(LCBUFF),IOUT,X(LCPER),NZ,X(LCVMX),    *VARt*
     3     X(LCFMX),X(LCVIZ),X(LCIZON),NUTOT,X(LCRPZ),X(LCSUMR),X(LCSUMD   *VAR*
     4     ),X(LCTSUM),RFACT,X(LCRES),MXCHN,X(LCNCH),X(LCNCHN),X(LCNUCH)   *VAR*
     5     ,X(LCCR),X(LCCC),X(LCCV),UCONV,VCONV,X(LCDELR),X(LCDELC),       *VAR*
     6     AREAU,AREAV,SMURCH,SMVRCH,IDRY,X(LCRUP),X(LCARZ),X(LCRIPY),     *VAR*
     7     X(LCRIPN),X(LCWAFR),X(LCMBND),SPLM)                             *VAR*
C7C5---PRINT AND OR SAVE HEADS AND DRAWDOWNS. PRINT OVERALL BUDGET.
      CALL BAS1OT(X(LCHNEW),X(LCSTRT),ISTRT,X(LCBUFF),X(LCIOFL),
     1        MSUM,X(LCIBOU),VBNM,VBVL,KKSTP,KKPER,DELT,
     2        PERTIM,TOTIM,ITMUNI,NCOL,NROW,NLAY,ICNVG,
     3     IHDDFL,IBUDFL,IHEDFM,IHEDUN,IDDNFM,IDDNUN,IOUT)
C
C7C5A--PRINT AND OR SAVE SUBSIDENCE, COMPACTION, AND CRITICAL HEAD.
      IF(IUNIT(19).GT.0) CALL IBS1OT(NCOL,NROW,NLAY,PERTIM,TOTIM,KSTP,  IBS
     1      KPER,NSTP,X(LCBUFF),X(LCSUB),X(LCHC),IIBSOC,ISUBFM,ICOMFM,  IBS
     2      IHCFM,ISUBUN,ICOMUN,IHCUN,IUNIT(19),IOUT)                   IBS
C
C7C6----IF ITERATION FAILED TO CONVERGE THEN STOP.
      IF(ICNVG.EQ.0) STOP
  200 CONTINUE
  300 CONTINUE
C
C8------END PROGRAM
```

Appendix 2. Example-model input data for Basic Package, BCF Package, River Package, SIP Package, and Output-Control Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW).

[BCF, block-centered flow; SIP, strongly implicit procedure. Line numbers 1-408 are not part of the input data]

Column Numbers

```
             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

A. Basic Package [input for Basic Package follows column numbers. Input consists of 68 records (lines 1-68). Input is read from FORTRAN unit number 5]

```
  1  SAMPLE OF VARIABLE-RECHARGE PACKAGE INPUT DATA
  2  1 LAYER VALLEY-FILL AQUIFER
  3          1        20        19         1         1
  4  11  0  0 12  0  0  0  0 18  0  0 19  0  0  0  0  0  0  0  0 20
  5          0         0
  6          5         1            (20I4)         3
  7    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  8    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  9    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 10    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 11    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 12    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 13    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 14    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 15    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 16    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 17    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 18    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 19    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 20    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 21    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 22    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 23    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 24    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 25    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 26    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 27        0.0
 28          5   .999999            (10F8.0)         5
 29    900.00  888.07  859.50  826.98  800.00  775.00  773.15  771.84  770.79  769.99
 30    770.79  771.84  773.15  775.00  800.00  826.98  859.50  888.07  900.00
 31    900.00  883.85  855.49  822.97  797.89  775.00  773.15  771.84  770.79  769.99
 32    770.79  771.84  773.15  775.00  799.73  826.44  858.96  887.53  900.00
 33    900.00  872.98  845.16  812.64  792.45  775.00  773.15  771.84  770.79  769.99
 34    770.79  771.84  773.15  775.00  798.95  824.87  857.39  885.96  900.00
 35    770.79  771.84  773.15  775.00  797.73  822.45  854.97  883.54  900.00
 36    900.00  850.48  823.79  791.27  781.21  775.00  773.15  771.84  770.79  769.99
 37    770.79  771.84  773.15  775.00  796.23  819.43  851.95  880.52  900.00
 38    900.00  848.34  821.76  789.24  780.14  775.00  773.15  771.84  770.79  769.99
 39    770.79  771.84  773.15  775.00  794.59  816.15  848.67  877.24  900.00
 40    900.00  854.52  827.63  795.11  783.23  775.00  773.15  771.84  770.79  769.99
 41    770.79  771.84  773.15  775.00  792.99  812.96  845.48  874.05  900.00
 42    900.00  866.42  838.93  806.41  789.17  775.00  773.15  771.84  770.79  769.99
 43    770.79  771.84  773.15  775.00  791.61  810.21  842.73  871.30  900.00
 44    900.00  879.01  850.89  818.37  795.47  775.00  773.15  771.84  770.79  769.99
 45    770.79  771.84  773.15  775.00  790.60  808.19  840.71  869.28  900.00
 46    900.00  886.99  858.47  825.95  799.46  775.00  773.15  771.84  770.79  769.99
 47    770.79  771.84  773.15  775.00  790.07  807.12  839.64  868.21  900.00
 48    900.00  886.99  858.47  825.95  799.46  775.00  773.15  771.84  770.79  769.99
 49    770.79  771.84  773.15  775.00  790.07  807.12  839.64  868.21  900.00
 50    900.00  879.01  850.89  818.37  795.47  775.00  773.15  771.84  770.79  769.99
 51    770.79  771.84  773.15  775.00  790.60  808.19  840.71  869.28  900.00
 52    900.00  866.42  838.93  806.41  789.17  775.00  773.15  771.84  770.79  769.99
 53    770.79  771.84  773.15  775.00  791.61  810.21  842.73  871.30  900.00
 54    900.00  854.52  827.63  795.11  783.23  775.00  773.15  771.84  770.79  769.99
 55    770.79  771.84  773.15  775.00  792.99  812.96  845.48  874.05  900.00
 56    900.00  848.34  821.76  789.24  780.14  775.00  773.15  771.84  770.79  769.99
 57    770.79  771.84  773.15  775.00  794.59  816.15  848.67  877.24  900.00
 58    900.00  850.48  823.79  791.27  781.21  775.00  773.15  771.84  770.79  769.99
 59    770.79  771.84  773.15  775.00  796.23  819.43  851.95  880.52  900.00
 60    900.00  860.04  832.87  800.35  785.98  775.00  773.15  771.84  770.79  769.99
 61    770.79  771.84  773.15  775.00  797.73  822.45  854.97  883.54  900.00
 62    900.00  872.98  845.16  812.64  792.45  775.00  773.15  771.84  770.79  769.99
 63    770.79  771.84  773.15  775.00  798.95  824.87  857.39  885.96  900.00
 64    900.00  883.85  855.49  822.97  797.89  775.00  773.15  771.84  770.79  769.99
 65    770.79  771.84  773.15  775.00  799.73  826.44  858.96  887.53  900.00
 66    900.00  888.07  859.50  826.98  800.00  775.00  773.15  771.84  770.79  769.99
 67    770.79  771.84  773.15  775.00  800.00  826.98  859.50  888.07  900.00
 68      86400.         1         1
```

Appendix 2. Example-model input data for Basic Package, BCF Package, River Package, SIP Package, and Output-Control Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

Column Numbers

```
             1         2         3         4         5         6         7         8
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

B. Block-Centered Flow (BCF) Package [input for BCF Package follows column numbers.Input consists of 89 records (lines 80-168). Input is read from FORTRAN unit number 11]

```
 80          1        35
 81  1
 82          0        1.
 83         11       1              (10F8.0)         0
 84    1000.    900.    700.    450.    300.    200.    150.    100.     75.     50.
 85      75.    100.    150.    200.    300.    450.    700.    900.   1000.
 86          0      400.
 87         11       1              (10E8.3)
 88 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
 89 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
 90 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
 91 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
 92 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
 93 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
 94 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
 95 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
 96 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
 97 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
 98 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
 99 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
100 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
101 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
102 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
103 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
104 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
105 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
106 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
107 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
108 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
109 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
110 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
111 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
112 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
113 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
114 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
115 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
116 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
117 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
118 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
119 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
120 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
121 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
122 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
123 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
124 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
125 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
126 .289E-05.289E-05.289E-05.289E-05.289E-05.116E-02.116E-02.116E-02.116E-02.116E-02
127 .116E-02.116E-02.116E-02.116E-02.289E-05.289E-05.289E-05.289E-05.289E-05
128         11       1              (10F8.0)
129   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
130   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
131   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
132   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
133   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
134   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
135   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
136   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
137   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
138   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
139   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
140   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
141   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
142   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
143   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
144   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
145   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
146   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
147   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
148   695.79  696.84  698.15  700.00  700.00  726.98  759.50  788.07  800.00
149   800.00  788.07  759.50  726.98  700.00  700.00  698.15  696.84  695.79  694.99
```

Appendix 2. Example-model input data for Basic Package, BCF Package, River Package, SIP Package, and Output-Control Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

Column Numbers

```
                  1         2         3         4         5         6         7         8
         12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

B. Block-Centered Flow (BCF) Package (continued)

```
150    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
151    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
152    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
153    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
154    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
155    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
156    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
157    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
158    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
159    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
160    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
161    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
162    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
163    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
164    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
165    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
166    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
167    800.00   788.07   759.50   726.98   700.00   700.00   698.15   696.84   695.79   694.99
168    695.79   696.84   698.15   700.00   700.00   726.98   759.50   788.07   800.00
```

C. River Package [input for River Package follows column numbers.Input consists of 22 records (lines 180-201) . Input is read from FORTRAN unit number 12]

```
180         20        -1
181         20
182          1         1         10     765.00  0.090000     760.00
183          1         2         10     765.00  0.090000     760.00
184          1         3         10     765.00  0.090000     760.00
185          1         4         10     765.00  0.090000     760.00
186          1         5         10     765.00  0.090000     760.00
187          1         6         10     765.00  0.090000     760.00
188          1         7         10     765.00  0.090000     760.00
189          1         8         10     765.00  0.090000     760.00
190          1         9         10     765.00  0.090000     760.00
191          1        10         10     765.00  0.090000     760.00
192          1        11         10     765.00  0.090000     760.00
193          1        12         10     765.00  0.090000     760.00
194          1        13         10     765.00  0.090000     760.00
195          1        14         10     765.00  0.090000     760.00
196          1        15         10     765.00  0.090000     760.00
197          1        16         10     765.00  0.090000     760.00
198          1        17         10     765.00  0.090000     760.00
199          1        18         10     765.00  0.090000     760.00
200          1        19         10     765.00  0.090000     760.00
201          1        20         10     765.00  0.090000     760.00
```

D. Strongly Implicit Procedure (SIP) Package [Input for SIP Package follows column numbers. Input consists of two records(lines 212 and 213). Input is read from FORTRAN unit number 18]

```
212        250         5
213        0.8    0.0001          0       .04         1
```

(E) Output-Control (OC) Package [Input for Output-Control Package follows column numbers. Input consists of three records (lines 223-225). Input is read from FORTRAN unit number 19]

```
223       4        0        9        0
223       0        1        1        1
225       1        0        1        0
```

Appendix 3. Example-model input data for the Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model MODFLOW

[Input for Variable-Recharge Package follows column numbers. Input consists of 442 records (lines 1-442). Input is read from FORTRAN unit number 20 as specified in IUNIT(21) of Basic Package. Record numbers 1 through 442 and comments in italics are not part of the input data]

```
                                    Column Numbers
            1         2         3         4         5         6         7         8
   12345678901234567890123456789012345678901234567890123456789012345678901234567890

 RECORD
 NUMBER                DATA FOR VAR1AL (See Input Instructions)
   1   360    2   33    6   12   40    1    1        1.0  0.10E-06
                           DATA FOR VAR1RP
   2  1.00 1.00 1.00 1.00 1.00 1.00                                  (RPZ ARRAY)
   3     0    2    0    1    0    0                                  (NCH ARRAY)
   4     4    4                                                      (NCH ARRAY)
   5     4                                                                "
   6     4    2    8    1    5   20                               (NMUCHN ARRAY)
   7  1.00 1.00 1.00 1.00 1.00 1.00                                  (FMX Array)
   8         5.         5.         5.         5.         5.         5.   (VMX ARRAY)
   9  0.00 0.90 0.00 0.95 0.00 0.00                                  (PER ARRAY)

 NUMCH=12 VIZ ARRAY RECORDS FOR SIMULATION OF STREAMS RECEIVING CHANNELED RUNOFF
                                                      Depth to:
          Sequence                             Stream      Streambed       Streambed
           Number     Row      Column     surface    Top     Bottom   conductance
  10          78        5           6     2.000      3.000      4.000   0.030000
  11          79        5           7     2.000      3.000      4.000   0.022000
  12          80        5           8     2.000      3.000      4.000   0.015000
  13          81        5           9     2.000      3.000      4.000   0.015000
  14          96        6           6     2.000      3.000      4.000   0.030000
  15          97        6           7     2.000      3.000      4.000   0.022000
  16          98        6           8     2.000      3.000      4.000   0.015000
  17          99        6           9     2.000      3.000      4.000   0.015000
  18         258       15           6     2.000      3.000      4.000   0.030000
  19         259       15           7     2.000      3.000      4.000   0.022000
  20         260       15           8     2.000      3.000      4.000   0.015000
  21         261       15           9     2.000      3.000      4.000   0.015000

          NUMU=40 VIZ ARRAY RECORDS FOR UNCHANNELED RUNOFF
  22           6        1           6     0.000      0.000      0.000   0.000000
  23          24        2           6     0.000      0.000      0.000   0.000000
  24          42        3           6     0.000      0.000      0.000   0.000000
  25          60        4           6     0.000      0.000      0.000   0.000000
  26          78        5           6     0.000      0.000      0.000   0.000000
  27          96        6           6     0.000      0.000      0.000   0.000000
  28         114        7           6     0.000      0.000      0.000   0.000000
  29         132        8           6     0.000      0.000      0.000   0.000000
  30         150        9           6     0.000      0.000      0.000   0.000000
  31         168       10           6     0.000      0.000      0.000   0.000000
  32         186       11           6     0.000      0.000      0.000   0.000000
  33         204       12           6     0.000      0.000      0.000   0.000000
  34         222       13           6     0.000      0.000      0.000   0.000000
  35         240       14           6     0.000      0.000      0.000   0.000000
  36         258       15           6     0.000      0.000      0.000   0.000000
  37         276       16           6     0.000      0.000      0.000   0.000000
  38         294       17           6     0.000      0.000      0.000   0.000000
  39         312       18           6     0.000      0.000      0.000   0.000000
  40         330       19           6     0.000      0.000      0.000   0.000000
  41         348       20           6     0.000      0.000      0.000   0.000000
  42          13        1          14     0.000      0.000      0.000   0.000000
  43          31        2          14     0.000      0.000      0.000   0.000000
  44          49        3          14     0.000      0.000      0.000   0.000000
  45          67        4          14     0.000      0.000      0.000   0.000000
  46          85        5          14     0.000      0.000      0.000   0.000000
  47         103        6          14     0.000      0.000      0.000   0.000000
  48         121        7          14     0.000      0.000      0.000   0.000000
  49         139        8          14     0.000      0.000      0.000   0.000000
  50         157        9          14     0.000      0.000      0.000   0.000000
  51         175       10          14     0.000      0.000      0.000   0.000000
  52         193       11          14     0.000      0.000      0.000   0.000000
  53         211       12          14     0.000      0.000      0.000   0.000000
  54         229       13          14     0.000      0.000      0.000   0.000000
  55         247       14          14     0.000      0.000      0.000   0.000000
  56         265       15          14     0.000      0.000      0.000   0.000000
  57         283       16          14     0.000      0.000      0.000   0.000000
  58         301       17          14     0.000      0.000      0.000   0.000000
  59         319       18          14     0.000      0.000      0.000   0.000000
  60         337       19          14     0.000      0.000      0.000   0.000000
  61         355       20          14     0.000      0.000      0.000   0.000000
```

Appendix 3. Example-model input data for the Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model MODFLOW (continued)

```
                             Column Numbers
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

IZONE ARRAY CONTAINING ZONE NUMBERS FOR VALLEY (0) AND UPLANDS (1-6)

62	1	1	1	1	1	0	0	0	0	0	0	0	0	0	6	6	6	6	6
63	2	1	1	1	1	0	0	0	0	0	0	0	0	0	6	6	6	6	6
64	2	2	1	1	1	0	0	0	0	0	0	0	0	0	6	6	6	6	6
65	2	2	2	1	1	0	0	0	0	0	0	0	0	0	6	6	6	6	6
66	2	2	2	2	2	0	0	0	0	0	0	0	0	0	6	6	6	6	6
67	2	2	2	2	2	0	0	0	0	0	0	0	0	0	6	6	6	6	6
68	2	2	2	2	3	0	0	0	0	0	0	0	0	0	6	6	6	6	6
69	2	2	2	3	3	0	0	0	0	0	0	0	0	0	6	6	6	6	6
70	2	2	3	3	3	0	0	0	0	0	0	0	0	0	6	6	6	6	6
71	2	3	3	3	3	0	0	0	0	0	0	0	0	0	6	6	6	6	6
72	4	3	3	3	3	0	0	0	0	0	0	0	0	0	6	6	6	6	6
73	4	4	3	3	3	0	0	0	0	0	0	0	0	0	6	6	6	6	6
74	4	4	4	3	3	0	0	0	0	0	0	0	0	0	6	6	6	6	6
75	4	4	4	4	3	0	0	0	0	0	0	0	0	0	6	6	6	6	6
76	4	4	4	4	4	0	0	0	0	0	0	0	0	0	6	6	6	6	6
77	4	4	4	4	5	0	0	0	0	0	0	0	0	0	6	6	6	6	6
78	4	4	4	5	5	0	0	0	0	0	0	0	0	0	6	6	6	6	6
79	4	4	5	5	5	0	0	0	0	0	0	0	0	0	6	6	6	6	6
80	4	5	5	5	5	0	0	0	0	0	0	0	0	0	6	6	6	6	6
81	5	5	5	5	5	0	0	0	0	0	0	0	0	0	6	6	6	6	6

ITMP=360 VARR ARRAY RECORDS CONTAINING LOCATION, LAND-SURFACE ELEVATION, AND RATE OF WAFR OF CELLS RECEIVING WAFR

82 360 1

	Layer	Row	Column	Land-surface elev.	Rate of WAFR
83	1	1	1	900.00	0.026425
84	1	1	2	888.07	0.023782
85	1	1	3	859.50	0.018497
86	1	1	4	826.98	0.011891
87	1	1	5	800.00	0.007927
88	1	1	6	775.00	0.005285
89	1	1	7	773.15	0.003964
90	1	1	8	771.84	0.002642
91	1	1	9	770.79	0.001982
92	1	1	11	770.79	0.001982
93	1	1	12	771.84	0.002642
94	1	1	13	773.15	0.003964
95	1	1	14	775.00	0.005285
96	1	1	15	800.00	0.007927
97	1	1	16	826.98	0.011891
98	1	1	17	859.50	0.018497
99	1	1	18	888.07	0.023782
100	1	1	19	900.00	0.026425
101	1	2	1	900.00	0.026425
102	1	2	2	883.85	0.023782
103	1	2	3	855.49	0.018497
104	1	2	4	822.97	0.011891
105	1	2	5	797.89	0.007927
106	1	2	6	775.00	0.005285
107	1	2	7	773.15	0.003964
108	1	2	8	771.84	0.002642
109	1	2	9	770.79	0.001982
110	1	2	11	770.79	0.001982
111	1	2	12	771.84	0.002642
112	1	2	13	773.15	0.003964
113	1	2	14	775.00	0.005285
114	1	2	15	799.73	0.007927
115	1	2	16	826.44	0.011891
116	1	2	17	858.96	0.018497
117	1	2	18	887.53	0.023782
118	1	2	19	900.00	0.026425
119	1	3	1	900.00	0.026425
120	1	3	2	872.98	0.023782
121	1	3	3	845.16	0.018497
122	1	3	4	812.64	0.011891
123	1	3	5	792.45	0.007927
124	1	3	6	775.00	0.005285
125	1	3	7	773.15	0.003964
126	1	3	8	771.84	0.002642
127	1	3	9	770.79	0.001982
128	1	3	11	770.79	0.001982
129	1	3	12	771.84	0.002642

Appendix 3. Example-model input data for the Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model MODFLOW (continued)

```
                           Column Numbers
         1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890123456789012345690
```

	Layer	Row	Column	Land-surface elev.	Rate of WAFR
VARR ARRAY RECORDS (continued)					
130	1	3	13	773.15	0.003964
131	1	3	14	775.00	0.005285
132	1	3	15	798.95	0.007927
133	1	3	16	824.87	0.011891
134	1	3	17	857.39	0.018497
135	1	3	18	885.96	0.023782
136	1	3	19	900.00	0.026425
137	1	4	1	900.00	0.026425
138	1	4	2	860.04	0.023782
139	1	4	3	832.87	0.018497
140	1	4	4	800.35	0.011891
141	1	4	5	785.98	0.007927
142	1	4	6	775.00	0.005285
143	1	4	7	773.15	0.003964
144	1	4	8	771.84	0.002642
145	1	4	9	770.79	0.001982
146	1	4	11	770.79	0.001982
147	1	4	12	771.84	0.002642
148	1	4	13	773.15	0.003964
149	1	4	14	775.00	0.005285
150	1	4	15	797.73	0.007927
151	1	4	16	822.45	0.011891
152	1	4	17	854.97	0.018497
153	1	4	18	883.54	0.023782
154	1	4	19	900.00	0.026425
155	1	5	1	900.00	0.026425
156	1	5	2	850.48	0.023782
157	1	5	3	823.79	0.018497
158	1	5	4	791.27	0.011891
159	1	5	5	781.21	0.007927
160	1	5	6	775.00	0.005285
161	1	5	7	773.15	0.003964
162	1	5	8	771.84	0.002642
163	1	5	9	770.79	0.001982
164	1	5	11	770.79	0.001982
165	1	5	12	771.84	0.002642
166	1	5	13	773.15	0.003964
167	1	5	14	775.00	0.005285
168	1	5	15	796.23	0.007927
169	1	5	16	819.43	0.011891
170	1	5	17	851.95	0.018497
171	1	5	18	880.52	0.023782
172	1	5	19	900.00	0.026425
173	1	6	1	900.00	0.026425
174	1	6	2	848.34	0.023782
175	1	6	3	821.76	0.018497
176	1	6	4	789.24	0.011891
177	1	6	5	780.14	0.007927
178	1	6	6	775.00	0.005285
179	1	6	7	773.15	0.003964
180	1	6	8	771.84	0.002642
181	1	6	9	770.79	0.001982
182	1	6	11	770.79	0.001982
183	1	6	12	771.84	0.002642
184	1	6	13	773.15	0.003964
185	1	6	14	775.00	0.005285
186	1	6	15	794.59	0.007927
187	1	6	16	816.15	0.011891
188	1	6	17	848.67	0.018497
189	1	6	18	877.24	0.023782
190	1	6	19	900.00	0.026425
191	1	7	1	900.00	0.026425
192	1	7	2	854.52	0.023782
193	1	7	3	827.63	0.018497
194	1	7	4	795.11	0.011891
195	1	7	5	783.23	0.007927
196	1	7	6	775.00	0.005285
197	1	7	7	773.15	0.003964
198	1	7	8	771.84	0.002642
199	1	7	9	770.79	0.001982

Appendix 3. Example-model input data for the Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model MODFLOW (continued)

```
                          Column Numbers
          1         2         3         4         5         6         7         8
 1234567890123456789012345678901234567890123456789012345678901234567890123456690
                                     Land-     Rate
                                     surface   of
               Layer     Row    Column  elev.     WAFR

VARR ARRAY RECORDS (continued),

  200         1         7        11    770.79   0.001982
  201         1         7        12    771.84   0.002642
  202         1         7        13    773.15   0.003964
  203         1         7        14    775.00   0.005285
  204         1         7        15    792.99   0.007927
  205         1         7        16    812.96   0.011891
  206         1         7        17    845.48   0.018497
  207         1         7        18    874.05   0.023782
  208         1         7        19    900.00   0.026425
  209         1         8         1    900.00   0.026425
  210         1         8         2    866.42   0.023782
  211         1         8         3    838.93   0.018497
  212         1         8         4    806.41   0.011891
  213         1         8         5    789.17   0.007927
  214         1         8         6    775.00   0.005285
  215         1         8         7    773.15   0.003964
  216         1         8         8    771.84   0.002642
  217         1         8         9    770.79   0.001982
  218         1         8        11    770.79   0.001982
  219         1         8        12    771.84   0.002642
  220         1         8        13    773.15   0.003964
  221         1         8        14    775.00   0.005285
  222         1         8        15    791.61   0.007927
  223         1         8        16    810.21   0.011891
  224         1         8        17    842.73   0.018497
  225         1         8        18    871.30   0.023782
  226         1         8        19    900.00   0.026425
  227         1         9         1    900.00   0.026425
  228         1         9         2    879.01   0.023782
  229         1         9         3    850.89   0.018497
  230         1         9         4    818.37   0.011891
  231         1         9         5    795.47   0.007927
  232         1         9         6    775.00   0.005285
  233         1         9         7    773.15   0.003964
  234         1         9         8    771.84   0.002642
  235         1         9         9    770.79   0.001982
  236         1         9        11    770.79   0.001982
  237         1         9        12    771.84   0.002642
  238         1         9        13    773.15   0.003964
  239         1         9        14    775.00   0.005285
  240         1         9        15    790.60   0.007927
  241         1         9        16    808.19   0.011891
  242         1         9        17    840.71   0.018497
  243         1         9        18    869.28   0.023782
  244         1         9        19    900.00   0.026425
  245         1        10         1    900.00   0.026425
  246         1        10         2    886.99   0.023782
  247         1        10         3    858.47   0.018497
  248         1        10         4    825.95   0.011891
  249         1        10         5    799.46   0.007927
  250         1        10         6    775.00   0.005285
  251         1        10         7    773.15   0.003964
  252         1        10         8    771.84   0.002642
  253         1        10         9    770.79   0.001982
  254         1        10        11    770.79   0.001982
  255         1        10        12    771.84   0.002642
  256         1        10        13    773.15   0.003964
  257         1        10        14    775.00   0.005285
  258         1        10        15    790.07   0.007927
  259         1        10        16    807.12   0.011891
  260         1        10        17    839.64   0.018497
  261         1        10        18    868.21   0.023782
  262         1        10        19    900.00   0.026425
  263         1        11         1    900.00   0.026425
  264         1        11         2    886.99   0.023782
  265         1        11         3    858.47   0.018497
  266         1        11         4    825.95   0.011891
  267         1        11         5    799.46   0.007927
  268         1        11         6    775.00   0.005285
  269         1        11         7    773.15   0.003964
  270         1        11         8    771.84   0.002642
```

Appendix 3. Example-model input data for the Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model MODFLOW (continued)

```
                                    Column Numbers
                1         2         3         4         5         6         7         8
       1234567890123456789012345678901234567890123456789012345678901234567890123456790
                                          Land-     Rate
                                          surface   of
             Layer     Row      Column    elev.     WAFR

VARR ARRAY RECORDS (continued))
```

	Layer	Row	Column	Land-surface elev.	Rate of WAFR
271	1	11	9	770.79	0.001982
272	1	11	11	770.79	0.001982
273	1	11	12	771.84	0.002642
274	1	11	13	773.15	0.003964
275	1	11	14	775.00	0.005285
276	1	11	15	790.07	0.007927
277	1	11	16	807.12	0.011891
278	1	11	17	839.64	0.018497
279	1	11	18	868.21	0.023782
280	1	11	19	900.00	0.026425
281	1	12	1	900.00	0.026425
282	1	12	2	879.01	0.023782
283	1	12	3	850.89	0.018497
284	1	12	4	818.37	0.011891
285	1	12	5	795.47	0.007927
286	1	12	6	775.00	0.005285
287	1	12	7	773.15	0.003964
288	1	12	8	771.84	0.002642
289	1	12	9	770.79	0.001982
290	1	12	11	770.79	0.001982
291	1	12	12	771.84	0.002642
292	1	12	13	773.15	0.003964
293	1	12	14	775.00	0.005285
294	1	12	15	790.60	0.007927
295	1	12	16	808.19	0.011891
296	1	12	17	840.71	0.018497
297	1	12	18	869.28	0.023782
298	1	12	19	900.00	0.026425
299	1	13	1	900.00	0.026425
300	1	13	2	866.42	0.023782
301	1	13	3	838.93	0.018497
302	1	13	4	806.41	0.011891
303	1	13	5	789.17	0.007927
304	1	13	6	775.00	0.005285
305	1	13	7	773.15	0.003964
306	1	13	8	771.84	0.002642
307	1	13	9	770.79	0.001982
308	1	13	11	770.79	0.001982
309	1	13	12	771.84	0.002642
310	1	13	13	773.15	0.003964
311	1	13	14	775.00	0.005285
312	1	13	15	791.61	0.007927
313	1	13	16	810.21	0.011891
314	1	13	17	842.73	0.018497
315	1	13	18	871.30	0.023782
316	1	13	19	900.00	0.026425
317	1	14	1	900.00	0.026425
318	1	14	2	854.52	0.023782
319	1	14	3	827.63	0.018497
320	1	14	4	795.11	0.011891
321	1	14	5	783.23	0.007927
322	1	14	6	775.00	0.005285
323	1	14	7	773.15	0.003964
324	1	14	8	771.84	0.002642
325	1	14	9	770.79	0.001982
326	1	14	11	770.79	0.001982
327	1	14	12	771.84	0.002642
328	1	14	13	773.15	0.003964
329	1	14	14	775.00	0.005285
330	1	14	15	792.99	0.007927
331	1	14	16	812.96	0.011891
332	1	14	17	845.48	0.018497
333	1	14	18	874.05	0.023782
334	1	14	19	900.00	0.026425
335	1	15	1	900.00	0.026425
336	1	15	2	848.34	0.023782
337	1	15	3	821.76	0.018497
338	1	15	4	789.24	0.011891
339	1	15	5	780.14	0.007927
340	1	15	6	775.00	0.005285

Appendix 3. Example-model input data for the Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model MODFLOW (continued)

```
                                     Column Numbers
          1         2         3         4         5         6         7         8
 12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

	Layer	Row	Column	Land-surface elev.	Rate of WAFR
VARR ARRAY RECORDS (continued)					
341	1	15	7	773.15	0.003964
342	1	15	8	771.84	0.002642
343	1	15	9	770.79	0.001982
344	1	15	11	770.79	0.001982
345	1	15	12	771.84	0.002642
346	1	15	13	773.15	0.003964
347	1	15	14	775.00	0.005285
348	1	15	15	794.59	0.007927
349	1	15	16	816.15	0.011891
350	1	15	17	848.67	0.018497
351	1	15	18	877.24	0.023782
352	1	15	19	900.00	0.026425
353	1	16	1	900.00	0.026425
354	1	16	2	850.48	0.023782
355	1	16	3	823.79	0.018497
356	1	16	4	791.27	0.011891
357	1	16	5	781.21	0.007927
358	1	16	6	775.00	0.005285
359	1	16	7	773.15	0.003964
360	1	16	8	771.84	0.002642
361	1	16	9	770.79	0.001982
362	1	16	11	770.79	0.001982
363	1	16	12	771.84	0.002642
364	1	16	13	773.15	0.003964
365	1	16	14	775.00	0.005285
366	1	16	15	796.23	0.007927
367	1	16	16	819.43	0.011891
368	1	16	17	851.95	0.018497
369	1	16	18	880.52	0.023782
370	1	16	19	900.00	0.026425
371	1	17	1	900.00	0.026425
372	1	17	2	860.04	0.023782
373	1	17	3	832.87	0.018497
374	1	17	4	800.35	0.011891
375	1	17	5	785.98	0.007927
376	1	17	6	775.00	0.005285
377	1	17	7	773.15	0.003964
378	1	17	8	771.84	0.002642
379	1	17	9	770.79	0.001982
380	1	17	11	770.79	0.001982
381	1	17	12	771.84	0.002642
382	1	17	13	773.15	0.003964
383	1	17	14	775.00	0.005285
384	1	17	15	797.73	0.007927
385	1	17	16	822.45	0.011891
386	1	17	17	854.97	0.018497
387	1	17	18	883.54	0.023782
388	1	17	19	900.00	0.026425
389	1	18	1	900.00	0.026425
390	1	18	2	872.98	0.023782
391	1	18	3	845.16	0.018497
392	1	18	4	812.64	0.011891
393	1	18	5	792.45	0.007927
394	1	18	6	775.00	0.005285
395	1	18	7	773.15	0.003964
396	1	18	8	771.84	0.002642
397	1	18	9	770.79	0.001982
398	1	18	11	770.79	0.001982
399	1	18	12	771.84	0.002642
400	1	18	13	773.15	0.003964
401	1	18	14	775.00	0.005285
402	1	18	15	798.95	0.007927
403	1	18	16	824.87	0.011891
404	1	18	17	857.39	0.018497
405	1	18	18	885.96	0.023782
406	1	18	19	900.00	0.026425
407	1	19	1	900.00	0.026425
408	1	19	2	883.85	0.023782

Appendix 4. Example-model output from U.S. Geological Survey modular 3-D finite-difference ground-water flow model MODFLOW

```
  U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL

 SAMPLE OF VARIABLE-RECHARGE PACKAGE INPUT DATA                  1 LAYER VALLEY-FILL AQUIFER
   1 LAYERS        20 ROWS        19 COLUMNS
  1 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS SECONDS

I/O UNITS:
ELEMENT OF IUNIT: 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
     I/O UNIT:11  0  0 12  0  0  0  0 18  0  0 19  0  0  0  0  0  0  0 20  0  0  0  0

BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  5
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL NOT BE SAVED -- DRAWDOWN CANNOT BE CALCULATED
    3083 ELEMENTS IN X ARRAY ARE USED BY BAS
    3083 ELEMENTS OF X ARRAY USED OUT OF 1000000

BCF3 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 3, 7/9/92 INPUT READ FROM UNIT 11
STEADY-STATE SIMULATION
CELL-BY-CELL FLOWS WILL BE RECORDED ON UNIT 35
HEAD AT CELLS THAT CONVERT TO DRY=  0.00000E+00
WETTING CAPABILITY IS NOT ACTIVE
     LAYER  AQUIFER TYPE    INTERBLOCK T
     ------------------------------------
        1        1         0-HARMONIC
     761 ELEMENTS IN X ARRAY ARE USED BY BCF
    3844 ELEMENTS OF X ARRAY USED OUT OF 1000000

RIV1 -- RIVER PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 12
MAXIMUM OF   20 RIVER NODES
CELL-BY-CELL FLOWS WILL BE PRINTED
     120 ELEMENTS IN X ARRAY ARE USED FOR RIVERS
    3964 ELEMENTS OF X ARRAY USED OUT OF 1000000

VAR1 -- VARIABLE RECHARGE PACKAGE, VERSION 6/95 INPUT READ FROM UNIT 20
MAXIMUM OF  360 VARIABLE RECHARGE NODES
UPLAND RUNOFF WILL BE DISTRIBUTED TO VALLEY
MAXIMUM OF  2 CHANNELS PER ZONE
NUMBER OF ZONES =  6
NUMBER OF CELLS DESIGNATED TO RECEIVE CHANNELED RUNOFF = 12
NUMBER OF CELLS DESIGNATED TO RECEIVE UNCHANNELED RUNOFF = 40
TOTAL NUMBER OF CELLS DESIGNATED TO RECEIVE UPLAND RUNOFF = 52
NUMBER OF ITERATIONS BETWEEN ALLOCATION OF RUNOFF =  1
DEPTH FOR FULL RECHARGE (RFACT) = 1.000
IF TOP LAYER GOES DRY RECHARGE WILL BE APPLIED TO NEXT LAYER
FLOW LIMIT TO RELEASE SEEPAGE CELL = 0.100000E-06
CELL-BY-CELL FLOWS WILL BE RECORDED ON UNIT 33
  3222 ELEMENTS IN X ARRAY ARE USED FOR VARIABLE RECHARGE
  7186 ELEMENTS OF X ARRAY USED OUT OF 1000000

SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 18
MAXIMUM OF 250 ITERATIONS ALLOWED FOR CLOSURE
 5 ITERATION PARAMETERS
    2525 ELEMENTS IN X ARRAY ARE USED BY SIP
    9711 ELEMENTS OF X ARRAY USED OUT OF 1000000
 SAMPLE OF VARIABLE-RECHARGE PACKAGE INPUT DATA                                1 LAYER VALLEY-FILL AQUIFER




            BOUNDARY ARRAY FOR LAYER  1 WILL BE READ ON UNIT  5 USING FORMAT:              (20I4)
   ----------------------------------------------------------------------------------------------

       1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19
....................................................................................

  1    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1

  2    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  .    .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
  .    .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
  .    .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
 19    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1

 20   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1

AQUIFER HEAD WILL BE SET TO 0.00000E+00 AT ALL NO-FLOW NODES (IBOUND=0).
```

```
               INITIAL HEAD FOR LAYER  1 WILL BE READ ON UNIT  5 USING FORMAT:           (10F8.0)
    ----------------------------------------------------------------------------------------------

          1       2       3       4       5       6       7       8       9      10      11      12      13      14      15
         16      17      18      19
..........................................................................................................................

  1  899.999 888.069 859.499 826.979 799.999 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 799.999
     826.979 859.499 888.069 899.999

  2  899.999 883.849 855.489 822.969 797.889 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 799.729
     826.439 858.959 887.529 899.999

  3  899.999 872.979 845.159 812.639 792.449 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 798.949
     824.869 857.389 885.959 899.999

  4  899.999 860.039 832.869 800.349 785.979 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 797.729
     822.449 854.969 883.539 899.999

  5  899.999 850.479 823.789 791.269 781.209 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 796.229
     819.429 851.949 880.519 899.999

  6  899.999 848.339 821.759 789.239 780.139 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 794.589
     816.149 848.669 877.239 899.999

  7  899.999 854.519 827.629 795.109 783.229 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 792.989
     812.959 845.479 874.049 899.999

  8  899.999 866.419 838.929 806.409 789.169 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 791.609
     810.209 842.729 871.299 899.999

  9  899.999 879.009 850.889 818.369 795.469 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 790.599
     808.189 840.709 869.279 899.999

 10  899.999 886.989 858.469 825.949 799.459 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 790.069
     807.119 839.639 868.209 899.999

 11  899.999 886.989 858.469 825.949 799.459 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 790.069
     807.119 839.639 868.209 899.999

 12  899.999 879.009 850.889 818.369 795.469 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 790.599
     808.189 840.709 869.279 899.999

 13  899.999 866.419 838.929 806.409 789.169 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 791.609
     810.209 842.729 871.299 899.999

 14  899.999 854.519 827.629 795.109 783.229 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 792.989
     812.959 845.479 874.049 899.999

 15  899.999 848.339 821.759 789.239 780.139 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 794.589
     816.149 848.669 877.239 899.999

 16  899.999 850.479 823.789 791.269 781.209 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 796.229
     819.429 851.949 880.519 899.999

 17  899.999 860.039 832.869 800.349 785.979 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 797.729
     822.449 854.969 883.539 899.999

 18  899.999 872.979 845.159 812.639 792.449 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 798.949
     824.869 857.389 885.959 899.999

 19  899.999 883.849 855.489 822.969 797.889 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 799.729
     826.439 858.959 887.529 899.999

 20  899.999 888.069 859.499 826.979 799.999 774.999 773.149 771.839 770.789 769.989 770.789 771.839 773.149 774.999 799.999
     826.979 859.499 888.069 899.999

HEAD PRINT FORMAT IS FORMAT NUMBER   4    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   0

HEADS WILL BE SAVED ON UNIT  9    DRAWDOWNS WILL BE SAVED ON UNIT  0

OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP

                                                   COLUMN TO ROW ANISOTROPY =   1.000000




                                                DELR WILL BE READ ON UNIT 11 USING FORMAT:           (10F8.0)
                             ----------------------------------------------------------------------------

  1000.0       900.00       700.00       450.00       300.00       200.00       150.00       100.00       75.000       50.000
  75.000       100.00       150.00       200.00       300.00       450.00       700.00       900.00       1000.0

                                                                       DELC =   400.0000
```

```


                            HYD. COND. ALONG ROWS FOR LAYER  1 WILL BE READ ON UNIT 11 USING FORMAT:          (10E8.3)
                         ----------------------------------------------------------------------------------------------

           1          2          3          4          5          6          7          8          9         10
          11         12         13         14         15         16         17         18         19
..............................................................................................................................

    1   2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03
        1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06

    2   2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03
        1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06
            .           .           .           .           .           .           .           .           .           .
            .           .           .           .           .           .           .           .           .           .

   19   2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03
        1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06

   20   2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03
        1.1600E-03  1.1600E-03  1.1600E-03  1.1600E-03  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06  2.8900E-06




                                          BOTTOM FOR LAYER  1 WILL BE READ ON UNIT 11 USING FORMAT:          (10F8.0)
                         ----------------------------------------------------------------------------------------------

           1          2          3          4          5          6          7          8          9         10
          11         12         13         14         15         16         17         18         19
..............................................................................................................................

    1    800.0      788.1      759.5      727.0      700.0      700.0      698.2      696.8      695.8      695.0
         695.8      696.8      698.2      700.0      700.0      727.0      759.5      788.1      800.0

    2    800.0      788.1      759.5      727.0      700.0      700.0      698.2      696.8      695.8      695.0
         695.8      696.8      698.2      700.0      700.0      727.0      759.5      788.1      800.0
           .          .          .          .          .          .          .          .          .          .
           .          .          .          .          .          .          .          .          .          .
           .          .          .          .          .          .          .          .          .          .
   19    800.0      788.1      759.5      727.0      700.0      700.0      698.2      696.8      695.8      695.0
         695.8      696.8      698.2      700.0      700.0      727.0      759.5      788.1      800.0

   20    800.0      788.1      759.5      727.0      700.0      700.0      698.2      696.8      695.8      695.0
         695.8      696.8      698.2      700.0      700.0      727.0      759.5      788.1      800.0




                                                   SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
                                                   -------------------------------------------

                                          MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =      250
                                                          ACCELERATION PARAMETER =    0.80000
                                               HEAD CHANGE CRITERION FOR CLOSURE =    0.10000E-03
                                               SIP HEAD CHANGE PRINTOUT INTERVAL =        1


     5 ITERATION PARAMETERS CALCULATED FROM SPECIFIED WSEED = 0.04000000 :

            0.0000000E+00  0.5527864E+00  0.8000000E+00  0.9105573E+00  0.9600000E+00
                                               STRESS PERIOD NO.   1, LENGTH =   86400.00
                                              ----------------------------------------------

                                              NUMBER OF TIME STEPS =     1

                                               MULTIPLIER FOR DELT =     1.000

                                            INITIAL TIME STEP SIZE =   86400.00




     20 RIVER REACHES

                 LAYER     ROW     COL     STAGE     CONDUCTANCE   BOTTOM ELEVATION   RIVER REACH
                 --------------------------------------------------------------------------------
                    1        1      10    765.0       0.9000E-01         760.0            1
                    1        2      10    765.0       0.9000E-01         760.0            2
                    .        .       .      .              .               .              .
                    .        .       .      .              .               .              .
                    .        .       .      .              .               .              .
                    1       19      10    765.0       0.9000E-01         760.0           19
                    1       20      10    765.0       0.9000E-01         760.0           20


```

***** VARIABLE RECHARGE DATA *****

PROPORTION OF INPUT WAFR ASSIGNED TO EACH ZONE = 1.00 1.00 1.00 1.00 1.00 1.00
NUMBER OF TRIBUTARY STREAMS/CHANNELS PER ZONE = 0 2 0 1 0 0
NUMBER OF CELLS PER CHANNEL FOR ZONE 2 ARE: 4 4
NUMBER OF CELLS PER CHANNEL FOR ZONE 4 ARE: 4
NUMBER OF CELLS PER ZONE RECIEVING UNCHANNELED RUNOFF = 4 2 8 1 5 20

PROPORTION OF UPLAND RUNOFF AVAILABLE TO RECHARGE VALLEY = 1.00 1.00 1.00 1.00 1.00 1.00

MAXIMUM ALLOWABLE UNCHANNELED RUNOFF PER CELL = 5.00 5.00 5.00 5.00 5.00 5.00

PROPORTION OF AVAILABLE UPLAND RUNOFF TREATED AS CHANNELED RUNOFFF = 0.00 0.90 0.00 0.95 0.00 0.00

RECHARGE RECORD	ROW	COLUMN	DEPTH TO WATER SURFACE	DEPTH TO STREAMBED TOP	DEPTH TO STREAMBED BOTTOM	CONDUCTANCE
78	5	6	2.000	3.000	4.000	0.030000
79	5	7	2.000	3.000	4.000	0.022000
80	5	8	2.000	3.000	4.000	0.015000
81	5	9	2.000	3.000	4.000	0.015000
96	6	6	2.000	3.000	4.000	0.030000
97	6	7	2.000	3.000	4.000	0.022000
98	6	8	2.000	3.000	4.000	0.015000
99	6	9	2.000	3.000	4.000	0.015000
258	15	6	2.000	3.000	4.000	0.030000
259	15	7	2.000	3.000	4.000	0.022000
260	15	8	2.000	3.000	4.000	0.015000
261	15	9	2.000	3.000	4.000	0.015000

RECHARGE RECORD	ROW	COLUMN	ZONE
6	1	6	1
24	2	6	1
42	3	6	1
60	4	6	1
78	5	6	2
96	6	6	2
114	7	6	3
132	8	6	3
150	9	6	3
168	10	6	3
186	11	6	3
204	12	6	3
222	13	6	3
240	14	6	3
258	15	6	4
276	16	6	5
294	17	6	5
312	18	6	5
330	19	6	5
348	20	6	5
13	1	14	6
31	2	14	6
49	3	14	6
67	4	14	6
85	5	14	6
103	6	14	6
121	7	14	6
139	8	14	6
157	9	14	6
175	10	14	6
193	11	14	6
211	12	14	6
229	13	14	6
247	14	14	6
265	15	14	6
283	16	14	6
301	17	14	6
319	18	14	6
337	19	14	6
355	20	14	6

```
                              *************** VAR-RECH ZONE ARRAY ****************

         1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19
 ...................................................................
   1     1  1  1  1  1  0  0  0  0  0  0  0  0  0  6  6  6  6  6
   2     2  1  1  1  1  0  0  0  0  0  0  0  0  0  6  6  6  6  6
   3     2  2  1  1  1  0  0  0  0  0  0  0  0  0  6  6  6  6  6
   4     2  2  2  1  1  0  0  0  0  0  0  0  0  0  6  6  6  6  6
   5     2  2  2  2  2  0  0  0  0  0  0  0  0  0  6  6  6  6  6
   6     2  2  2  2  2  0  0  0  0  0  0  0  0  0  6  6  6  6  6
   7     2  2  2  2  3  0  0  0  0  0  0  0  0  0  6  6  6  6  6
   8     2  2  2  3  3  0  0  0  0  0  0  0  0  0  6  6  6  6  6
   9     2  2  3  3  3  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  10     2  3  3  3  3  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  11     4  3  3  3  3  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  12     4  4  3  3  3  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  13     4  4  4  3  3  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  14     4  4  4  4  3  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  15     4  4  4  4  4  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  16     4  4  4  4  5  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  17     4  4  4  5  5  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  18     4  4  5  5  5  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  19     4  5  5  5  5  0  0  0  0  0  0  0  0  0  6  6  6  6  6
  20     5  5  5  5  5  0  0  0  0  0  0  0  0  0  6  6  6  6  6



   360 VARIABLE RECHARGE CELLS


      SUM OF WATER-AVAILABLE-FOR-RECHARGE FOR STRESS PERIOD  1 =    4.0958


      UPLAND WATER-AVAILABLE-FOR-RECHARGE =   3.5409     AREA OF UPLANDS =  53600000.0


      VALLEY WATER-AVAILABLE-FOR-RECHARGE =  0.55492     AREA OF VALLEY  =   8400000.0


    26 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD  1

 MAXIMUM HEAD CHANGE FOR EACH ITERATION:

  HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL
 ------------------------------------------------------------------------------------------------------------------------------------
   -1.968     (  1,  6,  6)  -3.743     (  1, 20,  5)  -2.647     (  1,  4, 15)  -1.238     (  1,  8, 15)  -1.028     (  1, 10, 15)
  -0.2027     (  1, 11, 15) -0.1542     (  1, 10,  6) -0.1499     (  1, 11,  6) -0.1321     (  1, 11,  6) -0.9488E-01 (  1, 11,  6)
  -0.1795E-01 (  1, 12,  6) -0.1696E-01 (  1, 12,  6) -0.1635E-01 (  1, 12,  6) -0.1427E-01 (  1, 12,  6) -0.1015E-01 (  1, 12,  6)
  -0.1915E-02 (  1, 12,  6) -0.1804E-02 (  1, 11,  6) -0.1737E-02 (  1, 12,  6) -0.1505E-02 (  1, 11,  6) -0.1058E-02 (  1, 11,  6)
  -0.2032E-03 (  1, 12,  6) -0.1940E-03 (  1, 12,  6) -0.1828E-03 (  1, 11,  6) -0.1591E-03 (  1, 12,  6) -0.1301E-03 (  1, 11,  6)
  -0.7533E-04 (  1,  4, 17)



 HEAD/DRAWDOWN PRINTOUT FLAG = 1     TOTAL BUDGET PRINTOUT FLAG = 1     CELL-BY-CELL FLOW TERM FLAG = 1

 OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
   HEAD    DRAWDOWN  HEAD  DRAWDOWN
 PRINTOUT  PRINTOUT  SAVE    SAVE
 ----------------------------------
     1         0       1       0
 "   CONSTANT HEAD" BUDGET VALUES WILL BE SAVED ON UNIT 35 AT END OF TIME STEP  1, STRESS PERIOD  1
 "FLOW RIGHT FACE " BUDGET VALUES WILL BE SAVED ON UNIT 35 AT END OF TIME STEP  1, STRESS PERIOD  1
 "FLOW FRONT FACE " BUDGET VALUES WILL BE SAVED ON UNIT 35 AT END OF TIME STEP  1, STRESS PERIOD  1

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   1   LAYER  1   ROW   1   COL  10   RATE -0.1790881

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   2   LAYER  1   ROW   2   COL  10   RATE -0.1812360

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   3   LAYER  1   ROW   3   COL  10   RATE -0.1866522

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   4   LAYER  1   ROW   4   COL  10   RATE -0.1979572

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   5   LAYER  1   ROW   5   COL  10   RATE -0.2193146

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   6   LAYER  1   ROW   6   COL  10   RATE -0.2158319

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   7   LAYER  1   ROW   7   COL  10   RATE -0.1868720

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   8   LAYER  1   ROW   8   COL  10   RATE -0.1704749

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH   9   LAYER  1   ROW   9   COL  10   RATE -0.1619769

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  10   LAYER  1   ROW  10   COL  10   RATE -0.1580658

    RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  11   LAYER  1   ROW  11   COL  10   RATE -0.1570331
```

Appendix 4. Example-model output from U.S. Geological Survey modular 3-D finite-difference ground-water flow model MODFLOW (continued)

```
 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  12   LAYER  1   ROW  12   COL  10   RATE -0.1585327

 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  13   LAYER  1   ROW  13   COL  10   RATE -0.1635095

 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  14   LAYER  1   ROW  14   COL  10   RATE -0.1741992

 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  15   LAYER  1   ROW  15   COL  10   RATE -0.1938922

 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  16   LAYER  1   ROW  16   COL  10   RATE -0.1789124

 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  17   LAYER  1   ROW  17   COL  10   RATE -0.1714142

 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  18   LAYER  1   ROW  18   COL  10   RATE -0.1681677

 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  19   LAYER  1   ROW  19   COL  10   RATE -0.1670142

 RIVER LEAKAGE   PERIOD  1   STEP  1   REACH  20   LAYER  1   ROW  20   COL  10   RATE -0.1667011

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


******************************************** VARIABLE RECHARGE BUDGET *********************************************

                                        STRESS PERIOD 1 TIME STEP 1


                               (WAFR IS THE WATER-AVAILABLE-FOR-RECHARGE IN L**3/T)

                            RECHARGE AREA OF UPLANDS =  53600000.0 ---WAFR =   3.5409

                             RECHARGE AREA OF VALLEY =   8400000.0 ---WAFR =  0.55492



                                                                                                  UPLAND          UPLAND    VALLEY CELLS
                         UPLAND                                   UPLAND       UPLAND       AVAILABLE       AVAILABLE    RECIEVING
                   REJECTED RECHARGE           UPLAND      SURFACE      AVAILABLE      CHANNELED     UNCHANNELED  UNCHANNELED
            (H=HSURF)   (RBOT<H<HSURF)        SEEPAGE      RUNOFF         RUNOFF         RUNOFF          RUNOFF        RUNOFF
      1     0.1189E-01     0.1314            0.2245E-02   0.1455        0.1455        0.0000E+00      0.1455           4
      2     0.2101         0.2939            0.3379E-01   0.5378        0.5378        0.4840          0.5378E-01       2
      3     0.2378E-01     0.1216            0.1454E-02   0.1468        0.1468        0.0000E+00      0.1468           8
      4     0.2101         0.2901            0.3377E-01   0.5340        0.5340        0.5073          0.2670E-01       1
      5     0.1189E-01     0.1338            0.2234E-02   0.1480        0.1480        0.0000E+00      0.1480           5
      6     0.1903          1.266            0.4226E-02    1.461         1.461        0.0000E+00       1.461          20
            ---------      ---------         ---------    ---------     ---------     ---------       -------     ---------
    TOTAL   0.6580          2.237            0.7772E-01    2.973         2.973        0.9913           1.982          40



                                      RECHARGE SUMMARY

               AREA                               DIRECT                         NET
   ZONE         L**2          WAFR          L**3/T        IN/YR          L**3/T          IN/YR
    1        3160000.      0.2088         0.6551E-01      7.845         0.6326E-01        7.576
    2        8300000.      0.5483         0.4434E-01      2.022         0.1055E-01       0.4810
    3        3880000.      0.2563         0.1109          10.82         0.1095            10.68
    4        8180000.      0.5404         0.4016E-01      1.858         0.6389E-02       0.2956
    5        3280000.      0.2167         0.7096E-01      8.187         0.6873E-01        7.929
    6       26800000.       1.770         0.3138          4.431         0.3096            4.371
                 DIRECT RECHARGE IS THE WAFR MINUS REJECTED RECHARGE
                 NET RECHARGE IS DIRECT RECHARGE MINUS OUTWARD SEEPAGE

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

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



                                      DISTRIBUTION OF UPLAND WATER-AVAILABLE-FOR-RECHARGE


                                          WAFR APPLIED TO UPLANDS =   3.541
                                  --------------------------------------------------



                                               REJECTED RECHARGE
                                    (WATER LEVEL AT LAND SURFACE) =  0.6580
               (WATER LEVEL BETWEEN LAND AND PSEUDO-LAND SURFACE) =   2.237
                                                                  (+)---------
                                                          TOTAL =   2.895

                                                  OUTWARD SEEPAGE =  0.7772E-01
                                                                  (+)---------
                                             TOTAL SURFACE RUNOFF =   2.973


                                                  DIRECT RECHARGE =  0.6457
                                                  OUTWARD SEEPAGE =  0.7772E-01
                                                                  (-)---------
```

Appendix 4. Example-model output from U.S. Geological Survey modular 3-D finite-difference ground-water flow model MODFLOW (continued)

```
                                       NET RECHARGE TO UPLANDS =  0.5680


                                          TOTAL SURFACE RUNOFF =   2.973
                                    UNAVAILABLE SURFACE RUNOFF =  0.0000E+00
                                                              (-)---------
                                      AVAILABLE SURFACE RUNOFF =   2.973


                                  AVAILABLE UNCHANNELED RUNOFF =   1.982
                                    AVAILABLE CHANNELED RUNOFF =  0.9913

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

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



                                     DISTRIBUTION OF VALLEY WATER-AVAILABLE-FOR-RECHARGE

                                          WAFR APPLIED TO VALLEY =  0.5549
                                ------------------------------------------------



                                              REJECTED RECHARGE
                                   (WATER LEVEL AT LAND SURFACE) =  0.0000E+00
              (WATER LEVEL BETWEEN LAND AND PSEUDO-LAND SURFACE) =  0.0000E+00
                                                                (+)---------
                                                           TOTAL =  0.0000E+00


                                                DIRECT RECHARGE =  0.5549

--------------------------------- DISTRIBUTION OF SURFACE RUNOFF FROM UPLANDS -----------------------------------
                                                     (L**3/T)



                                          CHANNELED RUNOFF TO VALLEY
                                        ----------------------------------------



                                        SIMULATED GAIN(-)/LOSS(+) FOR CHANNELS



                                                  STREAMFLOW            STREAMFLOW          NET GAIN(-)
                               ZONE    CHANNEL       AT VALLEY WALL      AT DOWNSTREAM CELL       OR LOSS(+)
                                 2       1        .241995              .942498E-01            0.147745
                                 2       2        .241995              .928131E-01            0.149182
                                 4       1        .507291              .351990                0.155301


        TOTAL CHANNELED UPLAND RUNOFF AVAILABLE TO RECHARGE VALLEY =   0.9913
                                       TOTAL OF CHANNEL GAINS(+) =   0.0000E+00
                                      TOTAL OF CHANNEL LOSSES(-) =   0.4522
                                                                (+)---------
                            TOTAL CHANNELED FLOW TO MAIN STREAM =   0.5391

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


                               STREAMFLOW AND STREAM/AQUIFER INTERACTION FOR CHANNEL REACHES
    ---------------------------------------------------------------------------------------------------------------
    ZONE    CHANNEL    LAYER    ROW    COLUMN     FLOW INTO        FLOW OUT         FLOW INTO        HEAD IN       HEAD IN
                                                  REACH          OF REACH          AQUIFER          REACH         AQUIFER
      2         1        1       5       6      0.2420          0.1820           0.6000E-01        773.0          768.8
      2         1        1       5       7      0.1820          0.1380           0.4400E-01        771.2          768.4
      2         1        1       5       8      0.1380          0.1107           0.2729E-01        769.8          768.0
      2         1        1       5       9      0.1107          0.9425E-01       0.1646E-01        768.8          767.7
      2         2        1       6       6      0.2420          0.1820           0.6000E-01        773.0          768.7
      2         2        1       6       7      0.1820          0.1380           0.4400E-01        771.2          768.4
      2         2        1       6       8      0.1380          0.1099           0.2807E-01        769.8          768.0
      2         2        1       6       9      0.1099          0.9281E-01       0.1711E-01        768.8          767.6
      4         1        1      15       6      0.5073          0.4473           0.6000E-01        773.0          768.3
      4         1        1      15       7      0.4473          0.4033           0.4400E-01        771.2          767.9
      4         1        1      15       8      0.4033          0.3733           0.3000E-01        769.8          767.6
      4         1        1      15       9      0.3733          0.3520           0.2130E-01        768.8          767.4

 ************************************************************************************************************************
```

Appendix 4. Example-model output from U.S. Geological Survey modular 3-D finite-difference ground-water flow model MODFLOW (continued)

```
                                          UNCHANNELED RUNOFF TO VALLEY
                                       -----------------------------------



                       CELL VALUES

                              LAND     AQUIFER   RECHARGE
   ZONE    ROW COLUMN LAYER SURFACE     HEAD      RATE
     1      1     6     1    775.00    767.89  0.3637E-01
     1      2     6     1    775.00    767.93  0.3637E-01
     1      3     6     1    775.00    768.02  0.3637E-01
     1      4     6     1    775.00    768.26  0.3637E-01


                                                                                              TOTALS

                                                                                       AVAILABLE                            REJECTED
                                                                           ZONE          RUNOFF        RECHARGE          RECHARGE


                                                                       -------------------------------------------------------
 ---------------------------------------------------                        1       0.1455         0.1455           0.0000E+00
     2      5     6     1    775.00    768.82  0.2689E-01
     2      6     6     1    775.00    768.74  0.2689E-01
 ---------------------------------------------------                        2       0.5378E-01     0.5378E-01       0.0000E+00
     3      7     6     1    775.00    767.96  0.1835E-01
     3      8     6     1    775.00    767.62  0.1835E-01
     3      9     6     1    775.00    767.47  0.1835E-01
     3     10     6     1    775.00    767.42  0.1835E-01
     3     11     6     1    775.00    767.40  0.1835E-01
     3     12     6     1    775.00    767.42  0.1835E-01
     3     13     6     1    775.00    767.50  0.1835E-01
     3     14     6     1    775.00    767.72  0.1835E-01
 ---------------------------------------------------                        3       0.1468         0.1468           0.0000E+00
     4     15     6     1    775.00    768.28  0.2670E-01
 ---------------------------------------------------                        4       0.2670E-01     0.2670E-01       0.0000E+00
     5     16     6     1    775.00    767.86  0.2959E-01
     5     17     6     1    775.00    767.69  0.2959E-01
     5     18     6     1    775.00    767.64  0.2959E-01
     5     19     6     1    775.00    767.63  0.2959E-01
     5     20     6     1    775.00    767.64  0.2959E-01
 ---------------------------------------------------                        5       0.1480         0.1480           0.0000E+00
     6      1    14     1    775.00    768.40  0.7304E-01
     6      2    14     1    775.00    768.42  0.7304E-01
     6      3    14     1    775.00    768.48  0.7304E-01
     6      4    14     1    775.00    768.57  0.7304E-01
     6      5    14     1    775.00    768.65  0.7304E-01
     6      6    14     1    775.00    768.60  0.7304E-01
     6      7    14     1    775.00    768.43  0.7304E-01
     6      8    14     1    775.00    768.27  0.7304E-01
     6      9    14     1    775.00    768.17  0.7304E-01
     6     10    14     1    775.00    768.11  0.7304E-01
     6     11    14     1    775.00    768.10  0.7304E-01
     6     12    14     1    775.00    768.12  0.7304E-01
     6     13    14     1    775.00    768.18  0.7304E-01
     6     14    14     1    775.00    768.27  0.7304E-01
     6     15    14     1    775.00    768.36  0.7304E-01
     6     16    14     1    775.00    768.34  0.7304E-01
     6     17    14     1    775.00    768.29  0.7304E-01
     6     18    14     1    775.00    768.26  0.7304E-01
     6     19    14     1    775.00    768.25  0.7304E-01
     6     20    14     1    775.00    768.24  0.7304E-01
 ---------------------------------------------------                        6        1.461          1.461           0.0000E+00

                          TOTAL AVAILABLE UNCHANNELED RUNOFF =    1.982

                           TOTAL REJECTED UNCHANNELED RUNOFF =  0.0000E+00

                                  TOTAL UNCHANNELED RECHARGE =    1.982
 ****************************************************************************************************************************


         COMPONENTS OF VARIABLE-RECHARGE TERMS IN VOLUMETRIC BUDGET AT END OF TIME STEP 1 IN STRESS PERIOD 1
    ------------------------------------------------------------------------------------------------------------------

                                   DIRECT RECHARGE TO UPLANDS =  0.6457       (  4.6IN./YR.)
                                    DIRECT RECHARGE TO VALLEY =  0.5549       ( 25.0IN./YR/)
                     VALLEY RECHARGE FROM UNCHANNELED SOURCES =   1.982
                       VALLEY RECHARGE FROM CHANNELED SOURCES =  0.4522
                                                              + -----------
                               VARIABLE-RECHARGE LEAKAGE (IN) =   3.634

                             UPLAND SEEPAGE TO LAND SURFACE   =  0.7772E-01
                             VALLEY SEEPAGE TO LAND SURFACE   =  0.0000E+00
                                 VALLEY DISCHARGE TO CHANNELS =  0.0000E+00
                                                              + -----------
                              VARIABLE-RECHARGE LEAKAGE (OUT) =  0.7772E-01
```

```
                                                ARRAY SHOWING STATUS OF TOPMOST CELLS

        (1----CELLS THAT RECEIVED RECHARGE FROM WAFR)

        (-99----OUTWARD SEEPAGE CELLS)

        (77----CELLS THAT RECEIVED UNCHANNELED RUNOFF)

        (88----CELLS CONTAINING EXPLICITLY SIMULATED STREAMS)

        (66----CELLS CONTAINING A SIMULATED STREAM AND THAT RECEIVED UNCHANNELED RUNOFF FROM UPLANDS)

        (0----INACTIVE OR CONSTANT HEAD CELLS)

       1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19
..................................................................
  1    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
  2    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
  3    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
  4    1-99  1-99  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
  5    1-99-99-99  1 77 88 88 88  0  1  1  1 77  1  1  1  1  1
  6    1-99-99-99  1 77 88 88 88  0  1  1  1 77  1  1  1  1  1
  7    1-99-99-99  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
  8    1-99  1-99  1 77  1  1  1  0  1  1  1 77  1  1  1-99  1
  9    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1-99  1-99  1
 10    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1-99  1-99  1
 11    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1-99  1-99  1
 12    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1-99  1-99  1
 13    1-99  1-99  1 77  1  1  1  0  1  1  1 77  1  1  1-99  1
 14    1-99-99-99  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
 15    1-99-99-99  1 77 88 88 88  0  1  1  1 77  1  1  1  1  1
 16    1-99-99-99  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
 17    1-99  1-99  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
 18    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
 19    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1
 20    1  1  1  1  1 77  1  1  1  0  1  1  1 77  1  1  1  1  1

       1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19
..................................................................

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

                              NUMBER OF SEEPAGE CELLS FOR LAYER 1 =   36

                     36 UPLAND SEEPAGE CELLS REPRESENT  18.6 PERCENT OF UPLAND RECHARGE AREA

                      0 VALLEY SEEPAGE CELLS REPRESENT   0.0 PERCENT OF VALLEY RECHARGE AREA

 ******************************************************************************************************************************
                         HEAD IN LAYER  1 AT END OF TIME STEP  1 IN STRESS PERIOD  1
            ----------------------------------------------------------------------

            1       2       3       4       5       6       7       8       9      10      11      12      13      14      15
           16      17      18      19
...............................................................................................................................

  1    899.94  887.85  859.26  826.58  792.79  767.89  767.56  767.31  767.12  766.99  767.19  767.47  767.86  768.40  793.31
       826.68  859.35  887.94  899.94

  2    899.93  883.62  855.22  822.60  791.54  767.93  767.59  767.34  767.15  767.01  767.22  767.50  767.89  768.42  793.14
       826.13  858.80  887.39  899.94

  3    899.89  872.95  845.03  812.56  788.75  768.02  767.68  767.42  767.22  767.07  767.28  767.56  767.95  768.48  792.71
       824.60  857.24  885.84  899.94

  4    899.85  860.04  832.86  800.35  785.05  768.26  767.90  767.60  767.37  767.20  767.40  767.67  768.05  768.57  792.06
       822.23  854.83  883.44  899.93

  5    899.82  850.48  823.79  791.27  780.65  768.82  768.42  768.02  767.69  767.44  767.60  767.83  768.16  768.65  791.23
       819.27  851.83  880.45  899.91

  6    899.82  848.34  821.76  789.24  779.64  768.74  768.35  767.97  767.65  767.40  767.56  767.78  768.12  768.60  790.27
       816.05  848.56  877.20  899.90

  7    899.83  854.52  827.63  795.11  782.47  767.96  767.68  767.42  767.23  767.08  767.27  767.55  767.92  768.43  789.28
       812.91  845.38  874.04  899.89

  8    899.86  866.42  838.87  806.41  786.73  767.62  767.37  767.17  767.01  766.89  767.10  767.37  767.76  768.27  788.42
       810.20  842.64  871.30  899.88

  9    899.91  878.87  850.69  818.13  789.98  767.47  767.24  767.05  766.91  766.80  767.00  767.27  767.65  768.17  787.79
       808.19  840.63  869.28  899.87

 10    899.94  886.68  858.15  825.47  792.01  767.42  767.18  766.99  766.86  766.76  766.95  767.22  767.60  768.11  787.46
       807.12  839.56  868.21  899.87

 11    899.94  886.68  858.15  825.47  792.00  767.40  767.16  766.98  766.85  766.74  766.94  767.21  767.59  768.10  787.45
```

```
       807.12  839.56  868.21  899.87

  12   899.91  878.87  850.69  818.13  789.95  767.42  767.18  767.00  766.86  766.76  766.96  767.23  767.61  768.12  787.76
       808.19  840.63  869.28  899.87

  13   899.86  866.42  838.87  806.41  786.67  767.50  767.26  767.07  766.93  766.82  767.01  767.29  767.67  768.18  788.36
       810.20  842.64  871.30  899.88

  14   899.83  854.52  827.63  795.11  782.45  767.72  767.47  767.24  767.07  766.94  767.13  767.40  767.77  768.27  789.17
       812.91  845.38  874.04  899.89

  15   899.82  848.34  821.76  789.24  779.61  768.28  767.95  767.64  767.37  767.15  767.31  767.54  767.88  768.36  790.12
       816.04  848.56  877.20  899.90

  16   899.82  850.48  823.79  791.27  780.58  767.86  767.56  767.32  767.13  766.99  767.18  767.45  767.82  768.34  791.04
       819.26  851.83  880.45  899.91

  17   899.85  860.04  832.86  800.35  785.00  767.69  767.41  767.19  767.03  766.90  767.10  767.38  767.77  768.29  791.89
       822.22  854.83  883.44  899.93

  18   899.89  872.95  845.03  812.55  788.54  767.64  767.36  767.14  766.98  766.87  767.07  767.34  767.73  768.26  792.58
       824.60  857.24  885.84  899.94

  19   899.93  883.62  855.22  822.60  791.36  767.63  767.35  767.13  766.97  766.86  767.05  767.33  767.72  768.25  793.03
       826.13  858.80  887.39  899.94

  20   899.94  887.85  859.26  826.57  792.62  767.64  767.35  767.13  766.97  766.85  767.05  767.33  767.71  768.24  793.21
       826.68  859.35  887.94  899.94

HEAD WILL BE SAVED ON UNIT  9 AT END OF TIME STEP  1, STRESS PERIOD  1




                             VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  1
                             ------------------------------------------------------------------------------

                   CUMULATIVE VOLUMES      L**3                                          RATES FOR THIS TIME STEP      L**3/T
                   ------------------                                                    ------------------------

                         IN:                                                                        IN:
                         ---                                                                        ---
                           STORAGE =   0.00000E+00                                                    STORAGE =   0.00000E+00
                     CONSTANT HEAD =   0.00000E+00                                              CONSTANT HEAD =   0.00000E+00
                     RIVER LEAKAGE =   0.00000E+00                                              RIVER LEAKAGE =   0.00000E+00
                  VAR-RECH LEAKAGE =   0.31402E+06                                           VAR-RECH LEAKAGE =    3.6345

                          TOTAL IN =   0.31402E+06                                                   TOTAL IN =    3.6345

                        OUT:                                                                       OUT:
                        ----                                                                       ----
                           STORAGE =   0.00000E+00                                                    STORAGE =   0.00000E+00
                     CONSTANT HEAD =   0.00000E+00                                              CONSTANT HEAD =   0.00000E+00
                     RIVER LEAKAGE =   0.30731E+06                                              RIVER LEAKAGE =    3.5568
                  VAR-RECH LEAKAGE =    6715.3                                               VAR-RECH LEAKAGE =   0.77723E-01

                         TOTAL OUT =   0.31403E+06                                                  TOTAL OUT =    3.6346

                          IN - OUT =   -8.0313                                                       IN - OUT =  -0.92745E-04

               PERCENT DISCREPANCY =                0.00                                 PERCENT DISCREPANCY =                0.00







         TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  1
                                   SECONDS        MINUTES         HOURS          DAYS          YEARS
                                ---------------------------------------------------------------------------
     TIME STEP LENGTH          86400.0        1440.00        24.0000        1.00000       0.273785E-02
   STRESS PERIOD TIME          86400.0        1440.00        24.0000        1.00000       0.273785E-02
TOTAL SIMULATION TIME          86400.0        1440.00        24.0000        1.00000       0.273785E-02
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW).

SUBROUTINE A. Allocation Module (VAR1AL)

This module reads and prints control data and allocates space for the Variable-Recharge Package in the X array (see MAIN program). The X array is the MODFLOW array in which all data arrays and lists for the entire model are stored.

Program listing for module VAR1AL

```
      SUBROUTINE VAR1AL(ISUM,LENX,LCVARR,MXVARR,NVARCH,IN,IOUT,MXCHN,
     1 IVARCB,LCVIZ,LCIZON,NCOL,NROW,NZ,NUTOT,LCRPZ,LCFMX,IMOD,
     2 LCVMX,LCSUMR,LCSUMD,LCTSUM,LCPER,RFACT,LCRES,LCNCHN,LCNCH,LCNUCH,
     3LCIUZ,NUMCH,NUMU,IDRY,LCRUP,LCARZ,LCRIPY,LCRIPN,LCWAFR,LCMBND,SPLM
     4)
C
C-----VERSION JAN2000 VAR1AL
C-----CHANGED CRITERIA OF SEEPAGE NODE IN VAR1FM AND VAR1BD
C     ******************************************************************
C     ALLOCATE ARRAY STORAGE FOR VARIABLE-RECHARGE
C     ******************************************************************
C
C     SPECIFICATIONS:
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
C
C1------IDENTIFY PACKAGE AND INITIALIZE NVARCH ( NUMBER OF CELLS RECEIV-
C1        ING WATER-AVAILABLE-FOR-RECHARGE (WAFR))
      WRITE(IOUT,1) IN
    1 FORMAT(1H0,'VAR1 -- VARIABLE RECHARGE PACKAGE, VERSION 6/95 INPUT
     1 READ FROM UNIT',I3)
      NVARCH=0
C2------READ & PRINT CONTROL DATA FOR VARIABLE RECHARGE PACKAGE.
      READ(IN,2)MXVARR,MXCHN,IVARCB,NZ,NUMCH,NUMU,IMOD,IDRY,RFACT,SPLM
    2 FORMAT(8I5,F10.0,E10.0)
      WRITE(IOUT,3) MXVARR
    3 FORMAT(1H ,'MAXIMUM OF',I5,' VARIABLE RECHARGE NODES')
      IF(NZ.GT.0) WRITE(IOUT,13)
   13 FORMAT(1H ,'UPLAND RUNOFF WILL BE DISTRIBUTED TO VALLEY')
      WRITE(IOUT,303) MXCHN
  303 FORMAT(1H ,'MAXIMUM OF',I3,' CHANNELS PER ZONE')
      WRITE(IOUT,304) NZ
  304 FORMAT(1H ,'NUMBER OF ZONES =',I3)
      WRITE(IOUT,306) NUMCH
  306 FORMAT(1H ,'NUMBER OF CELLS DESIGNATED TO RECEIVE CHANNELED RUNOFF
     1 =',I3)
      WRITE(IOUT,307) NUMU
  307 FORMAT(1H ,'NUMBER OF CELLS DESIGNATED TO RECEIVE UNCHANNELED RUNO
     1FF =',I3)
      NUTOT=NUMCH+NUMU
      WRITE(IOUT,305) NUTOT
  305 FORMAT(1H ,'TOTAL NUMBER OF CELLS DESIGNATED TO RECEIVE UPLAND RUN
     1OFF =',I3)
      WRITE(IOUT,333) IMOD
  333 FORMAT(1H ,'NUMBER OF ITERATIONS BETWEEN ALLOCATION OF RUNOFF =',
     1I3)
      IF(RFACT.EQ.0.) RFACT=0.1
      WRITE(IOUT,335) RFACT
  335 FORMAT(1H ,'DEPTH FOR FULL RECHARGE (RFACT) =',F6.3)
      IF(IDRY.NE.0) WRITE(IOUT,336)
  336 FORMAT(1H ,'IF TOP CELL GOES DRY RECHARGE WILL BE APPLIED TO CELL
     1 UNDERNEATH')
      WRITE(IOUT,337) SPLM
  337 FORMAT(1H ,'FLOW LIMIT TO RELEASE SEEPAGE CELL = ',E12.6)
      IF(IVARCB.GT.0) WRITE(IOUT,9) IVARCB
    9 FORMAT(1H ,'CELL-BY-CELL FLOWS WILL BE RECORDED ON UNIT',I3)
      IF(IVARCB.LT.0) WRITE(IOUT,8)
    8 FORMAT(1H ,'CELL-BY-CELL FLOWS WILL BE PRINTED')
C3------SET LCVARR, THE LOCATION OF THE FIRST ELEMENT OF THE VARIABLE
C3        RECHARGE LIST (VARR), EQUAL TO ISUM, THE ADDRESS OF FIRST UNUSED
C3        SPACE OF THE X ARRAY.
      LCVARR=ISUM
C4------CALCULATE AMOUNT OF ARRAY SPACE USED BY THE PACKAGE; NAMELY BY
C4        ARRAYS: VARR, VIZ, IZONE, RPZ, FMX, VMX, SUMR, SUMD, TSUM, PER
C4        RES, NCHN, NCH, NUCH, RUP, ARZ, WAFR, RIPY, RIPYN AND IUZ.
      ISP=5*MXVARR
      ISUM=ISUM+ISP
      LCVIZ=ISUM
      MZ=NZ
      IF(NZ.EQ.0) MZ=1
      IF(NUTOT.EQ.0) NUTOT=1
      ISUM=ISUM+10*NUTOT
      LCIZON=ISUM
      ISUM=ISUM+NROW*NCOL
      LCRPZ=ISUM
```

```
      ISUM=ISUM+MZ
      LCFMX=ISUM
      ISUM=ISUM+MZ
      LCVMX=ISUM
      ISUM=ISUM+MZ
      LCSUMR=ISUM
      ISUM=ISUM+MZ
      LCSUMD=ISUM
      ISUM=ISUM+MZ
      LCTSUM=ISUM
      ISUM=ISUM+MZ
      LCPER=ISUM
      ISUM=ISUM+MZ
      LCRES=ISUM
      ISUM=ISUM+MZ
      LCNCHN=ISUM
      ISUM=ISUM+MZ*MXCHN
      LCNCH=ISUM
      ISUM=ISUM+MZ
      LCNUCH=ISUM
      ISUM=ISUM+MZ
      LCRUP=ISUM
      ISUM=ISUM+MZ
      LCARZ=ISUM
      ISUM=ISUM+MZ
      LCWAFR=ISUM
      ISUM=ISUM+MZ
      LCRIPY=ISUM
      ISUM=ISUM+MZ
      LCRIPN=ISUM
      ISUM=ISUM+MZ
      LCIUZ=ISUM
      ISUM=ISUM+NUMU
      LCMBND=ISUM
      ISUM=ISUM+NROW*NCOL
      ISP=ISP+10*NUTOT+2*(NROW*NCOL)+15*MZ+MZ*MXCHN+NUMU
C5------PRINT THE AMOUNT OF SPACE USED BY VARIABLE-RECHARGE PACKAGE
      WRITE (IOUT,4)ISP
    4 FORMAT(1X,I6,' ELEMENTS IN X ARRAY ARE USED FOR VARIABLE RECHARGE'
     1)
      ISUM1=ISUM-1
      WRITE(IOUT,5)ISUM1,LENX
    5 FORMAT(1X,I6,' ELEMENTS OF X ARRAY USED OUT OF ',I7)
C6------PRINT WARNING MESSAGE IF SIZE OF X ARRAY EXCEEDS DIMENSION OF X
      IF(ISUM1.GT.LENX) WRITE(IOUT,6)
    6 FORMAT(1X,'   ***X ARRAY MUST BE DIMENSIONED LARGER***')
C7------RETURN
      RETURN
      END
```

List of variables for module VAR1AL

Variable	Range	Definition
ISUM	Global	Index number of the lowest element in the X array which has not yet been allocated. When space is allocated for an array, the size of the array is added to ISUM
LENX	Global	Length of the X array in words. This should always be equal to the dimension of X specified in the MAIN program
LCVARR	Package	Location in the X array of the first element of array VARR
MXVARR	Package	Maximum number of VARR records for simulation
NVARCH	Package	Number of VARR records for stress period; one record per cell
IN	Global	Primary unit number from which input for this package is read
IOUT	Global	Primary unit number for all output. IOUT = 6
MXCHN	Package	Maximum number of simulated streams (channels) for all zones
IVARCB	Package	Flag or unit number on which Variable-Recharge flow is written
LCVIZ	Package	Location in the X array of the first element of array VIZ
LCIZON	Package	Location in the X array of the first element of array IZONE
NCOL	Global	Number of columns in the grid
NROW	Global	Number of rows in the grid
NZ	Package	Number of upland subbasins (zones) in Variable-Recharge zone array
NUTOT	Package	Total number of cells designated to receive unchanneled or channeled runoff
LCRPZ	Package	Location in the X array of the first element of array RPZ
LCFMX	Package	Location in the X array of the first element of array FMX
IMOD	Package	Number of iterations between distribution of upland runoff to specified cells
LCVMX	Package	Location in the X array of the first element of array VMX
LCSUMR	Package	Location in the X array of the first element of array SUMVRR
LCSUMD	Package	Location in the X array of the first element of array SUMVD
LCTSUM	Package	Location in the X array of the first element of array TSUM
LCPER	Package	Location in the X array of the first element of array PER

Variable	Range	Definition
RFACT	Package	Depth (below land surface) to pseudo-land surface
LCRES	Package	Location in the X array of the first element of array SUMRES
LCNCHN	Package	Location in the X array of the first element of array NCHN
LCNCH	Package	Location in the X array of the first element of array NCH
LCNUCH	Package	Location in the X array of the first element of array NUCH
LCIUZ	Package	Location in the X array of the first element of array IUZ
NUMCH	Package	Total number of cells designated to receive channeled runoff
NUMU	Package	Total number of cells designated to receive unchanneled runoff
IDRY	Package	Flag that is used when a cell goes dry
LCRUP	Package	Location in the X array of the first element of array RUP
LCARZ	Package	Location in the X array of the first element of array AREAZ
LCRIPY	Package	Location in the X array of the first element of array RUIPY
LCRIPN	Package	Location in the X array of the first element of array RUIPYN
LCWAFR	Package	Location in the X array of the first element of array TWAFR
LCMBND	Package	Location of the X array of the first element of array MBOUND
SPLM	Package	Minimum flow criteria that must be exceeded before a seepage cell (constant head) is converted to an active cell
ISP	Module	Accumulator--the number of elements of the X array used by this package
MZ	Module	Temporary name for NZ
ISUM1	Module	Total number of X array elements used by all packages thus far

SUBROUTINE B. Read and Prepare Module (VAR1RP)

This module reads and prints input data and builds VIZ and VARR lists.

Program listing for module VAR1RP

```
      SUBROUTINE VAR1RP(VARR,VIZ,IZONE,NVARCH,MXVARR,IN,IOUT,NCOL,NROW,
     1NZ,KPER,NUTOT,RPZ,FMX,VMX,PER,MXCHN,NCH,NCHN,NMUCHN,SUMRCH,NLAY,
     2IBOUND,DELC,DELR,ITMUNI,UCONV,VCONV,AREAU,AREAV,SMURCH,SMVRCH,
     3IUZ,MBOUND,NUMCH,NUMU)
C
C-----VERSION JAN2000 VAR1RP
C     ******************************************************************
C     READ VARIABLE RECHARGE INPUT DATA
C     ******************************************************************
C
C     SPECIFICATIONS:
C     ------------------------------------------------------------------
      DIMENSION VARR(5,MXVARR),VIZ(10,NUTOT),IZONE(NCOL,NROW),MBOUND(NC
     1OL,NROW)
      DIMENSION RPZ(NZ),FMX(NZ),VMX(NZ),PER(NZ),NCH(NZ),NCHN(NZ,MXCHN),
     1NMUCHN(NZ),IBOUND(NCOL,NROW,NLAY),DELC(NROW),DELR(NCOL),IUZ(NUMU)
C     ------------------------------------------------------------------
C
C------IN THE FOLLOWING COMMENT STATEMENTS, WAFR IS THE ABBREVIATION FOR
C      WATER-AVAILABLE-FOR-RECHARGE
C1------INITIALIZE ARRAYS IF FIRST STRESS PERIOD
      IF(KPER.GT.1) GO TO 333
      DO 3031 II=1,NUTOT
      VIZ(1,II)=0.0
      VIZ(2,II)=0.0
      VIZ(3,II)=0.0
      VIZ(4,II)=0.0
      VIZ(5,II)=0.0
      VIZ(6,II)=0.0
      VIZ(7,II)=0.0
      VIZ(8,II)=0.0
      VIZ(9,II)=0.0
      VIZ(10,II)=0.0
 3031 CONTINUE
      DO 3032 I=1,NROW
      DO 3033 J=1,NCOL
      MBOUND(J,I)=0
 3033 IZONE(J,I)=0
 3032 CONTINUE
      DO 3036 II=1,NZ
      VMX(II)=0.0
      FMX(II)=0.0
      PER(II)=0.0
      NCH(II)=0
      NMUCHN(II)=0
 3036 RPZ(II)=0
C
C2------IF NO UPLAND SUBBASINS (NZ=O), UPLAND SURFACE RUNOFF IS NOT
C2        CALCULATED AND DISTRIBUTED TO VALLEY. IF SO, GO TO 333 TO READ
C2        WAFR FOR SIMULATION OF AREAL RECHARGE ONLY
      IF(NZ.EQ.0) GO TO 333
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

```
C
C3------READ AND PRINT DATA THAT DETERMINES HOW UPLAND SURFACE-RUNOFF IS
C3      ALLOCATED (ONCE PER SIMULATION)
      WRITE(IOUT,63)
   63 FORMAT(1H ,//35X,'***** VARIABLE RECHARGE DATA *****')
C
C4------READ AND PRINT MULTIPLICATIVE FACTOR TO MODIFY WAFR OF EACH UP-
C4      LAND ZONE. IF WAFR OF A ZONE IS NOT TO BE MODIFIED, RPZ IS UNITY
      READ(IN,604) (RPZ(II),II=1,NZ)
 604  FORMAT(16F5.0)
      WRITE(IOUT,703) (RPZ(II),II=1,NZ)
  703 FORMAT(1H0,/5X,'PROPORTION OF INPUT WAFR ASSIGNED TO EACH ZONE ='
     115F5.2)
C
C5------READ AND PRINT NUMBER OF SIMULATED TRIBUTARY STREAMS FLOWING
C5      FROM EACH UPLAND ZONE
      READ(IN,603) (NCH(II),II=1,NZ)
      WRITE(IOUT,704) (NCH(II),II=1,NZ)
  704 FORMAT(5X,'NUMBER OF TRIBUTARY STREAMS/CHANNELS PER ZONE =',20I3)
C
C6------READ AND PRINT NUMBER OF CELLS FOR EACH SIMULATED STREAM
      DO 691 II=1,NZ
      NUM=NCH(II)
      IF(NUM.EQ.0) GO TO 691
      READ(IN,603) (NCHN(II,N),N=1,NUM)
      WRITE(IOUT,705)II,(NCHN(II,N),N=1,NUM)
  705 FORMAT(5X,'NUMBER OF CELLS PER CHANNEL FOR ZONE',I3,' ARE:',20I3)
  691 CONTINUE
C
C7------READ AND PRINT NUMBER OF CELLS RECIEVING UPLAND UNCHANNELED
C7      RUNOFF FOR EACH UPLAND SUBBASIN (ZONE)
      READ(IN,603) (NMUCHN(II),II=1,NZ)
      WRITE(IOUT,706) (NMUCHN(II),II=1,NZ)
  706 FORMAT(5X,'NUMBER OF CELLS PER ZONE RECIEVING UNCHANNELED RUNOFF =
     1',20I3)
C
C8------READ PROPORTION (MULTIPLICATIVE FACTOR) OF UPLAND RUNOFF
C8      AVAILABLE TO RECHARGE VALLEY
      READ(IN,604) (FMX(II),II=1,NZ)
      WRITE(IOUT,707) (FMX(II),II=1,NZ)
  603 FORMAT(20I5)
  707 FORMAT(1H0,/5X,'PROPORTION OF UPLAND RUNOFF AVAILABLE TO RECHARGE
     1 VALLEY =',7F10.2)
  605 FORMAT(16F6.2)
C
C9------READ MAXIMUM ALLOWABLE RUNOFF FOR CELLS RECIEVING UNCHANNELED
C9      RUNOFF
      READ(IN,6042) (VMX(II),II=1,NZ)
 6042 FORMAT(8F10.0)
      WRITE(IOUT,708) (VMX(II),II=1,NZ)
  708 FORMAT(1H0,/5X,'MAXIMUM ALLOWABLE UNCHANNELED RUNOFF PER CELL
     1 =',7F10.2)
      READ(IN,604) (PER(II),II=1,NZ)
      WRITE(IOUT,709) (PER(II),II=1,NZ)
  709 FORMAT(1H0,/5X,'PROPORTION OF AVAILABLE UPLAND RUNOFF TREATED AS C
     1HANNELED RUNOFFF =',15F5.2)
 444  IF(NZ.EQ.0) GO TO 333
C
C10-----IF THERE ARE EXPLICITLY SIMULATED STREAMS PRINT TITLE
      IF(NUMCH.GT.0) THEN
      WRITE(IOUT,6387)
 6387 FORMAT(1H ,//5X,'RECHARGE',26X,'DEPTH TO',8X,'DEPTH TO',8X,'DEPTH
     1 TO'/,6X,'RECORD',6X,'ROW',6X,'COLUMN',4X,'WATER SURFACE',2X,'STRE
     2AMBED TOP',2X,'STREAMBED BOTTOM',4X,'CONDUCTANCE')
      WRITE(IOUT,6388)
 6388 FORMAT(5X,95('-'))
      END IF
C
C11-----READ DATA PERTAINING TO CELLS RECIEVING UPLAND CHANNELED RUNOFF
C11     FOLLOWED BY DATA FOR CELLS RECIEVING UNCHANNELED RUNOFF, AND
C11     BUILD VIZ LIST
      DO 69 II=1,NUTOT
      READ(IN,6) ISEQ,IROW,ICOL,DTSS,DTTSB,DTBSB,SBC
    6 FORMAT(3I10,4F10.0)
   62 FORMAT(1X,3I10,3F15.3,F20.6)
      VIZ(1,II)=ISEQ
      VIZ(2,II)=IROW
      VIZ(3,II)=ICOL
      VIZ(4,II)=DTSS
      VIZ(5,II)=DTTSB
      VIZ(6,II)=DTBSB
      VIZ(7,II)=SBC
      VIZ(8,II)=0.0
      VIZ(9,II)=0.0
      VIZ(10,II)=0.0
   69 CONTINUE
C
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

```
C12-----PRINT VIZ RECORDS FOR CELLS RECIEVING CHANNELED RUNOFF
      IF(NUMCH.GT.0) THEN
      DO 409 II=1,NUMCH
      I1=VIZ(1,II)
      I2=VIZ(2,II)
      I3=VIZ(3,II)
  409 WRITE(IOUT,62) ISEQ,IROW,ICOL,VIZ(4,II),VIZ(5,II),VIZ(6,II),VIZ(7
     1,II)
      END IF
C
C13-----PRINT VIZ RECORDS FOR CELLS RECIEVING UNCHANNELED RUNOFF
      IF(NUMU.GT.O) THEN
      WRITE(IOUT,6287)
 6287 FORMAT(1H ,//5X,'RECHARGE',/6X,'RECORD',6X,'ROW',6X,'COLUMN',6X,'Z
     1ONE')
      WRITE(IOUT,6388)
      JJ=0
      DO 303 II=1,NZ
      NN=NMUCHN(II)
      IF(NN.EQ.0) GO TO 303
C
C14-----IUZ IS AN ARRAY USED TO STORE UPLAND ZONE-NUMBERS ASSOCIATED
C14       WITH CELLS RECIEVING UPLAND RUNOFF
      DO 302 LL=1,NN
      JJ=JJ+1
  302 IUZ(JJ)=II
  303 CONTINUE
       ISTART=NUMCH+1
       IEND=ISTART+NUMU-1
       L=0
       DO 410 II=ISTART,IEND
       L=L+1
       I1=VIZ(1,II)
       I2=VIZ(2,II)
       I3=VIZ(3,II)
  410 WRITE(IOUT,23) I1,I2,I3,IUZ(L)
   23 FORMAT(1X,4I10)
      END IF
C
C15-----READ AND PRINT IZONE ARRAY DELINEATING UPLAND SUBBASINS(ZONES)
      DO 79 I=1,NROW
   79 READ(IN,66) (IZONE(J,I),J=1,NCOL)
   66 FORMAT(20I4)
      WRITE(IOUT,65)
   65 FORMAT(1H ,//29X,'*************** VAR-RECH ZONE ARRAY ************
     1****')
      CALL UCOLNO(1,NCOL,4,40,3,IOUT)
      DO 89 I=1,NROW
   89 WRITE(IOUT,67) I,(IZONE(J,I),J=1,NCOL)
  607 CONTINUE
   67 FORMAT(1HO,I3,1X,40(I3)/(5X,40(I3)))
  333 CONTINUE
C
C16-----READ ITMP AND NPRINT; ITMP IS THE NUMBER OF CELLS RECIEVING WAFR
C16       FOR THE STRESS PERIOD OR A FLAG INDICATING THAT DATA (VARR ARRAY)
C16       FROM LAST STRESS PERIOD SHOULD BE REUSED. NPRINT IS A FLAG; TO
C16       SUPRESS PRINTING OF VARR ARRAY DATA, SET NPRINT=1
      READ(IN,8)ITMP,NPRINT
    8 FORMAT(2I10)
C
C17-----TEST ITMP.
      IF(ITMP.GE.0)GO TO 50
C
C18-----IF ITMP <0 THEN REUSE DATA FROM LAST STRESS PERIOD.
      WRITE(IOUT,7)
    7 FORMAT(1H0,'REUSING VARIABLE RECHARGE DATA  FROM LAST STRESS PERIO
     1D')
      GO TO 260
C
C19-----IF ITMP=> ZERO THEN IT IS THE NUMBER OF VARR RECORDS
   50 NVARCH=ITMP
C
C20-----IF NVARCH>MXVARR THEN STOP.
      IF(NVARCH.LE.MXVARR)GO TO 100
      WRITE(IOUT,99)NVARCH,MXVARR
   99 FORMAT(1H0,'NVARCH(',I4,') IS GREATER THAN MXVARR(',I4,')')
C
C21-----ABNORMAL STOP-NUMBER OF CELLS RECIEVING WAFR IN STRESS PERIOD
C21       EXCEEDS SPECIFIED MAXIMUM FOR SIMULATION
      STOP
C
C22-----PRINT NUMBER OF CELLS RECIEVING WAFR  IN THIS STRESS PERIOD
  100 WRITE(IOUT,1)NVARCH
    1 FORMAT(1H0,//1X,I5,' VARIABLE RECHARGE CELLS')
C
C23-----IF THERE ARE NO CELLS  THEN RETURN.
      IF(NVARCH.EQ.0) GO TO 260
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

```
C
C24-----PRINT TITLE IF NPRINT=0
      IF(NPRINT.EQ.0) WRITE(IOUT,3)
    3 FORMAT(1H0,15X,'LAYER',5X,'ROW',5X,'COLUMN',4X,'ELEVATION',10X,'RA
     1TE OF WAFR'/1X,15X,70('-'))
C
C25-----INITIALIZE ACCUMULATORS
      SMURCH=0.0
      SMVRCH=0.0
      AREAU=0.0
      AREAV=0.0
C
C26-----READ WAFR DATA AND BUILD VARR LIST
      DO 250 II=1,NVARCH
      READ(IN,4)K,I,J,VARR(4,II),VARR(5,II)
    4 FORMAT(3I10,2F10.0)
      CVAR=VARR(5,II)
C
C27-----PRINT VARR ARRAY DATA IF NPRINT=0
      IF(NPRINT.NE.0) GO TO 9321
      WRITE(IOUT,5) K,I,J,VARR(4,II),VARR(5,II)
 9321 CONTINUE
    5 FORMAT(1X,15X,I4,I9,I8,4X,F13.2,5X,G14.5)
      VARR(1,II)=K
      VARR(2,II)=I
      VARR(3,II)=J
C
C28-----IF CELL IS INACTIVE DO NOT PROCESS.
      IF(IBOUND(J,I,K).EQ.0) GO TO 250
C
C29-----OBTAIN SUMS OF: WAFR(SMVRCH) AND AREA(AREAV) FOR ACTIVE CELLS IN
C29       VALLEY (IZONE=0); WAFR(SMURCH) AND AREA(AREAU) FOR ACTIVE CELLS
C29       IN THE UPLANDS (IZONE>0)
      IF(IZONE(J,I).EQ.0) THEN
      SMVRCH=SMVRCH+CVAR
      AREAV=AREAV+DELC(I)*DELR(J)
      END IF
      IF(IZONE(J,I).GT.0) THEN
      ILOC=IZONE(J,I)
      SMURCH=SMURCH+CVAR*RPZ(ILOC)
      AREAU=AREAU+DELC(I)*DELR(J)
      END IF
  250 CONTINUE
C30-----SET FLAGS IN MBOUND ARRAY FOR CELLS RECIEVING UPLAND RUNOFF.
C30       MBOUND=77 DENOTES THAT A CELL RECEIVES UNCHANNELED RUNOFF
C30       MBOUND=88 DENOTES THAT A CELL RECEIVES CHANNELED RUNOFF (CELL
C30       IS EXPLICITLY SIMULATED AS A STREAM).
C30       MBOUND=66 DENOTES A CELL THAT RECEIVES BOTH UNCHANNELED AND
C30       CHANNELED RUNOFF.
      DO 799 II=1,NUTOT
      ISEQ=VIZ(1,II)
      K=VARR(1,ISEQ)
      I=VIZ(2,II)
      J=VIZ(3,II)
      SBC=VIZ(7,II)
      IF(SBC.NE.0.0) MBOUND(J,I)=88
      ISET=0
      IF(SBC.LT.1.0E-07.AND.MBOUND(J,I).EQ.88) MBOUND(J,I)=66
      IF(MBOUND(J,I).EQ.66) ISET=66
      IF(SBC.LT.1.0E-07.AND.ISET.NE.66) MBOUND(J,I)=77
 799  CONTINUE
C
C31-----SUM WAFR FOR ALL ACTIVE CELLS
      SUMRCH=SMURCH+SMVRCH
C
C32-----PRINT SMVRCH, SMURCH, SMURCH, AREAV AND AREAU FOR CURRENT
C32       STRESS PERIOD
      WRITE(IOUT,650) KPER,SUMRCH
      WRITE(IOUT,651) SMURCH,AREAU
  651 FORMAT(1H0,/5X,' UPLAND WATER-AVAILABLE-FOR-RECHARGE =',G13.5,' AR
     1EA OF UPLANDS =',F12.1)
      WRITE(IOUT,652) SMVRCH,AREAV
  652 FORMAT(1H0,/5X,' VALLEY WATER-AVAILABLE-FOR-RECHARGE =',G13.5,' AR
     1EA OF VALLEY  =',F12.1)
  650 FORMAT(1H0,/5X,' SUM OF WATER-AVAILABLE-FOR-RECHARGE FOR STRESS PE
     1RIOD',I3,' = ',G13.5)
C
C33-----COMPUTE FACTORS TO CONVERT FLOW TO INCHES PER YEAR.
      GO TO (810,820,830,840,850),ITMUNI
  810 TIME=86400.*365.
      GO TO 888
  820 TIME=1440.*365.
      GO TO 888
  830 TIME=24.*365.
      GO TO 888
  840 TIME=365.
      GO TO 888
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

```
  850 TIME=1.0
  888 CONTINUE
      VCONV=12.*TIME
      UCONV=12.*TIME
C
C34-----RETURN
  260 RETURN
         END
```

List of variables for module VAR1RP

Variable	Range	Definition
VARR	Package	DIMENSION(5, MXVARR), For each cell: a record containing layer, row, column, land-surface elevation and water-available-for-recharge (WAFR)
VIZ	Package	DIMENSION(10,NUTOT), For each cell receiving upland surface runoff the first 3 elements are: VARR record sequence-number, row, and column. In addition, if a cell receives channeled runoff, elements 4, 5, and 6 contain depth below land surface to: stream surface, to top of streambed, and to bottom of streambed. Element 7 contains streambed conductance.
IZONE	Package	DIMENSION(NCOL,NROW), Variable-Recharge zone numbers
NVARCH	Package	Number of VARR records for stress period; one record per cell
MXVARR	Package	Maximum number of VARR records for simulation
IN	Global	Primary unit number from which input for this package is read
IOUT	Global	Primary unit number for all output. IOUT= 6
NCOL	Global	Number of columns in the grid
NROW	Global	Number of rows in the grid
NZ	Package	Number of upland subbasins(zones) in Variable-Recharge zone array
KPER	Global	Stress period counter
NUTOT	Package	Total number of cells receiving unchanneled or channeled runoff
RPZ	Package	Dimension(NZ), For each zone: a multiplicative factor to modify WAFR values
FMX	Package	DIMENSION(NZ), For each zone: a multiplicative factor to modify upland surface runoff
VMX	Package	DIMENSION(NZ), For each zone: upper bound of unchanneled runoff for each cell receiving runoff from the zone
PER	Package	DIMENSION(NZ), For each zone: proportion of upland surface runoff that becomes channeled runoff
MXCHN	Package	Maximum number of simulated streams (channels) for all zones
NCH	Package	DIMENSION(NZ), For each zone: number of simulated streams
NCHN	Package	DIMENSION(NZ,MXCHN), For each stream (channel), of each zone: number of cells containing a stream reach,
NMUCHN	Package	DIMENSION(NZ), For each zone: number of cells receiving unchanneled runoff
SUMRCH	Package	Accumulator--total WAFR applied to model
NLAY	Global	Number of layers in grid
IBOUND	Global	DIMENSION(NCOL,NROW,NLAY), Status of each cell: < 0, constant head; = -99, seepage cell; > 0, variable head cell; = 66, cell receives both unchanneled and channeled runoff; = 77, cell receives channeled runoff; = 88, cell receives unchanneled runoff
DELC	Global	DIMENSION(NROW), Cell dimension in the column direction. DELC(I) contains the width of row I.
DELR	Global	DIMENSION(NCOL), Cell dimension in the row direction. DELR(J) contains the width of column J.
ITMUNI	Package	Code for time units for this problem (see McDonald and Harbaugh,1988)
UCONV	Package	Factor to convert ft/sec to in/yr
VCONV	Package	Factor to convert ft/sec to in/yr
AREAU	Package	Accumulator--for area of active cells in uplands
AREAV	Package	Accumulator--for area of active cells in valley
SMURCH	Package	Accumulator--for total input WAFR to uplands
SMVRCH	Package	Accumulator--for total input WAFR to valley
IUZ	Package	DIMENSION(NUMU), For each cell receiving upland runoff: stores the zone number from which the runoff originates
MBOUND	Package	DIMENSION(NCOL,NROW), Variable Recharge code values of topmost model cells
NUMCH	Package	Total number of cells designated to receive channeled runoff
NUMU	Package	Total number of cells designated to receive unchanneled runoff
II	Module	Index for VIZ records, for zones, and for VARR records
NUM	Module	Temporary name for number of streams(channels) per zone
ISEQ	Module	Temporary name for VIZ(1,II), VARR record sequence-number
IROW	Module	Temporary name for VIZ(2,II), row of cell
ICOL	Module	Temporary name for VIZ(3,II), column of cell
DTSS	Module	Temporary name for VIZ(4,II), depth to stream surface
DTTSB	Module	Temporary name for VIZ(5,II, depth to top of streambed
DTBSB	Module	Temporary name for VIZ(6,II), depth to bottom of streambed
SBC	Module	Temporary name for VIZ(7,II), streambed conductance of streambed
ISET	Module	Temporary name for MBOUND value of cells receiving upland runoff
NN	Module	Temporary name for number of cells, per zone, designated to receive unchanneled runoff
LL	Module	Index for cells designated to receive unchanneled runoff
JJ	Module	Counter for cells designated to receive unchanneled runoff
ISTART	Module	Initial index of VIZ array list for cells receiving unchanneled runoff

Variable	Range	Definition
IEND	Module	Last index of VIZ array list for cells receiving unchanneled runoff
L	Module	Counter for zone number
ITMP	Module	Number of cells receiving WAFR for stress period, or flag indicating VARR array data from previous stress period is to be used
NPRINT	Module	Print flag; If NPRINT = 0, VARR data is printed
K	Module	Temporary name for VARR(1,JJ) and index for layer
I	Module	Temporary name for VARR(2,JJ) and index for rows
J	Module	Temporary name for VARR(3,JJ) and index for columns
CVAR	Module	Temporary name for VARR(5,L), WAFR of cell
ILOC	Module	Temporary name for Variable-Recharge zone number of cell
TIME	Module	Number of model time unit per year

SUBROUTINE C. Formulation Module (VAR1FM)

This module adds terms pertaining to the Variable-Recharge Package to the accumulators HCOF and RHS of the finite-difference equations.

Program listing for module VAR1FM

```
      SUBROUTINE VAR1FM(NVARCH,MXVARR,VARR,HNEW,HCOF,RHS,IBOUND,
     1 NCOL,NROW,NLAY,NZ,VIZ,IZONE,IOUT,NUTOT,RPZ,FMX,IMOD,KITER,
     2 VMX,PER,SUMVRR,SUMVD,TSUM,RFACT,SUMRES,MXCHN,NCH,NCHN,NMUCHN,
     3 CR,CC,CV,MBOUND,IDRY,SPLM)
C
C-----VERSION JAN2000 VAR1FM
C     ****************************************************************
C     ADD VARIABLE RECHARGE TERMS TO RHS AND HCOF
C     ****************************************************************
C
C     SPECIFICATIONS:
C     ----------------------------------------------------------------
C
      DOUBLE PRECISION HNEW,H,HD1,HD2,HD3,HD4,HD5
      DIMENSION VARR(5,MXVARR),HNEW(NCOL,NROW,NLAY),MBOUND(NCOL,NROW),
     1 HCOF(NCOL,NROW,NLAY),RHS(NCOL,NROW,NLAY),IBOUND(NCOL,NROW,NLAY)
      DIMENSION VIZ(10,NUTOT),IZONE(NCOL,NROW),RPZ(NZ),
     1FMX(NZ),VMX(NZ),SUMVRR(NZ),SUMVD(NZ),TSUM(NZ),PER(NZ),SUMRES(NZ),
     2NCH(NZ),NCHN(NZ,MXCHN),NMUCHN(NZ),CR(NCOL,NROW,NLAY),CC(NCOL,NROW,
     3NLAY),CV(NCOL,NROW,NLAY)
C     ----------------------------------------------------------------
C
C-------IN THE FOLLOWING COMMENT STATEMENTS WAFR IS THE ABBREVIATION FOR
C       WATER-AVAILABLE-FOR-RECHARGE
C1------IF NVARCH<=0 THERE ARE NO VARIABLE-RECHARGE RECORDS. RETURN.
      IF(NVARCH.LE.0)RETURN
C
C1A-----INITIALIZE ARRAYS
      DO 79 L=1,NZ
      SUMVRR(L)=0.0
      SUMRES(L)=0.0
      SUMVD(L)=0.0
   79 TSUM(L)=0.0
C
C2------PROCESS EACH CELL IN THE VARR LIST.
      DO 101 L=1,NVARCH
C
C3------GET LAYER, ROW, COLUMN OF CELL RECIEVING WAFR
      Q1=0.0
      Q2=0.0
      Q3=0.0
      Q4=0.0
      Q5=0.0
      QTOT=0.0
      IL=VARR(1,L)
      IR=VARR(2,L)
      IC=VARR(3,L)
      IF(IDRY.NE.0) GO TO 888
      IF(IBOUND(IC,IR,IL).EQ.0) GO TO 101
  888 CONTINUE
C
C4------IF CELL IS DRY AND IDRY IS ZERO, CUTOFF WAFR TO CELL; OTHERWISE
C4       PLACE WAFR IN CELL IN LAYER BELOW
      LL=IL+1
      IIL=IL
      IF(IBOUND(IC,IR,IL).EQ.0.AND.LL.GT.NLAY)  GO TO 101
      IF(IBOUND(IC,IR,IL).EQ.0) IIL=IL+1
      IF(IBOUND(IC,IR,IL).EQ.0) VARR(1,L)=IIL
      IL=IIL
C ********************************************************************
C
```

```
C5------SINCE THE CELL IS INTERNAL GET THE WAFR DATA
      HSURF=VARR(4,L)
      ILOC=IZONE(IC,IR)
      CVAR=VARR(5,L)
      IF(ILOC.NE.0) CVAR=CVAR*RPZ(ILOC)
      RBOT=HSURF-RFACT
      IF(RFACT.EQ.0.0) FACT=1.0
      IF(RFACT.NE.0.0) FACT=1./RFACT
      CVARS=CVAR*FACT
      H=HNEW(IC,IR,IL)
C6------DETERMINE IF THERE IS OUTWARD SEEPAGE IN CELLS WITH SIMULATED
C6      HEAD AT OR BELOW LAND SURFACE THAT ARE NOT A CONVENTIONAL CONS-
C6      TANT HEAD CELL OR DO NOT CONTAIN AN EXPLICITLY SIMULATED STREAM.
C6      COMPUTE NET FLOW BETWEEN CELL AND 5 ADJACENT CELLS. IF NET FLOW
C6      IS INTO CELL (QTOT>0), CELL IS A SEEPAGE CELL AND IS CODED WITH
C6      IBOUND=-99. IF NET FLOW IS OUT OF CELL (QTOT<0), CELL IS MADE
C6      ACTIVE (MBOUND=1)
      IF(IBOUND(IC,IR,IL).LT.0.AND.IBOUND(IC,IR,IL).NE.-99) GO TO 4444
      IF(MBOUND(IC,IR).EQ.88.OR.MBOUND(IC,IR).EQ.66) GO TO 4444
      IF(H.LT.HSURF) GO TO 4444
      IF(IC.GT.1) THEN
      HD1=HNEW(IC-1,IR,IL)-H
      Q1=HD1*CR(IC-1,IR,IL)
      END IF
      IF(IC.LT.NCOL) THEN
      HD2=H-HNEW(IC+1,IR,IL)
      Q2=-HD2*CR(IC,IR,IL)
      END IF
      IF(IR.GT.1) THEN
      HD4=HNEW(IC,IR-1,IL)-H
      Q4=HD4*CC(IC,IR-1,IL)
      END IF
      IF(IR.LT.NROW) THEN
      HD3=H-HNEW(IC,IR+1,IL)
      Q3=-HD3*CC(IC,IR,IL)
      END IF
      IF(IL.LT.NLAY) THEN
      HD5=H-HNEW(IC,IR,IL+1)
      Q5=-HD5*CV(IC,IR,IL)
      END IF
      QTOT=Q1+Q2+Q3+Q4+Q5
C
C6A-----SET SEEPAGE CELLS(IBOUND=-99)
      IF(H.GE.HSURF) THEN
      IBOUND(IC,IR,IL) = -99
      MBOUND(IC,IR)=-99
      HNEW(IC,IR,IL)=HSURF
      END IF
C
C6B-----RELEASE SEEPAGE CELL ONLY IF NET FLOW TO CELL IS NEGATIVE AND
C6B     EXCEEDS FLOW LIMIT(SPLM). THIS IS TO MINIMIZE NEGATIVE FLOW
C6B     THAT MAY RESULT FROM NUMERICAL IMPRECISION
      REL=QTOT+SPLM
      IF(IBOUND(IC,IR,IL).EQ.-99.AND.REL.LE.0.0) THEN
      IBOUND(IC,IR,IL)=1
      MBOUND(IC,IR)=1
      CVARS=0.0
      HNEW(IC,IR,IL)=H
      END IF
      IF(H.LT.HSURF) IBOUND(IC,IR,IL)=1
      IF(H.LT.HSURF) MBOUND(IC,IR)=1
      IF(IBOUND(IC,IR,IL).LT.0) GO TO 100
C
C7------COMPARE AQUIFER HEAD TO PSEUDO-LAND SURFACE (RBOT); IF HEAD IS
C7      BELOW RBOT THERE IS FULL RECHARGE (WAFR=CVARS)
 4444 IF(H.LE.RBOT)GO TO 96
C
C8------SINCE HEAD>RBOT ADD TERMS TO RHS AND HCOF SUCH THAT RECHARGE IS
C8      LINEAR FROM LAND SURFACE TO PSEUDO-LAND SURFACE
      RHS(IC,IR,IL)=RHS(IC,IR,IL)-CVARS*HSURF
      HCOF(IC,IR,IL)=HCOF(IC,IR,IL)-CVARS
      GO TO 100
C
C9-----SINCE HEAD<RBOT ADD TERM ONLY TO RHS.
   96 RHS(IC,IR,IL)=RHS(IC,IR,IL) -CVAR
C
C10-----IF THERE ARE NO UPLAND ZONES PASS TO 101. OTHERWISE CALCULATE
C10     REJECTED RECHARGE(SUMVRR), OUTWARD SEEPAGE(SUMVD), RESIDUAL
C10     RECHARGE(SUMRES) AND SURFACE RUNOFF(TSUM) FOR EACH UPLAND SUB-
C10     BASIN. DO NOT CALCULATE RUNOFF IF ITERATION NUMBER IS NOT AN
C10     INTEGRAL MULTIPLE OF IMOD
  100 IF(NZ.EQ.0) GO TO 101
      IF(MOD(KITER,IMOD).NE.0) GO TO 101
C
C10A----SUM REJECTED RECHARGE AND SEEPAGE FOR UPLAND ZONES
      ILL=IZONE(IC,IR)
      IF(H.LE.RBOT) GO TO 101
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

```
C
C10B----BY-PASS RUNOFF COMPUTATION FOR VALLEY CELLS.
      IF(ILL.EQ.0) GO TO 101
      IF(H.LT.HSURF) GO TO 301
C
C10C----HEAD IS AT SURFACE ELEVATION SO DETERMINE QUANTITY OF
C10C    REJECTED RECHARGE, SEEPAGE, AND RUNOFF FOR EACH ZONE.
      SUMVRR(ILL)=SUMVRR(ILL)+CVAR
      SUMVD(ILL)=SUMVD(ILL)+QTOT
      TSUM(ILL)=TSUM(ILL)+CVAR+QTOT
      GO TO 101
C
C11-----IF HEAD IS BELOW LAND SURFACE BUT ABOVE PSEUDO-LAND SURFACE,
C11     ACCOUNT FOR WAFR THAT DOES NOT ENTER UPLANDS BECAUSE OF LINEAR
C11     RELATION BETWEEN SURFACE AND PSEUDO-LAND SURFACE(SUMRES) AND
C11     ADD TO SURFACE RUNOFF(TSUM)
  301 CONTINUE
      AA=CVAR*(1.-(HSURF-H)*FACT)
      SUMRES(ILL)=SUMRES(ILL) + AA
      TSUM(ILL)=TSUM(ILL) + AA
  101 CONTINUE
C
C12-----DO NOT DISTRIBUTE RUNOFF IF NZ=0 OR IF ITERATION NUMBER IS NOT
C12     AN INTEGRAL MULTILPLE OF IMOD.
      IF(NZ.EQ.0) GO TO 201
      IF(MOD(KITER,IMOD).NE.0) GO TO 201
C
C13-----FOR EACH ZONE, MODIFY UPLAND RUNOFF AVAILABLE TO RECHARGE VALLEY
C13     BY SPECIFIED VALUE OF FMX
      DO 103 L=1,NZ
  103 TSUM(L)=TSUM(L)*FMX(L)
C ******************* PROCESS CHANELED RUNOFF *************************
C14-----DISTRIBUTE PART OF RUNOFF FROM UPLANDS DESIGNATED AS AVAILABLE
C14     CHANNELED RUNOFF TO UPSTREAM CELLS OF SIMULATED STREAMS.
C14     THE AVAILABLE CHANNELED RUNOFF IS APPORTIONED EQUALLY TO EACH
C14     TRIBUTARY STREAM ASSOCIATED WITH AN UPLAND SUBBASIN AND IS THE
C14     FLOW(FLOWIN) AT THE UPSTREAM CELL OF THE SIMULATED STREAM
      JJ=0
      DO 400 L=1,NZ
      NUMCHN=NCH(L)
      IF(NUMCHN.EQ.0) GO TO 400
      AVFLOW=TSUM(L)*PER(L)/NUMCHN
C
C14A----START DO LOOP FOR STREAMS FROM SUBBASIN(ZONE) L
      DO 401 N=1,NUMCHN
      NUMNDS=NCHN(L,N)
      FLOWIN=AVFLOW
C
C14B----START DO LOOP FOR REACHES IN STREAM N. PLACE FLOWIN IN 8TH
C14B    ELEMENT OF VIZ ARRAY RECORD; PROCESS EACH CELL CONTAINING A
C14B    A STREAM REACH IN ORDER ACCORDING TO VIZ LIST
      DO 402 M=1,NUMNDS
      IF(M.NE.1) FLOWIN=VIZ(8,JJ)
      JJ=JJ+1
C
C14C----GET ROW, COLUMN, VARR-LIST RECORD NUMBER, LAYER OF CELL AND
C14C    ELEVATION OF STREAM SURFACE AND TOP AND BOTTOM OF STREAMBED
C14C    FROM VIZ AND VARR ARRAYS
      NR=VIZ(2,JJ)
      NC=VIZ(3,JJ)
      LU=VIZ(1,JJ)
      NL=VARR(1,LU)
      IF(IBOUND(NC,NR,NL).EQ.0) GO TO 402
C
C-------NOTE THAT CODE FROM HERE TO END OF DO-402-LOOP IS EXTRACTED AND
C       MODIFIED FROM PRUDIC STREAM-PACKAGE MODULE (STR1FM)
      HSTR=VARR(4,LU)-VIZ(4,JJ)
      IF(FLOWIN.LE.0.0) HSTR=VARR(4,LU)-VIZ(5,JJ)
      SBOT=VARR(4,LU)-VIZ(6,JJ)
      H=HNEW(NC,NR,NL)
      CSTR=VIZ(7,JJ)
      T=HSTR-SBOT
C
C14D----COMPUTE LEAKAGE(FLOBOT) AS FUNCTION OF HEADS IN STREAM(HSTR)
C14D    AND AQUIFER(H).
      FLOBOT=CSTR*(HSTR-H)
C
C14E----RECOMPUTE LEAKAGE IF HEAD IN AQUIFER IS BELOW STREAMBED
C14E    BOTTOM (SBOT).
      IQFLG=0
      IF(H.GT.SBOT) GO TO 312
      IQFLG=1
      FLOBOT=CSTR*T
C
C14F----SET LEAKAGE EQUAL TO STREAM INFLOW IF LEAKAGE EXCEEDS INFLOW.
  312 IF(FLOBOT.LE.FLOWIN) GO TO 320
      IQFLG=1
```

```
      FLOBOT=FLOWIN
C
C14G----STREAMFLOW OUT(FLOWOT),IS STREAMFLOW IN(FLOWIN) MINUS LEAKAGE
  320 FLOWOT=FLOWIN-FLOBOT
C
C14H----IF STREAMFLOW OUT IS LESS THAN OR EQUAL TO ZERO, FLOWOT= 0
      IF(FLOWOT.LE.0.0) FLOWOT=0.0
C
C14I----STORE STREAM INFLOW, OUTFLOW, AND LEAKAGE FOR EACH REACH IN
C14I    THE 8TH, 9TH AND 10TH ELEMENTS OF CORRESPONDING VIZ RECORD
      VIZ(8,JJ)=FLOWOT
      VIZ(9,JJ)=FLOWIN
      VIZ(10,JJ)=FLOBOT
C
C14J----DO NOT COMPUTE COEFFICIENTS (RHS AND HCOF) FOR SOLUTION IF
C14J    STREAM IS DRY AND LEAKAGE IS POSITIVE
      IF(FLOWIN.LE.0.0.AND.FLOBOT.GE.0.0) GO TO 402
C
C14K----IF HEAD>BOTTOM ALTITUDE ADD TERMS TO RHS AND HCOF.
      IF(IQFLG.GT.0) GO TO 403
      RHS(NC,NR,NL)=RHS(NC,NR,NL) -CSTR*HSTR
      HCOF(NC,NR,NL)=HCOF(NC,NR,NL)-CSTR
      GO TO 402
C
C14L----IF HEAD<BOTTOM ADD TERM TO RHS ONLY.
  403 RHS(NC,NR,NL)=RHS(NC,NR,NL)-FLOBOT
  402 CONTINUE
  401 CONTINUE
  400 CONTINUE
C *********************PROCESS UNCHANNELED FLOW ***********************
      DO 500 L=1,NZ
C
C15-----DETERMINE NUMBER OF CELLS RECIEVING UNCHANNELED RUNOFF FROM
C15     EACH ZONE
      NMUNDS=NMUCHN(L)
      IF(NMUNDS.EQ.0) GO TO 500
C
C15A----GET ROW, COLUMN, VARR-LIST RECORD NUMBER AND LAYER OF CELLS RE-
C15A    CIEVING UPLAND UNCHANNELED RUNOFF AND LAND SURFACE ALTITUDE
C15A    FROM VIZ AND VARR ARRAYS
      DO 501 N=1,NMUNDS
      JJ=JJ+1
      NR=VIZ(2,JJ)
      NC=VIZ(3,JJ)
      LU=VIZ(1,JJ)
      NL=VARR(1,LU)
      IF(IBOUND(NC,NR,NL).EQ.0) GO TO 501
      H=HNEW(NC,NR,NL)
      HSURF=VARR(4,LU)
C
C15B----FOR EACH ZONE, CALCULATE AMOUNT OF UNCHANNELED RUNOFF AND DIV-
C15B    IDE BY THE NUMBER OF CELLS RECIEVING THE RUNOFF, TO GET THE
C15B    AMOUNT OF UNCHANNELED RUNOFF AVAILABLE TO EACH CELL
      VIZ(8,JJ)=TSUM(L)*(1.-PER(L))/NMUNDS
      WA=VIZ(8,JJ)
C
C15C----IF AVAILABLE RUNOFF(WA) EXCEEDS SPECIFIED MAXIMUM (VMX), RESET
C15C    AVAILABLE RUNOFF TO SPECIFIED MAXIMUM
      IF(WA.GT.VMX(L)) WA=VMX(L)
      VIZ(9,JJ)=VMX(L)
      RBOT=HSURF-RFACT
      FACT=1./RFACT
      IF(H.GE.HSURF) GO TO 501
      IF(H.LE.RBOT) GO TO 966
C
C15D----IF HEAD IS BETWEEN LAND SURFACE AND PSDEUDO-LAND SURFACE ADD
C15D    TERMS TO RHS AND HCOF, SUCH THAT RECHARGE IS LINEAR FROM LAND
C15D    SURFACE TO THE PSEUDO-LAND SURFACE
      RHS(NC,NR,NL)=RHS(NC,NR,NL)-WA*HSURF*FACT
      HCOF(NC,NR,NL)=HCOF(NC,NR,NL)-WA*FACT
      URECH=WA*(HSURF-H)*FACT
      GO TO 502
C
C15E----IF HEAD IS BELOW THE PSEUDO-LAND SURFACE(RBOT) ADD TERM TO RHS
C15E    ONLY.
  966 RHS(NC,NR,NL)=RHS(NC,NR,NL) -WA
C
C15F----PLACE UNCHANNELED RECHARGE TO CELL IN 10TH ELEMENT OF CORRES-
C15F    PONDING VIZ RECORD
      URECH=WA
  502 VIZ(10,JJ)=URECH
  501 CONTINUE
  500 CONTINUE
  201 CONTINUE
C
C16-----RETURN
      RETURN
      END
```

List of variables for module VAR1FM

Variable	Range	Definition
NVARCH	Package	Number of VARR records for stress period; one record per cell
MXVARR	Package	Maximum number of VARR records for simulation
VARR	Package	DIMENSION(5,MXVARR), For each cell: a record containing layer, row, column, land-surface elevation and water-available-for-recharge (WAFR)
HNEW	Global	DIMENSION(NCOL,NROW,NLAY), Most recent estimate of head in each cell. HNEW changes at each iteration
HCOF	Global	DIMENSION(NCOL,NROW,NLAY), Coefficient of head in cell (J,I,K) in the finite difference equation
RHS	Global	DIMENSION(NCOL,NROW,NLAY), Right hand side of finite-difference equation. RHS is an accumulation of terms from several different packages
IBOUND	Global	DIMENSION(NCOL,NROW,NLAY), Status of each cell: < 0, constant head; = -99, seepage cell; > 0, variable-head cell; = 66, cell receives both unchanneled and channeled runoff; = 77, cell receives channeled runoff; = 88, cell receives unchanneled runoff
NCOL	Global	Number of columns in the grid
NROW	Global	Number of rows in the grid
NLAY	Global	Number of layers in the grid
NZ	Package	Number of upland subbasins (zones) in Variable -Recharge zone array
VIZ	Package	DIMENSION(10,NUTOT), For each cell receiving upland surface runoff, the first 3 elements are: VARR record sequence-number, row, and column. If cell receives only unchanneled runoff, elements 4, 5, 6, and 7 are blank, and elements 8, 9, and 10 are reserved for available unchanneled-runoff, maximum available unchanneled-runoff and recharge, respectively. If cell receives channeled runoff, elements 4, 5, and 6 contain depth below land surface,to stream surface, to top of streambed, and to bottom of streambed. Element 7 contains streambed conductance. The 8th, 9th, and 10th elements are reserved for simulated streamflow at the upstream and downstream ends of a stream reach and the flow between the stream and underlying aquifer
IZONE	Package	DIMENSION(NCOL,NROW), Variable-Recharge zone numbers
IOUT	Global	Primary unit number for all output. IOUT=6
NUTOT	Package	Total number of cells receiving unchanneled or channeled runoff
RPZ	Package	DIMENSION(NZ), For each zone: a multiplicative factor to modify WAFR values
FMX	Package	DIMENSION(NZ), For each zone: a multiplicative factor to modify upland surface runoff
IMOD	Package	Number of iterations between distribution of upland runoff to specified cells
KITER	Package	Iteration counter
VMX	Package	DIMENSION(NZ), For each zone: upper bound of unchanneled runoff for each cell receiving runoff from the zone
PER	Package	DIMENSION(NZ), For each zone: proportion of upland surface runoff that becomes channeled runoff
SUMVRR	Package	DIMENSION(NZ), For each zone: sum of rejected recharge
SUMVD	Package	DIMENSION(NZ), For each zone: sum of discharge (seepage)
TSUM	Package	DIMENSION(NZ), For each zone: sum of available upland surface runoff
RFACT	Package	Depth (below land surface) to pseudo-land surface
SUMRES	Package	DIMENSION(NZ), For each zone sum of residual recharge
MXCHN	Package	Maximum number of simulated streams (channels) for all zones
NCH	Package	DIMENSION(NZ), For each zone: number of simulated streams
NCHN	Package	DIMENSION(NZ,MXCHN), For each stream (channel) of each zone: number of cells containing a stream reach
NMUCHN	Package	DIMENSION(NZ), For each zone: number of cells receiving unchanneled runoff
CR	Global	DIMENSION(NCOL,NROW,NLAY), Conductance in the row direction, CR(J,I,K) contains conductance between cells (J,I,K) and (J+1,I,K)
CC	Global	DIMENSION(NCOL,NROW,NLAY), Conductance in the column direction, CC(J,I,K) contains conductance between cells (J,I,K) and (J,I+1,K)
CV	Global	DIMENSION(NCOL,NROW,NLAY), Conductance in the layer direction, CV(J,I,K) contains conductance between cells (J,I,K) and (J,I,K+1)
MBOUND	Package	DIMENSION(NCOL,NROW), Variable Recharge code values of topmost model cells
IDRY	Package	Flag that is used when a cell goes dry. If IDRY = 0, WAFR is not applied, If IDRY is not zero, WAFR is applied to active cell below dry cell
SPLM	Package	Minimum flow criteria that must be exceeded before a seepage cell (constant head) is converted to an active cell.
Q1	Module	Flow between cell (J,I,K) and cell(J-1,I,K)
Q2	Module	Flow between cell(J,I,K) and cell(J+1,I,k)
Q3	Module	Flow between cell(J.I.K) and cell(J,I+1,K)
Q4	Module	Flow between cell(J,I,K) and cell(J,I-1,K)
Q5	Module	Flow between cell(J,I,K) and cell(J,I,K+1)
Qtot	Module	Total flow between cell(J,I,K) and 5 adjacent cells.
IL	Module	Temporary name for VARR(1,L), layer of cell receiving WAFR
IR	Module	Temporary name for VARR(2,L), row of cell receiving WAFR
IC	Module	Temporary name for VARR(3,L), column of cell receiving WAFR
LL and IIL	Module	Temporary name for cell layer
HSURF	Module	Temporary name for VARR(4,L), land-surface elevation of cell
RBOT	Module	Elevation of pseudo-land surface
ILOC	Module	Temporary name of Variable-Recharge zone number of cell
CVAR	Module	Temporary name for VARR(5,L), WAFR of cell
CVARS	Module	Proportionality factor used to calculate recharge when head is between land surface and pseudo-land surface
FACT	Module	If RFACT > 0, Fact is reciprocal of RFACT. If RFACT = 0, FACT = 1.0
H	Module	Temporary name for head in cell (J,I,K)
HD1	Module	Head difference between cell(J,I,K) and cell(J-1,I,K)
HD2	Module	Head difference between cell(J,I,K) and cell(J+1,I,K)

Variable	Range	Definition
HD3	Module	Head difference between cell(J,I,K) and cell(J,I+1,K)
HD4	Module	Head difference between cell(J,I,K) and cell(J,I-1,K)
HD5	Module	Head difference between cell(J,I,K) and cell(J,I,K+1)
REL	Module	Net flow between cell(J,I,K) and 5 adjacent cells (sum of QTOT and SPLM)
AA	Module	Part of WAFR applied to a cell that is rejected because head is between land surface and pseudo-land surface
NUMCHN	Module	Temporary name for number of simulated streams in zone
AVFLOW	Module	For each zone: flow applied to upstream cell of each simulated stream
NUMNDS	Module	Temporary name for number of cells, per stream, containing a stream reach
FLOWIN	Module	Streamflow into a reach
M	Module	Index for cells containing a stream reach
JJ	Module	Counter for VIZ records
NR	Module	Temporary name for VIZ(2,JJ), row of cell
NC	Module	Temporary name for VIZ(3,JJ), column of cell
LU	Module	Temporary name for VIZ(1,JJ), VARR record sequence-number
NL	Module	Temporary name for VARR(1,LU), layer of cell
HSTR	Module	Stream stage in reach
SBOT	Module	Elevation of streambed bottom
CSTR	Module	Temporary name for streambed hydraulic conductance
T	Module	Difference between stream stage and elevation of streambed bottom
FLOBOT	Module	Leakage into or out of cell through the streambed
IQFLG	Module	Flag for assigning proper terms to RHS and HCOF. If zero, head in cell is greater than streambed bottom. If one, head in cell is less than or equal to streambed bottom
NMUNDS	Module	Temporary name for number of cells receiving unchanneled runoff for a zone
FLOWOT	Module	Streamflow out of reach
L	Module	Index for zone or VARR record
N	Module	Index for cell receiving upland runoff or simulated stream
WA	Module	For each zone: available unchanneled runoff applied to each cell designated to receive runoff from the zone
URECH	Module	Recharge to cell designated to receive unchanneled runoff

SUBROUTINE D. Budget Module (VAR1BD)

This module calculates in detail how WAFR is distributed to the model and calculates rates and volumes of the Variable-Recharge budget.

Program listing for module VAR1BD

```
      SUBROUTINE VAR1BD(NVARCH,MXVARR,VARR,IBOUND,HNEW,
     1 NCOL,NROW,NLAY,DELT,VBVL,VBNM,MSUM,IBUDFL,KSTP,KPER,IVARCB,
     2 ICBCFL,BUFF,IOUT,PER,NZ,VMX,FMX,
     3 VIZ,IZONE,NUTOT,RPZ,SUMVRR,SUMVD,TSUM,RFACT,SUMRES,MXCHN,
     4 NCH,NCHN,NMUCHN,CR,CC,CV,UCONV,VCONV,DELR,DELC,AREAU,
     5 AREAV,SMURCH,SMVRCH,IDRY,RUP,AREAZ,RUIPY,RUIPYN,TWAFR,MBOUND,
     6SPLM)
C-----VERSION JAN2000 VAR1BD
C-------BUDGET INFORMATION MODIFIED OCT 1993 AND AUGUST 1999
C     ****************************************************************
C     CALCULATE VOLUMETRIC BUDGET FOR VARIABLE RECHARGE
C     ****************************************************************
C
C     SPECIFICATIONS:
C     ----------------------------------------------------------------
      CHARACTER*4 VBNM,TEXT
      DOUBLE PRECISION HNEW,H,HD1,HD2,HD3,HD4,HD5,CVAR,CVARS
      DIMENSION VARR(5,MXVARR),IBOUND(NCOL,NROW,NLAY),
     1 HNEW(NCOL,NROW,NLAY),VBVL(4,20),VBNM(4,20),
     2 BUFF(NCOL,NROW,NLAY),PER(NZ),SUMRES(NZ),MBOUND(NCOL,NROW),
     3 VIZ(10,NUTOT),IZONE(NCOL,NROW),RPZ(NZ),VMX(NZ),FMX(NZ),
     4 SUMVRR(NZ),SUMVD(NZ),TSUM(NZ),NCH(NZ),NCHN(NZ,MXCHN),NMUCHN(NZ),
     5 CR(NCOL,NROW,NLAY),CC(NCOL,NROW,NLAY),CV(NCOL,NROW,NLAY),
     6 DELR(NCOL),DELC(NROW),RUP(NZ),AREAZ(NZ),RUIPY(NZ),RUIPYN(NZ),
     7 TWAFR(NZ)
      DIMENSION TEXT(4)
      DATA TEXT(1),TEXT(2),TEXT(3),TEXT(4) /'VAR-','RECH',' LEA','KAGE'/
C     ----------------------------------------------------------------
C-------IN THE FOLLOWING COMMENT STATEMENTS WAFR IS THE ABBREVIATION FOR
C       WATER-AVAILABLE-FOR-RECHARGE
C1------INITIALIZE CELL-BY-CELL BUDGET TERM FLAG (IBD) AND
C1      ACCUMULATORS FOR MODEL BUDGET TERMS
      IBD=0
      RATIN=0.
      RATOUT=0.
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

```
      RATINV=0.0
      RATINU=0.0
      RATOTU=0.0
      RATOTV=0.0
      RESU=0.0
      RESV=0.0
      REJRU=0.0
      REJRV=0.0
C
C2------IF NO VARIABLE RECHARGE CELLS, KEEP ZEROES IN ACCUMULATORS
      IF(NVARCH.EQ.0) GO TO 200
C
C3------TEST TO SEE IF CELL-BY-CELL TERMS ARE NEEDED.
      IF(ICBCFL.EQ.0.OR.IVARCB.LE.0 ) GO TO 10
C
C3A-----CELL-BY-CELL TERMS ARE NEEDED, SET IBD AND CLEAR BUFFER.
      IBD=1
      DO 5 IL=1,NLAY
      DO 5 IR=1,NROW
      DO 5 IC=1,NCOL
      BUFF(IC,IR,IL)=0.
    5 CONTINUE
C
C4------INITIALIZE ARRAYS, VARIABLES AND ADDITIONAL ACCUMULATORS
   10 CONTINUE
C4A-----INITIALIZE ACCUMULATORS FOR ZONE BUDGET TERMS
      DO 8931 L=1,NZ
      AREAZ(L)=0.0
      TWAFR(L)=0.0
      RUP(L)=0.0
      RUIPY(L)=0.0
      RUIPYN(L)=0.0
 8931 CONTINUE
      SUMVF=0.0
      SUMUF=0.0
      AREAUF=0.0
      AREAVF=0.0
C*************************START MAJOR DO LOOP***************************
      DO 100 L=1,NVARCH
      Q1=0.0
      Q2=0.0
      Q3=0.0
      Q4=0.0
      Q5=0.0
      QTOT=0.0
      RATE=0.0
C
C5------GET LAYER, ROW & COLUMN OF CELL RECIEVING WAFR FROM VARR LIST
      IL=VARR(1,L)
      IR=VARR(2,L)
      IC=VARR(3,L)
C------IF IDRY.EQ.0 AND CELL IS DRY(IBOUND=0) DO NOT PROCESS
      IF(IDRY.NE.0) GO TO 888
      IF(IBOUND(IC,IR,IL).EQ.0) GO TO 100
  888 CONTINUE
C
C6------IF IDRY IS NOT ZERO AND CELL IS DRY(IBOUND=0), PLACE WAFR IN
C6       LAYER BELOW
      LL=IL+1
      IIL=IL
      IF(IBOUND(IC,IR,IL).EQ.0.AND.LL.GT.NLAY) GO TO 100
      IF(IBOUND(IC,IR,IL).EQ.0) IIL=IL+1
      IF(IBOUND(IC,IR,IL).EQ.0)  VARR(1,L)=IIL
      IL=IIL
C
C7------COMPUTE AREA OF ACTIVE CELLS IN UPLANDS AND IN VALLEY.
      IF(IZONE(IC,IR).EQ.0) AREAVF=AREAVF+DELC(IR)*DELR(IC)
      IF(IZONE(IC,IR).GT.0) THEN
      AREAUF=AREAUF+DELC(IR)*DELR(IC)
      LP=IZONE(IC,IR)
      AREAZ(LP)=AREAZ(LP)+DELC(IR)*DELR(IC)
      END IF
C
C8------GET LAND-SURFACE ELEVATION AND WAFR FROM VARR LIST
      HSURF=VARR(4,L)
      ILOC=IZONE(IC,IR)
      CVAR=VARR(5,L)
C
C8A-----MODIFY WAFR OF EACH UPLAND ZONE BY RPZ FACTOR AND ADD TO TWAFR
C8A      (TOTAL WAFR ACCUMULATOR FOR ZONE)
      IF(ILOC.NE.0) CVAR=CVAR*RPZ(ILOC)
      TWAFR(ILOC)=TWAFR(ILOC)+CVAR
      RBOT=HSURF-RFACT
      IF(RFACT.EQ.0.0) FACT=1.0
      IF(RFACT.NE.0.0) FACT=1./RFACT
      CVARS=CVAR*FACT
      H=HNEW(IC,IR,IL)
```

```
C
C9------DETERMINE FINAL SET OF SEEPAGE CELLS AND COMPUTE SEEPAGE.
C9      BYPASS FLOW CALCULATION IF CELL IS A CONVENTIONAL CONSTANT HEAD
C9      CELL OR IF FINAL HEAD IS BELOW LAND SURFACE,OR IF CELL IS PART
C9      OF A CHANNEL (MBOUND=88, OR MBOUND=66)
      IF(IBOUND(IC,IR,IL).LT.0.AND.IBOUND(IC,IR,IL).NE.-99) GO TO 5555
      IF(MBOUND(IC,IR).EQ.88.OR.MBOUND(IC,IR).EQ.66) GO TO 5555
      IF(H.LT.HSURF) THEN
      IBOUND(IC,IR,IL)=1
      MBOUND(IC,IR)=1
      GO TO 5555
      END IF
C
C9A-----COMPUTE FLOW BETWEEN CELL AND 5 ADJACENT CELLS
      IF(IC.GT.1) THEN
      HD1=HNEW(IC-1,IR,IL)-H
      Q1=HD1*CR(IC-1,IR,IL)
      END IF
      IF(IC.LT.NCOL) THEN
      HD2=H-HNEW(IC+1,IR,IL)
      Q2=-HD2*CR(IC,IR,IL)
      END IF
      IF(IR.GT.1) THEN
      HD4=HNEW(IC,IR-1,IL)-H
      Q4=HD4*CC(IC,IR-1,IL)
      END IF
      IF(IR.LT.NROW) THEN
      HD3=H-HNEW(IC,IR+1,IL)
      Q3=-HD3*CC(IC,IR,IL)
      END IF
      IF(IL.LT.NLAY) THEN
      HD5=H-HNEW(IC,IR,IL+1)
      Q5=-HD5*CV(IC,IR,IL)
      END IF
      QTOT=Q1+Q2+Q3+Q4+Q5
C
C9B-----IF WATER LEVEL REACHES LAND SURFACE MAKE A SEEPAGE CELL BY SET-
C9B     TING IBOUND AND MBOUND TO -99
      IF(H.GE.HSURF) THEN
      IBOUND(IC,IR,IL)=-99
      MBOUND(IC,IR)=-99
      HNEW(IC,IR,IL)=HSURF
      RATE=-QTOT
      END IF
C
C9C-----RELEASE SEEPAGE CELL (SET IBOUND = 1), IF NET FLOW TO CELL IS
C9C     NEGATIVE AND EXCEEDS FLOW LIMIT (SPLM)
      REL=QTOT+SPLM
      IF(IBOUND(IC,IR,IL).EQ.-99.AND.REL.LE.0.0) THEN
      IBOUND(IC,IR,IL)=1
      MBOUND(IC,IR)=1
      CVARS=0.0
      END IF
 5555 CONTINUE
C
C10-----IF HEAD>RBOT, RECHARGE IS LINEAR FROM LAND SURFACE TO PSEUDO-
C10     LAND SURFACE; ADD RECHARGE TO RATE ACCUMULATOR
      IF(IBOUND(IC,IR,IL).GT.0) THEN
      IF(H.GT.RBOT)RATE=CVARS*(HSURF-H)
      END IF
C
C10B----IF HEAD<RBOT, THERE IS FULL RECHARGE TO THE CELL; ADD RECH-
C10B    ARGE TO RATE ACCUMULATOR
      IF(IBOUND(IC,IR,IL).GT.0) THEN
      IF(H.LE.RBOT)RATE=CVARS*(HSURF-RBOT)
      END IF
C
C11-----SUM INPUT WAFR FOR ACTIVE CELLS IN VALLEY (SUMVF) AND IN UP-
C11     LANDS (SUMUF)
      IF(IZONE(IC,IR).EQ.0) SUMVF=SUMVF+CVAR
      IF(IZONE(IC,IR).GT.0) SUMUF=SUMUF+CVAR
C
C12-----PRINT HEADING IF CELL-BY-CELL RECHARGE IS TO BE PRINTED
      IF(IVARCB.LT.0.AND.ICBCFL.NE.0) WRITE(IOUT,900) (TEXT(N),N=1,4),
     1    KPER,KSTP,L,IL,IR,IC,RATE
  900 FORMAT(1H0,4A4,'   PERIOD',I3,'   STEP',I3,'  RECORD',I4,
     1    '   LAYER',I3,'   ROW',I4,'   COL',I4,'   RATE',G15.5)
C
C13-----IF CELL-BY-CELL RECHARGE OR DISCHARGE IS TO BE SAVED,
C13     ADD RATE TO BUFFER. FLOW IS PLACED IN LAYER 1 OF BUFF ARRAY
C
C13A----IF HEAD IN CELL IS BELOW LAND SURFACE, FLOW IN BUFF ARRAY
C13A    REPRESENTS RECHARGE; IF CELL IS AN OUTWARD SEEPAGE CELL, FLOW
C13A    IN BUFF ARRAY REPRESENTS DISCHARGE
      IF(IBD.EQ.1) BUFF(IC,IR,1)=BUFF(IC,IR,IL)+RATE
C
C13B----DETERMINE IF FLOW IS INTO OR OUT OF AQUIFER
```

```
      IF(RATE)94,100,96
C
C13C----AQUIFER IS DISCHARGING ; SUBTRACT RATE FROM RATOUT.
   94 RATOUT=RATOUT-RATE
C
C13D----IF A VALLEY CELL, PLACE DISCHARGE IN ACCUMULATOR (RATOTV)
C13D    AND PLACE WAFR IN REJECTED RECHARGE ACCUMULATOR (REJRV)
      IF(IZONE(IC,IR).EQ.0) THEN
      RATOTV=RATOTV-RATE
      REJRV=REJRV+CVAR
      END IF
C
C13E----IF AN UPLAND CELL, PLACE DISCHARGE IN  ACCUMULATOR (RATOTU)
C13E    AND PLACE WAFR IN REJECTED RECHARGE ACCUMULATOR (REJRU)
      IF(IZONE(IC,IR).GT.0) THEN
      RATOTU=RATOTU-RATE
      REJRU=REJRU+CVAR
      END IF
      GO TO 100
C
C14-----RATE IS POSITIVE HENCE AQUIFER IS RECHARGED ; ADD RATE TO RATIN
   96 RATIN=RATIN+RATE
C
C14A----IF A VALLEY CELL, PLACE RECHARGE AND RESIDUAL IN ACCUMULATORS,
C14A    RATINV AND RESV
      IF(IZONE(IC,IR).EQ.0) THEN
      RATINV=RATINV+RATE
      RESV=RESV+(CVAR-RATE)
      END IF
C
C14B----IF AN UPLAND CELL, PLACE RECHARGE AND RESIDUAL IN ACCUMULATORS,
C14B    RATINU AND RESU
      IF(IZONE(IC,IR).GT.0) THEN
      RATINU=RATINU+RATE
      RESU=RESU+(CVAR-RATE)
C
C14C----PLACE DIRECT RECHARGE TO ZONE IN ZONAL ACCUMULATOR (RUP)
      LP=IZONE(IC,IR)
      RUP(LP)=RUP(LP)+RATE
      END IF
  100 CONTINUE
C***************************END MAJOR DO LOOP*************************
C****ALL NVARCH CELLS DESIGNATED TO RECEIVE WAFR HAVE BEEN PROCESSED****
C
C15-----COMPUTE NET(RUIPYN) AND DIRECT(RUIPY) RECHARGE TO ZONES IN IN/YR
      DO 1269 L=1,NZ
      RUIPYN(L)=((RUP(L)-SUMVD(L))/AREAZ(L))*UCONV
 1269 RUIPY(L)=(RUP(L)/AREAZ(L))*UCONV
C
C16-----PRINT VARIABLE-RECHARGE BUDGET IF THERE ARE UPLAND ZONES AND
C16      IF FLAG (IBUDFL) FOR PRINTING VOLUMETRIC BUDGET IS NOT ZERO;
C16      PRINT TITLE, STRESS PERIOD, TIME STEP, AREA OF ACTIVE CELLS
C16      AND WAFR FOR UPLANDS AND VALLEY PARTS OF MODEL
      IF(NZ.EQ.0) GO TO 444
      IF(IBUDFL.EQ.0) GO TO 666
      UCONVF=UCONV/AREAUF
      VCONVF=VCONV/AREAVF
      WRITE(IOUT,5551)
      WRITE(IOUT,71)
   71 FORMAT(1H1,//46('*'),' VARIABLE RECHARGE BUDGET ',45('*'))
      WRITE(IOUT,73) KPER,KSTP
   73 FORMAT(1H0,45X,'STRESS PERIOD',I2,' TIME STEP',I2)
C
C17-----WRITE AREA OF UPLANDS AND VALLEY RECIEVING WAFR AND TOTAL WAFR
      WRITE(IOUT,7723)
      WRITE(IOUT,3276) AREAUF,SUMUF
 3276 FORMAT(1H /32X,'RECHARGE AREA OF UPLANDS =',F12.1,' ---WAFR =',G13
     1.5)
      WRITE(IOUT,3275) AREAVF,SUMVF
 3275 FORMAT(1H /33X,'RECHARGE AREA OF VALLEY =',F12.1,' ---WAFR =',G13.
     15)
      WRITE(IOUT,755)
  755 FORMAT(1H0,//87X,'UPLAND',10X,'UPLAND',4X,'VALLEY CELLS',
     1/27X,'UPLAND',27X,'UPLAND',
     27X,'UPLAND',7X,'AVAILABLE',7X,'AVAILABLE',4X,'RECIEVING',/21X,
     3'REJECTED RECHARGE',10X,'UPLAND',5X,'SURFACE',6X,'AVAILABLE',5X,
     4'CHANNELED',6X,'UNCHANNELED',2X,'UNCHANNELED',/14X,'(H=HSURF)',3X,
     5'(RBOT<H<HSURF)',7X,'SEEPAGE',5X,'RUNOFF',8X,'RUNOFF',9X,'RUNOFF',
     69X,'RUNOFF',7X,'RUNOFF')
 5551 FORMAT(1H0,1X,'***************************************************
     1****************************************************************
     2********')
C
C18-----PRINT UPLAND SUMS FOR EACH SUBBASIN: PRINT REJECTED RECHARGE,
C18      SEEPAGE, SURFACE RUNOFF,AND  AVAILABLE: SURFACE,CHANNELED AND
C18      UNCHANNELED RUNOFF AND NUMBER OF CELLS RECIEVING UNCHANNELED
C18      RUNOFF AS COMPUTED PRIOR TO LAST ITERATION OF MODEL
```

```
      NUNU=0
      TTSUM=0.0
      CSUM=0.0
      USUM=0.0
      DO 79 L=1,NZ
      NMUNDS=NMUCHN(L)
      XX=TSUM(L)*PER(L)
      YY=TSUM(L)-XX
      TT=TSUM(L)/FMX(L)
      USUM=USUM+YY
      CSUM=CSUM+XX
      TTSUM=TTSUM+TT
      NUNU=NUNU+NMUNDS
   79 WRITE(IOUT,78) L,SUMVRR(L),SUMRES(L),SUMVD(L),TT,TSUM(L),
     1XX,YY,NMUCHN(L)
   78 FORMAT(7X,I2,3X,G12.4,3X,G12.4,5X,G12.4,1X,G12.4,1X,G12.4,2X,
     1G12.4,4X,G12.4,5X,I3)
C
C18A----PRINT UPLAND SUMS FOR ENTIRE MODEL: PRINT REJECTED RECHARGE,
C18A    SEEPAGE, SURFACE RUNOFF, AND  AVAILABLE: SURFACE, CHANNELED,
C18A    AND UNCHANNELED RUNOFF AND NUMBER OF CELL RECIEVING UNCHANNELED
C18A    RUNOFF AS COMPUTED PRIOR TO LAST MODEL ITERATION
      SUM=0.0
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 89 L=1,NZ
      SUM3=SUM3+SUMRES(L)
      SUM1=SUM1+SUMVRR(L)
      SUM2=SUM2+SUMVD(L)
   89 SUM=SUM+TSUM(L)
      WRITE(IOUT,7683)
 7683 FORMAT(14X,9('-'),6X,9('-'),8X,9('-'),4X,9('-'),4x,9('-'),5X,9('-'
     1),7X,7('-'),5X,9('-'))
      WRITE(IOUT,7684) SUM1,SUM3,SUM2,TTSUM,SUM,CSUM,USUM,NUNU
 7684 FORMAT(6X,'TOTAL',1X,G12.4,3X,G12.4,5X,G12.4,1X,G12.4,1X,G12.4,2X,
     1G12.4,4X,G12.4,5X,I3)
C
C19-----PRINT RECHARGE SUMMARY FOR EACH UPLAND SUBBASIN; PRINT AREA,
C19     WAFR, DIRECT RECHARGE(WAFR-REJECTED RECHARGE) AND NET RECHARGE
C19     (DIRECT RECHARGE -SEEPAGE)
      WRITE(IOUT,7055)
 7055 FORMAT(1H0,//44X,'RECHARGE SUMMARY'//18X,'AREA',29X,'DIRECT',21X,'
     1NET'/5X,'ZONE',9X,'L**2',10X,'WAFR',9X,'L**3/T',7X,'IN/YR',9X,'L**
     23/T',8X,'IN/YR')
      DO 7057 L=1,NZ
      XNR=RUP(L)-SUMVD(L)
 7057 WRITE(IOUT,7056) L,AREAZ(L),TWAFR(L),RUP(L),RUIPY(L),XNR,RUIPYN(L)
 7056 FORMAT(5X,I2,4X,F11.0,4X,G12.4,3X,G12.4,2X,G12.4,1X,G12.4,4X,G12.4
     1)
 7723 FORMAT(1H0,/35X,'(WAFR IS THE WATER-AVAILABLE-FOR-RECHARGE IN L**3
     1/T)')
      WRITE(IOUT,7726)
 7726 FORMAT(20X,'DIRECT RECHARGE IS THE WAFR MINUS REJECTED RECHARGE')
      WRITE(IOUT,7724)
 7724 FORMAT(20X,'NET RECHARGE IS DIRECT RECHARGE MINUS OUTWARD SEEPAGE'
     1)
      WRITE(IOUT,5551)
      WRITE(IOUT,5551)
  693 FORMAT(5X,' SUM OF VAR-RECH REJECTED RECHARGE AND DISCHARGE FOR NO
     1DE(',I3,',',I3,') IS',G12.4)
C
C20-----PRINT DETAILED SUMMARY OF WAFR UPLAND BUDGET. NOTE THAT MOST OF
C20     THE BUDGET VALUES HAVE BEEN PREVIOUSLY WRITTEN.
      WRITE(IOUT,9121)
 9121 FORMAT(1H0,//,40X,'DISTRIBUTION OF UPLAND WATER-AVAILABLE-FOR-RECH
     1ARGE')
      WRITE(IOUT,9111) SUMUF
 9111 FORMAT(1H0,/44X,'WAFR APPLIED TO UPLANDS =',G12.4)
      WRITE(IOUT,2981)
 2981 FORMAT(35X,50('-'))
      WRITE(IOUT,4114)
 4114 FORMAT(1H0,/49X,'REJECTED RECHARGE')
      REJ=SUM1
      WRITE(IOUT,9112) REJ
 9112 FORMAT(38X,'(WATER LEVEL AT LAND SURFACE) =',G12.4)
      WRITE(IOUT,8112) SUM3
 8112 FORMAT(17X,'(WATER LEVEL BETWEEN LAND AND PSEUDO-LAND SURFACE) =',
     1G12.4)
      WRITE(IOUT,3112)
 3112 FORMAT(69X,'(+)',9('-'))
      TRCH=REJ+SUM3
      WRITE(IOUT,9122) TRCH
 9122 FORMAT(62X,'TOTAL =',G12.4)
      WRITE(IOUT,9113) RATOTU
 9113 FORMAT(1H0,51X,'OUTWARD SEEPAGE =',G12.4)
      WRITE(IOUT,3112)
```

```
      SUM4=SUM1+SUM2+SUM3
      WRITE(IOUT,9114) SUM4
 9114 FORMAT(47X,'TOTAL SURFACE RUNOFF =',G12.4)
      WRITE(IOUT,9115) RATINU
 9115 FORMAT(1H0,/51X,' DIRECT RECHARGE =',G12.4)
      WRITE(IOUT,8113) RATOTU
 8113 FORMAT(52X,'OUTWARD SEEPAGE =',G12.4)
      WRITE(IOUT,2917)
 2917 FORMAT(69X,'(-)',9('-'))
      FAVW=RATINU-RATOTU
      WRITE(IOUT,9116) FAVW
 9116 FORMAT(43X,' NET RECHARGE TO UPLANDS =',G12.4)
      WRITE(IOUT,8114) SUM4
 8114 FORMAT(1H0,/47X,'TOTAL SURFACE RUNOFF =',G12.4)
      UR=SUM4-SUM
      WRITE(IOUT,9117) UR
 9117 FORMAT(41X,'UNAVAILABLE SURFACE RUNOFF =',G12.4)
      WRITE(IOUT,2917)
      WRITE(IOUT,9118) SUM
 9118 FORMAT(43X,'AVAILABLE SURFACE RUNOFF =',G12.4)
      WRITE(IOUT,9119) USUM
 9119 FORMAT(1H0,/39X,'AVAILABLE UNCHANNELED RUNOFF =',G12.4)
      WRITE(IOUT,9120) CSUM
 9120 FORMAT(41X,'AVAILABLE CHANNELED RUNOFF =',G12.4)
      WRITE(IOUT,5551)
      WRITE(IOUT,5551)
C
C20A----PRINT DETAILED SUMMARY OF WAFR BUDGET FOR VALLEY
      WRITE(IOUT,7031)
 7031 FORMAT(1H0,//40X,'DISTRIBUTION OF VALLEY WATER-AVAILABLE-FOR-RECHA
     1RGE')
      WRITE(IOUT,7032) SUMVF
 7032 FORMAT(1H0,/45X,'WAFR APPLIED TO VALLEY =',G12.4)
      WRITE(IOUT,2981)
      WRITE(IOUT,4114)
      WRITE(IOUT,7033) REJRV
 7033 FORMAT(38X,'(WATER LEVEL AT LAND SURFACE) =',G12.4)
      WRITE(IOUT,7034) RESV
 7034 FORMAT(17X,'(WATER LEVEL BETWEEN LAND AND PSEUDO-LAND SURFACE) =',
     1G12.4)
      WRITE(IOUT,3112)
      TRCH=REJRV+RESV
      WRITE(IOUT,9036) TRCH
 9036 FORMAT(62X,'TOTAL =',G12.4)
      WRITE(IOUT,7035) RATINV
 7035 FORMAT(1H0,/52X,'DIRECT RECHARGE =',G12.4)
      WRITE(IOUT,5551)
      WRITE(IOUT,5551)
C
C21-----PRINT HOW UPLAND SURFACE RUNOFF IS DISTRIBUTED TO THE VALLEY
      WRITE(IOUT,694)
  694 FORMAT(1H0,//1X,34('-'),' DISTRIBUTION OF SURFACE RUNOFF FROM UPLA
     1NDS ',36('-'))
      WRITE(IOUT,6863)
 6863 FORMAT(57X,'(L**3/T)')
      IF(MXCHN.EQ.0) GO TO 666
C ********************* PROCESS CHANNELED RUNOFF ***********************
C
C22-----PRINT TITLES FOR CHANNELED RUNOFF OUTPUT
      WRITE(IOUT,3801)
      WRITE(IOUT,622)
      WRITE(IOUT,718)
 3801 FORMAT(1H0,//47X,'CHANNELED RUNOFF TO VALLEY')
  718 FORMAT(1H0,//45X,'SIMULATED GAIN(-)/LOSS(+) FOR CHANNELS')
  622 FORMAT(43X,42('-'))
      WRITE(IOUT,719)
  719 FORMAT(1H0,//54X,'STREAMFLOW',12X,'STREAMFLOW',10X,'NET GAIN(-)'/3
     10X,'ZONE',4X,'CHANNEL',7X,'AT VALLEY WALL',6X,'AT DOWNSTREAM CELL'
     2,7X,'OR LOSS(+)')
  666 CONTINUE
C
C23-----ZERO ACCUMULATORS FOR FLOW IN/OUT OF STREAM (CHANNEL) REACHES,
C23      AND FLOW BETWEEN STREAM AND AQUIFER.
      TCGL=0.0
      TCWA=0.0
      TGAIN=0.0
      TLOSS=0.0
C
C24-----CODE TO COMPUTE FLOWOT,FLOWIN, AND FLOBOT (COMMENTS C25-C25I) IS
C24      SIMILAR TO CODE IN VAR1FM (SEE COMMENTS C14-C14I OF VAR1FM). IT
C24      IS REPEATED HERE TO ACCOUNT FOR FINAL ITERATION HEAD CHANGES
C
C25-----DISTRIBUTE PART OF RUNOFF FROM UPLANDS DESIGNATED AS AVAILABLE
C25      CHANNELED RUNOFF TO UPSTREAM CELLS OF SIMULATED STREAMS.
C25      THE AVAILABLE CHANNELED RUNOFF IS APPORTIONED EQUALLY TO EACH
C25      TRIBUTARY STREAM ASSOCIATED WITH AN UPLAND SUBBASIN AND IS THE
C25      FLOW (FLOWIN) AT THE UPSTREAM CELL OF THE SIMULATED STREAM
```

```
      JJ=0
      DO 400 L=1,NZ
      NUMCHN=NCH(L)
      IF(NUMCHN.EQ.0) GO TO 400
      CFLOW=TSUM(L)*PER(L)
      AVFLOW=CFLOW/NUMCHN
      TCWA=TCWA+CFLOW
C
C25A----START DO LOOP FOR STREAMS FROM SUBBASIN(ZONE) L
      DO 401 N=1,NUMCHN
      NUMNDS=NCHN(L,N)
      FLOWIN=AVFLOW
C
C25B----START DO LOOP FOR REACHES IN STREAM N. PLACE FLOWIN IN 8TH
C25B    ELEMENT OF VIZ ARRAY RECORD; PROCESS EACH CELL CONTAINING A
C25B    STREAM REACH ACCORDING TO VIZ LIST
      DO 402 M=1,NUMNDS
      IF(M.NE.1) FLOWIN=VIZ(8,JJ)
      JJ=JJ+1
C
C25C----GET ROW, COLUMN, VARR-LIST RECORD NUMBER, LAYER OF CELL AND
C25C    ELEVATION OF STREAM SURFACE AND TOP AND BOTTOM OF STREAMBED
C25C    FROM VIZ AND VARR ARRAYS
      NR=VIZ(2,JJ)
      NC=VIZ(3,JJ)
      LU=VIZ(1,JJ)
      NL=VARR(1,LU)
      IF(IBOUND(NC,NR,NL).EQ.0) GO TO 402
      HSTR=VARR(4,LU)-VIZ(4,JJ)
      IF(FLOWIN.LE.0.0) HSTR=VARR(4,LU)-VIZ(5,JJ)
      SBOT=VARR(4,LU)-VIZ(6,JJ)
      H=HNEW(NC,NR,NL)
      CSTR=VIZ(7,JJ)
      T=HSTR-SBOT
C
C25D----COMPUTE LEAKAGE(FLOWBOT) AS FUNCTION OF HEADS IN STREAM(HSTR)
C25D    AND AQUIFER(H)
      FLOBOT=CSTR*(HSTR-H)
C
C25E----RECOMPUTE LEAKAGE IF HEAD IN AQUIFER IS BELOW STREAMBED
C25E    BOTTOM(SBOT)
      IF(H.GT.SBOT) GO TO 312
      FLOBOT=CSTR*T
C
C25F----SET LEAKAGE EQUAL TO STREAM INFLOW IF LEAKAGE EXCEEDS INFLOW.
  312 IF(FLOBOT.LE.FLOWIN) GO TO 320
      FLOBOT=FLOWIN
C
C25G----STREAMFLOW OUT(FLOWOT)IS STREAMFLOW IN(FLOWIN) MINUS LEAKAGE
  320 FLOWOT=FLOWIN-FLOBOT
C
C25H----IF STREAMFLOW OUT IS LESS THAN OR EQUAL TO ZERO,SET FLOWOT TO 0.
      IF(FLOWOT.LE.0.0) FLOWOT=0.0
C
C25I----STORE STREAM INFLOW, OUTFLOW, AND LEAKAGE FOR EACH REACH IN
C25I    8TH, 9TH AND 10TH ELEMENTS OF CORRESPONDING VIZ RECORD
      VIZ(8,JJ)=FLOWOT
      VIZ(9,JJ)=FLOWIN
      VIZ(10,JJ)=FLOBOT
C
C25J----CALCULATE AND PRINT STREAM GAINS AND LOSSES FOR STREAM REACHES
      IF(FLOBOT)494,488,496
C
C26-----FLOW THROUGH BOTTOM OF  IS NEGATIVE HENCE STREAM IS GAINING.
C26     PLACE GAIN IN ACCUMULATORS RATOUT(FOR MODEL) AND TGAIN(FOR CHAN-
C26     NELED RUNOFF) BUDGETS.
  494 RATOUT=RATOUT-FLOBOT
      TGAIN=TGAIN-FLOBOT
      GO TO 488
C
C27-----FLOW THROUGH BOTTOM OF REACH IS POSITIVE HENCE SREAM IS LOSING
C27     PLACE LOSS IN ACCUMULATORS RATIN AND TLOSS
  496 RATIN=RATIN+FLOBOT
      TLOSS=TLOSS+FLOBOT
  488 CONTINUE
  402 CONTINUE
C
C28-----COMPUTE DIFFERENCE BETWEEN FLOW INTO UPSTREAM CELL AND FLOW OUT
C28     OF DOWNSTREAM CELL FOR NTH CHANNEL OF SUBBASIN L AND WRITE NET
C28     GAIN OR LOSS (CRECH) FOR THE CHANNEL
      LL=JJ-NUMNDS+1
      CRECH=VIZ(9,LL)-VIZ(8,JJ)
      IF(IBUDFL.EQ.0) GO TO 7201
      IF(MXCHN.EQ.0) GO TO 7201
      WRITE(IOUT,720) L,N,VIZ(9,LL),VIZ(8,JJ),CRECH
  720 FORMAT(31X,I2,7X,I2,9X,G11.6,11X,G11.6,12X,G13.6)
 7201 CONTINUE
```

```
C
C28A----PLACE NET GAIN OR LOSS IN ACCUMULATOR (TCGL)
      TCGL=TCGL+CRECH
  401 CONTINUE
  400 CONTINUE
C
C29-----PRINT SUMMARY OF DISTRIBUTION OF CHANNELED RUNOFF WITHIN VALLEY
      IF(IBUDFL.EQ.0) GO TO 777
      IF(MXCHN.NE.0) THEN
      WRITE(IOUT,323) TCWA
  323 FORMAT(1H0,/10X,'TOTAL CHANNELED UPLAND RUNOFF AVAILABLE TO RECHAR
     1GE VALLEY = 'G12.4)
      WRITE(IOUT,319) TGAIN
  319 FORMAT(43X,'TOTAL OF CHANNEL GAINS(+) = ',G12.4)
      WRITE(IOUT,318) TLOSS
  318 FORMAT(42X,'TOTAL OF CHANNEL LOSSES(-) = ',G12.4)
      WRITE(IOUT,3112)
      TCRES=TCWA-TCGL
      WRITE(IOUT,823)TCRES
  823 FORMAT(33X,'TOTAL CHANNELED FLOW TO MAIN STREAM = ',G12.4)
      END IF
C
C30-----PRINT STREAM-AQUIFER INTERACTION FOR EACH CHANNEL REACH
      IF(MXCHN.EQ.0) GO TO 913
      WRITE(IOUT,5551)
      WRITE(IOUT,905)
  905 FORMAT(1H0,/30X,'STREAMFLOW AND STREAM/AQUIFER INTERACTION FOR CHA
     1NNEL REACHES')
      WRITE(IOUT,4327)
      WRITE(IOUT,907)
  907 FORMAT(5X,'ZONE',4X,'CHANNEL',4X,'LAYER',4X,'ROW',4X,'COLUMN',5X,'
     1FLOW INTO',8X,'FLOW OUT',9X,'FLOW INTO',8X,'HEAD IN',7X,'HEAD IN'/
     252X,'REACH',10X,'OF REACH',11X,'AQUIFER',10X,'REACH',8X,'AQUIFER')
      JJ=0
      DO 910 L=1,NZ
      NUMCHN=NCH(L)
      IF(NUMCHN.EQ.0) GO TO 910
      DO 911 N=1,NUMCHN
      NUMNDS=NCHN(L,N)
      DO 912 M=1,NUMNDS
      JJ=JJ+1
      NR=VIZ(2,JJ)
      NC=VIZ(3,JJ)
      LU=VIZ(1,JJ)
      NL=VARR(1,LU)
      HSTR=VARR(4,LU)-VIZ(4,JJ)
      IF(VIZ(9,JJ).EQ.0.0) HSTR=VARR(4,LU)-VIZ(5,JJ)
      H=HNEW(NC,NR,NL)
C
C31-----PRINT ORIGIN OF CHANNELED RUNOFF(UPLAND ZONE NUMBER),CHANNEL
C31      NUMBER,LAYER, ROW, COLUMN, STREAMFLOW AT UPSTREAM END OF CELL,
C31      STREAMFLOW AT DOWNSTREAM END OF CELL, FLOW BETWEEN AQUIFER AND
C31      STREAM(IF +, FLOW IS INTO AQUIFER; IF -. FLOW IS INTO STREAM),
C31      HEAD IN REACH AND HEAD IN AQUIFER FOR EACH CELL CONTAINING A
C31      TRIBUTARY STREAM REACH
      WRITE(IOUT,906) L,N,NL,NR,NC,VIZ(9,JJ),VIZ(8,JJ),VIZ(10,JJ),HSTR,H
  906 FORMAT(6X,I2,8X,I2,7X,I2,7X,I2,7X,I2,5X,G11.4,6X,G11.4,6X,G11.4,5X
     1,F8.1,6X,F8.1)
C
C32-----PLACE FLOW BETWEEN CHANNEL AND AQUIFER (FLOBOT) IN BUFF ARRAY OF
C32      LAYER ONE
      IF(IBD.EQ.1) BUFF(NC,NR,1)=BUFF(NC,NR,1)+VIZ(10,JJ)
  912 CONTINUE
  911 CONTINUE
  910 CONTINUE
  913 CONTINUE
C ***************************** PROCESS UNCHANNELED FLOW ***************
      WRITE(IOUT,5551)
      WRITE(IOUT,5551)
C
C33-----PRINT TITLES FOR UNCHANNELED RUNOFF OUTPUT
      WRITE(IOUT,388)
  388 FORMAT(1H0,//45X,' UNCHANNELED RUNOFF TO VALLEY')
      WRITE(IOUT,492)
  492 FORMAT(43X,35('-'))
  387 FORMAT(1H0,/80X,'TOTALS',//73X,'AVAILABLE',21X,'REJECTED',
     1/61X,'ZONE',9X,'RUNOFF'7X,'RECHARGE',8X,'RECHARGE')
      WRITE(IOUT,389)
  389 FORMAT(1H0,/22X,'CELL VALUES',//29X,'LAND',5X,'AQUIFER',3X,'RECHA
     1RGE',/4X,'ZONE',3X,'ROW',1X,'COLUMN',1X,'LAYER',1x,'SURFACE',5X,'
     2HEAD',5X,'RATE')
  777 CONTINUE
C
C34-----COMPUTE QUANTITY OF UNCHANNELED RECHARGE AND RESIDUAL FOR EACH
C34      CELL RECIEVING UNCHANNELED UPLAND RUNOFF
      TUWA=0.0
      TUR=0.0
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

```
      DO 500 L=1,NZ
      NMUNDS=NMUCHN(L)
      IF(NMUNDS.EQ.0) GO TO 500
      SUMWA=0.0
      SUMR=0.0
      DO 501 N=1,NMUNDS
      RATE=0.0
      JJ=JJ+1
      NR=VIZ(2,JJ)
      NC=VIZ(3,JJ)
      LU=VIZ(1,JJ)
      NL=VARR(1,LU)
      H=HNEW(NC,NR,NL)
      HSURF=VARR(4,LU)
C
C34A----DIVIDE AVAILABLE UNCHANNELED UPLAND RUNOFF FOR ZONE L BY NUMBER
C34A    OF CELLS DESIGNATED TO RECEIVE THE RUNOFF(NMUNDS), TO GET AMOUNT
C34A    OF AVAILABLE RUNOFF FOR EACH CELL
      WA=TSUM(L)*(1.-PER(L))/NMUNDS
C
C34B----IF AMOUNT OF AVAILABLE UNCHANNELED RUNOFF PER CELL EXCEEDS
C34B    SPECIFIED MAXIMUM VALUE (VMX) RESET AVAILABLE RUNOFF PER CELL
C34B    TO VMX FOR ZONE L
      IF(WA.GT.VMX(L)) WA=VMX(L)
      RBOT=HSURF-RFACT
      FACT=1./RFACT
C
C34C----IF HEAD IS AT OR ABOVE LAND SURFACE OR CELL HAS 'DRIED UP' THERE
C34C    THERE IS NO UNCHANNELED RECHARGE TO CELL
      IF(IBOUND(NC,NR,NL).EQ.0) GO TO 300
      IF(H.GE.HSURF) GO TO 300
C
C34D----HEAD IS BELOW LAND SURFACE, SET MBOUND VALUE OF CELL TO 77(IF
C34D    CELL DOES NOT CONTAIN A STREAM REACH) TO INDICATE CELL RECEIVES
C34D    UNCHANNELED RECHARGE. IF CELL CONTAINS A SIMULATED STREAM REACH
C34D    AND RECEIVES UNCHANNELED RUNOFF RETAIN THE MBOUND CODE OF 66
      IF(MBOUND(NC,NR).NE.66) MBOUND(NC,NR)=77
C
C34E----HEAD IS BETWEEN LAND SURFACE AND PSEUDO LAND SURFACE SO RECHARGE
C34E    IS LINEAR FROM LAND SURFACE TO PSEUDO LAND SURFACE
      IF(H.LE.RBOT) GO TO 966
      RATE=WA*(HSURF-H)*FACT
      GO TO 502
C
C34F----H IS BELOW PSEUDO LAND SURFACE, RECHARGE EQUALS AVAILABLE RUNOFF
  966 RATE=WA
  502 CONTINUE
      IF(ABS(RATE).LT.1.0E-07) GO TO 300
C
C35-----PLACE UNCHANNELED RECHARGE IN BUFF ARRAY.
      IF(IBD.EQ.1) BUFF(NC,NR,1)=BUFF(NC,NR,NL)+RATE
      RATIN=RATIN+RATE
  300 CONTINUE
C
C36----ADD AVAILABLE RUNOFF AND RECHARGE TO ACCUMULATORS
      SUMWA=SUMWA+WA
      SUMR=SUMR+RATE
      IF(IBUDFL.EQ.0) GO TO 501
C
C37-----PRINT DATA FOR CELLS DESIGNATED TO RECEIVE UNCHANNELED RUNOFF,
C37     PRINT UPLAND SUBBASIN ZONE NUMBER FROM WHICH UNCHANNELED RUNOFF
C37     IS DERIVED, MODEL ROW AND COLUMN, LAND SURFACE ALTITUDE, HEAD IN
C37     CELL, AND RECHARGE RATE
      WRITE(IOUT,6741) L,NR,NC,NL,HSURF,H,RATE
 6741 FORMAT(2X,I5,1x,I5,1x,I5,1x,I5,2F10.2,G12.4)
  501 CONTINUE
C
C38-----CALCULATE REJECTED RECHARGE FOR RUNOFF FROM ZONE L
      RES=SUMWA-SUMR
C
C39-----PLACE AVAILABLE RUNOFF AND RECHARGE TO CELLS DESIGNATED TO RE-
C39     CIEVE THE RUNOFF FROM ZONE L IN ACCUMULATORS
      TUWA=TUWA+SUMWA
      TUR=TUR+SUMR
      IF(IBUDFL.EQ.0) GO TO 500
      IF(L.EQ.1) THEN
      WRITE(IOUT,387)
      WRITE(IOUT,4077)
 4077 FORMAT(1H0,56X,55('-'))
      END IF
C
C40-----PRINT ZONE NUMBER OF SUBBASIN,TOTAL RECHARGE TO CELLS AND
C40     TOTAL REJECTED RECHARGE FOR UPLAND RUNOFF FROM SUBBASIN L
      WRITE(IOUT,386) L,SUMWA,SUMR,RES
  386 FORMAT(1X,51('-'),10X,I2,5X,G12.4,3X,G12.4,5X,G12.4)
  500 CONTINUE
C
```

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

```
C41-----CALCULATE TOTAL REJECTED RECHARGE FOR ALL CELLS DESIGNATED TO
C41     RECEIVE UNCHANNELED RUNOFF
      TURES=TUWA-TUR
      IF(IBUDFL.EQ.0) GO TO 444
C
C42-----PRINT TOTALS OF AVAILABLE UNCHANNELED RUNOFF, REJECTED RECHARGE
C42     AND RECHARGE FOR ALL CELLS THAT RECEIVED UNCHANNELED RUNOFF
      WRITE(IOUT,385) TUWA
  385 FORMAT(1H0,/27X,'TOTAL AVAILABLE UNCHANNELED RUNOFF =',G12.4)
      WRITE(IOUT,383) TURES
      WRITE(IOUT,384) TUR
  384 FORMAT(1H0,34X,'TOTAL UNCHANNELED RECHARGE =',G12.4)
  383 FORMAT(1H0,27X,'TOTAL REJECTED UNCHANNELED RUNOFF ='G12.4)
 6558 FORMAT(43X,40('-'))
 6663 FORMAT(65X,8('-'))
      WRITE(IOUT,5551)
      WRITE(IOUT,5551)
C
C43-----WRITE THE COMPONENTS OF THE "VAR-LEAKAGE IN AND OUT" TERMS THAT
C43     APPEAR IN "THE VOLUMETRIC BUDGET FOR ENTIRE MODEL AT THE END OF
C43     TIME STEP KPER AND STRESS PERIOD KSTP"
      WRITE(IOUT,5560)KPER,KSTP
 5560 FORMAT(1H ,//11X,'COMPONENTS OF VARIABLE-RECHARGE TERMS IN VOLUMET
     1RIC BUDGET AT END OF TIME STEP',I2,' IN STRESS PERIOD',I2)
      WRITE(IOUT,4327)
 4327 FORMAT(5X,116('-'))
      RC1=RATINU*UCONVF
      WRITE(IOUT,5561) RATINU,RC1
 5561 FORMAT(1H ,/33X,'  DIRECT RECHARGE TO UPLANDS =',G12.4,'  (',F5.1,
     1 'IN./YR.)')
      RC2=RATINV*VCONVF
      WRITE(IOUT,5562) RATINV,RC2
 5562 FORMAT(1H ,32X,'   DIRECT RECHARGE TO VALLEY =',G12.4,'  (',F5.1,'
     1IN./YR/)')
      WRITE(IOUT,6563) TUR
 6563 FORMAT(1H ,20X,'VALLEY RECHARGE FROM UNCHANNELED SOURCES =',G12.4)
      WRITE(IOUT,5563) TLOSS
 5563 FORMAT(1H ,22X,'VALLEY RECHARGE FROM CHANNELED SOURCES =',G12.4)
      WRITE(IOUT,6654)
      TTT=RATINU+RATINV+TUR+TLOSS
 6654 FORMAT(1H ,62X,'+ -----------')
      WRITE(IOUT,5564) TTT
 5564 FORMAT(1H ,24X,'      VARIABLE-RECHARGE LEAKAGE (IN) =',G12.4)
      WRITE(IOUT,5565) RATOTU
 5565 FORMAT(1H ,/17X,'            UPLAND SEEPAGE TO LAND SURFACE   =',G
     112.4)
      WRITE(IOUT,5566) RATOTV
 5566 FORMAT(1H ,16X,'             VALLEY SEEPAGE TO LAND SURFACE   =',G1
     12.4)
      WRITE(IOUT,5569) TGAIN
 5569 FORMAT(33X,'VALLEY DISCHARGE TO CHANNELS =',G12.4)
      WRITE(IOUT,6654)
      OOO=RATOTU+RATOTV+TGAIN
      WRITE(IOUT,5567) OOO
 5567 FORMAT(1H ,23X,'      VARIABLE-RECHARGE LEAKAGE (OUT) =',G12.4)
      WRITE(IOUT,5551)
  444 CONTINUE
C
C44-----MOVE RATES,VOLUMES & LABELS INTO ARRAYS FOR PRINTING.
  200 VBVL(3,MSUM)=RATIN
      VBVL(4,MSUM)=RATOUT
      VBVL(1,MSUM)=VBVL(1,MSUM)+RATIN*DELT
      VBVL(2,MSUM)=VBVL(2,MSUM)+RATOUT*DELT
      VBNM(1,MSUM)=TEXT(1)
      VBNM(2,MSUM)=TEXT(2)
      VBNM(3,MSUM)=TEXT(3)
      VBNM(4,MSUM)=TEXT(4)
      IF(IBUDFL.EQ.0) GO TO 111
C
C45-----IF VARIABLE RECHARGE FLOW IS TO BE SAVED CALL ULASAV.
C45     FLOW IN TOPMOST ACTIVE LAYER IS PLACED IN A SINGLE LAYER.
C45     QUANTITY SAVED CONSISTS OF: RECHARGE TO CELL IF HEAD IS BELOW
C45     LAND SURFACE, AND SEEPAGE TO CELL IF HEAD IS AT LAND SURFACE.
C45     IF A TRIBUTARY STREAM REACH RESIDES IN CELL, THE FLOW BETWEEN
C45     AQUIFER AND STREAM (FLOBOT) IS INCLUDED.
      IF(IBD.EQ.1) CALL ULASAV(BUFF,TEXT,KSTP,KPER,1.,1.,NCOL,NROW,1,IVA
     1RCB)
  999 CONTINUE
C
C46-----PRINT MBOUND ARRAY SHOWING CODES FOR VARIABLE RECHARGE IN
C46     TOPMOST MODEL CELLS
      WRITE(IOUT,5551)
      WRITE(IOUT,4634)
 4634 FORMAT(1H /45X,' ARRAY SHOWING STATUS OF TOPMOST CELLS')
      WRITE(IOUT,4638)
 4638 FORMAT(1H0,7X,'(1----CELLS THAT RECEIVED RECHARGE FROM WAFR)')
      WRITE(IOUT,7164)
```

```
 7164 FORMAT(1H0,7X,'(-99----OUTWARD SEEPAGE CELLS)')
      WRITE(IOUT,7165)
 7165 FORMAT(1H0,7X,'(77----CELLS THAT RECEIVED UNCHANNELED RUNOFF)')
        WRITE(IOUT,7166)
 7166 FORMAT(1H0,7X,'(88----CELLS CONTAINING EXPLICITLY SIMULATED STREAM
     1S)')
      WRITE(IOUT,7163)
 7163 FORMAT(1H0,7X,'(66----CELLS CONTAINING A SIMULATED STREAM AND THAT
     1 RECEIVED UNCHANNELED RUNOFF FROM UPLANDS)')
      WRITE(IOUT,4337)
 4337 FORMAT(1H0,7X,'(0----INACTIVE OR CONSTANT HEAD CELLS)')
      CALL UCOLNO(1,NCOL,4,40,3,IOUT)
      DO 4632 IR=1,NROW
 4632 WRITE(IOUT,4633) IR,(MBOUND(IC,IR),IC=1,NCOL)
 4631 CONTINUE
      CALL UCOLNO(1,NCOL,4,40,3,IOUT)
      WRITE(IOUT,5551)
 4633 FORMAT(1HO,I3,1X,40(I3)/(5X,40(I3)))
  111 CONTINUE
C
C47-----CALCULATE SEEPAGE AREA AND IT'S PERCENT OF TOTAL ACTIVE AREA
      DO 5631 IL=1,NLAY
      ISUMU=0
      ISUMV=0
      AREAUS=0.0
      AREAVS=0.0
      DO 5632 IR=1,NROW
      DO 5633 IC=1,NCOL
      IF(IZONE(IC,IR).GT.0.AND.IBOUND(IC,IR,IL).EQ.-99) THEN
      AREAUS=AREAUS+DELC(IR)*DELR(IC)
      ISUMU=ISUMU+1
      END IF
      IF(IZONE(IC,IR).EQ.0.AND.IBOUND(IC,IR,IL).EQ.-99) THEN
      AREAVS=AREAVS+DELC(IR)*DELR(IC)
      ISUMV=ISUMV+1
      END IF
 5633 CONTINUE
 5632 CONTINUE
      ISUMSN=ISUMU+ISUMV
      WRITE(IOUT,1894) IL,ISUMSN
      PERU=(AREAUS/AREAU)*100.
      PERV=(AREAVS/AREAV)*100.
      WRITE(IOUT,1893) ISUMU,PERU
 1893 FORMAT(1H /20X,I4,' UPLAND SEEPAGE CELLS REPRESENT ',F5.1,' PERCEN
     1T OF UPLAND RECHARGE AREA')
      WRITE(IOUT,1892) ISUMV,PERV
 1892 FORMAT(1H /20X,I4,' VALLEY SEEPAGE CELLS REPRESENT ',F5.1,' PERCEN
     1T OF VALLEY RECHARGE AREA')
 1894 FORMAT(1H /30X,' NUMBER OF SEEPAGE CELLS FOR LAYER',I2,' = ',I4)
 5631 CONTINUE
      WRITE(IOUT,5551)
C
C48-----INCREMENT BUDGET COUNTER
      MSUM=MSUM+1
C
C49-----RETURN
      RETURN
      END
```

List of variables for module VAR1BD

Variable	Range	Definition
NVARCH	Package	Number of VARR records for stress period; one record per cell
MXVARR	Package	Maximum number of VARR records for simulation
VARR	Package	DIMENSION(5,MXVARR), For each cell: a record containing layer, row, column, land-surface elevation, and water-available-for-recharge (WAFR)
IBOUND	Global	DIMENSION(NCOL,NROW,NLAY), Status of each cell: < 0, constant head; = -99, seepage cell; > 0, variable-head cell; = 66, cell receives both unchanneled and channeled runoff; = 77, cell receives channeled runoff; = 88, cell receives unchanneled runoff
HNEW	Global	DIMENSION(NCOL,NROW,NLAY), Most recent estimate of head in each cell. HNEW changes each iteration.
NCOL	Global	Number of columns in the grid
NROW	Global	Number of rows in the grid
NLAY	Global	Number of layers in the grid
DELT	Global	Length of current time step
VBVL	Global	DIMENSION(4,20), Entries for the volumetric budget. For flow component N, the values in VBVL are: (1,N), rate for the current time step into the flow field; (2,N), rate for the current time step out of flow field; (3,N), volume into the flow field during simulation; (4,N), volume out of flow field during simulation
VBNM	Global	DIMENSION(4,20), Labels for entries in the volumetric budget
MSUM	Global	Counter for budget entries and labels in VBVL and VBNM
IBUDFL	Global	Budget print flag for time step. If zero, overall budget will not be printed; if not zero, overall budget will be printed
KSTP	Global	Time step counter. Reset at start of each stress period
KPER	Global	Stress period counter

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

Variable	Range	Definition
IVARCB	Package	Flag: If zero, Variable-Recharge flow will not be recorded or printed. If < 0, flow will be printed whenever ICBCFL is set. If > 0, and ICBCFL is set, flow will be recorded on unit = IVARCB
ICBCFL	Global	Flag: If zero, flow (variable recharge) will not be recorded or printed for the current time step. If not zero, flow will be either printed or recorded (depending on IVARCB) for current time step
BUFF	Global	DIMENSION(NCOL,NROW,NLAY), Buffer used to accumulate information before printing or recording it.
IOUT	Global	Primary unit number for all printed output. IOUT = 6.
PER	Package	DIMENSION(NZ), For each zone: proportion of upland surface runoff that becomes channeled runoff
NZ	Package	Number of upland subbasins (zones) in Variable-Recharge zone array
VMX	Package	DIMENSION(NZ), For each zone: upper bound of unchanneled runoff for each cell receiving runoff from the zone
FMX	Package	DIMENSION(NZ), For each zone: a multiplicative factor to modify upland surface runoff
VIZ	Package	DIMENSION(10,NUTOT), For each cell receiving upland surface runoff: VARR record sequence-number, row, and column; all other elements are blank if cell receives only unchanneled runoff. If cell receives channeled runoff, elements 4, 5, and 6 contain depth below land surface: to stream surface, to top of streambed, and to bottom of stream-bed. Element 7 contains streambed conductance. The 8th, 9th and 10th elements are reserved for simulated streamflow at the upstream and downstream ends of a stream reach and the flow between the stream and underlying aquifer.
IZONE	Package	DIMENSION(NCOL,NROW), Variable-Recharge zone numbers
NUTOT	Package	Total number of cells receiving unchanneled or channeled runoff
RPZ	Package	DIMENSION(NZ), For each zone: a multiplicative factor to modify WAFR values
SUMVRR	Package	DIMENSION(NZ), For each zone: sum of rejected recharge
SUMVD	Package	DIMENSION(NZ), For each zone: sum of discharge (seepage)
TSUM	Package	DIMENSION(NZ), For each zone: sum of available upland surface runoff
RFACT	Package	Depth (below land surface) to pseudo-land surface
SUMRES	Package	DIMENSION(NZ), For each zone: sum of residual recharge
MXCHN	Package	Maximum number of simulated streams for all zones
NCH	Package	DIMENSION(NZ), For each zone: number of simulated streams
NCHN	Package	DIMENSION(NZ,MXCHN), For each stream (channel) of each zone: number of cells containing a stream reach
NMUCHN	Package	DIMENSION(NZ), For each zone: number of cells receiving unchanneled runoff
SUMRCH	Package	Accumulator--total WAFR applied to model
CR	Global	DIMENSION(NCOL,NROW,NLAY), Conductance in the row direction, CR(J,I,K) contains conductance between cells(J,I,K) and (J+1,I,K)
CC	Global	DIMENSION(NCOL,NROW,NLAY), Conductance in the column direction, CC(J,I,K) contains conductance between cells (J,I,K) and (J,I+1,K)
CV	Global	DIMENSION(NCOL,NROW,NLAY), Conductance in the layer direction, CV(J,I,K) contains conductance between cells (J,I,K) and (J,I,K+1)
UCONV	Package	Factor to convert ft/sec to in/yr
VCONV	Package	Factor to convert ft/sec to in/yr
DELR	Global	DIMENSION(NCOL), Cell dimension in the row direction. DELR(J) contains the width of column J
DELC	Global	DIMENSION(NROW), Cell dimension in the column direction. DELC(I) contains the width of row I
AREAU	Package	Area of active cells in uplands
AREAV	Package	Area of active cells in valley
SMURCH	Package	Accumulator--for total input WAFR to uplands
SMVRCH	Package	Accumulator--for total input WAFR to valley
IDRY	Package	Flag used when a cell goes dry. If IDRY = 0, WAFR is not applied, If IDRY is not zero, WAFR is applied to active cell below dry cell
RUP	Package	DIMENSION(NZ), For each zone: sum of direct recharge
AREAZ	Package	DIMENSION(NZ), For each zone: area of active cells
RUIPY	Package	DIMENSION(NZ), For each zone: sum of direct recharge in in/yr
RUIPYN	Package	DIMENSION(NZ), For each zone: sum of net recharge in in/yr
TWAFR	Package	DIMENSION(NZ), For each zone: sum of WAFR
MBOUND	Package	DIMENSION(NCOL,NROW), Variable Recharge code values of top most model cells
SPLM	Package	Minimum flow criteria that must be exceeded before a seepage cell (constant head) is converted to an active cell
IBD	Module	
RATIN	Module	Accumulator --recharge to model (uplands and valley)
RATOUT	Module	Accumulator -- discharge (seepage) from model (uplands and valley)
RATINV	Module	Accumulator --direct recharge to valley
RATINU	Module	Accumulator-- direct recharge to uplands
RATOTU	Module	Accumulator--discharge (seepage) from uplands
RATOTV	Module	Accumulator--discharge (seepage) from valley
RESU	Module	Accumulator-- part of upland WAFR that is rejected as a result of linear recharge relation when head is between land surface and pseudo-land surface
RESV	Module	Accumulator-- part of valley WAFR that is rejected as a result of linear recharge relation when head is between land surface and pseudo-land surface
REJRU	Module	Accumulator--upland WAFR that is rejected when head is at or above land surface
REJRV	Module	Accumulator--valley WAFR that is rejected when head is at or above land surface
SUMVF	Module	Accumulator--WAFR applied to valley
SUMUF	Module	Accumulator--WAFR applied to uplands
AREAUF	Module	Accumulator--active area of uplands
AREAVF	Module	Accumulator--active area of valley
Q1	Module	Flow between cell(J,I,K) and cell(J-1,I,K)
Q2	Module	Flow between cell(J,I,K) and cell(J+1,I,K)

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

Variable	Range	Definition
Q3	Module	Flow between cell(J,I,K) and cell(J,I+1,K)
Q4	Module	Flow between cell(J,I,K) and cell(J,I-1,K)
Q5	Module	Flow between cell(J,I,K) and cell(J,I,K+1)
QTOT	Module	Total flow between cell(J,I,K) and 5 adjacent cells.
RATE	Module	Accumulator--for flow; recharge (plus flow) or discharge (negative flow)
IL	Module	Temporary name for VARR(1,L), and index for layer
IR	Module	Temporary name for VARR(2,L), and index for row
IC	Module	Temporary name for VARR(3,L), and index for column
LL	Module	Temporary name for cell layer
IIL	Module	Temporary name for cell layer
LP and ILOC	Module	Temporary name for Variable-Recharge zone number of cell
HSURF	Module	Temporary name for VARR(4,L), land-surface elevation of cell
CVAR	Module	Temporary name for VARR(5,L), WAFR of cell
RBOT	Module	Elevation of pseudo-land surface
FACT	Module	If RFACT > 0, FACT is reciprocal of RFACT. If RFACT = 0, Fact =1.0
CVARS	Module	Proportionality factor used to calculate recharge when head is between land surface and pseudo-land surface
H	Module	Temporary name for head in cell (J,I,K)
HD1	Module	Head difference between cell(J,I,K) and cell(J-1,I,K)
HD2	Module	Head difference between cell(J,I,K) and cell(J+1,I,K)
HD3	Module	Head difference between cell(J,I,K) and cell(J,I+1,K)
HD4	Module	Head difference between cell(J,I,K) and cell(J,I-1,K)
HD5	Module	Head difference between cell(J,I,K) and cell(J,I,K+1)
REL	Module	Net flow between cell(J,I,K) and 5 adjacent cells (sum of QTOT and SPLM)
UCONVF	Module	Factor to convert cubic ft/sec to in/yr
VCONVF	Module	Factor to convert cubic ft/sec to in/yr
NUNU	Module	Accumulator--For model: number of cells receiving unchanneled recharge
TTSUM	Module	Accumulator--For model: upland surface runoff
CSUM	Module	Accumulator--For model: available channeled runoff
NMUNDS	Module	Accumulator--For each zone: number of cells receiving unchanneled runoff
USUM	Module	Accumulator--For model: available unchanneled runoff
XX	Module	Accumulator--For each zone: available channeled runoff
YY	Module	Accumulator--For each zone: available unchanneled runoff
TT	Module	Accumulator--For each zone: upland surface runoff
SUM	Module	Accumulator-For model: available upland surface runoff
SUM1	Module	Accumulator--For model: upland rejected recharge
SUM2	Module	Accumulator-For model: upland discharge (seepage)
SUM3	Module	Accumulator--For model: upland residual recharge (part of WAFR rejected because head is between landsurface and pseuso-land surface
XNR	Module	For model: total upland recharge
SUMUF	Module	Accumulator--For model: WAFR applied to uplands
SUMVF	Module	Accumulator--For model: WAFR applied to valley
REJ	Module	For model: upland rejected recharge (when water level is at or above land surface)
TRCH	Module	For model: total upland rejected recharge
SUM4	Module	For model: total upland surface runoff
FAVW	Module	For model: total net recharge to uplands
UR	Module	For model: unavailable upland surface runoff
TCGL	Module	Accumulator--For all streams: total net gains or losses
TCWA	Module	Accumulator--For model: total available channeled runoff
JJ	Module	Index for Viz record corresponding to cell containing a stream reach
TGAIN	Module	Accumulator--For model: total of stream gains
TLOSS	Module	Accumulator--For model: total of stream losses
L	Module	Index for upland zone numbers 1, 2,.....NZ
NUMCHN	Module	Temporary name for number of simulated streams (channels) in zone
CFLOW	Module	Temporary name for available channeled runoff for zone
AVFLOW	Module	For each zone: flow applied to upstream cell of each simulated stream
N	Module	For each zone: index for number of streams (channels)
NUMNDS	Module	Temporary name for number of cells, per stream, containing a stream reach
FLOWIN	Module	Streamflow into a stream reach
M	Module	Index for number of cells comprising stream N of zone L
NR	Module	Temporary name for VIZ(2,JJ), row of cell
NC	Module	Temporary name for VIZ(3,JJ), column of cell
LU	Module	Temporary name for VIZ(1,JJ), VARR record sequence-number

Appendix 5. List of program and variables for Variable-Recharge Package of U.S. Geological Survey modular finite-difference ground-water flow model (MODFLOW) (continued).

Variable	Range	Definition
NL	Module	Temporary name of VARR(1,LU), layer number of cell
HSTR	Module	Stream stage in reach
SBOT	Module	Elevation of stream bottom
CSTR	Module	Temporary name for streambed hydraulic conductance
T	Module	Difference between stream stage and elevation of streambed bottom
FLOBOT	Module	Leakage into or out of cell through the streambed
FLOWOT	Module	Streamflow out of reach
LL	Module	Index of first (upstream) cell of a simulated stream
CRECH	Module	Difference between flow in first (upstream) cell of a stream and flow in last cell (downstream) or flow to “main stream” of valley. If positive there is a net stream loss; if negative there is a net stream gain
TCRES	Module	Difference between total available channeled runoff and TCGL
TUWA	Module	Accumulator--For model: total available unchanneled runoff
TUR	Module	Accumulator--For model: total recharge from unchanneled runoff
SUMWA	Module	Accumulator--For each zone: total available unchanneled runoff
SUMR	Module	Accumulator--For each zone: total unchanneled recharge to cells designated to receive the runoff from the zone
WA	Module	For each zone: available unchanneled runoff applied to each cell designated to receive runoff from the zone
RES	Module	For each zone: total unchanneled runoff that is rejected
TURES	Module	For model: total unchanneled runoff that is rejected
RC1	Module	For model: direct recharge to uplands in in/yr
RC2	Module	For model: direct recharge to valley in in/yr
TTT	Module	For model: total recharge to uplands and valley for Variable-Recharge package. Same as volumetric budget term"VAR-RECH LEAKAGE (IN)”
OOO	Module	For model: total discharge from uplands and valley for Variable-Recharge package. Same as volumetric budget term"VAR-RECH LEAKAGE (OUT)"
ISUMSN	Module	Accumulator--For model: number of seepage cells
ISUMU	Module	Accumulator--For model: number of upland seepage cells
ISUMV	Module	Accumulator--For model: number of valley seepage cells
AREAUS	Module	Accumulator--For model: area of upland seepage cells
AREAVS	Module	Accumulator--For model: area of valley seepage cells
PERU	Module	Percentage of active upland area containing seepage cells
PERV	Module	Percentage of active valley area containing seepage cells