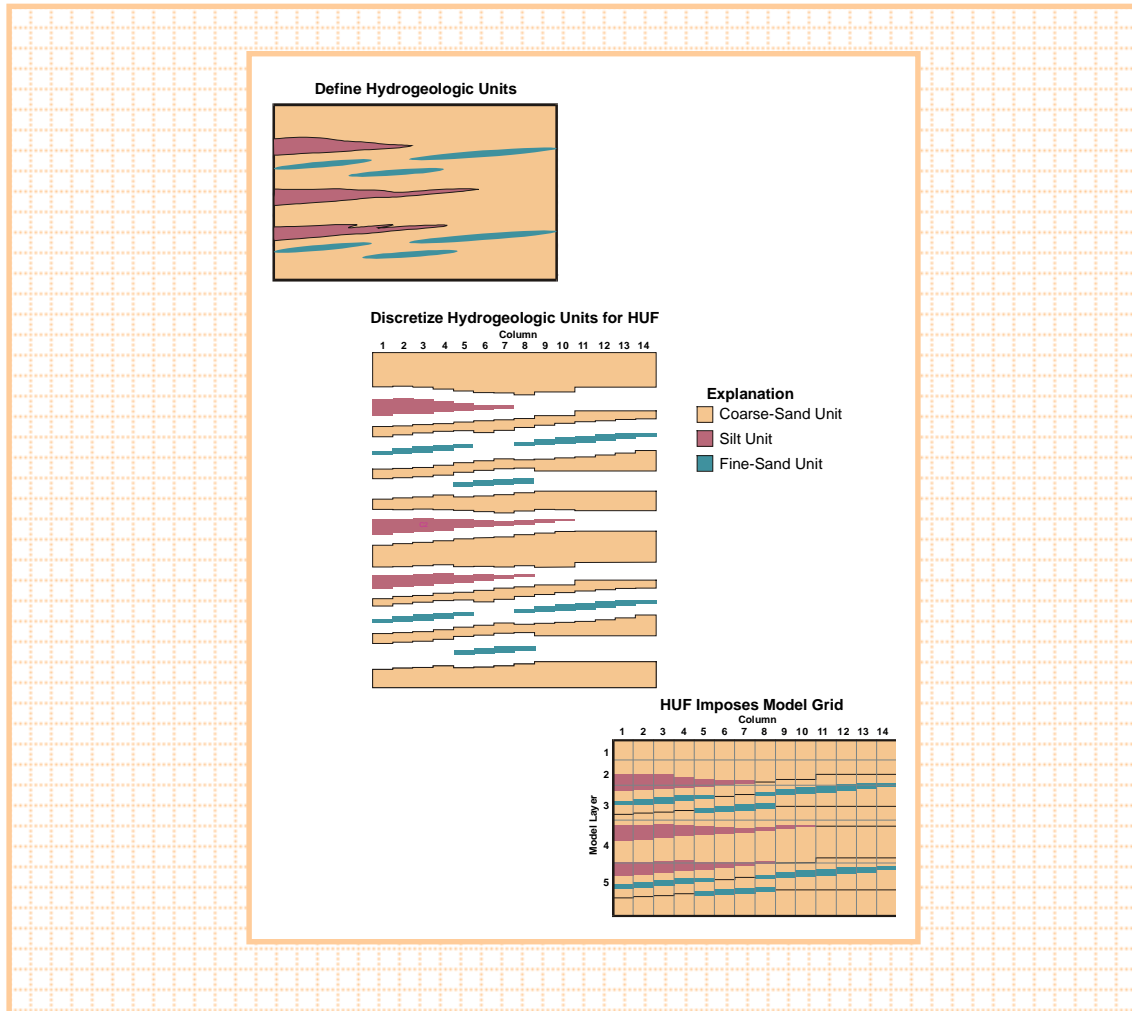




Prepared in cooperation with the
U.S. Department of Energy

MODFLOW-2000, THE U.S. GEOLOGICAL SURVEY MODULAR GROUND-WATER MODEL — DOCUMENTATION OF THE HYDROGEOLOGIC-UNIT FLOW (HUF) PACKAGE

Open-File Report 00-342



U.S. Department of the Interior
U.S. Geological Survey

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FLOW (HUF) PACKAGE**

By EVAN R. ANDERMAN¹ *and* MARY C. HILL²

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Denver, Colorado
2000

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PREFACE

This report describes the Hydrogeologic-Unit Flow (HUF) Package for the computer program MODFLOW-2000. The performance of the program has been tested in a variety of applications. Future applications, however, might reveal errors that were not detected in the test simulations. Users are requested to notify the U.S. Geological Survey of any errors found in this document or the computer program using the email address available at the web address below. Updates might occasionally be made to both this document and to HUF. Users can check for updates on the Internet at URL http://water.usgs.gov/software/ground_water.html/.

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**MODFLOW-2000,
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DOCUMENTATION OF THE
HYDROGEOLOGIC-UNIT FLOW (HUF) PACKAGE**

By Evan R. Anderman¹ *and* Mary C. Hill²

ABSTRACT

This report documents the Hydrogeologic-Unit Flow (HUF) Package for the ground-water modeling computer program MODFLOW-2000. The HUF Package is an alternative internal flow package that allows the vertical geometry of the system hydrogeology to be defined explicitly within the model using hydrogeologic units that can be different than the definition of the model layers. The HUF Package works with all the processes of MODFLOW-2000. For the Ground-Water Flow Process, the HUF Package calculates effective hydraulic properties for the model layers based on the hydraulic properties of the hydrogeologic units, which are defined by the user using parameters. The hydraulic properties are used to calculate the conductance coefficients and other terms needed to solve the ground-water flow equation. The sensitivity of the model to the parameters defined within the HUF Package input file can be calculated using the Sensitivity Process, using observations defined with the Observation Process. Optimal values of the parameters can be estimated by using the Parameter-Estimation Process. The HUF Package is nearly identical to the Layer-Property Flow (LPF) Package, the major difference being the definition of the vertical geometry of the system hydrogeology. Use of the HUF Package is illustrated in two test cases, which also serve to verify the performance of the package by showing that the Parameter-Estimation Process produces the true parameter values when exact observations are used.

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INTRODUCTION

Ground-water flow models are, by definition, simplified representations of often highly complex hydrogeologic flow systems. Generally, incorporating as much available hydrogeologic information as possible into the formulation of the conceptual and numerical models of the flow system is advantageous. This hydrogeologic information takes many forms, including maps that show outcropping surfaces of geologic units and faults, cross sections derived from geophysical surveys and well-bore information that show the likely subsurface location of geologic units and faults, maps of water-table levels, independent point well data, maps showing the hydraulic properties of the subsurface materials. This information is used to classify the geologic units into hydrogeologic units, which are convenient units with which to define hydrologic properties.

Once a conceptual model of the system is defined, the model domain is subdivided horizontally and vertically into discrete blocks to facilitate solution of the ground-water flow equation. Though for simplicity and numerical accuracy, associating individual hydrogeologic units with model layers is advantageous; hydrogeologic units often have characteristics that make them difficult or impossible to represent with any model. For example, hydrogeologic units may be very thin or pinch out or be faulted and discontinuous. These limitations can be reduced or eliminated by refining the grid representing the system and by using a more flexible grid structure, but fine grids can result in long execution times that would prohibit the many model runs needed to understand system dynamics and the relation of model results to calibration data; flexible grid structures also can produce numerical difficulties.

The solution to this problem has been to group similar hydrogeologic units so that model layers represent more than one unit. Effective model input values are usually calculated outside of the model by using data-manipulation programs that are custom written by the modeler for the situation. This process can be time consuming and subject to introduction of errors.

The U.S. Geological Survey, in cooperation with the U.S. Department of Energy, initiated the development of the Hydrogeologic-Unit Flow (HUF) Package of MODFLOW-2000, which automates this process by allowing the geometry of the hydrogeologic units to be defined independently of the model layers. The HUF Package determines the units that apply to each model layer for each row and column and calculates model-layer horizontal and vertical conductance and specific storage internally. Characteristics for the model grid are obtained by averaging and by using the assumption that the hydrogeologic units that occur within each model finite-difference cell are virtually horizontal. Hydrogeologic units that pinch out and are

discontinuous are defined by specifying the top altitude and thickness of hydrogeologic units, based on defined rows and columns of the finite-difference grid. Hydraulic properties are assigned to the hydrogeologic units by using parameters (Harbaugh and others, 2000, p. 12).

One of the advantages of the HUF Package is that it provides a ready tool for the results of sophisticated three-dimensional data-base, data-manipulation, and visualization software, such as Stratamodel, Earthvision, Lynx Geosystems, TechBase, or Integraph Voxel Analyst to be used with MODFLOW-2000. This information can be used in the other flow packages, but some manipulation is needed to translate the information to the correct format.

Dr. Anderman's contribution to the development of the HUF Package and its documentation was funded through U.S. Geological Survey contracts 99CRSA0301, 99CRSA1084, and 00CRSA0825.

Purpose and Scope

This report documents the conceptualization and implementation of the HUF Package. The capabilities of the HUF Package are illustrated through the use of two test cases, which also serve to verify the conceptualization and implementation of the package. The input requirements for the HUF Package are presented in Appendix A. The derivation of equations for the Sensitivity Process part of the HUF Package is presented in Appendix B.

The HUF Package is similar to the Layer-Property Flow (LPF) Package documented in Harbaugh and others (2000) and the Block-Centered Flow (BCF) Package documented in McDonald and Harbaugh (1988) in that it is an internal flow package that calculates the conductance coefficients and other terms needed to solve the flow equation. The principal difference between the HUF Package and the BCF or LPF Packages is that in the HUF Package hydraulic properties are assigned on the basis of hydrogeologic units that are geometrically distinct from the model layers. The conceptual approach and governing equations of the HUF Package are presented in the following sections. Many of the algorithms used in the HUF Package are identical to those in the LPF Package (Harbaugh and others, 2000) and are not described in this report.

The HUF Package supports parameters that are used to define the following hydraulic properties, which are listed with their parameter type: horizontal hydraulic conductivity (HK), horizontal anisotropy (HANI), vertical hydraulic conductivity (VK), vertical anisotropy (VANI), specific storage (SS), and specific yield (SY). One parameter can apply to more than one

hydrogeologic unit. This approach is useful, for example, when separately defined units are thought to have similar hydraulic properties. The HUF Package allows the use of multiplication and zone arrays in the definition of parameters. The HUF Package also allows additive-parameters (Harbaugh and others, 2000, p.16) to be used so that hydraulic properties for hydrogeologic units are defined by multiple parameters. Parameters defined in the HUF Package input file can be estimated by using the Parameter-Estimation Process of MODFLOW-2000, and by using observations defined with the Observation-Process capabilities of MODFLOW-2000; both are documented in Hill and others (2000).

The differences between the LPF and HUF Packages are as follows:

- (1) As discussed above, in the HUF Package, the vertical geometry of the system hydrogeology is defined separately from the model-layer definition, and the averaging used to obtain model-layer properties is based on the assumption that the hydrogeologic layers are horizontal or nearly horizontal. This assumption affects calculations both in the Ground-Water Flow Process and the Sensitivity Process, as discussed in this report.
- (2) HUF uses only harmonic calculation of horizontal conductances.
- (3) In the HUF Package, hydraulic characteristics for the hydrogeologic units are required to be specified using parameters; LPF's option of specifying properties through array definition is not available in HUF.
- (4) The HUF Package does not support the concept of a quasi-three-dimensional confining layer; confining layers are always represented as individual hydrogeologic units in the HUF Package.

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The authors acknowledge Richard Waddell of HSI-Geotrans, Inc. for his encouragement to develop the Hydrogeologic-Unit Flow Package. The authors also acknowledge the following U.S. Geological Survey personnel: Frank D'Agnese and Claudia Faunt for their guidance and their examples that guided package development; Ned Banta and Grady O'Brien for their much appreciated debugging of the package; and Wayne Belcher, Arlen Harbaugh, and Celso Puente for their critical reviews that greatly improved the document.

CONCEPTUALIZATION AND IMPLEMENTATION OF THE HYDROGEOLOGIC-UNIT FLOW PACKAGE

The HUF Package links defined hydrogeologic units to the solution of the ground-water flow equation of MODFLOW-2000 (fig. 1). A cross section is shown in figure 1 for illustrative purposes, but the hydrogeologic units are three-dimensional. The progression begins with the definition of hydrogeologic units (fig. 1A), where subsurface deposits have been grouped, based on their hydraulic characteristics, as being part of an aquifer unit, a confining unit, or a sand-lens unit. In this report, the three units are identified as type A, C, or L, where material classified as a certain type is thought to have similar hydraulic characteristics wherever it exists. When using the HUF Package, the criterion of no vertically repeated units needs to be imposed, so that 17 model units would be needed to define this system. The term “model unit” is used to describe the input to the HUF Package; in cases where hydrogeologic units are not repeated vertically, the model unit is identical to the hydrogeologic unit, otherwise a model unit represents one piece of the larger hydrogeologic unit. Different defined model units can, however, be grouped together so that they are assigned the same hydraulic parameters and represent a single hydrogeologic unit. Thus, the HUF Package input files can be constructed such that the system described in figure 1A can be thought of as consisting of three hydrogeologic units defined on the basis of hydraulic characteristics, which is discussed more below.

In the HUF Package, hydrogeologic units are defined by the top altitude and thickness of each hydrogeologic unit for each cell in the model grid. Figure 1B shows one row of the finite-difference grid for which the model layers are not yet defined. The hydrogeologic units are represented within MODFLOW-2000 as follows: for each row and column location, the top altitude and thickness of each hydrogeologic unit has been interpreted as being constant, so that the smooth surfaces of figure 1A are now discrete. If a hydrogeologic unit does not occur at a row and column location, then the thickness needs to be set to zero. This description indicates that given the HUF Package capabilities, the hydrogeologic units need to be defined such that no unit is repeated vertically for a single row, column location. As long as this restriction is observed, some of the 17 hydrogeologic units could be combined. For example, units L1, L2, and L3 in figure 1 cannot be defined as a single hydrogeologic unit in the HUF Package, but L1 and L3 could. Overlying pieces of the same material thus need to be represented as multiple hydrogeologic units, but can be combined under one parameter definition.

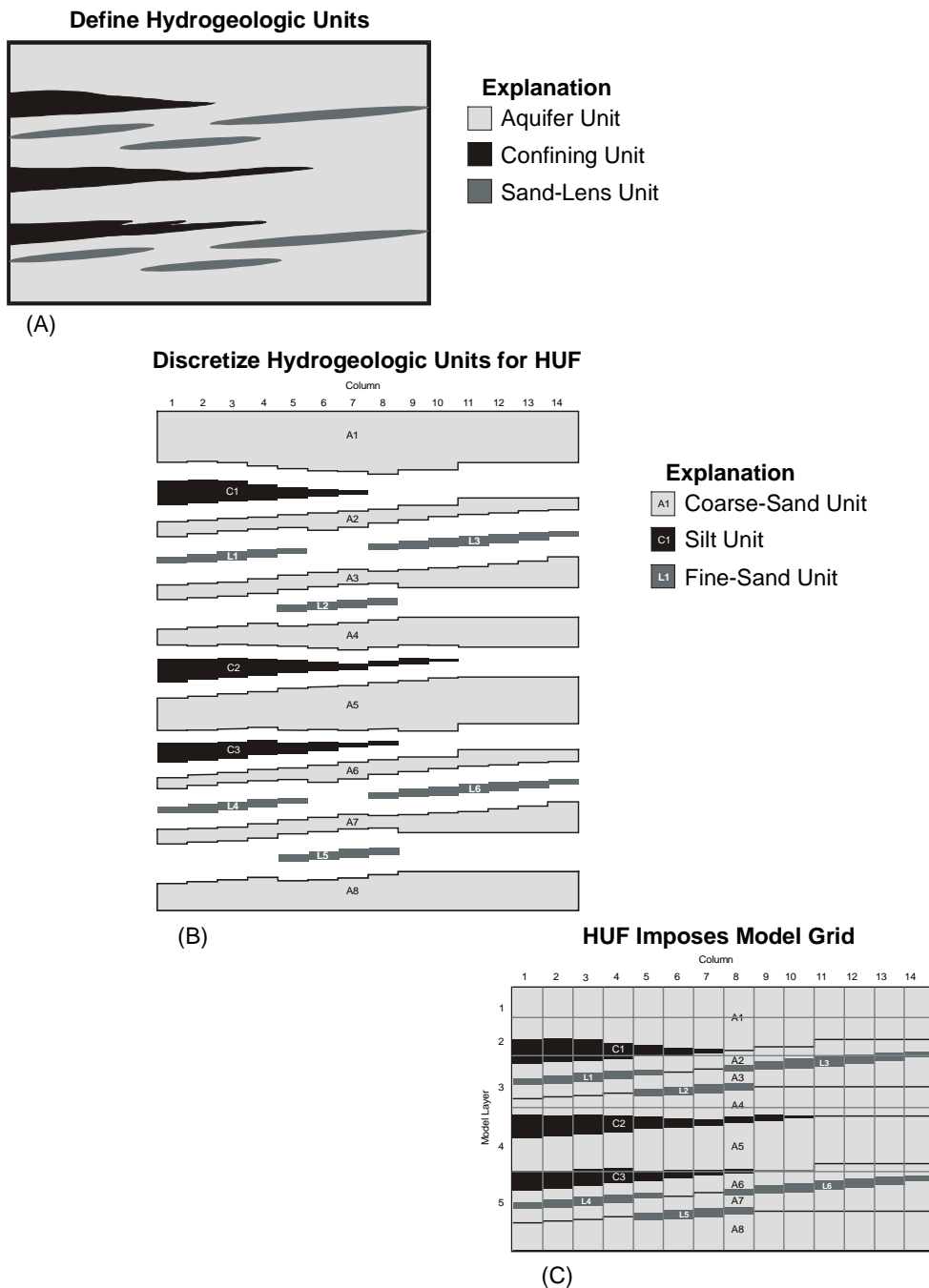


Figure 1. Hypothetical situation involving definition of hydrogeologic units. (A) Definition of hydrogeologic units, which is part of the data preparation step of ground-water model development (the data can be organized using some of the software listed for (B)); (B) Horizontal discretization of hydrogeologic units used to construct the HUF Package input file (the discretization can be performed by software such as Stratamodel, Earthvision, Arcview, and Voxel Analyst, and by some MODFLOW-2000 graphical user interfaces), with the 17 hydrogeologic units shown exploded; (C) Assignment of hydrogeologic units to model layers (performed by the Hydrogeologic-Unit Flow Package).

In the situation shown in figure 1, if each occurrence of the three types of units (A, C, and L) are assigned the same horizontal hydraulic conductivity and the same vertical hydraulic conductivity, six parameters are needed. The parameter for the horizontal hydraulic conductivity of material type A would be defined by listing all of the A hydrogeologic units – A1, A2, A3, and so on. Similarly, the parameter for the vertical hydraulic conductivity of material type A would be defined by listing all of the A hydrogeologic units – A1, A2, A3, and so on. This definition would be repeated for C and L.

The last step of the sequence shown in figure 1 is that the model-layer geometry is superimposed on the subsurface material (fig. 1C). For each finite-difference cell thus defined, the resident hydrogeologic-unit hydraulic properties are used in the HUF Package to calculate the cell hydraulic properties from which the horizontal and vertical conductances and primary storage capacity are calculated. For convertible layers, the location of the water table is accounted for as needed. For the Sensitivity Process of the HUF Package, the right-hand side of the sensitivity equation of Hill and others (2000, p. 68-70) is calculated for the parameters defined for the hydrogeologic units. The equations and procedures used to accomplish these tasks are described in the following sections.

Calculating Conductances

By using hydrogeologic-unit top altitudes and thicknesses, which are part of the input data, the HUF Package determines the hydrogeologic units that apply to each model layer (fig. 1C), calculates the effective hydraulic conductivity for the horizontal and vertical directions for each grid cell, and uses these conductivities to calculate the horizontal and vertical conductances. If the simulation is transient, then the HUF Package also calculates the effective specific storage for the model layers and uses the specific yield for the unit that the water table intersects at any given time step. For convertible layers, the HUF Package accounts for the location of the free water surface during each outer iteration by recalculating all of the conductances and storage coefficients.

Transmissivity and Horizontal Conductances

In the horizontal direction, transmissivities are used in the harmonic mean formulation to calculate the conductances needed for solution, as discussed by Harbaugh and others (2000, p. 25-27) and McDonald and Harbaugh (1988, p. 5-8). The HUF Package does not currently support other conductance calculation methods.

Transmissivity in the row direction $TR_{i,j,k}$ for a cell at row i , column j , and layer k is calculated as:

$$TR_{i,j,k} = \sum_{g=1}^n KH_{i,j,g} thk_{g,i,j,k}, \quad (1)$$

where

- n is the number of hydrogeologic units within the finite-difference cell;
- $KH_{i,j,g}$ is equal to $\sum_{l=1}^p Kh_l m_{l,i,j,g}$;
- Kh_l is the value of horizontal hydraulic conductivity parameter l ;
- $thk_{g,i,j,k}$ is the thickness of hydrogeologic unit g in cell i, j, k ;
- p is the number of additive parameters that define the hydraulic conductivity of hydrogeologic unit g ; and
- $m_{l,i,j,g}$ is the multiplication factor for parameter l .

The value of the multiplication factor $m_{l,i,j,g}$ is defined by the multiplication array. If a multiplication array is not specified, then $m_{l,i,j,g}$ equals 1.

Horizontal conductance $CR_{i,j+1/2,k}$ for the material between cell centers i, j, k and $i, j+1, k$ is calculated from the transmissivities as described for the LPF Package (Harbaugh and others, 2000, p. 27) as:

$$CR_{i,j+1/2,k} = 2\Delta c_i \frac{TR_{i,j,k} TR_{i,j+1,k}}{TR_{i,j,k} \Delta r_{j+1} + TR_{i,j+1,k} \Delta r_j}, \quad (2)$$

where

- Δr_j is the cell width of column j , and
- Δc_i is the cell width of row i .

Transmissivity in the column direction $TC_{i,j,k}$ for a cell at row i , column j , and layer k is calculated as:

$$TC_{i,j,k} = \sum_{g=1}^n KH_{i,j,g} thk_{g,i,j,k} HANI_{i,j,g}, \quad (3)$$

where

$HANI_{i,j,g}$ is equal to $\sum_{l=1}^p Hani_l m_{l,i,j,g}$ or 1 if $Hani_l$ is not defined, and $Hani_l$ is the value of horizontal anisotropy parameter l .

Horizontal conductance in the column direction $CC_{i+1/2,j,k}$ for the material between cell centers i, j, k and $i+1, j, k$ is calculated from the transmissivities as:

$$CC_{i+1/2,j,k} = 2\Delta r_j \frac{TC_{i,j,k} TC_{i+1,j,k}}{TC_{i,j,k} \Delta c_{i+1} + TC_{i+1,j,k} \Delta c_i}. \quad (4)$$

Vertical Conductances

The vertical conductance $CV_{i,j,k+1/2}$ for the material between cell centers i, j, k and $i, j, k+1$ is calculated as:

$$CV_{i,j,k+1/2} = \frac{\Delta r_j \Delta c_i}{\sum_{g=1}^n \frac{thk_{g,i,j,k+1/2}}{KV_{i,j,g}}}, \quad (5)$$

where

$thk_{g,i,j,k+1/2}$ is the hydrogeologic unit g thickness that occurs between the two cell centers,

$KV_{i,j,g}$ is equal to $\sum_{l=1}^p Kv_l m_{l,i,j,g}$, and

Kv_l is the vertical hydraulic conductivity of parameter l .

Storage Terms

For confined cells, the storage capacity of the cell is calculated in a similar manner to effective transmissivity. The primary storage capacity for a given cell is calculated as:

$$SCI_{i,j,k} = \Delta r_j \Delta c_i \sum_{g=1}^n SS_{i,j,g} thk_{g,i,j,k}, \quad (6)$$

where

$SS_{i,j,g}$ is equal to $\sum_{l=1}^p Ss_l m_{l,i,j,g}$, and

Ss_l is the specific storage of parameter l .

SY parameters are used to calculate the secondary storage-capacity value for each cell as:

$$SC2_{i,j,k} = \Delta r_j \Delta c_i SY_{i,j,g}, \quad (7)$$

where

$$SY_{i,j,g} \text{ is equal to } \sum_{l=1}^p Sy_l m_{l,i,j,g}, \text{ and}$$

Sy_l is the specific yield of parameter l .

For cells that contain a water table, the HUF Package was implemented to use the specific yield for the hydrogeologic unit that contains the water table to calculate the storage flow. For transient simulations, if the water table spans several hydrogeologic units during a time step, the specific yield for each of those units is used with the change in saturated thickness of the unit to calculate the storage flow for that particular cell. If the cell converts between a saturated and unsaturated condition during a time step, then the change in storage from both the confined and unconfined parts are included in the storage flow.

Definition of Model Layers

Although the HUF Package allows model layers to be defined independently of hydrogeologic units, careful definition of the model layers is important to represent properly the flow through the simulated area. Specifying model-layer boundaries that coincide with or are parallel to hydrogeologic-unit boundaries is helpful. Further discussion of optimal grid design is beyond the scope of this report.

Interpolation of Hydraulic Heads to Hydrogeologic Units

The HUF Package has an option that allows the modeled hydraulic heads in the hydrogeologic units to be printed and saved in a manner similar to the modeled hydraulic heads. The heads in the hydrogeologic units are interpolated from the heads in the model layers using a linear-interpolation algorithm. The interpolation algorithm is based on the assumption that head varies linearly in the vertical direction within a given hydrogeologic unit and that the vertical flow through each individual unit is equal to the overall flow from one layer to an adjacent layer. The output consists of one array of interpolated-head values for each hydrogeologic unit. The head is assigned the value of HNOFLO (Harbaugh and others, 2000, p. 50) at all locations where a hydrogeologic unit does not exist.

PROGRAM DESCRIPTION

The HUF Package was written within the modular framework of MODFLOW-2000 and works independently of most of the other packages. The flow of subroutines called from the main program by the HUF Package (fig. 2) is similar to the Layer-Property Flow Package and most other packages in that there is a Ground-Water Flow Process (GWF) allocate subroutine (GWF1HUF1AL), a GWF read-and-prepare subroutine (GWF1HUF1RQ), a GWF formulate subroutine (GWF1HUF1FM), several GWF volumetric-budget calculation subroutines (GWF1SHUF1S, GWF1SHUF1F, and GWF1SHUF1B), and subroutines that formulate the right-hand side for calculating sensitivities. Subroutine GWF1HUF1SP, which is part of GWF, takes the parameter definitions and formulates the conductance matrices needed to solve the flow equation. This subroutine is also called from subroutine GWF1HUF1FM to recalculate the conductances for cells in layers with variable saturated thickness. Subroutine GWF1SHUF1S calculates the contribution to the flow in each cell due to storage changes and, for unconfined cells, calls GWF1SHUF1SC2 to calculate the contribution to flow from specific yield. The HUF Package is written in standard FORTRAN77 and should be compatible with any standard FORTRAN77 compiler.

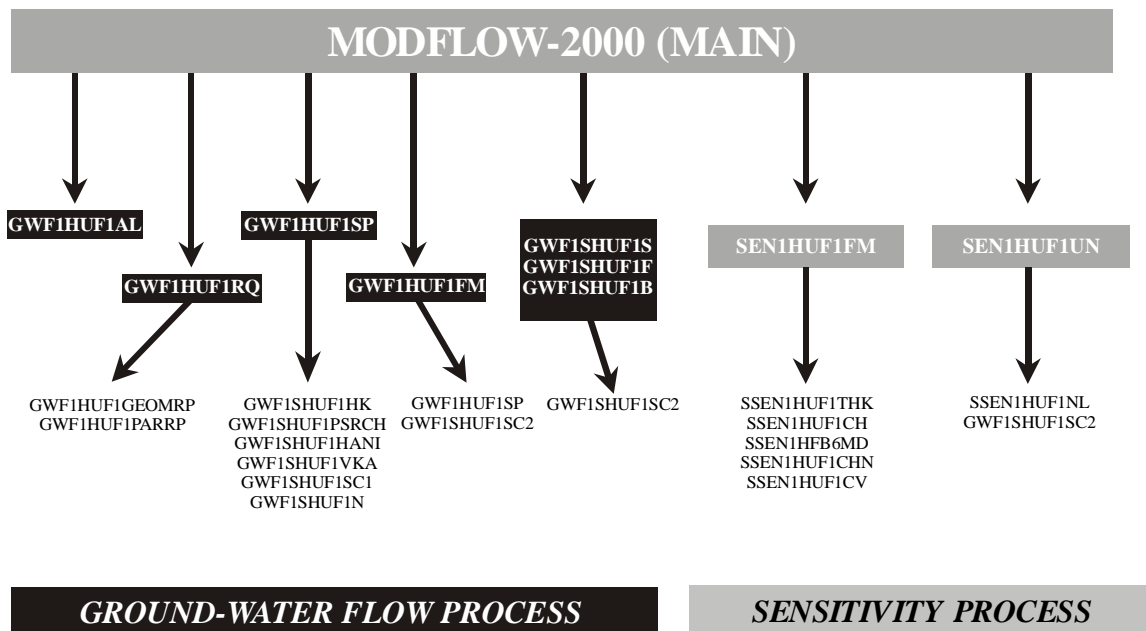


Figure 2. Flowchart of subroutines used by the Hydrogeologic-Unit Flow Package.

SIMULATION EXAMPLES

To test the functionality of the HUF Package, two test cases were developed. Test Case 1 was designed to test the transient capabilities of the HUF Package and is modified from test case 1 of MODFLOW-2000 Observation, Sensitivity, and Parameter-Estimation Processes (Hill and others, 2000). Test Case 2 was designed to test the steady-state capabilities of the HUF Package and is based on test case 1 used for the Advective-Transport Observation (ADV) Package (Anderman and Hill, 1997) and test case 2 of MODFLOW-2000 Observation, Sensitivity, and Parameter-Estimation Processes (Hill and others, 2000). Test Cases 1 and 2 are fully described below; the references are provided for informational purposes only because these test cases have been published previously.

Test Case 1: Transient

Test Case 1 is a system composed of two confined aquifers that are separated by a confining unit (fig. 3). A facies change exists in the lower aquifer where the lower unit thins away from the adjacent hillside and the upper unit thickens. Inflow occurs as areal recharge and as head-dependent flow across the boundary adjacent to the hillside. Outflow occurs as pumpage from wells. A river boundary is present opposite from the hillside. No-flow boundaries are specified on the remaining two sides and on the bottom of the model domain. The system is simulated using three model layers: one for each aquifer and one for the confining unit. Pumpage (Q of fig. 3) consists of four wells completed in layer 3 and one well in layer 1, each pumping 1 cubic meter per second (m^3/s) throughout the simulation. Four stress periods are used to represent 282.8 days.

Four hydrogeologic units were used to represent the hydrogeology of the system. These units correspond to the upper aquifer, confining unit, upper facies of the lower aquifer, and the lower facies of the lower aquifer.

Thirteen parameters were defined using the HUF Package and were included in the parameter estimation (table 1). The four hydrogeologic units were given values of horizontal hydraulic conductivity (HK), vertical hydraulic conductivity (VK), and specific storage (SS) that were different for the aquifers and confining unit. As only the upper aquifer converts from confined to unconfined conditions during the simulation, specific yield (SY) was only assigned to HGU1.

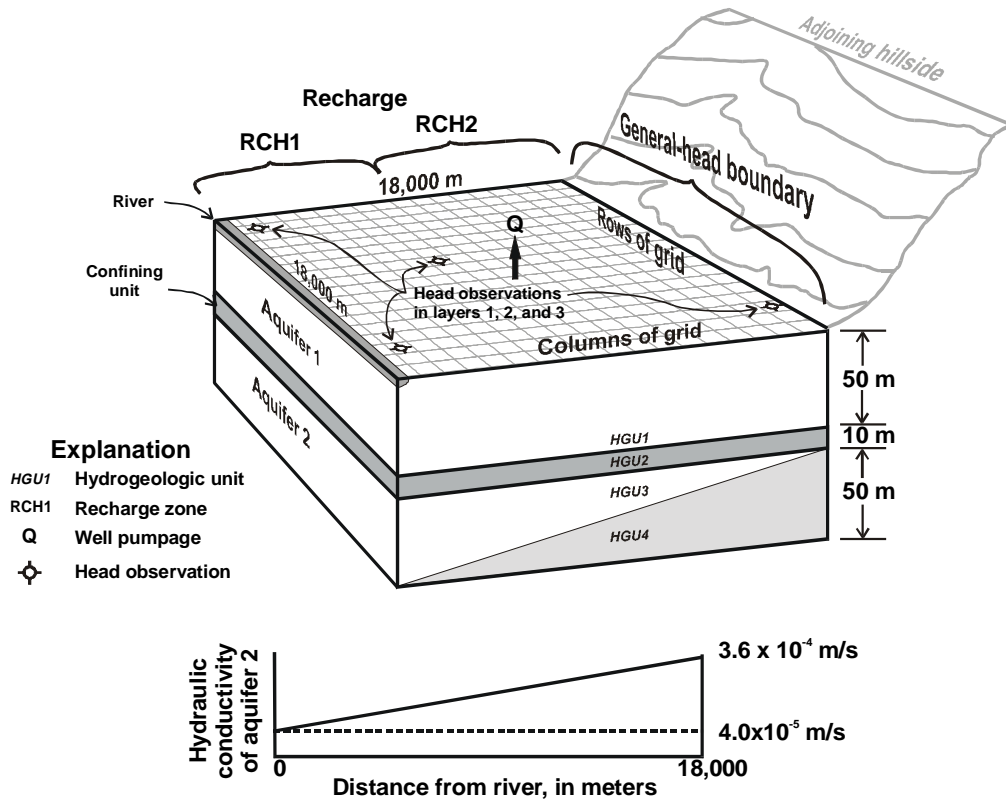


Figure 3. Test Case 1 model grid, boundary conditions, and head-observation locations used in parameter estimation. (From Hill and others, 2000.)

Table 1. Labels, descriptions, and true values for the parameters for Test Case 1 [m/s, meters per second; m, meter; --, no units]

Label	Description	Units	True value
HK1	Horizontal hydraulic conductivity of aquifer 1	m/s	3.0×10^{-4}
HK2	Horizontal hydraulic conductivity of confining unit	m/s	2.0×10^{-7}
HK3	Base horizontal hydraulic conductivity of the upper facies of aquifer 2 (fig. 3)	m/s	4.0×10^{-5}
HK4	Base horizontal hydraulic conductivity of the lower facies of aquifer 2 (fig. 3)	m/s	4.0×10^{-5}
VK1	Vertical hydraulic conductivity of aquifer 1	m/s	3.0×10^{-4}
VK2	Vertical hydraulic conductivity of confining unit	m/s	2.0×10^{-7}
VK3	Base vertical hydraulic conductivity of the upper facies of aquifer 2	m/s	4.0×10^{-5}
VK4	Base vertical hydraulic conductivity of the lower facies of aquifer 2	m/s	4.0×10^{-5}
SS1	Specific storage of aquifer 1	m^{-1}	1.0×10^{-3}
SS2	Specific storage of confining unit	m^{-1}	1.0×10^{-6}
SS3	Specific storage of the upper facies of aquifer 2	m^{-1}	1.0×10^{-3}
SS4	Specific storage of the lower facies of aquifer 2	m^{-1}	1.0×10^{-3}
SY1	Specific yield of aquifer 1	--	0.1

Observations in the parameter estimation consisted of heads observed at 4 different times at 12 locations (fig. 3) and flow from the general-head boundary observed at 4 different times. The observations used in the parameter estimation were computed by a forward simulation with the true parameter values specified in table 1.

By using the HUF Package, the true values were estimated to three significant figures for the HK1, SS1, and SY1 parameters included in the estimation. The parameter-estimation closure criteria TOL (Hill and others, 2000, p. 79) was set to 0.01 and, because of the highly nonlinear nature of this problem, the parameter estimation took 20 iterations to converge. Some insignificant variation was noted in the third significant figure of the estimated values of the remaining parameters. This variation indicates that parameter estimation using the HUF Package is able to reproduce the true parameter values when exact observations are used in the regression and, therefore, provides a test of the sensitivity and regression calculations for steady-state and transient parameters.

Test Case 2: Steady State

Test Case 2 includes features common to a complex three-dimensional ground-water flow model. This test case was developed to test all parameter types and many of the capabilities of the HUF Package. The hydrogeologic units were defined to correspond with the model layers; therefore, Test Case 2 is not a good illustration of how the HUF Package should be used in practice. Ten variants of the basic test case were developed in which the basic test case is modified in that the definition of the hydrogeologic units and(or) the vertical discretization are modified; all other aspects of the system remain the same. The model grid (fig. 4) has a uniform grid spacing of 1,500 meters (m) in both horizontal directions. Constant-head boundaries comprise parts of the western and eastern boundaries, with no flow across the remaining boundaries. Springs are represented using either the Drain or General-Head Boundary Packages of McDonald and Harbaugh (1988) and Harbaugh and others (2000). Wells are present at selected nodes, with pumpage at rates ranging from 100 to 200 m³/d.

The hydraulic-conductivity distribution of the system can be thought of as being divided vertically into three horizons and horizontally into four zones (fig. 4). All four zones are present in the middle horizon; three are present in the top and bottom horizons (fig. 4). This distribution allows for testing of the HUF Package with hydrogeologic units that extend vertically throughout

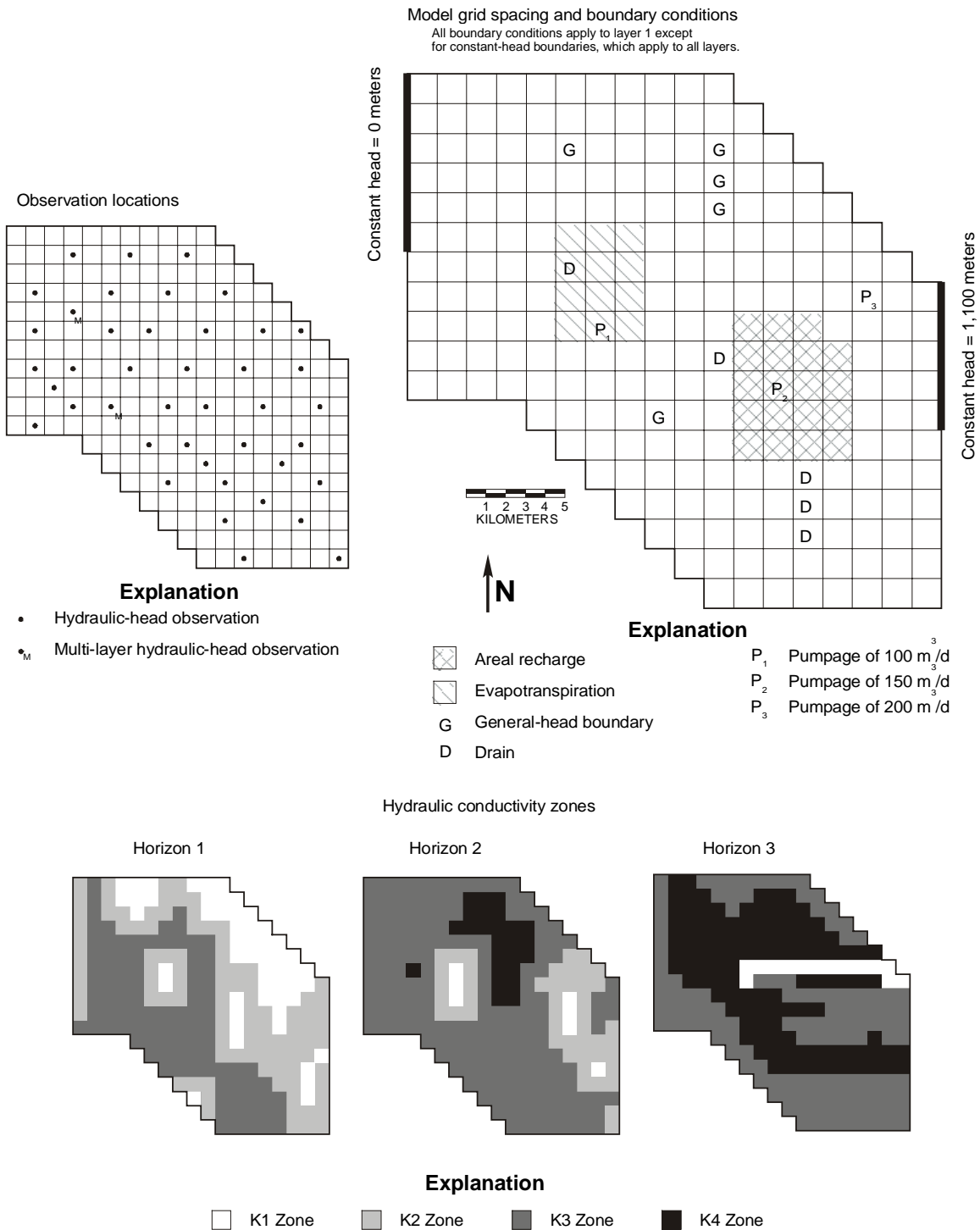


Figure 4. Test Case 2 model grid, boundary conditions, observation locations, and hydraulic conductivity zonation used in parameter estimation. (From Anderman and Hill, 1997.)

Table 2. Labels, descriptions, and true values for the parameters for Test Case 1
[m/d, meters per day; m²/d, square meters per day; --, no units]

Label	Description	Units	True Value
HK1	Horizontal hydraulic conductivity of zone 1 (fig. 4)	m/d	1.00
HK2	Horizontal hydraulic conductivity of zone 2 (fig. 4)	m/d	1.00x10 ⁻²
HK3	Horizontal hydraulic conductivity of zone 3 (fig. 4)	m/d	1.00x10 ⁻⁴
HK4	Horizontal hydraulic conductivity of zone 4 (fig. 4)	m/d	1.00x10 ⁻⁶
HANI	Horizontal anisotropy of the entire model grid, used in Variant 10	--	1.00
<i>Either vertical hydraulic conductivity or vertical anisotropy (see below) are used.</i>			
VK12_1	Vertical hydraulic conductivity of zone 1 for hydrogeologic units in horizons 1 and 2	m/d	2.50x10 ⁻¹
VK12_2	Vertical hydraulic conductivity of zone 2 for hydrogeologic units in horizons 1 and 2	m/d	2.50x10 ⁻³
VK12_3	Vertical hydraulic conductivity of zone 3 for hydrogeologic units in horizons 1 and 2	m/d	2.50x10 ⁻⁵
VK12_4	Vertical hydraulic conductivity of zone 4 for hydrogeologic units in horizons 1 and 2	m/d	2.50x10 ⁻⁷
VK3_1	Vertical hydraulic conductivity of zone 1 for hydrogeologic units in horizon 3	m/d	1.00
VK3_3	Vertical hydraulic conductivity of zone 3 for hydrogeologic units in horizon 3	m/d	1.00x10 ⁻⁴
VK3_4	Vertical hydraulic conductivity of zone 4 for hydrogeologic units in horizon 3	m/d	1.00x10 ⁻⁶
VANI12	Vertical anisotropy of layers 1 and 2	--	4.0
VANI3	Vertical anisotropy of layer 3	--	1.0
RCH	Areal recharge rate applied to the area shown in figure 4	m/d	3.10x10 ⁻⁴
ETM	Maximum evapotranspiration rate applied to area shown in figure 4	m/d	4.00x10 ⁻⁴
GHB	Conductance of head-dependent boundaries G shown in figure 4 represented using the general-head boundary package.	m ² /d	1.00
KDR	Conductance of the head-dependent boundaries D shown in figure 4 using the drain package.	m ² /d	1.00
HFB	Conductance of the hydraulic flow barriers described under Variant 8.	m/d	1.00x10 ⁻⁶

the model or units that are defined over smaller vertical extents. Fifteen parameters of the test case are described (table 2) along with their true (assigned) values.

The hydraulic conductivity field of this problem can be represented in two ways using the HUF Package. First, the hydrogeologic units can be defined using the zones and the horizons, which demonstrates hydrogeologic units that are repeated vertically. This method was used for variant 1, where HGU1_1 represents zone 1 in layer 1, HGU1_2 represents zone 2 in layer 1, and so on. The thicknesses of the hydrogeologic units are nonzero where the zone is present and zero everywhere else in the layer. Alternatively, for variants 2 through 10, the hydrogeologic units are defined on the basis of the horizons; the hydrogeologic units can include parts from more than one zone within the horizon. The appropriate method for representing the hydrogeologic units depends on the situation, as follows. The first method produces more individually defined hydrogeologic units that are then lumped under one parameter; the second method produces fewer individually defined hydrogeologic units that may be more difficult to define.

The definition of hydrogeologic units that were used to define the HK and VK or VANI parameters are shown in figure 5 and table 3. Either vertical hydraulic conductivity or vertical anisotropy were used but not both, although HUF is capable of having both parameter types present to define properties for different hydrogeologic units. The observations (fig. 4) used in the parameter estimation were generated by running the model with the true parameter values; no noise was added. The flows simulated at the hydraulic-head-dependent boundaries (fig. 4) also were used as observations in the parameter estimation.

The definition of the hydrogeologic units and vertical discretization of the particular variants are described in the following sections.

Variant 1 (Base case)

In Variant 1, one hydrogeologic unit is used to represent each of the zones in each of the horizons. Where hydrogeologic units are absent, thickness equals zero; the zone capability of the HUF Package was not used.

Table 3. Hydrogeologic-unit names used (fig. 5) to define horizontal hydraulic-conductivity (HK), vertical hydraulic-conductivity (VK), vertical-anisotropy (VANI), and horizontal-anisotropy (HANI) parameters in Test Case 2

[--, not used]

Parameter	Zone	Variant 1	Variant 2	Variant 3	Variants 4-6, 8	Variant 7	Variant 9	Variant 10
HK1	1	1_1, 2_1, 3_1	1, 2, 3	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5
HK2	2	1_2, 2_2, 3_2	1, 2, 3	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5
HK3	3	1_3, 2_3, 3_3	1, 2, 3	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5
HK4	4	1_4, 2_4, 3_4	1, 2, 3	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	1, 2, 3, 4, 5
VK12_1	1	1_1, 2_1	1, 2	1, 2, 3, 4	1, 2, 3, 4	--	--	--
VK12_2	2	1_2, 2_2	1, 2	1, 2, 3, 4	1, 2, 3, 4	--	--	--
VK12_3	3	1_3, 2_3	1, 2	1, 2, 3, 4	1, 2, 3, 4	--	--	--
VK12_4	4	1_4, 2_4	1, 2	1, 2, 3, 4	1, 2, 3, 4	--	--	--
VK3_1	1	3_1	3	5, 6	5	--	--	--
VK3_3	3	3_3	3	5, 6	5	--	--	--
VK3_4	4	3_4	3	5, 6	5	--	--	--
VANI12	All	--	--	--	--	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4
VANI3	All	--	--	--	--	5, 6	5	5
HANI1	All	--	--	--	--	--	--	1, 2, 3, 4, 5

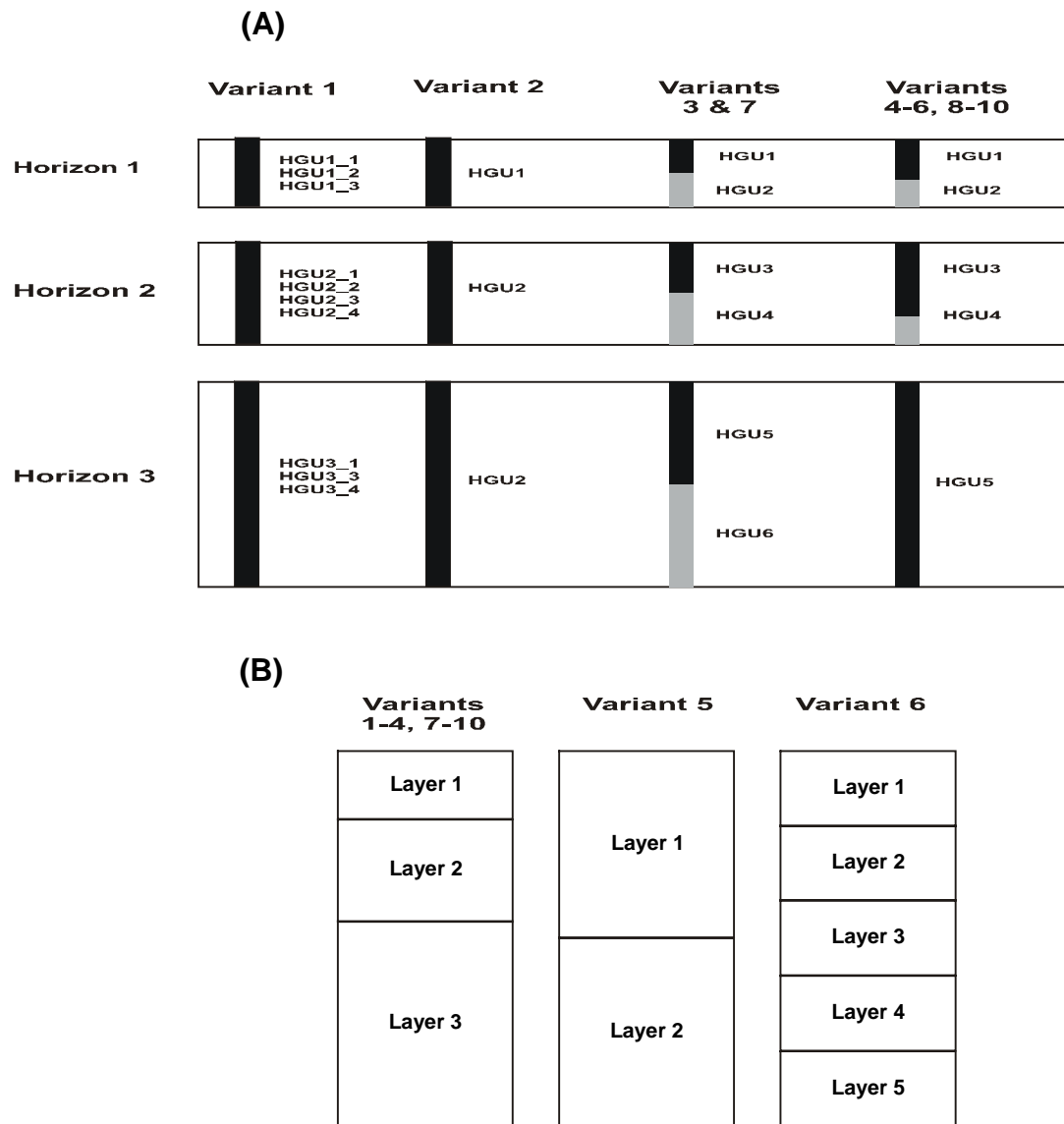


Figure 5. Schematic representation of (A) hydrogeologic units used to represent each of the horizons in the variants of Test Case 2, and (B) model-layer thicknesses.

Variant 2 (Using zone definition)

In Variant 2, one hydrogeologic unit represents each of the horizons, and the different hydraulic-conductivity zones (fig. 3) are defined using the zone arrays of HUF. Variant duplicates Variant 1; the definition of the hydrogeologic units and the geometry of the model layers is identical.

Variant 3 (6 HGU's, equal half layers)

In Variant 3, each of the hydrogeologic units of Variant 2 was cut in half, so that two units were present in each of the three model layers for a total of six hydrogeologic units.

Variant 4 (5 HGU's, complex geometry)

The geometry of the hydrogeologic units was slightly more complex in Variant 4 with five hydrogeologic units present in the three model layers. The units had the following thicknesses, in order from top to bottom: 300, 200, 550, 200, and 1,500 m. Units 1 and 2 are contained in layer 1, units 3 and 4 are contained in layer 2, and unit 5 is contained in layer 3.

Variant 5 (2 model layers)

Identical to Variant 4 except that two equal-thickness model layers are used, each 1,375 m thick. The results from the forward simulation are different than previously obtained so that it was necessary to generate new values to be used as observations.

Variant 6 (5 model layers)

Identical to Variant 4 except that five equal-thickness model layers are used, each 550 m thick. The results from the forward simulation are different than previously obtained so that it was necessary to generate new values to be used as observations.

Variant 7 (Vertical anisotropy parameters)

Identical to Variant 3 except that two VANI parameters are used to represent vertical hydraulic conductivity.

Variant 8 (Hydrologic-Flow Barrier parameter)

Identical to Variant 4 with a hydrologic-flow barrier (HFB) parameter added. Two flow barriers are represented by the HFB parameter; one is located in rows 5 through 9 between columns 2 and 3 of layer 1, the second is located in rows 11 through 15 between columns 10 and 11 of layer 2.

Variant 9 (Variable saturated thickness)

Identical to Variant 4 with parameter definition from Variant 7 except that the layer type is 1 for all layers. Only cells in layer 1 have variable saturated thickness.

Variant 10 (Horizontal anisotropy parameter)

Identical to Variant 4 with parameter definition from Variant 7 and an additional HANI parameter representing horizontal anisotropy for the entire model grid.

Results

MODFLOW-2000 with the HUF Package was able to estimate the true parameter values to three significant digits for all of the variants except for Variant 5. The parameter-estimation closure criteria TOL (Hill and others, 2000, p. 79) was set to 0.01. All of the variants converged except Variant 5. Variant 5 did not converge because all of the VK parameters were highly correlated with one another. With only two numerical layers in the model grid, each vertical conductance value was determined from three VK parameters. Thus, coordinated changes in the VK parameters would result in the same vertical conductance value. For most parameters, the true parameter values were estimated with a precision of three significant figures; for less sensitive parameters, there was some insignificant variation in the third significant figure. The parameter estimation took from 5 to 18 iterations to converge. From these results it can be concluded that parameter estimation using the HUF Package is able to reproduce the true parameter values when exact observations are used in the regression, and this forms a test of the sensitivity and regression calculations.

REFERENCES CITED

- Anderman, E.R. and Hill, M.C., 1997, Advective-Transport Observation (ADV) Package, A computer program for adding advective-transport observations of steady-state flow fields to the three-dimensional ground-water flow parameter-estimation model MODFLOWP: U.S. Geological Survey Open-File Report 97-14, 67 p.
- Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, MODFLOW-2000, the U.S. Geological Survey modular ground-water model – user guide to modularization concepts and the ground-water flow process: U.S. Geological Survey Open-File Report 00-92, 121 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.
- _____ 1992, A computer program (MODFLOWP) for estimating parameters of a transient, three-dimensional, ground-water flow model using nonlinear regression: U.S. Geological Survey Open-File Report 91-484, 358 p.
- Hill, M.C., Banta, E.R., Harbaugh, A.W., and Anderman, E.R., 2000, MODFLOW-2000, the U.S. Geological Survey modular ground-water model—user guide to the observation, sensitivity, and parameter-estimation processes and three post-processing programs: U.S. Geological Survey Open-File Report 00-184, 210 p.
- 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, Chapter A1, 586 p.
- 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.

APPENDIX A: INPUT INSTRUCTIONS

Input for the Hydrogeologic Unit Flow (HUF) Package is read from the file that has type "HUF" in the name file. Free format is used for reading all values.

FOR EACH SIMULATION

0. [#Text]

Item 0 is optional -- “#” must be in column 1. Item 0 can be repeated multiple times.

1. IHUFCB HDRY NHUF NPHUF IOHUF
2. LTHUF (NLAY)
3. LAYWT (NLAY)
4. WETFCT IWETIT IHDWET

Include Item 4 only if LAYWT indicates at least one wettable layer.

5. WETDRY (NCOL, NROW)

Repeat Item 5 for each layer for which LAYWET is not 0.

Arrays are read by the array-reading utility module, U2DREL.

6. HGUNAM
7. TOP (NCOL, NROW)
8. THCK (NCOL, NROW)

Repeat Items 6-8 for each hydrogeologic unit to be defined (that is, NHUF times).

9. HGUNAM HGUHANI HGUVANI

Repeat Item 9 for each hydrogeologic unit. If HGUNAM is set to “ALL”, HGUHANI and HGUVANI are set for all hydrogeologic units and only one Item 9 is necessary. Otherwise, HGUNAM must correspond to one of the names defined in Item 6, and there must be NHUF repetitions of Item 9. The repetitions can be in any order.

10. PARNAM PARTYP Parval NCLU
11. HGUNAM Mltarr Zonarr IZ

Each Item 11 record is called a parameter cluster. Repeat Item 11 NCLU times.

Repeat Items 10-11 for each parameter to be defined (that is, NPHUF times).

12. 'PRINT' HGUNAM PRINTCODE PRINTFLAGS

Item 12 is optional and is included only for hydrogeologic units for which printing is desired. Item 12 must start with the word PRINT. If HGUNAM is set to ALL, PRINTCODE and PRINTFLAGS are set for all hydrogeologic units, and only one Item 12 is necessary. Otherwise, HGUNAM must correspond to one of the names defined in Item 6.

Explanation of Variables Read by the Hydrogeologic-Unit Flow Package

Text – is a character variable (199 characters) that starts in column 2. Any characters can be included in Text. The “#” character must be in column 1. Text is printed when the file is read.

IHUF_{CB} – is a flag and a unit number.

> 0 – the unit number to which cell-by-cell flow terms will be written when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control (Harbaugh and others, 2000, p. 55). The terms that are saved are storage, constant-head flow, and flow between adjacent cells.

0 – cell-by-cell flow terms will not be written.

< 0 – cell-by-cell flow for constant-head cells will be written in the listing file when "SAVE BUDGET" or a non-zero value for ICBCFL is specified in Output Control. Cell-by-cell flow to storage and between adjacent cells will not be written to any file.

HDRY – is the head that is assigned to cells that are converted to dry during a simulation.

Although this value plays no role in the model calculations, it is useful as an indicator when looking at the resulting heads that are output from the model. HDRY is thus similar to HNOFLO in the Basic Package, which is the value assigned to cells that are no-flow cells at the start of a model simulation.

NHUF – is the number of hydrogeologic units defined using the HUF package.

NPHUF – is the number of HUF parameters.

IOHUF – is a flag and a unit number.

0 – interpolated heads will not be written.

>0 – calculated heads will be interpolated and written on unit IOHUF for each hydrogeologic unit using the format defined in the output-control file.

LTHUF – is a flag specifying the layer type. Read one value for each layer; each element holds the code for the respective layer. There is a limit of 200 layers. Use as many records as needed to enter a value for each layer.

0 – indicates a confined layer.

not 0 – indicates a convertible layer.

LAYWT – is a flag that indicates if wetting is active. Read one value per layer.

0 – indicates wetting is inactive.

1 – indicates wetting is active.

WETFCT – is a factor that is included in the calculation of the head that is initially established at a cell when the cell is converted from dry to wet. (See IHDWET.)

IWETIT – is the iteration interval for attempting to wet cells. Wetting is attempted every IWETIT iterations. If using the preconditioned conjugate gradient (PCG) solver (Hill, 1990), this applies to outer iterations, not inner iterations. If IWETIT is 0, it is changed to 1.

IHDWET – is a flag that determines which equation is used to define the initial head at cells that become wet:

If IHDWET = 0, equation 3a from McDonald and others (1992) is used:

$$h = BOT + WETFCT (h_n - BOT)$$

If IHDWET is not 0, equation 3b from McDonald and others (1992) is used:

$$h = BOT + WETFCT (WETDRY)$$

WETDRY – is a combination of the wetting threshold and a flag to indicate which neighboring cells can cause a cell to become wet. If WETDRY < 0, only the cell below a dry cell can cause the cell to become wet. If WETDRY > 0, the cell below a dry cell and the four horizontally adjacent cells can cause a cell to become wet. If WETDRY is 0, the cell cannot be wetted. The absolute value of WETDRY is the wetting threshold. When the sum of BOT and the absolute value of WETDRY at a dry cell is equaled or exceeded by the head at an adjacent cell, the cell is wetted. Read only if LAYTYP is not 0 and LAYWET is not 0.

HGUNAM – is the name of the hydrogeologic unit. This name can consist of up to 10 characters and is not case sensitive.

TOP – is the elevation of the top of the hydrogeologic unit.

THCK – is the thickness of the hydrogeologic unit.

HGUHANI – is a flag and a horizontal anisotropy value for a hydrogeologic unit. Horizontal anisotropy is the ratio of hydraulic conductivity along columns to hydraulic conductivity along rows. Read one value for each hydrogeologic unit unless HGUNAM is set to ALL.

0 – indicates that horizontal anisotropy will be defined using a HANI parameter.

>0 – HGUHANI is the horizontal anisotropy of the entire hydrogeologic unit.

HGUVANI – is a flag that indicates whether array VK is vertical hydraulic conductivity or the ratio of horizontal to vertical hydraulic conductivity. Read only one value for each hydrogeologic unit unless HGUNAM is set to ALL.

0 – indicates VK is hydraulic conductivity (VK parameter must be used).

>0 – indicates VK is the ratio of horizontal to vertical hydraulic conductivity and HGUVANI is the vertical anisotropy of the entire hydrogeologic unit. Value is ignored if a VANI parameter is defined for the corresponding hydrogeologic unit.

PARNAM – is the name of a parameter to be defined. This name can consist of up to 10 characters and is not case sensitive.

PARTYP – is the type of parameter to be defined. For the HUF Package, the allowed parameter types are:

HK – defines variable HK, horizontal hydraulic conductivity.

HANI – defines variable HANI, horizontal anisotropy.

VK – defines variable VK, vertical hydraulic conductivity, for units for which HGUVANI is set to zero.

VANI – defines variable VANI, vertical anisotropy, for units for which HGUVANI is set greater than zero.

SS – defines variable Ss, the specific storage.

SY – defines variable Sy, the specific yield.

Parval – is the initial value of the parameter; however, this value can be replaced by a value specified in the Sensitivity Process input file.

NCLU – is the number of clusters required to define the parameter. Each Item-12 record is a cluster (variables Layer, Mltarr, Zonarr, and IZ).

HGUNAM – is the hydrogeologic unit to which the parameter applies.

Mltarr – is the name of the multiplier array to be used to define array values that are associated with a parameter. The name “NONE” means that there is no multiplier array, and the array values will be set equal to Parval.

Zonarr – is the name of the zone array to be used to define array elements that are associated with a parameter. The name “ALL” means that there is no zone array and that all elements in the hydrogeologic unit are part of the parameter.

IZ – is up to 10 zone numbers (separated by spaces) that define the array elements that are associated with a parameter. The first zero or non-numeric value terminates the list. These values are not used if Zonarr is specified as “ALL”.

PRINTCODE – determines the format for printing the values of the hydraulic-property arrays for the hydrogeologic unit as defined by parameters. The print codes are the same as those used in an array control record (Harbaugh and others, 2000, p. 87).

PRINTFLAGS – determines the hydraulic-property arrays to be printed and must be set to “ALL” or any of the following: “HK”, “HANI”, “VK”, “SS”, or “SY”. Arrays will be printed only for those properties that are listed. When VK is specified, the property printed depends on the setting of HGUVANI.

Test Case 1 Sample Files

Input File

```
# HUF file for Test Case 1
#
  0 -999.  4  16   00  Item 1:  IHUFCB HDRY NHUF NPHUF IOHUF
  1  1      1           Item 2:  LTHUF
  0  0      0           Item 3:  LAYWT
HG01                        Item 6:  HGUNAM
CONSTANT   150.           Item 7:  TOP
CONSTANT   50.           Item 8:  THCK
HG02                        Item 6:  HGUNAM
CONSTANT   100.          Item 7:  TOP
CONSTANT   10.           Item 8:  THCK
HG03                        Item 6:  HGUNAM
CONSTANT   90.           Item 7:  TOP
INTERNAL    1.00 (15F5.0)  -2   Item 8:  THCK
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
47.5 45.0 42.5 40.0 37.5 35.0 32.5 30.0 27.5 25.0 22.5 20.0 17.5 15.0 12.5
10.0  7.5  5.0
HG04                        Item 6:  HGUNAM
INTERNAL    1.00 (15F5.0)  -2   Item 7:  TOP
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
```

Test Case 1 Sample Files – Input File

```

42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
42.5 45.0 47.5 50.0 52.5 55.0 57.5 60.0 62.5 65.0 67.5 70.0 72.5 75.0 77.5
80.0 82.5 85.0
INTERNAL 1.00 (15F5.0) -2 Item 8: THCK
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0 32.5 35.0 37.5
40.0 42.5 45.0
ALL 1.0 0 Item 9: HGUNAM HGUHANI HGUVANI
HK1 HK 3.0E-4 1 Item 10: PARNAM PARTY Parval NCLU
HGU1 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
HK2 HK 2.0E-7 1 Item 10: PARNAM PARTY Parval NCLU
HGU2 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
HK3 HK 4.0E-5 1 Item 10: PARNAM PARTY Parval NCLU
HGU3 TMULT ALL Item 11: HUFNAM Mltarr Zonarr IZ
HK4 HK 4.0E-5 1 Item 10: PARNAM PARTY Parval NCLU
HGU4 TMULT ALL Item 11: HUFNAM Mltarr Zonarr IZLU
VKA1 VK 3.0E-4 1 Item 10: PARNAM PARTY Parval NCLU
HGU1 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
VKA2 VK 2.0E-7 1 Item 10: PARNAM PARTY Parval NCLU
HGU2 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
VKA3 VK 4.0E-5 1 Item 10: PARNAM PARTY Parval NCLU
HGU3 TMULT ALL Item 11: HUFNAM Mltarr Zonarr IZ
VKA4 VK 4.0E-5 1 Item 10: PARNAM PARTY Parval NCLU
HGU4 TMULT ALL Item 11: HUFNAM Mltarr Zonarr IZ
SS1 SS 1.0E-3 1 Item 10: PARNAM PARTY Parval NCLU
HGU1 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
SS2 SS 1.0E-6 1 Item 10: PARNAM PARTY Parval NCLU
HGU2 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
SS3 SS 1.0E-3 1 Item 10: PARNAM PARTY Parval NCLU
HGU3 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
SS4 SS 1.0E-3 1 Item 10: PARNAM PARTY Parval NCLU
HGU4 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
SY1 SY 1.0E-1 1 Item 10: PARNAM PARTY Parval NCLU
HGU1 NONE ALL Item 11: HUFNAM Mltarr Zonarr IZ
SY2 SY 1.0E-2 1 Item 10: PARNAM PARTY Parval NCLU

```

Test Case 1 Sample Files – Input File

```
HGU2    NONE    ALL          Item 11: HUFNAM    Mltarr    Zonarr    IZ
SY3     SY      1.0E-1  1      Item 10: PARNAM    PARTYP    Parval    NCLU
HGU3    NONE    ALL          Item 11: HUFNAM    Mltarr    Zonarr    IZ
SY4     SY      1.0E-1  1      Item 10: PARNAM    PARTYP    Parval    NCLU
HGU4    NONE    ALL          Item 11: HUFNAM    Mltarr    Zonarr    IZ
PRINT  HGU3    20    ALL          Item 12: HGUNAM    PRINTCODE  PRINTFLAGS
```

GLOBAL Output File

An example of the excerpted GLOBAL output file for Test Case 1 is shown below. The HUF Package output appears in bold, and three dots (...) indicates omitted output.

```
MODFLOW-2000
U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
VERSION 1.0.2 08/21/2000
```

This model run produced both GLOBAL and LIST files. This is the GLOBAL file.

```
GLOBAL LISTING FILE: tcltr.glo
UNIT      3

OPENING tcltr.lst
FILE TYPE:LIST UNIT  4
# Observation-Process Files

OPENING tcltr.obs
FILE TYPE:OBS UNIT  40

OPENING tcltr.hob
FILE TYPE:HOB UNIT  41

OPENING tcltr.ogb
FILE TYPE:GBOB UNIT  42
# Sensitivity and Parameter-Estimation Process Files
#sen      39 tcltr.sen
#pes      43 tcltr.pes
#Flow-Process files

OPENING tcltr.bas
FILE TYPE:BAS6 UNIT  5

OPENING tcltr.huf
FILE TYPE:HUF UNIT  7

OPENING tcltr.wel
FILE TYPE:WEL UNIT  8

OPENING tcltr.pcg
FILE TYPE:PCG UNIT  9

OPENING tcltr.dis
FILE TYPE:DIS UNIT 10

OPENING tcltr.oc
FILE TYPE:OC UNIT 11

OPENING tcltr.ghb
FILE TYPE:GHB UNIT 12

OPENING tcltr.riv
FILE TYPE:RIV UNIT 13

OPENING tcltr.sh
FILE TYPE:DATA UNIT 14

OPENING tcltr.rch
FILE TYPE:RCH UNIT 31

OPENING tcltr.mlt
FILE TYPE:MULT UNIT 32

OPENING tcltr.zon
FILE TYPE:ZONE UNIT 33

DISCRETIZATION INPUT DATA READ FROM UNIT 10
# DIS file for test case tcltr
```

Test Case 1 Sample Files – GLOBAL Output File

```

#
  3 LAYERS          18 ROWS          18 COLUMNS
  4 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS SECONDS
MODEL LENGTH UNIT IS FEET

THE OBSERVATION PROCESS IS ACTIVE
THE SENSITIVITY PROCESS IS INACTIVE
THE PARAMETER-ESTIMATION PROCESS IS INACTIVE

MODE: FORWARD WITH OBSERVATIONS

ZONE OPTION, INPUT READ FROM UNIT 33
  1 ZONE ARRAYS

MULTIPLIER OPTION, INPUT READ FROM UNIT 32
  2 MULTIPLIER ARRAYS
Confining bed flag for each layer:
  0   0   0

  9432 ELEMENTS OF GX ARRAY USED OUT OF 9432
  972  ELEMENTS OF GZ ARRAY USED OUT OF 972
 1296 ELEMENTS OF IG ARRAY USED OUT OF 1296

          DELR = 1000.00
          DELC = 1000.00

TOP ELEVATION OF LAYER 1 = 150.000

MODEL LAYER BOTTOM EL. = 100.000    FOR LAYER 1
MODEL LAYER BOTTOM EL. = 90.0000    FOR LAYER 2
MODEL LAYER BOTTOM EL. = 40.0000    FOR LAYER 3

STRESS PERIOD      LENGTH          TIME STEPS      MULTIPLIER FOR DELT      SS FLAG
-----
  1             87162.00             1              1.200                   TR
  2             261486.0             1              1.200                   TR
  3             522972.0             1              1.200                   TR
  4             2.3567440E+07         9              1.200                   TR

TRANSIENT SIMULATION

          MULT. ARRAY: TMULT
READING ON UNIT 32 WITH FORMAT: (18F3.0)

          MULT. ARRAY: RCHMULT
READING ON UNIT 32 WITH FORMAT: (9F8.0)

          ZONE ARRAY: RCHZONE
READING ON UNIT 33 WITH FORMAT: (18I2)

HUF1 -- HYDROGEOLOGIC-UNIT FLOW PACKAGE, ' VERSION 0.13-ERA, 9/26/00
INPUT READ FROM UNIT 7
This preliminary version is not to be released
outside the U.S. Geological Survey

# HUF file for Test Case 1
#
HEAD AT CELLS THAT CONVERT TO DRY= -999.00
Hydrogeologic-Unit Flow Package Active with 16 parameters
 16 Named Parameters
TRANSIENT SIMULATION

INTERPRETATION OF LAYER FLAGS:
LAYER      LTHUF      LAYER TYPE      LAYWT WETTABILITY
-----
  1          1    CONVERTIBLE      0    NON-WETTABLE

```

Test Case 1 Sample Files – GLOBAL Output File

2 2 CONVERTIBLE 0 NON-WETTABLE
 3 3 CONVERTIBLE 0 NON-WETTABLE

7776 ELEMENTS IN X ARRAY ARE USED BY HUF
 20 ELEMENTS IN IX ARRAY ARE USED BY HUF

PCG2 -- CONJUGATE GRADIENT SOLUTION PACKAGE, VERSION 2.4, 12/29/98
 MAXIMUM OF 500 CALLS OF SOLUTION ROUTINE
 MAXIMUM OF 8 INTERNAL ITERATIONS PER CALL TO SOLUTION ROUTINE
 MATRIX PRECONDITIONING TYPE : 1
 10916 ELEMENTS IN X ARRAY ARE USED BY PCG
 28000 ELEMENTS IN IX ARRAY ARE USED BY PCG
 1944 ELEMENTS IN Z ARRAY ARE USED BY PCG

OBS1BAS6 -- OBSERVATION PROCESS, VERSION 1.0, 4/27/99
 INPUT READ FROM UNIT 40
 OBSERVATION GRAPH-DATA OUTPUT FILES WILL NOT BE PRINTED

HEAD OBSERVATIONS -- INPUT READ FROM UNIT 41

NUMBER OF HEADS.....: 48
 NUMBER OF MULTILAYER HEADS.....: 0
 MAXIMUM NUMBER OF LAYERS FOR MULTILAYER HEADS....: 0

OBS1GHB6 -- OBSERVATION PROCESS (GENERAL HEAD BOUNDARY FLOW OBSERVATIONS)
 VERSION 1.0, 10/15/98
 INPUT READ FROM UNIT 42

NUMBER OF FLOW-OBSERVATION GENERAL-HEAD-CELL GROUPS: 1
 NUMBER OF CELLS IN GENERAL-HEAD-CELL GROUPS.....: 72
 NUMBER OF GENERAL-HEAD-CELL FLOWS.....: 4

1023 ELEMENTS IN X ARRAY ARE USED FOR OBSERVATIONS
 30 ELEMENTS IN Z ARRAY ARE USED FOR OBSERVATIONS
 503 ELEMENTS IN IX ARRAY ARE USED FOR OBSERVATIONS

COMMON ERROR VARIANCE FOR ALL OBSERVATIONS SET TO: 1.000

19715 ELEMENTS OF X ARRAY USED OUT OF 19715
 1974 ELEMENTS OF Z ARRAY USED OUT OF 1974
 28523 ELEMENTS OF IX ARRAY USED OUT OF 28523
 0 ELEMENTS OF XHS ARRAY USED OUT OF 1

HEAD OBSERVATION VARIANCES ARE MULTIPLIED BY: 1.000

OBSERVED HEAD DATA -- TIME OFFSETS ARE MULTIPLIED BY: 1.0000

OBS#	OBSERVATION NAME	REFER.		OBSERVATION	STATISTIC	STATISTIC TYPE	PLOT SYM.
		STRESS PERIOD	TIME OFFSET				
1	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
1	H1_8_8_1	1	0.8716E+05	152.3	1.000	STD. DEV.	1
2	H1_8_8_2	2	0.2615E+06	152.3	1.000	STD. DEV.	1
3	H1_8_8_3	3	0.5230E+06	152.2	1.000	STD. DEV.	1
4	H1_8_8_4	4	0.2357E+08	140.9	1.000	STD. DEV.	1
5	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
5	H2_8_8_1	1	0.8716E+05	152.3	1.000	STD. DEV.	1
6	H2_8_8_2	2	0.2615E+06	152.3	1.000	STD. DEV.	1
7	H2_8_8_3	3	0.5230E+06	152.2	1.000	STD. DEV.	1
8	H2_8_8_4	4	0.2357E+08	140.1	1.000	STD. DEV.	1
9	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
9	H3_8_8_1	1	0.8716E+05	152.3	1.000	STD. DEV.	1
10	H3_8_8_2	2	0.2615E+06	152.2	1.000	STD. DEV.	1
11	H3_8_8_3	3	0.5230E+06	152.1	1.000	STD. DEV.	1
12	H3_8_8_4	4	0.2357E+08	139.3	1.000	STD. DEV.	1
13	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
13	H1_2_2_1	1	0.8716E+05	110.0	1.000	STD. DEV.	1
14	H1_2_2_2	2	0.2615E+06	110.1	1.000	STD. DEV.	1
15	H1_2_2_3	3	0.5230E+06	110.3	1.000	STD. DEV.	1
16	H1_2_2_4	4	0.2357E+08	117.7	1.000	STD. DEV.	1
17	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
17	H2_2_2_1	1	0.8716E+05	110.0	1.000	STD. DEV.	1

Test Case 1 Sample Files – GLOBAL Output File

18	H2_2_2_2	2	0.2615E+06	110.1	1.000	STD. DEV.	1
19	H2_2_2_3	3	0.5230E+06	110.2	1.000	STD. DEV.	1
20	H2_2_2_4	4	0.2357E+08	117.2	1.000	STD. DEV.	1
21	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
21	H3_2_2_1	1	0.8716E+05	110.0	1.000	STD. DEV.	1
22	H3_2_2_2	2	0.2615E+06	110.0	1.000	STD. DEV.	1
23	H3_2_2_3	3	0.5230E+06	110.1	1.000	STD. DEV.	1
24	H3_2_2_4	4	0.2357E+08	116.6	1.000	STD. DEV.	1
25	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
25	H1_16_16_1	1	0.8716E+05	176.2	1.000	STD. DEV.	1
26	H1_16_16_2	2	0.2615E+06	176.2	1.000	STD. DEV.	1
27	H1_16_16_3	3	0.5230E+06	176.7	1.000	STD. DEV.	1
28	H1_16_16_4	4	0.2357E+08	240.1	1.000	STD. DEV.	1
29	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
29	H2_16_16_1	1	0.8716E+05	176.1	1.000	STD. DEV.	1
30	H2_16_16_2	2	0.2615E+06	176.2	1.000	STD. DEV.	1
31	H2_16_16_3	3	0.5230E+06	176.7	1.000	STD. DEV.	1
32	H2_16_16_4	4	0.2357E+08	240.2	1.000	STD. DEV.	1
33	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
33	H3_16_16_1	1	0.8716E+05	176.1	1.000	STD. DEV.	1
34	H3_16_16_2	2	0.2615E+06	176.2	1.000	STD. DEV.	1
35	H3_16_16_3	3	0.5230E+06	176.6	1.000	STD. DEV.	1
36	H3_16_16_4	4	0.2357E+08	240.3	1.000	STD. DEV.	1
37	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
37	H1_16_2_1	1	0.8716E+05	110.0	1.000	STD. DEV.	1
38	H1_16_2_2	2	0.2615E+06	110.1	1.000	STD. DEV.	1
39	H1_16_2_3	3	0.5230E+06	110.3	1.000	STD. DEV.	1
40	H1_16_2_4	4	0.2357E+08	117.7	1.000	STD. DEV.	1
41	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
41	H2_16_2_1	1	0.8716E+05	110.0	1.000	STD. DEV.	1
42	H2_16_2_2	2	0.2615E+06	110.1	1.000	STD. DEV.	1
43	H2_16_2_3	3	0.5230E+06	110.2	1.000	STD. DEV.	1
44	H2_16_2_4	4	0.2357E+08	117.2	1.000	STD. DEV.	1
45	W2L	-4	0.000	979.0	5.000	STD. DEV.	1
TRANSIENT DATA AT THIS LOCATION, ITT = 1							
45	H3_16_2_1	1	0.8716E+05	110.0	1.000	STD. DEV.	1
46	H3_16_2_2	2	0.2615E+06	110.0	1.000	STD. DEV.	1
47	H3_16_2_3	3	0.5230E+06	110.1	1.000	STD. DEV.	1
48	H3_16_2_4	4	0.2357E+08	116.6	1.000	STD. DEV.	1

OBS#	OBSERVATION NAME	LAY	ROW	COL	HEAD CHANGE REFERENCE OBSERVATION		
					ROW OFFSET	COL OFFSET (IF > 0)	
1	H1_8_8_1	1	8	8	0.000	0.000	0
2	H1_8_8_2	1	8	8	0.000	0.000	0
3	H1_8_8_3	1	8	8	0.000	0.000	0
4	H1_8_8_4	1	8	8	0.000	0.000	0
5	H2_8_8_1	2	8	8	0.000	0.000	0
6	H2_8_8_2	2	8	8	0.000	0.000	0
7	H2_8_8_3	2	8	8	0.000	0.000	0
8	H2_8_8_4	2	8	8	0.000	0.000	0
9	H3_8_8_1	3	8	8	0.000	0.000	0
10	H3_8_8_2	3	8	8	0.000	0.000	0
11	H3_8_8_3	3	8	8	0.000	0.000	0
12	H3_8_8_4	3	8	8	0.000	0.000	0
13	H1_2_2_1	1	2	2	0.000	0.000	0
14	H1_2_2_2	1	2	2	0.000	0.000	0
15	H1_2_2_3	1	2	2	0.000	0.000	0
16	H1_2_2_4	1	2	2	0.000	0.000	0
17	H2_2_2_1	2	2	2	0.000	0.000	0
18	H2_2_2_2	2	2	2	0.000	0.000	0
19	H2_2_2_3	2	2	2	0.000	0.000	0
20	H2_2_2_4	2	2	2	0.000	0.000	0
21	H3_2_2_1	3	2	2	0.000	0.000	0
22	H3_2_2_2	3	2	2	0.000	0.000	0
23	H3_2_2_3	3	2	2	0.000	0.000	0

Test Case 1 Sample Files – GLOBAL Output File

24	H3_2_2_4	3	2	2	0.000	0.000	0
25	H1_16_16_1	1	16	16	0.000	0.000	0
26	H1_16_16_2	1	16	16	0.000	0.000	0
27	H1_16_16_3	1	16	16	0.000	0.000	0
28	H1_16_16_4	1	16	16	0.000	0.000	0
29	H2_16_16_1	2	16	16	0.000	0.000	0
30	H2_16_16_2	2	16	16	0.000	0.000	0
31	H2_16_16_3	2	16	16	0.000	0.000	0
32	H2_16_16_4	2	16	16	0.000	0.000	0
33	H3_16_16_1	3	16	16	0.000	0.000	0
34	H3_16_16_2	3	16	16	0.000	0.000	0
35	H3_16_16_3	3	16	16	0.000	0.000	0
36	H3_16_16_4	3	16	16	0.000	0.000	0
37	H1_16_2_1	1	16	2	0.000	0.000	0
38	H1_16_2_2	1	16	2	0.000	0.000	0
39	H1_16_2_3	1	16	2	0.000	0.000	0
40	H1_16_2_4	1	16	2	0.000	0.000	0
41	H2_16_2_1	2	16	2	0.000	0.000	0
42	H2_16_2_2	2	16	2	0.000	0.000	0
43	H2_16_2_3	2	16	2	0.000	0.000	0
44	H2_16_2_4	2	16	2	0.000	0.000	0
45	H3_16_2_1	3	16	2	0.000	0.000	0
46	H3_16_2_2	3	16	2	0.000	0.000	0
47	H3_16_2_3	3	16	2	0.000	0.000	0
48	H3_16_2_4	3	16	2	0.000	0.000	0

GENERAL-HEAD-CELL FLOW OBSERVATION VARIANCES ARE MULTIPLIED BY: 1.000

OBSERVED GENERAL-HEAD-CELL FLOW DATA
 -- TIME OFFSETS ARE MULTIPLIED BY: 1.0000

GROUP NUMBER: 1 BOUNDARY TYPE: GHB NUMBER OF CELLS IN GROUP: -18
 NUMBER OF FLOW OBSERVATIONS: 4

OBS#	OBSERVATION NAME	REFER. STRESS PERIOD	TIME OFFSET	OBSERVED BOUNDARY FLOW		STATISTIC	STATISTIC TYPE	PLOT SYM.
				GAIN (-) OR LOSS (+)				
49	GHB1	1	0.8716E+05	30.60	0.5000E-01	COEF. VAR.		3
50	GHB2	2	0.2615E+06	29.20	0.5000E-01	COEF. VAR.		3
51	GHB3	3	0.5230E+06	26.90	0.5000E-01	COEF. VAR.		3
52	GHB4	4	0.2357E+08	9.620	0.5000E-01	COEF. VAR.		3

LAYER	ROW	COLUMN	FACTOR
1.	1.	18.	1.00
1.	2.	18.	1.00
1.	3.	18.	1.00
1.	4.	18.	1.00
1.	5.	18.	1.00
1.	6.	18.	1.00
1.	7.	18.	1.00
1.	8.	18.	1.00
1.	9.	18.	1.00
1.	10.	18.	1.00
1.	11.	18.	1.00
1.	12.	18.	1.00
1.	13.	18.	1.00
1.	14.	18.	1.00
1.	15.	18.	1.00
1.	16.	18.	1.00
1.	17.	18.	1.00
1.	18.	18.	1.00

NQC CAN BE REDUCED FROM 72 TO 18

SOLUTION BY THE CONJUGATE-GRADIENT METHOD

```

-----
MAXIMUM NUMBER OF CALLS TO PCG ROUTINE = 500
MAXIMUM ITERATIONS PER CALL TO PCG = 8
MATRIX PRECONDITIONING TYPE = 1
RELAXATION FACTOR (ONLY USED WITH PRECOND. TYPE 1) = 0.10000E+01
PARAMETER OF POLYNOMIAL PRECOND. = 2 (2) OR IS CALCULATED : 2
HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-03
RESIDUAL CHANGE CRITERION FOR CLOSURE = 0.10000E-03
PCG HEAD AND RESIDUAL CHANGE PRINTOUT INTERVAL = 999
PRINTING FROM SOLVER IS LIMITED(1) OR SUPPRESSED (>1) = 2
DAMPING PARAMETER = 0.10000E+01
  
```

WETTING CAPABILITY IS NOT ACTIVE IN ANY LAYER

Test Case 1 Sample Files – GLOBAL Output File

HUF1 -- HYDROGEOLOGIC-UNIT FLOW PACKAGE

```
-----
TOP ELEVATN: HGU1      = 150.000
    THICKNESS: HGU1      = 50.0000
TOP ELEVATN: HGU2      = 100.000
    THICKNESS: HGU2      = 10.0000
TOP ELEVATN: HGU3      = 90.0000
```

```
    THICKNESS: HGU3
READING ON UNIT 7 WITH FORMAT: (15F5.0)
```

```
    TOP ELEVATN: HGU4
READING ON UNIT 7 WITH FORMAT: (15F5.0)
```

```
    THICKNESS: HGU4
READING ON UNIT 7 WITH FORMAT: (15F5.0)
```

INTERPRETATION OF UNIT FLAGS:

```
UNIT      HANI      VK/VANI
-----
HGU1      1.000000     VERTICAL K
HGU2      1.000000     VERTICAL K
HGU3      1.000000     VERTICAL K
HGU4      1.000000     VERTICAL K
```

```
PARAMETER NAME:HK1      TYPE:HK  UNITS: 1
The parameter value from the package file is: 3.00000E-04
UNIT HGU1      CORRESPONDS TO UNIT NO. 1
    LAYER: 1      MULTIPLIER:NONE  ZONE:ALL
```

```
PARAMETER NAME:HK2      TYPE:HK  UNITS: 1
The parameter value from the package file is: 2.00000E-07
UNIT HGU2      CORRESPONDS TO UNIT NO. 2
    LAYER: 2      MULTIPLIER:NONE  ZONE:ALL
```

```
PARAMETER NAME:HK3      TYPE:HK  UNITS: 1
The parameter value from the package file is: 4.00000E-05
UNIT HGU3      CORRESPONDS TO UNIT NO. 3
    LAYER: 3      MULTIPLIER:TMULT  ZONE:ALL
```

```
PARAMETER NAME:HK4      TYPE:HK  UNITS: 1
The parameter value from the package file is: 4.00000E-05
UNIT HGU4      CORRESPONDS TO UNIT NO. 4
    LAYER: 4      MULTIPLIER:TMULT  ZONE:ALL
```

```
PARAMETER NAME:VKA1     TYPE:VK  UNITS: 1
The parameter value from the package file is: 3.00000E-04
UNIT HGU1      CORRESPONDS TO UNIT NO. 1
    LAYER: 1      MULTIPLIER:NONE  ZONE:ALL
```

```
PARAMETER NAME:VKA2     TYPE:VK  UNITS: 1
The parameter value from the package file is: 2.00000E-07
UNIT HGU2      CORRESPONDS TO UNIT NO. 2
    LAYER: 2      MULTIPLIER:NONE  ZONE:ALL
```

```
PARAMETER NAME:VKA3     TYPE:VK  UNITS: 1
The parameter value from the package file is: 4.00000E-05
UNIT HGU3      CORRESPONDS TO UNIT NO. 3
    LAYER: 3      MULTIPLIER:TMULT  ZONE:ALL
```

```
PARAMETER NAME:VKA4     TYPE:VK  UNITS: 1
The parameter value from the package file is: 4.00000E-05
UNIT HGU4      CORRESPONDS TO UNIT NO. 4
    LAYER: 4      MULTIPLIER:TMULT  ZONE:ALL
```

```
PARAMETER NAME:SS1      TYPE:SS  UNITS: 1
The parameter value from the package file is: 1.00000E-03
```

Test Case 1 Sample Files – GLOBAL Output File

```

UNIT HGU1      CORRESPONDS TO UNIT NO.    1
                LAYER: 1  MULTIPLIER:NONE  ZONE:ALL

PARAMETER NAME:SS2      TYPE:SS  UNITS: 1
The parameter value from the package file is: 1.00000E-06
UNIT HGU2      CORRESPONDS TO UNIT NO.    2
                LAYER: 2  MULTIPLIER:NONE  ZONE:ALL

PARAMETER NAME:SS3      TYPE:SS  UNITS: 1
The parameter value from the package file is: 1.00000E-03
UNIT HGU3      CORRESPONDS TO UNIT NO.    3
                LAYER: 3  MULTIPLIER:NONE  ZONE:ALL

PARAMETER NAME:SS4      TYPE:SS  UNITS: 1
The parameter value from the package file is: 1.00000E-03
UNIT HGU4      CORRESPONDS TO UNIT NO.    4
                LAYER: 4  MULTIPLIER:NONE  ZONE:ALL

PARAMETER NAME:SY1      TYPE:SY  UNITS: 1
The parameter value from the package file is: 0.10000
UNIT HGU1      CORRESPONDS TO UNIT NO.    1
                LAYER: 1  MULTIPLIER:NONE  ZONE:ALL

PARAMETER NAME:SY2      TYPE:SY  UNITS: 1
The parameter value from the package file is: 1.00000E-02
UNIT HGU2      CORRESPONDS TO UNIT NO.    2
                LAYER: 2  MULTIPLIER:NONE  ZONE:ALL

PARAMETER NAME:SY3      TYPE:SY  UNITS: 1
The parameter value from the package file is: 0.10000
UNIT HGU3      CORRESPONDS TO UNIT NO.    3
                LAYER: 3  MULTIPLIER:NONE  ZONE:ALL

PARAMETER NAME:SY4      TYPE:SY  UNITS: 1
The parameter value from the package file is: 0.10000
UNIT HGU4      CORRESPONDS TO UNIT NO.    4
                LAYER: 4  MULTIPLIER:NONE  ZONE:ALL

ITRSS
  1

```

```

Reading PRINTCODE information
UNIT HGU3      CORRESPONDS TO UNIT NO.    3

```

PRINTCODE FLAGS ARE SET AS FOLLOWS

UNIT	HK	HANI	VK	SS	SY
HGU1	0	0	0	0	0
HGU2	0	0	0	0	0
HGU3	20	20	20	20	20
HGU4	0	0	0	0	0

0 Well parameters

0 River parameters

0 GHB parameters

2 Recharge parameters

```

PARAMETER NAME:RCH1      TYPE:RCH  CLUSTERS: 1
Parameter value from package file is: 1.00000E-08
                MULTIPLIER ARRAY: NONE  ZONE ARRAY: RCHZONE
                ZONE VALUES: 1

```

```

PARAMETER NAME:RCH2      TYPE:RCH  CLUSTERS: 1
Parameter value from package file is: 1.50000E-08
                MULTIPLIER ARRAY: NONE  ZONE ARRAY: RCHZONE
                ZONE VALUES: 2

```

18 PARAMETERS HAVE BEEN DEFINED IN ALL PACKAGES.
(SPACE IS ALLOCATED FOR 500 PARAMETERS.)

ORDERED DEPENDENT-VARIABLE WEIGHTED RESIDUALS

```

NUMBER OF RESIDUALS INCLUDED: 52
-0.932E-02 -0.496E-03 -0.443E-03 -0.443E-03 -0.427E-03 -0.397E-03 -0.397E-03
-0.397E-03 -0.336E-03 -0.336E-03 -0.328E-03 -0.328E-03 -0.305E-03 -0.298E-03
-0.275E-03 -0.275E-03 -0.275E-03 -0.244E-03 -0.244E-03 -0.237E-03 -0.237E-03

```

Test Case 1 Sample Files – GLOBAL Output File

```

-0.183E-03 -0.183E-03 -0.183E-03 -0.168E-03 -0.145E-03 -0.122E-03 -0.122E-03
-0.122E-03 -0.916E-04 -0.458E-04 -0.458E-04 -0.305E-04 -0.153E-04 0.610E-04
0.763E-04 0.763E-04 0.130E-03 0.130E-03 0.145E-03 0.145E-03 0.153E-03
0.397E-03 0.404E-03 0.427E-03 0.427E-03 0.488E-03 0.133E-02 0.163E-02
0.265E-02 0.205E-01 0.248E-01

```

SMALLEST AND LARGEST DEPENDENT-VARIABLE WEIGHTED RESIDUALS

SMALLEST WEIGHTED RESIDUALS			LARGEST WEIGHTED RESIDUALS		
OBS#	OBSERVATION	WEIGHTED RESIDUAL	OBS#	OBSERVATION	WEIGHTED RESIDUAL
51	GHB3	-0.93169E-02	49	GHB1	0.24769E-01
44	H2_16_2_4	-0.49591E-03	50	GHB2	0.20492E-01
40	H1_16_2_4	-0.44250E-03	52	GHB4	0.26469E-02
25	H1_16_16_1	-0.44250E-03	4	H1_8_8_4	0.16327E-02
6	H2_8_8_2	-0.42725E-03	12	H3_8_8_4	0.13275E-02

CORRELATION BETWEEN ORDERED WEIGHTED RESIDUALS AND
NORMAL ORDER STATISTICS (EQ.38 OF TEXT) = 0.333

COMMENTS ON THE INTERPRETATION OF THE CORRELATION BETWEEN
WEIGHTED RESIDUALS AND NORMAL ORDER STATISTICS:

The critical value for correlation at the 5% significance level is 0.956

IF the reported CORRELATION is GREATER than the 5% critical value, ACCEPT the hypothesis that the weighted residuals are INDEPENDENT AND NORMALLY DISTRIBUTED at the 5% significance level. The probability that this conclusion is wrong is less than 5%.

IF the reported correlation IS LESS THAN the 5% critical value REJECT the hypothesis that the weighted residuals are INDEPENDENT AND NORMALLY DISTRIBUTED at the 5% significance level.

The analysis can also be done using the 10% significance level.
The associated critical value is 0.964

LIST Output File

An example of the excerpted LIST output file for Test Case 1 is shown below. The HUF Package output appears in bold, and three dots (...) indicates omitted output.

```

                                MODFLOW-2000
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                                VERSION 1.0.2 08/21/2000

This model run produced both GLOBAL and LIST files.  This is the LIST file.

# MODULAR MODEL - TWO-LAYER EXAMPLE PROBLEM, TRANSIENT, TEST CASE TC1TR
#
THE FREE FORMAT OPTION HAS BEEN SELECTED
  3 LAYERS           18 ROWS           18 COLUMNS
  4 STRESS PERIOD(S) IN SIMULATION

BAS6 -- BASIC PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT  5
      15 ELEMENTS IN IR ARRAY ARE USED BY BAS

WEL6 -- WELL PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT  8
No named parameters
MAXIMUM OF      5 ACTIVE WELLS AT ONE TIME
      20 ELEMENTS IN RX ARRAY ARE USED BY WEL

RIV6 -- RIVER PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT 13
No named parameters
MAXIMUM OF     18 ACTIVE RIVER REACHES AT ONE TIME
      108 ELEMENTS IN RX ARRAY ARE USED BY RIV

GHB6 -- GHB PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT 12
No named parameters
MAXIMUM OF     36 ACTIVE GHB CELLS AT ONE TIME
      180 ELEMENTS IN RX ARRAY ARE USED BY GHB

RCH6 -- RECHARGE PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT 31
  2 Named Parameters
OPTION 1 -- RECHARGE TO TOP LAYER
      324 ELEMENTS IN RX ARRAY ARE USED BY RCH
      324 ELEMENTS IN IR ARRAY ARE USED BY RCH

      632 ELEMENTS OF RX ARRAY USED OUT OF      632
      339 ELEMENTS OF IR ARRAY USED OUT OF      339
1
# MODULAR MODEL - TWO-LAYER EXAMPLE PROBLEM, TRANSIENT, TEST CASE TC1TR
#

      BOUNDARY ARRAY =           1 FOR LAYER  1

      BOUNDARY ARRAY =           1 FOR LAYER  2

      BOUNDARY ARRAY =           1 FOR LAYER  3

AQUIFER HEAD WILL BE SET TO  0.0000  AT ALL NO-FLOW NODES (IBOUND=0).

      INITIAL HEAD FOR LAYER  1
READING ON UNIT  14 WITH FORMAT: (10F13.0)

      INITIAL HEAD FOR LAYER  2
READING ON UNIT  14 WITH FORMAT: (10F13.0)

      INITIAL HEAD FOR LAYER  3
READING ON UNIT  14 WITH FORMAT: (10F13.0)

OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
HEAD PRINT FORMAT CODE IS  20  DRAWDOWN PRINT FORMAT CODE IS  0

```


Test Case 1 Sample Files – LIST Output File

5 3 10 10 -1.000

5 WELLS

REACH NO.	LAYER	ROW	COL	STAGE	CONDUCTANCE	BOTTOM EL.
1	1	1	1	100.0	1.000	90.00
2	1	2	1	100.0	1.000	90.00
3	1	3	1	100.0	1.000	90.00
4	1	4	1	100.0	1.000	90.00
5	1	5	1	100.0	1.000	90.00
6	1	6	1	100.0	1.000	90.00
7	1	7	1	100.0	1.000	90.00
8	1	8	1	100.0	1.000	90.00
9	1	9	1	100.0	1.000	90.00
10	1	10	1	100.0	1.000	90.00
11	1	11	1	100.0	1.000	90.00
12	1	12	1	100.0	1.000	90.00
13	1	13	1	100.0	1.000	90.00
14	1	14	1	100.0	1.000	90.00
15	1	15	1	100.0	1.000	90.00
16	1	16	1	100.0	1.000	90.00
17	1	17	1	100.0	1.000	90.00
18	1	18	1	100.0	1.000	90.00

18 RIVER REACHES

BOUND. NO.	LAYER	ROW	COL	STAGE	CONDUCTANCE
1	1	1	18	350.0	0.1000E-01
2	1	2	18	350.0	0.1000E-01
3	1	3	18	350.0	0.1000E-01
4	1	4	18	350.0	0.1000E-01
5	1	5	18	350.0	0.1000E-01
6	1	6	18	350.0	0.1000E-01
7	1	7	18	350.0	0.1000E-01
8	1	8	18	350.0	0.1000E-01
9	1	9	18	350.0	0.1000E-01
10	1	10	18	350.0	0.1000E-01
11	1	11	18	350.0	0.1000E-01
12	1	12	18	350.0	0.1000E-01
13	1	13	18	350.0	0.1000E-01
14	1	14	18	350.0	0.1000E-01
15	1	15	18	350.0	0.1000E-01
16	1	16	18	350.0	0.1000E-01
17	1	17	18	350.0	0.1000E-01
18	1	18	18	350.0	0.1000E-01
19	3	1	18	350.0	0.1000E-01
20	3	2	18	350.0	0.1000E-01
21	3	3	18	350.0	0.1000E-01
22	3	4	18	350.0	0.1000E-01
23	3	5	18	350.0	0.1000E-01
24	3	6	18	350.0	0.1000E-01
25	3	7	18	350.0	0.1000E-01
26	3	8	18	350.0	0.1000E-01
27	3	9	18	350.0	0.1000E-01
28	3	10	18	350.0	0.1000E-01
29	3	11	18	350.0	0.1000E-01
30	3	12	18	350.0	0.1000E-01
31	3	13	18	350.0	0.1000E-01
32	3	14	18	350.0	0.1000E-01
33	3	15	18	350.0	0.1000E-01
34	3	16	18	350.0	0.1000E-01
35	3	17	18	350.0	0.1000E-01
36	3	18	18	350.0	0.1000E-01

36 GHB CELLS

RECH array defined by the following parameters:

Parameter: RCH1
Parameter: RCH2

RECHARGE

SOLVING FOR HEAD

HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1
CELL-BY-CELL FLOW TERM FLAG = 0

Test Case 1 Sample Files – LIST Output File

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

HEAD DRAWDOWN HEAD DRAWDOWN
 PRINTOUT PRINTOUT SAVE SAVE

 1 0 0 0
 1
 HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

...

1
 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

...

1
 HEAD IN LAYER 3 AT END OF TIME STEP 1 IN STRESS PERIOD 1

...

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 =	651601.0000	STORAGE =	7.4757
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	0.0000	WELLS =	0.0000
RIVER LEAKAGE =	0.0000	RIVER LEAKAGE =	0.0000
HEAD DEP BOUNDS =	5328314.5000	HEAD DEP BOUNDS =	61.1312
RECHARGE =	353006.0625	RECHARGE =	4.0500
TOTAL IN =	6332921.5000	TOTAL IN =	72.6569
OUT:		OUT:	
----		----	
STORAGE =	5698661.5000	STORAGE =	65.3801
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	435810.0000	WELLS =	5.0000
RIVER LEAKAGE =	198362.3906	RIVER LEAKAGE =	2.2758
HEAD DEP BOUNDS =	0.0000	HEAD DEP BOUNDS =	0.0000
RECHARGE =	0.0000	RECHARGE =	0.0000
TOTAL OUT =	6332834.0000	TOTAL OUT =	72.6559
IN - OUT =	87.5000	IN - OUT =	1.0147E-03
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	87162.	1452.7	24.212	1.0088	2.76200E-03
STRESS PERIOD TIME	87162.	1452.7	24.212	1.0088	2.76200E-03
TOTAL TIME	87162.	1452.7	24.212	1.0088	2.76200E-03

1
 1

STRESS PERIOD NO. 2, LENGTH = 261486.0

NUMBER OF TIME STEPS = 1

MULTIPLIER FOR DELT = 1.200

INITIAL TIME STEP SIZE = 261486.0

REUSING NON-PARAMETER WELLS FROM LAST STRESS PERIOD

Test Case 1 Sample Files – LIST Output File

5 WELLS

REUSING NON-PARAMETER RIVER REACHES FROM LAST STRESS PERIOD

18 RIVER REACHES

REUSING NON-PARAMETER GHB CELLS FROM LAST STRESS PERIOD

36 GHB CELLS

RECH array defined by the following parameters:

Parameter: RCH1
Parameter: RCH2

RECHARGE

SOLVING FOR HEAD

HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1
CELL-BY-CELL FLOW TERM FLAG = 0
REUSING PREVIOUS VALUES OF IOFLG

1 HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 2

...

1 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 2

...

1 HEAD IN LAYER 3 AT END OF TIME STEP 1 IN STRESS PERIOD 2

...

1 VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 2

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
-----		-----	
IN:		IN:	
---		---	
STORAGE =	2154857.7500	STORAGE =	5.7489
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	0.0000	WELLS =	0.0000
RIVER LEAKAGE =	0.0000	RIVER LEAKAGE =	0.0000
HEAD DEP BOUNDS =	20593000.0000	HEAD DEP BOUNDS =	58.3767
RECHARGE =	1412024.2500	RECHARGE =	4.0500
TOTAL IN =	24159882.0000	TOTAL IN =	68.1756
OUT:		OUT:	
----		----	
STORAGE =	21999544.0000	STORAGE =	62.3394
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	1743240.0000	WELLS =	5.0000
RIVER LEAKAGE =	416905.6562	RIVER LEAKAGE =	0.8358
HEAD DEP BOUNDS =	0.0000	HEAD DEP BOUNDS =	0.0000
RECHARGE =	0.0000	RECHARGE =	0.0000
TOTAL OUT =	24159690.0000	TOTAL OUT =	68.1752
IN - OUT =	192.0000	IN - OUT =	4.1199E-04
PERCENT DISCREPANCY =	0.00	PERCENT DISCREPANCY =	0.00

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 2

Test Case 1 Sample Files – LIST Output File

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	2.61486E+05	4358.1	72.635	3.0265	8.28599E-03
STRESS PERIOD TIME	2.61486E+05	4358.1	72.635	3.0265	8.28599E-03
TOTAL TIME	3.48648E+05	5810.8	96.847	4.0353	1.10480E-02

1
1

STRESS PERIOD NO. 3, LENGTH = 522972.0

NUMBER OF TIME STEPS = 1

MULTIPLIER FOR DELT = 1.200

INITIAL TIME STEP SIZE = 522972.0

REUSING NON-PARAMETER WELLS FROM LAST STRESS PERIOD

5 WELLS

REUSING NON-PARAMETER RIVER REACHES FROM LAST STRESS PERIOD

18 RIVER REACHES

REUSING NON-PARAMETER GHB CELLS FROM LAST STRESS PERIOD

36 GHB CELLS

RECH array defined by the following parameters:

Parameter: RCH1
Parameter: RCH2

RECHARGE

SOLVING FOR HEAD

HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1
CELL-BY-CELL FLOW TERM FLAG = 0

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

HEAD	DRAWDOWN	HEAD	DRAWDOWN
PRINTOUT	PRINTOUT	SAVE	SAVE
0	0	0	0

1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 3

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	4792874.5000	STORAGE =	5.0443
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	0.0000	WELLS =	0.0000
RIVER LEAKAGE =	0.0000	RIVER LEAKAGE =	0.0000
HEAD DEP BOUNDS =	48794636.0000	HEAD DEP BOUNDS =	53.9257
RECHARGE =	3530060.7500	RECHARGE =	4.0500
TOTAL IN =	57117572.0000	TOTAL IN =	63.0200
OUT:		OUT:	
STORAGE =	52126352.0000	STORAGE =	57.6069
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	4358100.0000	WELLS =	5.0000
RIVER LEAKAGE =	632880.8750	RIVER LEAKAGE =	0.4130
HEAD DEP BOUNDS =	0.0000	HEAD DEP BOUNDS =	0.0000
RECHARGE =	0.0000	RECHARGE =	0.0000
TOTAL OUT =	57117332.0000	TOTAL OUT =	63.0199
IN - OUT =	240.0000	IN - OUT =	8.3923E-05
PERCENT DISCREPANCY =	0.00	PERCENT DISCREPANCY =	0.00

Test Case 1 Sample Files – LIST Output File

```

          TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 3
          SECONDS      MINUTES      HOURS      DAYS      YEARS
-----
TIME STEP LENGTH 5.22972E+05  8716.2    145.27    6.0529    1.65720E-02
STRESS PERIOD TIME 5.22972E+05  8716.2    145.27    6.0529    1.65720E-02
TOTAL TIME 8.71620E+05  14527.    242.12    10.088    2.76200E-02

```

1
1

STRESS PERIOD NO. 4, LENGTH = 0.2356744E+08

NUMBER OF TIME STEPS = 9

MULTIPLIER FOR DELT = 1.200

INITIAL TIME STEP SIZE = 1133110.

REUSING NON-PARAMETER WELLS FROM LAST STRESS PERIOD

5 WELLS

REUSING NON-PARAMETER RIVER REACHES FROM LAST STRESS PERIOD

18 RIVER REACHES

REUSING NON-PARAMETER GHB CELLS FROM LAST STRESS PERIOD

36 GHB CELLS

RECH array defined by the following parameters:

Parameter: RCH1
Parameter: RCH2

RECHARGE

SOLVING FOR HEAD

HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1

CELL-BY-CELL FLOW TERM FLAG = 0

REUSING PREVIOUS VALUES OF IOFLG

1

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
-----		-----	
IN:		IN:	
---		---	
STORAGE =	10166688.0000	STORAGE =	4.7425
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	0.0000	WELLS =	0.0000
RIVER LEAKAGE =	0.0000	RIVER LEAKAGE =	0.0000
HEAD DEP BOUNDS =	102304648.0000	HEAD DEP BOUNDS =	47.2240
RECHARGE =	8119154.5000	RECHARGE =	4.0500
TOTAL IN =	120590488.0000	TOTAL IN =	56.0166
OUT:		OUT:	
----		----	
STORAGE =	109484688.0000	STORAGE =	50.6203
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	10023648.0000	WELLS =	5.0000
RIVER LEAKAGE =	1082042.8750	RIVER LEAKAGE =	0.3964
HEAD DEP BOUNDS =	0.0000	HEAD DEP BOUNDS =	0.0000
RECHARGE =	0.0000	RECHARGE =	0.0000
TOTAL OUT =	120590376.0000	TOTAL OUT =	56.0167
IN - OUT =	112.0000	IN - OUT =	-1.1063E-04
PERCENT DISCREPANCY =	0.00	PERCENT DISCREPANCY =	0.00

Test Case 1 Sample Files – LIST Output File

```

          TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 4
                SECONDS      MINUTES      HOURS      DAYS      YEARS
-----
TIME STEP LENGTH 1.13311E+06  18885.      314.75     13.115    3.59061E-02
STRESS PERIOD TIME 1.13311E+06  18885.      314.75     13.115    3.59061E-02
TOTAL TIME 2.00473E+06  33412.      556.87     23.203    6.35260E-02
    
```

1

SOLVING FOR HEAD

```

HEAD/DRAWDOWN PRINTOUT FLAG = 1      TOTAL BUDGET PRINTOUT FLAG = 1
CELL-BY-CELL FLOW TERM FLAG = 0
REUSING PREVIOUS VALUES OF IOFLG
    
```

1

```

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 2 IN STRESS PERIOD 4
-----
    
```

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
---		---	
STORAGE =	16386104.0000	STORAGE =	4.5740
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	0.0000	WELLS =	0.0000
RIVER LEAKAGE =	0.0000	RIVER LEAKAGE =	0.0000
HEAD DEP BOUNDS =	158912464.0000	HEAD DEP BOUNDS =	41.6316
RECHARGE =	13626067.0000	RECHARGE =	4.0500
TOTAL IN =	188924624.0000	TOTAL IN =	50.2556
OUT:		OUT:	
----		----	
STORAGE =	170418144.0000	STORAGE =	44.8129
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	16822306.0000	WELLS =	5.0000
RIVER LEAKAGE =	1684351.8750	RIVER LEAKAGE =	0.4430
HEAD DEP BOUNDS =	0.0000	HEAD DEP BOUNDS =	0.0000
RECHARGE =	0.0000	RECHARGE =	0.0000
TOTAL OUT =	188924800.0000	TOTAL OUT =	50.2558
IN - OUT =	-176.0000	IN - OUT =	-2.0981E-04
PERCENT DISCREPANCY =	0.00	PERCENT DISCREPANCY =	0.00

1

```

          TIME SUMMARY AT END OF TIME STEP 2 IN STRESS PERIOD 4
                SECONDS      MINUTES      HOURS      DAYS      YEARS
-----
TIME STEP LENGTH 1.35973E+06  22662.      377.70     15.738    4.30873E-02
STRESS PERIOD TIME 2.49284E+06  41547.      692.46     28.852    7.89934E-02
TOTAL TIME 3.36446E+06  56074.      934.57     38.941    0.10661
    
```

1

SOLVING FOR HEAD

```

HEAD/DRAWDOWN PRINTOUT FLAG = 1      TOTAL BUDGET PRINTOUT FLAG = 1
CELL-BY-CELL FLOW TERM FLAG = 0
    
```

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

```

HEAD   DRAWDOWN  HEAD   DRAWDOWN
PRINTOUT PRINTOUT  SAVE   SAVE
-----
0       0         0       0
    
```

1

```

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 3 IN STRESS PERIOD 4
-----
    
```

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

Test Case 1 Sample Files – LIST Output File

```

---
STORAGE = 23453994.0000
CONSTANT HEAD = 0.0000
WELLS = 0.0000
RIVER LEAKAGE = 0.0000
HEAD DEP BOUNDS = 219173856.0000
RECHARGE = 20234362.0000

TOTAL IN = 262862224.0000

OUT:
-----
STORAGE = 235403488.0000
CONSTANT HEAD = 0.0000
WELLS = 24980696.0000
RIVER LEAKAGE = 2478269.2500
HEAD DEP BOUNDS = 0.0000
RECHARGE = 0.0000

TOTAL OUT = 262862464.0000

IN - OUT = -240.0000

PERCENT DISCREPANCY = 0.00

---
STORAGE = 4.3317
CONSTANT HEAD = 0.0000
WELLS = 0.0000
RIVER LEAKAGE = 0.0000
HEAD DEP BOUNDS = 36.9322
RECHARGE = 4.0500

TOTAL IN = 45.3138

OUT:
-----
STORAGE = 39.8273
CONSTANT HEAD = 0.0000
WELLS = 5.0000
RIVER LEAKAGE = 0.4866
HEAD DEP BOUNDS = 0.0000
RECHARGE = 0.0000

TOTAL OUT = 45.3139

IN - OUT = -4.5776E-05

PERCENT DISCREPANCY = 0.00

```

```

TIME SUMMARY AT END OF TIME STEP 3 IN STRESS PERIOD 4
          SECONDS      MINUTES      HOURS      DAYS      YEARS
-----
TIME STEP LENGTH 1.63168E+06  27195.    453.24    18.885    5.17048E-02
STRESS PERIOD TIME 4.12452E+06  68742.    1145.7    47.737    0.13070
TOTAL TIME 4.99614E+06  83269.    1387.8    57.826    0.15832

```

1

SOLVING FOR HEAD

```

HEAD/DRAWDOWN PRINTOUT FLAG = 1      TOTAL BUDGET PRINTOUT FLAG = 0
CELL-BY-CELL FLOW TERM FLAG = 0
REUSING PREVIOUS VALUES OF IOFLG

```

SOLVING FOR HEAD

```

HEAD/DRAWDOWN PRINTOUT FLAG = 1      TOTAL BUDGET PRINTOUT FLAG = 0
CELL-BY-CELL FLOW TERM FLAG = 0
REUSING PREVIOUS VALUES OF IOFLG

```

SOLVING FOR HEAD

```

CELL CONVERSIONS FOR ITER.= 10 LAYER= 1 STEP= 6 PERIOD= 4 (ROW,COL)
DRY( 9, 10)

```

```

HEAD/DRAWDOWN PRINTOUT FLAG = 1      TOTAL BUDGET PRINTOUT FLAG = 0
CELL-BY-CELL FLOW TERM FLAG = 0

```

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

```

HEAD   DRAWDOWN HEAD DRAWDOWN
PRINTOUT PRINTOUT SAVE   SAVE
-----
0       0       0       0

```

SOLVING FOR HEAD

```

HEAD/DRAWDOWN PRINTOUT FLAG = 1      TOTAL BUDGET PRINTOUT FLAG = 0
CELL-BY-CELL FLOW TERM FLAG = 0
REUSING PREVIOUS VALUES OF IOFLG

```

SOLVING FOR HEAD

```

HEAD/DRAWDOWN PRINTOUT FLAG = 1      TOTAL BUDGET PRINTOUT FLAG = 0
CELL-BY-CELL FLOW TERM FLAG = 0
REUSING PREVIOUS VALUES OF IOFLG

```

SOLVING FOR HEAD

```

HEAD/DRAWDOWN PRINTOUT FLAG = 1      TOTAL BUDGET PRINTOUT FLAG = 0
CELL-BY-CELL FLOW TERM FLAG = 0

```

Test Case 1 Sample Files – LIST Output File

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

HEAD PRINTOUT	DRAWDOWN PRINTOUT	HEAD SAVE	DRAWDOWN SAVE
0	0	0	0

1
VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 9 IN STRESS PERIOD 4

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
IN:		IN:	
STORAGE =	63072188.0000	STORAGE =	1.0275
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	0.0000	WELLS =	0.0000
RIVER LEAKAGE =	0.0000	RIVER LEAKAGE =	0.0000
HEAD DEP BOUNDS =	691365760.0000	HEAD DEP BOUNDS =	19.5218
RECHARGE =	98751168.0000	RECHARGE =	4.0350
TOTAL IN =	853189120.0000	TOTAL IN =	24.5843
OUT:		OUT:	
STORAGE =	731379584.0000	STORAGE =	19.8770
CONSTANT HEAD =	0.0000	CONSTANT HEAD =	0.0000
WELLS =	107060016.0000	WELLS =	4.0000
RIVER LEAKAGE =	14750643.0000	RIVER LEAKAGE =	0.7073
HEAD DEP BOUNDS =	0.0000	HEAD DEP BOUNDS =	0.0000
RECHARGE =	0.0000	RECHARGE =	0.0000
TOTAL OUT =	853190272.0000	TOTAL OUT =	24.5843
IN - OUT =	-1152.0000	IN - OUT =	-1.7166E-05
PERCENT DISCREPANCY =	0.00	PERCENT DISCREPANCY =	0.00

1
TIME SUMMARY AT END OF TIME STEP 9 IN STRESS PERIOD 4

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	4.87217E+06	81203.	1353.4	56.391	0.15439
STRESS PERIOD TIME	2.35674E+07	3.92791E+05	6546.5	272.77	0.74681
TOTAL TIME	2.44391E+07	4.07318E+05	6788.6	282.86	0.77443

DATA AT HEAD LOCATIONS

OBS#	OBSERVATION NAME	MEAS. HEAD	CALC. HEAD	RESIDUAL	WEIGHT** .5	WEIGHTED RESIDUAL
1	H1_8_8_1	152.270	152.270	-0.458E-04	1.00	-0.458E-04
2	H1_8_8_2	152.282	152.282	0.427E-03	1.00	0.427E-03
3	H1_8_8_3	152.216	152.216	-0.183E-03	1.00	-0.183E-03
4	H1_8_8_4	140.927	140.925	0.163E-02	1.00	0.163E-02
5	H2_8_8_1	152.266	152.266	-0.916E-04	1.00	-0.916E-04
6	H2_8_8_2	152.264	152.264	-0.427E-03	1.00	-0.427E-03
7	H2_8_8_3	152.172	152.172	-0.168E-03	1.00	-0.168E-03
8	H2_8_8_4	140.111	140.111	-0.397E-03	1.00	-0.397E-03
9	H3_8_8_1	152.262	152.262	-0.122E-03	1.00	-0.122E-03
10	H3_8_8_2	152.247	152.247	-0.305E-03	1.00	-0.305E-03
11	H3_8_8_3	152.128	152.128	-0.305E-04	1.00	-0.305E-04
12	H3_8_8_4	139.296	139.295	0.133E-02	1.00	0.133E-02
13	H1_2_2_1	110.016	110.016	-0.328E-03	1.00	-0.328E-03
14	H1_2_2_2	110.128	110.128	-0.237E-03	1.00	-0.237E-03
15	H1_2_2_3	110.342	110.342	0.130E-03	1.00	0.130E-03
16	H1_2_2_4	117.746	117.746	-0.298E-03	1.00	-0.298E-03
17	H2_2_2_1	110.002	110.002	-0.183E-03	1.00	-0.183E-03
18	H2_2_2_2	110.075	110.075	-0.336E-03	1.00	-0.336E-03
19	H2_2_2_3	110.230	110.230	0.763E-04	1.00	0.763E-04
20	H2_2_2_4	117.178	117.178	-0.145E-03	1.00	-0.145E-03
21	H3_2_2_1	109.987	109.987	0.145E-03	1.00	0.145E-03
22	H3_2_2_2	110.021	110.021	-0.275E-03	1.00	-0.275E-03
23	H3_2_2_3	110.115	110.115	-0.397E-03	1.00	-0.397E-03
24	H3_2_2_4	116.597	116.597	-0.153E-04	1.00	-0.153E-04
25	H1_16_16_1	176.152	176.152	-0.443E-03	1.00	-0.443E-03

Test Case 1 Sample Files – LIST Output File

26	H1_16_16_2	176.244	176.244	0.610E-04	1.00	0.610E-04
27	H1_16_16_3	176.720	176.720	0.488E-03	1.00	0.488E-03
28	H1_16_16_4	240.060	240.060	-0.275E-03	1.00	-0.275E-03
29	H2_16_16_1	176.140	176.140	-0.244E-03	1.00	-0.244E-03
30	H2_16_16_2	176.209	176.209	0.427E-03	1.00	0.427E-03
31	H2_16_16_3	176.673	176.673	-0.122E-03	1.00	-0.122E-03
32	H2_16_16_4	240.181	240.181	0.397E-03	1.00	0.397E-03
33	H3_16_16_1	176.129	176.129	-0.458E-04	1.00	-0.458E-04
34	H3_16_16_2	176.173	176.173	-0.244E-03	1.00	-0.244E-03
35	H3_16_16_3	176.627	176.627	0.153E-03	1.00	0.153E-03
36	H3_16_16_4	240.301	240.301	-0.122E-03	1.00	-0.122E-03
37	H1_16_2_1	110.016	110.016	-0.328E-03	1.00	-0.328E-03
38	H1_16_2_2	110.128	110.128	-0.237E-03	1.00	-0.237E-03
39	H1_16_2_3	110.342	110.342	0.130E-03	1.00	0.130E-03
40	H1_16_2_4	117.742	117.742	-0.443E-03	1.00	-0.443E-03
41	H2_16_2_1	110.002	110.002	-0.183E-03	1.00	-0.183E-03
42	H2_16_2_2	110.075	110.075	-0.336E-03	1.00	-0.336E-03
43	H2_16_2_3	110.230	110.230	0.763E-04	1.00	0.763E-04
44	H2_16_2_4	117.174	117.174	-0.496E-03	1.00	-0.496E-03
45	H3_16_2_1	109.987	109.987	0.145E-03	1.00	0.145E-03
46	H3_16_2_2	110.021	110.021	-0.275E-03	1.00	-0.275E-03
47	H3_16_2_3	110.115	110.115	-0.397E-03	1.00	-0.397E-03
48	H3_16_2_4	116.594	116.594	0.404E-03	1.00	0.404E-03

STATISTICS FOR HEAD RESIDUALS :
 MAXIMUM WEIGHTED RESIDUAL : 0.163E-02 OBS# 4
 MINIMUM WEIGHTED RESIDUAL :-0.496E-03 OBS# 44
 AVERAGE WEIGHTED RESIDUAL :-0.448E-04
 # RESIDUALS >= 0. : 15
 # RESIDUALS < 0. : 33
 NUMBER OF RUNS : 28 IN 48 OBSERVATIONS

SUM OF SQUARED WEIGHTED RESIDUALS (HEADS ONLY) 0.80469E-05

DATA FOR FLOWS REPRESENTED USING THE GENERAL-HEAD BOUNDARY PACKAGE

OBS#	OBSERVATION NAME	MEAS. FLOW	CALC. FLOW	RESIDUAL	WEIGHT**0.5	WEIGHTED RESIDUAL
49	GHB1	30.6	30.6	0.379E-01	0.654	0.248E-01
50	GHB2	29.2	29.2	0.299E-01	0.685	0.205E-01
51	GHB3	26.9	26.9	-0.125E-01	0.743	-0.932E-02
52	GHB4	9.62	9.62	0.127E-02	2.08	0.265E-02

STATISTICS FOR GENERAL-HEAD BOUNDARY FLOW RESIDUALS :
 MAXIMUM WEIGHTED RESIDUAL : 0.248E-01 OBS# 49
 MINIMUM WEIGHTED RESIDUAL :-0.932E-02 OBS# 51
 AVERAGE WEIGHTED RESIDUAL : 0.965E-02
 # RESIDUALS >= 0. : 3
 # RESIDUALS < 0. : 1
 NUMBER OF RUNS : 3 IN 4 OBSERVATIONS

SUM OF SQUARED WEIGHTED RESIDUALS
 (GENERAL-HEAD BOUNDARY FLOWS ONLY) 0.11273E-02

SUM OF SQUARED WEIGHTED RESIDUALS (ALL DEPENDENT VARIABLES) 0.11353E-02

STATISTICS FOR ALL RESIDUALS :
 AVERAGE WEIGHTED RESIDUAL : 0.701E-03
 # RESIDUALS >= 0. : 18
 # RESIDUALS < 0. : 34
 NUMBER OF RUNS : 30 IN 52 OBSERVATIONS

THE NUMBER OF RUNS EQUALS THE EXPECTED NUMBER OF RUNS

Test Case 2 Variant 4 Sample Files

Input File

```

# HUF file for Test Case 2 Variant 4
#
0 -999. 5 12 00      Item 1: IHUFCEB HDRY NHUF NPHUF IOHUF
0 0 0              Item 2: LTHUF
0 0 0              Item 3: LAYWT
HGU1
INTERNAL          1.0 (9f10.2)          20          Item 6: HGUNAM
                Item 7: TOP
0.00 466.66 970.89 979.17 979.48 980.07 1025.00 1123.69 1184.28
1185.76 1186.51 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00
0.00 460.53 968.83 979.02 979.21 979.77 1015.11 1103.04 1170.61
1186.49 1187.26 1188.65 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00
0.00 432.95 961.24 973.60 978.55 957.74 987.47 1088.84 1179.69
1186.78 1187.39 1190.05 1191.79 9999.00 9999.00 9999.00 9999.00 9999.00
0.00 291.69 752.49 967.22 971.47 964.35 990.43 1082.56 1176.54
1177.24 1159.66 1192.36 1193.54 1194.92 9999.00 9999.00 9999.00 9999.00
0.00 220.86 552.04 799.15 897.53 929.42 956.07 983.73 1077.55
1147.71 1154.33 1194.15 1195.09 1196.29 1197.29 9999.00 9999.00 9999.00
0.00 188.80 463.00 692.59 852.09 892.57 932.76 906.94 1007.63
1147.73 1201.15 1195.77 1196.37 1197.88 1198.28 1198.34 9999.00 9999.00
27.65 189.71 420.51 653.17 857.06 922.11 1014.73 951.16 1023.76
1183.96 1259.68 1242.39 1215.40 1200.60 1200.03 1198.83 1197.33 9999.00
50.33 209.99 431.34 642.47 850.77 944.38 1014.46 953.31 1036.80
1233.05 1337.05 1346.38 1256.78 1205.05 1203.72 1200.92 1197.30 1100.00
67.18 233.93 444.97 634.74 835.28 925.80 971.05 931.50 1049.61
1275.58 1407.16 1449.87 1356.59 1209.95 1209.11 1204.70 1176.94 1100.00
77.44 262.59 462.38 635.42 812.44 951.31 990.28 999.73 1107.81
1286.30 1395.35 1453.25 1424.78 1276.80 1214.27 1202.18 1159.09 1100.00
207.65 336.39 484.48 640.95 809.63 926.59 996.19 1045.80 1129.56
1312.27 1441.08 1456.96 1447.99 1315.52 1217.30 1204.81 1157.15 1100.00
9999.00 9999.00 9999.00 9999.00 871.62 949.88 1018.16 1062.88 1036.73
1312.10 1459.70 1459.79 1479.20 1375.99 1284.80 1218.50 1164.71 1100.00
9999.00 9999.00 9999.00 9999.00 9999.00 1000.38 1063.05 1123.83 1184.97
1336.58 1482.97 1513.53 1515.39 1419.18 1314.91 1228.81 1181.96 1153.66
9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 1117.51 1183.17 1225.02
1283.48 1375.39 1404.99 1388.08 1333.35 1276.05 1215.86 1193.01 1177.67
9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 1239.21 1241.07
1242.52 1282.86 1303.60 1286.91 1219.00 1240.73 1206.68 1193.28 1188.76
9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 1241.55
1242.06 1255.55 1262.52 1249.10 1206.20 1216.15 1197.47 1193.35 1192.28
9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00
1242.22 1246.68 1247.25 1238.52 1221.48 1209.43 1195.85 1194.18 1193.66
9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00 9999.00
9999.00 1244.51 1242.16 1234.80 1222.75 1208.12 1195.45 1194.60 1194.10
CONSTANT 300.0          Item 8: THCK
HGU2
INTERNAL          1.0 (9f10.2)          20          Item 6: HGUNAM
                Item 7: TOP
-300.00 166.66 670.89 679.17 679.48 680.07 725.00 823.69 884.28
885.76 886.51 0.00 0.00 0.00 0.00 0.00 0.00 0.00
-300.00 160.53 668.83 679.02 679.21 679.77 715.11 803.04 870.61
886.49 887.26 888.65 0.00 0.00 0.00 0.00 0.00 0.00
-300.00 132.95 661.24 673.60 678.55 657.74 687.47 788.84 879.69
886.78 887.39 890.05 891.79 0.00 0.00 0.00 0.00 0.00
-300.00 -8.31 452.49 667.22 671.47 664.35 690.43 782.56 876.54
877.24 859.66 892.36 893.54 894.92 0.00 0.00 0.00 0.00
-300.00 -79.14 252.04 499.15 597.53 629.42 656.07 683.73 777.55
847.71 854.33 894.15 895.09 896.29 897.29 0.00 0.00 0.00
-300.00 -111.20 163.00 392.59 552.09 592.57 632.76 606.94 707.63
847.73 901.15 895.77 896.37 897.88 898.28 898.34 0.00 0.00
-272.35 -110.29 120.51 353.17 557.06 622.11 714.73 651.16 723.76
883.96 959.68 942.39 915.40 900.60 900.03 898.83 897.33 0.00
-249.67 -90.01 131.34 342.47 550.77 644.38 714.46 653.31 736.80
933.05 1037.05 1046.38 956.78 905.05 903.72 900.92 897.30 800.00
-232.82 -66.07 144.97 334.74 535.28 625.80 671.05 631.50 749.61
975.58 1107.16 1149.87 1056.59 909.95 909.11 904.70 876.94 800.00
-222.56 -37.41 162.38 335.42 512.44 651.31 690.28 699.73 807.81
986.30 1095.35 1153.25 1124.78 976.80 914.27 902.18 859.09 800.00
-92.35 36.39 184.48 340.95 509.63 626.59 696.19 745.80 829.56
1012.27 1141.08 1156.96 1147.99 1015.52 917.30 904.81 857.15 800.00
0.00 0.00 0.00 0.00 571.62 649.88 718.16 762.88 736.73
1012.10 1159.70 1159.79 1179.20 1075.99 984.80 918.50 864.71 800.00
0.00 0.00 0.00 0.00 0.00 700.38 763.05 823.83 884.97
1036.58 1182.97 1213.53 1215.39 1119.18 1014.91 928.81 881.96 853.66

```


Test Case 2 Variant 4 Sample Files – Input File

0.00	0.00	0.00	0.00	0.00	0.00	817.51	883.17	925.02
983.48	1075.39	1104.99	1088.08	1033.35	976.05	915.86	893.01	877.67
0.00	0.00	0.00	0.00	0.00	0.00	0.00	939.21	941.07
942.52	982.86	1003.60	986.91	919.00	940.73	906.68	893.28	888.76
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	941.55
942.06	955.55	962.52	949.10	906.20	916.15	897.47	893.35	892.28
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
942.22	946.68	947.25	938.52	921.48	909.43	895.85	894.18	893.66
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	944.51	942.16	934.80	922.75	908.12	895.45	894.60	894.10
CONSTANT	200.0				Item 8: THCK			
HGU3				20	Item 6: HGUNAM			
INTERNAL	1.0 (9f10.2)			20	Item 7: TOP			
-500.00	-33.34	470.89	479.17	479.48	480.07	525.00	623.69	684.28
685.76	686.51	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00
-500.00	-39.47	468.83	479.02	479.21	479.77	515.11	603.04	670.61
686.49	687.26	688.65	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00
-500.00	-67.05	461.24	473.60	478.55	457.74	487.47	588.84	679.69
686.78	687.39	690.05	691.79	9999.00	9999.00	9999.00	9999.00	9999.00
-500.00	-208.31	252.49	467.22	471.47	464.35	490.43	582.56	676.54
677.24	659.66	692.36	693.54	694.92	9999.00	9999.00	9999.00	9999.00
-500.00	-279.14	52.04	299.15	397.53	429.42	456.07	483.73	577.55
647.71	654.33	694.15	695.09	696.29	697.29	9999.00	9999.00	9999.00
-500.00	-311.20	-37.00	192.59	352.09	392.57	432.76	406.94	507.63
647.73	701.15	695.77	696.37	697.88	698.28	698.34	9999.00	9999.00
-472.35	-310.29	-79.49	153.17	357.06	422.11	514.73	451.16	523.76
683.96	759.68	742.39	715.40	700.60	700.03	698.83	697.33	9999.00
-449.67	-290.01	-68.66	142.47	350.77	444.38	514.46	453.31	536.80
733.05	837.05	846.38	756.78	705.05	703.72	700.92	697.30	600.00
-432.82	-266.07	-55.03	134.74	335.28	425.80	471.05	431.50	549.61
775.58	907.16	949.87	856.59	709.95	709.11	704.70	676.94	600.00
-422.56	-237.41	-37.62	135.42	312.44	451.31	490.28	499.73	607.81
786.30	895.35	953.25	924.78	776.80	714.27	702.18	659.09	600.00
-292.35	-163.61	-15.52	140.95	309.63	426.59	496.19	545.80	629.56
812.27	941.08	956.96	947.99	815.52	717.30	704.81	657.15	600.00
9999.00	9999.00	9999.00	9999.00	371.62	449.88	518.16	562.88	536.73
812.10	959.70	959.79	979.20	875.99	784.80	718.50	664.71	600.00
9999.00	9999.00	9999.00	9999.00	9999.00	500.38	563.05	623.83	684.97
836.58	982.97	1013.53	1015.39	919.18	814.91	728.81	681.96	653.66
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	617.51	683.17	725.02
783.48	875.39	904.99	888.08	833.35	776.05	715.86	693.01	677.67
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	739.21	741.07
742.52	782.86	803.60	786.91	719.00	740.73	706.68	693.28	688.76
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	741.55
742.06	755.55	762.52	749.10	706.20	716.15	697.47	693.35	692.28
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00
742.22	746.68	747.25	738.52	721.48	709.43	695.85	694.18	693.66
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00
9999.00	744.51	742.16	734.80	722.75	708.12	695.45	694.60	694.10
CONSTANT	550.0				Item 8: THCK			
HGU4				20	Item 6: HGUNAM			
INTERNAL	1.0 (9f10.2)			20	Item 7: TOP			
-1050.00	-583.34	-79.11	-70.83	-70.52	-69.93	-25.00	73.69	134.28
135.76	136.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-1050.00	-589.47	-81.17	-70.98	-70.79	-70.23	-34.89	53.04	120.61
136.49	137.26	138.65	0.00	0.00	0.00	0.00	0.00	0.00
-1050.00	-617.05	-88.76	-76.40	-71.45	-92.26	-62.53	38.84	129.69
136.78	137.39	140.05	141.79	0.00	0.00	0.00	0.00	0.00
-1050.00	-758.31	-297.51	-82.78	-78.53	-85.65	-59.57	32.56	126.54
127.24	109.66	142.36	143.54	144.92	0.00	0.00	0.00	0.00
-1050.00	-829.14	-497.96	-250.85	-152.47	-120.58	-93.93	-66.27	27.55
97.71	104.33	144.15	145.09	146.29	147.29	0.00	0.00	0.00
-1050.00	-861.20	-587.00	-357.41	-197.91	-157.43	-117.24	-143.06	-42.37
97.73	151.15	145.77	146.37	147.88	148.28	148.34	0.00	0.00
-1022.35	-860.29	-629.49	-396.83	-192.94	-127.89	-35.27	-98.84	-26.24
133.96	209.68	192.39	165.40	150.60	150.03	148.83	147.33	0.00
-999.67	-840.01	-618.66	-407.53	-199.23	-105.62	-35.54	-96.69	-13.20
183.05	287.05	296.38	206.78	155.05	153.72	150.92	147.30	50.00
-982.82	-816.07	-605.03	-415.26	-214.72	-124.20	-78.95	-118.50	-0.39
225.58	357.16	399.87	306.59	159.95	159.11	154.70	126.94	50.00
-972.56	-787.41	-587.62	-414.58	-237.56	-98.69	-59.72	-50.27	57.81
236.30	345.35	403.25	374.78	226.80	164.27	152.18	109.09	50.00
-842.35	-713.61	-565.52	-409.05	-240.37	-123.41	-53.81	-4.20	79.56
262.27	391.08	406.96	397.99	265.52	167.30	154.81	107.15	50.00
0.00	0.00	0.00	0.00	-178.38	-100.12	-31.84	12.88	-13.27
262.10	409.70	409.79	429.20	325.99	234.80	168.50	114.71	50.00
0.00	0.00	0.00	0.00	0.00	-49.62	13.05	73.83	134.97
286.58	432.97	463.53	465.39	369.18	264.91	178.81	131.96	103.66
0.00	0.00	0.00	0.00	0.00	0.00	67.51	133.17	175.02
233.48	325.39	354.99	338.08	283.35	226.05	165.86	143.01	127.67
0.00	0.00	0.00	0.00	0.00	0.00	0.00	189.21	191.07

Test Case 2 Variant 4 Sample Files – Input File

192.52	232.86	253.60	236.91	169.00	190.73	156.68	143.28	138.76
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	191.55
192.06	205.55	212.52	199.10	156.20	166.15	147.47	143.35	142.28
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
192.22	196.68	197.25	188.52	171.48	159.43	145.85	144.18	143.66
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	194.51	192.16	184.80	172.75	158.12	145.45	144.60	144.10
CONSTANT	200.0							
HGU5					Item 7: HGUNAM			
INTERNAL	1.0 (9f10.2)		20		Item 8: TOP			
-1250.00	-783.34	-279.11	-270.83	-270.52	-269.93	-225.00	-126.31	-65.72
-64.24	-63.49	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00
-1250.00	-789.47	-281.17	-270.98	-270.79	-270.23	-234.89	-146.96	-79.39
-63.51	-62.74	-61.35	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00
-1250.00	-817.05	-288.76	-276.40	-271.45	-292.26	-262.53	-161.16	-70.31
-63.22	-62.61	-59.95	-58.21	9999.00	9999.00	9999.00	9999.00	9999.00
-1250.00	-958.31	-497.51	-282.78	-278.53	-285.65	-259.57	-167.44	-73.46
-72.76	-90.34	-57.64	-56.46	-55.08	9999.00	9999.00	9999.00	9999.00
-1250.00	-1029.14	-697.96	-450.85	-352.47	-320.58	-293.93	-266.27	-172.45
-102.29	-95.67	-55.85	-54.91	-53.71	-52.71	9999.00	9999.00	9999.00
-1250.00	-1061.20	-787.00	-557.41	-397.91	-357.43	-317.24	-343.06	-242.37
-102.27	-48.85	-54.23	-53.63	-52.12	-51.72	-51.66	9999.00	9999.00
-1222.35	-1060.29	-829.49	-596.83	-392.94	-327.89	-235.27	-298.84	-226.24
-66.04	9.68	-7.61	-34.60	-49.40	-49.97	-51.17	-52.67	9999.00
-1199.67	-1040.01	-818.66	-607.53	-399.23	-305.62	-235.54	-296.69	-213.20
-16.95	87.05	96.38	6.78	-44.95	-46.28	-49.08	-52.70	-150.00
-1182.82	-1016.07	-805.03	-615.26	-414.72	-324.20	-278.95	-318.50	-200.39
25.58	157.16	199.87	106.59	-40.05	-40.89	-45.30	-73.06	-150.00
-1172.56	-987.41	-787.62	-614.58	-437.56	-298.69	-259.72	-250.27	-142.19
36.30	145.35	203.25	174.78	26.80	-35.73	-47.82	-90.91	-150.00
-1042.35	-913.61	-765.52	-609.05	-440.37	-323.41	-253.81	-204.20	-120.44
62.27	191.08	206.96	197.99	65.52	-32.70	-45.19	-92.85	-150.00
9999.00	9999.00	9999.00	9999.00	-378.38	-300.12	-231.84	-187.12	-213.27
62.10	209.70	209.79	229.20	125.99	34.80	-31.50	-85.29	-150.00
9999.00	9999.00	9999.00	9999.00	9999.00	-249.62	-186.95	-126.17	-65.03
86.58	232.97	263.53	265.39	169.18	64.91	-21.19	-68.04	-96.34
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	-132.49	-66.83	-24.98
33.48	125.39	154.99	138.08	83.35	26.05	-34.14	-56.99	-72.33
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	-10.79	-8.93
-7.48	32.86	53.60	36.91	-31.00	-9.27	-43.32	-56.72	-61.24
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	-8.45
-7.94	5.55	12.52	-0.90	-43.80	-33.85	-52.53	-56.65	-57.72
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00
-7.78	-3.32	-2.75	-11.48	-28.52	-40.57	-54.15	-55.82	-56.34
9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00	9999.00
9999.00	-5.49	-7.84	-15.20	-27.25	-41.88	-54.55	-55.40	-55.90
CONSTANT	1500.0				Item 8: THCK			
ALL	1.0	0			Item 9: HGUNAM	HGUHANI	HGUVANI	
HK1	HK	1.0	5	Item 10: PARNAM	PARTYP	Parval	NCLU	
HGU1	NONE	ZLAY1	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU2	NONE	ZLAY1	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU3	NONE	ZLAY2	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU4	NONE	ZLAY2	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU5	NONE	ZLAY3	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HK2	HK	1.0E-2	5	Item 10: PARNAM	PARTYP	Parval	NCLU	
HGU1	NONE	ZLAY1	2	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU2	NONE	ZLAY1	2	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU3	NONE	ZLAY2	2	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU4	NONE	ZLAY2	2	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU5	NONE	ZLAY3	2	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HK3	HK	1.0E-4	5	Item 10: PARNAM	PARTYP	Parval	NCLU	
HGU1	NONE	ZLAY1	3	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU2	NONE	ZLAY1	3	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU3	NONE	ZLAY2	3	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU4	NONE	ZLAY2	3	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU5	NONE	ZLAY3	3	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HK4	HK	1.0E-6	5	Item 10: PARNAM	PARTYP	Parval	NCLU	
HGU1	NONE	ZLAY1	4	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU2	NONE	ZLAY1	4	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU3	NONE	ZLAY2	4	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU4	NONE	ZLAY2	4	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU5	NONE	ZLAY3	4	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
VKA12_1	VK	0.25	4	Item 10: PARNAM	PARTYP	Parval	NCLU	
HGU1	NONE	ZLAY1	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU2	NONE	ZLAY1	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU3	NONE	ZLAY2	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU4	NONE	ZLAY2	1	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
VKA12_2	VK	2.5E-3	4	Item 10: PARNAM	PARTYP	Parval	NCLU	
HGU1	NONE	ZLAY1	2	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU2	NONE	ZLAY1	2	Item 11: HGUNAM	Mltarr	Zonarr	IZ	
HGU3	NONE	ZLAY2	2	Item 11: HGUNAM	Mltarr	Zonarr	IZ	

Test Case 2 Variant 4 Sample Files – Input File

HGU4	NONE	ZLAY2	2		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
VKA12_3	VK	2.5E-5	4		Item 10:	PARNAM	PARTYP	Parval	NCLU
HGU1	NONE	ZLAY1	3		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
HGU2	NONE	ZLAY1	3		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
HGU3	NONE	ZLAY2	3		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
HGU4	NONE	ZLAY2	3		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
VKA12_4	VK	2.5E-7	4		Item 10:	PARNAM	PARTYP	Parval	NCLU
HGU1	NONE	ZLAY1	4		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
HGU2	NONE	ZLAY1	4		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
HGU3	NONE	ZLAY2	4		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
HGU4	NONE	ZLAY2	4		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
VKA3_1	VK	1.0	1		Item 10:	PARNAM	PARTYP	Parval	NCLU
HGU5	NONE	ZLAY3	1		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
VKA3_2	VK	1.0E-2	1		Item 10:	PARNAM	PARTYP	Parval	NCLU
HGU5	NONE	ZLAY3	2		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
VKA3_3	VK	1.0E-4	1		Item 10:	PARNAM	PARTYP	Parval	NCLU
HGU5	NONE	ZLAY3	3		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
VKA3_4	VK	1.0E-6	1		Item 10:	PARNAM	PARTYP	Parval	NCLU
HGU5	NONE	ZLAY3	4		Item 11:	HGUNAM	Mltarr	Zonarr	IZ
PRINT	HGU2	2	ALL		Item 12:	HGUNAM	PRINTCODE	PRINTFLAGS	

GLOBAL Output File

An example of the excerpted GLOBAL output file for Test Case 2, Variant 4 is shown below.

The HUF Package output appears in bold, and three dots (...) indicates omitted output.

```

                                MODFLOW-2000
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                                VERSION 1.0.2 08/21/2000

This model run produced both GLOBAL and LIST files.  This is the GLOBAL file.

GLOBAL LISTING FILE: tc2var4.glo
                        UNIT 1

OPENING tc2var4.lst
FILE TYPE:LIST UNIT 2

OPENING tc2var4.huf
FILE TYPE:HUF UNIT 11

OPENING tc2var4.sen
FILE TYPE:SEN UNIT 38
#Common files

OPENING ..\common\tc2.bas
FILE TYPE:BAS6 UNIT 8

OPENING ..\common\tc2.dis
FILE TYPE:DIS UNIT 9

OPENING ..\common\tc2.wel
FILE TYPE:WEL UNIT 12

OPENING ..\common\tc2.drn
FILE TYPE:DRN UNIT 13

OPENING ..\common\tc2.evt
FILE TYPE:EVT UNIT 15

OPENING ..\common\tc2.ghb
FILE TYPE:GHB UNIT 17

OPENING ..\common\tc2.rch
FILE TYPE:RCH UNIT 18

OPENING ..\common\tc2.oc
FILE TYPE:OC UNIT 22

OPENING ..\common\tc2.pcg
FILE TYPE:PCG UNIT 23

OPENING ..\common\tc2.obs
FILE TYPE:OBS UNIT 37

OPENING ..\common\tc2.zon
FILE TYPE:ZONE UNIT 39

```

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

OPENING ..\common\tc2.hob
FILE TYPE:HOB UNIT 40

OPENING ..\common\tc2.odr
FILE TYPE:DROB UNIT 41

OPENING ..\common\tc2.ogb
FILE TYPE:GBOB UNIT 42

OPENING ..\common\tc2.pes
FILE TYPE:PES UNIT 44

OPENING ..\common\tc2.b
FILE TYPE:DATA UNIT 48

OPENING ..\common\tc2.bin
FILE TYPE:DATA(BINARY) UNIT 49

DISCRETIZATION INPUT DATA READ FROM UNIT 9
DIS file for test case ymptc

3 LAYERS 18 ROWS 18 COLUMNS
1 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS DAYS
MODEL LENGTH UNIT IS METERS

THE OBSERVATION PROCESS IS ACTIVE
THE SENSITIVITY PROCESS IS ACTIVE
THE PARAMETER-ESTIMATION PROCESS IS ACTIVE

MODE: PARAMETER ESTIMATION

ZONE OPTION, INPUT READ FROM UNIT 39
4 ZONE ARRAYS
Confining bed flag for each layer:
0 0 0

8784	ELEMENTS OF GX ARRAY USED OUT OF	8784
972	ELEMENTS OF GZ ARRAY USED OUT OF	972
2268	ELEMENTS OF IG ARRAY USED OUT OF	2268

DELR = 1500.00

DELC = 1500.00

TOP ELEVATION OF LAYER 1
READING ON UNIT 9 WITH FORMAT: (18F10.2)

MODEL LAYER BOTTOM EL. FOR LAYER 1
READING ON UNIT 9 WITH FORMAT: (18F10.2)

MODEL LAYER BOTTOM EL. FOR LAYER 2
READING ON UNIT 9 WITH FORMAT: (18F10.2)

MODEL LAYER BOTTOM EL. FOR LAYER 3
READING ON UNIT 9 WITH FORMAT: (18F10.2)

STRESS PERIOD	LENGTH	TIME STEPS	MULTIPLIER FOR DELT	SS FLAG
1	86400.00	1	1.000	SS

STEADY-STATE SIMULATION

ZONE ARRAY: ZLAY1
READING ON UNIT 39 WITH FORMAT: (I1,17I2)

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

ZONE ARRAY: ZLAY2
 READING ON UNIT 39 WITH FORMAT: (I1,17I2)

ZONE ARRAY: ZLAY3
 READING ON UNIT 39 WITH FORMAT: (I1,17I2)

ZONE ARRAY: RCHETM
 READING ON UNIT 39 WITH FORMAT: (I1,17I2)

HUF1 -- HYDROGEOLOGIC UNIT FLOW PACKAGE, ' VERSION 0.13-ERA, 9/26/00
 INPUT READ FROM UNIT 11

HUF file for Test Case 2 Variant 4
 #
 HEAD AT CELLS THAT CONVERT TO DRY= -999.00
 Hydrogeologic Unit Package Active with 12 parameters
 12 Named Parameters
 STEADY-STATE SIMULATION

INTERPRETATION OF LAYER FLAGS:

LAYER	LTHUF	LAYER TYPE	LAYWT	WETTABILITY
1	0	CONFINED	0	NON-WETTABLE
2	0	CONFINED	0	NON-WETTABLE
3	0	CONFINED	0	NON-WETTABLE

7776 ELEMENTS IN X ARRAY ARE USED BY HUF
 25 ELEMENTS IN IX ARRAY ARE USED BY HUF

PCG2 -- CONJUGATE GRADIENT SOLUTION PACKAGE, VERSION 2.4, 12/29/98
 MAXIMUM OF 250 CALLS OF SOLUTION ROUTINE
 MAXIMUM OF 8 INTERNAL ITERATIONS PER CALL TO SOLUTION ROUTINE
 MATRIX PRECONDITIONING TYPE : 1
 6916 ELEMENTS IN X ARRAY ARE USED BY PCG
 14000 ELEMENTS IN IX ARRAY ARE USED BY PCG
 1944 ELEMENTS IN Z ARRAY ARE USED BY PCG

SEN1BAS6 -- SENSITIVITY PROCESS, VERSION 1.0, 10/15/98
 INPUT READ FROM UNIT 38

NUMBER OF PARAMETER VALUES TO BE READ FROM SEN FILE: 15
 ISENALL.....: 0
 SENSITIVITIES WILL BE STORED IN MEMORY
 FOR UP TO 15 PARAMETERS

1725 ELEMENTS IN X ARRAY ARE USED FOR SENSITIVITIES
 972 ELEMENTS IN Z ARRAY ARE USED FOR SENSITIVITIES
 30 ELEMENTS IN IX ARRAY ARE USED FOR SENSITIVITIES

PES1BAS6 -- PARAMETER-ESTIMATION PROCESS, VERSION 1.0, 07/22/99
 INPUT READ FROM UNIT 44
 # PES file for test case tc2
 #

MAXIMUM NUMBER OF PARAMETER-ESTIMATION ITERATIONS (MAX-ITER) = 30
 MAXIMUM PARAMETER CORRECTION (MAX-CHANGE) ----- = 2.0000
 CLOSURE CRITERION (TOL) ----- = 0.10000E-01
 SUM OF SQUARES CLOSURE CRITERION (SOSC) ----- = 0.0000

FLAG TO GENERATE INPUT NEEDED BY BEALE-2000 (IBEFLG) ----- = 0
 FLAG TO GENERATE INPUT NEEDED BY YCINT-2000 (IYCFLG) ----- = 0
 OMIT PRINTING TO SCREEN (IF = 1) (IOSTAR) ----- = 0
 ADJUST GAUSS-NEWTON MATRIX WITH NEWTON UPDATES (IF = 1)(NOPT) = 0
 NUMBER OF FLETCHER-REEVES ITERATIONS (NFIT) ----- = 0
 CRITERION FOR ADDING MATRIX R (SOSR) ----- = 0.0000
 INITIAL VALUE OF MARQUARDT PARAMETER (RMAR) ----- = 0.10000E-02
 MARQUARDT PARAMETER MULTIPLIER (RMARM) ----- = 1.5000
 APPLY MAX-CHANGE IN REGRESSION SPACE (IF = 1) (IAP) ----- = 0

FORMAT CODE FOR COVARIANCE AND CORRELATION MATRICES (IPRCOV) = 8
 PRINT PARAMETER-ESTIMATION STATISTICS
 EACH ITERATION (IF > 0) (IPRINT) ----- = 0
 PRINT EIGENVALUES AND EIGENVECTORS OF
 COVARIANCE MATRIX (IF > 0) (LPRINT) ----- = 0

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

SEARCH DIRECTION ADJUSTMENT PARAMETER (CSA) ----- = 0.80000E-01
 MODIFY CONVERGENCE CRITERIA (IF > 0) (FCONV) ----- = 0.0000
 CALCULATE SENSITIVITIES USING FINAL
 PARAMETER ESTIMATES (IF > 0) (LASTX) ----- = 0
 NUMBER OF USUALLY POS. PARAMETERS THAT MAY BE NEGATIVE (NPNG) = 0
 NUMBER OF PARAMETERS WITH CORRELATED PRIOR INFORMATION (IFPR) = 0
 NUMBER OF PRIOR-INFORMATION EQUATIONS (MPR) ----- = 0

832 ELEMENTS IN X ARRAY ARE USED FOR PARAMETER ESTIMATION
 730 ELEMENTS IN Z ARRAY ARE USED FOR PARAMETER ESTIMATION
 32 ELEMENTS IN IX ARRAY ARE USED FOR PARAMETER ESTIMATION

OBS1BAS6 -- OBSERVATION PROCESS, VERSION 1.0, 4/27/99
 INPUT READ FROM UNIT 37
 OBSERVATION GRAPH-DATA OUTPUT FILES WILL NOT BE PRINTED
 DIMENSIONLESS SCALED OBSERVATION SENSITIVITIES WILL BE PRINTED

HEAD OBSERVATIONS -- INPUT READ FROM UNIT 40

NUMBER OF HEADS.....: 42
 NUMBER OF MULTILAYER HEADS.....: 2
 MAXIMUM NUMBER OF LAYERS FOR MULTILAYER HEADS....: 3

OBS1DRN6 -- OBSERVATION PROCESS (DRAIN FLOW OBSERVATIONS)
 VERSION 1.0, 10/15/98
 INPUT READ FROM UNIT 41

NUMBER OF FLOW-OBSERVATION DRAIN-CELL GROUPS.....: 5
 NUMBER OF CELLS IN DRAIN-CELL GROUPS.....: 5
 NUMBER OF DRAIN-CELL FLOWS.....: 5

OBS1GHB6 -- OBSERVATION PROCESS (GENERAL HEAD BOUNDARY FLOW OBSERVATIONS)
 VERSION 1.0, 10/15/98
 INPUT READ FROM UNIT 42

NUMBER OF FLOW-OBSERVATION GENERAL-HEAD-CELL GROUPS: 5
 NUMBER OF CELLS IN GENERAL-HEAD-CELL GROUPS.....: 5
 NUMBER OF GENERAL-HEAD-CELL FLOWS.....: 5

3377 ELEMENTS IN X ARRAY ARE USED FOR OBSERVATIONS
 132 ELEMENTS IN Z ARRAY ARE USED FOR OBSERVATIONS
 509 ELEMENTS IN IX ARRAY ARE USED FOR OBSERVATIONS

COMMON ERROR VARIANCE FOR ALL OBSERVATIONS SET TO: 1.000

20626 ELEMENTS OF X ARRAY USED OUT OF 20626
 3778 ELEMENTS OF Z ARRAY USED OUT OF 3778
 14596 ELEMENTS OF IX ARRAY USED OUT OF 14596
 14580 ELEMENTS OF XHS ARRAY USED OUT OF 14580

INFORMATION ON PARAMETERS LISTED IN SEN FILE

NAME	ISENS	LN	VALUE IN SEN INPUT FILE	LOWER REASONABLE LIMIT	UPPER REASONABLE LIMIT	ALTERNATE SCALING FACTOR
HK1	1	0	1.5000	-1.4000	-0.80000	0.10000E-02
HK2	1	0	0.15000E-01	0.20000E-08	0.20000E-06	0.10000E-04
HK3	1	0	0.15000E-03	0.10000E-08	0.10000E-06	0.10000E-06
HK4	1	0	0.12000E-05	0.12000E-03	0.12000E-01	0.10000E-08
VKA12_1	1	0	0.33300	0.13000E-03	0.13000E-01	0.13000E-01
VKA12_2	1	0	0.38500E-02	0.13000E-03	0.13000E-01	0.13000E-01
VKA12_3	1	0	0.42900E-04	0.13000E-03	0.13000E-01	0.13000E-01
VKA12_4	1	0	0.28600E-06	0.13000E-03	0.13000E-01	0.13000E-01
VKA3_1	1	0	1.6700	0.30000E-04	0.30000E-02	0.30000E-02
VKA3_3	1	0	0.12500E-03	0.30000E-04	0.30000E-02	0.30000E-02
VKA3_4	1	0	0.16000E-05	0.30000E-04	0.30000E-02	0.30000E-02
DRAIN	1	0	1.5000	0.10000E-07	0.10000E-05	0.10000E-05
GHB	1	0	1.5000	0.20000E-04	0.20000E-02	0.20000E-02
RCH	1	0	0.35000E-03	0.40000E-05	0.40000E-03	0.40000E-03
ETM	1	0	0.45000E-03	0.40000E-05	0.40000E-03	0.40000E-03

FOR THE PARAMETERS LISTED IN THE TABLE ABOVE, PARAMETER VALUES IN INDIVIDUAL PACKAGE INPUT FILES ARE REPLACED BY THE VALUES FROM THE SEN INPUT FILE. THE ALTERNATE SCALING FACTOR IS USED TO SCALE SENSITIVITIES IF IT IS LARGER THAN THE PARAMETER VALUE IN ABSOLUTE VALUE AND THE PARAMETER IS NOT LOG-TRANSFORMED.

HEAD OBSERVATION VARIANCES ARE MULTIPLIED BY: 1.000

OBSERVED HEAD DATA -- TIME OFFSETS ARE MULTIPLIED BY: 1.0000

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

...

SOLUTION BY THE CONJUGATE-GRADIENT METHOD

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-----
MAXIMUM NUMBER OF CALLS TO PCG ROUTINE = 250
MAXIMUM ITERATIONS PER CALL TO PCG = 8
MATRIX PRECONDITIONING TYPE = 1
RELAXATION FACTOR (ONLY USED WITH PRECOND. TYPE 1) = 0.10000E+01
PARAMETER OF POLYNOMIAL PRECOND. = 2 (2) OR IS CALCULATED : 2
HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-03
RESIDUAL CHANGE CRITERION FOR CLOSURE = 0.80000E+02
PCG HEAD AND RESIDUAL CHANGE PRINTOUT INTERVAL = 999
PRINTING FROM SOLVER IS LIMITED(1) OR SUPPRESSED (>1) = 1
DAMPING PARAMETER = 0.10000E+01

```

CONVERGENCE CRITERIA FOR SENSITIVITIES

PARAMETER	HCLOSE	RCLOSE
HK1	0.66667E-06	0.53333
HK2	0.66667E-04	53.333
HK3	0.66667E-02	5333.3
HK4	0.83333	0.66667E+06
VKA12_1	0.30030E-05	2.4024
VKA12_2	0.25974E-03	207.79
VKA12_3	0.23310E-01	18648.
VKA12_4	3.4965	0.27972E+07
VKA3_1	0.59880E-06	0.47904
VKA3_3	0.80000E-02	6400.0
VKA3_4	0.62500	0.50000E+06
DRAIN	0.66667E-06	0.53333
GHB	0.66667E-06	0.53333
RCH	0.28571E-02	2285.7
ETM	0.22222E-02	1777.8

WETTING CAPABILITY IS NOT ACTIVE IN ANY LAYER

HUF1 -- HYDROGEOLOGIC UNIT FLOW PACKAGE

```

TOP ELEVATN: HGU1
READING ON UNIT 11 WITH FORMAT: (9F10.2)

```

... THICKNESS: HGU1 = 300.000

```

TOP ELEVATN: HGU2
READING ON UNIT 11 WITH FORMAT: (9F10.2)

```

... THICKNESS: HGU2 = 200.000

```

TOP ELEVATN: HGU3
READING ON UNIT 11 WITH FORMAT: (9F10.2)

```

... THICKNESS: HGU3 = 550.000

```

TOP ELEVATN: HGU4
READING ON UNIT 11 WITH FORMAT: (9F10.2)

```

... THICKNESS: HGU4 = 200.000

```

TOP ELEVATN: HGU5
READING ON UNIT 11 WITH FORMAT: (9F10.2)

```

...

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

THICKNESS: HGU5 = 1500.00

INTERPRETATION OF UNIT FLAGS:

UNIT	HANI	VK/VANI
HGU1	1.000000	VERTICAL K
HGU2	1.000000	VERTICAL K
HGU3	1.000000	VERTICAL K
HGU4	1.000000	VERTICAL K
HGU5	1.000000	VERTICAL K

PARAMETER NAME:HK1 TYPE:HK UNITS: 5
 The parameter value from the package file is: 1.0000
 This parameter value has been replaced by the value from the
 Sensitivity Process file: 1.5000

UNIT HGU1 CORRESPONDS TO UNIT NO. 1
 LAYER: 1 MULTIPLIER:NONE ZONE:ZLAY1
 ZONE VALUES: 1

UNIT HGU2 CORRESPONDS TO UNIT NO. 2
 LAYER: 2 MULTIPLIER:NONE ZONE:ZLAY1
 ZONE VALUES: 1

UNIT HGU3 CORRESPONDS TO UNIT NO. 3
 LAYER: 3 MULTIPLIER:NONE ZONE:ZLAY2
 ZONE VALUES: 1

UNIT HGU4 CORRESPONDS TO UNIT NO. 4
 LAYER: 4 MULTIPLIER:NONE ZONE:ZLAY2
 ZONE VALUES: 1

UNIT HGU5 CORRESPONDS TO UNIT NO. 5
 LAYER: 5 MULTIPLIER:NONE ZONE:ZLAY3
 ZONE VALUES: 1

PARAMETER NAME:HK2 TYPE:HK UNITS: 5
 The parameter value from the package file is: 1.00000E-02
 This parameter value has been replaced by the value from the
 Sensitivity Process file: 1.50000E-02

UNIT HGU1 CORRESPONDS TO UNIT NO. 1
 LAYER: 1 MULTIPLIER:NONE ZONE:ZLAY1
 ZONE VALUES: 2

UNIT HGU2 CORRESPONDS TO UNIT NO. 2
 LAYER: 2 MULTIPLIER:NONE ZONE:ZLAY1
 ZONE VALUES: 2

UNIT HGU3 CORRESPONDS TO UNIT NO. 3
 LAYER: 3 MULTIPLIER:NONE ZONE:ZLAY2
 ZONE VALUES: 2

UNIT HGU4 CORRESPONDS TO UNIT NO. 4
 LAYER: 4 MULTIPLIER:NONE ZONE:ZLAY2
 ZONE VALUES: 2

UNIT HGU5 CORRESPONDS TO UNIT NO. 5
 LAYER: 5 MULTIPLIER:NONE ZONE:ZLAY3
 ZONE VALUES: 2

PARAMETER NAME:HK3 TYPE:HK UNITS: 5
 The parameter value from the package file is: 1.00000E-04
 This parameter value has been replaced by the value from the
 Sensitivity Process file: 1.50000E-04

UNIT HGU1 CORRESPONDS TO UNIT NO. 1
 LAYER: 1 MULTIPLIER:NONE ZONE:ZLAY1
 ZONE VALUES: 3

UNIT HGU2 CORRESPONDS TO UNIT NO. 2
 LAYER: 2 MULTIPLIER:NONE ZONE:ZLAY1
 ZONE VALUES: 3

UNIT HGU3 CORRESPONDS TO UNIT NO. 3
 LAYER: 3 MULTIPLIER:NONE ZONE:ZLAY2
 ZONE VALUES: 3

UNIT HGU4 CORRESPONDS TO UNIT NO. 4
 LAYER: 4 MULTIPLIER:NONE ZONE:ZLAY2
 ZONE VALUES: 3

UNIT HGU5 CORRESPONDS TO UNIT NO. 5
 LAYER: 5 MULTIPLIER:NONE ZONE:ZLAY3
 ZONE VALUES: 3

PARAMETER NAME:HK4 TYPE:HK UNITS: 5
 The parameter value from the package file is: 1.00000E-06
 This parameter value has been replaced by the value from the
 Sensitivity Process file: 1.20000E-06

UNIT HGU1 CORRESPONDS TO UNIT NO. 1
 LAYER: 1 MULTIPLIER:NONE ZONE:ZLAY1
 ZONE VALUES: 4

UNIT HGU2 CORRESPONDS TO UNIT NO. 2
 LAYER: 2 MULTIPLIER:NONE ZONE:ZLAY1

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

```

ZONE VALUES:      4
UNIT HGU3          CORRESPONDS TO UNIT NO.      3
                   LAYER: 3 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      4
UNIT HGU4          CORRESPONDS TO UNIT NO.      4
                   LAYER: 4 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      4
UNIT HGU5          CORRESPONDS TO UNIT NO.      5
                   LAYER: 5 MULTIPLIER:NONE     ZONE:ZLAY3
                   ZONE VALUES:      4

PARAMETER NAME:VKA12_1      TYPE:VK  UNITS:  4
The parameter value from the package file is: 0.25000
This parameter value has been replaced by the value from the
Sensitivity Process file: 0.33300
UNIT HGU1          CORRESPONDS TO UNIT NO.      1
                   LAYER: 1 MULTIPLIER:NONE     ZONE:ZLAY1
                   ZONE VALUES:      1
UNIT HGU2          CORRESPONDS TO UNIT NO.      2
                   LAYER: 2 MULTIPLIER:NONE     ZONE:ZLAY1
                   ZONE VALUES:      1
UNIT HGU3          CORRESPONDS TO UNIT NO.      3
                   LAYER: 3 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      1
UNIT HGU4          CORRESPONDS TO UNIT NO.      4
                   LAYER: 4 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      1

PARAMETER NAME:VKA12_2      TYPE:VK  UNITS:  4
The parameter value from the package file is: 2.50000E-03
This parameter value has been replaced by the value from the
Sensitivity Process file: 3.85000E-03
UNIT HGU1          CORRESPONDS TO UNIT NO.      1
                   LAYER: 1 MULTIPLIER:NONE     ZONE:ZLAY1
                   ZONE VALUES:      2
UNIT HGU2          CORRESPONDS TO UNIT NO.      2
                   LAYER: 2 MULTIPLIER:NONE     ZONE:ZLAY1
                   ZONE VALUES:      2
UNIT HGU3          CORRESPONDS TO UNIT NO.      3
                   LAYER: 3 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      2
UNIT HGU4          CORRESPONDS TO UNIT NO.      4
                   LAYER: 4 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      2

PARAMETER NAME:VKA12_3      TYPE:VK  UNITS:  4
The parameter value from the package file is: 2.50000E-05
This parameter value has been replaced by the value from the
Sensitivity Process file: 4.29000E-05
UNIT HGU1          CORRESPONDS TO UNIT NO.      1
                   LAYER: 1 MULTIPLIER:NONE     ZONE:ZLAY1
                   ZONE VALUES:      3
UNIT HGU2          CORRESPONDS TO UNIT NO.      2
                   LAYER: 2 MULTIPLIER:NONE     ZONE:ZLAY1
                   ZONE VALUES:      3
UNIT HGU3          CORRESPONDS TO UNIT NO.      3
                   LAYER: 3 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      3
UNIT HGU4          CORRESPONDS TO UNIT NO.      4
                   LAYER: 4 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      3

PARAMETER NAME:VKA12_4      TYPE:VK  UNITS:  4
The parameter value from the package file is: 2.50000E-07
This parameter value has been replaced by the value from the
Sensitivity Process file: 2.86000E-07
UNIT HGU1          CORRESPONDS TO UNIT NO.      1
                   LAYER: 1 MULTIPLIER:NONE     ZONE:ZLAY1
                   ZONE VALUES:      4
UNIT HGU2          CORRESPONDS TO UNIT NO.      2
                   LAYER: 2 MULTIPLIER:NONE     ZONE:ZLAY1
                   ZONE VALUES:      4
UNIT HGU3          CORRESPONDS TO UNIT NO.      3
                   LAYER: 3 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      4
UNIT HGU4          CORRESPONDS TO UNIT NO.      4
                   LAYER: 4 MULTIPLIER:NONE     ZONE:ZLAY2
                   ZONE VALUES:      4

PARAMETER NAME:VKA3_1      TYPE:VK  UNITS:  1
The parameter value from the package file is: 1.0000

```

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

This parameter value has been replaced by the value from the Sensitivity Process file: 1.6700
 UNIT HGU5 CORRESPONDS TO UNIT NO. 5
 LAYER: 5 MULTIPLIER:NONE ZONE:ZLAY3
 ZONE VALUES: 1

PARAMETER NAME:VKA3_2 TYPE:VK UNITS: 1
 The parameter value from the package file is: 1.00000E-02
 UNIT HGU5 CORRESPONDS TO UNIT NO. 5
 LAYER: 5 MULTIPLIER:NONE ZONE:ZLAY3
 ZONE VALUES: 2

PARAMETER NAME:VKA3_3 TYPE:VK UNITS: 1
 The parameter value from the package file is: 1.00000E-04
 This parameter value has been replaced by the value from the Sensitivity Process file: 1.25000E-04
 UNIT HGU5 CORRESPONDS TO UNIT NO. 5
 LAYER: 5 MULTIPLIER:NONE ZONE:ZLAY3
 ZONE VALUES: 3

PARAMETER NAME:VKA3_4 TYPE:VK UNITS: 1
 The parameter value from the package file is: 1.00000E-06
 This parameter value has been replaced by the value from the Sensitivity Process file: 1.60000E-06
 UNIT HGU5 CORRESPONDS TO UNIT NO. 5
 LAYER: 5 MULTIPLIER:NONE ZONE:ZLAY3
 ZONE VALUES: 4

ITRSS 0

Reading PRINTCODE information
 UNIT HGU2 CORRESPONDS TO UNIT NO. 2

PRINTCODE FLAGS ARE SET AS FOLLOWS

UNIT	HK	HANI	VK	SS	SY
HGU1	0	0	0	0	0
HGU2	20	20	20	0	0
HGU3	0	0	0	0	0
HGU4	0	0	0	0	0
HGU5	0	0	0	0	0

0 Well parameters

1 Drain parameters

PARAMETER NAME:DRAIN TYPE:DRN CLUSTERS: 1
 Parameter value from package file is: 1.0000
 This value has been changed to: 1.5000 , as read from
 the Sensitivity Process file
 NUMBER OF ENTRIES: 5

DRAIN NO.	LAYER	ROW	COL	DRAIN EL.	STRESS FACTOR
1	1	7	6	400.0	1.000
2	1	10	11	550.0	1.000
3	1	14	14	1200.	1.000
4	1	15	14	1200.	1.000
5	1	16	14	1200.	1.000

1 Evapotranspiration parameters

PARAMETER NAME:ETM TYPE:EVT CLUSTERS: 1
 Parameter value from package file is: 4.00000E-04
 This value has been changed to: 4.50000E-04, as read from
 the Sensitivity Process file
 MULTIPLIER ARRAY: NONE ZONE ARRAY: RCHETM
 ZONE VALUES: 2

1 GHB parameters

PARAMETER NAME:GHB TYPE:GHB CLUSTERS: 1
 Parameter value from package file is: 1.0000
 This value has been changed to: 1.5000 , as read from
 the Sensitivity Process file
 NUMBER OF ENTRIES: 5

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

BOUND.	NO.	LAYER	ROW	COL	STAGE	STRESS FACTOR
1	1	3	6	350.0	1.000	1.000
2	1	3	11	500.0	1.000	1.000
3	1	4	11	500.0	1.000	1.000
4	1	5	11	500.0	1.000	1.000
5	1	12	9	1000.	1.000	1.000

1 Recharge parameters

PARAMETER NAME:RCH TYPE:RCH CLUSTERS: 1
 Parameter value from package file is: 3.10000E-04
 This value has been changed to: 3.50000E-04, as read from
 the Sensitivity Process file
 MULTIPLIER ARRAY: NONE ZONE ARRAY: RCHETM
 ZONE VALUES: 1

16 PARAMETERS HAVE BEEN DEFINED IN ALL PACKAGES.
 (SPACE IS ALLOCATED FOR 500 PARAMETERS.)

OBSERVATION SENSITIVITY TABLE(S) FOR PARAMETER-ESTIMATION ITERATION 1

FOR THE SCALING OF THE SENSITIVITIES BELOW, B IS REPLACED BY
 BSCAL (THE ALTERNATE SCALING FACTOR) FOR PARAMETER(S):
 VKA12_2 VKA12_3 VKA12_4 VKA3_3 VKA3_4 RCH

DIMENSIONLESS SCALED SENSITIVITIES (SCALED BY B*(WT**.5))

...

STARTING VALUES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
1.500	1.5000E-02	1.5000E-04	1.2000E-06	0.3330	3.8500E-03
4.2900E-05	2.8600E-07	1.670	1.2500E-04	1.6000E-06	1.500
1.500	3.5000E-04	4.5000E-04			

SUMS OF SQUARED, WEIGHTED RESIDUALS:
 ALL DEPENDENT VARIABLES: 3288.2
 DEP. VARIABLES PLUS PARAMETERS: 3288.2

PARAMETER VALUES AND STATISTICS FOR ALL PARAMETER-ESTIMATION ITERATIONS

MODIFIED GAUSS-NEWTON CONVERGES IF THE ABSOLUTE VALUE OF THE MAXIMUM
 FRACTIONAL PARAMETER CHANGE (MAX CALC. CHANGE) IS LESS THAN TOL OR IF THE
 SUM OF SQUARED, WEIGHTED RESIDUALS CHANGES LESS THAN SOSOC OVER TWO
 PARAMETER-ESTIMATION ITERATIONS.

MODIFIED GAUSS-NEWTON PROCEDURE FOR PARAMETER-ESTIMATION ITERATION NO. = 1

VALUES FROM SOLVING THE NORMAL EQUATION :
 MARQUARDT PARAMETER ----- = 0.0000
 MAX. FRAC. PAR. CHANGE (TOL= 0.100E-01) = -.84183
 OCCURRED FOR PARAMETER "VKA3_4" TYPE U

CALCULATION OF DAMPING PARAMETER
 MAX-CHANGE SPECIFIED: 2.00 USED: 2.00
 OSCILL. CONTROL FACTOR (1, NO EFFECT)-- = 1.0000
 DAMPING PARAMETER (RANGE 0 TO 1) ----- = 1.0000
 CONTROLLED BY PARAMETER "VKA3_4" TYPE U

UPDATED ESTIMATES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
0.9807	9.1555E-03	8.5516E-05	6.2954E-07	0.1294	2.1816E-03
1.5859E-05	4.3503E-07	0.4923	1.5541E-04	2.5308E-07	0.9163
0.9555	3.2754E-04	4.2061E-04			

SUMS OF SQUARED, WEIGHTED RESIDUALS:
 ALL DEPENDENT VARIABLES: 1496.9
 DEP. VARIABLES PLUS PARAMETERS: 1496.9

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

MODIFIED GAUSS-NEWTON PROCEDURE FOR PARAMETER-ESTIMATION ITERATION NO. = 2

VALUES FROM SOLVING THE NORMAL EQUATION :
 MARQUARDT PARAMETER ----- = 0.0000
 MAX. FRAC. PAR. CHANGE (TOL= 0.100E-01) = 1.2835
 OCCURRED FOR PARAMETER "VKA3_4 " TYPE U

CALCULATION OF DAMPING PARAMETER
 MAX-CHANGE SPECIFIED: 2.00 USED: 2.00
 OSCILL. CONTROL FACTOR (1, NO EFFECT)-- = 0.32795
 DAMPING PARAMETER (RANGE 0 TO 1) ----- = 0.32795
 CONTROLLED BY PARAMETER "VKA3_4 " TYPE U

UPDATED ESTIMATES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
0.9920	9.3795E-03	8.8347E-05	7.4045E-07	0.1364	2.2569E-03
1.7898E-05	3.9770E-07	0.6774	1.5910E-04	3.5960E-07	0.9390
0.9730	3.2119E-04	4.1316E-04			

SUMS OF SQUARED, WEIGHTED RESIDUALS:
 ALL DEPENDENT VARIABLES: 697.47
 DEP. VARIABLES PLUS PARAMETERS: 697.47

MODIFIED GAUSS-NEWTON PROCEDURE FOR PARAMETER-ESTIMATION ITERATION NO. = 3

VALUES FROM SOLVING THE NORMAL EQUATION :
 MARQUARDT PARAMETER ----- = 0.0000
 MAX. FRAC. PAR. CHANGE (TOL= 0.100E-01) = 1.1402
 OCCURRED FOR PARAMETER "VKA3_4 " TYPE U

CALCULATION OF DAMPING PARAMETER
 MAX-CHANGE SPECIFIED: 2.00 USED: 2.00
 OSCILL. CONTROL FACTOR (1, NO EFFECT)-- = 1.0000
 DAMPING PARAMETER (RANGE 0 TO 1) ----- = 1.0000
 CONTROLLED BY PARAMETER "VKA3_4 " TYPE U

UPDATED ESTIMATES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
1.010	9.9074E-03	9.6262E-05	1.1291E-06	0.1709	2.4462E-03
2.3227E-05	2.8983E-07	1.247	1.1821E-04	7.6964E-07	0.9918
1.007	3.0878E-04	3.9877E-04			

SUMS OF SQUARED, WEIGHTED RESIDUALS:
 ALL DEPENDENT VARIABLES: 4.6752
 DEP. VARIABLES PLUS PARAMETERS: 4.6752

MODIFIED GAUSS-NEWTON PROCEDURE FOR PARAMETER-ESTIMATION ITERATION NO. = 4

VALUES FROM SOLVING THE NORMAL EQUATION :
 MARQUARDT PARAMETER ----- = 0.0000
 MAX. FRAC. PAR. CHANGE (TOL= 0.100E-01) = 0.33212
 OCCURRED FOR PARAMETER "VKA3_4 " TYPE U

CALCULATION OF DAMPING PARAMETER
 MAX-CHANGE SPECIFIED: 2.00 USED: 2.00
 OSCILL. CONTROL FACTOR (1, NO EFFECT)-- = 1.0000
 DAMPING PARAMETER (RANGE 0 TO 1) ----- = 1.0000
 CONTROLLED BY PARAMETER "VKA3_4 " TYPE U

UPDATED ESTIMATES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
1.003	9.9937E-03	9.9292E-05	1.1065E-06	0.2147	2.4934E-03
2.4865E-05	2.5633E-07	1.262	1.0332E-04	1.0253E-06	0.9993
1.003	3.0977E-04	4.0005E-04			

SUMS OF SQUARED, WEIGHTED RESIDUALS:
 ALL DEPENDENT VARIABLES: 0.67760E-01
 DEP. VARIABLES PLUS PARAMETERS: 0.67760E-01

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

MODIFIED GAUSS-NEWTON PROCEDURE FOR PARAMETER-ESTIMATION ITERATION NO. = 5

VALUES FROM SOLVING THE NORMAL EQUATION :
 MARQUARDT PARAMETER ----- = 0.0000
 MAX. FRAC. PAR. CHANGE (TOL= 0.100E-01) = -.26155
 OCCURRED FOR PARAMETER "VKA3_1 " TYPE U

CALCULATION OF DAMPING PARAMETER
 MAX-CHANGE SPECIFIED: 2.00 USED: 2.00
 OSCILL. CONTROL FACTOR (1, NO EFFECT)-- = 1.0000
 DAMPING PARAMETER (RANGE 0 TO 1) ----- = 1.0000
 CONTROLLED BY PARAMETER "VKA3_1 " TYPE U

UPDATED ESTIMATES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
0.9999	9.9958E-03	9.9922E-05	1.0050E-06	0.2443	2.4986E-03
2.4986E-05	2.5024E-07	0.9316	1.0006E-04	1.0081E-06	0.9994
0.9998	3.0986E-04	3.9984E-04			

SUMS OF SQUARED, WEIGHTED RESIDUALS:
 ALL DEPENDENT VARIABLES: 0.70503E-02
 DEP. VARIABLES PLUS PARAMETERS: 0.70503E-02

MODIFIED GAUSS-NEWTON PROCEDURE FOR PARAMETER-ESTIMATION ITERATION NO. = 6

VALUES FROM SOLVING THE NORMAL EQUATION :
 MARQUARDT PARAMETER ----- = 0.0000
 MAX. FRAC. PAR. CHANGE (TOL= 0.100E-01) = 0.66359E-01
 OCCURRED FOR PARAMETER "VKA3_1 " TYPE U

CALCULATION OF DAMPING PARAMETER
 MAX-CHANGE SPECIFIED: 2.00 USED: 2.00
 OSCILL. CONTROL FACTOR (1, NO EFFECT)-- = 0.84405
 DAMPING PARAMETER (RANGE 0 TO 1) ----- = 0.84405
 CONTROLLED BY PARAMETER "VKA3_1 " TYPE U

UPDATED ESTIMATES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
0.9997	9.9959E-03	9.9945E-05	1.0018E-06	0.2489	2.4987E-03
2.4989E-05	2.5003E-07	0.9838	9.9976E-05	1.0021E-06	0.9994
0.9997	3.0987E-04	3.9983E-04			

SUMS OF SQUARED, WEIGHTED RESIDUALS:
 ALL DEPENDENT VARIABLES: 0.32119E-03
 DEP. VARIABLES PLUS PARAMETERS: 0.32119E-03

MODIFIED GAUSS-NEWTON PROCEDURE FOR PARAMETER-ESTIMATION ITERATION NO. = 7

VALUES FROM SOLVING THE NORMAL EQUATION :
 MARQUARDT PARAMETER ----- = 0.0000
 MAX. FRAC. PAR. CHANGE (TOL= 0.100E-01) = 0.14268E-01
 OCCURRED FOR PARAMETER "VKA3_1 " TYPE U

CALCULATION OF DAMPING PARAMETER
 MAX-CHANGE SPECIFIED: 2.00 USED: 2.00
 OSCILL. CONTROL FACTOR (1, NO EFFECT)-- = 1.0000
 DAMPING PARAMETER (RANGE 0 TO 1) ----- = 1.0000
 CONTROLLED BY PARAMETER "VKA3_1 " TYPE U

UPDATED ESTIMATES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
0.9996	9.9959E-03	9.9949E-05	1.0012E-06	0.2499	2.4988E-03
2.4990E-05	2.4997E-07	0.9978	9.9960E-05	1.0010E-06	0.9994
0.9996	3.0987E-04	3.9983E-04			

SUMS OF SQUARED, WEIGHTED RESIDUALS:
 ALL DEPENDENT VARIABLES: 0.70775E-04
 DEP. VARIABLES PLUS PARAMETERS: 0.70775E-04

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MODIFIED GAUSS-NEWTON PROCEDURE FOR PARAMETER-ESTIMATION ITERATION NO. = 8

VALUES FROM SOLVING THE NORMAL EQUATION :
 MARQUARDT PARAMETER ----- = 0.0000
 MAX. FRAC. PAR. CHANGE (TOL= 0.100E-01) = 0.25789E-03
 OCCURRED FOR PARAMETER "VKA3_1 " TYPE U

CALCULATION OF DAMPING PARAMETER
 MAX-CHANGE SPECIFIED: 2.00 USED: 2.00
 OSCILL. CONTROL FACTOR (1, NO EFFECT)-- = 1.0000
 DAMPING PARAMETER (RANGE 0 TO 1) ----- = 1.0000
 CONTROLLED BY PARAMETER "VKA3_1 " TYPE U

UPDATED ESTIMATES OF REGRESSION PARAMETERS :

HK1 VKA12_3 GHB	HK2 VKA12_4 RCH	HK3 VKA3_1 ETM	HK4 VKA3_3	VKA12_1 VKA3_4	VKA12_2 DRAIN
0.9996	9.9959E-03	9.9950E-05	1.0012E-06	0.2499	2.4988E-03
2.4990E-05	2.4996E-07	0.9981	9.9959E-05	1.0010E-06	0.9994
0.9996	3.0987E-04	3.9983E-04			

*** PARAMETER ESTIMATION CONVERGED BY SATISFYING THE TOL CRITERION ***

OBSERVATION SENSITIVITY TABLE(S) FOR PARAMETER-ESTIMATION ITERATION 8

FOR THE SCALING OF THE SENSITIVITIES BELOW, B IS REPLACED BY
 BSCAL (THE ALTERNATE SCALING FACTOR) FOR PARAMETER(S):
 VKA12_2 VKA12_3 VKA12_4 VKA3_3 VKA3_4 RCH
 ETM

DIMENSIONLESS SCALED SENSITIVITIES (SCALED BY B*(WT**.5))

OBS #	PARAMETER: OBSERVATION	HK1	HK2	HK3	HK4	VKA12_1
1	W2L	4.22	22.8	-11.2	-0.915E-01	0.297E-01
2	WL2	4.15	17.3	-9.22	-0.777E-01	0.253E-01
3	WL2	4.38	-8.84	-1.59	-0.186E-01	0.330E-02
4	WL4	1.48	6.94	-5.78	-0.110	0.262E-01
5	WL4	4.28	24.8	-11.0	-0.898E-01	0.397E-01
6	WL4	4.31	-6.51	-2.26	-0.198E-01	0.931E-02
7	WL4	3.25	-8.75	-1.43	-0.172E-01	0.275E-02
8	WL5	5.38	16.0	-10.1	-2.13	0.197
9	WL6	1.63	1.96	-1.99	-0.979E-02	0.727E-01
10	WL6	12.0	15.8	-0.344	-0.267E-02	0.793
11	WL6	12.1	12.8	0.147	0.182E-02	0.732
12	WL6	2.51	-9.25	-1.58	-0.177E-01	-0.596E-06
13	WL6	2.19	-8.74	-1.31	-0.161E-01	0.257E-02
14	WL6	2.10	-8.76	-1.25	-0.155E-01	0.234E-02
15	WL8	2.47	-5.16	4.90	0.146	0.126
16	WL8	8.15	2.81	3.59	0.112	0.450
17	WL8	14.0	-1.64	-0.144	-0.113E-03	1.22
18	WL8	4.53	-21.3	-1.45	-0.305E-01	0.159
19	WL8	0.999	-17.8	-1.55	-0.187E-01	-0.137E-01
20	WL8	1.58	-8.90	-1.22	-0.151E-01	0.368E-02
21	WL9	5.51	-3.00	6.72	0.237	0.282
22	WL10	7.96	-1.51	6.51	0.275	0.396
23	WL10	12.7	2.45	-2.55	-2.09	0.594
24	WL10	8.50	-10.6	0.425	-0.229E-01	0.387
25	WL10	0.231	-39.0	-2.77	-0.278E-01	-0.451E-01
26	WL10	-0.586	-19.6	-1.40	-0.173E-01	-0.967E-01
27	WL10	0.185	-5.43	-0.642	-0.796E-02	-0.382E-01
28	WL11	4.06	-7.29	7.11	0.236	0.200
29	WL12	5.76	-9.22	0.640	0.723E-01	0.261
30	WL12	0.592	-35.1	-1.03	-0.707E-01	0.147E-01
31	WL12	-1.01	-56.7	-2.44	-0.243E-01	-0.748E-01
32	WL12	-0.687	-13.6	-0.863	-0.107E-01	-0.995E-01
33	WL13	-0.989	-56.4	-3.77	-0.300E-01	-0.534E-01
34	WL13	-0.797	-28.0	-1.09	-0.129E-01	-0.972E-01
35	WL14	1.90	-24.4	-1.39	0.424E-01	0.746E-01
36	WL14	-0.446	-45.5	-1.65	-0.344E-01	-0.370E-01
37	WL14	-0.434	-12.1	-0.443	-0.627E-02	-0.642E-01
38	WL15	-0.107	-5.29	2.22	0.976E-03	-0.137E-01
39	WL16	0.434	-23.2	-1.06	0.468E-01	0.438E-03
40	WL16	-0.508	-12.6	-0.416	-0.610E-02	-0.632E-01
41	WL18	0.190	-18.1	-1.18	0.436E-01	-0.154E-01
42	WL18	-0.489	-12.3	-0.334	-0.557E-02	-0.621E-01
43	DRN1	-0.397	-0.365	0.954E-02	0.518E-04	-0.291E-01

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44	DRN1	-0.455E-02	0.768	0.546E-01	0.547E-03	0.889E-03
45	DRN1	0.854E-01	3.51	0.168	0.163E-02	0.945E-02
46	DRN1	0.939E-01	4.64	-1.95	-0.856E-03	0.120E-01
47	DRN1	0.580E-01	7.82	-1.82	-0.128E-01	0.157E-01
48	GHB1	-0.112	-0.714	0.287	0.238E-02	-0.833E-03
49	GHB2	-0.102	0.213	0.372E-01	0.441E-03	-0.760E-04
50	GHB3	-0.901E-01	0.655E-01	0.369E-01	0.432E-03	-0.780E-04
51	GHB4	-0.732E-01	0.191E-01	0.355E-01	0.419E-03	-0.587E-04
52	GHB5	-0.351	1.93	-2.05	0.113E-03	-0.152E-01

COMPOSITE SCALED SENSITIVITIES ((SUM OF THE SQUARED VALUES)/ND)**.5
 4.65 18.8 3.74 0.420 0.272

DIMENSIONLESS SCALED SENSITIVITIES (SCALED BY B*(WT**.5))

OBS #	PARAMETER: OBSERVATION	VKA12_2	VKA12_3	VKA12_4	VKA3_1	VKA3_3
1	W2L	-43.8	-402.	2.22	-0.184E-01	0.106
2	WL2	-46.3	-336.	-16.6	-0.217E-01	0.354E-01
3	WL2	-58.4	-96.6	-104.	-0.380E-01	-0.236
4	WL4	-11.9	0.117E+04	5.68	0.190E-02	0.391E-01
5	WL4	-42.1	-384.	6.30	-0.137E-01	0.112
6	WL4	-57.2	-114.	-269.	-0.350E-01	-0.226
7	WL4	-58.9	-91.3	-102.	-0.385E-01	-0.235
8	WL5	-23.8	0.169E+04	332.	0.594E-01	-0.188
9	WL6	-4.15	0.105E+04	4.03	0.254E-01	0.238
10	WL6	26.1	10.7	36.1	0.279	-0.497E-01
11	WL6	30.1	7.12	50.3	0.255	0.284E-01
12	WL6	-57.9	-118.	-268.	-0.368E-01	-0.289
13	WL6	-59.4	-85.8	-95.1	-0.391E-01	-0.232
14	WL6	-59.6	-81.0	-89.7	-0.393E-01	-0.229
15	WL8	-1.04	626.	3.94	0.509E-01	3.10
16	WL8	0.987	-952.	1.55	0.175	-6.13
17	WL8	2.72	2.28	32.1	0.318	-0.502E-01
18	WL8	-39.0	-284.	-0.928E+04	0.410E-01	0.165
19	WL8	-62.1	-135.	-130.	-0.382E-01	-0.428
20	WL8	-58.9	-78.4	-86.9	-0.389E-01	-0.230
21	WL9	-0.400	-0.105E+04	10.8	0.117	0.201E-01
22	WL10	0.837E-01	-0.170E+04	17.1	0.171	-8.07
23	WL10	-0.249	903.	34.2	0.270	13.1
24	WL10	-13.1	-439.	-505.	0.167	1.70
25	WL10	-57.3	-296.	-272.	-0.302E-01	-0.907
26	WL10	-66.9	-104.	-103.	-0.375E-01	-0.282
27	WL10	-29.3	-42.0	-45.3	-0.199E-01	-0.222
28	WL11	-0.953	63.9	11.9	0.863E-01	16.6
29	WL12	-11.5	443.	-36.7	0.119	0.635
30	WL12	-41.1	-148.	-167.	0.216E-02	1.28
31	WL12	-64.5	-313.	-182.	-0.322E-01	-0.968
32	WL12	-39.5	-52.4	-61.1	-0.238E-01	-0.432
33	WL13	-60.1	-388.	-214.	-0.306E-01	-1.05
34	WL13	-56.3	-87.5	-75.1	-0.246E-01	-0.435
35	WL14	-28.6	390.	-83.7	0.350E-01	0.569
36	WL14	-47.9	-428.	-146.	-0.165E-01	-3.69
37	WL14	-22.1	-30.1	-39.3	-0.137E-01	-0.253
38	WL15	-8.33	182.	-15.5	-0.353E-02	-0.628
39	WL16	-28.2	221.	-74.5	0.449E-02	-2.91
40	WL16	-23.4	-23.7	-40.6	-0.140E-01	-0.245
41	WL18	-24.3	353.	-57.7	0.357E-04	1.15
42	WL18	-22.3	-26.3	-39.6	-0.136E-01	-0.234
43	DRN1	-0.673	-0.189	-0.982	-0.928E-02	0.217E-02
44	DRN1	1.13	5.83	5.36	0.594E-03	0.179E-01
45	DRN1	5.67	18.3	9.68	0.263E-02	0.656E-01
46	DRN1	7.30	-159.	13.6	0.309E-02	0.551
47	DRN1	11.4	-490.	24.4	0.304E-02	0.208
48	GHB1	1.16	10.0	-0.128	0.469E-03	-0.297E-02
49	GHB2	1.42	2.30	2.51	0.925E-03	0.571E-02
50	GHB3	1.41	2.30	2.94	0.919E-03	0.572E-02
51	GHB4	1.41	2.39	3.90	0.909E-03	0.598E-02
52	GHB5	2.31	-309.	9.97	-0.678E-02	-0.160

COMPOSITE SCALED SENSITIVITIES ((SUM OF THE SQUARED VALUES)/ND)**.5
 35.9 513. 0.129E+04 0.950E-01 3.37

DIMENSIONLESS SCALED SENSITIVITIES (SCALED BY B*(WT**.5))

OBS #	PARAMETER: OBSERVATION	VKA3_4	DRAIN	GHB	RCH	ETM
1	W2L	-33.6	-1.77	-25.3	30.7	-2.57
2	WL2	-27.3	-1.86	-22.7	32.4	-2.50
3	WL2	-6.98	-2.27	-8.66	40.7	-2.14
4	WL4	-166.	-0.539	-7.03	8.53	-1.30

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5	WL4	-32.1	-1.74	-26.9	29.7	-2.87
6	WL4	-7.16	-2.24	-9.76	40.0	-2.34
7	WL4	-6.62	-2.28	-7.94	41.0	-2.14
8	WL5	0.558E+04	-1.48	-14.2	17.6	-7.51
9	WL6	-59.3	-0.376	-2.65	3.52	-2.49
10	WL6	-0.468	-2.45	-0.699	3.20	-32.7
11	WL6	2.86	-1.02	-0.606	3.30	-32.6
12	WL6	-7.48	-2.90	-9.63	45.7	-2.16
13	WL6	-6.34	-2.27	-7.01	41.1	-2.14
14	WL6	-6.14	-2.23	-6.57	40.6	-2.13
15	WL8	55.3	-0.375	-0.934	2.09	-3.89
16	WL8	-8.72	-1.23	-1.84	4.54	-13.7
17	WL8	0.716E-01	-0.926	-0.554	3.39	-15.2
18	WL8	-6.35	-5.76	-5.26	59.5	-7.71
19	WL8	-10.0	-3.70	-6.41	56.9	-2.17
20	WL8	-5.96	-2.22	-6.29	40.8	-2.09
21	WL9	134.	-0.737	-1.12	3.70	-8.68
22	WL10	200.	-0.970	-1.00	5.14	-12.1
23	WL10	0.685E+04	-1.12	-0.748	5.17	-17.7
24	WL10	42.3	-4.39	-2.66	33.1	-13.5
25	WL10	-14.3	-17.7	-5.70	104.	-2.00
26	WL10	-6.44	-3.18	-6.19	61.2	-2.07
27	WL10	-3.02	-1.22	-3.21	22.8	-1.07
28	WL11	175.	-0.540	-0.676	3.18	-6.07
29	WL12	74.3	-2.36	-3.61	23.9	-8.40
30	WL12	24.3	-6.94	-5.57	78.0	-3.00
31	WL12	-11.5	-7.39	-5.72	116.	-1.96
32	WL12	-4.14	-2.04	-3.91	39.9	-1.31
33	WL13	-17.2	-9.09	-5.80	119.	-2.05
34	WL13	-6.01	-3.23	-4.11	65.2	-1.39
35	WL14	59.4	-4.42	-3.94	54.0	-4.17
36	WL14	-75.2	-6.80	-4.70	93.9	-2.11
37	WL14	-1.77	-1.71	-2.30	29.2	-0.783
38	WL15	2.57	-3.85	-0.736	12.3	-0.291
39	WL16	79.1	-4.09	-3.10	50.3	-2.21
40	WL16	-1.27	-1.81	-2.36	30.4	-0.807
41	WL18	79.1	-3.19	-2.66	40.1	-1.70
42	WL18	-0.359	-1.74	-2.31	29.4	-0.793
43	DRN1	0.271E-01	-3.17	0.178E-01	-0.987E-01	0.814
44	DRN1	0.282	-2.98	0.112	-2.04	0.393E-01
45	DRN1	1.08	-2.53	0.450	-8.28	0.153
46	DRN1	-2.25	0.457E-01	0.645	-10.8	0.255
47	DRN1	-23.0	1.03	1.17	-17.7	0.593
48	GHB1	0.846	0.470E-01	-2.54	-0.811	0.695E-01
49	GHB2	0.166	0.550E-01	-3.13	-0.988	0.519E-01
50	GHB3	0.165	0.556E-01	-2.98	-0.991	0.520E-01
51	GHB4	0.167	0.588E-01	-2.94	-1.01	0.518E-01
52	GHB5	-9.27	0.420	-0.287	-4.50	0.602

COMPOSITE SCALED SENSITIVITIES ((SUM OF THE SQUARED VALUES)/ND)**.5
 0.123E+04 3.93 7.61 43.4 8.36

PARAMETER	COMPOSITE SCALED SENSITIVITY
HK1	4.64572E+00
HK2	1.88031E+01
HK3	3.74500E+00
HK4	4.20112E-01
VKA12_1	2.71863E-01
VKA12_2	3.59047E+01
VKA12_3	5.13260E+02
VKA12_4	1.29274E+03
VKA3_1	9.49773E-02
VKA3_3	3.37216E+00
VKA3_4	1.22659E+03
DRAIN	3.93459E+00
GHB	7.61336E+00
RCH	4.33604E+01
ETM	8.36342E+00

FINAL PARAMETER VALUES AND STATISTICS:

PARAMETER NAME(S) AND VALUE(S):

HK1	HK2	HK3	HK4	VKA12_1	VKA12_2
VKA12_3	VKA12_4	VKA3_1	VKA3_3	VKA3_4	DRAIN
GHB	RCH	ETM			
0.9996	9.9959E-03	9.9950E-05	1.0012E-06	0.2499	2.4988E-03
2.4990E-05	2.4996E-07	0.9981	9.9959E-05	1.0010E-06	0.9994
0.9996	3.0987E-04	3.9983E-04			

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

SUMS OF SQUARED WEIGHTED RESIDUALS:
 OBSERVATIONS PRIOR INFO. TOTAL
 0.706E-04 0.00 0.706E-04

 SELECTED STATISTICS FROM MODIFIED GAUSS-NEWTON ITERATIONS

ITER.	MAX. PARAMETER PARNAM	CALC. CHANGE MAX. CHANGE	MAX. CHANGE ALLOWED	DAMPING PARAMETER
1	VKA3_4	-0.841826	2.00000	1.0000
2	VKA3_4	1.28345	2.00000	0.32795
3	VKA3_4	1.14025	2.00000	1.0000
4	VKA3_4	0.332119	2.00000	1.0000
5	VKA3_1	-0.261548	2.00000	1.0000
6	VKA3_1	0.663591E-01	2.00000	0.84405
7	VKA3_1	0.142675E-01	2.00000	1.0000
8	VKA3_1	0.257887E-03	2.00000	1.0000

SUMS OF SQUARED WEIGHTED RESIDUALS FOR EACH ITERATION

ITER.	OBSERVATIONS	PRIOR INFO.	TOTAL
1	3288.2	0.0000	3288.2
2	1496.9	0.0000	1496.9
3	697.47	0.0000	697.47
4	4.6752	0.0000	4.6752
5	0.67760E-01	0.0000	0.67760E-01
6	0.70503E-02	0.0000	0.70503E-02
7	0.32119E-03	0.0000	0.32119E-03
8	0.70775E-04	0.0000	0.70775E-04
FINAL	0.70643E-04	0.0000	0.70643E-04

*** PARAMETER ESTIMATION CONVERGED BY SATISFYING THE TOL CRITERION ***

 COVARIANCE MATRIX FOR THE PARAMETERS

	HK1 VKA12_2 VKA3_4	HK2 VKA12_3 DRAIN	HK3 VKA12_4 GHB	HK4 VKA3_1 RCH	VKA12_1 VKA3_3 ETM
HK1	1.03696E-07	1.02094E-10	1.06613E-12	-1.91894E-13	-1.35507E-07
	9.97668E-11	4.11943E-13	1.78167E-13	-1.58327E-06	-1.92891E-12
	-2.41057E-13	1.67224E-08	2.06771E-08	4.86439E-12	9.76711E-12
HK2	1.02094E-10	2.03120E-12	1.88059E-14	5.17223E-16	1.59427E-10
	4.31163E-13	3.77560E-15	-7.74737E-17	2.28515E-09	3.82222E-14
	5.60387E-16	1.42097E-10	1.90330E-10	5.77090E-14	7.65767E-14
HK3	1.06613E-12	1.88059E-14	4.65769E-16	-5.34395E-17	1.80080E-12
	5.70361E-15	2.83309E-17	1.22041E-18	1.60811E-11	6.41508E-16
	-4.73536E-17	1.46667E-12	7.31866E-13	5.68597E-16	7.86773E-16
HK4	-1.91894E-13	5.17223E-16	-5.34395E-17	2.52602E-17	2.45374E-12
	1.93744E-16	1.51911E-17	-1.70751E-18	-3.35257E-11	-4.07653E-16
	2.50390E-17	3.38873E-15	1.65449E-13	1.20316E-17	-3.51991E-17
VKA12_1	-1.35507E-07	1.59427E-10	1.80080E-12	2.45374E-12	1.43296E-06
	1.32235E-10	2.93182E-13	-3.36752E-13	-1.50771E-05	-1.48068E-11
	2.98492E-12	1.00497E-08	-8.24051E-09	5.32192E-12	-1.10176E-11
VKA12_2	9.97668E-11	4.31163E-13	5.70361E-15	1.53744E-16	1.32235E-10
	2.56580E-13	1.03581E-15	9.87578E-17	-4.39940E-09	1.25173E-15
	2.52799E-16	4.88268E-11	3.59922E-11	1.58871E-14	1.94025E-14
VKA12_3	4.11943E-13	3.77560E-15	2.83309E-17	1.51911E-17	2.93182E-13
	1.03581E-15	6.30185E-17	-1.62152E-18	-4.04200E-12	-7.38609E-16
	1.33232E-17	2.54873E-13	3.24808E-13	1.12636E-16	1.54886E-16
VKA12_4	1.78167E-13	-7.74737E-17	1.22041E-18	-1.70751E-18	-3.36752E-13
	9.87578E-17	-1.62152E-18	4.49197E-18	-1.97796E-12	4.67777E-17
	-1.84357E-18	-3.84993E-15	1.60693E-14	1.37836E-18	6.99979E-18
VKA3_1	-1.58327E-06	2.28515E-09	1.60811E-11	-3.35257E-11	-1.50771E-05
	-4.39940E-09	-4.04200E-12	-1.97796E-12	3.33630E-04	5.20934E-10
	-4.04983E-11	-1.56115E-07	1.17661E-07	-2.16065E-11	2.64854E-10
VKA3_3	-1.92891E-12	3.82222E-14	6.41508E-16	-4.07653E-16	-1.48068E-11
	1.25173E-15	-7.38609E-16	4.67777E-17	5.20934E-10	5.24233E-14
	-4.31975E-16	2.77248E-12	3.75402E-12	1.00751E-15	1.45134E-15
VKA3_4	-2.41057E-13	5.60387E-16	-4.73536E-17	2.50390E-17	2.98492E-12
	2.52799E-16	1.33232E-17	-1.84357E-18	-4.04983E-11	-4.31975E-16
	2.55340E-17	1.07736E-14	1.44004E-13	1.44377E-17	-4.14456E-17
DRAIN	1.67224E-08	1.42097E-10	1.46667E-12	3.38873E-15	1.00497E-08
	4.88268E-11	2.54873E-13	-3.84993E-15	-1.56115E-07	2.77248E-12

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

GHB	1.07736E-14	2.51984E-08	1.36041E-08	4.91344E-12	5.94491E-12
	2.06771E-08	1.90330E-10	7.31866E-13	1.65449E-13	-8.24051E-09
	3.59922E-11	3.24808E-13	1.60693E-14	1.17661E-07	3.75402E-12
	1.44004E-13	1.36041E-08	2.49382E-08	5.41178E-12	7.41861E-12
RCH	4.86439E-12	5.77090E-14	5.68597E-16	1.20316E-17	5.32192E-12
	1.58871E-14	1.12636E-16	1.37836E-18	-2.16065E-11	1.00751E-15
	1.44377E-17	4.91344E-12	5.41178E-12	1.74363E-15	2.30081E-15
ETM	9.76711E-12	7.65767E-14	7.86773E-16	-3.51991E-17	-1.10176E-11
	1.94025E-14	1.54886E-16	6.99979E-18	2.64854E-10	1.45134E-15
	-4.14456E-17	5.94491E-12	7.41861E-12	2.30081E-15	4.04871E-15

PARAMETER SUMMARY

PHYSICAL PARAMETER VALUES --- NONE OF THE PARAMETERS IS LOG TRANSFORMED

PARAMETER:	HK1	HK2	HK3	HK4	VKA12_1
* = LOG TRNS:					
UPPER 95% C.I.	1.00E+00	1.00E-02	1.00E-04	1.01E-06	2.52E-01
FINAL VALUES	1.00E+00	1.00E-02	9.99E-05	1.00E-06	2.50E-01
LOWER 95% C.I.	9.99E-01	9.99E-03	9.99E-05	9.91E-07	2.47E-01
STD. DEV.	3.22E-04	1.43E-06	2.16E-08	5.03E-09	1.20E-03
COEF. OF VAR. (STD. DEV. / FINAL VALUE); "--" IF FINAL VALUE = 0.0	3.22E-04	1.43E-04	2.16E-04	5.02E-03	4.79E-03
REASONABLE					
UPPER LIMIT	-8.00E-01	2.00E-07	1.00E-07	1.20E-02	1.30E-02
REASONABLE					
LOWER LIMIT	-1.40E+00	2.00E-09	1.00E-09	1.20E-04	1.30E-04
ESTIMATE ABOVE (1)					
BELOW(-1)LIMITS	1	1	1	-1	1
ENTIRE CONF. INT.					
ABOVE(1)BELOW(-1)	1	1	1	-1	1

PHYSICAL PARAMETER VALUES --- NONE OF THE PARAMETERS IS LOG TRANSFORMED

PARAMETER:	VKA12_2	VKA12_3	VKA12_4	VKA3_1	VKA3_3
* = LOG TRNS:					
UPPER 95% C.I.	2.50E-03	2.50E-05	2.54E-07	1.04E+00	1.00E-04
FINAL VALUES	2.50E-03	2.50E-05	2.50E-07	9.98E-01	1.00E-04
LOWER 95% C.I.	2.50E-03	2.50E-05	2.46E-07	9.61E-01	9.95E-05
STD. DEV.	5.07E-07	7.94E-09	2.12E-09	1.83E-02	2.29E-07
COEF. OF VAR. (STD. DEV. / FINAL VALUE); "--" IF FINAL VALUE = 0.0	2.03E-04	3.18E-04	8.48E-03	1.83E-02	2.29E-03
REASONABLE					
UPPER LIMIT	1.30E-02	1.30E-02	1.30E-02	3.00E-03	3.00E-03
REASONABLE					
LOWER LIMIT	1.30E-04	1.30E-04	1.30E-04	3.00E-05	3.00E-05
ESTIMATE ABOVE (1)					
BELOW(-1)LIMITS	0	-1	-1	1	0
ENTIRE CONF. INT.					
ABOVE(1)BELOW(-1)	0	-1	-1	1	0

PHYSICAL PARAMETER VALUES --- NONE OF THE PARAMETERS IS LOG TRANSFORMED

PARAMETER:	VKA3_4	DRAIN	GHB	RCH	ETM
* = LOG TRNS:					

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

UPPER 95% C.I.	1.01E-06	1.00E+00	1.00E+00	3.10E-04	4.00E-04
FINAL VALUES	1.00E-06	9.99E-01	1.00E+00	3.10E-04	4.00E-04
LOWER 95% C.I.	9.91E-07	9.99E-01	9.99E-01	3.10E-04	4.00E-04
STD. DEV.	5.05E-09	1.59E-04	1.58E-04	4.18E-08	6.36E-08
COEF. OF VAR. (STD. DEV. / FINAL VALUE); "-" IF FINAL VALUE = 0.0	5.05E-03	1.59E-04	1.58E-04	1.35E-04	1.59E-04
REASONABLE UPPER LIMIT	3.00E-03	1.00E-06	2.00E-03	4.00E-04	4.00E-04
REASONABLE LOWER LIMIT	3.00E-05	1.00E-08	2.00E-05	4.00E-06	4.00E-06
ESTIMATE ABOVE (1)					
BELOW(-1)LIMITS	-1	1	1	0	0
ENTIRE CONF. INT.					
ABOVE(1)BELOW(-1)	-1	1	1	0	0

SOME PARAMETER VALUES ARE OUTSIDE THEIR USER-SPECIFIED REASONABLE RANGES TO A STATISTICALLY SIGNIFICANT EXTENT, BASED ON LINEAR THEORY. THIS IMPLIES THAT THERE ARE PROBLEMS WITH THE OBSERVATIONS, THE MODEL DOES NOT ADEQUATELY REPRESENT THE PHYSICAL SYSTEM, THE DATA ARE NOT CONSISTENT WITH THEIR SIMULATED EQUIVALENTS, OR THE SPECIFIED MINIMUM AND/OR MAXIMUM ARE NOT REASONABLE. CHECK YOUR DATA, CONCEPTUAL MODEL, AND MODEL DESIGN.

CORRELATION MATRIX FOR THE PARAMETERS

	HK1 VKA12_2 VKA3_4	HK2 VKA12_3 DRAIN	HK3 VKA12_4 GHB	HK4 VKA3_1 RCH	VKA12_1 VKA3_3 ETM
HK1	1.0000	0.22246	0.15341	-0.11857	-0.35153
	0.61164	0.16115	0.26105	-0.26918	-2.61619E-02
	-0.14814	0.32714	0.40661	0.36176	0.47668
HK2	0.22246	1.0000	0.61141	7.22077E-02	9.34480E-02
	0.59725	0.33372	-2.56484E-02	8.77822E-02	0.11713
	7.78131E-02	0.62809	0.84567	0.96971	0.84443
HK3	0.15341	0.61141	1.0000	-0.49267	6.97049E-02
	0.52174	0.16536	2.66809E-02	4.07941E-02	0.12982
	-0.43422	0.42811	0.21474	0.63095	0.57293
HK4	-0.11857	7.22077E-02	-0.49267	1.0000	0.40784
	6.03904E-02	0.38075	-0.16030	-0.36520	-0.35425
	0.98591	4.24749E-03	0.20845	5.73295E-02	-0.11007
VKA12_1	-0.35153	9.34480E-02	6.97049E-02	0.40784	1.0000
	0.21808	3.08522E-02	-0.13273	-0.68956	-5.40236E-02
	0.49347	5.28870E-02	-4.35918E-02	0.10647	-0.14465
VKA12_2	0.61164	0.59725	0.52174	6.03904E-02	0.21808
	1.0000	0.25759	9.19902E-02	-0.47550	1.07929E-02
	9.87652E-02	0.60724	0.44995	0.75111	0.60199
VKA12_3	0.16115	0.33372	0.16536	0.38075	3.08522E-02
	0.25759	1.0000	-9.63761E-02	-2.78760E-02	-0.40637
	0.33214	0.20226	0.25910	0.33979	0.30663
VKA12_4	0.26105	-2.56484E-02	2.66809E-02	-0.16030	-0.13273
	9.19902E-02	-9.63761E-02	1.0000	-5.10936E-02	9.63958E-02
	-0.17214	-1.14432E-02	4.80117E-02	1.55747E-02	5.19048E-02
VKA3_1	-0.26918	8.77822E-02	4.07941E-02	-0.36520	-0.68956
	-0.47550	-2.78760E-02	-5.10936E-02	1.0000	0.12456
	-0.43878	-5.38426E-02	4.07915E-02	-2.83287E-02	0.22788
VKA3_3	-2.61619E-02	0.11713	0.12982	-0.35425	-5.40236E-02
	1.07929E-02	-0.40637	9.63958E-02	0.12456	1.0000
	-0.37337	7.62817E-02	0.10382	0.10538	9.96203E-02
VKA3_4	-0.14814	7.78131E-02	-0.43422	0.98591	0.49347
	9.87652E-02	0.33214	-0.17214	-0.43878	-0.37337
	1.0000	1.34312E-02	0.18046	6.84246E-02	-0.12890
DRAIN	0.32714	0.62809	0.42811	4.24749E-03	5.28870E-02
	0.60724	0.20226	-1.14432E-02	-5.38426E-02	7.62817E-02
	1.34312E-02	1.0000	0.54269	0.74126	0.58857
GHB	0.40661	0.84567	0.21474	0.20845	-4.35918E-02
	0.44995	0.25910	4.80117E-02	4.07915E-02	0.10382
	0.18046	0.54269	1.0000	0.82069	0.73830
RCH	0.36176	0.96971	0.63095	5.73295E-02	0.10647
	0.75111	0.33979	1.55747E-02	-2.83287E-02	0.10538
	6.84246E-02	0.74126	0.82069	1.0000	0.86595
ETM	0.47668	0.84443	0.57293	-0.11007	-0.14465
	0.60199	0.30663	5.19048E-02	0.22788	9.96203E-02

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

-0.12890 0.58857 0.73830 0.86595 1.0000

THE CORRELATION OF THE FOLLOWING PARAMETER PAIRS >= .95

PARAMETER	PARAMETER	CORRELATION
HK2	RCH	0.97
HK4	VKA3_4	0.99

THE CORRELATION OF THE FOLLOWING PARAMETER PAIRS IS BETWEEN .90 AND .95

PARAMETER	PARAMETER	CORRELATION
RCH	ETM	0.87

THE CORRELATION OF THE FOLLOWING PARAMETER PAIRS IS BETWEEN .85 AND .90

PARAMETER	PARAMETER	CORRELATION
RCH	ETM	0.87

CORRELATIONS GREATER THAN 0.95 COULD INDICATE THAT THERE IS NOT ENOUGH INFORMATION IN THE OBSERVATIONS AND PRIOR USED IN THE REGRESSION TO ESTIMATE PARAMETER VALUES INDIVIDUALLY. TO CHECK THIS, START THE REGRESSION FROM SETS OF INITIAL PARAMETER VALUES THAT DIFFER BY MORE THAN TWO STANDARD DEVIATIONS FROM THE ESTIMATED VALUES. IF THE RESULTING ESTIMATES ARE WELL WITHIN ONE STANDARD DEVIATION OF THE PREVIOUSLY ESTIMATED VALUE, THE ESTIMATES ARE PROBABLY DETERMINED INDEPENDENTLY WITH THE OBSERVATIONS AND PRIOR USED IN THE REGRESSION. OTHERWISE, YOU MAY ONLY BE ESTIMATING THE RATIO OR SUM OF THE HIGHLY CORRELATED PARAMETERS. THE INITIAL PARAMETER VALUES ARE IN THE SEN FILE.

LEAST-SQUARES OBJ FUNC (DEP.VAR. ONLY)- = 0.70643E-04
 LEAST-SQUARES OBJ FUNC (W/PARAMETERS)-- = 0.70643E-04
 CALCULATED ERROR VARIANCE----- = 0.19093E-05
 STANDARD ERROR OF THE REGRESSION----- = 0.13818E-02
 CORRELATION COEFFICIENT----- = 1.0000
 W/PARAMETERS----- = 1.0000
 ITERATIONS----- = 8

MAX LIKE OBJ FUNC = 311.04
 AIC STATISTIC---- = 341.04
 BIC STATISTIC---- = 370.31

ORDERED DEPENDENT-VARIABLE WEIGHTED RESIDUALS

NUMBER OF RESIDUALS INCLUDED: 52

-0.291E-02	-0.260E-02	-0.135E-02	-0.132E-02	-0.117E-02	-0.512E-03	-0.313E-03
-0.269E-03	-0.244E-03	-0.232E-03	-0.146E-03	-0.146E-03	-0.146E-03	-0.122E-03
-0.116E-03	-0.977E-04	-0.732E-04	-0.732E-04	-0.732E-04	-0.610E-04	-0.488E-04
0.00	0.00	0.00	0.122E-04	0.244E-04	0.244E-04	0.244E-04
0.244E-04	0.732E-04	0.732E-04	0.854E-04	0.916E-04	0.977E-04	0.122E-03
0.122E-03	0.122E-03	0.146E-03	0.146E-03	0.159E-03	0.195E-03	0.250E-03
0.256E-03	0.262E-03	0.269E-03	0.366E-03	0.415E-03	0.483E-03	0.488E-03
0.707E-03	0.795E-03	0.689E-02				

SMALLEST AND LARGEST DEPENDENT-VARIABLE WEIGHTED RESIDUALS

SMALLEST WEIGHTED RESIDUALS			LARGEST WEIGHTED RESIDUALS		
OBS#	NAME	WEIGHTED RESIDUAL	OBS#	NAME	WEIGHTED RESIDUAL
50	GHB3	-0.29115E-02	45	DRN1	0.68890E-02
48	GHB1	-0.25987E-02	52	GHB5	0.79482E-03
46	DRN1	-0.13482E-02	49	GHB2	0.70749E-03
25	WL10	-0.13184E-02	31	WL12	0.48828E-03
43	DRN1	-0.11661E-02	51	GHB4	0.48281E-03

CORRELATION BETWEEN ORDERED WEIGHTED RESIDUALS AND NORMAL ORDER STATISTICS (EQ.38 OF TEXT) = 0.512

COMMENTS ON THE INTERPRETATION OF THE CORRELATION BETWEEN WEIGHTED RESIDUALS AND NORMAL ORDER STATISTICS:

The critical value for correlation at the 5% significance level is 0.956

IF the reported CORRELATION is GREATER than the 5% critical value, ACCEPT the hypothesis that the weighted residuals are INDEPENDENT AND NORMALLY DISTRIBUTED at the 5% significance level. The probability that this conclusion is wrong is less than 5%.

IF the reported correlation IS LESS THAN the 5% critical value REJECT the hypothesis that the weighted residuals are INDEPENDENT AND NORMALLY DISTRIBUTED at the 5% significance level.

The analysis can also be done using the 10% significance level. The associated critical value is 0.964

Test Case 2 Variant 4 Sample Files – GLOBAL Output File

*** PARAMETER ESTIMATION CONVERGED BY SATISFYING THE TOL CRITERION ***

LIST Output File

An example of the excerpted LIST output file for Test Case 2, Variant 4 is shown below. The HUF Package output appears in bold, and three dots (...) indicates omitted output.

MODFLOW-2000
U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
VERSION 1.0.2 08/21/2000

This model run produced both GLOBAL and LIST files. This is the LIST file.

THIS FILE CONTAINS OUTPUT UNIQUE TO FINAL PARAMETER VALUES
--REGRESSION HAS CONVERGED
SENSITIVITIES ARE CALCULATED USING PREVIOUS SET OF PARAMETER VALUES
CURRENT VALUES OF PARAMETERS LISTED IN THE SEN FILE:

PARAMETER NAME	PARAMETER TYPE	PARAMETER VALUE	FOOT- NOTE
HK1	HK	0.99961	*
HK2	HK	9.99594E-03	*
HK3	HK	9.99499E-05	*
HK4	HK	1.00120E-06	*
VKA12_1	VK	0.24987	*
VKA12_2	VK	2.49876E-03	*
VKA12_3	VK	2.49898E-05	*
VKA12_4	VK	2.49959E-07	*
VKA3_1	VK	0.99809	*
VKA3_3	VK	9.99589E-05	*
VKA3_4	VK	1.00102E-06	*
DRAIN	DRN	0.99942	*
GHB	GHB	0.99965	*
RCH	RCH	3.09867E-04	*
ETM	EVT	3.99829E-04	*

* INDICATES VALUE ADJUSTABLE BY PARAMETER-
ESTIMATION PROCESS

REBOUND tc2var4.lst
FILE TYPE:LIST UNIT 2

REBOUND ..\common\tc2.bas
FILE TYPE:BAS6 UNIT 8

REBOUND ..\common\tc2.dis
FILE TYPE:DIS UNIT 9

REBOUND ..\common\tc2.wel
FILE TYPE:WEL UNIT 12

REBOUND ..\common\tc2.drn
FILE TYPE:DRN UNIT 13

REBOUND ..\common\tc2.evt
FILE TYPE:EVT UNIT 15

REBOUND ..\common\tc2.ghb
FILE TYPE:GHB UNIT 17

REBOUND ..\common\tc2.rch
FILE TYPE:RCH UNIT 18

REBOUND ..\common\tc2.oc
FILE TYPE:OC UNIT 22

REBOUND ..\common\tc2.obs
FILE TYPE:OBS UNIT 37

REBOUND ..\common\tc2.zon

Test Case 2 Variant 4 Sample Files – LIST Output File

```

FILE TYPE:ZONE    UNIT  39

REWOUND ..\common\tc2.hob
FILE TYPE:HOB    UNIT  40

REWOUND ..\common\tc2.odr
FILE TYPE:DROB   UNIT  41

REWOUND ..\common\tc2.ogb
FILE TYPE:GBOB   UNIT  42

REWOUND ..\common\tc2.b
FILE TYPE:DATA   UNIT  48

REWOUND ..\common\tc2.bin
FILE TYPE:DATA(BINARY) UNIT  49

# MODFLOW-2000 SIMULATION OF DEATH VALLEY TEST CASE 1
# test case ymptc
THE FREE FORMAT OPTION HAS BEEN SELECTED
  3 LAYERS          18 ROWS          18 COLUMNS
  1 STRESS PERIOD(S) IN SIMULATION

BAS6 -- BASIC PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT  8
      15 ELEMENTS IN IR ARRAY ARE USED BY BAS

WEL6 -- WELL PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT 12
No named parameters
MAXIMUM OF      3 ACTIVE WELLS AT ONE TIME
      12 ELEMENTS IN RX ARRAY ARE USED BY WEL

DRN6 -- DRAIN PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT 13
  1 Named Parameters      5 List entries
MAXIMUM OF      5 ACTIVE DRAINS AT ONE TIME
      50 ELEMENTS IN RX ARRAY ARE USED BY DRN

EVT6 -- EVAPOTRANSPIRATION PACKAGE, VERSION 6, 1/11/2000
      INPUT READ FROM UNIT 15
  1 Named Parameters
OPTION 1 -- EVAPOTRANSPIRATION FROM TOP LAYER
      972 ELEMENTS IN RX ARRAY ARE USED BY EVT
      324 ELEMENTS IN IR ARRAY ARE USED BY EVT

GHB6 -- GHB PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT 17
  1 Named Parameters      5 List entries
MAXIMUM OF      5 ACTIVE GHB CELLS AT ONE TIME
      50 ELEMENTS IN RX ARRAY ARE USED BY GHB

RCH6 -- RECHARGE PACKAGE, VERSION 6, 1/11/2000 INPUT READ FROM UNIT 18
  1 Named Parameters
OPTION 1 -- RECHARGE TO TOP LAYER
      324 ELEMENTS IN RX ARRAY ARE USED BY RCH
      324 ELEMENTS IN IR ARRAY ARE USED BY RCH

      1408 ELEMENTS OF RX ARRAY USED OUT OF      1408
      663 ELEMENTS OF IR ARRAY USED OUT OF      663
1
# MODFLOW-2000 SIMULATION OF DEATH VALLEY TEST CASE 1
# test case ymptc

      BOUNDARY ARRAY FOR LAYER  1
READING ON UNIT  8 WITH FORMAT: (18I3)

      BOUNDARY ARRAY FOR LAYER  2
READING ON UNIT  8 WITH FORMAT: (18I3)

      BOUNDARY ARRAY FOR LAYER  3
READING ON UNIT  8 WITH FORMAT: (18I3)

AQUIFER HEAD WILL BE SET TO  9999.0    AT ALL NO-FLOW NODES (IBOUND=0).

      INITIAL HEAD FOR LAYER  1
READING ON UNIT  8 WITH FORMAT: (18F10.2)

```

Test Case 2 Variant 4 Sample Files – LIST Output File

INITIAL HEAD FOR LAYER 2
 READING ON UNIT 8 WITH FORMAT: (18F10.2)

INITIAL HEAD FOR LAYER 3
 READING ON UNIT 8 WITH FORMAT: (18F10.2)

OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
 HEAD PRINT FORMAT CODE IS 20 DRAWDOWN PRINT FORMAT CODE IS 0
 HEADS WILL BE SAVED ON UNIT 49 DRAWDOWNS WILL BE SAVED ON UNIT 0

HYD. COND. ALONG ROWS FOR UNIT HGU2

HYD. COND. ALONG ROWS						
	1	2	3	4	5	6
	7	8	9	10	11	12
	13	14	15	16	17	18
1	9.9959E-03	9.9950E-05	9.9959E-03	0.9996	0.9996	0.9996
	9.9959E-03	9.9959E-03	0.9996	0.9996	0.9996	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
2	9.9959E-03	9.9950E-05	9.9959E-03	0.9996	0.9996	0.9996
	9.9959E-03	9.9959E-03	9.9959E-03	0.9996	0.9996	0.9996
	0.000	0.000	0.000	0.000	0.000	0.000
3	9.9959E-03	9.9950E-05	9.9959E-03	9.9959E-03	0.9996	9.9959E-03
	9.9959E-03	9.9950E-05	9.9959E-03	0.9996	0.9996	0.9996
	0.9996	0.000	0.000	0.000	0.000	0.000
4	9.9959E-03	9.9950E-05	9.9950E-05	9.9959E-03	9.9959E-03	9.9959E-03
	9.9950E-05	9.9950E-05	9.9959E-03	9.9959E-03	9.9959E-03	0.9996
	0.9996	0.9996	0.000	0.000	0.000	0.000
5	9.9959E-03	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05
	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03	0.9996
	0.9996	0.9996	0.9996	0.000	0.000	0.000
6	9.9959E-03	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03
	9.9959E-03	9.9959E-03	9.9950E-05	9.9950E-05	9.9959E-03	0.9996
	0.9996	0.9996	0.9996	0.9996	0.000	0.000
7	9.9959E-03	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03
	0.9996	9.9959E-03	9.9950E-05	9.9950E-05	9.9959E-03	9.9959E-03
	9.9959E-03	0.9996	0.9996	0.9996	0.9996	0.000
8	9.9959E-03	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03
	0.9996	9.9959E-03	9.9950E-05	9.9950E-05	9.9959E-03	9.9959E-03
	9.9959E-03	0.9996	0.9996	0.9996	0.9996	9.9959E-03
9	9.9959E-03	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03
	9.9959E-03	9.9959E-03	9.9950E-05	9.9950E-05	9.9959E-03	0.9996
	9.9959E-03	0.9996	0.9996	0.9996	9.9959E-03	9.9959E-03
10	9.9959E-03	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05
	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03	0.9996
	9.9959E-03	9.9959E-03	0.9996	9.9959E-03	9.9959E-03	9.9959E-03
11	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05
	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03	0.9996
	9.9959E-03	9.9959E-03	0.9996	9.9959E-03	9.9959E-03	9.9959E-03
12	0.000	0.000	0.000	0.000	9.9950E-05	9.9950E-05
	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03	0.9996
	9.9959E-03	9.9959E-03	9.9959E-03	9.9959E-03	9.9959E-03	9.9959E-03
13	0.000	0.000	0.000	0.000	0.000	9.9950E-05
	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03	9.9959E-03
	9.9959E-03	9.9959E-03	9.9959E-03	9.9959E-03	9.9959E-03	0.9996
14	0.000	0.000	0.000	0.000	0.000	0.000
	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05	9.9950E-05
	9.9950E-05	9.9959E-03	9.9959E-03	9.9959E-03	0.9996	9.9959E-03
15	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	9.9959E-03	9.9959E-03	9.9959E-03	9.9950E-05	9.9950E-05
	9.9950E-05	9.9950E-05	9.9959E-03	9.9959E-03	0.9996	9.9959E-03
16	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.9996	9.9959E-03	9.9950E-05	9.9950E-05
	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03	0.9996	9.9959E-03
17	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	9.9959E-03	9.9950E-05	9.9950E-05
	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03	9.9959E-03	9.9959E-03
18	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	9.9950E-05	9.9950E-05
	9.9950E-05	9.9950E-05	9.9950E-05	9.9959E-03	9.9959E-03	9.9959E-03

Test Case 2 Variant 4 Sample Files – LIST Output File

HORIZ. ANI. (COL./ROW) FOR UNIT HGU2

HORIZ. ANI. (COL./ROW) = 1.00000

VERTICAL HYD. COND. FOR UNIT HGU2

VERTICAL HYD. COND.

	1	2	3	4	5	6
	7	8	9	10	11	12
	13	14	15	16	17	18
1	2.4988E-03	2.4990E-05	2.4988E-03	0.2499	0.2499	0.2499
	2.4988E-03	2.4988E-03	0.2499	0.2499	0.2499	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
2	2.4988E-03	2.4990E-05	2.4988E-03	0.2499	0.2499	0.2499
	2.4988E-03	2.4988E-03	2.4988E-03	0.2499	0.2499	0.2499
	0.000	0.000	0.000	0.000	0.000	0.000
3	2.4988E-03	2.4990E-05	2.4988E-03	2.4988E-03	0.2499	2.4988E-03
	2.4988E-03	2.4990E-05	2.4988E-03	0.2499	0.2499	0.2499
	0.2499	0.000	0.000	0.000	0.000	0.000
4	2.4988E-03	2.4990E-05	2.4990E-05	2.4988E-03	2.4988E-03	2.4988E-03
	2.4990E-05	2.4990E-05	2.4988E-03	2.4988E-03	2.4988E-03	0.2499
	0.2499	0.2499	0.000	0.000	0.000	0.000
5	2.4988E-03	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05
	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03	0.2499
	0.2499	0.2499	0.2499	0.000	0.000	0.000
6	2.4988E-03	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03
	2.4988E-03	2.4988E-03	2.4990E-05	2.4990E-05	2.4988E-03	0.2499
	0.2499	0.2499	0.2499	0.2499	0.000	0.000
7	2.4988E-03	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03
	0.2499	2.4988E-03	2.4990E-05	2.4990E-05	2.4988E-03	2.4988E-03
	2.4988E-03	0.2499	0.2499	0.2499	0.2499	0.000
8	2.4988E-03	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03
	0.2499	2.4988E-03	2.4990E-05	2.4990E-05	2.4988E-03	2.4988E-03
	2.4988E-03	0.2499	0.2499	0.2499	0.2499	2.4988E-03
9	2.4988E-03	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03
	2.4988E-03	2.4988E-03	2.4990E-05	2.4990E-05	2.4988E-03	0.2499
	2.4988E-03	0.2499	0.2499	0.2499	2.4988E-03	2.4988E-03
10	2.4988E-03	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05
	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03	0.2499
	2.4988E-03	2.4988E-03	0.2499	2.4988E-03	2.4988E-03	2.4988E-03
11	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05
	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03	0.2499
	2.4988E-03	2.4988E-03	0.2499	2.4988E-03	2.4988E-03	2.4988E-03
12	0.000	0.000	0.000	0.000	2.4990E-05	2.4990E-05
	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03	0.2499
	2.4988E-03	2.4988E-03	2.4988E-03	2.4988E-03	2.4988E-03	2.4988E-03
13	0.000	0.000	0.000	0.000	0.000	2.4990E-05
	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03	2.4988E-03
	2.4988E-03	2.4988E-03	2.4988E-03	2.4988E-03	2.4988E-03	0.2499
14	0.000	0.000	0.000	0.000	0.000	0.000
	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05	2.4990E-05
	2.4990E-05	2.4988E-03	2.4988E-03	2.4988E-03	0.2499	2.4988E-03
15	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	2.4988E-03	2.4988E-03	2.4988E-03	2.4990E-05	2.4990E-05
	2.4990E-05	2.4990E-05	2.4988E-03	2.4988E-03	0.2499	2.4988E-03
16	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.2499	2.4988E-03	2.4990E-05	2.4990E-05
	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03	0.2499	2.4988E-03
17	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	2.4988E-03	2.4990E-05	2.4990E-05
	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03	2.4988E-03	2.4988E-03
18	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	2.4990E-05	2.4990E-05
	2.4990E-05	2.4990E-05	2.4990E-05	2.4988E-03	2.4988E-03	2.4988E-03

1

STRESS PERIOD NO. 1, LENGTH = 86400.00

NUMBER OF TIME STEPS = 1

MULTIPLIER FOR DELT = 1.000

INITIAL TIME STEP SIZE = 86400.00

WELL NO.	LAYER	ROW	COL	STRESS RATE
1	1	9	7	-100.0

Test Case 2 Variant 4 Sample Files – LIST Output File

```

2      1      8      16      -200.0
3      1     11      13      -150.0
    
```

3 WELLS

Parameter: DRAIN

DRAIN NO.	LAYER	ROW	COL	DRAIN EL.	CONDUCTANCE
1	1	7	6	400.0	0.9994
2	1	10	11	550.0	0.9994
3	1	14	14	1200.	0.9994
4	1	15	14	1200.	0.9994
5	1	16	14	1200.	0.9994

5 DRAINS

ET SURFACE = 1000.00

EVTR array defined by the following parameters:

Parameter: ETM

EVAPOTRANSPIRATION RATE

...

EXTINCTION DEPTH = 950.000

Parameter: GHB

BOUND. NO.	LAYER	ROW	COL	STAGE	CONDUCTANCE
1	1	3	6	350.0	0.9996
2	1	3	11	500.0	0.9996
3	1	4	11	500.0	0.9996
4	1	5	11	500.0	0.9996
5	1	12	9	1000.	0.9996

5 GHB CELLS

RECH array defined by the following parameters:

Parameter: RCH

RECHARGE

...

SOLVING FOR HEAD

31 CALLS TO PCG ROUTINE FOR TIME STEP 1 IN STRESS PERIOD 1
237 TOTAL ITERATIONS

MAXIMUM HEAD CHANGE FOR LAST ITER1 ITERATIONS
(1 INDICATES THE FIRST INNER 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
0 0.4549E-03 (3, 2, 7)	0 0.2154E-03 (3, 2, 7)	0 0.1476E-02 (3, 2, 7)	1 -0.1075E-02 (3, 2, 7)	0 -0.3808E-03 (3, 2, 7)
0 -0.4910E-03 (3, 2, 7)	0 -0.7622E-04 (3, 8, 14)	1 0.5274E-04 (3, 2, 7)		

MAXIMUM RESIDUAL FOR LAST ITER1 ITERATIONS
(1 INDICATES THE FIRST INNER ITERATION):

RESIDUAL LAYER,ROW,COL	RESIDUAL LAYER,ROW,COL	RESIDUAL LAYER,ROW,COL	RESIDUAL LAYER,ROW,COL	RESIDUAL LAYER,ROW,COL
0 0.5231E-01 (3, 8, 17)	0 0.5100E-01 (3, 8, 17)	0 -0.4193E-01 (3, 7, 8)	1 0.4077E-01 (3, 8, 17)	0 0.4023E-01 (3, 8, 17)
0 0.3917E-01 (3, 8, 17)	0 0.3853E-01 (3, 8, 17)	1 0.3845E-01 (3, 8, 17)		

Test Case 2 Variant 4 Sample Files – LIST Output File

HEAD/DRAWDOWN PRINTOUT FLAG = 1 TOTAL BUDGET PRINTOUT FLAG = 1
 CELL-BY-CELL FLOW TERM FLAG = 0

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

HEAD PRINTOUT	DRAWDOWN PRINTOUT	HEAD SAVE	DRAWDOWN SAVE
1	0	1	0

1

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

...

1

 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

...

1

 HEAD IN LAYER 3 AT END OF TIME STEP 1 IN STRESS PERIOD 1

...

HEAD WILL BE SAVED ON UNIT 49 AT END OF TIME STEP 1, STRESS PERIOD 1

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 =	0.0000	STORAGE =	0.0000
CONSTANT HEAD =	500247744.0000	CONSTANT HEAD =	5789.9043
WELLS =	0.0000	WELLS =	0.0000
DRAINS =	0.0000	DRAINS =	0.0000
ET =	0.0000	ET =	0.0000
HEAD DEP BOUNDS =	0.0000	HEAD DEP BOUNDS =	0.0000
RECHARGE =	1144523264.0000	RECHARGE =	13246.7969
TOTAL IN =	1644771072.0000	TOTAL IN =	19036.7012
OUT:		OUT:	
STORAGE =	0.0000	STORAGE =	0.0000
CONSTANT HEAD =	367566688.0000	CONSTANT HEAD =	4254.2441
WELLS =	38880000.0000	WELLS =	450.0000
DRAINS =	131773312.0000	DRAINS =	1525.1541
ET =	878034688.0000	ET =	10162.4385
HEAD DEP BOUNDS =	228519264.0000	HEAD DEP BOUNDS =	2644.8989
RECHARGE =	0.0000	RECHARGE =	0.0000
TOTAL OUT =	1644774016.0000	TOTAL OUT =	19036.7344
IN - OUT =	-2944.0000	IN - OUT =	-3.3203E-02
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	7.46496E+09	1.24416E+08	2.07360E+06	86400.	236.55	
STRESS PERIOD TIME	7.46496E+09	1.24416E+08	2.07360E+06	86400.	236.55	
TOTAL TIME	7.46496E+09	1.24416E+08	2.07360E+06	86400.	236.55	

1

DATA AT HEAD LOCATIONS

OBS#	OBSERVATION NAME	MEAS. HEAD	CALC. HEAD	RESIDUAL	WEIGHT** .5	WEIGHTED RESIDUAL
1	W2L	979.029	979.029	0.427E-03	0.200	0.854E-04

Test Case 2 Variant 4 Sample Files – LIST Output File

2	WL2	1015.113	1015.112	0.488E-03	0.200	0.977E-04
3	WL2	1186.494	1186.494	0.00	0.200	0.00
4	WL4	291.694	291.695	-0.580E-03	0.200	-0.116E-03
5	WL4	964.356	964.355	0.128E-02	0.200	0.256E-03
6	WL4	1176.542	1176.543	-0.732E-03	0.200	-0.146E-03
7	WL4	1192.363	1192.363	0.00	0.200	0.00
8	WL5	760.721	760.720	0.134E-02	0.200	0.269E-03
9	WL6	188.804	188.805	-0.732E-03	0.200	-0.146E-03
10	WL6	892.570	892.571	-0.122E-02	0.200	-0.244E-03
11	WL6	906.942	906.941	0.732E-03	0.200	0.146E-03
12	WL6	1201.148	1201.148	0.122E-03	0.200	0.244E-04
13	WL6	1197.885	1197.885	-0.244E-03	0.200	-0.488E-04
14	WL6	1198.344	1198.344	-0.366E-03	0.200	-0.732E-04
15	WL8	209.993	209.992	0.125E-02	0.200	0.250E-03
16	WL8	642.477	642.476	0.793E-03	0.200	0.159E-03
17	WL8	1014.458	1014.458	0.610E-04	0.200	0.122E-04
18	WL8	1233.051	1233.051	0.122E-03	0.200	0.244E-04
19	WL8	1256.783	1256.784	-0.610E-03	0.200	-0.122E-03
20	WL8	1200.920	1200.921	-0.732E-03	0.200	-0.146E-03
21	WL9	444.975	444.975	0.458E-03	0.200	0.916E-04
22	WL10	635.429	635.429	-0.305E-03	0.200	-0.610E-04
23	WL10	941.034	941.035	-0.116E-02	0.200	-0.232E-03
24	WL10	1107.806	1107.807	-0.488E-03	0.200	-0.977E-04
25	WL10	1395.352	1395.359	-0.659E-02	0.200	-0.132E-02
26	WL10	1276.801	1276.800	0.610E-03	0.200	0.122E-03
27	WL10	1159.089	1159.089	-0.366E-03	0.200	-0.732E-04
28	WL11	336.394	336.393	0.131E-02	0.200	0.262E-03
29	WL12	1062.879	1062.879	0.366E-03	0.200	0.732E-04
30	WL12	1312.104	1312.103	0.977E-03	0.200	0.195E-03
31	WL12	1479.198	1479.196	0.244E-02	0.200	0.488E-03
32	WL12	1218.503	1218.503	0.122E-03	0.200	0.244E-04
33	WL13	1482.972	1482.970	0.183E-02	0.200	0.366E-03
34	WL13	1314.911	1314.910	0.610E-03	0.200	0.122E-03
35	WL14	1225.021	1225.021	0.122E-03	0.200	0.244E-04
36	WL14	1404.986	1404.984	0.208E-02	0.200	0.415E-03
37	WL14	1193.007	1193.006	0.610E-03	0.200	0.122E-03
38	WL15	1219.002	1219.003	-0.134E-02	0.200	-0.269E-03
39	WL16	1262.521	1262.521	0.00	0.200	0.00
40	WL16	1197.466	1197.466	0.366E-03	0.200	0.732E-04
41	WL18	1234.803	1234.803	-0.366E-03	0.200	-0.732E-04
42	WL18	1194.097	1194.096	0.732E-03	0.200	0.146E-03

STATISTICS FOR HEAD RESIDUALS :
 MAXIMUM WEIGHTED RESIDUAL : 0.488E-03 OBS# 31
 MINIMUM WEIGHTED RESIDUAL : -0.132E-02 OBS# 25
 AVERAGE WEIGHTED RESIDUAL : 0.163E-04
 # RESIDUALS >= 0. : 27
 # RESIDUALS < 0. : 15
 NUMBER OF RUNS : 16 IN 42 OBSERVATIONS

SUM OF SQUARED WEIGHTED RESIDUALS (HEADS ONLY) 0.30516E-05

DATA FOR FLOWS REPRESENTED USING THE DRAIN PACKAGE

OBS#	OBSERVATION NAME	MEAS. FLOW	CALC. FLOW	RESIDUAL	WEIGHT** .5	WEIGHTED RESIDUAL
43	DRN1	-522.	-522.	-0.183	0.639E-02	-0.117E-02
44	DRN1	-845.	-845.	-0.130	0.394E-02	-0.512E-03
45	DRN1	-133.	-133.	0.275	0.251E-01	0.689E-02
46	DRN1	-19.0	-19.0	-0.768E-02	0.175	-0.135E-02
47	DRN1	-6.20	-6.20	-0.581E-03	0.538	-0.313E-03

STATISTICS FOR DRAIN FLOW RESIDUALS :
 MAXIMUM WEIGHTED RESIDUAL : 0.689E-02 OBS# 45
 MINIMUM WEIGHTED RESIDUAL : -0.135E-02 OBS# 46
 AVERAGE WEIGHTED RESIDUAL : 0.710E-03
 # RESIDUALS >= 0. : 1
 # RESIDUALS < 0. : 4
 NUMBER OF RUNS : 3 IN 5 OBSERVATIONS

SUM OF SQUARED WEIGHTED RESIDUALS (DRAIN FLOWS ONLY) 0.50996E-04

DATA FOR FLOWS REPRESENTED USING THE GENERAL-HEAD BOUNDARY PACKAGE

OBS#	OBSERVATION NAME	MEAS. FLOW	CALC. FLOW	RESIDUAL	WEIGHT** .5	WEIGHTED RESIDUAL
48	GHB1	-608.	-608.	-0.474	0.548E-02	-0.260E-02
49	GHB2	-687.	-687.	0.146	0.485E-02	0.707E-03
50	GHB3	-660.	-659.	-0.576	0.505E-02	-0.291E-02

Test Case 2 Variant 4 Sample Files – LIST Output File

51 GHB4	-654.	-654.	0.947E-01	0.510E-02	0.483E-03
52 GHB5	-36.7	-36.7	0.875E-02	0.908E-01	0.795E-03

STATISTICS FOR GENERAL-HEAD BOUNDARY FLOW RESIDUALS :

MAXIMUM WEIGHTED RESIDUAL : 0.795E-03 OBS# 52
MINIMUM WEIGHTED RESIDUAL : -0.291E-02 OBS# 50
AVERAGE WEIGHTED RESIDUAL : -0.705E-03
RESIDUALS >= 0. : 3
RESIDUALS < 0. : 2
NUMBER OF RUNS : 4 IN 5 OBSERVATIONS

SUM OF SQUARED WEIGHTED RESIDUALS

(GENERAL-HEAD BOUNDARY FLOWS ONLY) 0.16595E-04

SUM OF SQUARED WEIGHTED RESIDUALS (ALL DEPENDENT VARIABLES) 0.70643E-04

STATISTICS FOR ALL RESIDUALS :

AVERAGE WEIGHTED RESIDUAL : 0.136E-04
RESIDUALS >= 0. : 31
RESIDUALS < 0. : 21
NUMBER OF RUNS : 22 IN 52 OBSERVATIONS

INTERPRETTING THE CALCULATED RUNS STATISTIC VALUE OF -1.03

NOTE: THE FOLLOWING APPLIES ONLY IF

RESIDUALS >= 0 . IS GREATER THAN 10 AND
RESIDUALS < 0. IS GREATER THAN 10

THE NEGATIVE VALUE MAY INDICATE TOO FEW RUNS:

IF THE VALUE IS LESS THAN -1.28, THERE IS LESS THAN A 10 PERCENT
CHANCE THE VALUES ARE RANDOM,

IF THE VALUE IS LESS THAN -1.645, THERE IS LESS THAN A 5 PERCENT
CHANCE THE VALUES ARE RANDOM,

IF THE VALUE IS LESS THAN -1.96, THERE IS LESS THAN A 2.5 PERCENT
CHANCE THE VALUES ARE RANDOM.

APPENDIX B: SENSITIVITY PROCESS – DERIVATION OF SENSITIVITY EQUATIONS FOR THE HYDROGEOLOGIC-UNIT FLOW PACKAGE

The governing equation for the calculation of sensitivities of heads at steady state with no unconfined cells is equation 23 from Hill and others (2000):

$$\underline{A}(0) \frac{\partial \underline{h}(0)}{\partial b_i} = - \frac{\partial \underline{A}(0)}{\partial b_i} \underline{h}(0) - \frac{\partial \underline{f}(0)}{\partial b_i}, \quad (\text{B-1})$$

where

$\underline{h}(0)$ is a vector of hydraulic heads [L],

$\underline{A}(0)$ equals $\underline{K} + \underline{P}(0)$ [L^2/T],

\underline{K} is a matrix of horizontal and vertical conductances [L^2/T],

$\underline{P}(0)$ is a diagonal matrix of conductances at head-dependent boundaries [L^2/T],

$\underline{f}(n)$ is the forcing function [L^3/T].

Underlined capital letters indicate matrices and underlined lower-case letters indicate vectors. MODFLOW-2000 calculates sensitivities by assembling the right-hand side of the equation and then solving to obtain the sensitivities. For the LPF Package, the first term on the right-hand side is non zero, and subroutine SENLPF1FM assembles the contributions. For the parameters used in the HUF Package, subroutine SENLPF1FM is replaced by SENHUF1FM.

Evaluating the derivative of matrix A, as needed in equation B-1, is accomplished by (1) taking the derivative of each term within the matrix, (2) multiplying by the correct hydraulic head, and (3) adding the result to the proper element of the vector that stores the right-hand side (RHS in MODFLOW-2000). A is a sparse, symmetric matrix, as discussed by McDonald and Harbaugh (1988), and the non-zero terms occur on the diagonal and three off diagonals on each side of the diagonal. Elements termed CC, which stands for conductance between columns, occur on the off-diagonals immediately adjacent to the diagonal. Elements termed CR, which stands for conductance between rows, occur further away from the diagonal. Elements termed CV, which stands for conductance in the vertical direction, occur farthest from the diagonal. The diagonal for each row of the matrix is a sum of the conductance term in that row and additional terms related to head-dependent boundaries. Calculation of the derivatives of the CC, CR, and CV terms and their multiplication by hydraulic head are discussed in this section.

APPENDIX B: SENSITIVITY PROCESS - DERIVATION

The derivatives of the CC, CR, and CV terms are calculated sequentially for each row and column in the grid. When calculated, the proper multiplication by hydraulic head is accomplished – these include once for each of the off-diagonal locations where the conductance occurs, and once for each of the two diagonal terms involved. The conductances apply between finite-difference cells, and here the conductance between the present cell and the next cell going in a positive direction always is considered.

For cells where the saturated thickness varies, the governing equation of sensitivities is equation 26 from Hill and others (2000):

$$\underline{A}(0) \left[\frac{\partial \underline{h}(0)}{\partial b_i} \right]^r = - \frac{\partial \underline{A}(0)}{\partial b_i} \underline{h}(0) - \frac{\partial \underline{f}(0)}{\partial b_i} - \frac{\partial \underline{A}(0)}{\partial \underline{h}(0)} \left[\frac{\partial \underline{h}(0)}{\partial b_i} \right]^{r-1} \underline{h}(0). \quad (\text{B-2})$$

The last term on the right-hand side is assembled in subroutine SENHUF1UN and the first term is assembled in subroutine SENHUF1FM.

For transient simulations, the governing flow equation is given as:

$$\underline{A}(m) \underline{h}(m) = \underline{B}(m-1) (\underline{h}(m-1) - \underline{TP}) + \underline{B}(m) \underline{TP} - \underline{f}(m), \quad (\text{B-3})$$

where:

$$\underline{A}(m) \text{ equals } \frac{-\underline{S}}{\Delta t(m)} + \underline{K} + \underline{P}(m) \text{ [L}^2/\text{T]},$$

\underline{S} is a diagonal matrix of specific storage multiplied by cell volume, or specific yield multiplied by cell area [L²],

$\Delta t(m)$ is the length of time step m [T],

\underline{K} is a matrix of horizontal and vertical conductances [L²/T],

$\underline{P}(m)$ is a diagonal matrix of conductances at head-dependent boundaries [L²/T],

$\underline{h}(m)$ is a vector of hydraulic heads at time step m [L],

$$\underline{B}(m) \text{ equals } \frac{-\underline{S}}{\Delta t(m)} \text{ [L}^2/\text{T]},$$

\underline{TP} is a vector of the top elevation of each cell [L], and

$\underline{f}(m)$ is the forcing function [L³/T].

The derivative of equation B-3 is given as:

APPENDIX B: SENSITIVITY PROCESS - DERIVATION

$$\begin{aligned} \underline{A}(m) \left[\frac{\partial \underline{h}(m)}{\partial b_i} \right]^r &= - \frac{\partial \underline{A}(m)}{\partial \underline{h}(m)} \left[\frac{\partial \underline{h}(m)}{\partial b_i} \right]^{r-1} \underline{h}(m) + \frac{\partial \underline{B}(m-1)}{\partial b_i} \underline{h}(m-1) + \underline{B}(m-1) \frac{\partial \underline{h}(m-1)}{\partial b_i} \\ &\quad - \frac{\partial \underline{B}(m-1)}{\partial b_i} \underline{TP} + \frac{\partial \underline{B}(m)}{\partial b_i} \underline{TP} - \frac{\partial \underline{A}(m)}{\partial b_i} \underline{h}(m) - \frac{\partial f(m)}{\partial b_i}, \end{aligned} \quad (\text{B-4a})$$

which differs slightly from equation 71b of Hill (1992) to account for cells which convert between confined and unconfined conditions. It is only during the transition from confined to unconfined conditions and conversely that $\underline{B}(m-1) \neq \underline{B}(m)$, otherwise the terms

$$- \frac{\partial \underline{B}(m-1)}{\partial b_i} \underline{TP} \quad \text{and} \quad \frac{\partial \underline{B}(m)}{\partial b_i} \underline{TP}$$

cancel each other and equation B-4 is identical to equation 71b

of Hill (1992). The first term on the right-hand side is accumulated in Subroutine SENHUF1UN; the remaining terms, except the $-\frac{\partial f(m)}{\partial b_i}$, are accumulated in Subroutine SENHUF1FM.

During the transition from confined to unconfined conditions in time step n , $\underline{B}(m-1)$ is only sensitive to an SS parameter and $\underline{B}(m)$ is only sensitive to an SY parameter which simplifies eq. B-4a. For an SS parameter during the transition to unconfined conditions, the following equation holds:

$$\begin{aligned} \underline{A}(m) \left[\frac{\partial \underline{h}(n)}{\partial SS} \right]^r &= - \frac{\partial \underline{A}(m)}{\partial \underline{h}(m)} \left[\frac{\partial \underline{h}(m)}{\partial SS} \right]^{r-1} \underline{h}(m) + \underline{B}(m-1) \frac{\partial \underline{h}(m-1)}{\partial SS} \\ &\quad + \frac{\partial \underline{B}(m-1)}{\partial SS} (\underline{h}(m-1) - \underline{TP}), \end{aligned} \quad (\text{B-4b})$$

and for an SY parameter, recognizing that $\frac{\partial \underline{B}(m)}{\partial SY} = \frac{\partial \underline{A}(m)}{\partial SY}$, the following equation holds:

$$\begin{aligned} \underline{A}(m) \left[\frac{\partial \underline{h}(m)}{\partial SY} \right]^r &= - \frac{\partial \underline{A}(m)}{\partial \underline{h}(m)} \left[\frac{\partial \underline{h}(m)}{\partial SY} \right]^{r-1} \underline{h}(m) + \underline{B}(m-1) \frac{\partial \underline{h}(m-1)}{\partial SY} \\ &\quad + \frac{\partial \underline{B}(m)}{\partial SY} (\underline{TP} - \underline{h}(m)). \end{aligned} \quad (\text{B-4c})$$

During the transition from unconfined to confined conditions, $\underline{B}(m-1)$ is only sensitive to an SY parameter and $\underline{B}(m)$ is only sensitive to an SS parameter. For an SS parameter during the transition to confined conditions, recognizing that $\frac{\partial \underline{B}(m)}{\partial SS} = \frac{\partial \underline{A}(m)}{\partial SS}$, the following equations hold:

$$\begin{aligned} \underline{A}(m) \left[\frac{\partial \underline{h}(m)}{\partial SS} \right]^r &= - \frac{\partial \underline{A}(m)}{\partial \underline{h}(m)} \left[\frac{\partial \underline{h}(m)}{\partial SS} \right]^{r-1} \underline{h}(m) + \underline{B}(m-1) \frac{\partial \underline{h}(m-1)}{\partial SS} \\ &+ \frac{\partial \underline{B}(m)}{\partial SS} (\underline{TP} - \underline{h}(m)) \end{aligned} \quad (\text{B-4d})$$

$$\begin{aligned} \underline{A}(m) \left[\frac{\partial \underline{h}(m)}{\partial SY} \right]^r &= - \frac{\partial \underline{A}(m)}{\partial \underline{h}(m)} \left[\frac{\partial \underline{h}(m)}{\partial SY} \right]^{r-1} \underline{h}(m) + \underline{B}(m-1) \frac{\partial \underline{h}(m-1)}{\partial SY} \\ &+ \frac{\partial \underline{B}(m-1)}{\partial SY} (\underline{h}(m-1) - \underline{TP}). \end{aligned} \quad (\text{B-4e})$$

HK Parameters

Horizontal hydraulic conductivity parameters affect matrix A. The CC and CR terms are treated nearly the same. CR terms are used in the derivation. Each CR term is of the form

$$CR_{i,j+1/2,k} = 2\Delta c_i \frac{TR_{i,j,k} TR_{i,j+1,k}}{TR_{i,j,k} \Delta r_{j+1} + TR_{i,j+1,k} \Delta r_j}, \quad (\text{B-5})$$

where

$$TR_{i,j,k} = \sum_{g=1}^n KH_{i,j,g} thk_{g,i,j,k}; \quad KH_{i,j,g} = \sum_{l=1}^p Kh_l m_{l,i,j,g}, \quad (\text{B-6a})$$

and

$$TR_{i,j+1,k} = \sum_{g=1}^n KH_{i,j+1,g} thk_{g,i,j+1,k}; \quad KH_{i,j+1,g} = \sum_{l=1}^p Kh_l m_{l,i,j+1,g}, \quad (\text{B-6b})$$

where

- n is the number of hydrogeologic units within the finite-difference cell,
- $thk_{g,i,j,k}$ is the thickness of hydrogeologic unit g in cell i, j, k ,
- p is the number of additive parameters that define the hydraulic conductivity of hydrogeologic unit g ,
- Kh_l is the horizontal hydraulic conductivity of parameter l , and

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$m_{l_{i,j,g}}$ is the multiplication factor for parameter l .

Because these are fairly complicated expressions, it is useful to proceed through a few elementary steps to determine the derivatives. Consider a ratio of two functions of a parameter named b , $u(b)/v(b)$. Basic calculus yields that

$$\frac{\partial}{\partial b} \left[\frac{u}{v} \right] = \frac{v \frac{\partial u}{\partial b} - u \frac{\partial v}{\partial b}}{v^2}. \quad (\text{B-7})$$

For equation B-5 above, u and v can be defined as:

$$u = TR_{i,j,k} TR_{i,j+1,k} \quad (\text{B-8a})$$

$$v = TR_{i,j,k} \Delta r_{j+1} + TR_{i,j+1,k} \Delta r_j, \quad (\text{B-8b})$$

so that

$$\frac{\partial u}{\partial b} = \frac{\partial u}{\partial Kh_l} = TR_{i,j,k} \frac{\partial TR_{i,j+1,k}}{\partial Kh_l} + TR_{i,j+1,k} \frac{\partial TR_{i,j,k}}{\partial Kh_l}, \quad (\text{B-9a})$$

and

$$\frac{\partial v}{\partial b} = \frac{\partial v}{\partial Kh_l} = \frac{\partial TR_{i,j,k}}{\partial Kh_l} \Delta r_{j+1} + \frac{\partial TR_{i,j+1,k}}{\partial Kh_l} \Delta r_j. \quad (\text{B-9b})$$

Using equation B-7 with these expressions yields:

$$\frac{\partial CR_{i,j+1/2,k}}{\partial Kh_l} = 2\Delta C_i \frac{v \frac{\partial u}{\partial Kh_l} - u \frac{\partial v}{\partial Kh_l}}{v^2}. \quad (\text{B-10})$$

The remaining derivatives needed are:

$$\frac{\partial TR_{i,j,k}}{\partial Kh_l} = \sum_{g=1}^n m_{l_{i,j,g}} thk_{g_{i,j,k}} \quad (\text{B-11a})$$

$$\frac{\partial TR_{i,j+1,k}}{\partial Kh_l} = \sum_{g=1}^n m_{l_{i,j+1,g}} thk_{g_{i,j+1,k}} \quad (\text{B-11b})$$

and

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$$\frac{\partial u}{\partial b} = \frac{\partial u}{\partial Kh_l} = TR_{i,j,k} \sum_{g=1}^n m_{i,j+1,g} thk_{g,i,j+1,k} + TR_{i,j+1,k} \sum_{g=1}^n m_{i,j,g} thk_{g,i,j,k} \quad (B-12a)$$

$$\frac{\partial v}{\partial b} = \frac{\partial v}{\partial Kh_l} = \Delta r_{j+1} \sum_{g=1}^n m_{i,j,g} thk_{g,i,j,k} + \Delta r_j \sum_{g=1}^n m_{i,j+1,g} thk_{g,i,j+1,k} . \quad (B-12b)$$

Contributions to the right-hand side are:

$$RHS_{i,j,k} = RHS_{i,j,k} + \frac{\partial CR_{i,j+1/2,k}}{\partial Kh_l} (h_{i,j,k} - h_{i,j+1,k}) \quad (B-13a)$$

$$RHS_{i,j+1,k} = RHS_{i,j+1,k} - \frac{\partial CR_{i,j+1/2,k}}{\partial Kh_l} (h_{i,j,k} - h_{i,j+1,k}) . \quad (B-13b)$$

A similar set of equations could be derived for CC.

HANI Parameters

HANI parameters affect the CC terms of matrix A. Each CC term is of the form

$$CC_{i+1/2,j,k} = 2\Delta r_j \frac{TC_{i+1,j,k} TC_{i,j,k}}{TC_{i,j,k} \Delta c_{i+1} + TC_{i+1,j,k} \Delta c_i} , \quad (B-14)$$

where

$$TC_{i,j,k} = \sum_{g=1}^n KH_{i,j,g} thk_{g,i,j,k} HANI_{i,j,g} ; HANI_{i,j,g} = \sum_{l=1}^p Hani_l m_{l,i,j,g} \quad (B-15)$$

$$TC_{i+1,j,k} = \sum_{g=1}^n KH_{i+1,j,g} thk_{g,i+1,j,k} HANI_{i+1,j,g} ; HANI_{i+1,j,g} = \sum_{l=1}^p Hani_l m_{l,i+1,j,g} .$$

For equation B-14 above, u and v can be defined as:

$$u = TC_{i+1,j,k} TC_{i,j,k} \quad (B-16a)$$

$$v = TC_{i,j,k} \Delta c_{i+1} + TC_{i+1,j,k} \Delta c_i \quad (B-16b)$$

$$\frac{\partial u}{\partial Hani_l} = \frac{\partial TC_{i+1,j,k}}{\partial Hani_l} TC_{i,j,k} + \frac{\partial TC_{i,j,k}}{\partial Hani_l} TC_{i+1,j,k} \quad (B-17a)$$

and

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$$\frac{\partial v}{\partial Hani_l} = \frac{\partial TC_{i,j,k}}{\partial Hani_l} \Delta c_{i+1} + \frac{\partial TC_{i+1,j,k}}{\partial Hani_l} \Delta c_i, \quad (\text{B-17B})$$

also

$$\begin{aligned} \frac{\partial TC_{i,j,k}}{\partial Hani_l} &= \sum_{g=1}^n KH_{i,j,g} thk_{g,i,j,k} m_{l,i,j,g} \\ \frac{\partial TC_{i+1,j,k}}{\partial Hani_l} &= \sum_{g=1}^n KH_{i+1,j,g} thk_{g,i+1,j,k} m_{l,i+1,j,g}. \end{aligned} \quad (\text{B-18})$$

VK Parameters

Vertical conductance (CV) represents the block of subsurface material between a cell center and the cell center below, and for approximately horizontal hydrogeologic layers is calculated as:

$$CV_{i,j,k+1/2} = \frac{\Delta r_j \Delta c_i}{\sum_{g=1}^n \frac{thk_{g,i,j,k+1/2}}{KV_{i,j,g}}}; KV_{i,j,g} = \sum_{l=1}^p K_{v_l} m_{l,i,j,g}, \quad (\text{B-19})$$

where

Δr_j is the cell width of column j ,

Δc_i is the cell width of row i ,

n is the number of hydrogeologic units that occur vertically between the two cell centers,

$thk_{g,i,j,k+1/2}$ is the hydrogeologic unit g thickness that occurs between the two cell centers,

p is the number of additive parameters that define the hydraulic conductivity of hydrogeologic unit g ,

K_{v_l} is the vertical hydraulic conductivity of parameter l , and

$m_{l,i,j,g}$ is the multiplication factor for parameter l .

The K_{v_l} terms are the parameters. For this equation, if u and v are defined as:

$$u = \Delta r_j \Delta c_i \quad (\text{B-20a})$$

$$v = \sum_{g=1}^n \frac{thk_{g,i,j,k+1/2}}{KV_{i,j,g}}, \quad (\text{B-20b})$$

then

$$\frac{\partial u}{\partial b} = \frac{\partial u}{\partial Kv_l} = 0 \quad (\text{B-21})$$

and

$$\frac{\partial v}{\partial b} = \frac{\partial v}{\partial Kv_l} = - \sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}} \frac{\partial Kv_{i,j,g}}{\partial Kv_l}}{Kv_{i,j,g}^2}. \quad (\text{B-22})$$

The remaining derivative is

$$\frac{\partial Kv_{i,j,g}}{\partial Kv_l} = m_{l_{i,j,g}}. \quad (\text{B-23})$$

Assembling these terms yields:

$$\frac{\partial CV_{i,j,k+1/2}}{\partial Kv_l} = \frac{-\Delta r_j \Delta c_i \left[- \sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}} \frac{\partial Kv_{i,j,g}}{\partial Kv_l}}{(Kv_{i,j,g})^2} \right]}{\left(\sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}}}{Kv_{i,j,g}} \right)^2} = \frac{CV_{i,j,k+1/2}^2}{\Delta r_j \Delta c_i} \left[\sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}} m_{l_{i,j,g}}}{(Kv_{i,j,g})^2} \right]. \quad (\text{B-24})$$

These terms would be contributed to the right-hand side as:

$$RHS_{i,j,k} = RHS_{i,j,k} + \frac{\partial CV_{i,j,k+1/2}}{\partial Kv_{l_{i,j,k+1/2}}} (h_{i,j,k} - h_{i,j,k+1}) \quad (\text{B-25a})$$

$$RHS_{i,j,k+1} = RHS_{i,j,k+1} - \frac{\partial CV_{i,j,k+1/2}}{\partial Kv_{l_{i,j,k+1/2}}} (h_{i,j,k} - h_{i,j,k+1}). \quad (\text{B-25b})$$

VANI Parameters

For VANI parameters, vertical conductance is expressed as:

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$$CV_{i,j,k+1/2} = \frac{\Delta r_j \Delta c_i}{\sum_{g=1}^n \left[\frac{thk_{g_{i,j,k+1/2}}}{\frac{\sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}}} \right]}, \quad (B-26)$$

which is dependent on both ANIV and Kh. The sensitivity of CV to VANI is derived first.

Because this is a complicated expression, it is useful to derive the sensitivity equation in several steps using equation B-7. First, assume the following definitions of u_1 and v_1 , which results in the derivatives shown:

$$u_1 = \sum_{l=1}^p Kh_l m_{l_{i,j,g}}; \quad \frac{\partial u_1}{\partial VANI_g} = 0 \quad (B-27a)$$

$$v_1 = VANI_g m_{g_{i,j}}; \quad \frac{\partial v_1}{\partial VANI_g} = m_{g_{i,j}}. \quad (B-27b)$$

Then, using equation B-7,

$$\frac{\partial \frac{u_1}{v_1}}{\partial VANI_g} = - \frac{m_{g_{i,j}} \sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{(VANI_g m_{g_{i,j}})^2}. \quad (B-27c)$$

Next, assume the following definitions of u_2 and v_2 ,

$$u_2 = thk_{g_{i,j,k+1/2}}; \quad \frac{\partial u_2}{\partial VANI_g} = 0 \quad (B-28a)$$

$$v_2 = \frac{\sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}}; \quad \frac{\partial v_2}{\partial VANI_g} = \frac{\frac{\partial u_1}{\partial v_1}}{\partial VANI_g}, \quad (B-28b)$$

which is shown in equation B-27c. Then, using equation B-7,

$$\frac{\partial \sum_{g=1}^n \frac{u_2}{v_2}}{\partial VANI_g} = \sum_{g=1}^n \frac{\partial \frac{u_2}{v_2}}{\partial VANI_g} = \sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}} \frac{m_{g_{i,j}} \sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{(VANI_g m_{g_{i,j}})^2}}{\left(\frac{\sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}} \right)^2}. \quad (B-28c)$$

Finally, assume the following definitions of u_3 and v_3 ,

$$u_3 = \Delta r_j \Delta c_i; \quad \frac{\partial u_3}{\partial VANI_g} = 0 \quad (\text{B-29a})$$

$$v_3 = \sum_{g=1}^n \left[\frac{thk_{g_{i,j,k+1/2}}}{\frac{\sum_{l=1}^p Kh_l m_{l,j,g}}{VANI_g m_{g_{i,j}}}} \right]; \quad \frac{\partial v_3}{\partial VANI_g} = \sum_{g=1}^n \left[\frac{\frac{\partial u_2}{\partial v_2}}{\frac{\partial v_2}{\partial VANI_g}} \right], \quad (\text{B-29b})$$

where the final term is given by equation B-28c. Applying equation B-7 one final time gives

$$\begin{aligned} \frac{\partial CV_{i,j,k+1/2}}{\partial VANI_g} &= \frac{-\Delta r_j \Delta c_i \sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}} \frac{m_{g_{i,j}} \sum_{l=1}^p Kh_l m_{l,j,g}}{(VANI_g m_{g_{i,j}})^p}}{\left(\frac{\sum_{l=1}^p Kh_l m_{l,j,g}}{VANI_g m_{g_{i,j}}} \right)^2}}{\left(\sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}}}{\frac{\sum_{l=1}^p Kh_l m_{l,j,g}}{VANI_g m_{g_{i,j}}}} \right)^2} \\ &= -\frac{CV_{i,j,k+1/2}^2}{\Delta r_j \Delta c_i} \sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}} \frac{m_{g_{i,j}} \sum_{l=1}^p Kh_l m_{l,j,g}}{(VANI_g m_{g_{i,j}})^p}}{\left(\frac{\sum_{l=1}^p Kh_l m_{l,j,g}}{VANI_g m_{g_{i,j}}} \right)^2}. \end{aligned} \quad (\text{B-29c})$$

The sensitivity of CV to Kh is derived in a similar manner. First, assume the following definitions of u_l and v_l which results in the derivatives shown:

$$u_1 = thk_{g_{i,j,k+1/2}}; \quad \frac{\partial u_1}{\partial Kh_l} = 0 \quad (\text{B-30a})$$

$$v_1 = \frac{\sum_{l=1}^p Kh_l m_{l,j,g}}{VANI_g m_{g_{i,j}}}; \quad \frac{\partial v_1}{\partial Kh_l} = \frac{m_{l,j,g}}{VANI_g m_{g_{i,j}}}. \quad (\text{B-30b})$$

Then, using equation B-7,

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$$\frac{\partial \sum_{g=1}^n \frac{u_1}{v_1}}{\partial Kh_l} = \sum_{g=1}^n \frac{\partial \frac{u_1}{v_1}}{\partial Kh_l} = \sum_{g=1}^n \frac{-thk_{g_{i,j,k+1/2}} \frac{m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}}}{\left(\frac{\sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}} \right)^2}. \quad (B-30c)$$

Next, assume the following definitions of u_2 and v_2 ,

$$u_2 = \Delta r_j \Delta c_i; \quad \frac{\partial u_2}{\partial Kh_l} = 0 \quad (B-31a)$$

$$v_2 = \sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}}}{\frac{\sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}}}; \quad \frac{\partial v_2}{\partial Kh_l} = \frac{\frac{\partial u_1}{\partial v_1}}{\frac{\partial v_1}{\partial Kh_l}}, \quad (B-31b)$$

which is shown in equation B-30c. Then, using equation B-7,

$$\begin{aligned} \frac{\partial CV_{i,j,k+1/2}}{\partial Kh_l} &= \frac{\Delta r_j \Delta c_i \sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}} \frac{m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}}}{\left(\frac{\sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}} \right)^2}}{\left(\sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}}}{\frac{\sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}}} \right)^2}} \\ &= \frac{CV_{i,j,k+1/2}^2}{\Delta r_j \Delta c_i} \sum_{g=1}^n \frac{thk_{g_{i,j,k+1/2}} \frac{m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}}}{\left(\frac{\sum_{l=1}^p Kh_l m_{l_{i,j,g}}}{VANI_g m_{g_{i,j}}} \right)^2}. \end{aligned} \quad (B-31c)$$

SS Parameters

SS parameters are used to populate the SC1 array using the following equation:

$$SC1_{i,j,k} = \Delta r_j \Delta c_i \sum_{g=1}^n SS_{i,j,g} thk_{g,i,j,k} ; SS_{i,j,g} = \sum_{l=1}^p Ss_l m_{l,i,j,g} , \quad (B-32)$$

which affects matrix A. Taking the derivative with respect to the SS parameter yields

$$\frac{\partial SC1_{i,j,k}}{\partial Ss_l} = \Delta r_j \Delta c_i thk_{g,i,j,k} m_{l,i,j,k} . \quad (B-33)$$

SY Parameters

The HUF Package was implemented such that the specific yield for the hydrogeologic unit in which the water table resides is used to calculate the contribution to the storage flow for a given cell. Should the water table span several hydrogeologic units during a time step, the specific yields for each of those units are used with the corresponding thickness of the units to calculate the contributions to the mass balance for that particular cell. SY parameters are used to calculate the SC2 value for each cell using the following equation

$$SC2_{i,j,k} = \Delta r_j \Delta c_i SY_{i,j,g} ; SY_{i,j,g} = \sum_{l=1}^p Sy_l m_{l,i,j,g} , \quad (B-34)$$

which affects matrix A. Taking the derivative with respect to the SY parameter yields

$$\frac{\partial SC2_{i,j,k}}{\partial Sy_l} = \Delta r_j \Delta c_i m_{l,i,j,k} . \quad (B-35)$$