

TUTORIAL ON GROUND WATER FLOW MODEL

DATA PREPARATION FOR THE USGS 3D GROUNDWATER FLOW MODEL

The groundwater flow model (McDonal and Harbough, 1984) discussed earlier is a modular three dimensional groundwater flow model having a main program and a large number of highly independent subroutines called modules.

For a typical simulation, the function which must be performed are shown in Fig.1. This is a flow chart for overall structure of the program and is also the flow chart for the main program. The work within the rectangles is performed by individual modules which are called by MAIN, i.e., the main program. Thus MAIN is an organised collection of fortran call statements which invoke modules to read data, perform calculations, and print results. MAIN does not do work; it merely calls modules which do work.

A 'Package' consists of all modules associated with a particular hydrologic feature, a solution method or the overall control of the simulation. For example, all the modules concerned with the simulation of wells, combined together form the well Package. Similarly, there are Packages to simulate the effects of rivers, areal recharge, drains, evapotranspiration and general head boundaries.

All the modules related to internal flow between model cells and flow into storage for a block-centred formulation are members of Block Centred Flow Package. The packages related to internal external flow are termed 'Flow-Component' Packages. Flow-Component terms to the finite difference equations.

An other set of Package termed 'Solver' Packages include modules needed to implement a particular solution algorithm. These Packages include the Strongly-Implicit procedure (SIP) and the Slice-Successive Overrelaxation (SSOR). The Solver and Flow-Component Packages are, in effect, the options available to the users of the user specifies which of the Flow-Component Packages are required for a simulation and which Solver Package is desired.

The 'Basic Package ' is used in any simulation irrespective of the opinions selected. It includes those modules which and organize a simulation. For example, it handles, initial conditions, boundary conditions and discretization of the aquifer into cells including time-discretization. The list of Packages with abbreviation and description is given in Table 1.

The period of simulation is divided into a series of 'stress periods' within which all external stresses are constant. Each stress period, in turn, may be divided into a series of time steps.

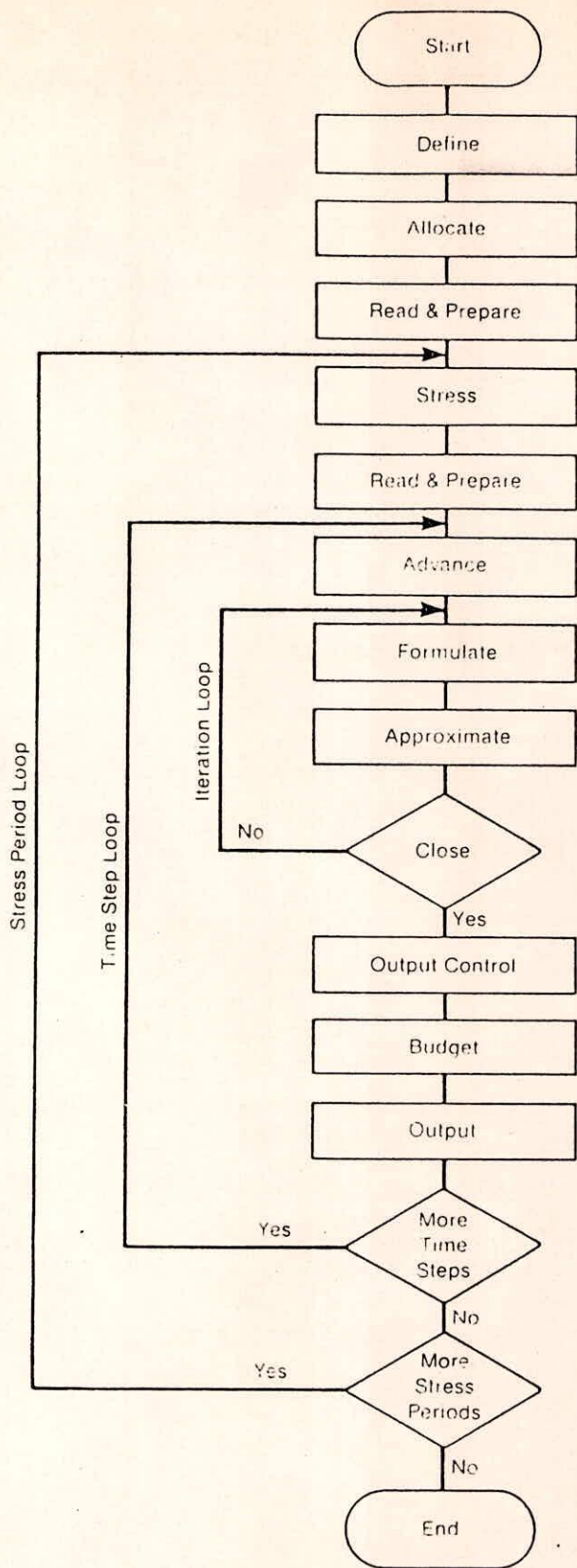
The primary modules (subroutines which are called from the main program) are arranged in a matrix format to illustrate the classification by package and by procedure in Table 2. Each row in the matrix correspond to procedures and the vertical column correspond to packages. An 'X' is entered in each block of the matrix for which the module exists. Absence of an 'X' means that a module representing that particular and procedure is not required. Entries marked with subscript 'S' indicate primary modules which utilize sub-modules in accomplishing their function. Sub-modules are the secondary modules contained in a particular package. Entries marked with subscript 'U' indicate modules which utilize utility modules. Utility modules are secondary modules available to many packages.

The input data files for different packages are as given below:

Package Name	Input Data File Name
Basic	USBAS.DAT
Block-Centered	USBCF.DAT
Well	USWEL.DAT
Recharge	USREC.DAT
River	USRIV.DAT
Drain	USDRAIN.DAT
E.T.	USEVT.DAT
General head boundary	USGHB.DAT
Strongly Implicit Program	USSIP.DAT
Slice-Successive Over relaxation	USSOR.DAT

Abbreviated input instructions for various packages have been given at Appendix A.

The tutorial problems along with prepared data files are given at Appendix B. And the results of simulation for tutorial problem is given at Appendix C.



DEFINE -- Read data specifying number of rows, columns, layers, stress periods, and major program options

ALLOCATE -- Allocate space in the computer to store data

READ AND PREPARE -- Read data which is constant throughout the simulation. Prepare the data by performing whatever calculations can be made at this stage.

STRESS -- Determine the length of a stress period and calculate terms to divide stress periods into time steps.

READ AND PREPARE -- Read data which changes from one stress period to the next. Prepare the data by performing whatever calculations can be made at this stage

ADVANCE -- Calculate length of time step and set heads at beginning of a new time step equal to heads calculated for the end of the previous time step.

FORMULATE -- Calculate the coefficients of the finite difference equations for each cell.

APROXIMATE -- Make one cut at approximating a solution to the system of finite difference equations.

OUTPUT CONTROL -- Determine whether results should be written or saved on disk for this time step. Send signals to the BUDGET and OUTPUT procedures to indicate exactly what information should be put out

BUDGET -- Calculate terms for the overall volumetric budget and calculate and save cell-by-cell flow terms for each component of flow.

OUTPUT -- Print and save heads, drawdown and overall volumetric budgets in accordance with signals from OUTPUT CONTROL procedure.

Figure 1 --Overall program structure.

Table 1.--List of packages.

<u>Package Name</u>	<u>Abbreviation</u>	<u>Package Description</u>
Basic	BAS	Handles those tasks that are part of the model as a whole. Among those tasks are: specification of boundaries, determination of time step length, establishment of initial conditions, and printing of results.
Block-Centered Flow	BCF	Calculates terms of finite-difference equations which represent flow within the porous medium; specifically, flow from cell to cell and flow into storage.
Well	WEL	Adds terms representing flow to wells to the finite-difference equations.
Recharge	RCH	Adds terms representing areally distributed recharge to the finite-difference equations.
River.	RIV	Adds terms representing flow to or from rivers to the finite-difference equations.
Drain	DRN	Adds terms representing flow to drains to the finite-difference equations.
Evapotranspiration	EVT	Adds terms representing ET to the finite-difference equations.
General-Head Boundaries	GHB	Adds terms representing general-head boundaries to the finite-difference equations.
Strongly Implicit Procedure	SIP	Iteratively solves the system of finite-difference equations using the Strongly Implicit Procedure.
Slice-Successive Overrelaxation	SOR	Iteratively solves the system of finite-difference equations using slice-successive overrelaxation.

Table 2 : Organization of modules by procedures and packages.

Procedures	Flow Component Packages								Solver Packages	
	Stress Packages									
	B A S	B C F	W E L	R C H	R I V	D R N	E V T	G H B	S I P	S O R
Define (DF)	X									
Allocate (AL)	X	X	X	X	X	X	X	X	X	X
Read & Prepare (RP)	X _U	X _{US}							X	X
Stress (ST)	X									
Read & Prepare (RP)			X	X _U	X	X	X _U	X		
Advance (AD)	X									
Formulate (FM)	X	X _S	X	X	X	X	X	X		
Approximate (AP)									X _S	X _S
Output Control (OC)	X									
Budget (BD)		X _{US}	X _U	X _U	X _U	X _U	X _U	X _U		
Output (OT)	X _U									

APPENDIX A

ABBREVIATED INPUT INSTRUCTIONS

These input instructions are intended as a quick reference for the experienced user. Most explanations that are contained in the complete input instructions given in package documentation have been omitted. The format of input fields is given only for those records that contain fields that are not 10 characters wide. Each input item, for which format is not given, is identified as either a record or an array. For records, the fields contained in the record are named. For arrays, only the array name is given. Input fields which contain codes or flags are described. All other field and array descriptions have been dropped.

Array Input

The real two-dimensional array reader (U2DREL), the integer two-dimensional array reader (U2DINT), and the real one-dimensional array reader (U1DREL) read one array-control record and, optionally, a data array in a format specified on the array-control record.

FOR REAL ARRAY READER (U2DREL or U1DREL)

Data:	LOCAT	CNSTNT	FMTIN	IPRN
Format:	I10	F10.0	5A4	I10

FOR INTEGER ARRAY READER (U2DINT)

Data:	LOCAT	ICONST	FMTIN	IPRN
Format:	I10	I10	5A4	I10

IPRN--is a flag indicating that the array being read should be printed and a code for indicating the format that should be used. It is used only if LOCAT is not equal to zero. The format codes are different for each of the three modules. IPRN is set to zero when the specified value exceeds those defined in the chart below. If IPRN is less than zero, the array will not be printed.

<u>IPRN</u>	<u>U2DREL</u>	<u>U2DINT</u>	<u>U1DREL</u>
0	10G11.4	10I11	10G12.5
1	11G10.3	60I1	
2	9G13.6	40I2	
3	15F7.1	30I3	
4	15F7.2	25I4	
5	15F7.3	20I5	
6	15F7.4		
7	20F5.0		
8	20F5.1		
9	20F5.2		
10	20F5.3		
11	20F5.4		
12	10G11.4		

LOCAT--indicates the location of the data which will be put in the array.
 If LOCAT < 0, unit number for unformatted records.
 If LOCAT = 0, all elements are set equal to CNSTNT or ICONST.
 If LOCAT > 0, unit number for formatted records.

Basic Package Input

Input for the Basic (BAS) Package except for output control is read from unit 1 as specified in the main program. If necessary, the unit number for BAS input can be changed to meet the requirements of a particular computer. Input for the output control option is read from the unit number specified in IUNIT(12).

FOR EACH SIMULATION

1. Record: HEADNG(32)
2. Record: HEADNG (continued)
3. Record: NLAY NROW NCOL NPER ITMUNI
4. Data: IUNIT(24)
Format: 24I3
(BCF WEL DRN RIV EVT XXX GHB RCH SIP XXX SOR OC)
 1 2 3 4 5 6 7 8 9 10 11 12
5. Record: IAPART ISTRT
6. Array: IBOUND(NCOL,NROW)
(One array for each layer in the grid)
7. Record: HNOFLO
8. Array: Shead(NCOL,NROW)
(One array for each layer in the grid)

FOR EACH STRESS PERIOD

9. Data: PERLEN NSTP TSMULT

ITMUNI--is the time unit of model data.

- | | |
|---------------|-----------|
| 0 - undefined | 3 - hours |
| 1 - seconds | 4 - days |
| 2 - minutes | 5 - years |

Consistent length and time units must be used for all model data. The user may choose one length unit and one time unit to be used to specify all input data.

IUNIT--is a 24-element table of input units for use by all major options.

IAPART--indicates whether array BUFF is separate from array RHS. If IAPART = 0, the arrays BUFF and RHS occupy the same space. This option conserves space. This option should be used unless some other package explicitly says otherwise.

If IAPART ≠ 0, the arrays BUFF and RHS occupy different space.

ISTRT--indicates whether starting heads are to be saved.

If ISTRT = 0, starting heads are not saved.

If ISTRT ≠ 0, starting heads are saved.

IBOUND--is the boundary array.

If IBOUND(I,J,K) < 0, cell I,J,K has a constant head.

If IBOUND(I,J,K) = 0, cell I,J,K is inactive.

If IBOUND(I,J,K) > 0, cell I,J,K is active.

HNOFLO--is the value of head to be assigned to all inactive cells.

Shead--is head at the start of the simulation.

PERLEN--is the length of a stress period.

NSTP--is the number of time steps in a stress period.

TSMULT--is the multiplier for the length of successive time steps.

Output Control Input

Input to Output Control is read from the unit specified in IUNIT(12). All printer output goes to unit 6 as specified in the main program. If necessary, the unit number for printer output can be changed to meet the requirements of a particular computer.

FOR EACH SIMULATION

1. Record: IHEDFM IDDNFM IHEDUN IDDNUN

FOR EACH TIME STEP

2. Record: INCODE IHDDFL IBUDFL ICBCFL

3. Record: Hdpr Ddpr Hdsv Ddsv

(Record 3 is read 0, 1, or NLAY times, depending on the value of INCODE.)

IHEDFM--is a code for the format in which heads will be printed.

IDDNFM--is a code for the format in which drawdowns will be printed.

	0 - (10G11.4)	7 - (20F5.0)
	1 - (11G10.3)	8 - (20F5.1)
positive--wrap	2 - (9G13.6)	9 - (20F5.2)
	3 - (15F7.1)	10 - (20F5.3)
negative--strip	4 - (15F7.2)	11 - (20F5.4)
	5 - (15F7.3)	12 - (10G11.4)
	6 - (15F7.4)	

IHEDUN--is the unit number on which heads will be saved.

IDDNUN--is the unit number on which drawdowns will be saved.

INCODE--is the head/drawdown output code.

If INCODE < 0, layer-by-layer specifications from the last time steps are used. Input item 3 is not read.

If INCODE = 0, all layers are treated the same way. Input item 3 will consist of one record. IOFLG array will be read.

If INCODE > 0, input item 3 will consist of one record for each layer.

IHDDFL--is a head and drawdown output flag.

If IHDDFL = 0, neither heads nor drawdowns will be printed or saved.

If IHDDFL ≠ 0, heads and drawdowns will be printed or saved.

IBUDFL--is a budget print flag.

If IBUDFL = 0, overall volumetric budget will not be printed.

If IBUDFL ≠ 0, overall volumetric budget will be printed.

ICBCFL--is a cell-by-cell flow-term flag.

If ICBCFL = 0, cell-by-cell flow terms are not saved or printed.

If ICBCFL ≠ 0, cell-by-cell flow terms are printed or recorded on disk depending on flags set in the component of flow packages, i.e., IWELCB, IRCHCB, etc.

Hdpr--is the output flag for head printout.

If Hdpr = 0, head is not printed for the corresponding layer.

If Hdpr ≠ 0, head is printed for the corresponding layer.

Ddpr--is the output flag for drawdown printout.

If Ddpr = 0, drawdown is not printed for the corresponding layer.

If Ddpr ≠ 0, drawdown is printed for the corresponding layer.

Hdsv--is the output flag for head save.

If Hdsv = 0, head is not saved for the corresponding layer.

If Hdsv ≠ 0, head is saved for the corresponding layer.

Ddsv--is the output flag for drawdown save.

If Ddsv = 0, drawdown is not saved for the corresponding layer.

If Ddsv ≠ 0, drawdown is saved for the corresponding layer.

Block-Centered Flow Package Input

Input for the BCF Package is read from the unit specified in IUNIT(1).

FOR EACH SIMULATION

1. Record: ISS IBCFCB
2. Data: LAYCON(NLAY) (maximum of 80 layers)
Format: 40I2
(If there are 40 or fewer layers, use one record.)

3. Array: TRPY(NLAY)
4. Array: DELR(NCOL)
5. Array: DELC(NROW)

All of the arrays (items 6-12) for layer 1 are read first; then all of the arrays for layer 2, etc.

IF THE SIMULATION IS TRANSIENT

6. Array: sf1(NCOL,NROW)

IF THE LAYER TYPE CODE (LAYCON) IS ZERO OR TWO

7. Array: Tran(NCOL,NROW)

IF THE LAYER TYPE CODE (LAYCON) IS ONE OR THREE

8. Array: HY(NCOL,NROW)

9. Array: BOT(NCOL,NROW)

IF THIS IS NOT THE BOTTOM LAYER

10. Array: Vcont(NCOL,NROW)

IF THE SIMULATION IS TRANSIENT AND THE LAYER TYPE CODE (LAYCON) IS TWO OR THREE

11. Array: sf2(NCOL,NROW)

IF THE LAYER TYPE CODE IS TWO OR THREE

12. Array: TOP(NCOL,NROW)

ISS--is the steady-state flag.

If ISS \neq 0, the simulation is steady state.

If ISS = 0, the simulation is transient.

IBCFCB--is a flag and a unit number.

If IBCFCB > 0, cell-by-cell flow terms will be recorded if ICBCFL (see Output Control) is set.

If IBCFCB = 0, cell-by-cell flow terms will not be printed or recorded.

If IBCFCB \leq 0, print flow for constant-head cells if ICBCFL is set.

LAYCON--is the layer type table: 0 - confined, 1 - unconfined,

2 - confined/unconfined (T constant), and 3 - confined/unconfined.

TRPY--is an anisotropy factor for each layer: T or K along a column to T or K along a row.

DELR--is the cell width along rows.

DELC--is the cell width along columns.

sf1--is the primary storage factor.

Tran--is the transmissivity along rows.

HY--is the hydraulic conductivity along rows.

BOT--is the elevation of the aquifer bottom.

Vcont--is the vertical hydraulic conductivity divided by the thickness from a layer to the layer beneath it.

sf2--is the secondary storage factor.

TOP--is the elevation of the aquifer top.

River Package Input

Input to the River (RIV) Package is read from the unit specified in IUNIT(4).

FOR EACH SIMULATION

1. Record: MXRIVR IRIVCB

FOR EACH STRESS PERIOD

2. Record: ITMP

3. Record: Layer Row Column Stage Cond Rbot
(Input item 3 normally consists of one record for each river reach. If ITMP is negative or zero, item 3 is not read.)

IRIVCB--is a flag and a unit number.

If IRIVCB > 0, cell-by-cell flow terms will be recorded.

If IRIVCB = 0, cell-by-cell flow terms will not be printed or recorded.

If IRIVCB < 0, river leakage will be printed if ICBCFL is set.

ITMP--is a flag and a counter.

If ITMP < 0, river data from the last stress period will be reused.

If ITMP \geq 0, ITMP will be the number of reaches active during the current stress period.

Recharge Package Input

Input to the Recharge (RCH) Package is read from the unit specified in IUNIT(8).

FOR EACH SIMULATION

1. Record: NRCHOP IRCHCB

FOR EACH STRESS PERIOD

2. Record: INRECH INIRCH

3. Array: RECH(NCOL,NROW)

IF THE RECHARGE OPTION IS EQUAL TO 2

4. Array: IRCH(NCOL,NROW)

NRCHOP--is the recharge option code.

1 - Recharge is only to the top grid layer.

2 - Vertical distribution of recharge is specified in array IRCH.

3 - Recharge is applied to the highest active cell in each vertical column.

IRCHCB--is a flag and a unit number.

If IRCHCB > 0, unit number for cell-by-cell flow terms.

If IRCHCB \leq 0, cell-by-cell flow terms will not be printed or recorded.

INRECH--is the RECH read flag.

If INRECH < 0, recharge rates from the preceding stress period are used.

If INRECH \geq 0, an array of recharge rates, (RECH) is read.

INIRCH--is similar to INRECH.

Well Package Input

Input for the Well (WEL) Package is read from the unit specified in IUNIT(2).

FOR EACH SIMULATION

1. Record: MXWELL IWELCB

FOR EACH STRESS PERIOD

2. Record: ITMP

3. Record: Layer Row Column Q

(Input item 3 normally consists of one record for each well. If ITMP is negative or zero, item 3 is not read.)

MXWELL--is the maximum number of wells used at any time.

IWELCB--is a flag and a unit number.

If IWELCB > 0, unit number for cell-by-cell flow terms.

If IWELCB = 0, cell-by-cell flow terms will not be printed or recorded.

If IWELCB < 0, well recharge will be printed whenever ICBCFL is set.

ITMP--is a flag and a counter.

If ITMP < 0, well data from the last stress period will be reused.

If ITMP \geq 0, ITMP will be the number of wells active during the current stress period.

Drain Package Input

Input to the Drain (DRN) Package is read from the unit specified in IUNIT(3).

FOR EACH SIMULATION

1. Record: MXDRN IDRNCB

FOR EACH STRESS PERIOD

2. Record: ITMP

3. Record: Layer Row Col Elevation Cond

(Input item 3 normally consists of one record for each drain. If ITMP is negative or zero, item 3 will not be read.)

MXDRN--is the maximum number of drain cells active at one time.

IDRNCB--is a flag and a unit number.

If IDRNCB > 0, unit number for cell-by-cell flow terms.

If IDRNCB = 0, cell-by-cell flow terms will not be printed or recorded.

If IDRNCB < 0, drain leakage for each cell will be printed whenever ICBCFL is set.

ITMP--is a flag and a counter.

If ITMP < 0, drain data from the last stress period will be reused.

If ITMP \geq 0, ITMP will be the number of drains active during the current stress period.

Evapotranspiration Package Input

Input to the Evapotranspiration (EVT) Package is read from the unit specified in IUNIT (5).

FOR EACH SIMULATION

1. Record: NEVTOP IEVTCB

FOR EACH STRESS PERIOD

2. Record: INSURF INEVTR INEXDP INIEVT

3. Array: SURF

4. Array: EVTR

5. Array: EXDP

IF THE ET OPTION IS EQUAL TO TWO

6. Array: IEVT

NEVTOP--is the evapotranspiration (ET) option code.

- 1 - ET is calculated only for cells in the top grid layer.
- 2 - The cell for each vertical column is specified by the user in array IEVT.

IEVTCB--is a flag and a unit number.

If IEVTCB > 0, unit number for cell-by-cell flow terms.

If IEVTCB ≤ 0, cell-by-cell flow terms will not be printed or recorded.

INSURF--is the ET surface (SURF) read flag.

If INSURF ≥ 0, an array containing the ET surface elevation will be read.

If INSURF < 0, the ET surface from the preceding stress period will be reused.

INEVTR--is similar to INSURF.

INEXDP--is similar to INSURF.

INIEVT--is similar to INSURF.

General-Head Boundary Package Input

Input for the General-Head Boundary (GHB) Package is read from the unit specified in IUNIT(7).

FOR EACH SIMULATION

1. Record: MXBND IGHBCB

FOR EACH STRESS PERIOD

2. Record: ITMP

3. Record: Layer Row Column Boundary Head Cond

(Input item 3 normally consists of one record for each GHB.

If ITMP is negative or zero, item 3 is not read.)

MXBND--is the maximum number of general-head boundary cells at one time.

IGHBCB--is a flag and a unit number.

If IGHBCB > 0, unit number for cell-by-cell flow terms.

If IGHBCB = 0, cell-by-cell flow terms will not be printed or recorded.

If IGHBCB < 0, boundary leakage for each cell will be printed whenever ICBCFL is set.

ITMP--is a flag and a counter.

If ITMP < 0, GHB data from the preceding stress period will be reused.

If ITMP > 0, ITMP is the number of general-head boundaries during the current stress period.

Strongly Implicit Procedure Package Input

Input to the Strongly Implicit Procedure (SIP) Package is read from the unit specified in IUNIT(9).

FOR EACH SIMULATION

1. Record: MXITER NPARM

2. Record: ACCL HCLOSE IPCALC WSEED IPRSIP

IPCALC--is a flag indicating where the iteration parameter seed will come from.

0 - the seed will be entered by the user.

1 - the seed will be calculated at the start of the simulation from problem parameters.

IPRSIP--is the printout interval for SIP.

Slice-Successive Overrelaxation Package Input

Input to the Slice-Successive Overrelaxation (SOR) Package is read from the unit specified in IUNIT(11).

FOR EACH SIMULATION

1. Record: MXITER

2. Record: ACCL HCLOSE IPRSOR

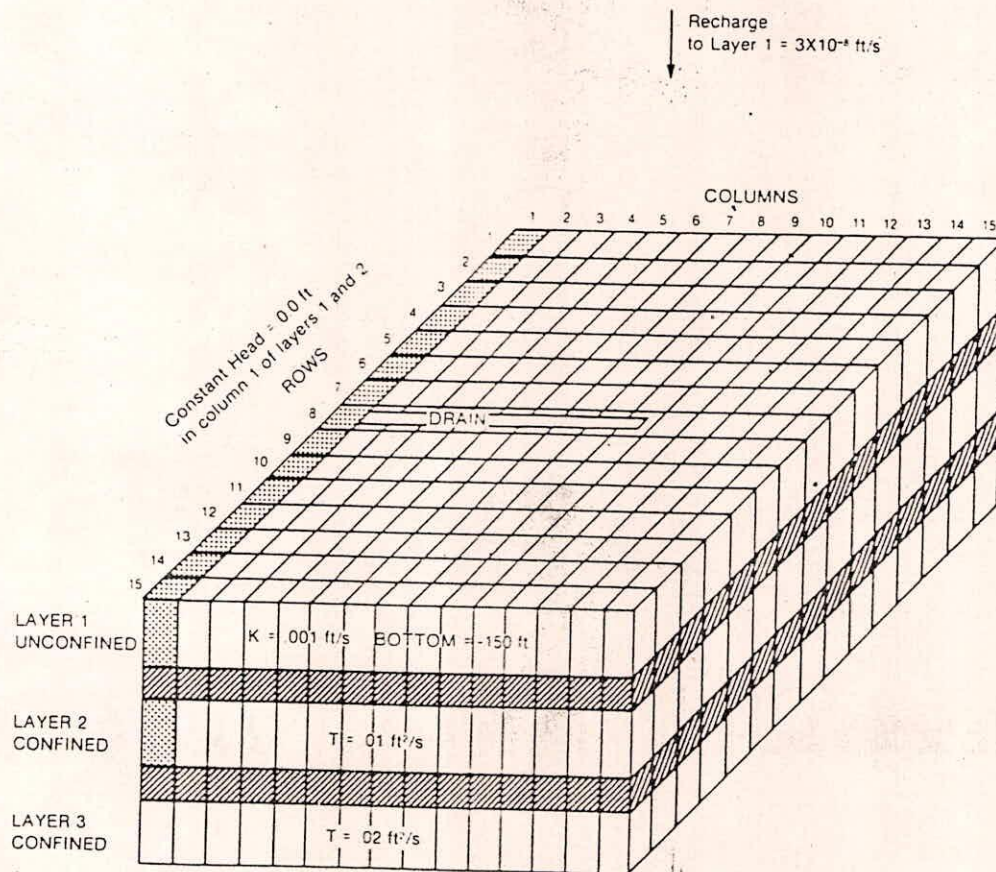
IPRSOR--is the printout interval for SOR.

L 3(b) (A-8)

APPENDIX B

SAMPLE PROBLEM

This sample problem is intended to illustrate input and output from the program. There are three simulated layers, as shown in the accompanying illustration, which are separated from each other by confining layers. Each layer is a square 75,000 feet on a side and is divided by a grid into 15 rows and 15 columns which form squares 5,000 feet on a side. Flow within the confining layers is not simulated, but the effects of the confining layers on flow between the active layers are incorporated in the vertical conductivity (VCONT) terms. Flow into the system is infiltration from precipitation; flow out of the system is to buried drain tubes, discharging wells, and a lake which is represented by a constant-head boundary.



Between layers 1 and 2 vertical hydraulic conductivity divided by thickness = 2×10^{-4} /s

Between layers 2 and 3 vertical hydraulic conductivity divided by thickness = 1×10^{-4} /s

L 3(b)(B-1)

Setting starting heads equal to 0.0, the program was run to get a steady-state solution. The Strongly Implicit Procedure was used to solve the system of difference equations: the error criterion was set at 0.001 feet, the acceleration parameter was set to 1.0, and the maximum number of iterations was set equal to 50. A seed of 0.001 was specified for use in calculating the iteration parameters; 31 iterations were needed to close.

List of Wells

Q = 5 ft³/s for each well

<u>Layer</u>	<u>Row</u>	<u>Column</u>
3	5	11
2	4	6
2	6	12
1	9	8
1	9	10
1	9	12
1	9	14
1	11	8
1	11	10
1	11	12
1	11	14
1	13	8
1	13	10
1	13	12
1	13	14

List of Drains

Conductance = 1 ft²/s

<u>Layer</u>	<u>Row</u>	<u>Column</u>	<u>Elevation</u>
1	8	2	0.0
1	8	3	0.0
1	8	4	10.0
1	8	5	20.0
1	8	6	30.0
1	8	7	50.0
1	8	8	70.0
1	8	9	90.0
1	8	10	100.0

L 3(b) (B-2)


```

//FT11F001 DD *
1 0 0 1 0 ISS,IBCFBD
0 1. TRPY
0 5000. DELR
0 5000. DELC
0 .001 HY-1
0 -150. BOT-1
0 2.E-8 VHY/THICK-1
0 .01 T-2
0 1.E-8 VHY/THICK-2
0 .02 T-3

/*
//FT18F001 DD *
1 0 NRCHOP,IRCHBD
1 INRECH
0 3.E-8 RECH-1

/*
//FT19F001 DD *
50 5 MXITER,NPARM
1. .001 0 .001 1 ACCL,ERR,IPCALC,WSEE

//FT13F001 DD *
9 0 MXDRAI,IDRNBD
9 NDRAIN
1 8 2 0. 1.E00
1 8 3 0. 1.E00
1 8 4 10. 1.E00
1 8 5 20. 1.E00
1 8 6 30. 1.E00
1 8 7 50. 1.E00
1 8 8 70. 1.E00
1 8 9 90. 1.E00
1 8 10 100. 1.E00

//FT12F001 DD *
15 0 MXWELL,IWELBD
15 NWELL
3 5 11 -5.
2 4 6 -5.
2 6 12 -5.
1 9 8 -5.
1 9 10 -5.
1 9 12 -5.
1 9 14 -5.
1 11 8 -5.
1 11 10 -5.
1 11 12 -5.
1 11 14 -5.
1 13 8 -5.
1 13 10 -5.
1 13 12 -5.
1 13 14 -5.

```

L 3(b) (B-4)

U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
 SAMPLE--3 LAYERS, 15 ROWS, 15 COLUMNS, STEADY STATE, CONSTANT HEADS COLUMN 1, LAYERS 1 AND 2, RECHARGE, WELLS AND DRAINS
 3 LAYERS 15 ROWS 15 COLUMNS

1 STRESS PERIOD(S) IN SIMULATION
 MODEL TIME UNIT IS SECONDS
 I/O UNITS:

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

BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 12/08/83 INPUT READ FROM UNIT 1
 ARRAYS RHS AND BUFF WILL SHARE MEMORY.
 START HEAD WILL NOT BE SAVED -- DRAWDOWN CANNOT BE CALCULATED

5892 ELEMENTS IN X ARRAY ARE USED BY BAS
 5892 ELEMENTS OF X ARRAY USED OUT OF 100000

BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 12/08/83 INPUT READ FROM UNIT 11
 STEADY-STATE SIMULATION

LAYER AQUIFER TYPE

 1 1
 2 0
 3 0

453 ELEMENTS IN X ARRAY ARE USED BY BCF
 6345 ELEMENTS OF X ARRAY USED OUT OF 100000

WELL1 -- WELL PACKAGE, VERSION 1, 12/08/83 INPUT READ FROM 12
 MAXIMUM OF 15 WELLS

60 ELEMENTS IN X ARRAY ARE USED FOR WELLS
 6405 ELEMENTS OF X ARRAY USED OUT OF 100000

DRN1 -- DRAIN PACKAGE, VERSION 1, 12/08/83 INPUT READ FROM UNIT 13
 MAXIMUM OF 9 DRAINS

45 ELEMENTS IN X ARRAY ARE USED FOR DRAINS
 6450 ELEMENTS OF X ARRAY USED OUT OF 100000

RCH1 -- RECHARGE PACKAGE, VERSION 1, 12/08/83 INPUT READ FROM UNIT 18
 OPTION 1 -- RECHARGE TO TOP LAYER

225 ELEMENTS OF X ARRAY USED FOR RECHARGE
 6675 ELEMENTS OF X ARRAY USED OUT OF 100000

SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 12/08/83 INPUT READ FROM UNIT 19
 MAXIMUM OF 50 ITERATIONS ALLOWED FOR CLOSURE

5 ITERATION PARAMETERS

2905 ELEMENTS IN X ARRAY ARE USED BY SIP
 9580 ELEMENTS OF X ARRAY USED OUT OF 100000

SAMPLE--3 LAYERS,15 ROWS,15 COLUMNS,STEADY STATE,CONSTANT HEADS COLUMN 1,LAYERS 1 AND 2,RECHARGE,WELLS AND DRAINS

BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (15I3)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (15I3)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1

L3(b) (c-2)

AQUIFER HEAD WILL BE SET TO 999.99 AT ALL NO-FLOW NODES (IBOUND=0).
 BOUNDARY ARRAY = 1 FOR LAYER 3
 INITIAL HEAD = .0 FOR LAYER 1
 INITIAL HEAD = .0 FOR LAYER 2
 INITIAL HEAD = .0 FOR LAYER 3

DEFAULT OUTPUT CONTROL --- THE FOLLOWING OUTPUT COMES AT THE END OF EACH STRESS PERIOD:
 TOTAL VOLUMETRIC BUDGET HEAD

COLUMN TO ROW ANISOTROPY = 1.000000
 DELR = 5000.000
 DELC = 5000.000
 HYD. COND. ALONG ROWS = .9999999E-03 FOR LAYER 1
 BOTTOM = -150.0000 FOR LAYER 1
 VERT HYD COND /THICKNESS = .2000000E-07 FOR LAYER 1
 TRANSMIS. ALONG ROWS = .1000000E-01 FOR LAYER 2
 VERT HYD COND /THICKNESS = .1000000E-07 FOR LAYER 2
 TRANSMIS. ALONG ROWS = .2000000E-01 FOR LAYER 3

SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

MAXIMUM ITERATIONS ALLOWED FOR CLOSURE = 50
 ACCELERATION PARAMETER = 1.0000
 HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-02
 SIP HEAD CHANGE PRINTOUT INTERVAL = 1

5 ITERATION PARAMETERS CALCULATED FROM SPECIFIED WSEED = 0.00100000 :

0.0 0.8221720E+00 0.9683772E+00 0.9943766E+00 0.9990000E+00
 STRESS PERIOD NO. 1, LENGTH = 86400.00

NUMBER OF TIME STEPS = 1
 MULTIPLIER FOR DELT = 1.000
 INITIAL TIME STEP SIZE = 86400.00

15 WELLS

LAYER	ROW	COL	STRESS RATE	WELL NO.
3	5	11	-5.0000	1
2	4	6	-5.0000	2
2	6	12	-5.0000	3
1	9	8	-5.0000	4
1	9	10	-5.0000	5
1	9	12	-5.0000	6
1	9	14	-5.0000	7
1	11	8	-5.0000	8
1	11	10	-5.0000	9
1	11	12	-5.0000	10
1	11	14	-5.0000	11
1	13	8	-5.0000	12
1	13	10	-5.0000	13
1	13	12	-5.0000	14
1	13	14	-5.0000	15

9 DRAINS

LAYER	ROW	COL	ELEVATION	CONDUCTANCE	DRAIN NO.
1	8	2	.0	1.000	1
1	8	3	.0	1.000	2
1	8	4	10.00	1.000	3
1	8	5	20.00	1.000	4
1	8	6	30.00	1.000	5
1	8	7	50.00	1.000	6
1	8	8	70.00	1.000	7
1	8	9	90.00	1.000	8
1	8	10	100.0	1.000	9

RECHARGE = .3000000E-07

31 ITERATIONS FOR TIME STEP 1 IN STRESS PERIOD 1

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

HEAD CHANGE	LAYER, ROW, COL	HEAD CHANGE	LAYER, ROW, COL	HEAD CHANGE	LAYER, ROW, COL				
-22.41	(3, 5, 11)	12.48	(1, 1, 15)	13.39	(3, 1, 14)	48.21	(1, 1, 15)	35.90	(3, 1, 13)
2.482	(1, 9, 14)	1.430	(3, 10, 13)	6.214	(1, 12, 14)	7.411	(3, 11, 14)	13.66	(1, 15, 15)
.5503	(3, 8, 7)	.4821	(2, 6, 9)	.4711	(3, 5, 10)	2.019	(1, 11, 14)	2.302	(3, 5, 13)
.1108	(1, 13, 12)	.7059E-01	(3, 12, 11)	.2819	(1, 14, 14)	.3141	(3, 13, 14)	.3321	(1, 15, 15)
.7855E-02	(1, 13, 12)	.1586E-01	(2, 11, 11)	.1777E-01	(3, 11, 10)	.7911E-01	(1, 14, 14)	.8500E-01	(3, 7, 14)
.4169E-02	(1, 13, 14)	.2555E-02	(3, 14, 15)	.9771E-02	(1, 14, 14)	.1082E-01	(3, 13, 14)	.1030E-01	(1, 15, 15)
.2426E-03	(1, 13, 12)								

L3(b)(c-4)

AQUIFER HEAD WILL BE SET TO 999.99 AT ALL NO-FLOW NODES (IBOUND=0).
 BOUNDARY ARRAY = 1 FOR LAYER 3
 INITIAL HEAD = .0 FOR LAYER 1
 INITIAL HEAD = .0 FOR LAYER 2
 INITIAL HEAD = .0 FOR LAYER 3

DEFAULT OUTPUT CONTROL -- THE FOLLOWING OUTPUT COMES AT THE END OF EACH STRESS PERIOD:
 TOTAL VOLUMETRIC BUDGET
 HEAD

COLUMN TO ROW ANISOTROPY = 1.000000
 DELR = 5000.000
 DELC = 5000.000
 HYD. COND. ALONG ROWS = .9999999E-03 FOR LAYER 1
 BOTTOM = -150.0000 FOR LAYER 1
 VERT HYD COND /THICKNESS = .2000000E-07 FOR LAYER 1
 TRANSMIS. ALONG ROWS = .1000000E-01 FOR LAYER 2
 VERT HYD COND /THICKNESS = .1000000E-07 FOR LAYER 2
 TRANSMIS. ALONG ROWS = .2000000E-01 FOR LAYER 3

SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

MAXIMUM ITERATIONS ALLOWED FOR CLOSURE = 50
 ACCELERATION PARAMETER = 1.0000
 HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-02
 SIP HEAD CHANGE PRINTOUT INTERVAL = 1

5 ITERATION PARAMETERS CALCULATED FROM SPECIFIED WSEED = 0.00100000 :

0.0 0.8221720E+00 0.9683772E+00 0.9943766E+00 0.9990000E+00
 STRESS PERIOD NO. 1, LENGTH = 86400.00

NUMBER OF TIME STEPS = 1
 MULTIPLIER FOR DELT = 1.000
 INITIAL TIME STEP SIZE = 86400.00

L 3(b) (c-3)

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

	1	2	3	4	5	6	7	8	9	10
1	0	24.66	43.73	59.02	71.61	82.32	91.72	99.86	106.7	112.5
2	117.2	121.1	124.1	126.2	127.3					
3	0	24.17	42.83	57.74	69.95	80.36	89.93	98.22	105.1	110.8
4	115.5	119.4	122.6	124.8	125.9					
5	0	23.17	41.03	55.19	66.53	75.77	86.29	95.02	102.0	107.4
6	111.8	116.0	119.5	121.9	123.2					
7	0	21.65	38.34	51.50	61.35	60.17	80.90	90.55	97.45	102.3
8	105.4	110.4	114.8	117.7	119.2					
9	0	19.48	34.65	47.07	57.44	66.30	76.85	85.57	92.00	95.41
10	91.09	102.1	108.6	112.4	114.2					
11	0	16.27	29.24	40.65	51.07	60.98	70.98	79.65	86.28	90.54
12	92.06	86.23	101.7	106.2	108.3					
13	0	11.38	20.95	31.05	41.25	51.70	62.90	72.48	79.76	84.73
14	88.35	91.24	96.22	99.65	101.6					
15	0	4.209	8.330	17.58	27.58	38.25	52.94	64.19	72.34	77.12
16	81.81	84.86	89.10	91.59	94.17					
17	0	10.38	18.96	27.98	36.79	45.16	52.86	56.13	65.08	66.79
18	73.87	74.48	80.77	80.84	86.38					
19	0	14.40	25.61	35.15	43.27	49.91	54.76	57.48	62.79	65.49
20	70.24	72.37	76.57	78.20	81.64					
21	0	16.87	29.70	39.78	47.56	53.05	55.68	54.09	60.20	60.04
22	66.37	66.18	72.16	71.75	77.51					
23	0	18.43	32.31	42.85	50.60	55.73	58.16	58.41	61.78	63.12
24	66.98	68.44	72.15	73.40	76.69					
25	0	19.42	33.98	44.91	52.80	57.85	59.78	57.50	62.53	61.65
26	67.16	66.48	71.84	71.06	76.37					
27	0	20.02	35.02	46.26	54.41	59.88	62.99	64.39	67.08	68.66
28	71.48	73.06	75.68	76.91	78.93					
29	0	20.30	35.52	46.94	55.28	61.07	64.84	67.34	69.76	71.84
30	74.11	76.04	78.04	79.49	80.65					

L 3(b) (7-6)

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

	1	2	3	4	5	6	7	8	9	10
1	1.800	24.34	43.36	58.70	71.33	82.06	91.48	99.63	106.5	112.3
2	1.764	120.9	123.9	126.0	127.1	80.07	89.68	97.99	104.9	110.6
3	1.691	119.2	122.4	124.6	125.7	75.28	85.98	94.77	101.7	107.2
4	1.578	22.86	40.67	54.87	66.20	62.69	80.41	90.28	97.19	101.9
5	1.415	115.7	119.3	121.7	123.0	65.80	76.54	85.30	91.67	94.17
6	1.176	100.7	108.2	112.1	114.0	60.67	70.70	79.38	86.01	90.12
7	1.8273	88.55	101.2	106.0	108.0	51.55	62.67	72.22	79.50	84.46
8	1.4331	90.77	95.94	101.4	101.4	39.84	53.40	64.07	72.11	76.95
9	1.7543	5.131	10.19	19.27	29.19	45.06	52.78	57.03	65.02	67.64
10	1.039	84.68	88.88	91.44	93.95	49.65	54.54	57.44	62.61	65.44
11	1.224	10.22	18.82	27.84	36.66	52.79	55.53	55.01	60.16	60.94
12	1.341	75.31	80.72	81.64	86.24	55.47	57.94	58.37	61.60	63.08
13	1.415	14.13	25.29	34.85	42.99	57.60	59.63	58.39	62.48	62.54
14	1.460	72.33	76.39	78.15	81.43	59.63	62.76	64.24	66.87	68.52
15	1.481	16.59	29.37	39.47	47.28	60.81	64.59	67.11	69.52	71.61
	73.87	67.06	72.13	72.60	77.38	60.81	64.59	67.11	69.52	71.61
		18.15	31.97	42.54	50.32	60.81	64.59	67.11	69.52	71.61
		68.41	71.97	73.36	76.49	60.81	64.59	67.11	69.52	71.61
		19.14	33.65	44.61	52.53	60.81	64.59	67.11	69.52	71.61
		67.35	71.80	71.90	76.24	60.81	64.59	67.11	69.52	71.61
		19.73	34.68	45.96	54.13	60.81	64.59	67.11	69.52	71.61
		72.91	75.47	76.77	78.71	60.81	64.59	67.11	69.52	71.61
		20.01	35.18	46.63	55.00	60.81	64.59	67.11	69.52	71.61
		75.82	77.81	79.27	80.42	60.81	64.59	67.11	69.52	71.61

L3(B) ((-7))

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:
---
STORAGE = .0
CONSTANT HEAD = .0
WELLS = .0
DRAINS = .0
RECHARGE = .13608E+08
TOTAL IN = .13608E+08
OUT:
---
STORAGE = .0
CONSTANT HEAD = .43265E+07
WELLS = .64800E+07
DRAINS = .28011E+07
RECHARGE = .0
TOTAL OUT = .13608E+08
IN - OUT = 184.00
PERCENT DISCREPANCY = 0.00

IN:
---
STORAGE = .0
CONSTANT HEAD = .0
WELLS = .0
DRAINS = .0
RECHARGE = 157.50
TOTAL IN = 157.50
OUT:
---
STORAGE = .0
CONSTANT HEAD = 50.075
WELLS = 75.000
DRAINS = 32.420
RECHARGE = .0
TOTAL OUT = 157.49
IN - OUT = .21210E-02
PERCENT DISCREPANCY = 0.00
    
```

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

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	86400.0	1440.00	24.0000	1.00000	.273785E-02
STRESS PERIOD TIME	86400.0	1440.00	24.0000	1.00000	.273785E-02
TOTAL SIMULATION TIME	86400.0	1440.00	24.0000	1.00000	.273785E-02

L 3(b) (C-8)