Techniques of Water-Resources Investigations of the United States Geological Survey

Chapter C1

FINITE-DIFFERENCE MODEL FOR AQUIFER SIMULATION IN TWO DIMENSIONS WITH RESULTS OF NUMERICAL EXPERIMENTS

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Book 7

AUTOMATED DATA PROCESSING AND COMPUTATIONS

If NWEL=0 the following set of cards is omitted.

DATA SET 1 (NWEL cards)

COLUMNS	*FORMAT*	*VARIABLE*	*DEFINITION*
1–10	G10.0	I	Row location of well.
11–20	G10.0	J	Column location of well.
21–30	G10.0	WELL (I,J)	Pumping rate (L^3/T), negative for a pumping well.
31–40	G10.0	RADIUS	Real well radius (L).

NOTE.—Radius is required only for those wells, if any, where computation of drawdown at a real well radius is to be made.

For each additional pumping period, another set of group IV cards is required (that is, NPER sets of group IV cards are required).

If another simulation is included in the same job, insert a blank card before the next group I cards.

Attachment IV

Sample Aquifer Simulation And Job Control Language

This appendix includes examples of job control language (JCL) for several different runs and an example problem designed to illustrate many of the options in the program. The grid and boundary conditions for the problem are given in figure 25. Figure 30 illustrates in cross section the type of problem being simulated, but note that it is not to scale.

The listing of data with the JCL examples is not on a coding form, but it should not be difficult to determine the proper location of the numbers since the fields are either 4 or 10 spaces. Zero values have not been coded on the data cards to avoid unnecessary punching.

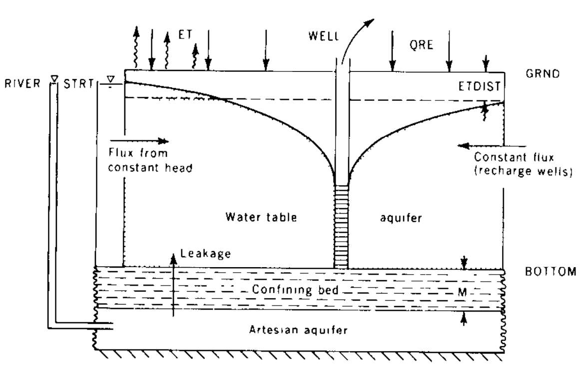


FIGURE 30.—Cross section illustrates several options included in the sample problem and identifies the meaning of several program parameters.

Figures 31 and 32 illustrate the JCL and data decks for two successive simulations of the sample problem. They are designed to show the use of disk facilities to store array data and interim results. The first run (fig. 31) is terminated after 5 iterations and interim results are stored on the data set specified by the FT04F001 DD statement. Note that arrays S, PERM, DELX, and DELY have been stored in the array data set specified by the FT02F001 DD statement (a 1 appears in column 40 of the parameter card for these arrays). The second run (fig. 32) continues computations from the previous stopping point and calculates a solution. Note that PHI, S, PERM, DELX, and DELY are read from disk storage. The final example (fig. 33) illustrates the JCL and data deck for a run without using the disk files. Following figure 33 is the output for the sample prob-

```
//   EXEC FORTGCG
//FORT.SYSIN DD *
```

Model source cards

```
/*
//GO.FT02F001 DD DSN=A442702.AZ100.AG4W0000.MATRIX,
//     UNIT=ONLINE,DISP=(NEW,KEEP),
//     SPACE=(560,(14)),DCB=(RECFM=F)
//GO.FT04F001 DD DSN=A442702.AZ100.AG4W0000.HEAD,
//     UNIT=ONLINE,DISP=(NEW,KEEP),SPACE=(TRK,(1,1),RLSE),
//     DCB=(RECFM=VBS,LRECL=1168,BLKSIZE=1172)
//GO.SYSIN DD *
```

```
                                                                  ---- SAMPLE AQUIFER PROBLEM ---
Group I          -
                 WATE LEAK      EVAP RECH SIP  CHEC           DK2  NUME HEAD
                         10        14         1         5
Group II         CONT               1         1      1500         1        .1  FEET
                          1         1      .003       .01         0    .4E-06        10        10
                          1         1         1

Group III
          STRT          100
                         -1         1                             1
          S






                                                                    1
                                                1   1   1   1   1   1
          PERM         .002         1                             1

                                    1   1   1       2   2   2   2
                                1   1   1   1   2   2   2   2   2   2
                                1   1   1   2   2   2   2   2   2   2
                                2   2   2   2   2   2   2   2   2   2
                                2   2   2   3   3   3   3   3   3   3
                                3   3   3   3   4   4   4   4   4
                        4   4   4   4   4   4   4   3   3   3   3   3
                                                3   3   3   3   3   3
          BOTTOM          0
          SY
          RATE       .3E-07
          RIVER         100
          M              10
          GRND          105
          QRE        .2E-07
                         50         1                             1
          DELX           20        14         9         9        14        21        31        41
                         37        25        17        11         9        13
                         50         1                             1
          DELY           10         5         7        10        14        18        27        30
                         31        12
Group IV                  1         0         6         1         1       1.0        24
                          4         4       .05
                          5         4       .05
                          6         4       .05
                          7         4       .05
                          4        11       -10         2
                          6         6       -10
/*
```

FIGURE 31.—JCL and data deck to copy some of the data sets on disk, compute for 5 iterations, and store the results on disk.

```
//   EXEC FORTGCG
//FORT.SYSIN DD *
```

Model source cards

```
/*
//GO.FT02F001 DD DSN=A442702.AZ100.AG4W0000.MATRIX,
//    UNIT=ONLINE,DISP=SHR,VOL=SER=SYS015
//GO.FT04F001 DD DSN=A442702.AZ100.AG4W0000.HEAD,
//    UNIT=ONLINE,DISP=SHR,VOL=SER=SYS011
//GO.SYSIN DD *
```

Group	Card									
Group I		---- SAMPLE AQUIFER PROBLEM ---								
		-								
		WATE LEAK EVAP REOH SIP CHEC DK1 NUME HEAD								
			10	14	1	50				
Group II		CONT		1	1	1500	1	.1 FEET		
			1	1	.003	.01	0	.4E-06	10	10
			1	1	1					
Group III	STRT		100							
	S				1	1				
	PERM				1	1				
	BOTTOM		0							
	SY									
	RATE		.3E-07							
	RIVER		100							
	M		10							
	GRND		105							
	QRE		.2E-07							
	DELX				1	1				
	DELY					1				
Group IV			1	0	6	1	1	1.0	24	
			4	4	.05					
			5	4	.05					
			6	4	.05					
			7	4	.05					
			4	11	-10	2				
			6	6	-10					

```
/*
//
```

FIGURE 32.—JCL and data deck to continue the previous run (fig. 31) to a solution.

lem generated using the JCL and problem deck shown in figure 33.

Figures 31 to 33 show that the source cards are being compiled for each run. It is more efficient, of course, to compile the source deck once and store it as a load module on disk. Subsequent runs can use the load module with considerable reduction in cards read, CPU time, and lines printed.

```
//   EXEC FORTGCG
//FORT.SYSIN DD *
```

Model source cards

```
/*
//GO.SYSIN DD *
```

Group I

```
                                                ---- SAMPLE AQUIFER PROBLEM ---
-
WATE LEAK      EVAP RECH SIP  CHEC                NUME HEAD
        10        14         1        50
```

Group II

```
CONT               1         1      1500         1        .1  FEET
         1         1      .003       .01         0    .4E-06        10        10
         1         1         1
```

Group III

STRT

```
       100
```

S

```
        -1         1







                                                   1
                               1   1   1   1   1   1
```

PERM

```
      .002         1

                      1   1   1       2   2   2   2
                  1   1   1   1   2   2   2   2   2   2
                  1   1   1   2   2   2   2   2   2   2
                  2   2   2   2   2   2   2   2   2   2
                  2   2   2   3   3   3   3   3   3   3
                  3   3   3   3   4   4   4   4   4
       4   4   4   4   4   4   4   3   3   3   3   3
                                  3   3   3   3   3   3
```

BOTTOM

```
         0
```

SY

RATE

```
    .3E-07
```

RIVER

```
       100
```

M

```
        10
```

GRND

```
       105
```

QRE

```
    .2E-07
```

DELX

```
        50         1
        20        14         9         9        14        21        31        41
        37        25        17        11         9        13
```

DELY

```
        50         1
        10         5         7        10        14        18        27        30
        31        12
```

Group IV

```
         1         0         6         1         1       1.0        24
         4         4       .05
         5         4       .05
         6         4       .05
         7         4       .05
         4        11       -10         2
         6         6       -10
/*
```

FIGURE 33.—JCL and data deck to simulate the sample problem without using disk files.

Program Output using data deck illustrated in figure 33

```
                                    U. S. G. S.

                            FINITE-DIFFERENCE MODEL
                                      FOR
                        SIMULATION OF GROUND-WATER FLOW

                                 JANUARY, 1975

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

                           ---- SAMPLE AQUIFER PROBLEM ----

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

SIMULATION OPTIONS:  WATE    LEAK         EVAP    RECH    SIP    CHEC                         NUME    HEAD

                                                   NUMBER OF ROWS =   10
                                                NUMBER OF COLUMNS =   14
      NUMBER OF WELLS FOR WHICH DRAWDOWN IS COMPUTED AT A SPECIFIED RADIUS =    1
                               MAXIMUM PERMITTED NUMBER OF ITERATIONS =   50

                                           WORDS OF Y VECTOR USED =   3731

                    ON ALPHAMERIC MAP:
                           MULTIPLICATION FACTOR FOR X DIMENSION =   1.000000
                           MULTIPLICATION FACTOR FOR Y DIMENSION =   1.000000
                                          MAP SCALE IN UNITS OF       FEET
                                        NUMBER OF    FEET   PER INCH =   1500.000
                             MULTIPLICATION FACTOR FOR DRAWDOWN =   1.000000
                                 MULTIPLICATION FACTOR FOR HEAD =   0.9999996E-01

                                     NUMBER OF PUMPING PERIODS =    1
                                  TIME STEPS BETWEEN PRINTOUTS =    1

                                    ERROR CRITERIA FOR CLOSURE =  0.3000000E-02
                                   STEADY STATE ERROR CRITERIA =  0.9999998E-02

                              SPECIFIC STORAGE OF CONFINING BED =  0.0
                                       EVAPOTRANSPIRATION RATE =  0.4000000E-06
                                         EFFECTIVE DEPTH OF ET =   10.00000

              MULTIPLICATION FACTOR FOR TRANSMISSIVITY IN X DIRECTION =   1.000000
                                                  IN Y DIRECTION =   1.000000

                                                  STARTING HEAD =   100.0000
```

STORAGE COEFFICIENT
MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.00000	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.00000	-1.00000	-1.00000	-1.00000	-1.00000	-1.00000	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

AQUIFER HYDRAULIC CONDUCTIVITY
MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.200E-02	0.200E-02	0.200E-02	0.0	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.0	0.0
3	0.0	0.0	0.0	0.200E-02	0.200E-02	0.200E-02	0.200E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.0
4	0.0	0.0	0.0	0.200E-02	0.200E-02	0.200E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.0
5	0.0	0.0	0.0	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.400E-02	0.0
6	0.0	0.0	0.0	0.400E-02	0.400E-02	0.400E-02	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.0
7	0.0	0.0	0.0	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.800E-02	0.800E-02	0.800E-02	0.800E-02	0.800E-02	0.0	0.0
8	0.0	0.800E-02	0.800E-02	0.800E-02	0.800E-02	0.800E-02	0.800E-02	0.800E-02	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.600E-02	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

AQUIFER BASE ELEVATION	=	0.0
SPECIFIC YIELD	=	0.0
CONFINING BED HYDRAULIC CONDUCTIVITY	=	0.3000000E-07
RIVER HEAD	=	100.0000
CONFINING BED THICKNESS	=	10.00000
LAND SURFACE ELEVATION	=	105.0000
AREAL RECHARGE RATE	=	0.2000000E-07

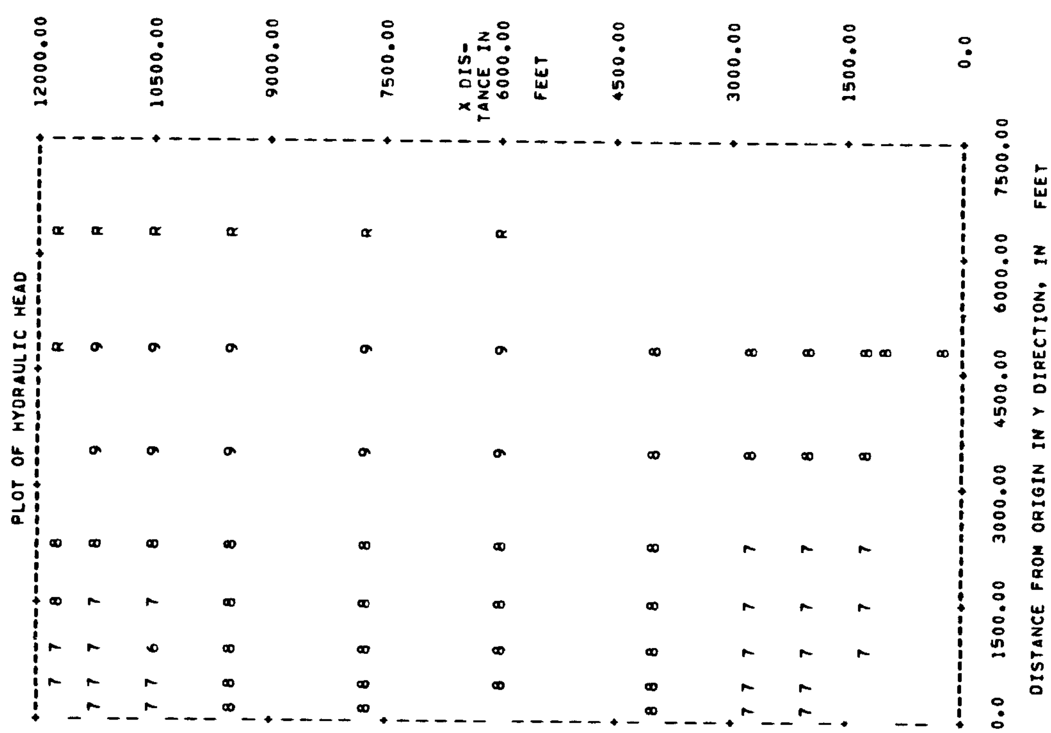
```
                                   GRID SPACING IN PROTOTYPE IN X DIRECTION
                                   ----------------------------------------

 1000.      700.      450.      450.      700.     1050.     1550.     2050.     1850.     1250.      850.      550.
  450.      650.

                                   GRID SPACING IN PROTOTYPE IN Y DIRECTION
                                   ----------------------------------------

  500.      250.      350.      500.      700.      900.     1350.     1500.     1550.      600.

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

                                                 BETA= 1.00

10 ITERATION PARAMETERS:  0.0              0.69039030 00  0.90414180 00  0.97032140 00  0.99081120 00. 0.0
                          0.69039030 00  0.90414180 00  0.97032140 00  0.99081120 00

                                       PUMPING PERIOD NO.   1:      1.00 DAYS
                                       --------------------------------------

                                         NUMBER OF TIME STEPS=     1

                                               DELT IN HOURS =    24.000

                                         MULTIPLIER FOR DELT =     1.000

                                                      6 WELLS
                                                    ---------

                                       I          J    PUMPING RATE  WELL RADIUS

                                       4          4          0.05
                                       5          4          0.05
                                       6          4          0.05
                                       7          4          0.05
                                       4         11        -10.00          2.00
                                       6          6        -10.00
```

```
------------------------------------------------------------
I              TIME STEP NUMBER =         1                I
------------------------------------------------------------

     SIZE OF TIME STEP IN SECONDS=      86400.00

          TOTAL SIMULATION TIME IN SECONDS=        86400.00
                                   MINUTES=         1440.00
                                     HOURS=           24.00
                                      DAYS=            1.00
                                     YEARS=            0.00

DURATION OF CURRENT PUMPING PERIOD IN DAYS=            1.00
                                     YEARS=            0.00


CUMULATIVE MASS BALANCE:              L**3                RATES FOR THIS TIME STEP:               L**3/T
-----------------------                                   -------------------------

         SOURCES:                                                             STORAGE =             0.0
         --------                                                            RECHARGE =             1.1873
                STORAGE =               0.0                             CONSTANT FLUX =             0.2000
               RECHARGE =          102586.63                                  PUMPING =           -20.0000
          CONSTANT FLUX =           17279.99                       EVAPOTRANSPIRATION =            -0.2412
          CONSTANT HEAD =         1418633.00                           CONSTANT HEAD:
                LEAKAGE =          210060.38                                       IN =            16.4194
          TOTAL SOURCES =         1748559.00                                      OUT =             0.0
                                                                             LEAKAGE:
         DISCHARGES:                                       FROM PREVIOUS PUMPING PERIOD =           0.0
         -----------                                                            TOTAL =             2.4313
     EVAPOTRANSPIRATION =           20837.56
          CONSTANT HEAD =               0.0                              SUM OF RATES =            -0.0032
       QUANTITY PUMPED =         1727998.00
                LEAKAGE =               0.0
        TOTAL DISCHARGE =         1748835.00

      DISCHARGE-SOURCES =             276.00
     PER CENT DIFFERENCE =              0.02


MAXIMUM HEAD CHANGE FOR EACH ITERATION:
---------------------------------------

      9.5204      4.8325      3.7815      7.4434      3.4337      2.6980      1.3149      1.8210      1.1354      0.8168

      0.4495      0.5055      0.3512      0.3693      0.2810      0.2107      0.0960      0.1267      0.0765      0.0509

      0.0297      0.0322      0.0225      0.0234      0.0179      0.0133      0.0060      0.0080      0.0048      0.0032

      0.0019

MAXIMUM CHANGE IN HEAD FOR THIS TIME STEP =     32.067
----------------------------------------------------

TIME STEP :  1
----------

ITERATIONS: 30
```

```
                     PLOT OF DRAWDOWN
+----------+----------+----------+----------+----------+  12000.00
  23 23  19   16                    R          R       I
I                                                      I
2525 24  20   15        9           1          R       I
I                                                      I
I                                                      I
2728 32  21   14        9           3          R       +  10500.00
I                                                      I
I                                                      I
1919 18  16   12        8           4          R       I
I                                                      I
+                                                      +   9000.00
I                                                      I
I                                                      I
I                                                      I
1413 13  12   10        8           4          R       I
+                                                      +   7500.00
I                                                      I
I                                                      I
I                                                      I  X DIS-
I                                                      I TANCE IN
  13 13  12   11        9           6          R       +   6000.00
I                                                      I
I                                                      I   FEET
I                                                      I
I                                                      I
+                                                      +   4500.00
I                                                      I
1717 17  17   16       14          12                  I
I                                                      I
I                                                      I
+                                                      +   3000.00
2020 21  22   27       18          15                  I
I                                                      I
I                                                      I
2021 21  22   22       18          15                  I
I                                                      I
+                                                      +   1500.00
  21 21  21   21       18          16                  I
                                   16                  I
I                                                      I
I                                                      I
I                                  16                  I
+----------+----------+----------+----------+----------+    0.0

0.0    1500.00    3000.00    4500.00    6000.00    7500.00
   DISTANCE FROM ORIGIN IN Y DIRECTION, IN   FEET
```

EXPLANATION

R = CONSTANT HEAD BOUNDARY
*** = VALUE EXCEEDED 3 FIGURES
MULTIPLICATION FACTOR =   1.000



EXPLANATION

R = CONSTANT HEAD BOUNDARY
*** = VALUE EXCEEDED 3 FIGURES
MULTIPLICATION FACTOR = 0.100

HEAD MATRIX

1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2	100.0	100.0	100.0	100.0	79.0	79.5	82.7	100.0	85.9	80.2	72.6	74.3	100.0	100.0
3	100.0	100.0	100.0	78.9	78.9	79.4	82.8	86.8	86.1	80.4	71.7	74.6	76.1	100.0
4	100.0	100.0	100.0	78.8	78.6	78.7	82.8	86.9	86.5	81.1	67.9	75.3	76.9	100.0
5	100.0	100.0	100.0	78.4	78.0	77.0	82.7	87.3	87.5	83.8	78.6	79.8	80.1	100.0
6	100.0	100.0	100.0	78.6	77.5	72.1	83.0	88.3	89.2	87.4	85.5	84.9	84.0	100.0
7	100.0	100.0	100.0	81.5	81.4	81.6	85.4	90.1	91.4	91.1	90.9	90.9	100.0	100.0
8	100.0	84.0	83.9	83.9	84.0	84.8	87.6	93.4	95.1	95.7	96.6	98.1	100.0	100.0
9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

DRAWDOWN

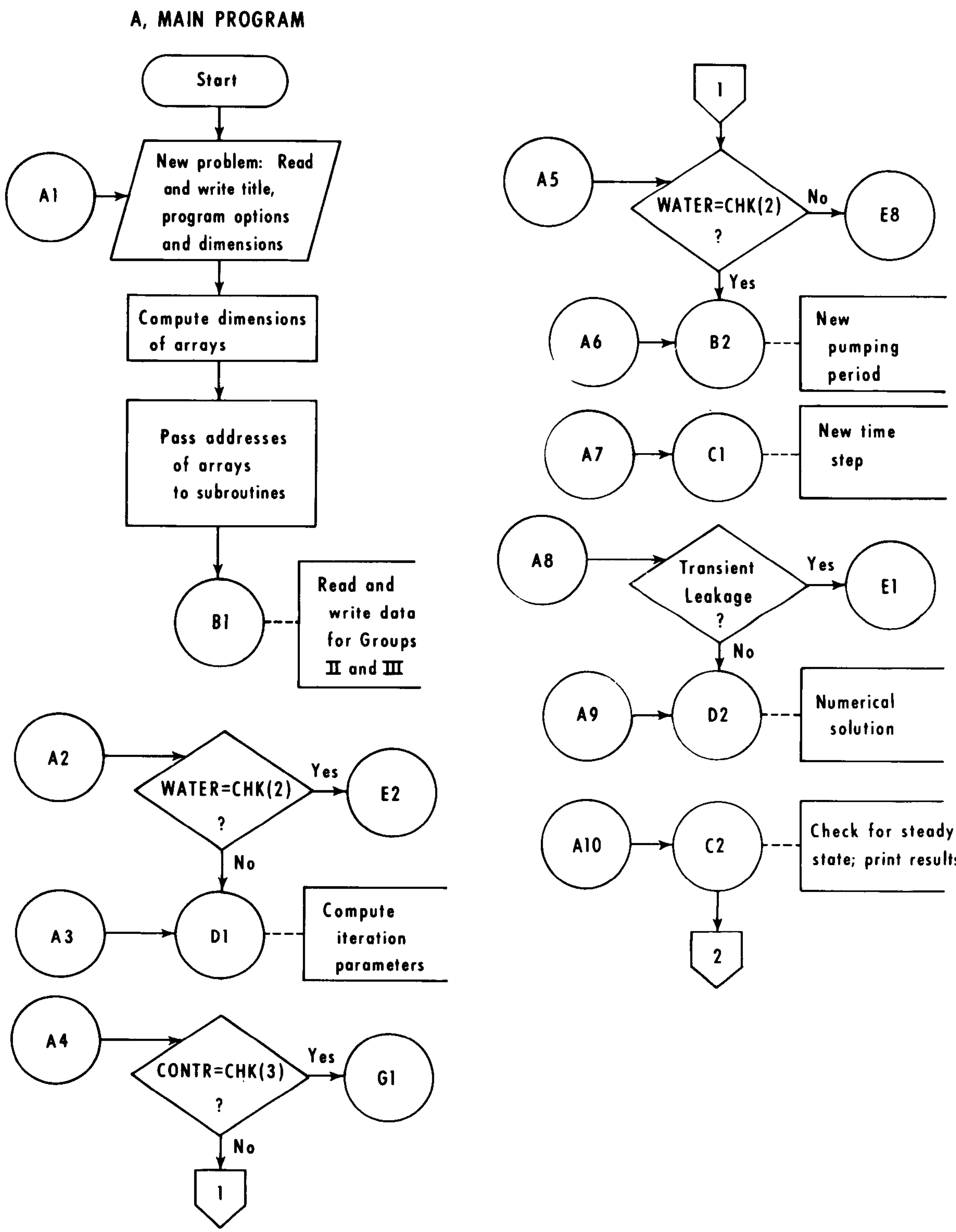
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	21.0	20.5	17.3	0.0	14.1	19.8	27.4	25.7	0.0	0.0
3	0.0	0.0	0.0	21.1	21.1	20.6	17.2	13.2	13.9	19.6	28.3	25.4	23.9	0.0
4	0.0	0.0	0.0	21.2	21.4	21.3	17.2	13.1	13.5	18.9	32.1	24.7	23.1	0.0
5	0.0	0.0	0.0	21.6	22.0	23.0	17.3	12.7	12.5	16.2	21.4	20.2	19.9	0.0
6	0.0	0.0	0.0	21.4	22.5	27.9	17.0	11.7	10.8	12.6	14.5	15.1	16.0	0.0
7	0.0	0.0	0.0	18.5	18.6	18.4	14.6	9.9	8.6	8.9	9.1	9.1	0.0	0.0
8	0.0	16.0	16.1	16.1	16.0	15.2	12.4	6.6	4.9	4.3	3.4	1.9	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HEAD AND DRAWDOWN IN PUMPING WELLS

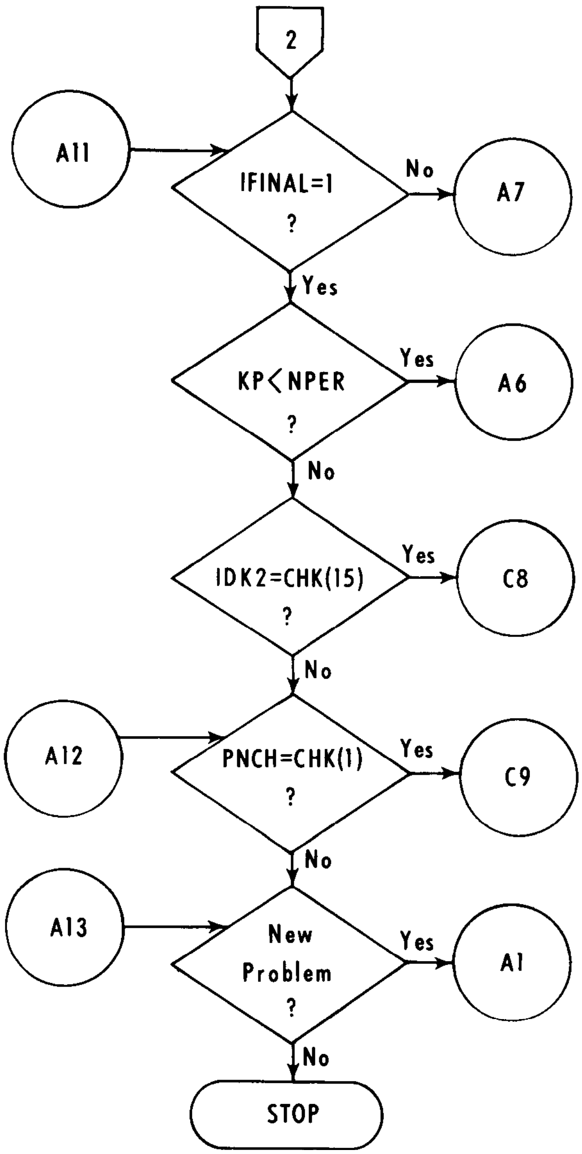
I	J	WELL RADIUS	HEAD	DRAWDOWN
4	11	2.00	35.10	64.90

Attachment V

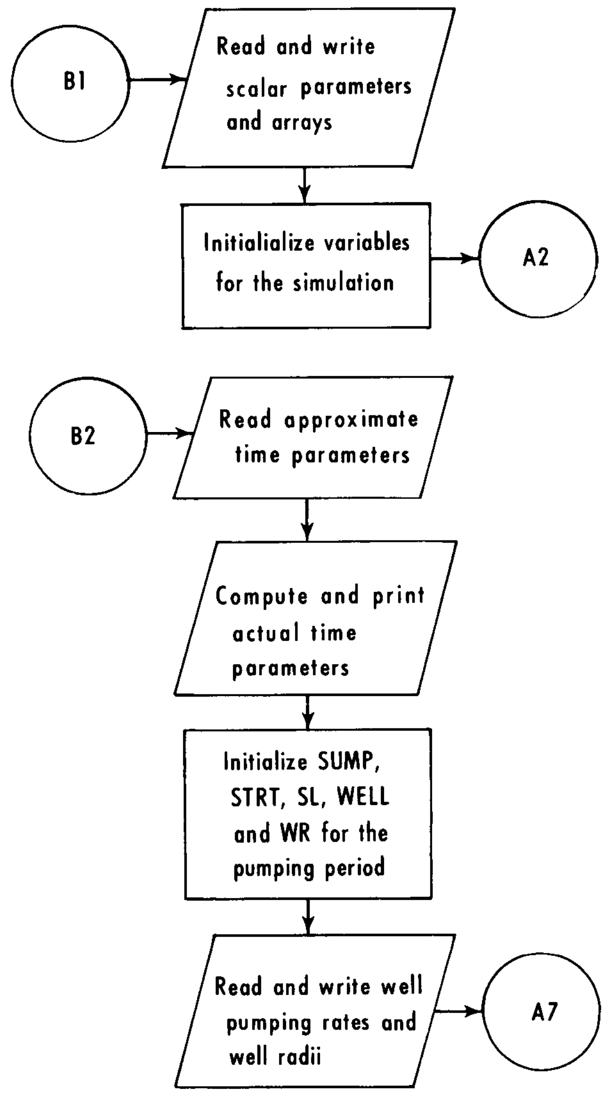
Generalized Flow Chart For Aquifer Simulation Model



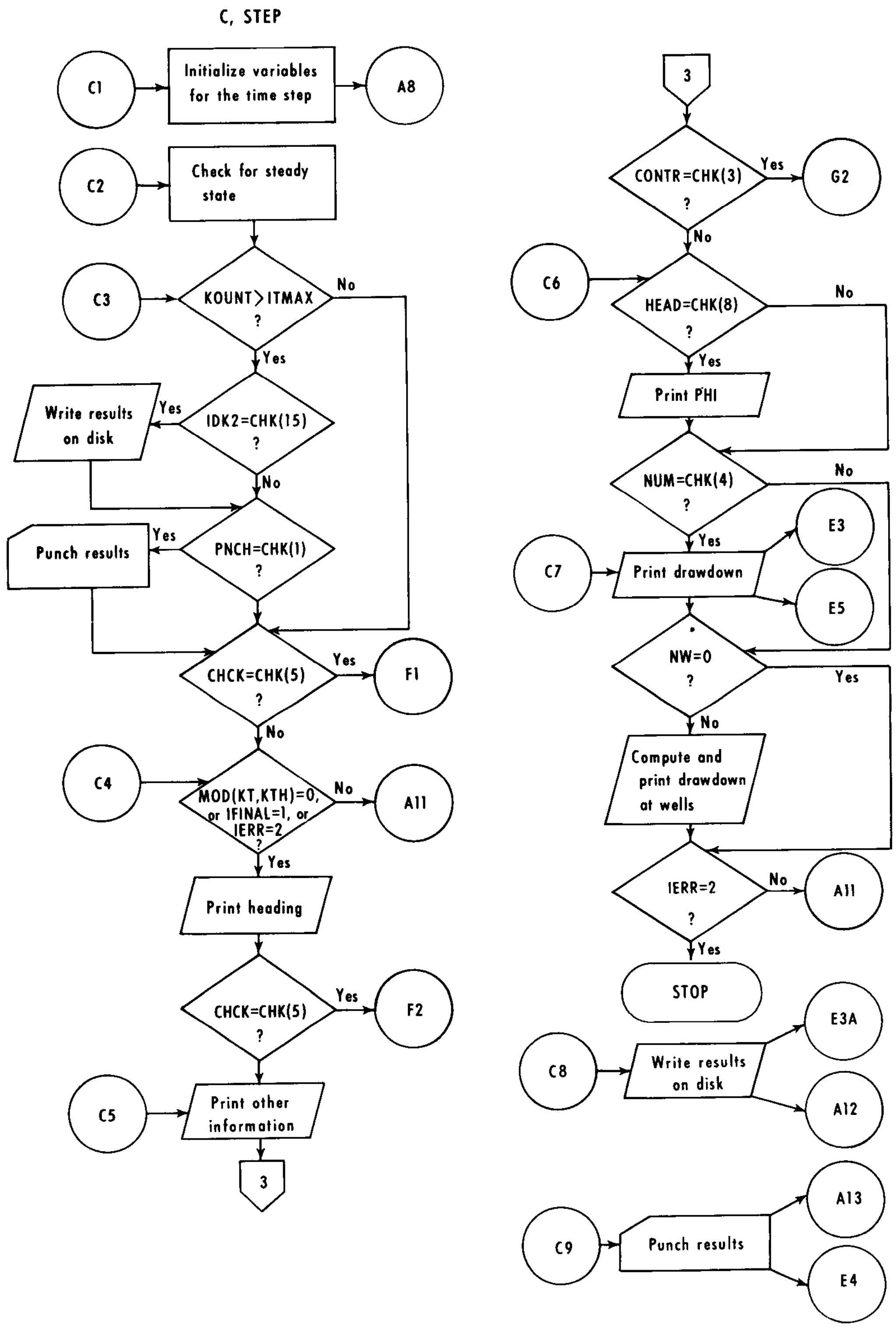
Flow chart—Continued



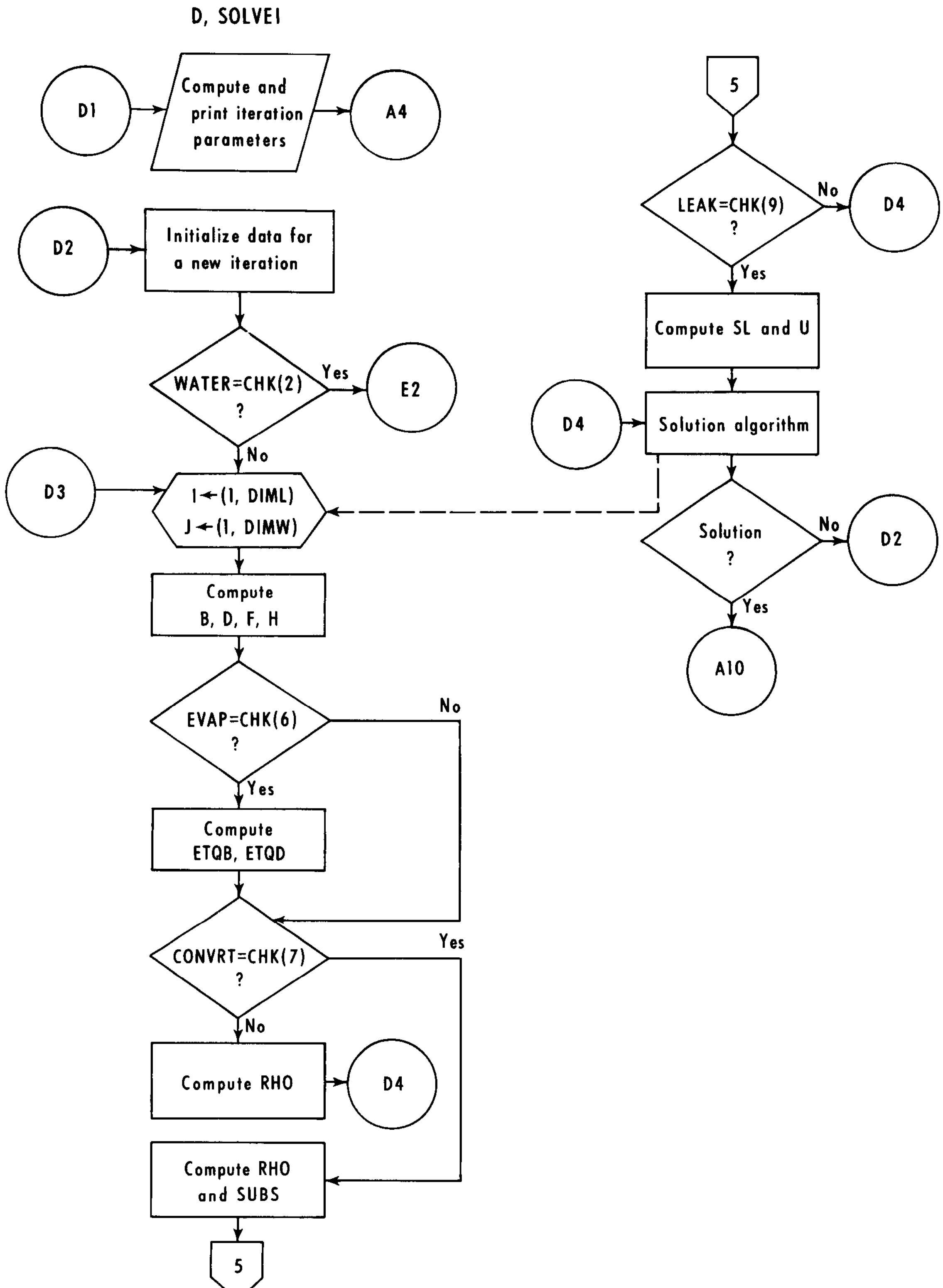
B, DATAI



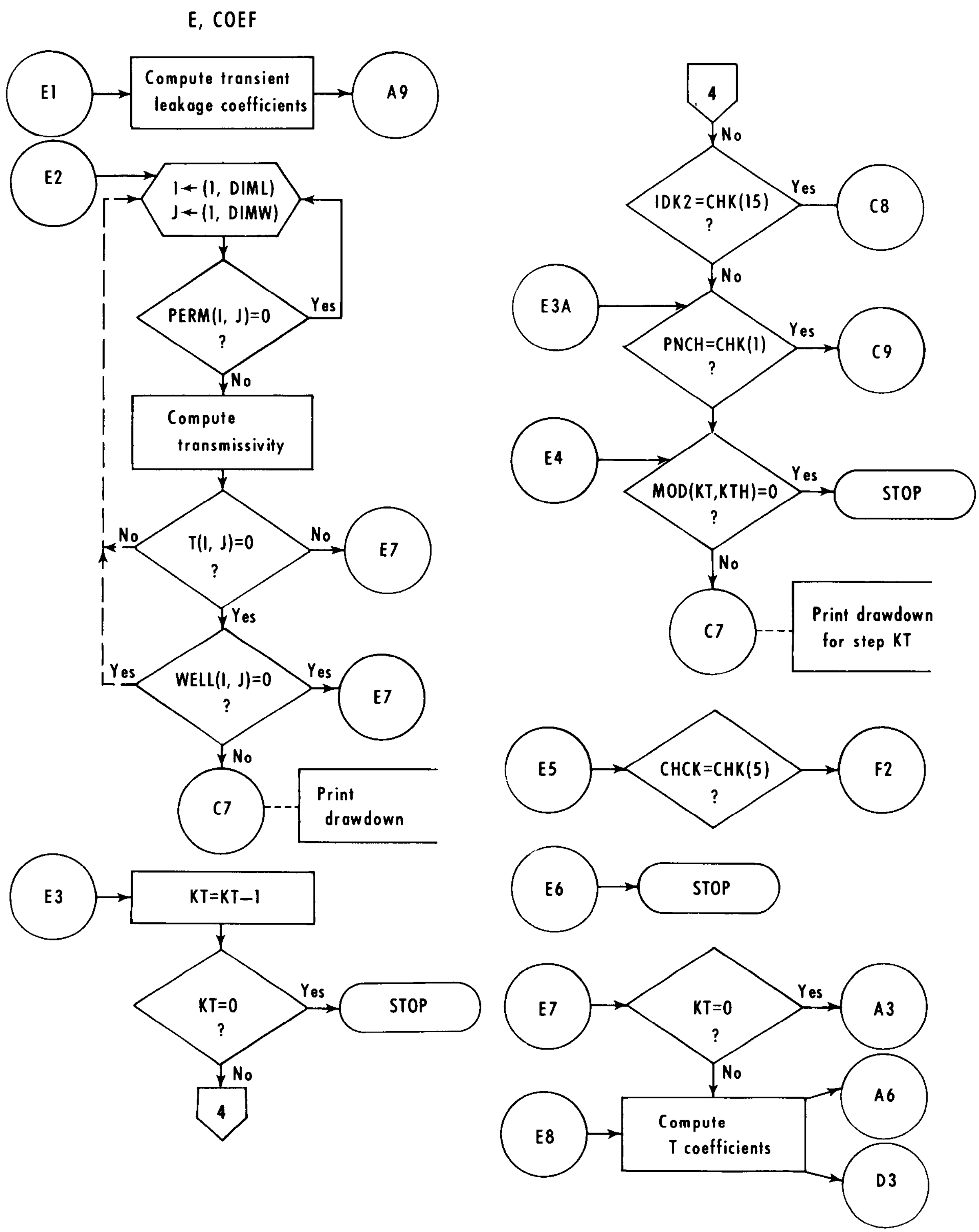
Flow chart—Continued



Flow chart—Continued

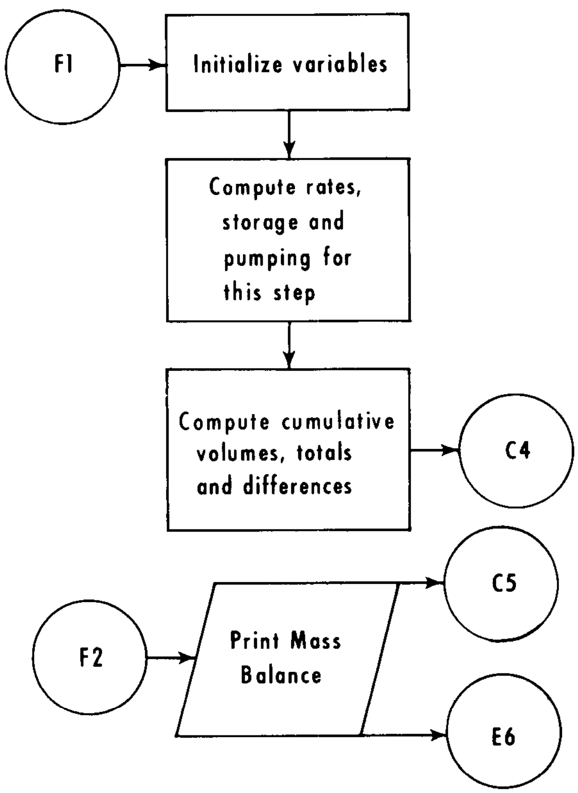


Flow chart—Continued

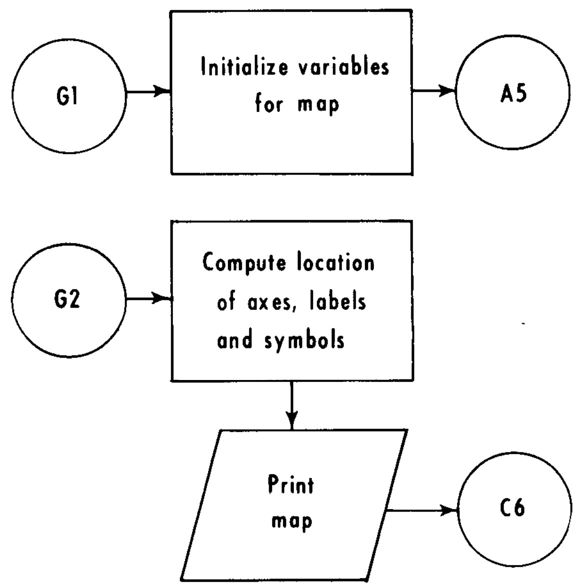


Flow chart—Continued

F, CHECKI



G, PRNTAI



Attachment VI
Definition Of Program Variables

```
A         IN DATAI, DUMMY ARRAY (DOES NOT USE CORE SPACE) USED TO
          OBTAIN ADDRESSES OF ARRAY DATA SETS;
ALFA      CORRECTION VECTOR FOR ROWS (LSOR);
          PARAMETER IN SIP ALGORITHM;
B         TC(I-1,J)/DELY(I) (1/T);
BE        PARAMETER IN THOMAS ALGORITHM;
BOTTOM    ELEVATION OF THE BOTTOM OF THE AQUIFER (L);
CDLT      MULTIPLYING FACTOR FOR THE TIME STEP;
CHCK      CONTAINS CHARACTER STRING FOR MASS BALANCE OPTION;
CHK       VECTOR CONTAINING PROBLEM OPTIONS;
CONTR     CONTAINS CHARACTER STRING FOR OPTION TO PRINT
          MAPS OF DRAWDOWN AND/OR HEAD;
CONVRT    CONTAINS CHARACTER STRING FOR WATER TABLE-ARTESIAN OPTION;
D         TR(I,J-1)/DELX(J) (1/T);
DDN       VECTOR THAT CONTAINS DRAWDOWN VALUES (L);
DEL       ARRAY USED IN SIP ALGORITHM;
DELT      TIME INCREMENT (T);
DELX      GRID SPACING IN THE X DIRECTION (L);
DELY      GRID SPACING IN THE Y DIRECTION (L);
DIML      NUMBER OF ROWS;
DIMW      NUMBER OF COLUMNS;
EROR      STEADY STATE EROR CRITERION (L);
ERR       CLOSURE CRITERION (L);
ETA       ARRAY USED IN SIP ALGORITHM;
ETDIST    DEPTH AT WHICH EVAPOTRANSPIRATION CEASES BELOW LAND
          SURFACE (L);
ETQB      THAT PART OF ET SOURCE TERM TREATED IMPLICITLY;
ETQD      THAT PART OF ET SOURCE TERM TREATED EXPLICITLY;
EVAP      CONTAINS CHARACTER STRING FOR EVAPOTRANSPIRATION OPTION;
F         TR(I,J)/DELX(J) (1/T);
FACT      SEE EXPLANATION IN GROUP III; ARRAY DATA;
FACTX     MULTIPLICATION FACTOR FOR TRANSMISSIVITY IN X DIRECTION;
FACTY     MULTIPLICATION FACTOR FOR TRANSMISSIVITY IN Y DIRECTION;
G         PARAMETER IN THOMAS ALGORITHM;
H         TC(I,J)/DELY(I) (1/T);
GRND      ELEVATION OF LAND SURFACE (L);
HEAD      CONTAINS CHARACTER STRING FOR OPTION TO PRINT HEAD VALUES;
HEADNG    TITLE FOR SIMULATION;
HMAX      MAXIMUM ITERATION PARAMETER (ADI);
          ACCELERATION PARAMETER (LSOR);
          BETA PARAMETER (SIP);
IC        INDICATOR USED TO DETERMINE THE TYPE OF ARRAY DATA;
IERR      = 0 PUMPING WELLS ARE IN SATURATED PART
          OF WATER TABLE AQUIFER;
          = 1 PUMPING WELL HAS GONE DRY;
IFINAL    = 0 ALL TIME STEPS EXCEPT THE LAST;
          = 1 LAST TIME STEP IN PUMPING PERIOD;
IFMT1,IFMT2,IFMT3  VARIABLE FORMAT ARRAYS PASSED TO DATAI VIA ARRAY
          ENTRY POINT;
IN        IN DATAI, DUMMY ARRAY TO WHICH NAME IS PASSED;
IN01      DIML-1;
IPRN      SEE EXPLANATION IN GROUP III; ARRAY DATA;
IRECS,IRECD  SEE EXPLANATION IN GROUP III,ARRAY DATA;
IRN       RECORD NUMBER USED FOR DISK STORAGE AND RETRIEVAL OF
          ARRAY DATA;
```

Definition of program variables—Continued

```
ITMAX     MAXIMUM NUMBER OF ITERATIONS PER TIME STEP;
IVAR      SEE EXPLANATION IN GROUP III; ARRAY DATA;
ISUM      THE CUMULATIVE WORDS OF STORAGE USED IN THE Y VECTOR;
IZ,JZ,ETC.DIMENSIONS OF ARRAYS IN MODEL,COMPUTED IN MAIN PROGRAM;
JN01      DIMW-1;
KEEP      HYDRAULIC HEAD AT THE PREVIOUS TIME STEP (L);
KKK       ASSOCIATED VARIABLE IN DEFINE FILE, INDICATES NUMBER OF
          NEXT RECORD;
KOUNT     ITERATION COUNTER;
KP        NUMBER OF THE PUMPING PERIOD;
KPM1      NUMBER OF PREVIOUS PUMPING PERIOD;
KT        TIME STEP COUNTER;
KTH       NUMBER OF TIME STEPS BETWEEN PRINTOUTS;
L         VECTOR CONTAINING INITIAL ADDRESS OF ARRAYS;
LEAK      CONTAINS CHARACTER STRING FOR LEAKAGE OPTION;
LENGTH    NUMBER OF ITERATION PARAMETERS (SIP,ADI);
          NUMBER OF ITERATIONS BETWEEN 2-D CORRECTION (LSOR);
M         THICKNESS OF CONFINING OR STREAM BED (L);
NPER      NUMBER OF PUMPING PERIODS;
NUM       CONTAINS CHARACTER STRING FOR OPTION TO PRINT DRAWDOWN;
NUMT      NUMBER OF TIME STEPS;
NW        NUMBER OF PUMPING WELLS FOR WHICH DRAWDOWN IS TO BE
          COMPUTED AT A 'REAL' WELL RADIUS;
NWEL      NUMBER OF WELLS FOR A PUMPING PERIOD;
NWR       LOCATION OF WELLS;
PNCH      CONTAINS CHARACTER STRING FOR OPTION TO PUNCH HYDRAULIC
          HEAD VALUES;
P         PRINTER UNIT NUMBER;
PARAM     ITERATION PARAMETER;
PERM      HYDRAULIC CONDUCTIVITY OF THE AQUIFER (L/T);
PHE       HYDRAULIC HEAD AT THE START OF THE ITERATION (L);
PHI       HYDRAULIC HEAD (L);
PU        PUNCH UNIT NUMBER;
QET       MAXIMUM EVAPOTRANSPIRATION RATE (L/T);
QRE       RECHARGE RATE (L/T);
R         READER UNIT NUMBER;
RADIUS    REAL WELL RADIUS (L);
RATE      VERTICAL HYDRAULIC CONDUCTIVITY OF THE CONFINING BED
          OR STREAM BED (L/T);
RECH      CONTAINS CHARACTER STRING FOR RECHARGE OPTION;
RHO       S/DELT (1/T);
RHOP      VECTOR CONTAINING ITERATION PARAMETERS;
RIVER     HYDRAULIC HEAD OF THE STREAM OR IN THE AQUIFER
          ABOVE OR BELOW THE PUMPED AQUIFER (L);
RW        WELL AND RECHARGE SOURCE TERM (L/T);
S         STORAGE COEFFICIENT;
SIP       CONTAINS CHARACTER STRING FOR SIP OPTION;
SL        STEADY PART OF LEAKAGE COEFFICIENT (L/T);
SLEAK     INITIAL & TRANSIENT LEAKAGE (L/T);
SS        SPECIFIC STORAGE OF CONFINING BED (1/L);
STORE     CONTAINS EITHER THE STORAGE COEFFICIENT OR SPECIFIC
          YIELD DEPENDING ON THE TYPE OF AQUIFER;
STRT      HYDRAULIC HEAD AT THE BEGINNING OF THE CURRENT
          PUMPING PERIOD (L);
SUBS      MODIFIES STORAGE TERM IN WATER TABLE-ARTESIAN CONVERSION;
SUM       TOTAL ELAPSED TIME IN THE SIMULATION (T);
SUMP      TOTAL ELAPSED TIME IN THE PUMPING PERIOD (T);
SURI      HYDRAULIC HEAD AT THE START OF THE SIMULATION (L);
SY        SPECIFIC YIELD;
T         TRANSMISSIVITY (L**2/T);
TC        HARMONIC AVERAGE OF T/DELY @ I+1/2,J (L/T);
```

Definition of program variables—Continued

```
TEMP      VECTOR FOR TEMPORARY STORAGE OF HYDRAULIC HEAD (L);
TEST      = 0 CLOSURE CRITERION SATISFIED;
          = 1 CLOSURE CRITERION NOT SATISFIED;
TEST2     MAXIMUM CHANGE IN HEAD FOR THE TIME STEP (L);
TEST3     VECTOR CONTAINING THE SUM OF THE ABSOLUTE VALUES
          OF HEAD CHANGES FOR EACH ITERATION (L);
TL        TRANSIENT PART OF LEAKAGE COEFFICIENT (1/T);
TMAX      NUMBER OF DAYS IN THE PUMPING PERIOD (T);
TMIN      MINIMUM VALUE OF DIMENSIONLESS TIME FOR THE CURRENT
          PUMPING PERIOD;
TOP       ELEVATION OF THE TOP OF THE AQUIFER (L);
TR        HARMONIC AVERAGE OF T/DELX @ I,J+1/2 (L/T);
TT        MAXIMUM VALUE OF DIMENSIONLESS TIME FOR THE CURRENT
          PUMPING PERIOD;
U         = 0 EXPLICIT TREATMENT OF TRANSIENT LEAKAGE;
          = 1 IMPLICIT TREATMENT OF TRANSIENT LEAKAGE;
U         INDICATES DEFINE FILE RECORD LENGTH SPECIFICATION IN WORDS;
V         ARRAY USED IN SIP ALGORITHM;
VF4       VARIABLE FORMAT FOR PRINTING HEAD AND DRAWDOWN;
WATER     CONTAINS CHARACTER STRING FOR WATER TABLE OPTION;
WELL      WELL DISCHARGE (L**3/T);
WR        WELL RADIUS (L);
XI        ARRAY CONTAINING INCREMENTAL HEAD VALUES IN SIP SOLUTION (L);
Y         VECTOR CONTAINING ARRAY STORAGE;
YDIM      LENGTH OF AQUIFER IN Y DIRECTION (L).

DEFINITION OF VARIABLES IN CHECKI SUBROUTINE
--------------------------------------------
CFLUX     INFLOW FROM RECHARGE WELLS (L**3/T);
CFLUXT    CUMULATIVE VOLUME OF WATER FROM RECHARGE WELLS (L**3);
CHD1      RATE OF OUTFLOW TO CONSTANT HEAD BOUNDARY (L**3/T);
CHD2      RATE OF INFLOW FROM CONSTANT HEAD BOUNDARY (L**3/T);
CHDT      CUMULATIVE DISCHARGE TO CONSTANT HEAD BOUNDARY (L**3);
CHST      CUMULATIVE VOLUME OF WATER INFLOW FROM CONSTANT
          HEAD BOUNDARY (L**3);
DIFF      ERROR IN MASS BALANCE (L**3);
ETFLUX    EVAPOTRANSPIRATION RATE (L**3/T);
ETFLXT    CUMULATIVE DISCHARGE BY ET (L**3);
FLUX      RATE OF LEAKAGE DUE TO GRADIENTS AT THE START
          OF THE PUMPING PERIOD (L**3/T);
FLUXS     NET LEAKAGE RATE (L**3/T);
FLXN      RATE OF DISCHARGE BY LEAKAGE (L**3/T);
FLXNT     CUMULATIVE VOLUME OF WATER DISCHARGED BY LEAKAGE (L**3);
FLXPT     CUMULATIVE VOLUME OF WATER INFLOW FROM LEAKAGE (L**3);
PERCNT    PERCENT ERROR IN CUMULATIVE MASS BALANCE;
PUMP      DISCHARGE FROM WELLS (L**3/T);
PUMPT     CUMULATIVE VOLUME OF WATER DISCHARGED BY PUMPING WELLS (L**3);
QREFLX    RECHARGE RATE (L**3/T);
QRET      CUMULATIVE VOLUME OF WATER DERIVED FROM RECHARGE (L**3);
STOR      RATE OF CHANGE IN STORAGE FOR THE TIME STEP (L**3/T);
STORT     CUMULATIVE VOLUME OF WATER DERIVED FROM STORAGE (L**3);
SUMR      SUM OF RECHARGE AND DISCHARGE RATES FOR THE TIME STEP (L**3/T);
TOTL1     CUMULATIVE VOLUME OF WATER FROM ALL SOURCES (L**3);
TOTL2     CUMULATIVE VOLUME OF WATER DISCHARGED FROM THE SYSTEM (L**3);
XNET      NET LEAKAGE RATE FOR A CELL (L**3/T).

DEFINITION OF VARIABLES IN THE PRINTAI SUBROUTINE
-------------------------------------------------
BLANK     CONTAINS BLANK SYMBOLS;
DINCH     NUMBER OF MAP UNITS PER INCH;
DIST      LOCATION OF NEXT COLUMN OF NODAL VALUES TO BE PRINTED;
```

Definition of variables in the PRNTAI subroutine—Continued

```
FACT1        FACTOR FOR ADJUSTING VALUE OF DRAWDOWN PRINTED;
FACT2        FACTOR FOR ADJUSTING VALUE OF HEAD PRINTED;
K            ADJUSTED VALUE OF DRAWDOWN OR HEAD;
MESUR        NAME OF MAP LENGTH UNIT;
N            INDEX FOR SYMBOLS;
NA           INDICES FOR LOCATING X LABEL;
NC           NUMBER OF BLANKS BEFORE GRAPH;
N1           NUMBER OF LINES PER INCH;
N2           NUMBER OF CHARACTERS PER INCH;
N3           NUMBER OF CHARACTERS PER LINE;
N4           NUMBER OF LINES IN THE PLOT;
N8           MAXIMUM NUMBER OF CHARACTERS IN Y DIRECTION;
NXD          NUMBER OF INCHES IN THE X DIMENSION OF PLOT;
NYD          NUMBER OF INCHES IN THE Y DIMENSION OF PLOT;
PRNT         CONTAINS THE ARRANGEMENT OF SYMBOLS FOR EACH LINE;
SPACNG       CONTOUR INTERVAL (L);
SYM          VECTOR CONTAINING SYMBOLS USED IN THE PLOT;
TITLE        TITLE FOR PLOT;
VF1,VF2,VF3 VARIABLE FORMATS FOR CENTERING PLOT;
XLABEL       LABEL FOR X AXIS;
XN           NUMBERS FOR X AXIS;
XN1          1 INCH/(N1*2);
XSCALE       MULTIPLICATION FACTOR TO CONVERT MODEL LENGTH UNIT
             TO UNIT USED IN X DIRECTION ON MAPS;
XSF          X SCALE FACTOR;
YLABEL       LABEL FOR Y AXIS;
YLEN         LOCATION OF NEXT VALUE IN THE COLUMN TO BE PRINTED;
YN           NUMBERS FOR Y AXIS;
YSCALE       MULTIPLICATION FACTOR TO CONVERT MODEL LENGTH UNIT
             TO UNIT USED IN Y DIRECTION ON MAPS;
YSF          Y SCALE FACTOR;
Z            LOCATION OF NEXT LINE TO BE PRINTED.
```