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Digital Computer Modeling of Limestone Groundwater Systems

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DIGITAL COMPUTER MODELING OF LIMESTONE GROUNDWATER SYSTEMS

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Lexington, Kentucky

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ABSTRACT

Because limestone groundwater flows mainly in discrete openings, limestone aquifers are fundamentally different from aquifers in granular rocks. A digital computer program which simulates flow in a limestone aquifer as a pipe network was written and compared with the Sinkhole Plain aquifer of west-central Kentucky.

A reasonably good fit between observed parameters of the aquifer and those calculated were obtained under assumed conditions of both laminar and turbulent flow in the aquifer. The indicated gross permeability of the aquifer is 5600 meinzers with an assumed aquifer thickness of 100 feet. The location and discharge of springs along the streams bounding the aquifer are predicted.

With further refinements to the computational routines, additional features of the aquifer can be modelled, and more refined predictions can be made of water budget parameters, location of flow paths, and development of the aquifer.

KEY WORDS: limestone aquifer/ground-water basin/digital computer models/ flownets.

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CHAPTER I

INTRODUCTION

Significance of Research

In many areas, water found in openings in the rock (groundwater) is a major water supply. Where the underlying rock is granular, such as the alluvium along major streams, the study, evaluation, and production of this groundwater is facilitated by the existence of a well-developed theory of the granular groundwater body.

Much of Kentucky, as well as large portions of other states, is underlain by limestone. Groundwater in limestone (and similar rocks) behaves quite differently than that in granular rocks. The permeability is localized in discrete openings, rather than in the intergrain pores of granular rocks, and the flow is often turbulent. The distribution of openings is irregular, and the openings themselves have been and are being enlarged by the flow of water within them.

Although flow assumptions borrowed from grannular rock theory (e.g., linear relationship between head loss and flow) are widely applied (with varying degrees of success) to limestones, it is evident that concepts and methods which take into account the nature of the limestone aquifer need to be developed.

The importance of limestone groundwater to Kentucky may be judged by the following summary derived from data in Mull, et al (1971).

Twenty-nine of Kentucky's 120 counties obtain some of their public and industrial water from limestone groundwater. Of these, 7 derive between 10 and 50% of their supply from this source, and six obtain more than half their supply from limestone. In this latter group, Hart, Russell, and Scott counties get more than 80% of their public and industrial water supply from this source, and Allen county receives all of its supply from limestone groundwater.

Currently, the probabilities of obtaining a yield sufficient for public or industrial water supply from a well drilled in a limestone area are quite low. An inspection of the data in Mull, et al (1971) shows only about one-fifth of the wells listed have a yield of 100 gallons/minute or greater. Large flows of water do exist, however, as evidenced by several springs discharging more than 1000 gallons/minute. It is evident that the development of a theory of limestone groundwater which would allow the prediction of the location of these large flows would be of considerable economic benefit.

A better understanding of groundwater in limestone would have benefits other than water supply. The prediction of reservoir leakage and of pollution paths is currently a difficult matter in the absence of a well-developed theory of limestone groundwater.

Project Objectives

The original objectives of the project (as described in the original proposal) were:

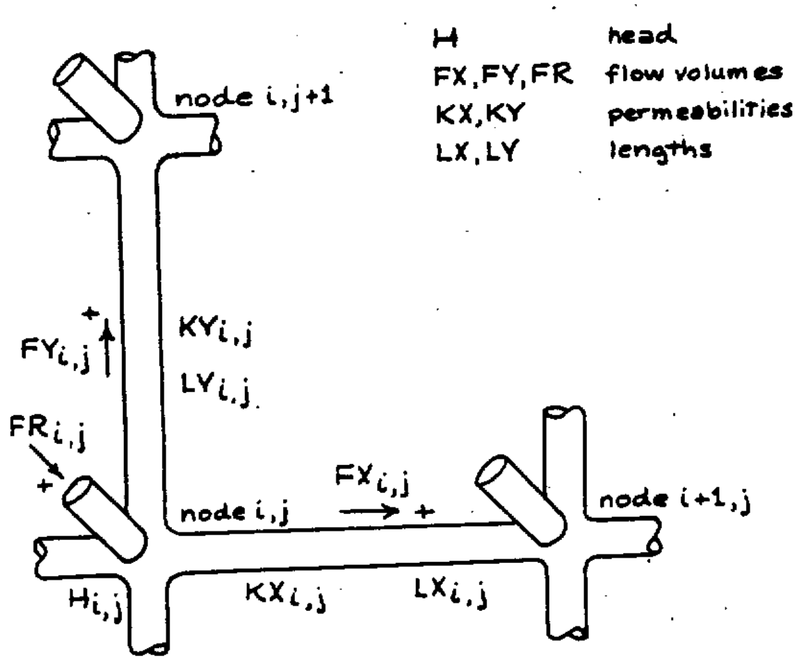
> To develop digital computer model techniques to describe limestone groundwater basins in two and three dimensions. Models will be developed for actual limestone aquifer systems with boundary conditions determined by geologic and geochemical data now available or to be acquired as part of the project. Numerical techniques will be used to obtain solutions to the models. Results will be made available on specific systems to guide groundwater surface water development and aid in pollution control. Training of one or tow graduate students in the techniques developed will be accomplished.

Midway through the first year of the planned two-year period the project was revised by shortening it to 14 months and reducing the funds to 42% of the original amount. This necessitated a drastic limitation of the project objectives, as discussed in a later section of this report.

CHAPTER II

DESCRIPTION OF PROGRAM KLAM (KENTUCKY LIMESTONE AQUIFER MODEL)

The aquifer is approximated as a 2-dimensional quadrilateral network of pipes. Each branch (pipe segment) has assigned or calculated values of flow volume, flow resistance (permeability), and length. Each node (junction of pipe segments) has assigned or calculated values of head and flow volume introduced from outside the system (recharge flow). The network is numbered as being in the first quadrant. The indexing scheme for nodes and branches is shown in Figure 1, together with the variables and the sign convention for flows.



INDEXING SCHEME FOR NETWORK PARAMETERS

FIGURE 1

Geometry

1. The node flow error (E) at a node is calculated as

$$E_{i,j} = FX_{i,j} + FY_{i,j} - FR_{i,j} - FX_{i-1,j} - FY_{i,j-1}$$

where the symbols are as shown in Figure 1.

2. The branch flow error (E-) in the four branches associated with the node is calculated as

$$EX_{i,j} = \frac{KX_{i,j} \cdot (H_{i,j} - H_{i+1,j})^{\frac{1}{n}}}{LX_{i,j}} - FX_{i,j}$$

for the branch to the right of the node and similarly for the remaining branches. In this expression n is 1 for the laminar flow models and 2 for the turbulent flow models.

3. The flow in each branch (including the recharge flow) about the node is corrected by an amount C- calculated as

$$CX_{i,j} = \frac{-R \cdot (1 - W) \cdot E_{i,j}}{M_{i,j}} + W \cdot EX_{i,j}$$

for the branch to the right of the node and similarly for the remaining branches. R is a relaxation coefficient, W a parameter to allow the relative influence of the two errors to be changed, and M is the number of branches around the node.

4. The head at the node is calculated from the heads at adjacent nodes and the new branch flows by averaging expressions similar to

$$H_{i,j} = \frac{LX_{i,j} \cdot (FX_{i,j})^{n}}{KX_{i,j}} + H_{i+1,j}$$

5. After the above computations are performed for each node, the entire procedure is iterated until convergence occurs.

Summary of Program

The program is written in Fortran IV and executed on an IBM 360/65 computer. When dimensioned to accommodate a 38 x 27 node network, 118K bytes of storage were required and 100 iterations required about 8 minutes of central processing unit time.

The program consists of a main program and 14 sub-routines.

1. MAIN - reads program parameter card, writes out parameters, and performs iterative computations described above.
2. IN1 - reads data for each node on separate card.
3. IN2 - reads data for all nodes on first card and changes for individual nodes on later cards.
4. IN3 - reads data for each node on cards punched by OUT4.
5. CAL1 - calculates KX and KY if undefined.
6. CAL2 - counts entered value and writes messages.
7. CAL3 - assigns starting values of unspecified flows.
8. CAL4 - assigns starting values of unspecified heads.
9. OUT1 - lists values after specified number of iterations.
10. OUT2 - lists final values in table form.
11. OUT3 - fills arrays for map output of final values.
12. OUT3A - lists final values in map form.
13. OUT3B - writes heading for map output.
14. OUT3C - writes error table for map output.
15. OUT4 - punches cards with final values.

In the initial stages, the program was titled LASP but this was changed to KLAM (Kentucky Limestone Aquifer Model) during the project. A complete listing of the program (slightly expanded for readability) will be found in the Appendix.

CHAPTER III

MODEL 1 - SINKHOLE PLAIN AQUIFER - LAMINAR FLOW

General

The Sinkhole Plain Aquifer was considered to be a continuous aquifer underlying the area shown on Figure 2. Its boundaries were taken to be the streams indicated, which are perennial and of sufficient size to be represented as double lines on 1/24,000 scale maps.

All of the rocks of the area are nearly flat-lying, with a general regional dip to the north of about 10 meters per kilometer. Pennsylvanian rocks crop out near the Green and Barren rivers in the northwest part of the area, otherwise only rocks of Mississippian age outcrop. The Pennsylvanian and upper Mississippian rocks are interbedded sandstones and shales with thin limestones in the Mississippian. The lower Mississippian rocks are almost entirely limestones and dolomites.

North of the south-facing Chester Escarpment, which roughly follows a line connecting the towns of Munfordville, Horse Cave, Cave City, Park City, and Bowling Green, most of the area is underlain by upper Mississippian and Pennsylvanian rocks, with the lower Mississippian limestones and dolomites cropping out only in the bottom of sinkholes and valleys. The portion of the area south of the escarpment, known as the Sinkhole Plain, is underlain by lower Mississippian rocks and is a typical karst, with few surface streams and, in many areas, a very high density of sinkholes. The average altitude is about 220 meters (750 feet) with an average local relief of about 20 meters (65 feet). The relief is fine-textured; a characteristic sinkhole diameter being 100 meters (300 feet).

The eastern part of the plateau north of the Chester escarpment is also a karst, but of a significantly different form. The average altitude of the

SINKHOLE PLAIN AQUIFER LOCATION MAP

Note: Diagonal names are of 7 1/2 minute quadrangles.

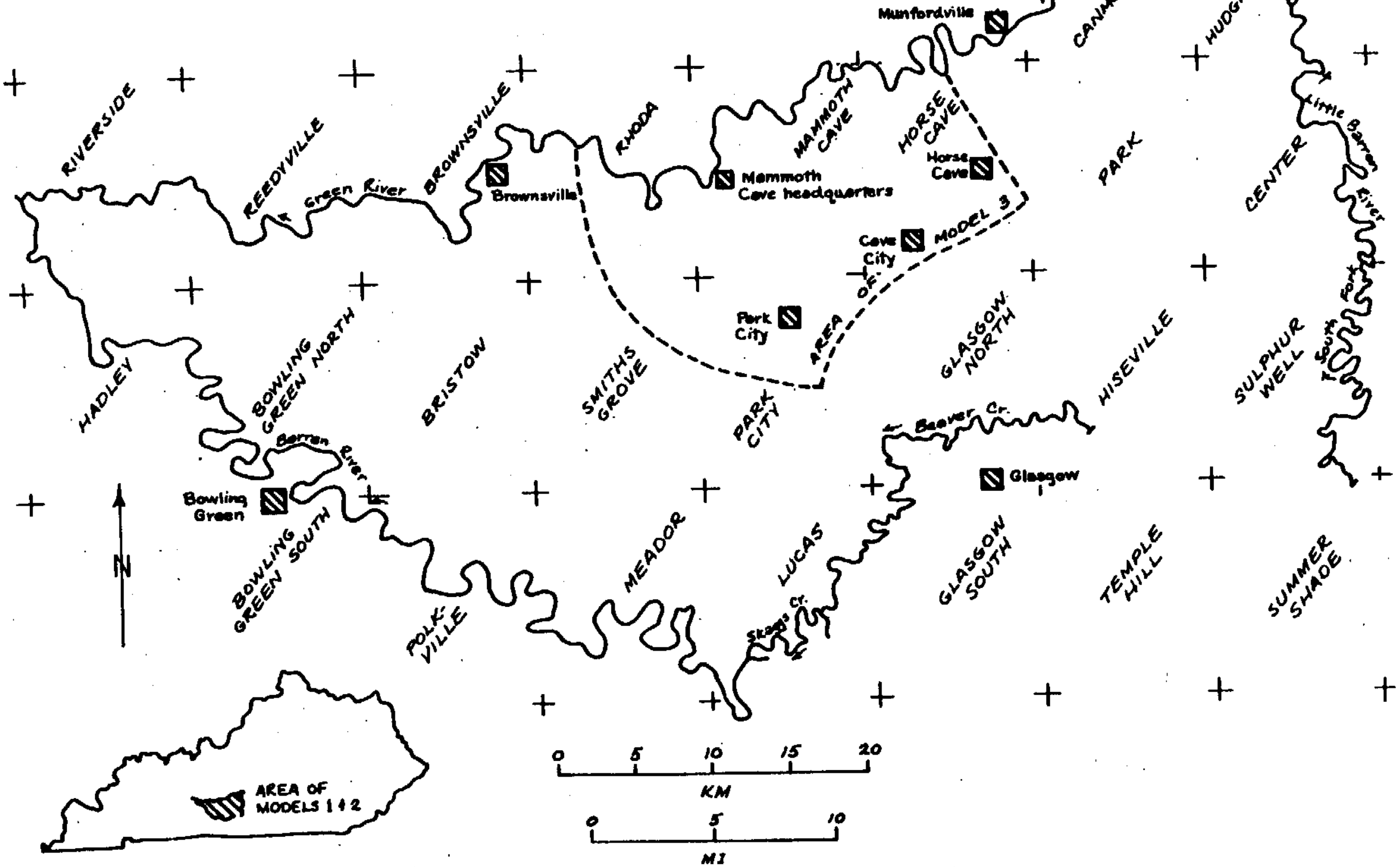


FIGURE 2

plateau tops is about 260 meters (850 feet) and that of the intervening sinkholes is 200 meters (650 feet). The local relief is thus three times that of the Sinkhole Plain. The texture is also much coarser with an average sinkhole diameter of about 1 km.

Parameters

A grid with a standard node interval of 12,500 feet was established (Figure 3). Nodes on the boundary were moved to fall on the bounding streams and the lengths of the branches connecting these nodes to the grid were shortened where necessary. Note that the orientation of the branch does not affect the computations. These boundary nodes were assigned head values taken from 1/24,000 scale topographic maps, and the recharge for these nodes was left unspecified (Figure 3). This model represents boundary geometry and heads prior to the construction and filling of a reservoir on the Barren River in the southermost part of the area.

There is very little surface drainage in the area, and a recharge for the interior nodes was calculated assuming that all non-evapotranspired precipitation (i.e., runoff plus infiltration) enters the aquifer as recharge. In a study of a geologically and climatologically similar area about 120 km to the west (Walker, 1956), the runoff varied from 3.4 inches to 70.7 inches per year over a ten year period. A figure of 30 in/yr was adopted for this model. This is equivalent to a recharge flow of 740 ft^3/min at each node.

During execution, the permeability (inverse flow resistance) of the branches was adjusted to obtain a fit to observed heads at interior points in the area (Figure 3).

Results

A solution judged to be satisfactory was obtained after 560 iterations. The trial and error method used to determine a permeability is not very efficient, and convergence could have been obtained in only 100 or so iterations if the permeability had been held constant. Final values for the branch flow, recharge flow, and head are shown on Figures 4, 5, and 6 respectively.

SINKHOLE PLAIN AQUIFER

NETWORK AND VALUES OF SPECIFIED PARAMETERS

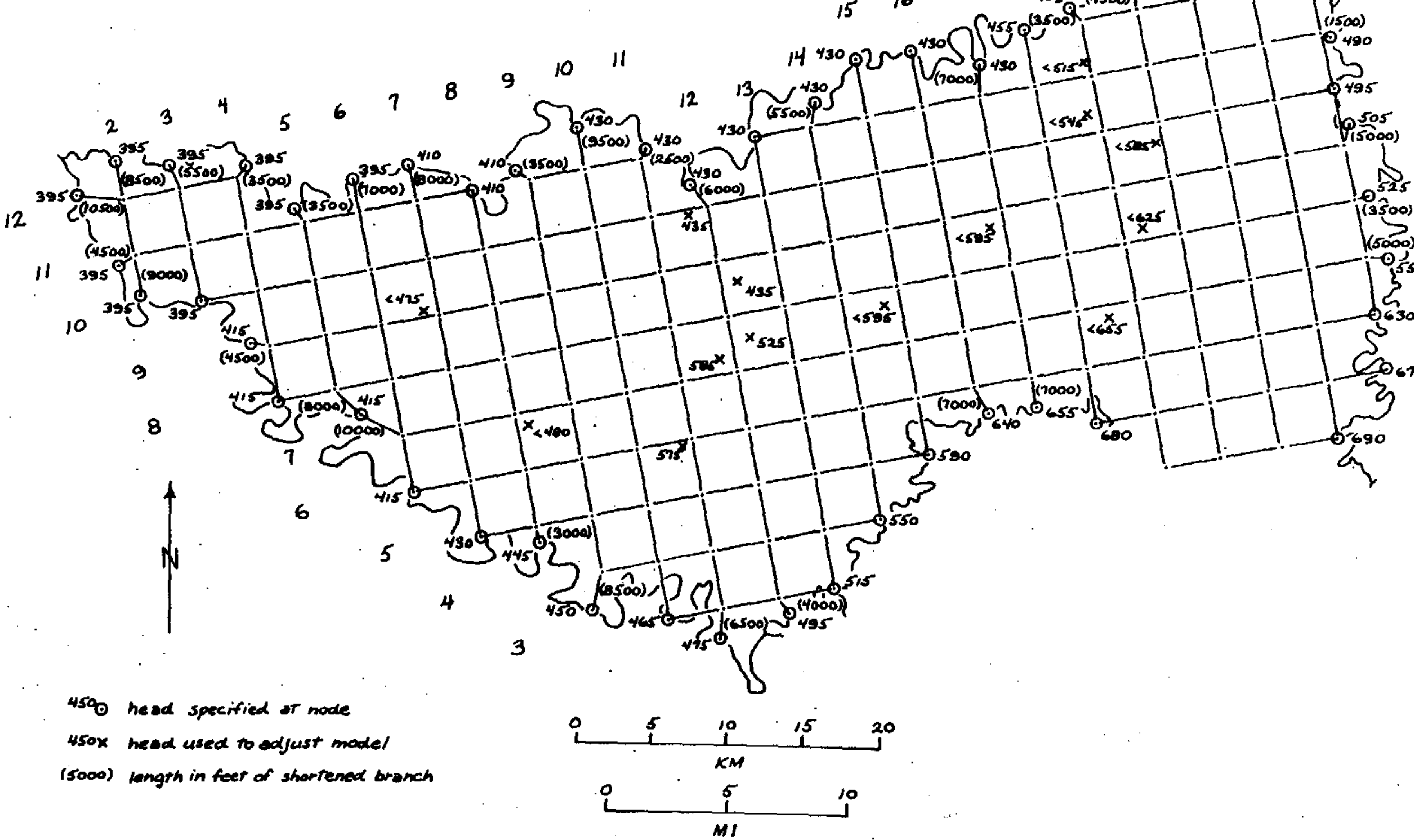


FIGURE 3

SINKHOLE PLAIN
AQUIFER
MODEL I VALUES OF FLOW IN BRANCHES

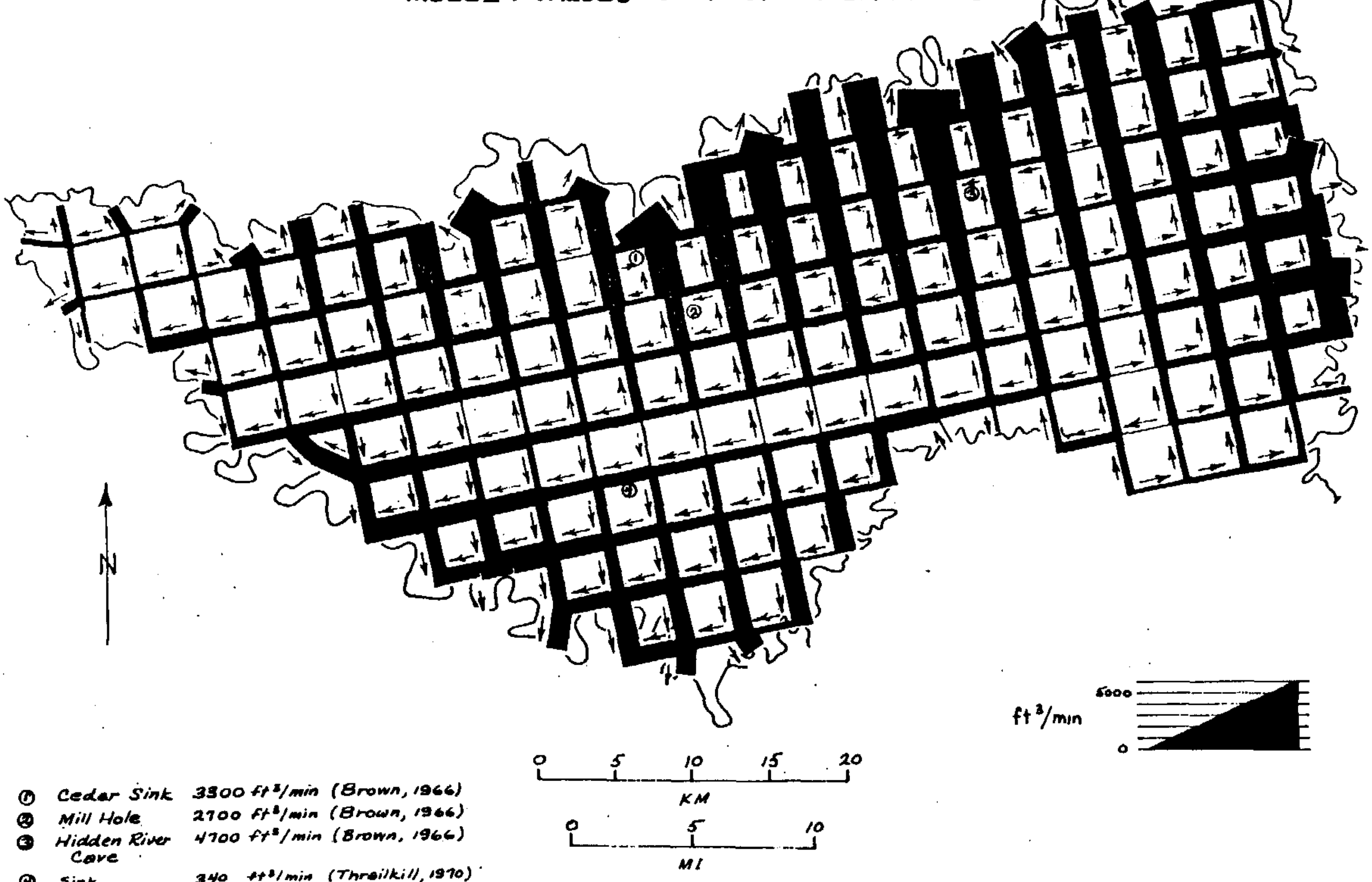


FIGURE 4

SINKHOLE PLAIN
AQUIFER

MODEL I VALUES OF RECHARGE

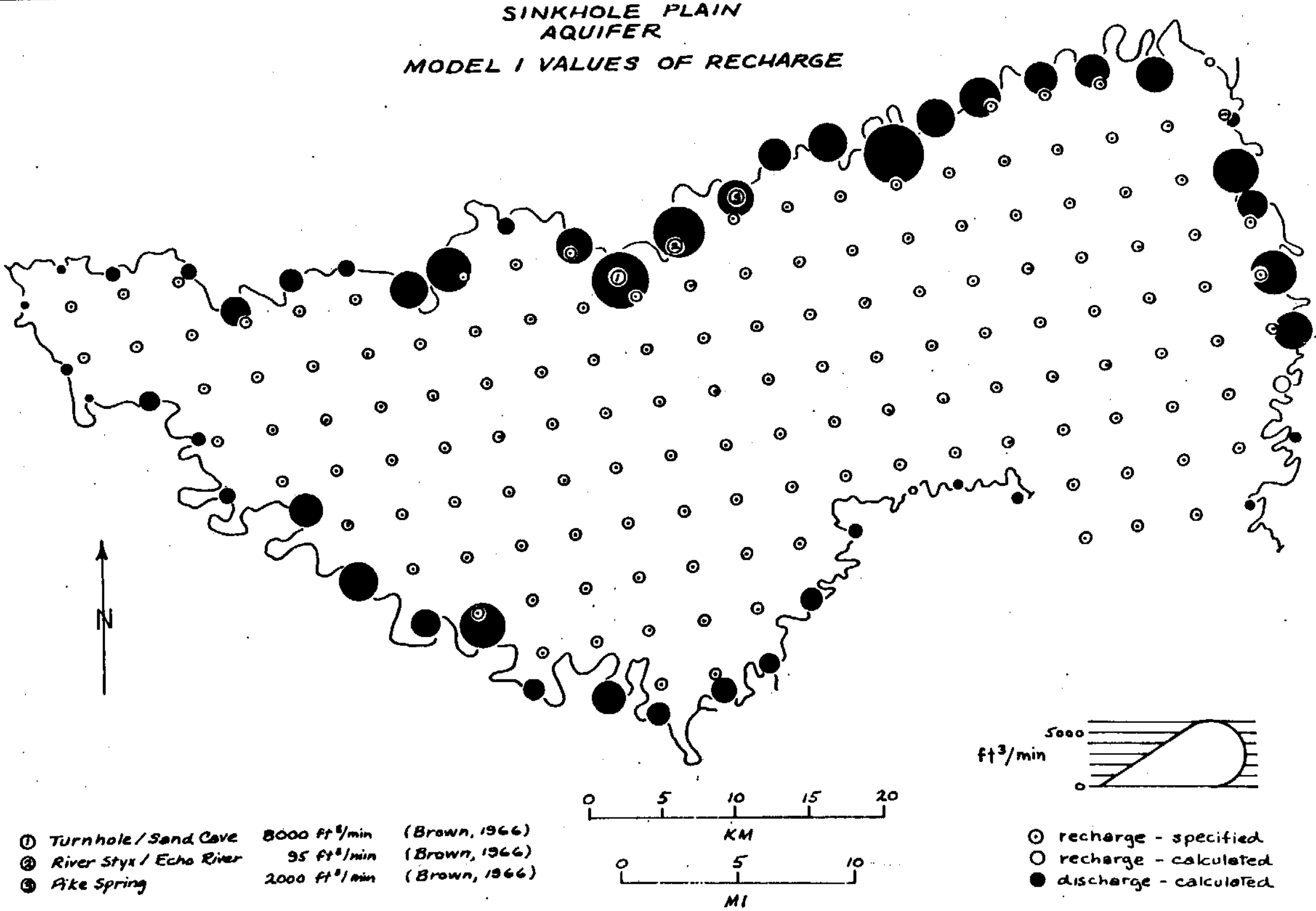


FIGURE 5

SINKHOLE PLAIN
AQUIFER
MODEL I VALUES OF HEAD

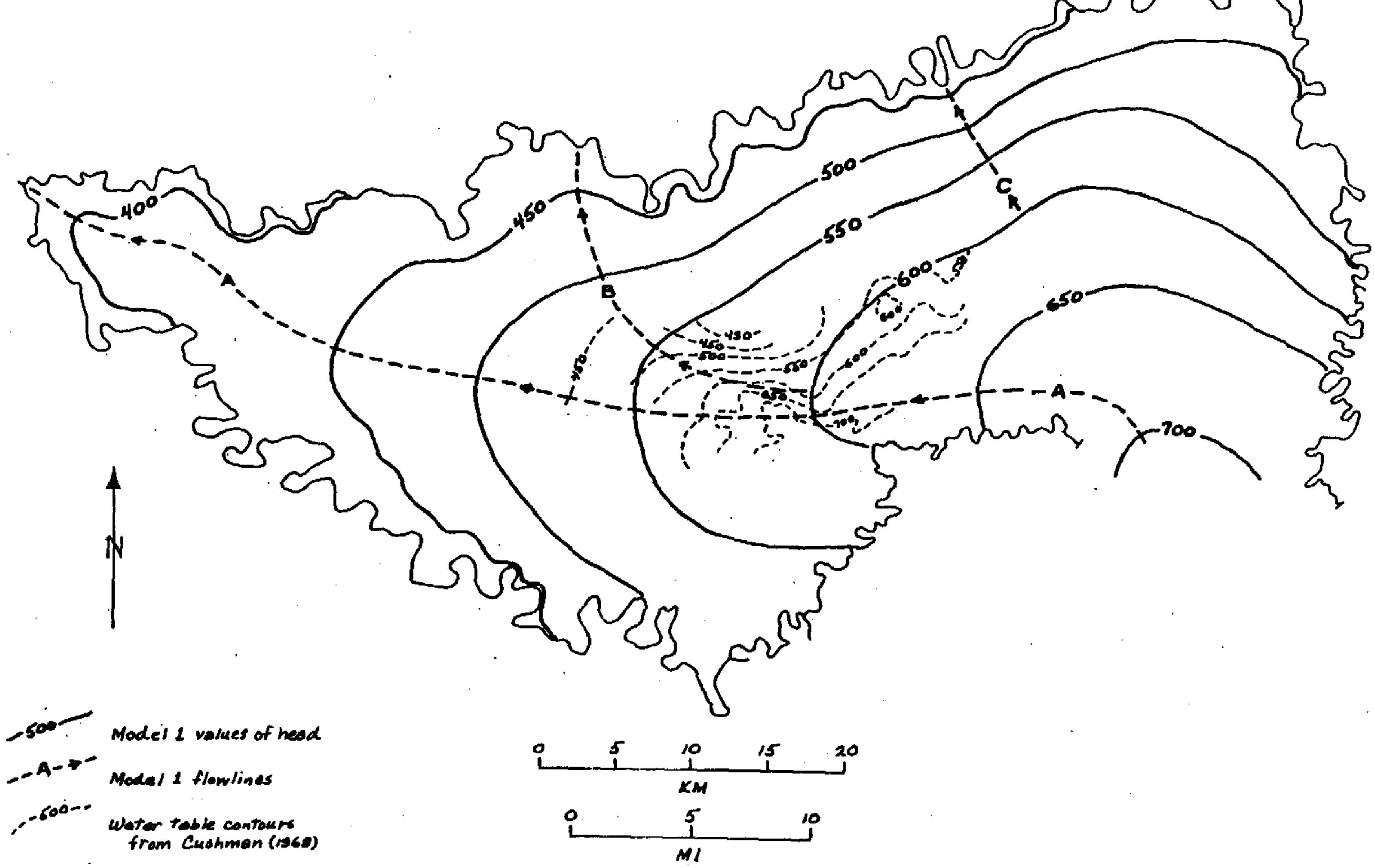


FIGURE 6

The final permeability used was 650, 000 ft^3/min (the appropriate units are those of discharge), which was judged to provide a satisfactory fit to the observed head at the interior points as shown in Table 1.

TABLE 1

COMPARISON OF OBSERVED AND CALCULATED HEADS FOR MODEL 1 (feet)

Point	Observed Head (Figure 3)	Head interpolated from Figure 6	Difference (Model 1 - observed)
1	475	465	-
2	480	500	+ 20
3	575	550	- 25
4	435	470	+ 35
5	585	565	- 20
6	435	545	+ 110
7	525	565	+ 40
8	595	600	+ 5
9	595	595	-
10	515	505	-
11	545	555	+ 10
12	655	665	+ 10
13	585	580	-
14	625	630	+ 5

Nine of the fourteen points were sinkholes which apparently did not reach the water table (no water was shown in them on the topographic map) and thus suggest only an upper limit for the head (points 1, 2, 8 through 14 in Table 1).

Assuming active flow occurs in the aquifer to a depth of 100 feet and with the pipe spacing of 12,500 ft, each branch corresponds to a cross-sectional area of the aquifer of 1.25×10^6 ft^2. The pipe flow permeability of 6.5×10^5 ft^3/min therefore corresponds to a diffuse flow permeability of .52 ft/min, or 5600 meinzers (1 meinzer is equivalent to 9.3×10^{-5} ft/min). This is a relatively high permeability, about that of a very well sorted, medium-grained sand (Davis and DeWiest, 1966, p. 164).

Data with which to evaluate the calculated branch flows and recharge (discharge) flows are limited. Flow estimates in streams appearing in four deep sinks or caves have been made, and are compared with the corresponding branch flows in Table 2. The location of these points is shown on Figure 4. Similarly, the calculated discharge is compared with the observed discharge in some large springs on the Green River (Figure 5 and Table 3).

The order-of-magnitude accordance between most observed branch flows and discharges and those calculated as Model 1 (Tables 2 and 3) suggests the model has some validity. The fact that the values calculated depended on the node spacing may indicate that a texture of about that used is present in the aquifer.

A water table map of part of the area (Cushman, 1968) based on well data is shown on Figure 6. Although large differences exist between the observed head and the calculated head, it is interesting to note that the groundwater divide between the Green and Barren Rivers suggested by the observed water table contours nearly coincides with the divide calculated for Model 1 (flow-line A on Figure 6).

Most of the observed discrepancies between Model 1 and observations of the aquifer can probably be explained by the general nature of the Model 1 parameters, such as recharge assumed constant both in time and space, uniform permeability throughout the aquifer, and uniform spacing of flow conduits. The very bad fit between water table contours and calculated heads near the center of the area, for example, can probably best be explained by much higher permeabilities in this area (which could be used in a refinement of Model 1). It appears, however, that Model 1 provides a reasonably good approximation of the aquifer and that the calculated parameters have some predictive value.

TABLE 2

COMPARISON OF OBSERVED FLOWS IN THE AQUIFER AND MODEL 1 CALCULATED BRANCH FLOWS (ft^3/min)

Point (Figure 4)	Apparent direction	Observed flow and reference	Corresponding branch between nodes indicated	Model 1 flow
1	north	3300 (Brown, 1966)	12, 9 and 12, 10	2700 north
2	north	2700 (Brown, 1966)	12, 8 and p2, 9	1600 north
3	north	4700 (Brown, 1966)	18, 9 and 18, 10	2200 north
4	west	340 (Thrailkill, 1970)	10, 6 and 11, 6	1000 west

TABLE 3

COMPARISON OF OBSERVED AND MODEL 1 CALCULATED DISCHARGES ON THE AQUIFER BOUNDARY (ft^3/min)

Point (Figure 5)	Observed discharge and reference	Corresponding node	Model 1 discharge
1	8000 (Brown, 1966)	12, 11	4900
2	95 (Brown, 1966)	13, 11	4700
3	2000 (Brown, 1966)	14, 12	3300

CHAPTER IV

MODEL 2 - SINKHOLE PLAIN AQUIFER TURBULENT FLOW

General and Parameters

The boundaries and parameters of Model 2 are the same as Model 1 except that turbulent flow in the wholly rough region was specified by assigning the value of 2.0 to the parameter n in steps 2 and 4 of the computational procedure discussed earlier. As with Model 1, the permeability was adjusted during execution to fit observed interior heads.

Results

A solution was obtained after 100 iterations starting with Model 1 values of variables. Head contours (water table elevation) are shown on Figure 7, and comparisons of Model 2, Model 1, and observed head, branch flows, and discharges are given in Tables 4, 5, and 6. The permeability arrived at by the same adjustment procedure used for Model 1 was 2×10^9 ft^6/min^2, or (45,000 ft^3/min)^2.

It is apparent that Model 2 is so similar to Model 1 that observed aquifer flows and heads are insufficient to test their relative validity.

SINKHOLE PLAIN
AQUIFER
MODEL 2 VALUES OF HEAD

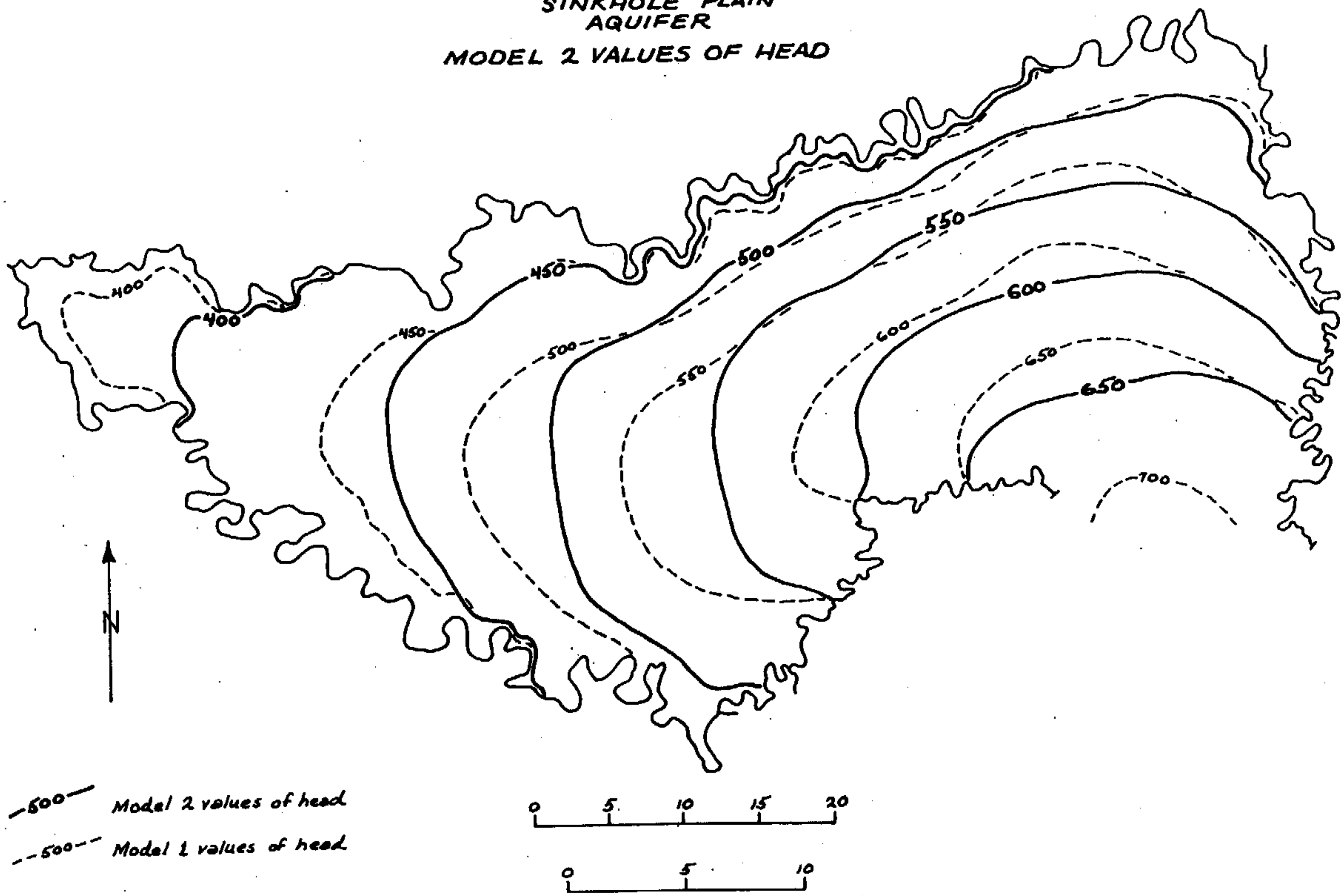


FIGURE 7

TABLE 4

COMPARISON OF OBSERVED AND CALCULATED HEADS FOR MODEL 2 (feet)

Point	Observed head (Figure 3)	Model 2 head interpolated from Figure 7	Difference (Model 2 - observed)	Model 1 difference (from Table 1)
1	475	445	-	-
2	480	470	-	+ 20
3	575	520	- 55	- 25
4	435	480	+ 45	+ 35
5	585	530	- 55	- 20
6	435	530	+ 95	+ 90
7	525	545	+ 20	+ 40
8	595	585	-	+ 5
9	595	590	-	-
10	515	505	-	-
11	545	545	-	+ 10
12	655	650	-	+ 10
13	585	565	-	-
14	625	610	-	+ 5

TABLE 5

COMPARISON OF OBSERVED FLOWS IN THE AQUIFER AND MODEL 2 CALCULATED BRANCH FLOWS (ft^3/min). SEE TABLE 2 FOR REFERENCE FOR OBSERVED FLOW AND BRANCH COORDINATES.

Point (Figure 4)	Apparent direction	Observed flow	Model 2 flow	Model 1 flow (from Table 2)
1	north	3300	2500 north	2700 north
2	north	2700	1600 north	1600 north
3	north	4700	2400 north	2200 north
4	west	340	1700 west	1000 west

TABLE 6

COMPARISON OF OBSERVED AND MODEL 2 CALCULATED DISCHARGES ON THE AQUIFER BOUNDARY (ft^3/min). SEE TABLE 3 FOR REFERENCE FOR OBSERVED FLOW AND NODE COORDINATES.

Point (Figure 5)	Observed discharge	Model 2 discharge	Model 1 discharge (from Table 1)
1	8000	4200	4900
2	95	5600	4700
3	2000	3400	3300

CHAPTER V

MODEL 3 - NORTH-CENTRAL SINKHOLE PLAIN AQUIFER - LAMINAR FLOW

General and Parameters

In order to investigate flow conditions using a finer grid and with more realistic (and complex) conditions, Model 3 was constructed of the north-central part of the Sinkhole Plain aquifer (Figure 2). Its boundaries were the Green River, the 600 ft. head contour from Model 1, and two Model 1 flow-lines (B and C on Figure 6). A grid spacing of 2500 feet was used.

Other than the finer grid spacing, the principal difference between this model and the previous ones is that it embodies an attempt to represent spatially varying recharge. As outlined earlier, the principal stratigraphic break divides the sedimentary rocks into a thick sequence of limestones and dolomites, of which the Girkin Limestone is the uppermost, overlain by a sequence of thin sandstones, shales, and limestones with the Big Clifty Sandstone at the base directly overlying the Girkin Limestone. The distribution of these two sequences (Gildersleeve, 1963, 1965; Haynes, 1962, 1964a, b, 1966; Klemic, 1963; Richards, 1964) is shown on Figure 8. To at least a good first approximation, no recharge enters the aquifer in areas underlain by the upper sequence (Big Clifty Sandstone and above) due to impermeable shales at the base of the Big Clifty Sandstone. In Model 3, the recharge of 29.6 ft^3/min (equivalent to 30 in/year) assigned to each node was introduced at nodes in the lower sequence (open circles on Figure 9) but diverted to the nearest lower sequence node (dotted circles on Figure 9) from nodes located in the outcrop area of the upper sequence (solid circles on Figure 9). Where two or more lower sequence nodes were equi-distant from an upper sequence node, the recharge was divided equally.

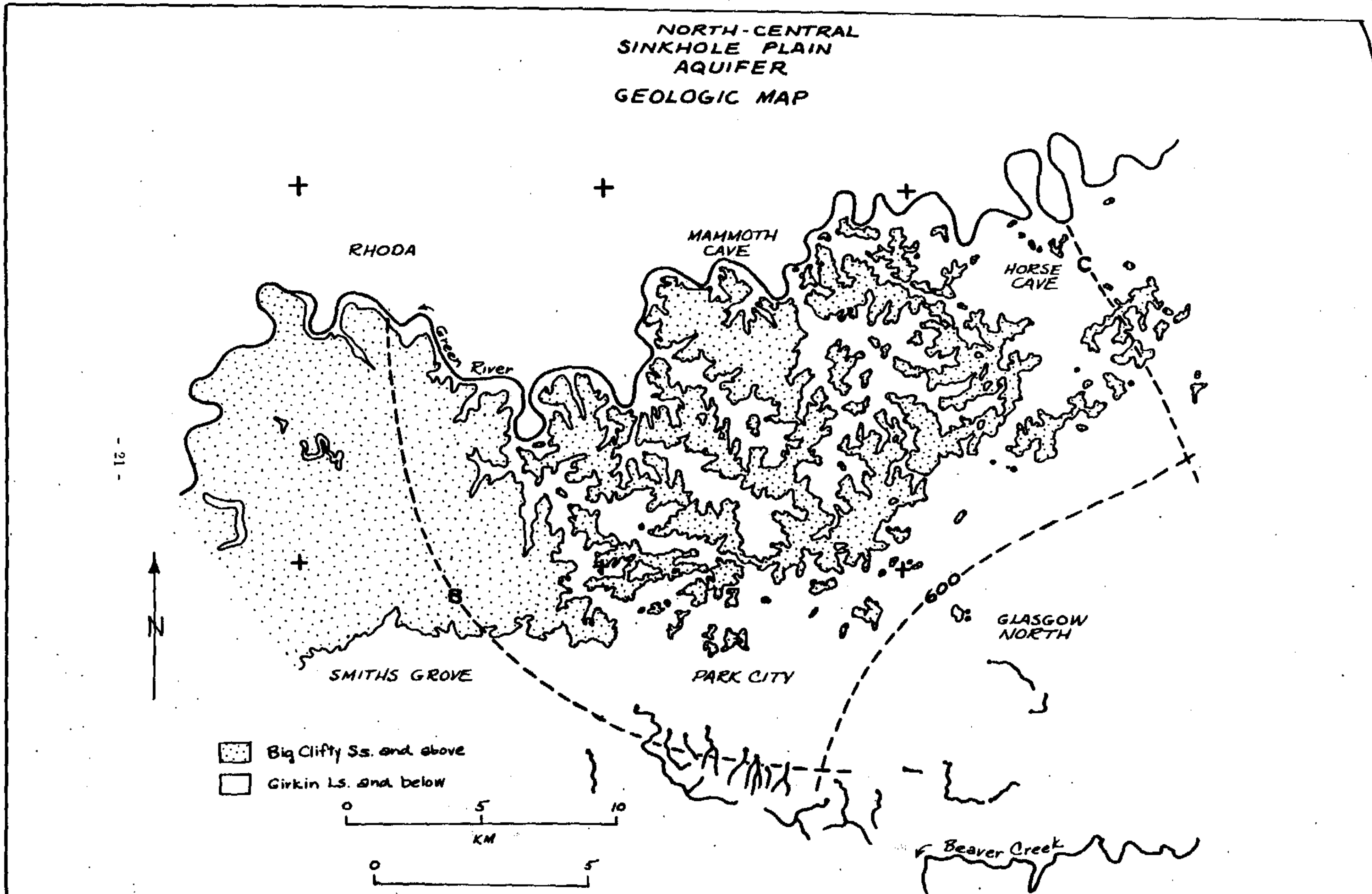

NORTH-CENTRAL
SINKHOLE PLAIN
AQUIFER
GEOLOGIC MAP
RHODA
MAMMOTH
CAVE
HORSE
CAVE
Green River
C
B
600
N
GLASGOW
NORTH
SMITHS GROVE
PARK CITY
Big Clifty Ss. and above
Girkin Ls. and below
0
5
10
KM
0
5
MI
Beaver Creek

FIGURE 8

NORTH-CENTRAL
SINKHOLE PLAIN
AQUIFER

MODEL 3 RECHARGE

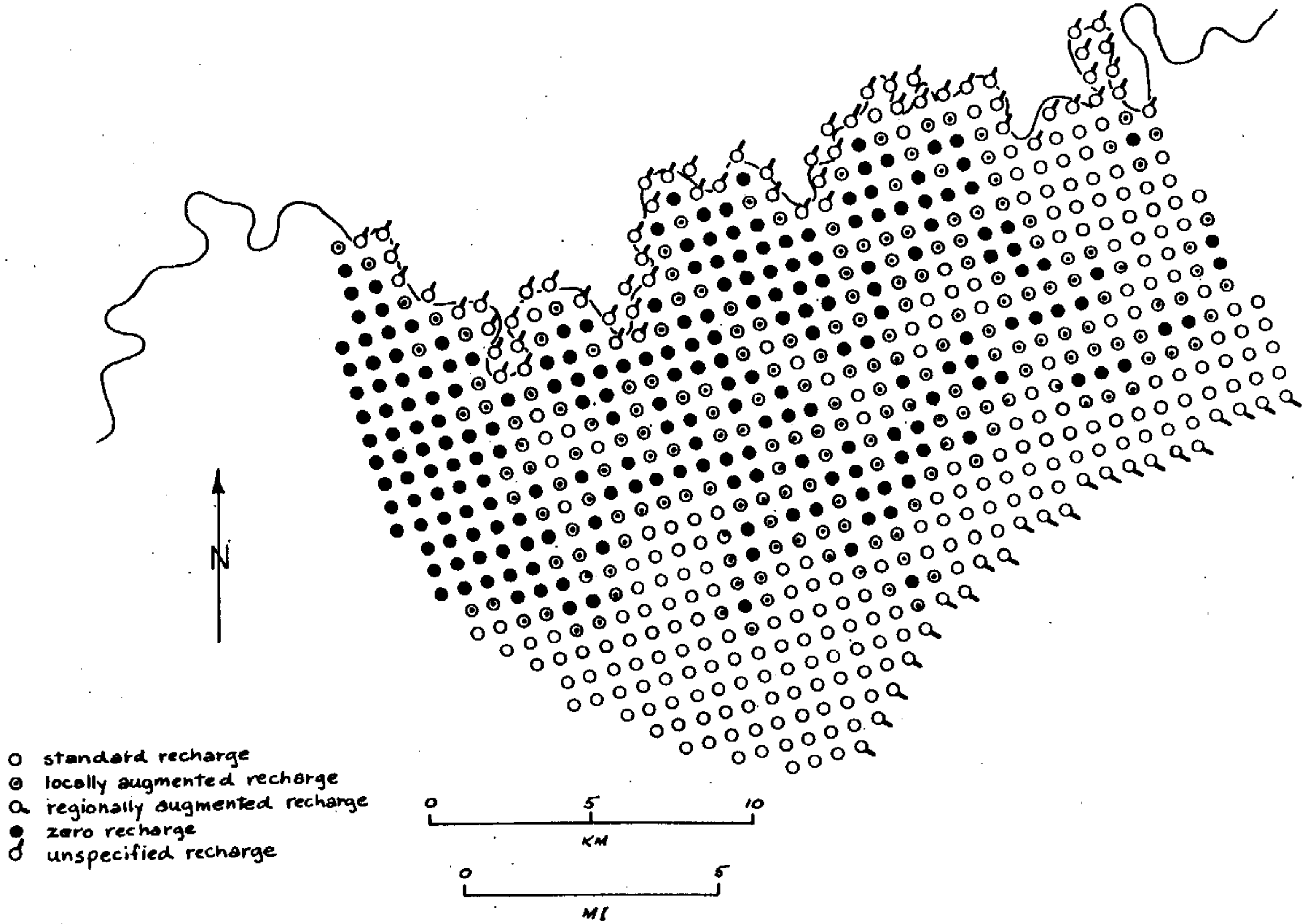


FIGURE 9

Aquifer flow entering the model from the southeast was taken to be that calculated in Model 1.

Results

After 1300 iterations, a satisfactorily convergent solution was still not obtained for Model 3 for reasons which will be discussed below. An approximate solution yielded the results shown on Figure 10 and listed in Table 7. A permeability of 130,000 ft^3/min was used; the same as that used for Model 1.

TABLE 7

COMPARISON OF OBSERVED AND MODEL 3 CALCULATED FLOWS AND DISCHARGES (ft^3/min)

Point (Figure 10)	Observed flow or discharge (See Figures 4 and 5 for reference)	Corresponding node or branch	Model 3 flow or discharge
1 + 2	discharge: 8000	7,20 + 8,20	- 400
3 + 4	discharge: 95	13,21 + 13,22	2400
5	discharge: 2000	21,23	7300
6	flow north: 3300	7,17 - 7,18	650 south
7	flow north: 2700	9,10 - 9,11	1400 south
8	flow north: 4700	36,13 - 36,14	9100 north

NORTH - CENTRAL
SINKHOLE PLAIN
AQUIFER

MODEL 3 VALUES OF HEAD

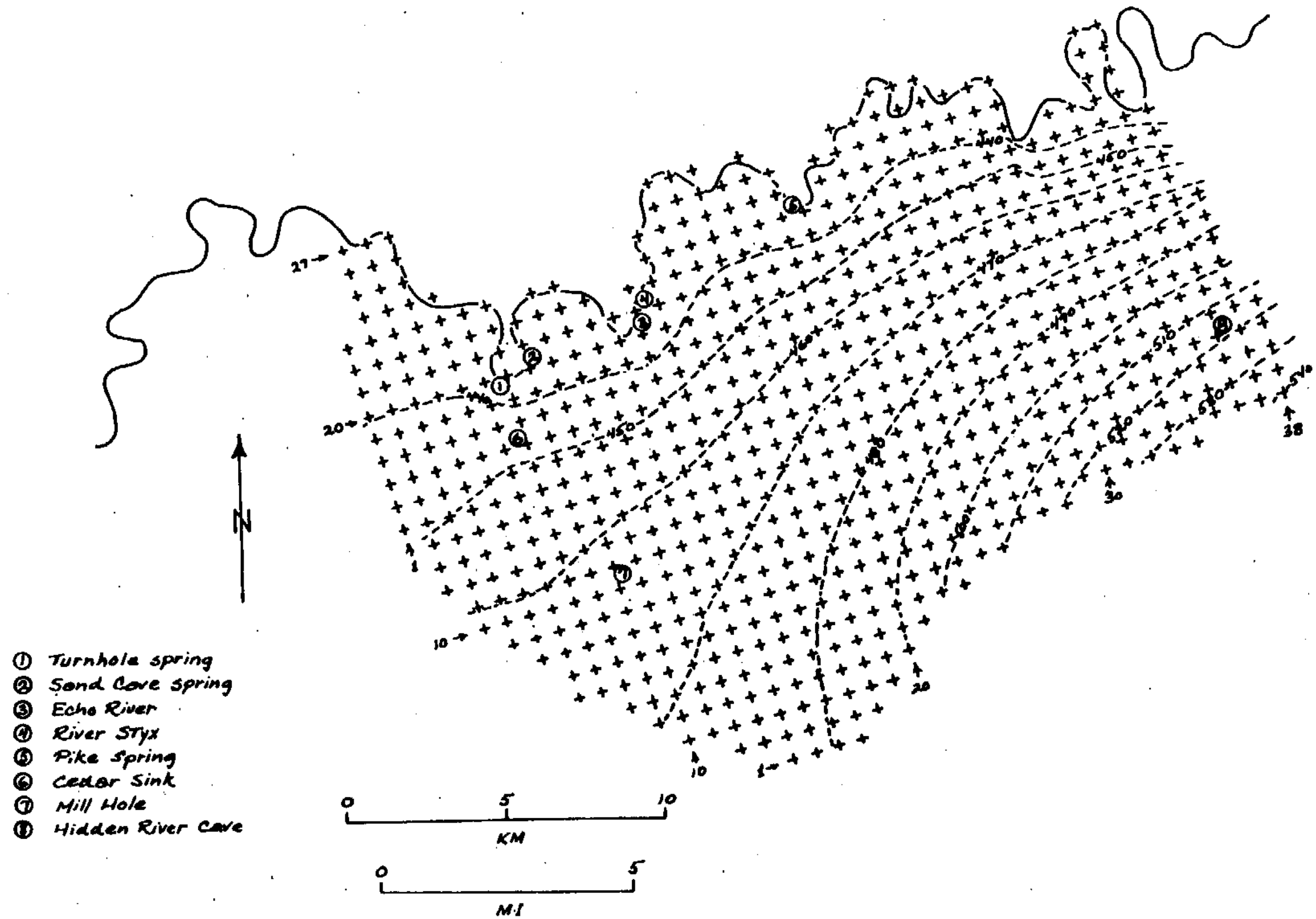


FIGURE 10

CHAPTER VI

CONCLUDING SUMMARY

The results presented in this report are believed to demonstrate the validity of the basic approach investigated. Models 1 and 2 of the entire Sinkhole Plain Aquifer show close correspondence with observed aquifer parameters. It has been shown that Model 1, calculated for laminar flow, and Model 2, calculated for turbulent (wholly rough) flow are sufficiently similar to require detailed observations of the aquifer to discriminate the flow regime in the aquifer, which confirms an earlier conclusion by the writer (Thrailkill, 1968). The existence of large discharges from the aquifer (probably in the form of underwater springs) predicted by the models suggests areas favorable for groundwater exploration and indicates flow paths of groundwater pollution in the area.

As stated in the introduction, the original objectives of the project were significantly reduced in number and scale as a result of time and funding reductions imposed on the project after its initiation. The revised objectives were to (1) write a digital computer program to model the flow in a limestone aquifer, (2) use the program to construct models of a real aquifer of interest, and (3) study the changes in an aquifer with time based on its response to currently available geochemical parameters. Objectives (1) and (2) were accomplished, although there are many routines in the program which require revision to improve their efficiency. The improvements needed in the program and the accomplishment of Objective (3) were prevented by the exhaustion of computer funds, even though a significant amount of non-project funds were also used. It is felt that the major objectives of the project were accomplished and that further work in this direction will provide considerable insight into the nature of the limestone aquifer.

PUBLICATIONS AND TRAINING ACCOMPLISHED

Publications

None as yet (other than progress report)

Training accomplished

One graduate student, David P. Beiter, was supported by and contributed to the project for the academic year 1970-71. Mr. Beiter's research project for the Ph. D. dissertation involves a study of the kinetic factors in the solutional enlargement of flow conduits in limestone.

Some of the results of this project are being utilized in a graduate course in hydrogeology now being offered.

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APPENDIX

KENTUCKY LIMESTONE AQUIFER MODEL

```
C
C ********************************************************************
C ***         *****                                  *****      *****
C ***  KLAM   *****  KENTUCKY LIMESTONE AQUIFER MODEL *****  KLAM *****
C ***         *****                                  *****      *****
C ********************************************************************
C
C *****************************************************************
C *************** MAIN *** MAIN *** MAIN ****************************
C *****************************************************************
C
C LOWEST STATEMENT NUMBER IS 510
C HIGHEST STATEMENT NUMBER IS 586
C HIGHEST STATEMENT NUMBER IS 585
C OTHER NUMBERS AVAILABLE ARE 538 THRU 543
C
      C=C
C
C ***************** DATA FORMAT ***************************************
C
C FIRST CARD IS PARAMETER CARD:
C
C    CARD COLUMNS
C
C      1 THRU  5    NO. OF NODES PER ROW (IMAX) - INTEGER
C      6 THRU 10    NO. OF ROWS OF NODES (JMAX) - INTEGER
C     11 THRU 15    MAXIMUM ACCEPTABLE ERROR IN FLOW AT A NODE (FERROR)
C     16 THRU 20    MAXIMUM ACCEPTABLE ERROR IN HEAD IN A BRANCH (HERROR)
C     21 THRU 25    TURBULENT FLOW EXPONENT (XP)
C     26 THRU 30    COEFFICIENT TO OVERRELAX (IF GREATER THAN 1) (ORLX)
C     31 THRU 35    MAXIMUM NO. OF ITERATIONS PERMITTED (MAXIT) - INTEGER
C
C     36            A 1 IN THIS COLUMN READS DATA WITH SUBROUTINE IN1
C     37            A 1 IN THIS COLUMN READS DATA WITH SUBROUTINE IN2
C     38            A 1 IN THIS COLUMN READS INITIAL VALUES WITH
C                   SUBROUTINE IN3
C
C     41            A 1 IN THIS COLUMN CAUSES OUTPUT WITH SUBROUTINE OUT1
C     42            A 1 IN THIS COLUMN CAUSES OUTPUT WITH SUBROUTINE OUT2
C     43            A 1 IN THIS COLUMN CAUSES OUTPUT WITH SUBROUTINE OUT3
```

```
C      44              A 1 IN THIS COLUMN PUNCHES FINAL VALUES WITH
C                      SUBROUTINE OUT4
C
      C=C
C
C      51              A DIGIT (N) IN THIS COLUMN CAUSES OUTPUT WITH OUT1
C                      EVERY 2**N AND (2**N)+1 ITERATIONS
C      52              MULTIPLIER (LEAVE BLANK FOR 1) OF HEAD ASSIGNED TO
C                      RECHARGE NODES IN SUBROUTINE CAL3 (MFAC)
C      53              A 1 IN THIS COLUMN CONTINUES EXECUTION IF NUMBER
C                      OF ENTERED VARIABLES IS NOT EQUAL TO REQUIRED NUMBER
C      54              A DIGIT (QI) IN THIS COLUMN IS AMOUNT IN TENTHS
C                      OF HEAD ERROR USED FOR FLOW ADJUSTMENT
C      55              A 1 IN THIS COLUMN MAKES QI AMOUNT IN HUNDREDTHS,
C                      A 2 IN THOUSANDTHS, AND A 3 IN TEN-THOUSANDTHS
C
C      61 THRU 69      A 1 IN THESE COLUMNS WILL CAUSE DELETION OF MAPS
C                      WRITTEN UNDER SUBROUTINE OUT3 AS FOLLOWS:
C
C                      61 MAP 1 (ENTERED HEAD - BH)
C                      62 MAP I (FINAL HEAD - H)
C                      63 MAP 3 (ENTERED RECHARGE - BFR)
C                      64 MAP 4 (FINAL RECHARGE - FR)
C                      65 MAP 5 (ENTERED BRANCH FLOW - BFX AND BFY)
C                      66 MAP 6 (FINAL BRANCH FLOW - FX AND FY)
C                      67 MAP 7 (ENTERED PERMEABILITY - BKX AND BKY)
C                      68 MAP 8 (FINAL PERMEABILITY - KX AND KY)
C                      69 MAP 9 (BRANCH LENGTH - BLX AND BLY)
C
      C=C
C
C SEE INPUT SUBROUTINE FOR REMAINING DATA FORMAT
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2       BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3        KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4       I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
```

```
C
C DECLARE MAIN VARIABLES
C
      INTEGER HEADIV,FREBR(5),QI
C
C READ PARAMETER CARD
C
      READ (5,531) IMAX,JMAX,FERROR,HERROR,XP,ORLX,MAXIT,IO1,IO4,IO6,
     2             IO2,IO3,IO5,IO7,MM1,MFAC,MGO,QI,JQ,ID1,ID2,ID3,ID4,
     3             ID5,ID6,ID7,ID8,ID9
  531 FORMAT (2I5,4F5.0,I5,3I1,2X,4I1,6X,5I1,5X,9I1)
      IF (MFAC.EQ.0) MFAC=1
C
C WRITE OUT PARAMETERS
C
      WRITE (6,523)
  523 FORMAT ('1PARAMETERS USED IN EXECUTION ARE:')
      WRITE (6,524) IMAX
  524 FORMAT ('0      MAXIMUM VALUE OF I (IMAX) IS ',I5)
      WRITE (6,525) JMAX
  525 FORMAT ('0      MAXIMUM VALUE OF J (JMAX) IS ',I5)
      WRITE (6,526) FERROR
  526 FORMAT ('0      MAXIMUM ERROR IN FLOW AT ANY NODE (FERROR) IS ',G10
     2.3)
      WRITE (6,561) HERROR
  561 FORMAT ('0      MAXIMUM ERROR IN HEAD IN ANY BRANCH (HERROR) IS ',G
     210.3)
      WRITE (6,585) QI
  585 FORMAT ('0      DISTRIBUTION FACTOR FOR HEAD ADJUSTMENT (QI) IS ',I
     21)
      IF (JQ.NE.0) WRITE (6,586) JQ
  586 FORMAT ('0      DISTRIBUTION FACTOR (QI) MULTIPLIED BY 10**-',I1)
      WRITE (6,559) XP
  559 FORMAT ('0      FLOW EXPONENT (XP) IS ',G10.3)
      WRITE (6,527) ORLX
  527 FORMAT ('0      RELAXATION COEFFICIENT (ORLX) IS ',G10.3)
      WRITE (6,528) MAXIT
  528 FORMAT ('0      MAXIMUM NUMBER OF ITERATIONS PERMITTED (MAXIT) IS '
     2,I5)
      IF (IO1.EQ.1) WRITE (6,571)
  571 FORMAT ('0      DATA READ WITH SUBROUTINE IN1')
```

```
      IF (ID4.EQ.1) WRITE (6,574)
  574 FORMAT ('0     DATA READ WITH SUBROUTINE IN2')
      IF (ID4.EQ.1) WRITE (6,553) MFAC
  553 FORMAT ('0              MULTIPLIER OF ',I1,' USED WITH CAL3')
      IF (ID6.EQ.1) WRITE (6,540)
  540 FORMAT ('0     INITIAL VALUES ENTERED WITH SUBROUTINE IN3')
      IF (ID2.EQ.1) WRITE (6,572)
  572 FORMAT ('0     OUTPUT WITH SUBROUTINE OUT1')
      IF (ID2.EQ.1) WRITE (6,575) MM1,MM1
  575 FORMAT ('0              OUTPUT EVERY 2**',I1,' AND (2**',I1,')+1 ITERA
     2TIONS')
      IF (ID3.EQ.1) WRITE (6,573)
  573 FORMAT ('0     OUTPUT WITH SUBROUTINE OUT2')
      IF (ID5.EQ.1) WRITE (6,557)
  557 FORMAT ('0     OUTPUT WITH SUBROUTINE OUT3. THE FOLLOWING MAPS HAV
     2E BEEN DELETED:')
      IF (ID1.EQ.1) WRITE (6,556)
  556 FORMAT ('0              MAP 1 (ENTERED HEAD - BH)')
      IF (ID2.EQ.1) WRITE (6,555)
  555 FORMAT ('0              MAP 2 (FINAL HEAD - H)')
      IF (ID3.EQ.1) WRITE (6,554)
  554 FORMAT ('0              MAP 3 (ENTERED RECHARGE - BFR)')
      IF (ID4.EQ.1) WRITE (6,522)
  522 FORMAT ('0              MAP 4 (FINAL RECHARGE - FR)')
      IF (ID5.EQ.1) WRITE (6,521)
  521 FORMAT ('0              MAP 5 (ENTERED BRANCH FLOW - BFX AND BFY)')
      IF (ID6.EQ.1) WRITE (6,517)
  517 FORMAT ('0              MAP 6 (FINAL BRANCH FLOW - FX AND FY)')
      IF (ID7.EQ.1) WRITE (6,513)
  513 FORMAT ('0              MAP 7 (ENTERED PERMEABILITY - BKX AND BKY)')
      IF (ID8.EQ.1) WRITE (6,576)
  576 FORMAT ('0              MAP 8 (FINAL PERMEABILITY - KX AND KY)')
      IF (ID9.EQ.1) WRITE (6,577)
  577 FORMAT ('0              MAP 9 (BRANCH LENGTH - BLX AND BLY)')
      IF (ID1.NE.1.AND.ID2.NE.1.AND.ID3.NE.1.AND.ID4.NE.1.AND.ID5.NE.1.
     2   AND.ID6.NE.1.AND.ID7.NE.1.AND.ID8.NE.1.AND.ID9.NE.1) WRITE
     3   (6,578)
  578 FORMAT ('0              NO MAPS DELETED')
      IF (ID7.EQ.1) WRITE (6,539)
  539 FORMAT ('0     FINAL VALUES PUNCHED WITH SUBROUTINE OUT4')
```

```
C  INITIALIZE ALL ARRAYS
C
      IMAXM1=IMAX-1
      JMAXM1=JMAX-1
      DO 529 I=1,IMAX
      DO 530 J=1,JMAX
      H(I,J)=0.
      BH(I,J)=0.
      FX(I,J)=0.
      BFX(I,J)=0.
      FY(I,J)=0.
      BFY(I,J)=0.
      FR(I,J)=0.
      BFR(I,J)=0.
      KX(I,J)=0.
      BKX(I,J)=0.
      KY(I,J)=0.
      BKY(I,J)=0.
      BLX(I,J)=0.
      BLY(I,J)=0.
  530 CONTINUE
  529 CONTINUE
      IF (I01.EQ.1) CALL IN1
      IF (I04.EQ.1) CALL IN2
C
C  TEST FOR CORRECT NUMBER OF ENTERED VALUES
C
      CALL CAL2 (MGO)
C
C  ASSIGN INITIAL VALUES
C
      IF (I06.EQ.1) CALL IN3
      IF (I06.NE.1) CALL CAL3 (MFAC,KCHEK)
C
C  **************** BEGIN ITERATIONS ***********************************
C
      IF (JQ.EQ.1) QI=.1*QI
      IF (JQ.EQ.2) QI=.01*QI
      IF (JQ.EQ.3) QI=.001*QI
      QH=.1*QI
      [illegible]
```

```
      KO2=0
      ITER=0
      KK=0
  550 ITER=ITER+1
      CNTER=0
      KNTR=0
C
C **************** BEGIN CALCULATIONS FOR EACH NODE *******************
C
      DO 511 I=1,IMAX
      DO 512 J=1,JMAX
C
C **************** CALCULATE KX AND KY IF UNDEFINED ********************
C
      IF (KCHEK.EQ.1) CALL CAL1
C
C ***************** BEGIN HEAD CALCULATIONS ****************************
C
      MFX1=1
      MFY1=1
      MFX2=1
      MFY2=1
      IF (FX(I-1,J).LT.0.) MFX1=-1
      AFX1=ABS(FX(I-1,J))
      IF (FY(I,J-1).LT.0.) MFY1=-1
      AFY1=ABS(FY(I,J-1))
      IF (FX(I,J).LT.0.) MFX2=-1
      AFX2=ABS(FX(I,J))
      IF (FY(I,J).LT.0.) MFY2=-1
      AFY2=ABS(FY(I,J))
C
C CHECK FOR ENTERED VALUE AND SKIP CALCULATIONS
C
  514 IF (BH(I,J).NE.0.) GO TO 515
C
C CALCULATE H IF I NE 1, J NE 1, I NE IMAX, J NE JMAX, I-1 KX NE 0, J-1
C KY NE 0, KX NE 0, OR KY NE 0
C
      IF (I.EQ.1.OR.J.EQ.1.OR.I.EQ.IMAX.OR.J.EQ.JMAX) GO TO 516
      IF (KX(I,J).LT.0.0001.OR.KY(I,J).LT.0.0001.OR.KX(I-1,J).LT.0.0001.
     2 OR.KY(I,J-1).LT.0.0001) GO TO 516
```

```
      IF ((FX(I-1,J  ).LT.1.0E-70.AND.FX(I-1,J  ).GT.-1.0E-70).OR.
     2    (FY(I  ,J-1).LT.1.0E-70.AND.FY(I  ,J-1).GT.-1.0E-70).OR.
     3    (FX(I  ,J  ).LT.1.0E-70.AND.FX(I  ,J  ).GT.-1.0E-70).OR.
     4    (FY(I  ,J  ).LT.1.0E-70.AND.FY(I  ,J  ).GT.-1.0E-70)) GOTO 516
      H(I,J)=(((-(BLX(I-1,J)*MFX1*(AFX1**XP))/KX(I-1,J))+H(I-1,J))
     2        +((-(BLY(I,J-1)*MFY1*(AFY1**XP))/KY(I,J-1))+H(I,J-1))
     3        +(( (BLX(I,J  )*MFX2*(AFX2**XP))/KX(I,J  ))+H(I+1,J))
     4        +(( (BLY(I,J  )*MFY2*(AFY2**XP))/KY(I,J  ))+H(I,J+1)))/4.
C
C SET BRANCH TERMS EQ 0 IF ALL FOUR BRANCHES NOT PRESENT
C
  516 IF (I.EQ.1) GO TO 518
      IF (KX(I-1,J).LT.0.0001) GO TO 518
      IF  (FX(I-1,J  ).LT.1.0E-70.AND.FX(I-1,J  ).GT.-1.0E-70) GO TO 518
      GO TO 519
  518 AHEAD=0.0
      GO TO 520
  519 AHEAD=   (-(BLX(I-1,J)*MFX1*(AFX1**XP))/KX(I-1,J))+H(I-1,J)
  520 IF (J.EQ.1) GO TO 552
      IF (KY(I,J-1).LT.0.0001) GO TO 552
      IF  (FY(I  ,J-1).LT.1.0E-70.AND.FY(I  ,J-1).GT.-1.0E-70) GO TO 552
      GO TO 563
  552 BHEAD=0.0
      GO TO 564
  563 BHEAD=   (-(BLY(I,J-1)*MFY1*(AFY1**XP))/KY(I,J-1))+H(I,J-1)
  564 IF (I.EQ.IMAX.OR.KX(I,J).LT.0.0001) GO TO 565
      IF  (FX(I  ,J  ).LT.1.0E-70.AND.FX(I  ,J  ).GT.-1.0E-70) GO TO 565
      GO TO 566
  565 CHEAD=0.0
      GO TO 567
  566 CHEAD=   ( (BLX(I,J  )*MFX2*(AFX2**XP))/KX(I,J  ))+H(I+1,J)
  567 IF (J.EQ.JMAX.OR.KY(I,J).LT.0.0001) GO TO 568
      IF  (FY(I  ,J  ).LT.1.0E-70.AND.FY(I  ,J  ).GT.-1.0E-70) GO TO 568
      GO TO 569
  568 DHEAD=0.0
      GO TO 570
  569 DHEAD=   ( (BLY(I,J  )*MFY2*(AFY2**XP))/KY(I,J  ))+H(I,J+1)
C
C COUNT NUMBER OF BRANCHES
C
  570 HEADIV=4
```

```
      IF (AHEAD.EQ.0.0) HEADIV=HEADIV-1
      IF (BHEAD.EQ.0.0) HEADIV=HEADIV-1
      IF (CHEAD.EQ.0.0) HEADIV=HEADIV-1
      IF (DHEAD.EQ.0.0) HEADIV=HEADIV-1
      IF (HEADIV.EQ.0) GO TO 515
C
C SUM BRANCH TERMS AND DIVIDE BY NUMBER OF BRANCHES
C
      H(I,J)=(AHEAD+BHEAD+CHEAD+DHEAD)/HEADIV
C
C **************** CALCULATE ERROR IN FLOW AT NODE ********************
C
C CALCULATE FLOW ERROR AND COMPARE WITH FERROR
C
  515 CONTINUE
      IF (I.EQ.1) GO TO 534
      IF (J.EQ.1) GO TO 535
      ERINF=FX(I,J)+FY(I,J)-FR(I,J)-FX(I-1,J)-FY(I,J-1)
      GO TO 536
  534 IF (J.EQ.1) GO TO 537
      ERINF=FX(I,J)+FY(I,J)-FR(I,J)-FY(I,J-1)
      GO TO 536
  537 ERINF=FX(I,J)+FY(I,J)-FR(I,J)
      GO TO 536
  535 ERINF=FX(I,J)+FY(I,J)-FR(I,J)-FX(I-1,J)
  536 ABER=ABS(ERINF)
      IF (ABER.GT.FERROR) CNTER=CNTER+1
C
C CALCULATE HEAD ERRORS IN BRANCHES
C
      MFLR=1
      MFLU=1
      MFLL=1
      MFLD=1
      AFLR=0.
      AFLU=0.
      AFLL=0.
      AFLD=0.
      CALFLR=0.
      CALFLU=0.
      CALFLL=0.
```

```
      CALFLD=0.
      IF (I.EQ.IMAX) GO TO 581
      IF        ((KX(I,J)*(H(I,J)-H(I+1,J))/BLX(I,J)).LT.0.) MFLR=-1
      AFLR=ABS (KX(I,J)*(H(I,J)-H(I+1,J))/BLX(I,J))
  581 IF (J.EQ.JMAX) GO TO 582
      IF        ((KY(I,J)*(H(I,J)-H(I,J+1))/BLY(I,J)).LT.0.) MFLU=-1
      AFLU=ABS (KY(I,J)*(H(I,J)-H(I,J+1))/BLY(I,J))
  582 IF (I.EQ.1) GO TO 583
      IF        ((KX(I-1,J)*(H(I,J)-H(I-1,J))/BLX(I-1,J)).GT.0.) MFLL=-1
      AFLL=ABS (KX(I-1,J)*(H(I,J)-H(I-1,J))/BLX(I-1,J))
  583 IF (J.EQ.1) GO TO 584
      IF        ((KY(I,J-1)*(H(I,J)-H(I,J-1))/BLY(I,J-1)).GT.0.) MFLD=-1
      AFLD=ABS (KY(I,J-1)*(H(I,J)-H(I,J-1))/BLY(I,J-1))
  584 IF (AFLR.NE.0.) CALFLR=(AFLR**(1./XP))*MFLR
      IF (AFLU.NE.0.) CALFLU=(AFLU**(1./XP))*MFLU
      IF (AFLL.NE.0.) CALFLL=(AFLL**(1./XP))*MFLL
      IF (AFLD.NE.0.) CALFLD=(AFLD**(1./XP))*MFLD
C
C DISTRIBUTE FLOW ERROR
C
      DO 538 L=1,5
  538 FREBR(L)=1
      IF (I.EQ.IMAX.OR.BFX(I,J).NE.0..OR.BKX(I,J).EQ.12345.) FREBR(1)=0
      IF (J.EQ.JMAX.OR.BFY(I,J).NE.0..OR.BKY(I,J).EQ.12345.) FREBR(2)=0
      IF (I.EQ.1) GO TO 580
      IF (BFX(I-1,J).NE.0..OR.BKX(I-1,J).EQ.12345.) FREBR(3)=0
  580 IF (J.EQ.1) GO TO 544
      IF (BFY(I,J-1).NE.0..OR.BKY(I,J-1).EQ.12345.) FREBR(4)=0
  544 IF (BFR(I,J).NE.0.) FREBR(5)=0
      IF (I.EQ.1) FREBR(3)=0
      IF (J.EQ.1) FREBR(4)=0
      TOTFRE=0.
      DO 545 L=1,5
  545 TOTFRE=TOTFRE+FREBR(L)
      IF (TOTFRE.EQ.0.) GO TO 562
      IF (FREBR(1).EQ.1) FX(I,J)=FX(I,J)-ORLX*((QF*ERINF/TOTFRE)
     2                           +(QH*(CALFLR-FX(I,J))))
      IF (FREBR(2).EQ.1) FY(I,J)=FY(I,J)-ORLX*((QF*ERINF/TOTFRE)
     2                           +(QH*(CALFLU-FY(I,J))))
      IF (FREBR(3).EQ.1) FX(I-1,J)=FX(I-1,J)+ORLX*((QF*ERINF/TOTFRE)
     2                           +(QH*(CALFLL-FX(I-1,J))))
```

```
      IF (FREBR(4).EQ.1) FY(I,J-1)=FY(I,J-1)+ORLX*((QF*ERINF/TOTFRE)
     2                         +(QH*(CALFLD-FY(I,J-1))))
      IF (FREBR(5).EQ.1) FR(I,J)=FR(I,J)+(ORLX*(ERINF/TOTFRE))
C
C CALCULATE HEAD ERRORS AND COMPARE WITH HERROR
C
      HEDERX=0.
      HEDERY=0.
      IF (I.EQ.IMAX) GO TO 547
      IF (KX(I,J).LT.0.0001) GO TO 547
      HEDERX=((BLX(I,J)*MFX2*(AFX2**XP))/KX(I,J))-H(I,J)+H(I+1,J)
  547 IF (J.EQ.JMAX) GO TO 546
      IF (KY(I,J).LT.0.0001) GO TO 546
      HEDERY=((BLY(I,J)*MFY2*(AFY2**XP))/KY(I,J))-H(I,J)+H(I,J+1)
  546 CONTINUE
      ABERX=ABS(HEDERX)
      ABERY=ABS(HEDERY)
      IF (ABERX.GT.HERROR) KNTR=KNTR+1
      IF (ABERY.GT.HERROR) KNTR=KNTR+1
      IF (KK.EQ.1) CALL OUT3C (KNTR,HEDERX,HEDERY)
  562 IF (IO2.EQ.1) CALL OUT1 (MM1,HEDERX,HEDERY,KNTR)
  551 CONTINUE
  512 CONTINUE
  511 CONTINUE
C
C ***************** TEST FOR NEXT ITERATION *****************************
C
      IF (IO3.EQ.1.AND.(ITER.EQ.MAXIT-1.OR.(CNTER.EQ.0.AND.KNTR.EQ.0)))
     2    CALL OUT2 (KO2)
      IF (IO7.EQ.1.AND.(ITER.EQ.MAXIT.OR.(CNTER.EQ.0.AND.KNTR.EQ.0)))
     2    CALL OUT4
      IF (IO5.EQ.1) GO TO 558
      IF (ITER.GE.MAXIT) GO TO 548
      IF (CNTER.EQ.0.AND.KNTR.EQ.0) GO TO 549
      GO TO 550
  548 WRITE (6,532) ITER,MAXIT
  532 FORMAT ('OEXECUTION TERMINATED - NUMBER OF ITERATIONS (',I5,') EQU
     2ALS MAXIMUM SPECIFIED (',I5,')')
      RETURN
  549 WRITE (6,533) FERROR,HERROR,ITER
  533 FORMAT ('OEXECUTION COMPLETED - ALL FLOW ERRORS BELOW MAXIMUM (',G
```

```
     212.5,') AND ALL HEAD ERRORS BELOW MAXIMUM (',G12.5,') - ',I5,' ITE
     3R.')
      RETURN
  558 CONTINUE
      IF (CNTER.EQ.0.AND.KNTR.EQ.0) GO TO 510
      IF (ITER.EQ.MAXIT-1) GO TO 510
      IF (ITER.EQ.MAXIT) GO TO 579
      GO TO 550
  510 CALL OUT3B (KK,FERROR,HERROR,MAXIT,KNTR)
      IF (KK.EQ.1) GO TO 550
  579 CONTINUE
      IF (IO5.EQ.1) CALL OUT3 (ID1,ID2,ID3,ID4,ID5,ID6,ID7,ID8,ID9)
      RETURN
      END
      SUBROUTINE IN1
C
C *******************************************************************
C **************** SUBROUTINE IN1 ***********************************
C *******************************************************************
C
C STATEMENT NUMBERS USED ARE 401,405,407,408,409,500,509,510
C
C ****************DATA FORMAT ***************************************
C
C DATA CARDS ARE NODE CARDS
C
C    CAN BE IN ANY ORDER BUT MUST BE ONE FOR EACH I AND J IN RECTANGULAR
C     ARRAY. ANY BLANK OR ZERO PUNCHED FIELDS WILL BE CONSIDERED
C     UNKNOWNS. ENTERED ZERO'S MUST BE PUNCHED 12345 IN LAST 5 COLUMNS
C     OR 12345. IN ANY PART OF FIELD. TOTAL NUMBER OF SPECIFIED HEAD,
C     FLOW; AND PERMEABILITY VALUES MUST = (3*IMAX*JMAX)-IMAX-JMAX.
C
C BLANK OR ZERO IN LENGTH FIELDS WILL BE CONSIDERED UNIT LENGTH,
C OTHERWISE PUNCH NUMBER. ZERO (12345) LENGTHS NOT PERMITTED.
C
      C=C
C
C    CARD COLUMNS
C
C      1 THRU  5   NODE NUMBER IN ROW (I) - INTEGER
C      6 THRU 10   ROW NUMBER (J) - INTEGER
```

```
C       11 THRU 20    HEAD AT NODE (BH(I,J))
C       21 THRU 30    FLOW IN +X DIRECTION FROM NODE (BFX(I,J))
C       31 THRU 40    FLOW IN +Y DIRECTION FROM NODE (BFY(I,J))
C       41 THRU 50    RECHARGE FLOW INTO NODE (BFR(I,J))
C       51 THRU 60    PERMEABILITY IN +X DIRECTION FROM NODE (BKX(I,J))
C       61 THRU 70    PERMEABILITY IN +Y DIRECTION FROM NODE (BKY(I,J))
C       71 THRU 75    LENGTH IN +X DIRECTION FROM NODE (BLX(I,J))
C       76 THRU 80    LENGTH IN +Y DIRECTION FROM NODE (BLY(I,J))
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2        BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3         KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4        I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C READ NODE CARDS
C
      NODMAX=IMAX*JMAX
      DO 500 L=1,NODMAX
  500 READ (5,401) I,J,BH(I,J),BFX(I,J),BFY(I,J),BFR(I,J),BKX(I,J),
     2             BKY(I,J),BLX(I,J),BLY(I,J)
  401 FORMAT (2I5,6F10.0,2F5.0)
C
C CORRECT LENGTH VALUES
C
      DO 405 I=1,IMAX
      DO 409 J=1,JMAX
      IF (BLX(I,J).EQ.0.) BLX(I,J)=1.
      IF (BLY(I,J).EQ.0.) BLY(I,J)=1.
  409 CONTINUE
  405 CONTINUE
C
C WRITE OUT ENTERED DATA
C
      WRITE(6,408)
  408 FORMAT('1                 I          J          BH          BFX         BFY
     2        BFR        BKX        BKY        BLX        BLY'//)
      DO 509 I=1,IMAX
```

```
      DO 510 J=1,JMAX
      WRITE(6,407) I,J,BH(I,J),BFX(I,J),BFY(I,J),BFR(I,J),BKX(I,J),
     2             BKY(I,J),BLX(I,J),BLY(I,J)
  407 FORMAT  (' ',12X,I5,5X,I5,3X,8F10.3)
  510 CONTINUE
  509 CONTINUE
C
C TEST FOR CORRECT NUMBER OF ENTERED VALUES
C
      CALL CAL2
C
C ASSIGN INITIAL VALUES
C
      CALL CAL3 (MFAC,KCHEK)
      RETURN
      END
      SUBROUTINE IN2
C
C ************************************************************************
C **************** SUBROUTINE IN2 ****************************************
C ************************************************************************
C
C HIGHEST STATEMENT NUMBER IS 116
C
C **************** DATA FORMAT *******************************************
C
C FIRST DATA CARD (AFTER PARAMETER CARD) IS GENERAL TO LOAD ALL ARRAYS.
C ENTER VALUES IN THREE OF FIRST SIX FOR CORRECT NUMBER OF ENTERED
C VALUES. BLANK OR ZERO CONSIDERED UNKNOWN, 12345.0 FOR ZERO, DECIMAL
C POINT TO RIGHT OF LAST POSITION UNLESS PUNCHED, ZERO BLX AND BLY
C NOT PERMITTED.
C
C    CARD COLUMNS
C
C      1 THRU 10   HEAD (BH)
C     11      20   FLOW IN BRANCH TO RIGHT, POSITIVE IF TO RIGHT (BFX)
C     21      30   FLOW IN BRANCH ABOVE, POSITIVE IF UP (BFY)
C     31      40   RECHARGE FLOW, POSITIVE IF INTO SYSTEM (BFR)
C     41      50   PERMEABILITY IN BRANCH TO RIGHT (BKX)
C     51      60   PERMEABILITY IN BRANCH ABOVE (BKY)
C     61      70   LENGTH OF BRANCH TO RIGHT (BLX)
```

```
C       71        80   LENGTH OF BRANCH ABOVE (BLY)
C
      C=C
C
C REMAINING DATA CARDS ARE CHANGE CARDS WITH FOUR NODES PER CARD
C
C    CARD COLUMNS
C
C          1          DIGIT INDICATING VARIABLE:
C         21
C         41             1 FOR BH       5 FOR BKX
C         61             2 FOR BFX      6 FOR BKY
C                        3 FOR BFY      7 FOR BLX
C                        4 FOR BFR      8 FOR BLY
C
C                        0 TO SIGNAL END OF DATA
C
C       2 THRU  5     NODE NUMBER IN ROW (I) - INTEGER
C      22        25
C      42        45
C      62        65
C
C      6,26,46,66     BLANK
C
C       7 THRU 10     ROW NUMBER (J) - INTEGER
C      27        30
C      47        50
C      67        70
C
      C=C
C
C      11 THRU 20     VALUE OF VARIABLE
C      31        40
C      51        60
C      71        80
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2       BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3        KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
```

```
     4          I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C DECLARE IN2 VARIABLES
C
      REAL IG1,IG2,IG3,IG4,IG5,IG6,IG7,IG8
C
C READ GENERAL DATA CARD
C
      READ (5,108) IG1,IG2,IG3,IG4,IG5,IG6,IG7,IG8
  108 FORMAT (8F10.0)
      DO 109 I=1,IMAX
      DO 110 J=1,JMAX
      BH(I,J)=IG1
      BFR(I,J)=IG4
  110 CONTINUE
  109 CONTINUE
      DO 111 I=1,IMAXM1
      DO 112 J=1,JMAX
      BFX(I,J)=IG2
      BKX(I,J)=IG5
      BLX(I,J)=IG7
  112 CONTINUE
  111 CONTINUE
      DO 113 I=1,IMAX
      DO 114 J=1,JMAXM1
      BFY(I,J)=IG3
      BKY(I,J)=IG6
      BLY(I,J)=IG8
  114 CONTINUE
  113 CONTINUE
C
C READ CHANGE DATA CARDS
C
  116 READ (5,100) IV1,I1,J1,V1,IV2,I2,J2,V2,IV3,I3,J3,V3,IV4,I4,J4,V4
  100 FORMAT (4(I1,I4,1X,I4,F10.0))
      I=I1
      J=J1
      IF (IV1.EQ.0) GO TO 115
      IF (IV1.EQ.1)  BH(I,J)=V1
```

```
      IF (IV1.EQ.2) BFX(I,J)=V1
      IF (IV1.EQ.3) BFY(I,J)=V1
      IF (IV1.EQ.4) BFR(I,J)=V1
      IF (IV1.EQ.5) BKX(I,J)=V1
      IF (IV1.EQ.6) BKY(I,J)=V1
      IF (IV1.EQ.7) BLX(I,J)=V1
      IF (IV1.EQ.8) BLY(I,J)=V1
      I=I2
      J=J2
      IF (IV2.EQ.0) GO TO 115
      IF (IV2.EQ.1)  BH(I,J)=V2
      IF (IV2.EQ.2) BFX(I,J)=V2
      IF (IV2.EQ.3) BFY(I,J)=V2
      IF (IV2.EQ.4) BFR(I,J)=V2
      IF (IV2.EQ.5) BKX(I,J)=V2
      IF (IV2.EQ.6) BKY(I,J)=V2
      IF (IV2.EQ.7) BLX(I,J)=V2
      IF (IV2.EQ.8) BLY(I,J)=V2
      I=I3
      J=J3
      IF (IV3.EQ.0) GO TO 115
      IF (IV3.EQ.1)  BH(I,J)=V3
      IF (IV3.EQ.2) BFX(I,J)=V3
      IF (IV3.EQ.3) BFY(I,J)=V3
      IF (IV3.EQ.4) BFR(I,J)=V3
      IF (IV3.EQ.5) BKX(I,J)=V3
      IF (IV3.EQ.6) BKY(I,J)=V3
      IF (IV3.EQ.7) BLX(I,J)=V3
      IF (IV3.EQ.8) BLY(I,J)=V3
      I=I4
      J=J4
      IF (IV4.EQ.0) GO TO 115
      IF (IV4.EQ.1)  BH(I,J)=V4
      IF (IV4.EQ.2) BFX(I,J)=V4
      IF (IV4.EQ.3) BFY(I,J)=V4
      IF (IV4.EQ.4) BFR(I,J)=V4
      IF (IV4.EQ.5) BKX(I,J)=V4
      IF (IV4.EQ.6) BKY(I,J)=V4
      IF (IV4.EQ.7) BLX(I,J)=V4
      IF (IV4.EQ.8) BLY(I,J)=V4
      GO TO 116
```

```
C
C WRITE OUT ENTERED DATA
C
  115 WRITE (6,101)
  101 FORMAT ('1DATA ENTERED USING SUBROUTINE IN2')
      WRITE (6,102)
  102 FORMAT ('0',14X,'I',9X,'J',9X,'BH',8X,'BFX',8X,'BFY',7X,'BFR',8X,
     2          'BKX',8X,'BKY',8X,'BLX',8X,'BLY')
      DO 103 I=1,IMAX
      WRITE (6,104)
  104 FORMAT (' ')
      DO 105 J=1,JMAX
      WRITE (6,107) I,J,BH(I,J),BFX(I,J),BFY(I,J),BFR(I,J),BKX(I,J),
     2              BKY(I,J),BLX(I,J),BLY(I,J)
  107 FORMAT (' ',12X,I5,5X,I5,3X,8(G10.3,1X))
  105 CONTINUE
  103 CONTINUE
      RETURN
      END
      SUBROUTINE IN3
C
C *********************************************************************
C **************** SUBROUTINE IN3 **************************************
C *********************************************************************
C
C HIGHEST STATEMENT NUMBER IS 104
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2         BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3          KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4         I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C READ INITIAL VALUES FROM CARDS
C
      READ (5,100) NCARD
  100 FORMAT (I10)
      DO 101 N=1,NCARD
```

```
      READ (5,102) I,J,H(I,J),FX(I,J),FY(I,J),FR(I,J),KX(I,J),KY(I,J)
  102 FORMAT (2I5,6E10.3)
  101 CONTINUE
C
C ASSIGN ENTERED VALUES IF DEFINED (TO PERMIT CHANGES)
C
      DO 103 I=1,IMAX
      DO 104 J=1,JMAX
      IF (BH (I,J).NE.0      .) H (I,J)=BH (I,J)
      IF (BH (I,J).EQ.12345.) H (I,J)=0.
      IF (BFX(I,J).NE.0      .) FX(I,J)=BFX(I,J)
      IF (BFX(I,J).EQ.12345.) FX(I,J)=0.
      IF (BFY(I,J).NE.0      .) FY(I,J)=BFY(I,J)
      IF (BFY(I,J).EQ.12345.) FY(I,J)=0.
      IF (BFR(I,J).NE.0      .) FR(I,J)=BFR(I,J)
      IF (BFR(I,J).EQ.12345.) FR(I,J)=0.
      IF (BKX(I,J).NE.0      .) KX(I,J)=BKX(I,J)
      IF (BKX(I,J).EQ.12345.) KX(I,J)=0.
      IF (BKY(I,J).NE.0      .) KY(I,J)=BKY(I,J)
      IF (BKY(I,J).EQ.12345.) KY(I,J)=0.
  104 CONTINUE
  103 CONTINUE
      RETURN
      END
      SUBROUTINE CAL1
C
C ******************************************************************
C *************** SUBROUTINE CAL1 **********************************
C ******************************************************************
C
C HIGHEST STATEMENT NUMBER IS 101
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2        BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3         KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4        I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
      IF (I.EQ.IMAX.OR.BKX(I,J).NE.0.) GO TO 100
```

```
      HDIF=H(I,J)-H(I+1,J)
      IF (HDIF.LT.0.00001.AND.HDIF.GT.-0.00001) HDIF=1.
      IF (FX(I,J).LT.1.0E-70.AND.FX(I,J).GT.-1.0E-70) GO TO 100
      AFX2=ABS(FX(I,J))
      KX(I,J)=ABS((BLX(I,J)*(AFX2**XP))/HDIF)
  100 IF (J.EQ.JMAX.OR.BKY(I,J).NE.0) GO TO 101
      HDIF=H(I,J)-H(I,J+1)
      IF (HDIF.LT.0.00001.AND.HDIF.GT.-0.00001) HDIF=1.
      IF (FY(I,J).LT.1.0E-70.AND.FY(I,J).GT.-1.0E-70) GO TO 101
      AFY2=ABS(FY(I,J))
      KY(I,J)=ABS((BLY(I,J)*(AFY2**XP))/HDIF)
  101 RETURN
      END
      SUBROUTINE CAL2 (MGO)
C
C ******************************************************************
C **************** SUBROUTINE CAL2 **********************************
C ******************************************************************
C
C HIGHEST STATEMENT NUMBER IS 115
C OTHER NUMBER AVAILABLE IS 106
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2         BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3          KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4         I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C COUNT ENTERED VALUES
C
      KOUNT=0
      DO 100 I=1,IMAX
      DO 101 J=1,JMAX
      IF (BH(I,J).NE.0) KOUNT=KOUNT+1
      IF (BFR(I,J).NE.0.) KOUNT=KOUNT+1
  101 CONTINUE
  100 CONTINUE
      DO 102 I=1,IMAXM1
```

```
      DO 103 J=1,JMAX                                                  CAL2
      IF (BFX(I,J).NE.0.) KOUNT=KOUNT+1                                CAL2
      IF (BKX(I,J).NE.0.) KOUNT=KOUNT+1                                CAL2
  103 CONTINUE                                                         CAL2
  102 CONTINUE                                                         CAL2
      DO 104 I=1,IMAX                                                  CAL2
      DO 105 J=1,JMAXM1                                                CAL2
      IF (BFY(I,J).NE.0.) KOUNT=KOUNT+1                                CAL2
      IF (BKY(I,J).NE.0.) KOUNT=KOUNT+1                                CAL2
  105 CONTINUE                                                         CAL2
  104 CONTINUE                                                         CAL2
C                                                                      CAL2
C MAKE TESTS                                                           CAL2
C                                                                      CAL2
      KBV=(3*IMAX*JMAX)-IMAX-JMAX                                      CAL2
      KDIF=IABS(KBV-KOUNT)                                             CAL2
      KK1=0                                                            CAL2
      IF (KBV.GT.KOUNT) KK1=1                                          CAL2
      IF (KBV.LT.KOUNT) KK1=2                                          CAL2
C                                                                      CAL2
C WRITE MESSAGES                                                       CAL2
C                                                                      CAL2
      WRITE (6,107)                                                    CAL2
  107 FORMAT ('1DATA CHECKED USING SUBROUTINE CAL2')                   CAL2
      IF (KK1.EQ.0) GO TO 108                                          CAL2
      IF (KK1.EQ.1) GO TO 109                                          CAL2
      GO TO 110                                                        CAL2
  108 WRITE (6,111) KOUNT,KBV                                          CAL2
  111 FORMAT ('0     NUMBER OF ENTERED VALUES (',I5,') EQUALS REQUIRED N CAL2
     2UMBER (',I5,')')                                                 CAL2
      RETURN                                                           CAL2
  109 CONTINUE                                                         CAL2
      IF (MGO.EQ.1) GO TO 114                                          CAL2
      WRITE (6,112) KOUNT,KBV,KDIF                                     CAL2
  112 FORMAT ('0     EXECUTION TERMINATED - NUMBER OF ENTERED VALUES (', CAL2
     2I5,') IS LESS THAN REQUIRED NUMBER (',I5,') BY ',I5)             CAL2
      CALL EXIT                                                        CAL2
  110 CONTINUE                                                         CAL2
      IF (MGO.EQ.1) GO TO 114                                          CAL2
      WRITE (6,113) KOUNT,KBV,KDIF                                     CAL2
  113 FORMAT ('0     EXECUTION TERMINATED - NUMBER OF ENTERED VALUES (', CAL2
```

```
     2I5,') EXCEEDS REQUIRED NUMBER (',I5,') BY ',I5)
      CALL EXIT
  114 CONTINUE
      WRITE (6,115) KOUNT,KBV
  115 FORMAT ('0      NUMBER OF ENTERED VALUES (',I5,') NOT EQUAL TO REQU
     2IRED NUMBER (',I5,') - EXECUTION CONTINUES')
      RETURN
      END
      SUBROUTINE CAL3 (MFAC,KCHEK)
C
C *********************************************************************
C **************** SUBROUTINE CAL3 *************************************
C *********************************************************************
C
C HIGHEST STATEMENT NUMBER IS 137
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2     BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3      KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4     I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C SUM AND COUNT SPECIFIED NON-ZERO BH
C
      SUMH=0.
      NUMH=0
      DO 100 I=1,IMAX
      DO 101 J=1,JMAX
      IF (BH(I,J).EQ.12345..OR.BH(I,J).EQ.0.) GO TO 103
      SUMH=SUMH+BH(I,J)
      NUMH=NUMH+1
  103 CONTINUE
  101 CONTINUE
  100 CONTINUE
C
C SUM AND COUNT SPECIFIED K AND SUM L
C
      SUMK=0.
```

```
      NUMK=0
      SUML=0.
      NUML=(2*IMAX*JMAX)-IMAX-JMAX
      DO 104 I=1,IMAXM1
      DO 105 J=1,JMAX
      IF (BKX(I,J).EQ.12345..OR.BKX(I,J).EQ.0.) GO TO 106
      SUMK=SUMK+BKX(I,J)
      NUMK=NUMK+1
  106 SUML=SUML+BLX(I,J)
  105 CONTINUE
  104 CONTINUE
      DO 107 I=1,IMAX
      DO 108 J=1,JMAXM1
      IF (BKY(I,J).EQ.12345..OR.BKY(I,J).EQ.0.) GO TO 109
      SUMK=SUMK+BKY(I,J)
      NUMK=NUMK+1
  109 SUML=SUML+BLY(I,J)
  108 CONTINUE
  107 CONTINUE
C
C CALCULATE BFR BALANCE
C
      SUMFR=0.
      DO 102 I=1,IMAX
      DO 110 J=1,JMAX
      IF (BFR(I,J).NE.12345..AND.BFR(I,J).NE.0.) SUMFR=SUMFR+BFR(I,J)
  110 CONTINUE
  102 CONTINUE
C
C COUNT UNSPECIFIED BFR EXCLUDING THOSE WITH INAPPROPRIATE HEAD
C
      IF (NUMH.EQ.0) NUMH=1
      HEADAV=SUMH/NUMH
      NUMFR=0
      DO 111 I=1,IMAX
      DO 112 J=1,JMAX
      IF (SUMFR.LE.0.) GO TO 113
      IF (BFR(I,J).NE.0.) GO TO 114
      IF (BH(I,J).EQ.12345..AND.HEADAV.GE.0.) NUMFR=NUMFR+1
      IF (BH(I,J).NE.0..AND.BH(I,J).NE.12345..AND.BH(I,J).LE.HEADAV)
     2   NUMFR=NUMFR+1
```

```
      GO TO 114
  113 IF (BFR(I,J).NE.0.) GO TO 114
      IF (BH(I,J).EQ.12345..AND.HEADAV.LE.0.) NUMFR=NUMFR+1
      IF (BH(I,J).NE.0..AND.BH(I,J).NE.12345..AND.BH(I,J).GE.HEADAV)
     2   NUMFR=NUMFR+1
  114 CONTINUE
  112 CONTINUE
  111 CONTINUE
C
C DISTRIBUTE FR TO BALANCE
C
      IF (NUMFR.EQ.0) NUMFR=1
      FRBAL=SUMFR/NUMFR
      DO 115 I=1,IMAX
      DO 116 J=1,JMAX
      IF (BFR(I,J).EQ.0.) GO TO 137
      FR(I,J)=BFR(I,J)
      IF (BFR(I,J).EQ.12345.) FR(I,J)=0.
      GO TO 118
  137 IF (SUMFR.LE.0.) GO TO 117
      IF (BH(I,J).EQ.12345..AND.HEADAV.GE.0.) FR(I,J)=-FRBAL
      IF (BH(I,J).NE.0..AND.BH(I,J).NE.12345..AND.BH(I,J).LE.HEADAV)
     2   FR(I,J)=-FRBAL
      GO TO 118
  117 IF (BH(I,J).EQ.12345..AND.HEADAV.LE.0.) FR(I,J)=-FRBAL
      IF (BH(I,J).NE.0..AND.BH(I,J).NE.12345..AND.BH(I,J).GE.HEADAV)
     2   FR(I,J)=-FRBAL
  118 CONTINUE
  116 CONTINUE
  115 CONTINUE
C
C ASSIGN INITIAL VALUES OF H
C
      IF (NUMK.EQ.0) NUMK=1
      KAVER=SUMK/NUMK
      LENGAV=SUML/NUML
      IF (KAVER.EQ.0.) KAVER=1.
      RATIO=LENGAV/KAVER
      IF (RATIO.EQ.0.) RATIO=1.
      DO 119 I=1,IMAX
      DO 120 J=1,JMAX
```

```
      IF (BH(I,J).NE.0.) H(I,J)=BH(I,J)
      IF (BH(I,J).EQ.0..AND.BFR(I,J).NE.0..AND.BFR(I,J).NE.12345.)
     2   H(I,J)=HEADAV+(MFAC*RATIO*BFR(I,J))
      IF (BH(I,J).EQ.0..AND.FR(I,J).NE.0.)
     2   H(I,J)=HEADAV+(MFAC*RATIO*FR(I,J))
  120 CONTINUE
  119 CONTINUE
      CALL CAL4
      DO 121 I=1,IMAX
      DO 122 J=1,JMAX
      IF (H(I,J).EQ.12345.) H(I,J)=0.
  122 CONTINUE
  121 CONTINUE
C
C ASSIGN INITIAL VALUES OF FX, FY, KX, AND KY
C
      KCHEK=0
      DO 129 I=1,IMAXM1
      DO 130 J=1,JMAX
      FX(I,J)=BFX(I,J)
      IF (BFX(I,J).EQ.12345.) FX(I,J)=0.
      IF (BKX(I,J).NE.0.) GO TO 135
      KX(I,J)=KAVER
      KCHEK=1
      GO TO 131
  135 KX(I,J)=BKX(I,J)
      IF (BKX(I,J).EQ.12345.) KX(I,J)=0.
  131 CONTINUE
  130 CONTINUE
  129 CONTINUE
      DO 132 I=1,IMAX
      DO 133 J=1,JMAXM1
      FY(I,J)=BFY(I,J)
      IF (BFY(I,J).EQ.12345.) FY(I,J)=0.
      IF (BKY(I,J).NE.0.) GO TO 136
      KY(I,J)=KAVER
      KCHEK=1
      GO TO 134
  136 KY(I,J)=BKY(I,J)
      IF (BKY(I,J).EQ.12345.) KY(I,J)=0.
  134 CONTINUE
```

```
  133 CONTINUE
  132 CONTINUE
C
C WRITE OUT ASSIGNED VALUES
C
      WRITE (6,123) MFAC
  123 FORMAT ('1INITIAL VALUES CALCULATED USING SUBROUTINE CAL3 WITH HEA
     2D MULTIPLIER OF ',I1)
      WRITE (6,124)
  124 FORMAT ('0',14X,'I',9X,'J',10X,'H',12X,'FX',12X,'FY',12X,'FR',12X,
     2          'KX',12X,'KY')
      DO 125 I=1,IMAX
      WRITE (6,126)
  126 FORMAT (' ')
      DO 127 J=1,JMAX
      WRITE (6,128) I,J,H(I,J),FX(I,J),FY(I,J),FR(I,J),KX(I,J),KY(I,J)
  128 FORMAT (' ',12X,I5,5X,I5,3X,6(G10.3,4X))
  127 CONTINUE
  125 CONTINUE
      RETURN
      END
      SUBROUTINE CAL4
C
C ******************************************************************
C **************** SUBROUTINE CAL4 ********************************
C ******************************************************************
C
C HIGHEST STATEMENT NUMBER IS 115
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2         BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3          KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4         I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C SET IA EQ 1 FOR NODES WITH ASSIGNED VALUES OF H
C
      DO 100 I=1,IMAX
```

```
      DO 101 J=1,JMAX
      IA(I,J)=0
      IF (H(I,J).EQ.0.) GO TO 102
      IA(I,J)=1
  102 CONTINUE
  101 CONTINUE
  100 CONTINUE
      NLIM=IMAX+JMAX-2
      DO 103 I=1,IMAX
      DO 104 J=1,JMAX
      IF (IA(I,J).NE.1) GO TO 105
      DO 106 N=1,NLIM
      DO 107 M=1,N
C
C SET THIRD QUADRANT
C
      IF (I-M.LT.1) GO TO 108
      IF (J-N+M.LT.1) GO TO 108
      IF (IA(I-M,J-N+M).EQ.0) GO TO 109
      IF (IA(I-M,J-N+M).LE.N+1) GO TO 108
  109 H(I-M,J-N+M)=H(I,J)
      IA(I-M,J-N+M)=N+1
  108 CONTINUE
C
C SET FOURTH QUADRANT
C
      IF (I-N+M.LT.1) GO TO 110
      IF (J+M.GT.JMAX) GO TO 110
      IF (IA(I-N+M,J+M).EQ.0) GO TO 111
      IF (IA(I-N+M,J+M).LE.N+1) GO TO 110
  111 H(I-N+M,J+M)=H(I,J)
      IA(I-N+M,J+M)=N+1
  110 CONTINUE
C
C SET FIRST QUADRANT
C
      IF (I+M.GT.IMAX) GO TO 112
      IF (J+N-M.GT.JMAX) GO TO 112
      IF (IA(I+M,J+N-M).EQ.0) GO TO 113
      IF (IA(I+M,J+N-M).LE.N+1) GO TO 112
  113 H(I+M,J+N-M)=H(I,J)
```

```
      IA(I+M,J+N-M)=N+1
  112 CONTINUE
C
C SET SECOND QUADRANT
C
      IF (I+N-M.GT.IMAX) GO TO 114
      IF (J-M.LT.1) GO TO 114
      IF (IA(I+N-M,J-M).EQ.0) GO TO 115
      IF (IA(I+N-M,J-M).LE.N+1) GO TO 114
  115 H(I+N-M,J-M)=H(I,J)
      IA(I+N-M,J-M)=N+1
  114 CONTINUE
  107 CONTINUE
  106 CONTINUE
  105 CONTINUE
  104 CONTINUE
  103 CONTINUE
      RETURN
      END
      SUBROUTINE OUT1 (MM1,HEDERX,HEDERY,KNTR)
C
C ***********************************************************************
C **************** SUBROUTINE OUT1 **************************************
C ***********************************************************************
C
C HIGHEST STATEMENT NUMBER IS 106
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2       BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3        KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4       I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C WRITE HEADING FOR PRELIMINARY VALUES
C
      IF (ITER.EQ.1.AND.I.EQ.1.AND.J.EQ.1) GO TO 100
      GO TO 104
  100 WRITE (6,106)
```

```
  106 FORMAT ('1OUTPUT WITH SUBROUTINE OUT1')
      WRITE (6,102)
  102 FORMAT('0ITERATION        I           J           H           FX           FY
     2         FR          KX          KY       ERINF       FEC   HEDERX     HEDERY
     3    HEC'//)
C
C CHECK FOR WRITE
C
  104 IF (ITER.EQ.1.AND.I.EQ.1.AND.J.EQ.1) MK1=0
      IF (ITER.EQ.1.AND.I.EQ.1.AND.J.EQ.1) MP1=2**MM1
      IF (ITER.EQ.1.OR.ITER.EQ.2) GO TO 101
      IF (ITER.EQ.MK1.OR.ITER.EQ.MK1+1) GO TO 101
      RETURN
C
C WRITE VALUES AT NODE
C
  101 WRITE (6,103) ITER,I,J,H(I,J),FX(I,J),FY(I,J),FR(I,J),KX(I,J),
     2              KY(I,J),ERINF,CNTER,HEDERX,HEDERY,KNTR
  103 FORMAT (' ',2X,I5,5X,I5,5X,I5,3X,7G10.3,1X,I3,1X,2G10.3,1X,I3)
      IF (I.NE.IMAX.OR.J.NE.JMAX) GO TO 105
      IF (ITER.EQ.MK1+1) MK1=MK1+MP1
  105 RETURN
      END
      SUBROUTINE OUT2 (KO2)
C
C ********************************************************************
C **************** SUBROUTINE OUT2 ***********************************
C ********************************************************************
C
C HIGHEST STATEMENT NUMBER IS 122
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2         BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3         KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4         I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
      IF (KO2.EQ.1) GO TO 121
      KO2=1
```

```
      WRITE (6,120)
  120 FORMAT ('1OUTPUT WITH SUBROUTINE OUT2')
      WRITE (6,100)
  100 FORMAT ('0       FINAL VALUES LISTED BELOW. ENTERED VALUE OF 12345 M
     2EANS ZERO; ENTERED VALUE OF ZERO MEANS NO VALUE (VALUE TO BE SOLVE
     3D FOR)')
      WRITE (6,122)
  122 FORMAT ('0       IF TERMINATION DUE TO ITERATION COUNT, VALUES LISTE
     2D ARE FOR NEXT TO LAST ITERATION')
  103 FORMAT (' ')
      WRITE (6,101)
  101 FORMAT ('0  I     J       ENTERED HEAD           FINAL HEAD         ENTE
     2RED RECHARGE      FINAL RECHARGE     ')
      WRITE (6,106)
  106 FORMAT ('                                                            (
     2FLOW INTO NODE IS POSITIVE)        ')
      DO 102 I=1,IMAX
      WRITE (6,103)
      DO 104 J=1,JMAX
      WRITE (6,105) I,J,BH(I,J),H(I,J),BFR(I,J),FR(I,J)
  105 FORMAT (' ',2I5,4G20.8)
  104 CONTINUE
  102 CONTINUE
      WRITE (6,107)
  107 FORMAT ('0  I     J     ENTERED FLOW IN       FINAL FLOW IN       ENTE
     2RED FLOW IN       FINAL FLOW IN     ')
      WRITE (6,108)
  108 FORMAT ('                   BRANCH TO RIGHT      BRANCH TO RIGHT       BR
     2ANCH ABOVE           BRANCH ABOVE       ')
      WRITE (6,109)
  109 FORMAT ('                          (FLOW TO RIGHT IS POSITIVE)
     2    (FLOW UP IS POSITIVE)              ')
      DO 110 I=1,IMAX
      WRITE (6,103)
      DO 111 J=1,JMAX
      WRITE (6,105) I,J,BFX(I,J),FX(I,J),BFY(I,J),FY(I,J)
  111 CONTINUE
  110 CONTINUE
      WRITE (6,112)
  112 FORMAT ('0  I     J     ENTERED PERM. IN      FINAL PERM. IN      ENTE
     2RED PERM. IN      FINAL PERM. IN    ')
```

```
      WRITE (6,108)
      DO 113 I=1,IMAX
      WRITE (6,103)
      DO 114 J=1,JMAX
      WRITE (6,105) I,J,BKX(I,J),KX(I,J),BKY(I,J),KY(I,J)
  114 CONTINUE
  113 CONTINUE
      WRITE (6,115)
  115 FORMAT ('0   I      J   ENTERED LENGTH OF   ENTERED LENGTH OF   ')
      WRITE (6,116)
  116 FORMAT ('                  BRANCH TO RIGHT        BRANCH ABOVE    ')
      DO 117 I=1,IMAX
      WRITE (6,103)
      DO 118 J=1,JMAX
      WRITE (6,119) I,J,BLX(I,J),BLY(I,J)
  119 FORMAT (' ',2I5,2G20.8)
  118 CONTINUE
  117 CONTINUE
  121 RETURN
      END
      SUBROUTINE OUT3 (ID1,ID2,ID3,ID4,ID5,ID6,ID7,ID8,ID9)
C
C *********************************************************************
C **************** SUBROUTINE OUT3 *************************************
C *********************************************************************
C
C HIGHEST STATEMENT NUMBER IS 134
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2        BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3         KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4        I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C DECLARE OUT3 VARIABLES
C
      DIMENSION A(4,16)
C
```

```
C INITIALIZE
C
      MAP=1
      ISHEET=1
      JSHEET=1
      M=1
      L=8
      LN=9
C
C SET ARRAY TO ZERO
C
  107 CONTINUE
      DO 101 M1=1,4
      DO 102 N=1,16
      A(M1,N)=0.
  102 CONTINUE
  101 CONTINUE
  100 CONTINUE
C
C SET VARIABLES FOR SHEET
C
      LMI7=L-7
      LPL1=L+1
      MPL1=M+1
      MPL2=M+2
      MPL3=M+3
      MPL4=M+4
C
C TRANSFER ACCORDING TO MAP
C
      IF (MAP.EQ.2) GO TO 110
      IF (MAP.EQ.3) GO TO 111
      IF (MAP.EQ.4) GO TO 112
      IF (MAP.EQ.5) GO TO 113
      IF (MAP.EQ.6) GO TO 114
      IF (MAP.EQ.7) GO TO 115
      IF (MAP.EQ.8) GO TO 116
      IF (MAP.EQ.9) GO TO 117
C
C FILL ARRAY FOR MAP 1 AND WRITE
C
```

```
      IF (ID1.EQ.1) GO TO 108
      DO 103 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 104 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 104
      A(M2,N)=BH(M1,L1)
  104 CONTINUE
  103 CONTINUE
      GO TO 118
C
C FILL ARRAY FOR MAP 2 AND WRITE
C
  110 IF (ID2.EQ.1) GO TO 108
      DO 119 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 120 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 120
      A(M2,N)=H(M1,L1)
  120 CONTINUE
  119 CONTINUE
      GO TO 118
C
C FILL ARRAY FOR MAP 3 AND WRITE
C
  111 IF (ID3.EQ.1) GO TO 108
      DO 121 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 122 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 122
      A(M2,N)=BFR(M1,L1)
  122 CONTINUE
  121 CONTINUE
      GO TO 118
C
C FILL ARRAY FOR MAP 4 AND WRITE
```

```
C
  112 IF (ID4.EQ.1) GO TO 108
      DO 123 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 124 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 124
      A(M2,N)=FR(M1,L1)
  124 CONTINUE
  123 CONTINUE
      GO TO 118
C
C FILL ARRAY FOR MAP 5 AND WRITE
C
  113 IF (ID5.EQ.1) GO TO 108
      DO 125 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 126 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 126
      A(M2,N)=BFY(M1,L1)
      A(M2,N+8)=BFX(M1,L1)
  126 CONTINUE
  125 CONTINUE
      GO TO 118
C
C FILL ARRAY FOR MAP 6 AND WRITE
C
  114 IF (ID6.EQ.1) GO TO 108
      DO 127 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 128 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 128
      A(M2,N)=FY(M1,L1)
      A(M2,N+8)=FX(M1,L1)
  128 CONTINUE
  127 CONTINUE
```

```
      GO TO 118
C
C FILL ARRAY FOR MAP 7 AND WRITE
C
  115 IF (ID7.EQ.1) GO TO 108
      DO 129 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 130 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 130
      A(M2,N)=BKY(M1,L1)
      A(M2,N+8)=BKX(M1,L1)
  130 CONTINUE
  129 CONTINUE
      GO TO 118
C
C FILL ARRAY FOR MAP 8 AND WRITE
C
  116 IF (ID8.EQ.1) GO TO 108
      DO 131 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 132 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 132
      A(M2,N)=KY(M1,L1)
      A(M2,N+8)=KX(M1,L1)
  132 CONTINUE
  131 CONTINUE
      GO TO 118
C
C FILL ARRAY FOR MAP 9 AND WRITE
C
  117 IF (ID9.EQ.1) GO TO 108
      DO 133 L1=LMI7,L
      N=IABS(L1-LN)
      M2=0
      DO 134 M1=M,MPL3
      M2=M2+1
      IF (M1.GT.IMAX.OR.L1.GT.JMAX) GO TO 134
```

```
      A(M2,N)=BLY(M1,L1)
      A(M2,N+8)=BLX(M1,L1)
  134 CONTINUE
  133 CONTINUE
      GO TO 118
C
C INCREMENT JSHEET
C
  105 CONTINUE
      IF (L.GT.JMAX) GO TO 106
      L=L+8
      JSHEET=JSHEET+1
      LN=LN+8
      GO TO 107
C
C INCREMENT ISHEET
C
  106 CONTINUE
      L=8
      JSHEET=1
      LN=9
      IF (M+4.GT.IMAX) GO TO 108
      M=M+4
      ISHEET=ISHEET+1
      GO TO 107
C
C INCREMENT MAP
C
  108 CONTINUE
      IF (MAP.EQ.9) GO TO 109
      ISHEET=1
      JSHEET=1
      M=1
      L=8
      LN=9
      MAP=MAP+1
      GO TO 107
C
C TRANSFER POINT FOR WRITE
C
  118 CALL OUT3A (MAP,M,L,MPL1,MPL2,MPL3,LMI7,ISHEET,JSHEET,MPL4,LPL1,A)
```

```
      GO TO 105
  109 RETURN
      END
      SUBROUTINE OUT3A (MAP,M,L,MPL1,MPL2,MPL3,LMI7,ISHEET,JSHEET,
     2                  MPL4,LPL1,A)
C
C ********************************************************************
C **************** SUBROUTINE OUT3A ***********************************
C ********************************************************************
C
C HIGHEST STATEMENT NUMBER IS 135
C OTHER NUMBERS AVAILABLE ARE 125 THRU 130
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2        BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3         KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4        I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C DECLARE OUT3A VARIABLES
C
      DIMENSION A(4,16)
C
C WRITE MAPS
C
      WRITE (6,131)
  131 FORMAT ('1',//////////)
      IF (MAP.EQ.5.OR.MAP.EQ.6.OR.MAP.EQ.7.OR.MAP.EQ.8.OR.MAP.EQ.9)
     2   GO TO 124
C
C WRITE NODE MAPS
C
C WRITE FIRST LINE
C
      IF (MAP.EQ.1) WRITE (6,100) M,MPL3,LMI7,L
  100 FORMAT (' ',6X,'ENTERED HEAD AT NODES (BH) - I FROM ',I2,' TO ',I2
     2,' - J FROM ',I2,' TO ',I2,23X,'MAP 1')
      IF (MAP.EQ.2) WRITE (6,111) M,MPL3,LMI7,L
```

```
  111 FORMAT (' ',6X,'FINAL HEAD AT NODES (H) - I FROM ',I2,' TO ',I2,'
     2- J FROM ',I2,' TO ',I2,26X,'MAP 2')
      IF (MAP.EQ.3) WRITE (6,112) M,MPL3;LMI7,L
  112 FORMAT (' ',6X,'ENTERED RECHARGE AT NODES (BFR) - I FROM ',I2,' TO
     2 ',I2,' - J FROM ',I2,' TO ',I2,18X,'MAP 3')
      IF (MAP.EQ.4) WRITE (6,113) M,MPL3;LMI7,L
  113 FORMAT (' ',6X,'FINAL RECHARGE AT NODES (FR) - I FROM ',I2,' TO ',
     2I2,' - J FROM ',I2,' TO ',I2,21X,'MAP 4')
C
C WRITE SECOND LINE
C
      WRITE (6,101) ISHEET,JSHEET
  101 FORMAT (' ',85X,'SHEET ',I2,'-',I2)
C
C WRITE THIRD LINE
C
      IF (MAP.EQ.1) WRITE (6,102)
  102 FORMAT (' ',11X,'(12345 INDICATES HEAD SPECIFIED AS ZERO, ZERO IND
     2ICATES NO HEAD SPECIFIED)')
      IF (MAP.EQ.2) WRITE (6,103)
      IF (MAP.EQ.3) WRITE (6,114)
  114 FORMAT (' ',11X,'(12345 INDICATES ZERO SPECIFIED, ZERO IS UNSPECIF
     2IED, FLOW OUT IS NEGATIVE)')
      IF (MAP.EQ.4) WRITE (6,115)
  115 FORMAT (' ',11X,'(FLOW OUT OF SYSTEM IS NEGATIVE)')
C
C WRITE HEADINGS
C
      WRITE (6,103)
  103 FORMAT (' ')
      WRITE (6,104) M,MPL1,MPL2,MPL3,MPL4
  104 FORMAT (' ',6X,'J=',4X,'I= ',I2,17X,I2,17X,I2,17X,I2,17X,I2)
      WRITE (6,103)
      WRITE (6,105) LPL1,LPL1
  105 FORMAT (' ',6X,I2,8X,'*',18X,'*',18X,'*',18X,'*',18X,'* ',I2)
      WRITE (6,106)
  106 FORMAT (' ')
C
C WRITE DATA
C
      DO 109 N=1,8
```

```
      IN=IABS(L+1-N)
      WRITE (6,107)
  107 FORMAT (' ',16X,'|',18X,'|',18X,'|',18X,'|')
      WRITE (6,103)
      WRITE (6,108) IN,A(1,N),A(2,N),A(3,N),A(4,N),IN
  108 FORMAT (' ',6X,I2,' (',G14.7,') - (',G14.7,') - (',G14.7,') - (',G
     214.7,') -',8X,'* ',I2)
      WRITE (6,106)
  109 CONTINUE
      WRITE (6,110) M,MPL1,MPL2,MPL3,MPL4
  110 FORMAT (' ',15X,I2,17X,I2,17X,I2,17X,I2,17X,I2)
      RETURN
C
C BRANCH MAPS
C
C WRITE FIRST LINE
C
  124 IF (MAP.EQ.5) WRITE (6,116) M,MPL3,LMI7,L
  116 FORMAT (' ',6X,'ENTERED FLOW IN BRANCHES (BFX AND BFY) - I FROM ',
     2I2,' TO ',I2,' - J FROM ',I2,' TO ',I2,11X,'MAP 5')
      IF (MAP.EQ.6) WRITE (6,117) M,MPL3,LMI7,L
  117 FORMAT (' ',6X,'FINAL FLOW IN BRANCHES (FX AND FY) - I FROM ',I2,'
     2 TO ',I2,' - J FROM ',I2,' TO ',I2,15X,'MAP 6')
      IF (MAP.EQ.7) WRITE (6,118) M,MPL3,LMI7,L
  118 FORMAT (' ',6X,'ENTERED PERMEABILITY IN BRANCHES (BKX AND BKY) - I
     2 FROM ',I2,' TO ',I2,' - J FROM ',I2,' TO ',I2,3X,'MAP 7')
      IF (MAP.EQ.8) WRITE (6,119) M,MPL3,LMI7,L
  119 FORMAT (' ',6X,'FINAL PERMEABILITY IN BRANCHES (KX AND KY) - I FRO
     2M ',I2,' TO ',I2,' - J FROM ',I2,' TO ',I2,7X,'MAP 8')
      IF (MAP.EQ.9) WRITE (6,120) M,MPL3,LMI7,L
  120 FORMAT (' ',6X,'LENGTH (ENTERED) OF BRANCHES (BLX AND BLY) - I FRO
     2M ',I2,' TO ',I2,' - J FROM ',I2,' TO ',I2,7X,'MAP 9')
C
C WRITE SECOND LINE
C
      WRITE (6,101) ISHEET,JSHEET
C
C WRITE THIRD LINE
C
      IF (MAP.EQ.5) WRITE (6,121)
  121 FORMAT (' ',11X,'(12345 IS O SPECIFIED, O IS UNSPECIFIED, FLOW DOW
```

```
     2N OR TO LEFT IS NEGATIVE)')
      IF (MAP.EQ.6) WRITE (6,122)
  122 FORMAT (' ',11X,'(FLOW DOWN OR TO LEFT IS NEGATIVE)')
      IF (MAP.EQ.7) WRITE (6,123)
  123 FORMAT (' ',11X,'(12345 IS ZERO SPECIFIED, ZERO IS UNSPECIFIED)')
      IF (MAP.EQ.8.OR.MAP.EQ.9) WRITE (6,103)
C
C WRITE HEADINGS
C
      WRITE (6,103)
      WRITE (6,104) M,MPL1,MPL2,MPL3,MPL4
      WRITE (6,103)
      WRITE (6,105) LPL1,LPL1
      WRITE (6,132)
  132 FORMAT (' ')
C
C WRITE DATA
C
      DO 133 N=1,8
      IN=IABS(L+1-N)
      WRITE (6,134) A(1,N),A(2,N),A(3,N),A(4,N)
  134 FORMAT (' ',9X,'(',G14.7,')    (',G14.7,')    (',G14.7,')    (',G14.7
     2,')')
      WRITE (6,103)
      WRITE (6,135) IN,A(1,N+8),A(2,N+8),A(3,N+8),A(4,N+8),IN
  135 FORMAT (' ',6X,I2,8X,'* (',G14.7,') * (',G14.7,') * (',G14.7,') *
     2(',G14.7,') * ',I2)
      WRITE (6,132)
  133 CONTINUE
      WRITE (6,110) M,MPL1,MPL2,MPL3,MPL4
      RETURN
      END
      SUBROUTINE OUT3B (KK,FERROR,HERROR,MAXIT,KNTR)
C
C *******************************************************************
C **************** SUBROUTINE OUT3B *********************************
C *******************************************************************
C
C HIGHEST STATEMENT NUMBER IS 112
C
C DECLARE COMMON VARIABLES
```

```
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2       BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3        KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4       I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C WRITE HEADINGS
C
      KK=KK+1
      IF (KK.NE.1) GO TO 112
      WRITE (6,100)
  100 FORMAT ('1',//////////)
      WRITE (6,101)
  101 FORMAT (' ',6X,'OUTPUT WITH SUBROUTINE OUT3')
      WRITE (6,102)
  102 FORMAT (' ')
      ITPL1=ITER+1
      IF (CNTER.NE.0.OR.KNTR.NE.0) GO TO 107
      WRITE (6,103) FERROR
  103 FORMAT (' ',11X,'ALL FLOW ERRORS LESS THAN VALUE SPECIFIED (',G10.
     23,') AND ALL HEAD ERRORS LESS THAN')
      WRITE (6,104) HERROR,ITPL1
  104 FORMAT (' ',11X,'VALUE SPECIFIED (',G10.3,'). VALUES OF THESE ERRO
     2RS FOR FOLLOWING ITERATION (',I2,') ARE')
      WRITE (6,105)
  105 FORMAT (' ',11X,'LISTED BELOW.')
      GO TO 106
  107 CONTINUE
      WRITE (6,108) FERROR
  108 FORMAT (' ',11X,'SOME FLOW ERRORS EXCEEDED VALUE SPECIFIED (',G10.
     23,') AND/OR SOME HEAD ERRORS')
      WRITE (6,109) HERROR
  109 FORMAT (' ',11X,'EXCEEDED VALUE SPECIFIED (',G10.3,') ON ITERATION
     2 PRECEDING MAXIMUM SPECIFIED. VALUES')
      WRITE (6,110) MAXIT
  110 FORMAT (' ',11X,'OF THESE ERRORS FOR THE MAXIMUM SPECIFIED ITERATI
     2ON (',I5,') ARE LISTED BELOW')
  106 WRITE (6,102)
      WRITE (6,111)
```

```
  111 FORMAT (' ',11X,'ENTERED AND FINAL VALUES OF VARIABLES FOLLOW THE
     2ERROR LISTING')
  112 RETURN
      END
      SUBROUTINE OUT3C (KNTR,HEDERX,HEDERY)
C
C ****************************************************************
C *************** SUBROUTINE OUT3C ********************************
C ****************************************************************
C
C HIGHEST STATEMENT NUMBER IS 111
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2        BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3         KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4        I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C WRITE HEADING ON FIRST SHEET
C
      IF (I.EQ.1.AND.J.EQ.1) LPK=1
      IF (I.EQ.1.AND.J.EQ.1) LPLIM=2
      IF (I.NE.1.OR.J.NE.1) GO TO 100
      WRITE (6,101)
  101 FORMAT ('0')
      WRITE (6,102)
  102 FORMAT (' ')
  100 IF (LPK.NE.LPLIM) GO TO 103
      WRITE (6,104)
  104 FORMAT ('1',/////////)
  103 IF (I.EQ.1.AND.J.EQ.1) GO TO 111
      IF (LPK.EQ.LPLIM) GO TO 111
      GO TO 105
  111 LPK=1
      LPLIM=38
      IF (1.EQ.1.AND.J.EQ.1) LPLIM=28
      WRITE (6,106)
  106 FORMAT (' ',40X,'CUM. FLOW',36X,'CUM. HEAD')
```

```
      WRITE (6,107)
  107 FORMAT (' ',15X,'I',6X,'J',9X,'FLOW',4X,'ERRORS GT',7X,'X BRANCH',
     28X,'Y BRANCH     ERRORS GT')
      WRITE (6,108)
  108 FORMAT (' ',32X,'ERROR',5X,'LIMIT',8X,'HEAD ERROR',6X,'HEAD ERROR
     2     LIMIT')
      WRITE (6,102)
  105 IF (J.NE.1) GO TO 109
      WRITE (6,102)
      LPK=LPK+1
  109 WRITE (6,110) I,J,ERINF,CNTER,HEDERX,HEDERY,KNTR
  110 FORMAT (' ',14X,I2,5X,I2,4X,G14.7,2X,I3,7X,G14.7,2X,G14.7,5X,I3)
      LPK=LPK+1
      RETURN
      END
      SUBROUTINE OUT4
C
C *************** SUBROUTINE OUT4 *************************************
C ********************************************************************
C ********************************************************************
C
C HIGHEST STATEMENT NUMBER IS 103
C
C DECLARE COMMON VARIABLES
C
      COMMON   H(38,27), BH(38,27), FX(38,27),BFX(38,27), FY(38,27),
     2        BFY(38,27), FR(38,27),BFR(38,27), KX(38,27),BKX(38,27),
     3         KY(38,27),BKY(38,27),BLX(38,27),BLY(38,27), IA(38,27),
     4        I,J,IMAX,JMAX,ITER,CNTER,ERINF,IMAXM1,JMAXM1,XP
      REAL KX,KY
      INTEGER CNTER
C
C PUNCH CARDS
C
      NCARD=IMAX*JMAX
      WRITE (7,100) NCARD
  100 FORMAT (I10)
      DO 101 I=1,IMAX
      DO 102 J=1,JMAX
      WRITE (7,103) I,J,H(I,J),FX(I,J),FY(I,J),FR(I,J),KX(I,J),KY(I,J)
  103 FORMAT (2I5,6E10.3)
```

```
102 CONTINUE
101 CONTINUE
    RETURN
    END
```