Groundwater impact screening model: Crandon Project waste disposal system: project report 9. v. 9 1982

Atlanta, Georgia: Golder Associates, Inc., 1982

https://digital.library.wisc.edu/1711.dl/GXJS333NCX7OF8J

GROUNDWATER IMPACT SCREENING MO
CRANDON PROJECT
WASTE DISPOSAL SYSTEM
PROJECT REPORT 9

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

Report on

GROUNDWATER IMPACT SCREENING MO
CRANDON PROJECT
WASTE DISPOSAL SYSTEM
PROJECT REPORT 9

Submitted to:

Exxon Minerals Company
P. O. Box 813
Rhinelander, Wisconsin 54501

DISTRIBUTION:

16 copies - Exxon Minerals Company
4 copies - Golder Associates

786085

March, 1982

GOLDER ASSOCIATES, INC. • 5125 PEACHTREE ROAD, ATLANTA, GEORGIA 30341, U.S.A. • TELEPHONE (404) 458-9686 • TELEX 700523

OFFICES IN UNITED STATES • CANADA • UNITED KINGDOM • AUSTRALIA

TABLE OF CONTENTS

SECTION PAGE

TABLE OF CONTENTS
(Page 2)

SECTION PAGE

SYMBOL DEFINITIONS

Symbol		Definition (Units)
a_L	-	Longitudinal dispersivity (L)
a_T	-	Transverse dispersivity (L)
B_L	-	Longitudinal linear dispersivity coefficient (LL^{-1})
B_T	-	Transverse linear dispersivity coefficient (LL^{-1})
BOT	-	Elevation of bottom of aquifer (L)
C	-	Concentration of solute (MM^{-1})
D	-	Bulk density of the porous media (ML^{-3})
d_c	-	Distance moved by convective flow (L)
D_h	-	Coefficient of hydrodynamic dispersion (L^2T^{-1})
d_L	-	Distance moved by dispersion along flow direction (L)
d_T	-	Distance moved by dispersion normal to flow direction (L)
Δt	-	Length of one timestep (T)
F	-	Head prediction factor (LL^{-1})
I	-	Groundwater gradient in the direction of flow
i	-	node count in x direction
j	-	node count in y direction
h	-	Elevation head of groundwater table (L)
t	-	Time since analysis began (T)
K	-	Hydraulic Conductivity (LT^{-1})
k_d	-	Distribution coefficient (L^3M^{-1})
M	-	Mass of solute injected (L^3)
n	-	Volumetric porosity of the porous media (L^3L^{-3})
Q	-	Inflow to groundwater system (L^3T^{-1})
q	-	Specific discharge (LT^{-1})
r_1, r_2	-	Uniformly distributed random numbers with mean 0 and standard deviation 1.

R_d - Retardation coefficient (LL^{-1})

S - Storage coefficient (L^3L^{-3})

S_L - Standard deviation of the concentration distribution along the flow direction (L)

S_T - Standard deviation of the concentration distribution normal to the flow direction (L)

t - Time (T)

T - Transmissivity - product of K and saturated thickness (L^2T^{-1})

$\overline{v}$ - Average pore velocity of groundwater (LT^{-1})

V - Darcy velocity of groundwater (LT^{-1})

x - Horizontal direction of Cartesian coordinate system

y - Vertical direction of Cartesian coordinate system

1.0 INTRODUCTION

This report describes the theory and application procedures of a computer program written by Golder Associates which analyzes the movement of waste facility seepage in an isotropic, saturated, homogenous, porous medium. The program combines a finite difference groundwater flow model with a discrete particle random walk model. Included are the basic theory employed in predicting the transient groundwater gradients and seepage transport, program description, input requirements, output options, a sample problem, and a listing of the program.

This GROUNDWATER IMPACT SCREENING MODEL was developed to provide an easily usable tool for estimating the effect of various approaches to the management of waste products from the proposed Crandon mill on the hydrologic system. The program allows the user to select a proposed waste disposal facility by defining its plan location and a flow history of seepage from each of the system components. The model simulates the dynamic response of the hydrologic system as it is influenced through time by the proposed facility. The results of the analysis consist of a series of "snapshots" of the groundwater table elevation and the seepage concentration in the groundwater over the study area at various times through the simulation. Due to the slow rate of seepage movement in the groundwater system, these "snapshots" are typically provided every 5 to 15 years through simulations that run for 60 to 150 years. In this manner the hydrologic impact can be assessed during the operation of the facility and for many years thereafter.

The program has been written to be simple in terms of its use and ease of modification. Features include:

- Simple input of limited quantity.
- Simple output options of limited quantity to aid remote terminal use.
- Programming is standard FORTRAN IV for maximum compatability between computer systems.
- Programming for maximum internal readability and ease of modifications.
- Relatively simple, unconditionally stable solution algorithms.
- Dimension independent input and output requiring only a consistent dimension set.
- Rapid, relatively inexpensive solution.
- Entire solution matrix is stored in memory to speed execution and minimize program complexity.

Unlike most models of this sort, the code is written to be modified. Different input and output systems will suit different aspects of the project, encouraging tailoring of the program to make the code suit the problem.

The model should be regarded in this application as a screening tool used to evaluate the relative impact on the hydrologic system of various waste disposal systems. The resulting seepage concentration contours do not take into account several factors, as listed below.

(a) The hydrochemical buffering effect of the unsaturated zone underlying the pond system and in the saturated zone.

(b) The model is a 2 dimensional representation and does not estimate vertical distribution of concentrations. The concentration contours presented are vertically integrated, i.e., they assume complete mixing of the seepage in the groundwater.

(c) The effects of seepage fluid dissemination by the process of molecular diffusion.

(d) Transit time of seepage between leaving the pond bottom and reaching the saturated groundwater zone is not considered.

The model should not be viewed as an exact model of the total Crandon hydrologic system (i.e. hydrochemical and hydrogeological) but rather as a screening tool to aid in determining the optimum site design and location of the proposed Waste Disposal Facility. Future enhancements to the model will allow for consideration of the above factors and perhaps others as the need arises and supporting data becomes available, providing for a groundwater impact assessment tool with a degree of accuracy suitable for its intended use.

2.0 CONCEPTUAL HYDROLOGIC MODEL

Most predictive efforts require the formulation of a model which adequately represents the system to be analyzed. This representation depends heavily upon the expected predictive use of the model. Once the model has been prepared and the user is assured of its accuracy in representing the system in question, predictions can be made by imposing a change in the system and observing the response of the model.

We consider that the model which has been developed for this effort adequately represents the hydrologic system at the Crandon site. The approximate extent of the model is the plan area bounded by Swamp Creek on the north, Ground Hemlock Slough on the east, Pickerel Lake on the south and Rolling Stone and Rice Lakes on the west. The actual boundary limits of the model are the stream channels and lake shores which are recharged by the groundwater. Figure 2.1 shows the study area and assumed boundaries of the hydrogeologic model. In cross-section the model consists of a layer of coarse grained stratified drift material which is effectively continuous over the plan area of the model. An idealized section is shown in Figure 2.2. The saturated thickness of this layer of coarse grained stratified drift varies over the model area. An isopach map of the saturated thickness of the coarse grained stratified drift was constructed from the borehole data, geologic sections and areal trends inferred from the block diagrams (included in Reference 1) and is included in Figure 2.3. The natural water input to the hydrologic model is the rainfall and snowmelt infiltration which percolates into this layer of coarse grained stratified drift. This idealized hydrogeologic system is based on the findings presented in the Geotechnical Investigation(1) and Pump Test and Analysis(2) prepared previously by Golder Associates.

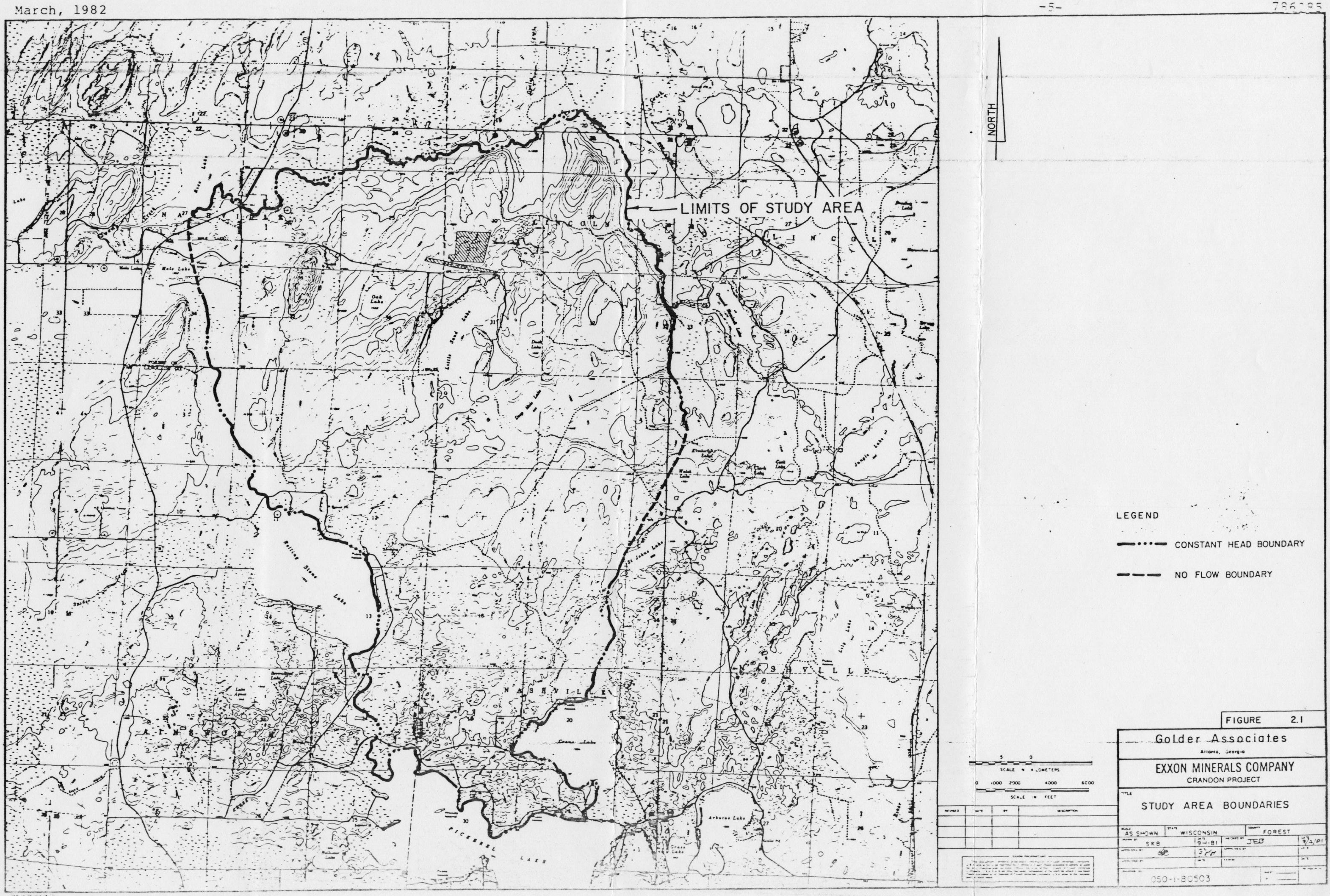


FIGURE 2.1

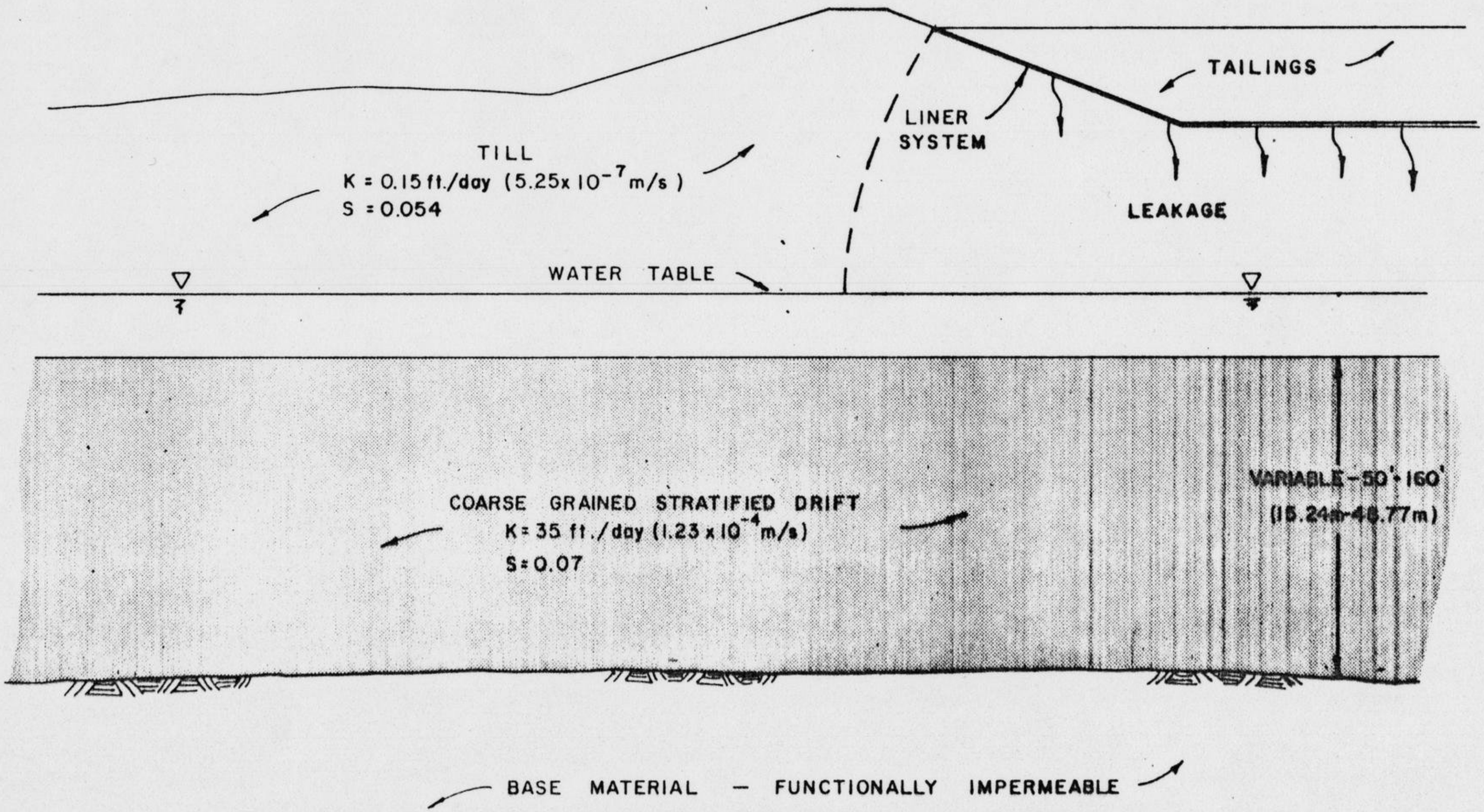
Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
STUDY AREA BOUNDARIES

AS SHOWN
WISCONSIN
FOREST
SKB
9-4-81
JEB
9/4/81

050-1-80503



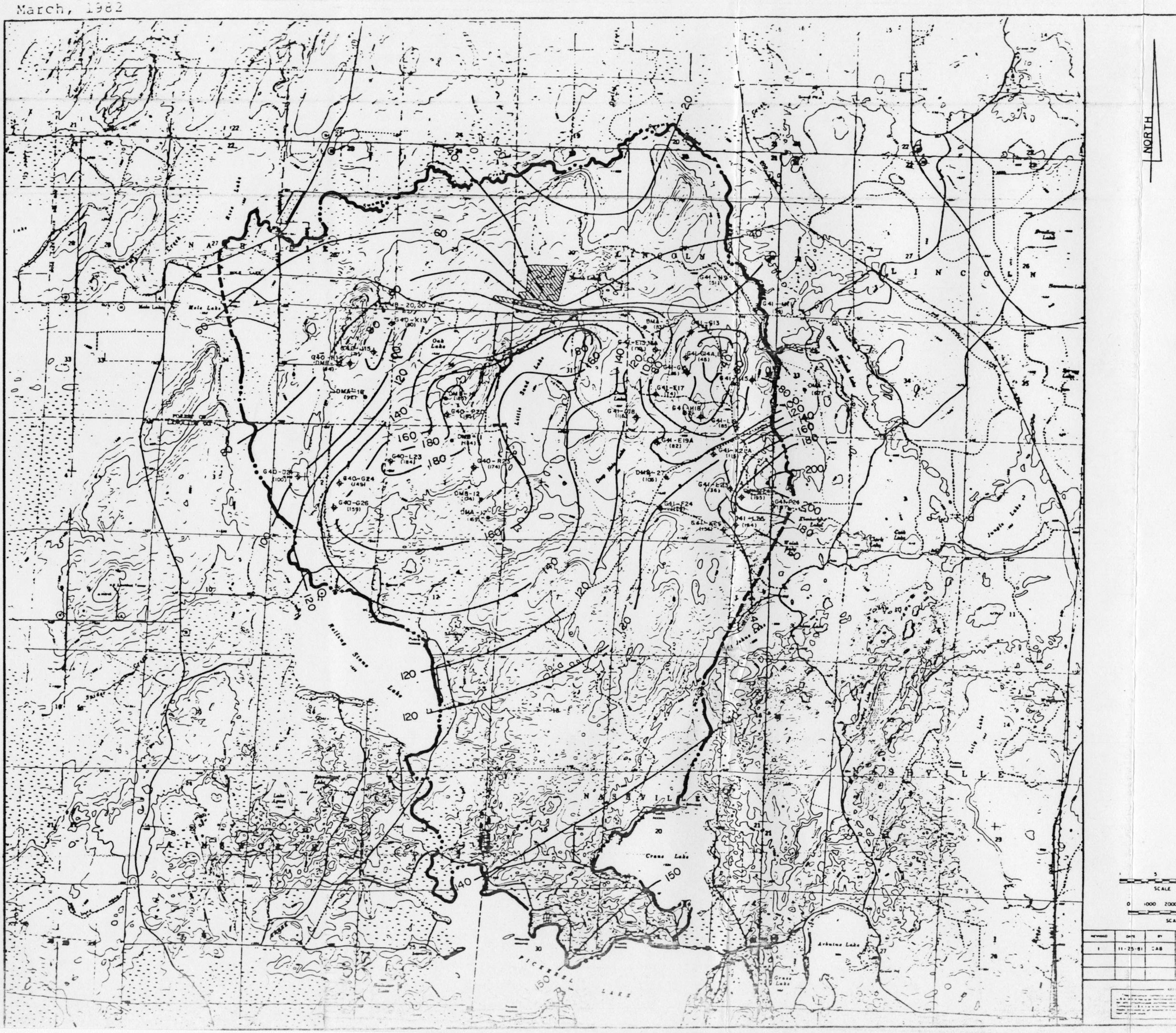
Golder Associates

JOB NO. 786085
DRAWN CAB
CHECKED JEB
SCALE NO SCALE
DATE 8-31-81
DWG. NO. 050-1-81112

HYDROGEOLOGIC MODEL
IDEALIZED CROSS SECTION

EXXON MINERALS COMPANY

FIGURE 2.2



LEGEND

—···—	CONSTANT HEAD BOUNDARY
— — —	NO FLOW BOUNDARY
—140—	ISOPACH CONTOURS (FEET)
G41-L19 (80) ✦	GOLDER ASSOCIATES BORING (THICKNESS IN FEET)
DMB-27 ● (105)	DAMES & MOORE BORING (THICKNESS IN FEET)

REVISED	DATE	BY	DESCRIPTION
1	11-25-81	CAB	80 CONTOUR @ G41-L19 REVISED

FIGURE 2.3

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE
COARSE GRAINED STRATIFIED DRIFT
ISOPACH CONTOURS

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY CAB	DATE 10-13-81	CHECKED BY JEB		8l
APPROVED BY JEB	DATE 11-9-81	APPROVED BY		
APPROVED BY	DATE			
DRAWING NO. 050-1-80517				

The primary use of this model is to predict the concentration distribution of waste facility seepage over the study area through time. The concentrations reported are the percent of seepage in the groundwater assuming complete mixing vertically across the coarse grained stratified drift. The concentration distribution is assumed to be dependent upon the following factors.

- Leakage rate of the waste disposal facility.
- Location and area of the waste disposal facility.
- Groundwater gradients over the study area, i.e. shape of the groundwater table.
- Characteristics of the porous media through which the seepage moves (hydraulic conductivity, porosity, storativity, dispersivity, and retardance).

Diffusion, density gradients and chemical reaction processes are not simulated. The leakage rate, location and area of the waste disposal facility are changes which are applied to the model in a predictive mode. The simulated groundwater gradients and porous media characteristics are input to the model and represent those which are prevalent in the layer of coarse grained stratified drift. The hydraulic conductivity of the coarse grained stratified drift is 2 to 3 orders of magnitude higher than the overlying and underlying layers of till giving rise to seepage transport velocities 100 to 1000 times faster in the coarse grained stratified drift. The hydrologic system is a semi-unconfined system but the model represents it as a single layer water table aquifer for conservative estimates of flow. The coarse grained stratified drift and upper till have hydraulic conductivity values which are different enough to show similar but lagging responses to stresses such as pumping or recharge. However, the groundwater heads in the two materials equilibrate after the stress has been removed. Since the bottom layer of till has a much lower permeability than the overlying coarse grained stratified drift, it is not affected by waste disposal system leakage which recharges the drift material. It is, therefore, appropriate to formulate the predictive model based on the hydraulic gradient and seepage transport in this layer of coarse grained stratified drift and to use the resulting model in the site screening analyses. Further refinements to the basic algorithms will provide a model which will be appropriate for the final groundwater impact assessment of the waste disposal system.

Once the idealized physical model has been formulated, a method of quantitative cause/effect analysis must be defined. The two basic processes which must be modeled are the changes in the distribution of the elevations of the groundwater table and the distribution of seepage in the groundwater with time. Each process has been represented by a set of equations. Detailed presentations of the theory of these two processes are included as Sections 3 and 4. All mathematical symbols are defined at the beginning of this report.

The methods used to solve the equations which govern the distribution of groundwater heads and seepage concentration are well suited for solution by a computer program. The program developed for this purpose is the GROUNDWATER IMPACT SCREENING MODEL which simulates changes in the groundwater gradients and seepage transport. The program itself is flexible enough to allow variation of the idealized physical model and to simulate a wide range of leakage histories but can represent only the general hydrogeologic model configuration outlined herein. Therefore, the computer program itself has been termed "the model" or the "GROUNDWATER IMPACT SCREENING MODEL". The combination of the idealized physical model, the mathematical equations, and the computer program represent the model which will be used in a cause/effect predictive mode. In its present form, the cause/effect predictive results are primarily useful in a relative screening mode, but they do represent an upper bound on concentrations to a high degree of confidence. The verification of the program is presented in Section 5; model calibration is included in Section 6; description of the computer program itself is included in Section 7; and Sections 8 and 9 outline the program input requirements and output reports.

3.0 GROUNDWATER FLOW SOLUTION THEORY

The governing equation assumed to represent the transient distribution of groundwater head in a confined, homogeneous, isotropic aquifer in two dimensions is (adapted from Reference 4):

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = \frac{S}{T} \frac{h}{t} + q \qquad (3.1)$$

Terms used in this section are defined at the beginning of this report. The above equation cannot be solved directly. By imposing a grid over the problem domain and approximating equation 3.1 in terms of its finite differences between the grid intersection points, a set of simultaneous equations, one representing each grid intersection (node point), can be formulated. The unknown in each equation is the head condition at the node in question at a given time. The known terms are the aquifer properties, T and S, the flow rate q, and the x, y and t values of the solution. This set of simultaneous equations is then solved iteratively using the solution method presented by Prickett and Lonnquist(3). Figure 8.1 illustrates the Exxon Crandon Project study area overlain by a matrix of discrete node points. This example case will be used throughout this report for demonstration purposes.

Solution of the simultaneous finite difference equations requires definition of the boundary conditions. These boundary conditions are; (1) the initial head configuration at each node point at the beginning of the analysis and (2) either "no-flow" or "constant head" nodes at the periphery of the study area. These boundary conditions are required to reduce the total number of unknowns to that which can be uniquely solved.

Having formulated the system of simultaneous, finite difference equations and defined the boundary conditions, the equations are solved to determine the head at each node. This is done using a modified form of the alternating direction implicit method first presented by Peaceman and Rachford(5) as described by Prickett and Lonnquist(3).

> "Briefly, the iterative alternating direction implicit method involves first, for a given time increment, reducing a large set of simultaneous equations down to a number of small sets. This is done by solving the node equations by Gauss elimination of an individual column of the model while all terms related to the nodes in adjacent columns are held constant. According to Peaceman, and Rachford (1955), the set of column equations is then implicit in the direction along the column and explicit in the direction orthogonal to the column alignment. The solution of the set of column equations is then a straightforward process.
>
> After all column equations have been processed column by column, attention is focused on solving the node equations again by Gauss elimination of an individual row while all terms related to adjacent rows are held constant. Finally, after all equations have been solved row by row, an 'iteration' has been completed. The above process is repeated a sufficient number of times to achieve convergence, and this completes the calculations for the given time increment. The calculated heads are then used as initial conditions for the next time increment. This total process is repeated for successive time increments. Peaceman and Rachford (1955) point out that this technique is unconditionally stable regardless of the size of the time increment."

The details of the solution methodology are outlined in Prickett and Lonnquist(3) in "Part 1. Mathematical Background".

The equations formulated thus far apply only to a confined aquifer. The program simulates unconfined and semi-unconfined aquifers by addition of a step to account for the change in transmissivity as the head at a given node rises or falls. The equivalent transmissivity in the x and y directions can be estimated by taking the geometric mean of the transmissivities between the node in question and the next adjacent node, as follows:

$$T_{i,j,x} = K_{i,j}\sqrt{(h_{i,j} - BOT_{i,j}) \cdot (h_{i+1,j} - BOT_{i+1,j})} \quad (3.2)$$

$$T_{i,j,y} = K_{i,j}\sqrt{(h_{i,j} - BOT_{i,j}) \cdot (h_{i,j+1} - BOT_{i,j+1})} \quad (3.3)$$

By correcting the transmissivities at each timestep a reasonable approximation of the behavior of an unconfined aquifer can be obtained. This approximation holds in areas where the phreatic surface is not excessively steep and the assumption of horizontal flow in the aquifer is honored. The predicted drawdowns from a pumping well are too large in the immediate vicinity of the well but are very close to the theoretical drawdowns a short distance from the well, as shown in Section 5.0, Program Verification.

If the timesteps chosen for a simulation are small with respect to the time frame of pumping or injection sequences, the response of the aquifer is fairly consistent through time. That is, if the head at a given node is dropping, then it is a good assumption that it will continue to drop during the next timestep. This assumption can be employed by use of a head prediction step prior to solution of the finite difference equations at each timestep, thereby significantly decreasing the iterations required for convergence. It should be noted that the same solution will be obtained whether or not the head predictor is employed. The head predictor adjustment is formulated by assuming that the ratio of the change in head between the two prior time cycles (at a given node) is a good estimate of the change in head over the next time cycle. This is shown by the following equations. The heads at times "t-2", "t-1" and "t" have been computed and the heads at time "t+1" are to be solved. A head prediction factor, F, is computed and used as shown below.

$$F = \frac{h_{i,j,t-1} - h_{i,j,t}}{h_{i,j,t-2} - h_{i,j,t-1}} \qquad (3.4)$$

$$h_{i,j,t+1} = h_{i,j,t} + (h_{i,j,t-1} - h_{i,j,t}) \cdot F \qquad (3.5)$$

Thus, the heads for the next timestep are the adjusted heads as computed above rather than the heads simulated at the end of the preceding timestep. The head prediction factor, F, is constrained between zero and five.

Several other points concerning the solution methodology employed are worthy of note.

Time Step - The finite difference solution of the differential equation of groundwater flow requires that both time and space be discretized. The size of the timesteps employed directly influence the accuracy of the solution obtained. The size of the timestep is dependent upon the size of the node spacing, the aquifer parameters, and the rate at which the aquifer is being pumped or recharged. The timestep should be chosen such that changes in the heads should be gradual through time. However, a timestep which is too small uses excessive computer time and does not gain significant additional accuracy. Time steps as small as a fraction of an hour are appropriate for a pumping well while monthly or even yearly timesteps are appropriate for gradual infiltration changes. Preliminary hand calculations and sensitivity analyses are recommended to determine the appropriate timestep and grid spacing.

Convergence Criteria - The implicit numerical scheme employed in this program is an approximate solution which is refined through successive iterations. Therefore, some criterion must be defined to determine when the solution has converged to an acceptable accuracy. This convergence criterion is implemented by comparing the difference in heads computed between two successive iterations. When this difference is within an acceptable value, convergence is reached. This program presents the difference in heads between iterations two ways. First, the sum of the change in heads for all nodes is computed. Secondly, the maximum head change at any node is found. Both values are reported and the program uses the sum of head changes as its convergence criteria. The iteration process stops when the sum of the head changes at every node point goes below a user defined limit. This method is most appropriate for regional groundwater simulations. The program also reports the value of the maximum head change at any node and can be easily modified to use this as a convergence criterion. This criterion would be more appropriate when simulating rapid changes to localized portions of an aquifer, such as pumping or injection wells.

Boundary Conditions - Boundary conditions must be defined for solution of the simultaneous finite difference equations. An initial or prior value of the head at each node is defined as either a somewhat arbitrary set of values at the beginning of the simulation or the heads from the immediately preceding timestep. The other set of boundary conditions required imply a known condition at the edge of the study area. These may be either "no-flow" (barrier) nodes or "constant-head" (recharge) nodes. Barrier boundaries are imposed by assigning a very low hydraulic conductivity (10^{-25}) at these nodes. Recharge boundaries are imposed by assigning a very high storage coefficient (such as 10^{25}) at these nodes. It should be realized that the edges of the finite difference grid represent barrier boundaries and effectively constitute a default condition if no boundary is explicitly set.

4.0 SEEPAGE TRANSPORT THEORY

The seepage transport theory employed in the program is based on the standard dispersive flow model summarized in Bear(6). The governing equation of seepage concentration distribution is:

$$C_{x,t} = \frac{M/n}{(4\pi D_h t)^{1/2}} \exp\left\{\frac{-(x-q/n)t^2}{4D_h t}\right\} \qquad (4.1)$$

This equation is similar in form to the equation which defines a normal probability distribution. This allows the following solution methodology.

A known mass of seepage is represented by a single "particle" whose movement in the groundwater system is tracked through time. Hundreds of particles are injected each timestep and their relative density over the study area is mapped at various times through the simulation. Particle density is transformed into seepage concentration by knowing the mass of seepage represented by each particle and the volume of groundwater within each cell. The concentration is the percent pond leakage in the groundwater assuming complete vertical mixing. That is, if the pond leakage had a sulfate concentration of 1500 mg/l and the simulated concentration is 10%, the groundwater would have a sulfate concentration of 150 mg/l. In this formulation, the following assumptions are made (symbols are defined at the beginning of this report):

- Seepage concentration C is low compared to the groundwater density, i.e. the amount of seepage does not affect the groundwater flow.

- The groundwater flow is steady over each timestep and two-dimensional.

- The porous medium is isotropic with respect to dispersion, and thus can be characterized by a longitudinal dispersivity a_L and a transverse dispersivity a_T.

- Any sorption reaction of the seepage with the formation is linear and instantaneous, and can be characterized by a distribution coefficient k_d. The retardation factor (R_d) is defined by:

$$R_d = \left(1 + \frac{D \cdot k_d}{n}\right) \qquad (4.2)$$

  where D is the bulk density and n the porosity of the porous media.

- seepage is completely mixed in the coarse grained stratified drift layer.

Based on these assumptions, the concentration distribution resulting from injection of a slug of unit mass of seepage into an aquifer at time t = 0 at the origin has the following characteristics:

- The centroid of a slug of seepage moves downstream at velocity $\overline{v}/R_d$, where $\overline{v}$, the average pore velocity of the fluid, is equal to V/n and V is the Darcy velocity. This distance is denoted as d_c and is defined as:

$$d_c = \frac{\overline{v} \cdot \Delta t}{R_d} \qquad (4.3)$$

- The average pore velocity, $\bar{v}$, is defined as:

$$\bar{v} = \frac{K \cdot I}{n} \qquad (4.5)$$

where K is the hydraulic conductivity, I is the gradient in the direction of flow and n is the volumetric porosity.

- With respect to the centroid, the concentration distribution is binormal--the product of a normal distribution in the flow direction with another normal distribution in the transverse direction.

- In the flow direction, the standard deviation of the normal distribution is:

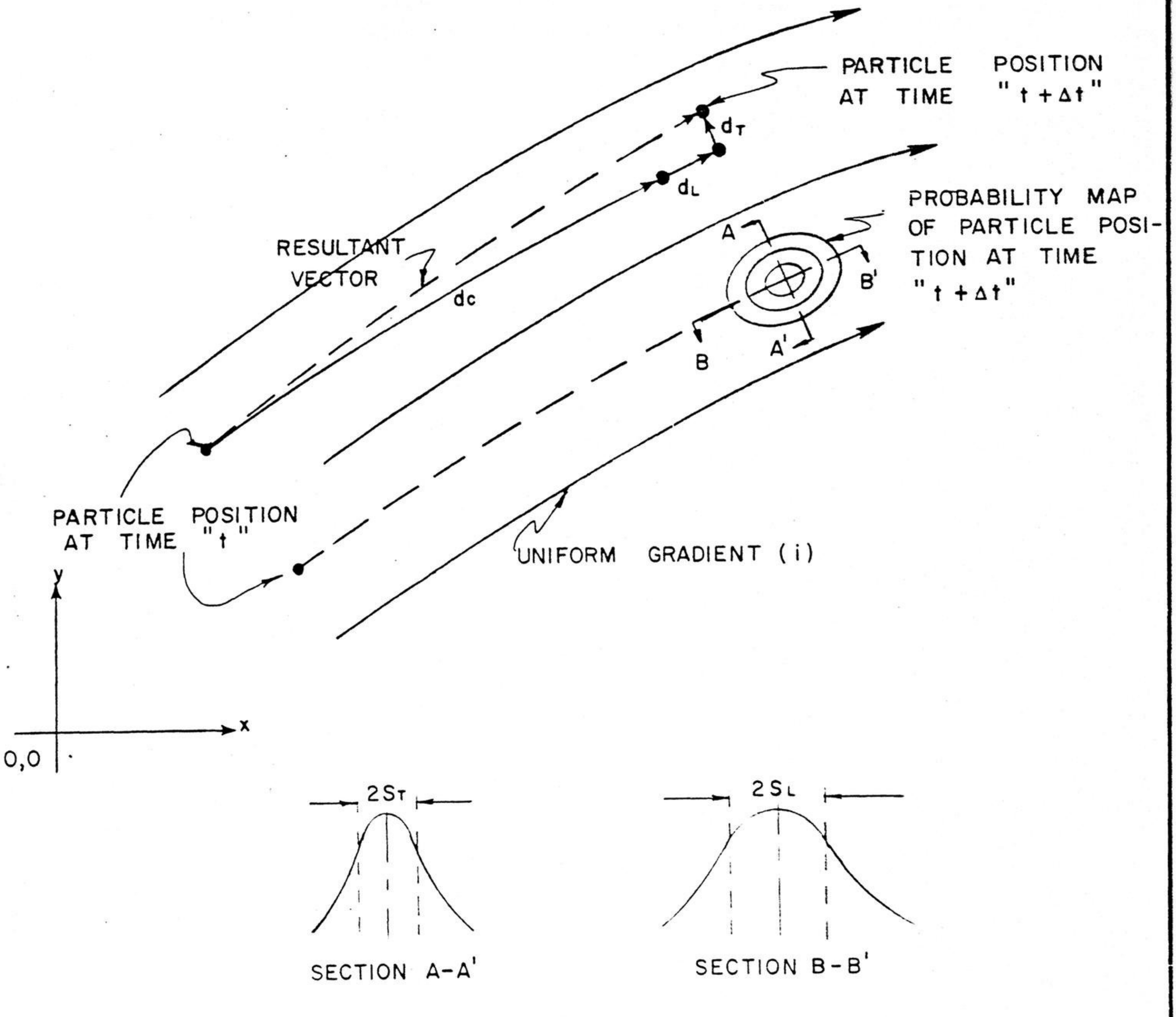
$$S_L = 2a_L\sqrt{(\bar{v}/R_d)\ \Delta t} = \sqrt{2a_L d_c} \qquad (4.6)$$

where d_c is the distance the centroid was moved and Δt is the simulation timestep.

In the transverse direction, the standard deviation is:

$$S_T = \sqrt{2a_T\ (\bar{v}/R_d)\ \Delta t} = \sqrt{2a_T d_c} = \sqrt{S_L\ \frac{a_T}{a_L}} \qquad (4.7)$$

The amplitudes of the longitudinal and transverse distributions are $1/S_L$ and $1/S_T$, respectively.



$$d_C = \frac{K \cdot i \cdot \Delta t}{n \cdot R_d} = \frac{\overline{V}\ \Delta t}{R_d}$$

$$d_L = r_1 \sqrt{2 a_L d_C} = r_1 s_L$$

$$d_T = r_2 \sqrt{2 a_T d_C} = r_2 s_T$$

JOB NO. 786085	SCALE NO SCALE	CONCEPTUAL PARTICLE MOVEMENT	
DRAWN CAB	DATE 5-7-81		
CHECKED JEB	DWG NO 050-1-81111		
Golder Associates		EXXON MINERALS COMPANY	FIGURE 4.1

Based on this formulation, the seepage transport algorithm used in the program is quite simple. Figure 4.1 illustrates the movement of single particles in a steady state flow field over one timestep. Each particle is moved a deterministic amount (d_c) down gradient from its existing position over a discrete timestep. In addition, each particle is moved a dispersive distance in the longitudinal (d_L) and transverse (d_T) directions. The values of d_L and d_T are computed by selecting a random, normally distributed number (r_1) of mean 0 and standard deviation 1, and multiplying it by the standard deviation of the longitudinal dispersivity:

$$d_L = r_1\sqrt{2d_c\ a_L} = r_1 S_L \tag{4.8}$$

Similarly, the transverse dispersion is given by:

$$d_T = r_2\sqrt{2d_c\ a_T} = r_2 S_T \tag{4.9}$$

Therefore, the vector describing the movement of a single particle over one timestep is the resultant of the sum of d_c and d_L in the direction of flow and d_T normal to the flow direction. The new position of each particle is computed by decomposing this vector into the X and Y coordinates of the problem domain and adding them to the previous position.

The user should be aware that there are some problems with the application of the basic theory of seepage transport. Experimental data has shown that the values of the dispersivities are very much a function of the scale of the test. Anderson stated in reference 7:

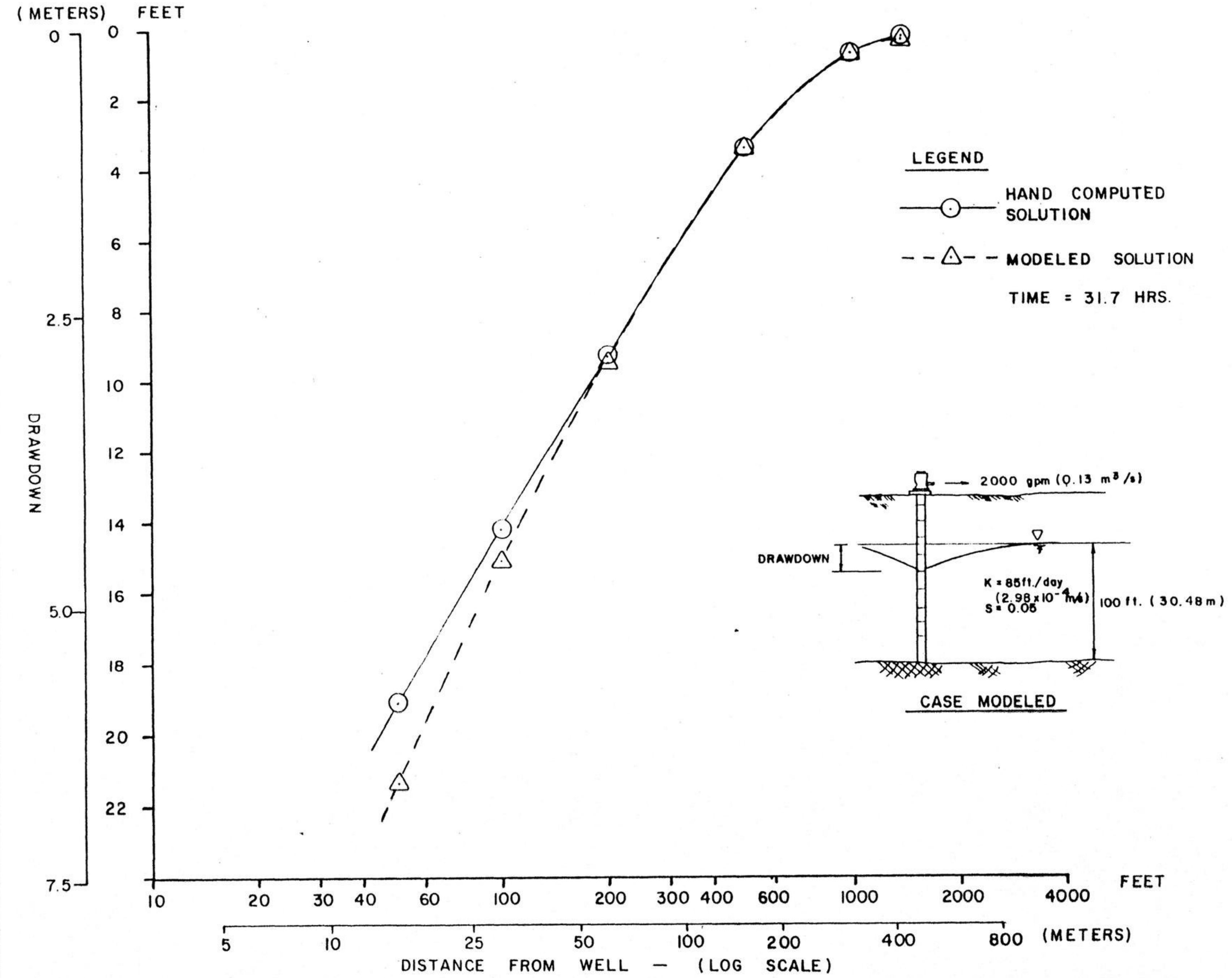
> "It is well known that the magnitude of the measured dispersivity changes, depending on the scale at which the measurements are taken. Laboratory experiments designed to measure dispersivity yield values in the range of 10^{-2} to 1 cm, while dispersivities of 10 to 100 meters have been obtained for field problems."

These problems relate to the difficulties in determining an appropriate value of dispersivity. It is recommended that a sensitivity analysis be made to determine the importance of the value of the dispersivity chosen in the problem situation being simulated. This will allow proper perspective to be placed on the selection of dispersivity and will allow the use of a conservative value if appropriate.

5.0 PROGRAM VERIFICATION

As stated at the end of Section 2.0, the "model" is taken to include the conceptual hydrogeologic model, its mathematical formulation and the computer program written to solve the equations. The computer program is further described in Section 7.0. This section presents the verification tests employed to insure that the equations are properly solved by the computer program. This verification process consists of a series of simulations which can be checked by hand calculations.

The two processes modeled by the program are; (1) the change in the groundwater table and (2) the transport of seepage in the groundwater. The change in groundwater heads through time is simulated in the program by a finite difference algorithm. Verification of this algorithm is provided by simulating simple drawdown and recharge cases which can be checked by hand computations. The drawdown case is an infinite, homogeneous, isotropic, unconfined aquifer with a saturated thickness of 100 feet (K=85 feet/day, S=0.05) from which 2000 gpm is being pumped. Figure 5.1 shows the idealized aquifer, the simulated solution and the hand calculated solution using the Boulton method(8). The simulated solution shows about 2 feet excess drawdown over the hand computed solution 50 feet from the well but the solutions match at 200 ft. and beyond. This difference is due to the discretization of time and space of the finite difference solution. A grid spacing of 50 feet and an initial timestep of 0.001 days (increasing by a factor of 1.25 each cycle) was used in the modeled analysis. Closer grid spacing would improve the match closer to the well. The recharge case is an infinite, homogeneous, isotropic, unconfined aquifer with an initial saturated thickness of 100 feet (K=0.5 feet/day, n=0.07) with infiltration being induced at



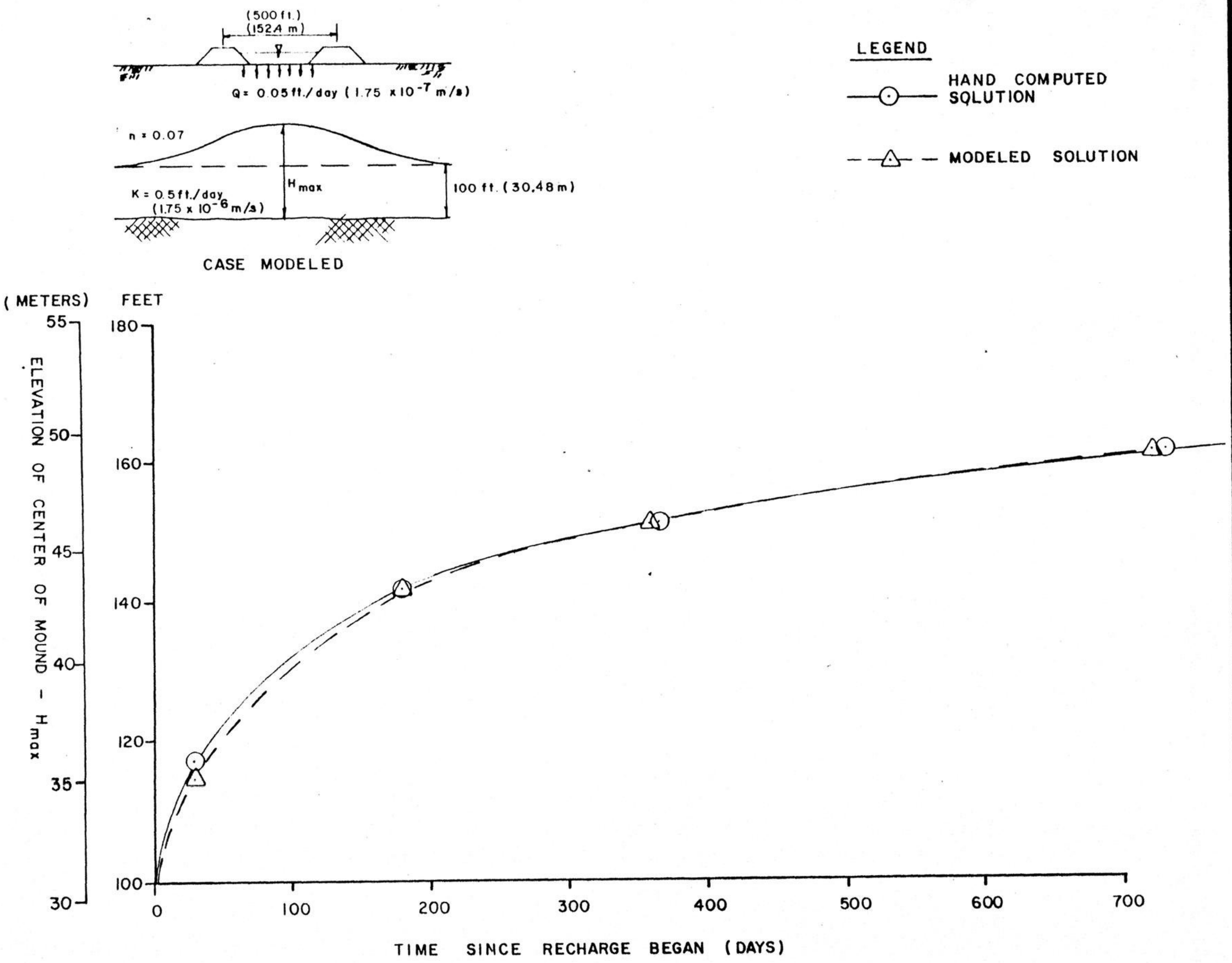
Golder Associates

JOB NO. 786085
DRAWN CAB
CHECKED JEB
SCALE AS SHOWN
DATE 7-8-81
DWG. NO. 050-1-81107

GROUNDWATER MODEL VERIFICATION
PUMPING CONDITION

EXXON MINERALS COMPANY

FIGURE 5.1



Golder Associates

JOB NO. 786085
DRAWN CAB
CHECKED JEB
SCALE AS SHOWN
DATE 7-8-81
DWG. NO. 050-1-81108

EXXON MINERALS COMPANY

GROUNDWATER MODEL VERIFICATION
RECHARGE CONDITION

FIGURE 5.2

a rate of 0.05 foot/day over a 500 foot area. Figure 5.2 shows the idealized aquifer, the simulated solution and the hand calculated solution using the Hantush method(9). The two solutions show a deviation of about 2 feet during the early part of the simulation. A finite difference grid spacing of 100 feet and a constant timestep of 30 days were used in the modeled analysis.

The second process modeled is the transport of seepage in the aquifer. The verification of this process is provided by modeling an instantaneous slug of a given mass of seepage in a homogeneous, isotropic aquifer (K = 10 feet/day, n = 0.25) under a uniform, constant gradient of 20 feet/mile. Neither solution considers retardation or chemical change. The hand solution is computed by solving the one dimensional equation of seepage transport. Figure 5.3 shows the aquifer and a cross section of the seepage slug 9 years after injection for the computer simulation and the hand solution.

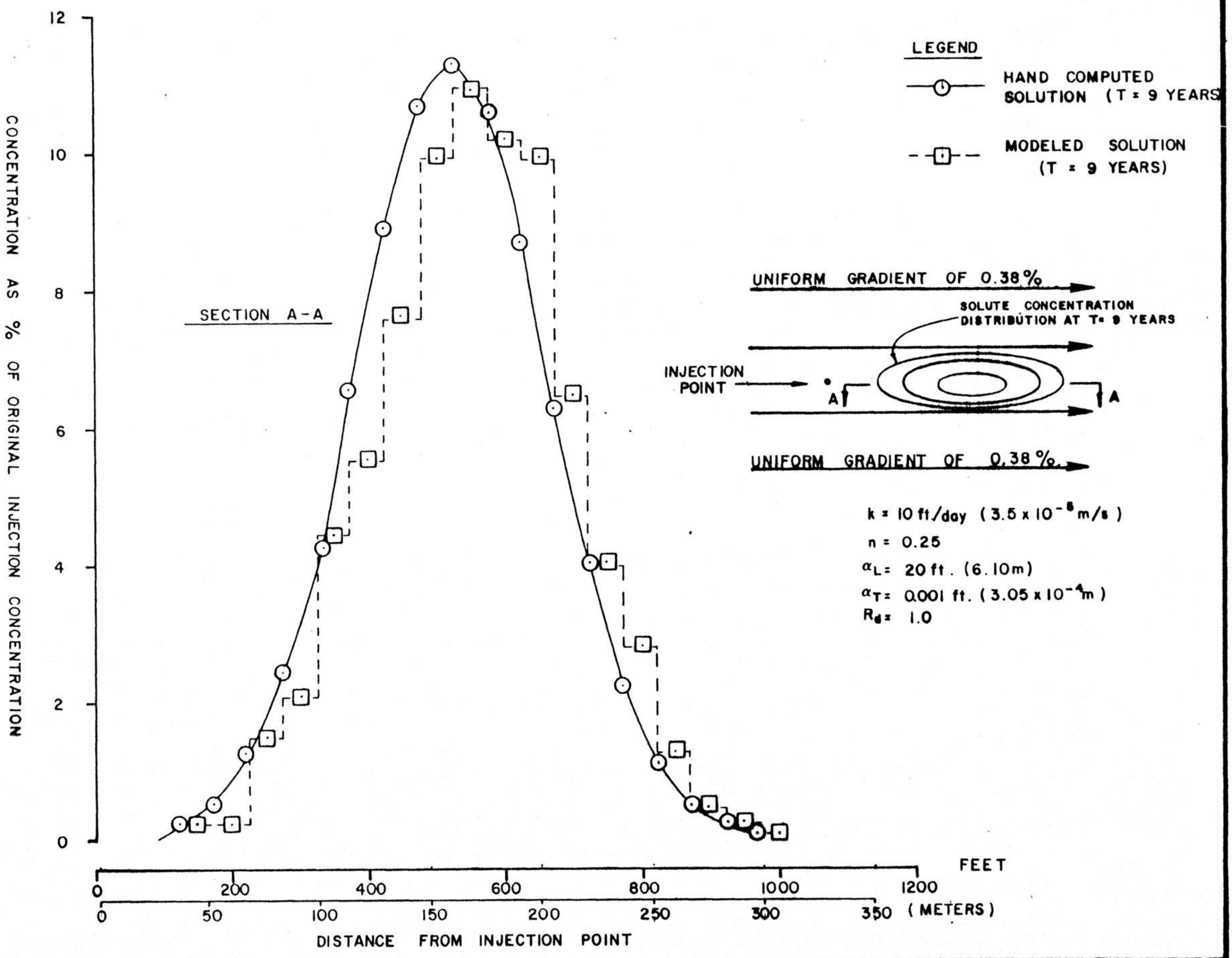
Golder Associates

JOB NO. 786085
DRAWN CAB
CHECKED JEB
SCALE AS SHOWN
DATE 8-21-81
DWG. NO. 050-1-81109

SOLUTE TRANSPORT MODEL VERIFICATION

EXXON MINERALS COMPANY

FIGURE 5.3



$k = 10$ ft/day (3.5×10^{-5} m/s)
$n = 0.25$
$\alpha_L = 20$ ft. (6.10m)
$\alpha_T = 0.001$ ft. (3.05×10^{-4} m)
$R_d = 1.0$

6.0 MODEL CALIBRATION

Due to the variable nature of the aquifer over the entire study site, some parameters in some areas of the model must be inferred. This is done by modifying the parameters in a logical fashion until the predicted results adequately match those observed in the field. This process is called calibration and is critical to the accuracy of the predictions based on the calibrated model. If too many parameters are inferred or set through calibration an unrealistic parameter set could be selected. This could result in a model calibration which matches the predicted and the observed results adequately but behaves erroneously when changes are imposed. Therefore, measured field data should be used as extensively as possible and unsupportable calibration refinements should be avoided.

The head simulation and the seepage transport algorithms may require calibration before using the model. The head solution is calibrated by determining as many of the aquifer parameters as possible through pumping tests, exploration borings, regional water balances, and other applicable sources. The remaining parameters are set to their most likely value. The model can then be calibrated by modifying parameters until the predicted head levels match observed heads in a steady state mode. The final head configuration is usually stored on a RESTART file to use as the initial heads in subsequent simulations. The transient behavior of the model should be calibrated if adequate observed data is available. Transient phenomenon such as spring snow melt or pumping wells are commonly used. If transient observed data is not available the model should still be checked with a reasonable estimate of seasonal variation of infiltration to insure that no extreme fluctuations take place in the model.

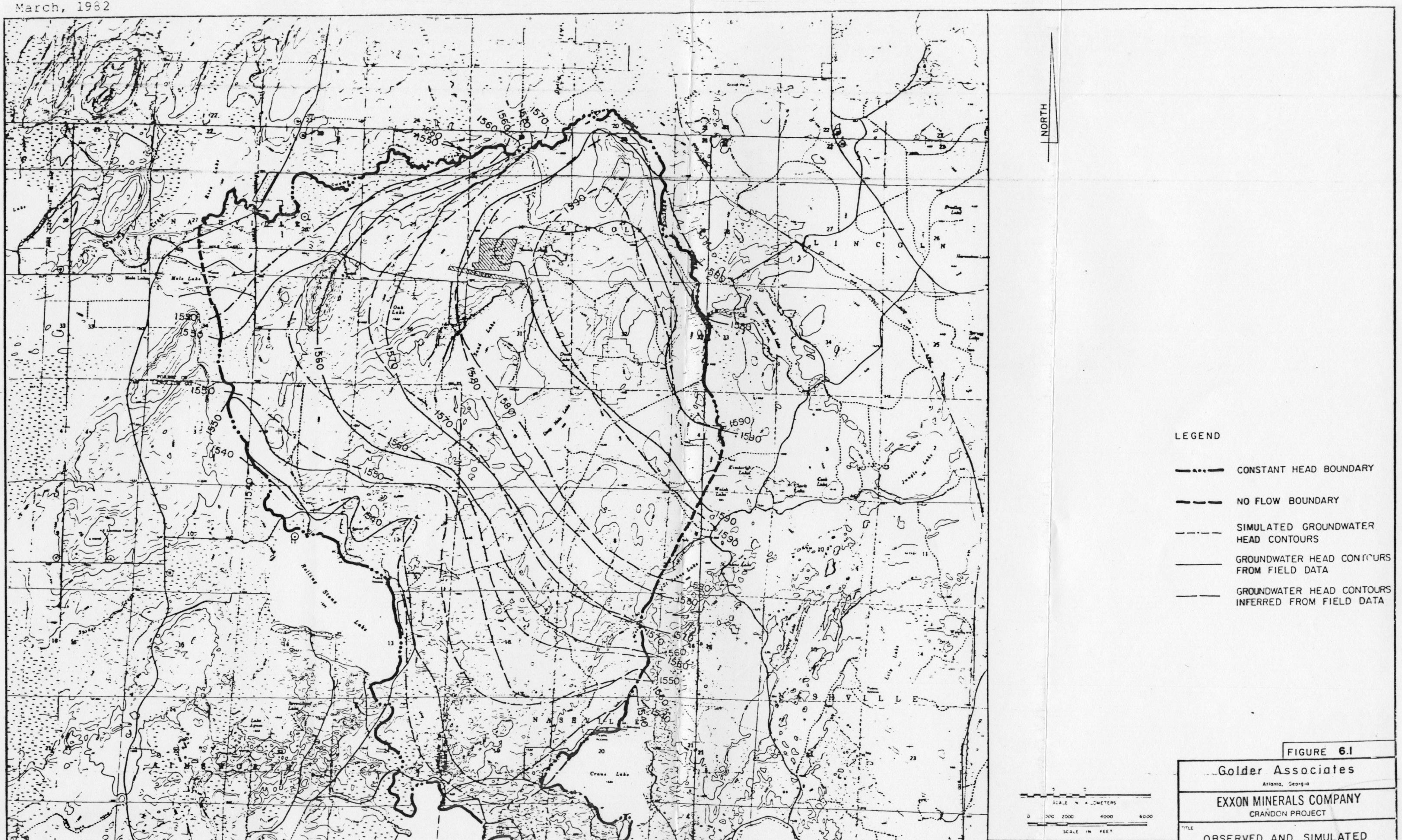
The seepage transport algorithm contains dispersion and retardation parameters which may be calibrated by comparing predicted seepage transport to observed. This is complicated, however, by the scale dependency of the coefficient of dispersivity. Also, such observed data is seldom available requiring the use of values from the literature.

In cases where calibration is nonexistent or weak, sensitivity studies should be made to determine the impact of the parameter values selected on the model results. Quite often some parameters are found to have very little effect over the range of required results and typical values may be used. Also, inferred parameters should be chosen in such a manner to insure conservative results.

The model calibration for the Crandon site was based on a detailed geologic investigation(1), pump test performed in June, 1980(2) and Dames and Moores environmental baseline study(10). This site specific data provided the initial set of data from which the calibration effort began. Simulated contours were compared to observed contours to determine the accuracy of the calibration. The observed groundwater contours used are those presented in reference 11 which reflects all data in the area gathered to date and a comprehensive set of piezometer readings in September, 1980.

Several parameters were based upon the above listed sources of information and were not varied during the calibration process. These were the average horizontal hydraulic conductivity of the coarse grained stratified drift of 35 feet/day and storage coefficients of the coarse grained stratified drift and upper till of 0.070 and 0.054, respectively. To calculate the groundwater head at a given node the model requires a value of aquifer transmissivity which is the product of hydraulic conductivity and saturated aquifer thickness at that point. Values of aquifer thickness were defined for each groundwater head node location. Calibration was achieved by varying the annual net infiltration between the values indicated in the environmental baseline report. A net annual groundwater recharge value of 12.5 inches generated simulated groundwater contours of the same general elevations as those observed. The observed groundwater contours (as presented in reference 11) and simulated groundwater contours are shown on Figure 6.1. The input parameter values are listed in the sample model output in Appendix B.

March, 1982



1	10-12-8.	CAB	RECALIBRATED GROUNDWATER HEAD CONTOURS 10-8-81

FIGURE 6.1

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
OBSERVED AND SIMULATED
GROUNDWATER HEAD CONTOURS

AS SHOWN	WISCONSIN	FOREST
SKB 9-1-81	JEB	9/4/81

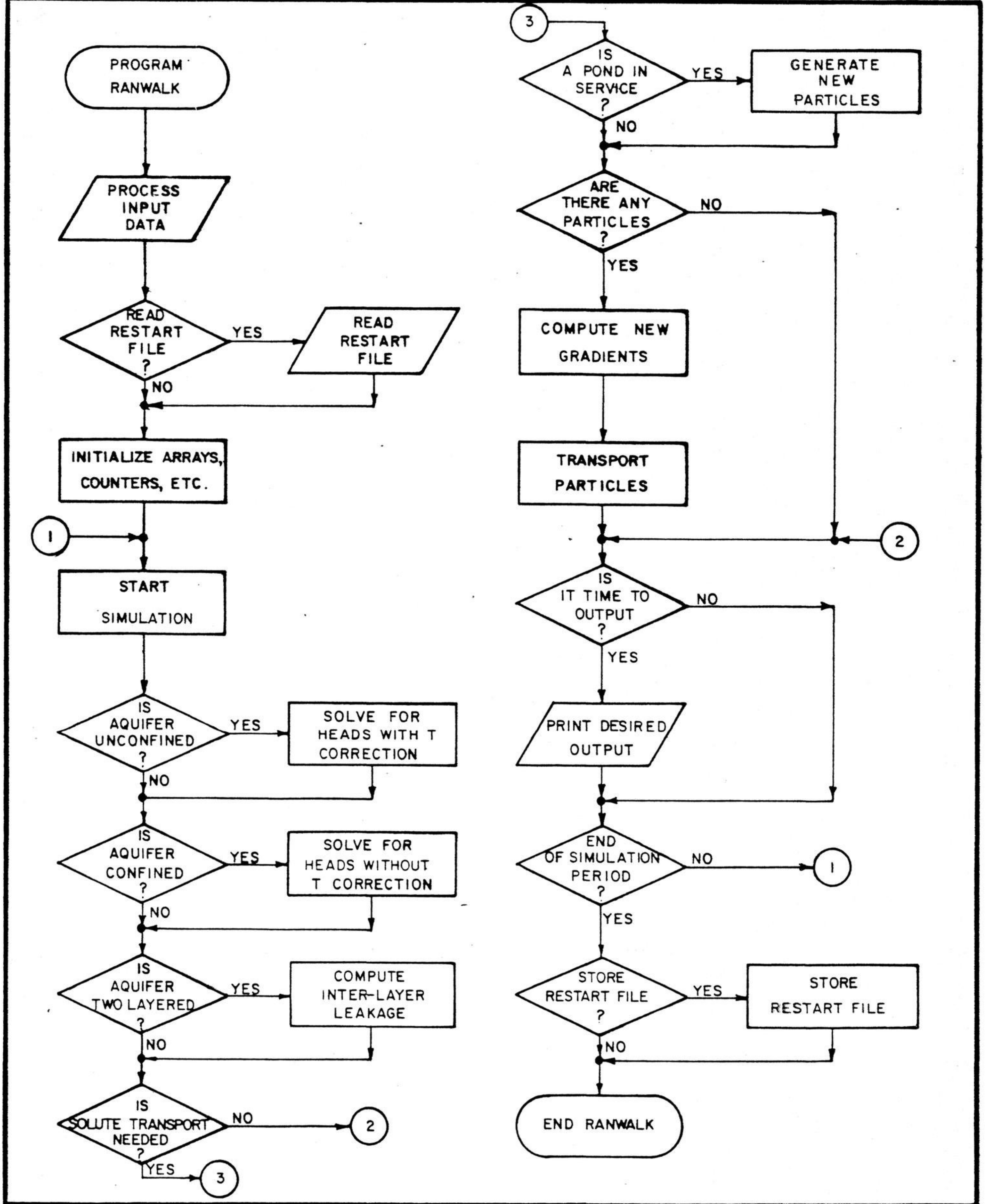
050-1-80504

7.0 PROGRAM DESCRIPTION

The GROUNDWATER IMPACT SCREENING MODEL was developed as a group of service routines which perform specific tasks controlled by a main program. The needed arrays are passed between program units primarily through named COMMON blocks. Flow of logic through the program is kept as linear as practical with entrance and exit from a program unit from the top and bottom only. This practice reduces the complexity of logic flow and minimizes debugging and modification efforts. The program is coded in FORTRAN with as little use of extensions as practical. This allows compatability of the program with many other computer systems. The program is thoroughly commented and each subprogram contains a description of its function and definition of the major variables used.

The flow chart of the program is shown in Figure 7.1. A brief description of the major subroutines is as follows:

RANWALK	-	This is the main program which controls the simulation and calls the major subroutines.
INPUT	-	Reads the input data which defines the problem to be simulated, sets various control parameters and loads operational arrays. An echo of the data is provided.
IADI	-	Solves the groundwater head at each node by using the iterative alternating direction implicit method as described in Section 3.0. Optionally makes an adjustment for transmissivity change in unconfined aquifers.
LEAK	-	Computes leakage between two aquifers based on the hydraulic conductivity of the upper layer and the vertical gradient (not used in present version of the program).



JOB NO. 786085	SCALE NOT TO SCALE	PROGRAM FLOWCHART
DRAWN SKB	DATE 8-21-81	
CHECKED JEB	DWG. NO. 050-1-81110	
Golder Associates	EXXON MINERALS COMPANY	FIGURE 7.1

GRADNT - Computes the groundwater gradient in the X and Y directions at each node point and resolves the resultant vector.

GENERAT - Generates discrete particles based on the particle volume and leakage history input to the model.

FIND - Finds the cell in which a given x, y point is located.

MOVE - Transports particles according to the algorithm discussed in Section 4.0.

ELIM - Eliminates particles which have moved to the boundary areas (streams, lakes, etc.) after each printstep.

HEDIN - Reads in the restart file, compares critical parameters and echos data to the output report.

HEDOUT - Stores simulation parameters, head configuration and optionally the particle locations on a restart file.

INTERP - Interpolates a leakage rate from the leakage history curve. Leakage rate is taken at time $t+0.5(\Delta t)$.

PLOT - Outputs the particle count matrix at each node, row by row.

PLOTR - Outputs the head elevation at each node, row by row.

PLOT3 - Plots a symbolic representation of the distribution of active and inactive particles by assigning a character which corresponds to a range of the number of particles in the cell.

OUTPUT - Prints the head matrix in block form, not to scale. The origin (node point 1,1) is located in lower left corner; the matrix is partitioned into slices 25 columns wide.

OUT2K - Prints the head or concentration matrix in block form to a scale of 1" = 2000'. Origin (node point 1,1) is located in the

		lower left corner; matrix is partitioned into slices 20 columns wide. In present version reported heads are actual head minus 1500 feet. Concentrations are computed as a percent of leachate in the groundwater contained in each cell.
OUT3K	-	Prints symbolic distribution of seepage concentration as a percent groundwater at a 1" to 2000' scale when a seepage grid spacing of DXPAR = 200 ft. and DYPAR = 333.3 ft.
ERPROC	-	Prints error messages on output report.

The program has been written so as to minimize the computational effort involved in the innermost loop elements, especially MOVE. Needed constants are evaluated and stored in matrices before entering this loop, and the algebraic expressions have been derived so as to minimize the use of trigonometric and other complex mathematical functions.

The program has several capabilities designed to increase the utility and efficiency of its use.

- Comprehensive set of error codes handled by a separate subroutine.
- Data array dump optionally provided upon trapping of a fatal program error (but not fatal system errors).
- Storage and retrieval of RESTART files which allow simulations to be stopped and restarted with or without change of parameters.
- Several output types, all user selectable.

A listing of the program is included as Appendix C of this report.

8.0 INPUT DATA

8.1 General

As in most simulation programs, the assembly of the input data constitutes the major portion of the effort to apply the model. Data input is mainly keyword directed to allow flexibility in input sequence and facilitate data modification. A description of needed data follows, in Sections 8.2 through 8.7 along with discussion of units. A summary of the input data requirements and input format is included in Section 8.8. The input is explained by use of the Crandon case as an example in which a sample case of a 85 acre pond leaking at 1.0 gpm for 30 years, increasing to 5 gpm thereafter is simulated. The example input is included in Appendix A and the corresponding output is provided as Appendix B.

8.2 Unit Convention

The program requires a consistent set of units. Length and time unit names are input to the model for information purposes only, no unit conversion or checking is performed. Although any consistent set of units can be used computationally, the output portion of the program presently reports in feet and days. All input parameters and output values used in the example case are in these units.

8.3 Definition of the Problem Space Domain

The space domain for the problem is a two-dimensional plane in space. This plane is single valued (i.e., does not double back on itself) but need not be flat or horizontal. All further discussion about the solution space assumes that the plane is reasonably flat, however, as it is assumed that distances in the plane are equal to horizontal distances. All geometry of the plane is projected onto a horizontal surface.

The solution domain is represented by two grids. The intersection of the grid lines in each grid define a "node point", which is at the center of a "cell". One grid controls the solution of the groundwater head and the other the concentration of seepage. The seepage grid must be an even integer subgrid (or equal to) the head grid. The groundwater head is computed at each head grid node point and the gradients in the x and y direction are computed by interpolating linearly between head node points. The seepage concentration distribution is based on the total seepage mass located in each seepage grid cell, yielding vertically integrated, totally mixed concentrations. The extent of the grids should be selected so as to minimize edge effects. Extending the grids to groundwater interacting rivers and lakes or groundwater ridges is recommended. Other considerations of grid selection are listed below.

- All cells in each grid have the same dimensions, but the two grids may differ.
- The origin of each grid is the origin of the models coordinate system (user may need to correct coordinates to conform to this criteria), and the two grids must use the same origin.
- Points in the domain, including node points, are referred to by their X, Y coordinates. Cells are referred to by their X, Y numbers counting from the origin (1,1).
- All coordinates and cell numbers in each grid are positive.

The program has the capability to print the head elevation and seepage concentration matrices at a scale of 1" to 2000' on a line printer. This is useful for overlaying simulated contours on USGS 7.5 minute quadrangle basemaps, but requires a 10.0 ver.:6.0 hor. distortion of the seepage concentration grid.

Selection of grid spacing and cell size is a compromise between the resolution of the results and cost of the simulation. The finite difference head solution increases in cost as the number of nodes increases due to the number of finite equations to be solved. Concentrations are based on the total seepage mass contained within a seepage grid cell and is reported at the node point. Therefore the broader the seepage grid spacing, the coarser the gradient definition and seepage concentration resolution. Simulation cost increases with the number of seepage grid cells since the total number of particles must be increased to keep an acceptable number of discrete particles in each active seepage cell. A final consideration is that the grid spacing be sufficient to outline features such as boundaries and material types.

The Crandon example, which will be used throughout this manual, is shown in Figure 8.1 which also shows the groundwater head grid. Figure 8.2 shows the subdivision of groundwater grid into seepage subgrids. The grids are defined by eight variables:

DX = Size of X dimension of each head cell
DY = Size of Y dimension of each head cell
NX = Number of head cells in X direction
NY = Number of head cells in Y direction
DXPAR = Size of X dimension of each seepage cell
DYPAR = Size of Y dimension of each seepage cell
NXPAR = Number of seepage cells in X direction
NYPAR = Number of seepage cells in Y direction

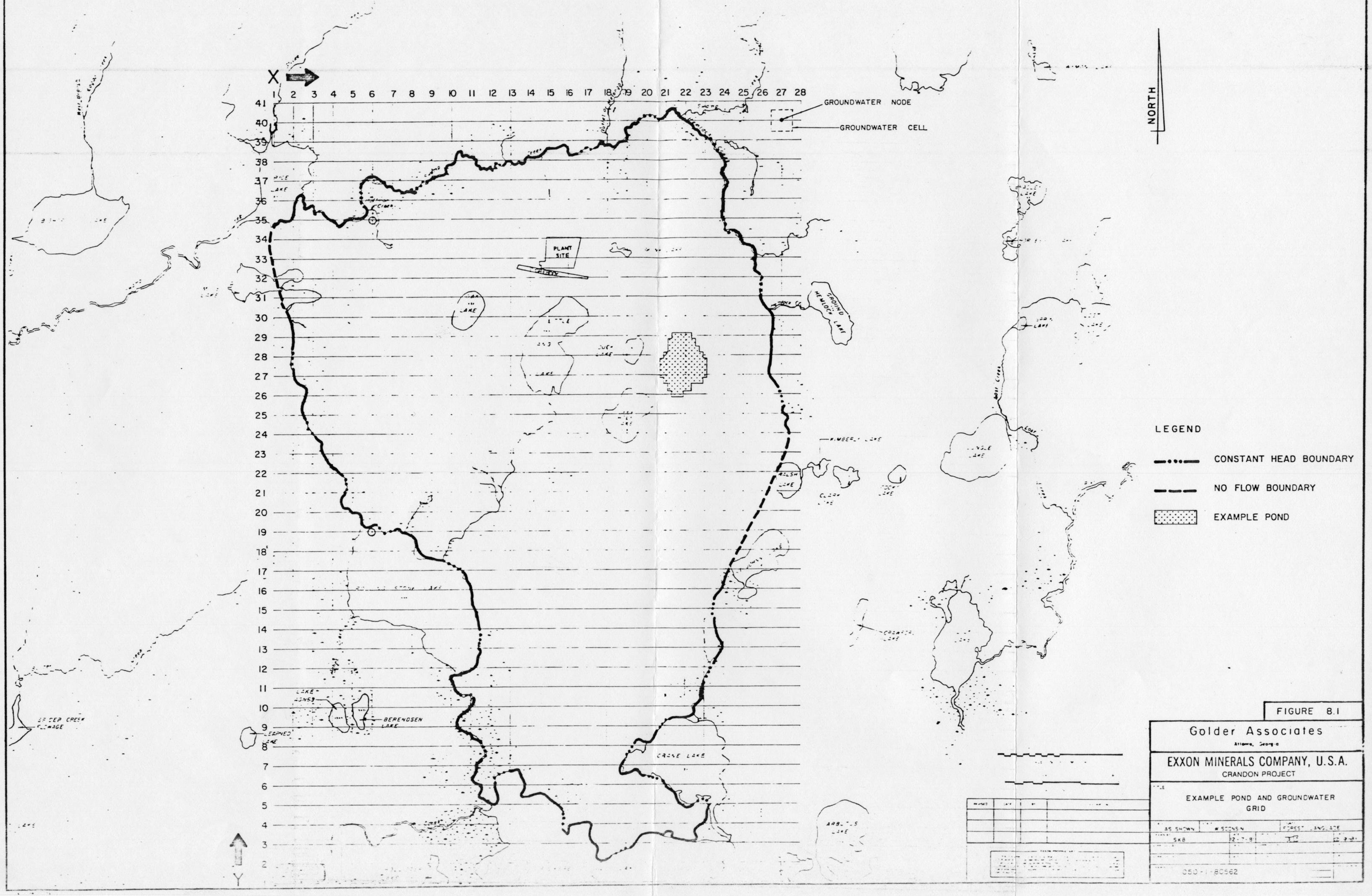


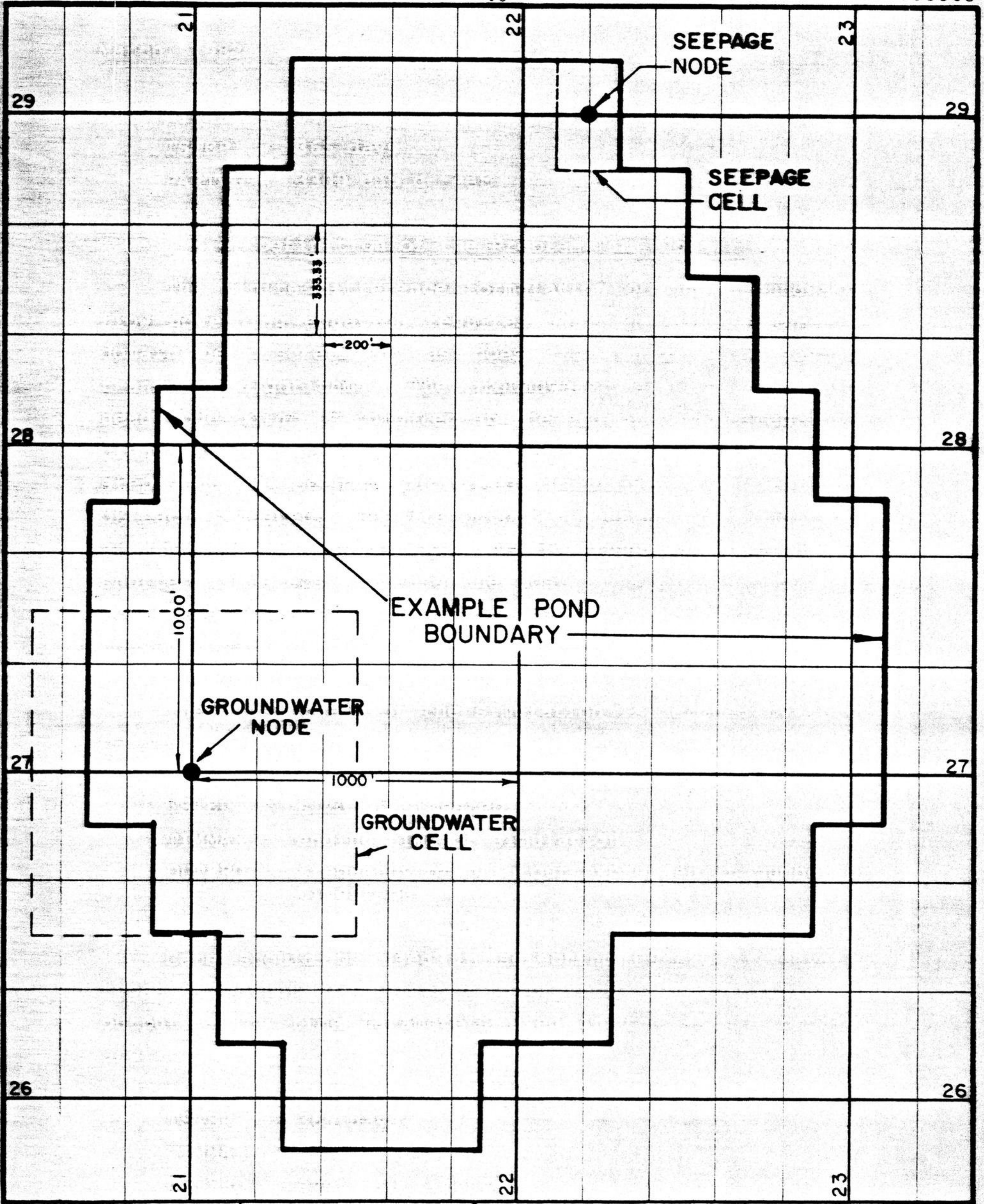
FIGURE 8.1

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

EXAMPLE POND AND GROUNDWATER GRID

AS SHOWN | WISCONSIN | FOREST, LANGLADE
SKB | 12-7-81
050-1-80562



JOB NO. 786085	SCALE 1" = 400'	GROUNDWATER AND SEEPAGE GRIDS
DRAWN SKB	DATE 12-7-81	
CHECKED JEB	DWG. NO. 050-1-80561	
Golder Associates		EXXON MINERALS COMPANY
		FIGURE 8.2

Two other parameters which effect the resolution and cost of simulation are the timestep and volume of leakage per discrete seepage particle (which controls total particle count). Selection of timestep should consider (1) required output frequency, (2) ratio of gradient induced (advective) particle movement to dispersive movement during each timestep and (3) convergence time for the head solution. The transport components (advective and dispersive) should be compared to prevent overpowering effects of either process. As shown by equations 4.3, 4.6 and 4.7 a short timestep and a large dispersivity or the inverse can result in odd transport behavior in extreme cases. Both the leakage rate and the timestep affect the iterations required for head solution convergence. Further discussion of the timestep follows in the next section.

The volume of seepage to be represented by each particle defines the average number of particles in each cell for a given cell size and leakage history. A maximum of 20,000 particles is allowed by the program. A rule of thumb for particle density is that the user should aim for an average of between 10 and 20 particles seepage per seepage cell within the seepage plume.

The master grid, timestep and particle volume for the sample problem is defined by the following parameters:

DX = 1000 feet
DY = 1000 feet
NX = 28 cells
NY = 41 cells
DXPAR = 200 feet
DYPAR = 333.3 feet
NXPAR = 140

NYPAR = 84
TSTEP = 365 days
PARTVL = 3300 cubic feet

8.4 Definition of the Problem Time Domain

The finite difference formulation of the groundwater flow governing equation requires that the simulation time domain be discretized, as does the random walk seepage transport algorithm. The groundwater elevation of each head node point is computed at the end of a timestep, gradients at each particle location are computed between timesteps and all seepage particles injected at the beginning of each timestep. Results output represent the conditions at the end of a timestep. As discussed in Section 8.3, shorter timesteps increase the cost of simulation but are sometimes required for output frequency or head solution convergence.

The time domain of the simulation is defined by three parameters:

TSTEP = size of timestep
TIMMAX = ending time of simulation
OUTFRQ = frequency of printout expressed in number of timesteps

Care should be used in selecting OUTFRQ if several types of output are selected to prevent vast quantities of output. The time parameters used in the sample problem are:

TSTEP = 365 days
TIMMAX = 18,250 days
OUTFRQ = every 10 timesteps

8.5 Definition of Material Types

Several physical characteristics of the aquifer are constant over broad regions of the study area. Input of these characteristics is done by use of material types. Each head cell is given a specific type number which is defined by a given set of parameter values. The program can presently accept up to 10 material types. The parameters which define each material type are:

NVM = material type number
K = hydraulic conductivity
S = storage coefficient
RE = normal recharge to aquifer
POR = porosity
DL = longitudinal disperssivity
DT = transverse dispersivity
RT = retardation

Several special materials are used for various types of boundaries in the model. A very small (10^{-25}) value for hydraulic conductivity represents a no-flow or barrier boundary; a very high (10^{25}) storage coefficient represents a constant head or recharge boundary; a zero value for porosity (not used in the head situation) represents no seepage transport areas. The barrier and recharge boundaries can be either rows or areas of cells encompassing the project area. "No transport" areas are those areas lying outside of the constant head and no flow boundaries.

The material type distribution over the model area is defined by two input methods. Initially, the entire matrix is set equal to the default material type. Specific head cells can then be set to actual material types by specifying the material type number over the head cell matrix, leaving a blank or zero for the head cells with the default material type. The material type definitions and their distribution over the head grid is shown in the sample input listed in Appendix A.

8.6 Definition of Leakage Histories

The primary use of the model is to impose a pond leakage at various seepage grid nodes and examine the impact on the head configuration and transport of seepages. The time trace of recharge rates is defined by a set of leakage histories. Up to 20 separate leakage histories can be defined which can overlap in time but not in space. Each leakage history is defined by the following parameters:

NLH = Leakage history identifier number

NLPTS = number of points on the time/rate leakage curve

NNODES = number of seepage grid nodes over which leakage is spread

TM(NLPTS) = time ordinates of the leakage curve (NLPTS values must be entered)

RATE(NLPTS) = flow rate ordinates of the leakage curve (NSPTS value must be entered)

NODES(NNODES) = column numbers (x-direction) of seepage cells (NNODES pairs must be entered)

NODES(NNODES) = row numbers (y-direction) of leakage cells (NNODES pairs must be entered)

The flow values in the leakage curve are total flows for the leakage area and are divided evenly over the appropriate seepage cells. Seepage particles are injected randomly over the cells in the leakage area. Leakage values at each simulation timestep are interpolated linearly from the time/rate curves active at that time. The leakage history used in the sample problem is shown in the sample input listing in Appendix A.

8.7 Definition of Initial Head Configuration

As stated in Section 3, the finite difference solution of the groundwater flow equation requires an initial head configuration, which can be specified at the beginning of each run or by use of a RESTART file, as discussed in the next paragraph. This initial condition can be chosen somewhat arbitrarily except that constant head nodes must be set to their fixed elevation. The solution scheme will iterate to the proper heads at other nodes. This is done through the default head parameter and/or the HEAD matrix input block. The initial groundwater head at nodes defined as constant head nodes must be set to the desired fixed head elevation using the HEAD input block. Heads at all other nodes can be input as zeros or blanks and specified by the default value. The default value should be an estimated areal average of the elevation of the phreatic surface since the further the initial head condition is from the field condition, the more iterations are required for convergence.

The model should be allowed to proceed under steady state conditions through enough timesteps until the change in heads has stabilized prior to imposing the leakage to minimize initial condition effects. Alternatively, the simulation can be terminated when steady state is reached and the heads stored on a RESTART file. Subsequent simulation can then utilize this stored head configuration to define the initial conditions and omit the warm-up period. Heads read from a RESTART file override the default or matrix defined head elevations input to the program.

8.8 Summary of Data Input Requirements

This section defines the format of the input data. Input is in fixed format and must occur in the given order for the first 6 data cards. Subsequent input is keyword directed and data blocks may be arranged in any order.

Card Number	Variable	Format	Description
1	TITLE	8A10	job title
2	TUNIT	A10	time units (information only)
	LUNIT	A10	length units (information only)
3	DX	F10.0	size of X dimension of each groundwater flow cell
	DY	F10.0	size of Y dimension of each groundwater flow cell
	NX	I10	number of groundwater flow cells in X direction
	NY	I10	number of groundwater flow cells in Y direction
	TSTEP	F10.0	timestep size
	TIMMAX	F10.0	ending time for simulation
	PARTVL	F10.0	volume of leakage represented by each discrete particle. Set to zero to inhibit seepage transport simulation.
4	DXPAR	F10.0	size of x dimension of each particle cell
	DYPAR	F10.0	size of y dimension of each particle cell
	NXPAR	I10	number of particle cells in x direction
	NYPAR	I10	number of particle cells in y direction
	KELIM	I2	indicator to control elimination of particles in no transport areas. 0 = eliminates particles only after each print step (default) 1 = eliminates particles after each time step

5	ISEED	I10	seed for random number generator
	MTYPE	I10	model type 1 = double layer aquifer 2 = unconfined aquifer (make transmissivity correction) 3 = confined aquifer (do not make transmissivity correction)
	MAXIT	I10	maximum number of iterations allowed for each step of finite difference groundwater model
	TOL	F10.0	convergence criteria (sum of differences between actual and calculated heads for all cells)
	OUTFRQ	I10	number of timesteps between report output, first timestep is always printed
	PRINT(10)	10I1	print output selector, each column represents an option which is requested by entering a 1 in the column, as defined below: 1 - dump head, bottom and material type array 2 - dump head array on program generated abort 3 - plots head matrix, 20 columns per page 4 - plots head matrix, 1" to 2000' scale 5 - plots concentration matrix, 1" to 2000' scale 6 - plots symbolic active and boundary particle summary 7 - prints detailed particle count by cell 8 - prints detailed gradients by cell 9 - prints iteration information for finite difference 10- Seepage grid output matrix (at 1" to 2000'

			when DXPAR = 200' and DYPAR = 333.3')
	IHEDIN	I10	file number for file containing restart information
	IHEDOT	I10	file number to output restart information for later use
6	HEAD(1,1)	F10.0	default head elevation
	BOT(1,1)	F10.0	default impermeable bottom elevation
	MATL(1,1)	I10	default material number
	THICK(1,1)	F10.0	default aquifer thickness

The default values of HEAD(1,1) BOT(1,1) MATL(1,1), and THICK (1,1) are automatically assigned to all cells. Modification of default values at various nodes, and initialization of material properties and definition of the leakage histories is done by keyword directed input. Default values are changed by inputting the entire matrix with the overriding value at the proper node and blanks or zeros in locations where defaults are to be used.

Use of keyword input provides increased flexibility in the modification and initialization of parameters and allows any order of data block input. Each keyword references a block of data.

KEYWORD	ACTION
HEAD	modify initial head elevation for any or all head cells
BOTTOM	modify impermeable bottom elevation for any or all head cells
MATERIAL	initialize material parameters for all material types
LEAKAGE	define leakage history parameters

TYPE	modify material type designation for any or all head cells
THICKNESS	modify aquifer thickness at any or all head cells
END	terminate input of data

Block data sets contain the proper keyword as the first card followed by the actual input data values as shown in the sample input in Appendix A.

Block data sets that modify default input values include HEAD, BOTTOM, THICKNESS and TYPE. Information to reference all head cell values in the grid must be included. A zero or blank for any head cell in the block data set results in retention of the default value. The number of head cells per card depends on the particular data set, 8 cells/card for HEAD, THICKNESS and BOTTOM and 80 cells/card for TYPE.

Data Type	Variable	Format	Description
HEAD	HEAD(NX,NY)	8F10.0	(NX*NY)/8+1 cards needed
BOTTOM	BOTT(NX,NY)	8F10.0	(NX*NY)/8+1 cards needed
THICKNESS	THIC(NX,NY)	8F10.0	(NX*NY)/8+1 cards needed
TYPE	MATL(NX,NY)	80A1	one card per row, NY records necessary

Insertion of a blank card results in retention of the default parameter for all cells referenced by that card. In the example input, insertion of the all zero card immediately following the keyword THIC results in retention of the default aquifer thickness for all nodes in grid row 41. This option reduces the amount of data entry necessary to produce a complete data set.

The MATERIAL and LEAKAGE block data sets are used to define the material properties and the pond leakage histories, respectively. Input format is different from that used in the HEAD, BOTTOM, THICKNESS and TYPE data blocks and is explained below.

MATERIAL:

One card must be input for each material type containing the following information (maximum of nine materials can be included). A card with a zero value of NM is required to terminate the material definition sequence.

Variable	Format	Description	Units
NM	I10	material sequence number	-
K	E10.3	hydraulic conductivity	L/T
S	E10.3	storage coefficient	-
RE	E10.3	natural recharge	L^3/T
POR	E10.3	material porosity	-
DL	E10.3	longitudinal dispersivity	L
DT	E10.3	transverse dispersivity	L
RT	E10.3	retardence	L/L

LEAKAGE:

Multiple cards needed to initialize each leakage history. Up to twenty leakage histories can be included. A card with a zero value of NL is required to terminate the LEAKAGE input sequence.

Card No.	Variable	Format	Description	Units
1	NL	I10	sequence number	---
	NLPT	I10	number of points in leakage history	---
	NNODES	I10	number of leaking cells	---

Repeat following card up to 5 times, 4 sets of TM and RATE per card

Card No.	Variable	Format	Description	Units
2	TM	F10.0	time ordinates of leakage curve	T
	RATE	F10.0	leak rate ordinates of leakage curve	L^3/T

Repeat following card up to 10 times, 10 sets of seepage cell x,y counts per card to define NNODES number of leaking cells

3	IX(1)	I4	cell count in x direction for first leaking cell	---
	IY(1)	I4	cell count in y direction for first leaking cell	---
	IX(2)	I4	cell count in x direction for 2nd leaking cell	---
	IY(2)	I4	cell count in y direction for 2nd leaking cell	---

(Repeat until all leaking cells are specified)

The keyword END, entered left justified, terminates reading of block data sets and initiates the modeling process. Appendix A contains an example input data set for the Crandon site.

9.0 PROGRAM OUTPUT

9.1 Output Reports

The output from the model is divided into 2 parts. The first is an echo of the input which defines the system being simulated. The printout from the example problem used in Section 8 is included in Appendix B. This printout was generated from the input data shown in Appendix A. The end of the first section of output is marked by "INPUT COMPLETE". The second portion of the output is optional and is controlled by the PRINT parameter on the second input card. PRINT allows output options to be selected. PRINT has 10 "flags" which may be set to either 1 or 0 with 1 denoting selection of that particular print option. A typical value for PRINT is shown by column below in which 5 print options are requested.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0	1	0	1	1	1	1	0	0	0

The print options selected by each column are defined below.

1 - Reversed Array Dumps

Prints out head, bottom and material type arrays as a check against input

2 - Array Dump Option

If the program aborts, head values are output at the time of program failure. However, system errors are not trapped and output is not provided when this type of error occurs.

3 - Head Array

Subroutine OUTPUT is called and the head matrix values are printed (not to scale). This option is used during model calibration.

4 - Head Array

Subroutine OUT2K is called and prints the head array during a seepage leakage run to a scale of 1"=2000' for plotting on U.S.G.S. quad sheet base maps. For Crandon simulation heads are printed from a 1500' reference elevation (i.e. reported 90 is actually elevation 1590').

5 - Concentration Array

Subroutine OUT2K prints the seepage concentration (as a percentage of pond leakage in groundwater) at each node for a given printstep at a 1"=2000' scale.

6 - Symbolic Plot

This option calls subroutine PLOT3 to plot the active and boundary particles for the given printstep, in symbolic form. The output matrix prints a single digit for each cell representing the range of particles contained in that cell.

7 - Particle Count

This option prints the abseepage particle count within each cell, acting as a check on the concentration values.

8 - Gradients

A detailed summary of the interpolated groundwater gradient in each cell is printed. Primarily used for initial run checking.

9 - Print Iteration Information

This option prints the iteration number and the two convergence criteria (EPSILON and EMAX) for each iteration. This is useful in detecting non-convergence of the iteration process. A condensed form of this output is provided by default and is sufficient for production runs.

10 - Print Particle Grid Matrix

Prints the symbolic value of the concentration of seepage in each particle grid. With a particle grid spacing of 200 ft. in the x direction and 333 ft. in the y direction this plot comes out at a scale of 1 inch to 2000 ft.

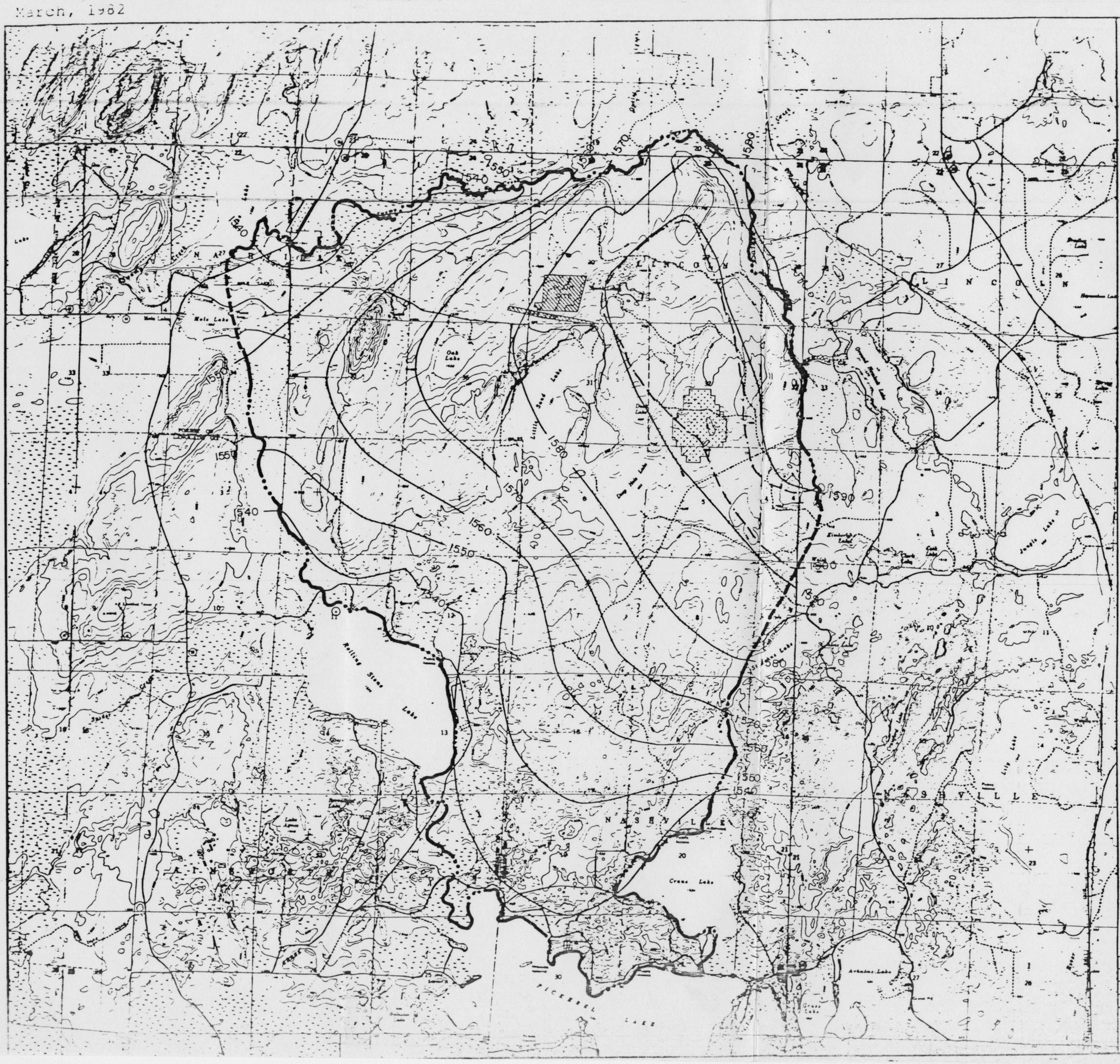
During normal production runs options 2, 4, and 10 are commonly used. Most of the other options are only used to debug failed runs, as they generate a large quantity of output.

By carefully selecting basemap scale and cell dimensions the computer plots can be overlayed on the basemap for direct comparison. A set of diagnostic input data printouts and various data plots are included in Appendix B. Plots prepared from this output are included as Figures 9.1 and 9.2.

Figure 9.1 shows a plot which was generated by overlaying the 1" to 2000' basemap over the printed heads (reported as feet over elevation 1500) and drawing contours. This output allows model calibration to observed data and illustrates changes in the groundwater contours resulting from the construction of the example tailings pond. Figure 9.2 shows the concentration contours over the study area as percent of seepage in the groundwater. These contours were also prepared by overlaying the printout on a 1" to 2000' basemap.

9.2 Interpretation of Output

The primary result of the simulation is the distribution of the concentration of a seepage in the groundwater or surface water system at various times. From the concentration array (select PRINT #10) contours of equal seepage concentration may be drawn at several points in time. These show the spread of the seepage plume at selected times during and after the active life of the tailings ponds system. Alternately, change in concentration through



LEGEND

- CONSTANT HEAD BOUNDARY
- NO FLOW BOUNDARY
- SIMULATED GROUNDWATER HEAD CONTOURS (AT TIME = 0 YEARS)
- SIMULATED GROUNDWATER HEAD CONTOURS (AT TIME = 51 YEARS)
- ▨ EXAMPLE POND

NOTE

ALL GROUNDWATER CONTOURS EXCEPT 1590' ARE UNCHANGED.

REVISED	DATE	BY	DESCRIPTION
1	2-9-8	CAB	RECALIBRATED GROUNDWATER HEAD CONTOURS 2-9-81

FIGURE 9.1

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE
SIMULATED TRANSIENT
GROUNDWATER CONTOURS

SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CAB
DATE 2-9-8
050-1-80506

March, 1982

LEGEND

—··—	CONSTANT HEAD BOUNDARY
— — —	NO FLOW BOUNDARY
——	CONTOURS SHOWING PERCENT CONCENTRATION OF WASTE LEACHATE IN GROUNDWATER AT TIME = 51 YEARS
▨	EXAMPLE POND

NOTE

1. CONCENTRATIONS SHOWN ARE APPROXIMATE.
2. DIFFUSION, RETARDATION AND CHEMICAL ATTENUATION EFFECTS ARE NOT INCLUDED IN ANALYSIS PRESENTED HEREIN.

FIGURE 9.2

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE
SOLUTE CONCENTRATION
CONTOURS

SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST, LANGLADE
CAB
12-7-81
050-1-80563

time at a certain cell can be computed to yield a time-concentration curve at points of interest.

The seepage concentration in surface waters can be determined from the volume of seepage discharged from the groundwater. This requires knowledge of the flow in the river or lake over the simulation period. A time trace of volume of seepage entering a given reach of stream or lake can be computed by using the detailed particle counts (select PRINT #7). Concentrations are computed by applying the mass of seepage to the appropriate volume of water. Linkage patterns and travel or flushing times of lakes and streams are required to properly account for the movement of seepage through the surface water system and to determine the time-concentration relationship in surface waters.

9.3 Error Codes

The program performs several checks to prevent system errors (division by zero, etc.) and to insure against illogical problem formulation. These errors are flagged in the various subroutines by setting an error code and calling the subroutine ERPROC. Error codes less than 99 are considered nonfatal information errors and do not cause the program to abort. Error codes equal to or greater than 100 are fatal and cause processing to terminate. Array dumps can be requested upon program abort by selecting PRINT #2. A definition of the error codes is listed below.

Error Code Number	Subroutine Referenced	Description	Remedy
101	IADI	Number of iterations needed for convergence exceeds Maximum number of iterations per timestep	- increase tolerance - increase number of iterations - recalibrate model

102	INPUT	The end of data cards was encountered before all parameters initialized, as, necessary parameters were never initialized	- make sure data file exists - review input data set for missing cards or data blocks
103	LEAK	The head falls below the bottom of the aquifer (negative head)	- review problem formulation - check pumpage rate
104	INPUT	The data block name used to define a data set (MATERIAL, HEAD, etc.) is not one of the six legal forms	- check input data set for misspelled data set keyword (only first four letters are used)
105	INPUT	Input data does not result in selection of the correct single layer confined model (only used for Crandon simulation)	- make sure variable M=3
106	HEDIN	The data file that is supposed to contain head and particle information does not contain enought information for a restart or does not exist	- check restart data file for completeness - check for correct file number - check for existence of restart file
107	GENERATE	More than 20,000 particles have been generated	- review and redefine particle history
108	HEDIN	Time unit mismatch between simulation run and restart file	- check time units on input data and restart file
109	HEDIN	Length unit mismatch between simulation run and restart file	- check length units on input data and restart file
110	HEDIN	Grid spacing mismatch between simulation run and restart file	- check grid spacing on input data and restart file
111	HEDIN	The restart file is empty	- check JCL string for misspelled data name - check to make sure input data file exists

10.0 SUMMARY

The GROUNDWATER IMPACT SCREENING MODEL presented in this report was developed by Golder Associates to aid in the evaluation of alternative sites and facility layouts for a proposed tailings disposal system at Exxon's Crandon, Wisconsin project. The model uses a finite difference groundwater flow solution and simulates seepage transport using the "random walk" algorithm because of its simplicity and rapid solution. These features are necessary since many analyses are required at the planning stages of site evaluation.

This model is presently being applied at Exxon's Crandon, Wisconsin project for determination of relative impacts of various siting alternatives and is functioning well. In this application, the change in groundwater system gradients are simulated over the analysis period. This allows the relative evaluation of the effects of pond seepage on the groundwater system, including both the effect on the groundwater gradients and the concentration distribution of pond seepage throughout the study area.

GOLDER ASSOCIATES

J E Baker

J. Edmund Baker, P.E.
Associate

Gary H. Collison

Gary H. Collison, P.E.
Associate

JEB:GHC:dap

REFERENCES

1. Golder Associates, Geotechnical Investigation, Crandon Project Waste Disposal System, Project Report 2, October, 1981.

2. Golder Associates, Pump Test and Analysis, Crandon Project Waste Disposal System, Project Report 4, September, 1981.

3. Prickett, T.A. and C.G. Lonnquist, Selected Digital Computer Techniques for Groundwater Resource Evaluation, Illinois State Water Survey, Urbana, 1971.

4. Freeze, R.A. and J.A. Cherry, Groundwater, Prentice-Hall, 1979.

5. Peaceman, D.W., and H.H. Rachford, Jr., "The Numerical solution of parabolic and elliptic differential equations", Journal Society of Industrial and Applied Mathematics v. 3: 28-41, 1955.

6. Bear, J., Hydraulics of Groundwater, McGraw-Hill, pp. 266, 1979.

7. Anderson, M.P., "Using Models to Simulate the Movement of Contaminants through Groundwater Flows Systems", CRC Critical Reviews in Environmental Control, v. 9, Issue 2, p. 124, 1979.

8. Boulton, N.W., "The drawdown of water table under non-steady conditions near a pumped well in an unconfined formation", Proc. Inst. Civ. Eng. (London) 3, part III, pp. 564-579, 1954.

9. Hantush, M.S., "Growth and decay of groundwater-mounds in response to uniform percolation", Water Resources Res. 3, pp. 227-234, 1967.

10. Dames & Moore, Environmental Baseline Report, Crandon Waste Disposal System, Section 2.1 - Surface Water, August, 1981.

11. Golder Associates, Groundwater Potientiometric Contours, Crandon Waste Disposal System, September, 1981.

APPENDIX A

Example Input

```
            EXXON-CRANDON     PROJECT REPORT    9.2 EXAMPLE CASE
DAYS      FEET
     1000.     1000.        28        41      365.  18250.00   3300.
       200.333.333333      140       123
   7823976          3      100       0.5        100101000011        10         11
     1590.     1450.         9       70.
TYPE
0000000
0000000000000000066666600
0000000000006666666622600
00000000666667777666226000
000066666888P88886622226000
066661111111122226422226
 6666111111122222222222286
 6111111111222222221112286
 61111211222222221411222286
 61111221122222222222222286
 511112212222222122222222266
 611112222232233322222222226
 611112222222333122222222226
 611112222221333112222222226
 611122222221333113222222226
 611122211121111132222222226
  61222221221111133322222226
  61222121221111113222222225
  66122111111111112222222215
   6111111111112222222111115
   6611161116222222221122115
    611611162222222222122115
    66661161222222222212215
      66161112222222211115
       6661111111111111115
         66111111111111116
          6111111111111116
          611111111111116
         6611111111111116
         6111111111111116
         661111111111116
          61111111111116
          61111111111666
          611111111116
          611111111116
          66661111111666
             661111111166
              66611111116
                61666666
                666
             00000
MATERIALS
         1  .370E+02  .700E-01  .285E+04      0.25      200.       20.        0.
         2  .370E+02  .054E+0   .285E+04      0.25      200.       20.        0.
         3  .370E+02  .054E+0   .285E+04      0.25      200.       20.        0.
         4  .370E+02  .054E+0   .285E+04      0.25      200.       20.        0.
         5  .100E-24  .540E-01                0.00      000.       00.        0.
         6  .370E+02  1.00E+25  .285E+04      0.00      000.       00.        0.
         7  .370E+02  .700E-01  .285E+04      0.25      200.       20.        0.
         8  .370E+02  .054E+0   .285E+04      0.25      200.       20.        0.
         9  .370E+02  .0700E+0  .285E+04      0.00      000.      000.      000.
000000000000000000000000000
THIC
```

```
       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
       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0
       0       0       0       5       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       5       7      12       0       0
       0       0       0       0
       0       0       0       0       0       0       0       0
       0       0       0       0       0       0      18       7
       5       5       7      10      16      20      25       0
       0       0       0       0
       0       0       0       0       0       0       0       0
       0      50      50      45      40      34      25      20
      17      16      17      20      24      28      33       0
       0       0       0       0
       0       0       0       0       0      55      56      57
      58      59      58      57      46      38      30      26
      25      24      25      27      31      36      39       0
       0       0       0       0
       0       0      55       0       0      59      60      63
      64      65      64      61      57      44      35      32
      28      30      32      35      39      42      46       0
       0       0       0       0
       0      57      59      60      63      64      67      71
      73      77      78      79      78      53      38      35
      35      37      39      42      44      48      52      55
       0       0       0       0
       0      58      62      64      68      70      72      77
      80      87      95      98      91      80      50      36
      36      40      50      55      55      54      55      60
      68       0       0       0
       0      63      65      68      70      74      77      82
      90     102     109     110     110     108     100      90
     100     108     109     108      87      62      62      64
      70       0       0       0
       0      67      68      71      74      77      81      78
      81     110     120     124     125     130     138     160
     181     170     140     125     100      60      40      40
      63       0       0       0
       0       0      72      74      76      79      85      71
     100     125     140     140     140     157     162     170
     175     160     144     120      80      60      40      40
      65      67       0       0
       0       0      74      76      79      84      93      82
     110     140     160     168     165     163     158     159
     150     150     143     106      75      65      50      58
      78      82       0       0
       0       0      76      78      82      87      94     100
     122     147     179     179     168     158     155     150
     143     140     130     110      79      67      55      60
      80      94       0       0
       0       0      78      81      88      93      98     119
     141     152     173     180     169     158     153     147
     140     132     126     115     103      81      67      76
      90     130       0       0
```

```
       0       0      83      87      93      98     116     143
     164     175     181     181     172     163     155     147
     140     133     123     112      98      93      93     115
     147     163       0       0
       0       0      87      93      98     114     140     160
     182     182     178     176     174     165     159     150
     141     133     122     113     110     109     120     134
     160     187     205       0
       0       0       0      97     110     135     153     168
     175     174     174     174     174     168     163     152
     143     135     125     115     115     122     129     138
     195     197     200       0
       0       0       0     100     121     142     165     170
     171     172     173     174     173     168     163     155
     147     135     123     112     120     125     130     140
     160     176       0       0
       0       0       0       0     123     142     164     165
     166     167     166     165     164     160     158     150
     143     134     120     110     125     128     133     137
     140     155       0       0
       0       0       0       0     124     139     152     158
     160     159     158     157     154     152     150     143
     137     127     115     115     125     127     130     133
     138     146       0       0
       0       0       0       0       0     135     142     147
     151     152     153     152     147     145     143     138
     130     122     115     115     123     127     130     135
     137       0       0       0
       0       0       0       0       0       0       0       0
     142     143     144     143     142     140     136     130
     125     117     110     116     125     127     130     133
       0       0       0       0
       0       0       0       0       0       0       0       0
       0     138     138     136     135     130     126     120
     115     110     115     120     125     128     130     133
       0       0       0       0
       0       0       0       0       0       0       0       0
       0       0     130     127     125     123     120     113
     107     113     120     123     125     127     132       0
       0       0       0       0
       0       0       0       0       0       0       0       0
       0       0       0     120     112     110     105     112
     118     121     123     125     127     131     133       0
       0       0       0       0
       0       0       0       0       0       0       0       0
       0       0       0     110     114     116     120     122
     123     125     128     130     132     134     136       0
       0       0       0       0
       0       0       0       0       0       0       0       0
       0       0       0     120     122     124     126     127
     128     129     130     132     134     136     137       0
       0       0       0       0
       0       0       0       0       0       0       0       0
       0       0       0     123     124     125     126     127
     128     129     131     133     135     137     138       0
       0       0       0       0
       0       0       0       0       0       0       0       0
       0       0       0     125     126     127     128     129
     132     133     135     137     138     139       0       0
       0       0       0       0
```

```
         0         0         0         0         0         0         0         0
         0         0       128       129       129       130       132       133
       134       135       136       138       139       142         0         0
         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0       130       131       132       133       134
       135       137       138       141       142       143         0         0
         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0       132       133       134       135       137
       138       140       142       144         0         0         0         0
         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0       134       135       137       139
       141       142       143         0         0         0         0         0
         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0       137         0       138       140       142
       143       144         0         0         0         0         0         0
         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0       139         0         0       143       144
       145       146       147       148       149         0         0         0
         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
       147       148       149       150       151       152       153         0
         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0       148       150       151       152       153         0         0
         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0       150         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         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         0         0         0         0         0         0
         0         0         0         0
LEAK
         1         5        85     (POND 2.50 YEARS
       0.00     192.00
    10950.      192.
    10951.      962.
    18250.      962.
   999999.      962.
 108   78 109   78 110   78 107   79 108   79 109   79 110   79 111   79 112   79 106   80
 107   80 108   80 109   80 110   80 111   80 112   80 113   80 114   80 115   80 105   81
 106   81 107   81 108   81 109   81 110   81 111   81 112   81 113   81 114   81 115   81
 116   81 105   82 106   82 107   82 108   82 109   82 110   82 111   82 112   82 113   82
 114   82 115   82 116   82 105   83 106   83 107   83 108   83 109   83 110   83 111   83
 112   83 113   83 114   83 115   83 116   83 106   84 107   84 108   84 109   84 110   84
 111   84 112   84 113   84 114   84 115   84 107   85 108   85 109   85 110   85 111   85
 112   85 113   85 114   85 107   86 108   86 109   86 110   86 111   86 112   86 113   86
 108   87 109   87 110   87 111   87 112   87
 00000000000000000000
 END
```

APPENDIX B

Example Output

```
**************************************************************************
*                                                                        *
*           GOLDER ASSOCIATES GROUNDWATER COMPUTING SYSTEM               *
*                                                                        *
*                  EXXON MINERALS CRANDON PROJECT                        *
*                                                                        *
*                GROUNDWATER IMPACT SCREENING MODEL                      *
*                                                                        *
*                MODIFICATION 6.1   03 DECEMBER 1981                     *
*                                                                        *
*           RUN TIME:  12.57.49.       RUN DATE:  81/12/07.              *
*                                                                        *
**************************************************************************
*                                                                        *
*        EXXON-CRANDON      PROJECT REPORT     9.2 EXAMPLE CASE          *
*                                                                        *
**************************************************************************


           --- UNITS ---

TIME UNITS = DAYS      LENGTH UNITS = FEET


                 ---  PROBLEM DEFINITION  ---

GRID SPACING IN X DIRECTION (FEET)                  DX =   1000.00
GRID SPACING IN Y DIRECTION (FEET)                  DY =   1000.00
NUMBER OF NODES IN X DIRECTION                      NX =        28
NUMBER OF NODES IN Y DIRECTION                      NY =        41
TIME STEP (DAYS)                                 TSTEP =    365.00
MAXIMUM RUN TIME(DAYS)                          TIMMAX =  18250.00
PARTICLE VOLUME (CU.FEET)                       PARTVL = 3300.0000

SUBGRID SPACING IN X DIRECTION (FEET)            DXPAR =      200.
SUBGRID SPACING IN Y DIRECTION (FEET)            DYPAR =      333.
NUMBER OF NODES IN SUBGRID X DIRECTION           NXPAR =       140
NUMBER OF NODES IN SUBGRID Y DIRECTION           NYPAR =       123
PARTICLES ELIMINATED ON PRINT STEP               KELIM =         0

RANDOM NUMBER                                    ISEED =   7823976
MODEL TYPE :  CONFINED ONE LAYER                 MTYPE =         3
MAXIMUM INTERATIONS PER TIME STEP               MAXIT =       100
ITERATION TOLERANCE (FEET)                         TOL =        1.
FREQUENCY OF OUTPUT (NO. OF TIMESTEPS)          OUTFRQ =        10
PRINTOUT OPTIONS (SEE DETAILS BELOW)            NDATPR =0101000011
RESTART CONDITION READ FROM FILE NUMBER         IHEDIN =        10
RESTART CONDTITON WRITTEN TO FILE NUMBER        IHEDOT =        11


--- PRINTOUT OPTIONS ---                                  SELECTED?

DUMP HEAD, BOTTOM AND MATERIAL TYPE ARRAY                     NO
DUMP HEAD ARRAY ON PROGRAM GENERATED ABORT                    YES
PLOT HEAD MATRIX, 20 COLUMNS PER PAGE                         NO
PLOT HEAD MATRIX, 1 INCH TO 2000 FEET SCALE                   YES
PLOT CONCENTRATION MATRIX, 1 INCH TO 2000 FEET SCALE          NO
PLOT SYMBOLIC ACTIVE AND BOUNDARY PARTICLE SUMMARY            NO
PRINT DETAILED PARTICLE COUNT BY CELL                         NO
PRINT DETAILED GRADIENTS BY CELL                              NO
PRINT ITERATION INFORMATION FOR FINITE DIFFERENCE             YES
PRINT SYMBOLIC CONCENTRATION CONTOURS (SUBGRID)               YES


---  DEFAULT VALUES  ---


GROUNDWATER HEAD ELEVATION   =      1590. FEET
BASE OF AQUIFER ELEVATION    =      1450. FEET
MATERIAL TYPE                =         9
AQUIFER THICKNESS            =    70.000 FEET
```

```
---  MATERIAL TYPE MATRIX ---

                                CELL NUMBER IN X DIRECTION
                                      1                   2
CELL NUMBER         1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8
Y DIRECTION         -------------------------------------------------------
-----------

   41               9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
   40               9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 6 6 6 6 6 6 9 9 9 9 9
   39               9 9 9 9 9 9 9 9 9 9 9 9 6 6 6 6 6 6 6 6 2 2 6 9 9 9 9 9
   38               9 9 9 9 9 9 9 9 6 6 6 6 6 7 7 7 7 6 6 6 2 2 6 9 9 9 9 9
   37               9 9 9 9 6 6 6 6 6 8 8 8 8 8 8 8 8 6 6 2 2 2 2 6 9 9 9 9
   36               9 6 6 6 6 1 1 1 1 1 1 1 1 2 2 2 2 6 4 2 2 2 2 6 9 9 9 9
   35               9 6 6 6 6 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 8 6 9 9 9
   34               9 6 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 1 1 1 2 2 8 6 9 9 9
   33               9 6 1 1 1 1 2 1 1 2 2 2 2 2 2 2 1 4 1 1 2 2 2 2 8 6 9 9
   32               9 6 1 1 1 1 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 8 6 9 9
   31               9 6 1 1 1 1 2 2 1 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 6 6 9
   30               9 6 1 1 1 1 2 2 2 2 2 3 2 2 3 3 3 2 2 2 2 2 2 2 2 2 6 9
   29               9 6 1 1 1 1 2 2 2 2 2 2 2 3 3 3 1 2 2 2 2 2 2 2 2 2 6 9
   28               9 6 1 1 1 1 2 2 2 2 2 2 1 3 3 3 1 1 2 2 2 2 2 2 2 2 6 9
   27               9 6 1 1 1 2 2 2 2 2 2 2 1 3 3 3 1 1 3 2 2 2 2 2 2 2 6 9
   26               9 6 1 1 1 2 2 2 1 1 1 2 1 1 1 1 1 3 2 2 2 2 2 2 2 2 6 9
   25               9 9 6 1 2 2 2 2 2 1 2 2 1 1 1 1 1 3 3 3 2 2 2 2 2 2 6 9
   24               9 9 6 1 2 2 2 1 2 1 2 2 1 1 1 1 1 1 3 2 2 2 2 2 2 2 5 9
   23               9 9 6 6 1 2 2 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 1 5 9
   22               9 9 9 6 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 1 1 1 1 1 5 9
   21               9 9 9 6 6 1 1 1 6 1 1 1 6 2 2 2 2 2 2 2 1 1 2 2 1 1 5 9
   20               9 9 9 9 6 1 1 6 1 1 1 6 2 2 2 2 2 2 2 2 2 1 2 2 1 1 5 9
   19               9 9 9 9 6 6 6 6 1 1 6 1 2 2 2 2 2 2 2 2 2 1 2 2 1 5 9 9
   18               9 9 9 9 9 9 6 6 1 6 1 1 1 2 2 2 2 2 2 2 1 1 1 1 5 9 9 9
   17               9 9 9 9 9 9 9 6 6 6 1 1 1 1 1 1 1 1 1 1 1 1 1 1 5 9 9 9
   16               9 9 9 9 9 9 9 9 9 6 6 1 1 1 1 1 1 1 1 1 1 1 1 1 6 9 9 9
   15               9 9 9 9 9 9 9 9 9 9 6 1 1 1 1 1 1 1 1 1 1 1 1 1 6 9 9 9
   14               9 9 9 9 9 9 9 9 9 9 6 1 1 1 1 1 1 1 1 1 1 1 1 6 9 9 9 9
   13               9 9 9 9 9 9 9 9 9 6 6 1 1 1 1 1 1 1 1 1 1 1 1 6 9 9 9 9
   12               9 9 9 9 9 9 9 9 9 6 1 1 1 1 1 1 1 1 1 1 1 1 1 6 9 9 9 9
   11               9 9 9 9 9 9 9 9 9 6 6 1 1 1 1 1 1 1 1 1 1 1 6 9 9 9 9 9
   10               9 9 9 9 9 9 9 9 9 9 6 1 1 1 1 1 1 1 1 1 1 1 6 9 9 9 9 9
    9               9 9 9 9 9 9 9 9 9 9 6 1 1 1 1 1 1 1 1 1 6 6 6 9 9 9 9 9
    8               9 9 9 9 9 9 9 9 9 9 6 1 1 1 1 1 1 1 1 1 6 9 9 9 9 9 9 9
    7               9 9 9 9 9 9 9 9 9 9 6 1 1 1 1 1 1 1 1 1 6 9 9 9 9 9 9 9
    6               9 9 9 9 9 9 9 9 9 9 6 6 6 6 1 1 1 1 1 1 6 6 6 9 9 9 9 9
    5               9 9 9 9 9 9 9 9 9 9 9 9 9 6 6 1 1 1 1 1 1 1 6 6 9 9 9 9
    4               9 9 9 9 9 9 9 9 9 9 5 9 9 9 6 6 6 1 1 1 1 1 1 6 9 9 9 9
    3               9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 6 1 6 6 6 6 6 6 9 9 9 9
    2               9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 6 6 6 9 9 9 9 9 9 9 9 9
    1               9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
```

```
--- MATERIAL TYPE DEFINITION ---

                                                                    LONGITUDINAL     TRANSVERSE
              PERMEABILITY                   RECHARGE               DISPERSIVITY    DISPERSIVITY
   NUMBER     (FEET/DAYS)    STORATIVITY  (CU.FEET/DAYS)   POROSITY    (FEET)          (FEET)        RETARDATION

      1         .37E+02        .70E-01       .29E+04      .250E+00    .200E+03        .200E+02        .100E+01
      2         .37E+02        .54E-01       .29E+04      .250E+00    .200E+03        .200E+02        .100E+01
      3         .37E+02        .54E-01       .29E+04      .250E+00    .200E+03        .200E+02        .100E+01
      4         .37E+02        .54E-01       .29E+04      .250E+00    .200E+03        .200E+02        .100E+01
      5         .10E-24        .54E-01      0.            0.          0.              0.              .100E+01
      6         .37E+02        .10E+26       .29E+04      0.          0.              0.              .100E+01
      7         .37E+02        .70E-01       .29E+04      .250E+00    .200E+03        .200E+02        .100E+01
      8         .37E+02        .54E-01       .29E+04      .250E+00    .200E+03        .200E+02        .100E+01
      9         .37E+02        .70E-01       .29E+04      0.          0.              0.              .100E+01
```

```
--- LEAKAGE HISTORIES ---


HISTORY NO.    1     NO. OF LEAKAGE CURVE POINTS =    5     NO. OF NODES =   85

            LEAKAGE CURVE
-----------------------------------
     TIME                 RATE

    (DAYS)           (CU.FEET/DAYS)
      0.00                192.00
  10950.00                192.00
  10951.00                962.00
  18250.00                962.00
 999999.00                962.00
                                           NODAL COORDINATES OF LEAKAGE FROM SOURCE    1

 X , Y      X , Y      X , Y      X , Y      X , Y      X , Y      X , Y      X , Y      X , Y      X , Y      X , Y      X , Y
108, 78    109, 78    110, 78    107, 79    108, 79    109, 79    110, 79    111, 79    112, 79    106, 80    107, 80    108, 80
109, 80    110, 80    111, 80    112, 80    113, 80    114, 80    115, 80    105, 81    106, 81    107, 81    108, 81    109, 81
110, 81    111, 81    112, 81    113, 81    114, 81    115, 81    116, 81    105, 82    106, 82    107, 82    108, 82    109, 82
110, 82    111, 82    112, 82    113, 82    114, 82    115, 82    116, 82    105, 83    106, 83    107, 83    108, 83    109, 83
110, 83    111, 83    112, 83    113, 83    114, 83    115, 83    116, 83    106, 84    107, 84    108, 84    109, 84    110, 84
111, 84    112, 84    113, 84    114, 84    115, 84    107, 85    108, 85    109, 85    110, 85    111, 85    112, 85    113, 85
114, 85    107, 86    108, 86    109, 86    110, 86    111, 86    112, 86    113, 86    108, 87    109, 87    110, 87    111, 87
112, 87

**** INPUT COMPLETE ****
```

```
       ---AQUIFER THICKNESS (FEET)---
 Y=   41
    1)    70.00    2)    70.00    3)    70.00    4)    70.00    5)    70.00    6)    70.00    7)    70.00    8)    70.00    9)    70.00
   10)    70.00   11)    70.00   12)    70.00   13)    70.00   14)    70.00   15)    70.00   16)    70.00   17)    70.00   18)    70.00
   19)    70.00   20)    70.00   21)    70.00   22)    70.00   23)    70.00   24)    70.00   25)    70.00   26)    70.00   27)    70.00
   28)    70.00
 Y=   40
    1)    70.00    2)    70.00    3)    70.00    4)    70.00    5)    70.00    6)    70.00    7)    70.00    8)    70.00    9)    70.00
   10)    70.00   11)    70.00   12)    70.00   13)    70.00   14)    70.00   15)    70.00   16)    70.00   17)    70.00   18)    70.00
   19)    70.00   20)     5.00   21)     6.00   22)    70.00   23)    70.00   24)    70.00   25)    70.00   26)    70.00   27)    70.00
   28)    70.00
 Y=   39
    1)    70.00    2)    70.00    3)    70.00    4)    70.00    5)    70.00    6)    70.00    7)    70.00    8)    70.00    9)    70.00
   10)    70.00   11)    70.00   12)    70.00   13)    70.00   14)    70.00   15)    70.00   16)    70.00   17)    70.00   18)    70.00
   19)    70.00   20)     5.00   21)     7.00   22)    12.00   23)    70.00   24)    70.00   25)    70.00   26)    70.00   27)    70.00
   28)    70.00
 Y=   38
    1)    70.00    2)    70.00    3)    70.00    4)    70.00    5)    70.00    6)    70.00    7)    70.00    8)    70.00    9)    70.00
   10)    70.00   11)    70.00   12)    70.00   13)    70.00   14)    70.00   15)    18.00   16)     7.00   17)     5.00   18)     5.00
   19)     7.00   20)    10.00   21)    16.00   22)    20.00   23)    25.00   24)    70.00   25)    70.00   26)    70.00   27)    70.00
   28)    70.00
 Y=   37
    1)    70.00    2)    70.00    3)    70.00    4)    70.00    5)    70.00    6)    70.00    7)    70.00    8)    70.00    9)    70.00
   10)    50.00   11)    50.00   12)    45.00   13)    40.00   14)    34.00   15)    25.00   16)    20.00   17)    17.00   18)    16.00
   19)    17.00   20)    20.00   21)    24.00   22)    28.00   23)    33.00   24)    70.00   25)    70.00   26)    70.00   27)    70.00
   28)    70.00
 Y=   36
    1)    70.00    2)    70.00    3)    70.00    4)    70.00    5)    70.00    6)    55.00    7)    56.00    8)    57.00    9)    58.00
   10)    59.00   11)    58.00   12)    57.00   13)    46.00   14)    38.00   15)    30.00   16)    26.00   17)    25.00   18)    24.00
   19)    25.00   20)    27.00   21)    31.00   22)    36.00   23)    39.00   24)    70.00   25)    70.00   26)    70.00   27)    70.00
   28)    70.00
 Y=   35
    1)    70.00    2)    70.00    3)    55.00    4)    70.00    5)    70.00    6)    59.00    7)    60.00    8)    63.00    9)    64.00
   10)    65.00   11)    64.00   12)    61.00   13)    57.00   14)    44.00   15)    35.00   16)    32.00   17)    28.00   18)    30.00
   19)    32.00   20)    35.00   21)    39.00   22)    42.00   23)    46.00   24)    70.00   25)    70.00   26)    70.00   27)    70.00
   28)    70.00
 Y=   34
```

```
   1)    70.00   2)    57.00   3)    59.00   4)    60.00   5)    63.00   6)    64.00   7)    67.00   8)    71.00   9)    73.00
  10)    77.00  11)    78.00  12)    79.00  13)    78.00  14)    53.00  15)    38.00  16)    35.00  17)    35.00  18)    37.00
  19)    39.00  20)    42.00  21)    44.00  22)    48.00  23)    52.00  24)    55.00  25)    70.00  26)    70.00  27)    70.00
  28)    70.00
Y=  33
   1)    70.00   2)    58.00   3)    62.00   4)    64.00   5)    68.00   6)    70.00   7)    72.00   8)    77.00   9)    80.00
  10)    87.00  11)    95.00  12)    98.00  13)    91.00  14)    80.00  15)    50.00  16)    36.00  17)    36.00  18)    40.00
  19)    50.00  20)    55.00  21)    55.00  22)    54.00  23)    55.00  24)    60.00  25)    69.00  26)    70.00  27)    70.00
  28)    70.00
Y=  32
   1)    70.00   2)    63.00   3)    65.00   4)    68.00   5)    70.00   6)    74.00   7)    77.00   8)    82.00   9)    90.00
  10)   102.00  11)   109.00  12)   110.00  13)   110.00  14)   108.00  15)   100.00  16)    90.00  17)   100.00  18)   108.00
  19)   109.00  20)   108.00  21)    87.00  22)    62.00  23)    62.00  24)    64.00  25)    70.00  26)    70.00  27)    70.00
  28)    70.00
Y=  31
   1)    70.00   2)    67.00   3)    68.00   4)    71.00   5)    74.00   6)    77.00   7)    81.00   8)    78.00   9)    81.00
  10)   110.00  11)   120.00  12)   124.00  13)   125.00  14)   130.00  15)   138.00  16)   160.00  17)   181.00  18)   170.00
  19)   140.00  20)   125.00  21)   100.00  22)    60.00  23)    40.00  24)    40.00  25)    63.00  26)    70.00  27)    70.00
  28)    70.00
Y=  30
   1)    70.00   2)    70.00   3)    72.00   4)    74.00   5)    76.00   6)    79.00   7)    85.00   8)    71.00   9)   100.00
  10)   125.00  11)   140.00  12)   140.00  13)   140.00  14)   157.00  15)   162.00  16)   170.00  17)   175.00  18)   160.00
  19)   144.00  20)   120.00  21)    80.00  22)    60.00  23)    40.00  24)    40.00  25)    65.00  26)    67.00  27)    70.00
  28)    70.00
Y=  29
   1)    70.00   2)    70.00   3)    74.00   4)    76.00   5)    79.00   6)    84.00   7)    93.00   8)    82.00   9)   110.00
  10)   140.00  11)   160.00  12)   168.00  13)   165.00  14)   163.00  15)   158.00  16)   159.00  17)   150.00  18)   150.00
  19)   143.00  20)   106.00  21)    75.00  22)    65.00  23)    50.00  24)    58.00  25)    78.00  26)    82.00  27)    70.00
  28)    70.00
Y=  28
   1)    70.00   2)    70.00   3)    76.00   4)    78.00   5)    82.00   6)    87.00   7)    94.00   8)   100.00   9)   122.00
  10)   147.00  11)   179.00  12)   179.00  13)   168.00  14)   158.00  15)   155.00  16)   150.00  17)   143.00  18)   140.00
  19)   130.00  20)   110.00  21)    79.00  22)    67.00  23)    55.00  24)    60.00  25)    80.00  26)    94.00  27)    70.00
  28)    70.00
Y=  27
   1)    70.00   2)    70.00   3)    78.00   4)    81.00   5)    88.00   6)    93.00   7)    98.00   8)   119.00   9)   141.00
  10)   152.00  11)   173.00  12)   180.00  13)   169.00  14)   158.00  15)   153.00  16)   147.00  17)   140.00  18)   132.00
  19)   126.00  20)   115.00  21)   103.00  22)    81.00  23)    67.00  24)    76.00  25)    90.00  26)   130.00  27)    70.00
  28)    70.00
Y=  26
   1)    70.00   2)    70.00   3)    83.00   4)    87.00   5)    93.00   6)    98.00   7)   116.00   8)   143.00   9)   164.00
  10)   175.00  11)   181.00  12)   181.00  13)   172.00  14)   163.00  15)   155.00  16)   147.00  17)   140.00  18)   133.00
  19)   123.00  20)   112.00  21)    98.00  22)    93.00  23)    93.00  24)   115.00  25)   147.00  26)   163.00  27)    70.00
  28)    70.00
Y=  25
   1)    70.00   2)    70.00   3)    87.00   4)    93.00   5)    98.00   6)   114.00   7)   140.00   8)   160.00   9)   182.00
  10)   182.00  11)   178.00  12)   176.00  13)   174.00  14)   165.00  15)   159.00  16)   150.00  17)   141.00  18)   133.00
  19)   122.00  20)   113.00  21)   110.00  22)   109.00  23)   120.00  24)   134.00  25)   160.00  26)   187.00  27)   205.00
  28)    70.00
Y=  24
   1)    70.00   2)    70.00   3)    70.00   4)    97.00   5)   110.00   6)   135.00   7)   153.00   8)   168.00   9)   175.00
  10)   174.00  11)   174.00  12)   174.00  13)   174.00  14)   168.00  15)   163.00  16)   152.00  17)   143.00  18)   135.00
  19)   125.00  20)   115.00  21)   115.00  22)   122.00  23)   129.00  24)   138.00  25)   195.00  26)   197.00  27)   200.00
  28)    70.00
Y=  23
   1)    70.00   2)    70.00   3)    70.00   4)   100.00   5)   121.00   6)   142.00   7)   165.00   8)   170.00   9)   171.00
  10)   172.00  11)   173.00  12)   174.00  13)   173.00  14)   168.00  15)   163.00  16)   155.00  17)   147.00  18)   135.00
  19)   123.00  20)   112.00  21)   120.00  22)   125.00  23)   130.00  24)   140.00  25)   160.00  26)   176.00  27)    70.00
  28)    70.00
Y=  22
```

```
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)  123.00    6)  142.00    7)  164.00    8)  165.00    9)  166.00
  10)  167.00   11)  166.00   12)  165.00   13)  164.00   14)  160.00   15)  158.00   16)  150.00   17)  143.00   18)  134.00
  19)  120.00   20)  110.00   21)  125.00   22)  128.00   23)  133.00   24)  137.00   25)  140.00   26)  155.00   27)   70.00
  28)   70.00
Y=  21
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)  124.00    6)  139.00    7)  152.00    8)  158.00    9)  160.00
  10)  159.00   11)  158.00   12)  157.00   13)  154.00   14)  152.00   15)  150.00   16)  145.00   17)  137.00   18)  127.00
  19)  115.00   20)  115.00   21)  125.00   22)  127.00   23)  130.00   24)  133.00   25)  138.00   26)  146.00   27)   70.00
  28)   70.00
Y=  20
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)  135.00    7)  142.00    8)  147.00    9)  151.00
  10)  152.00   11)  153.00   12)  152.00   13)  147.00   14)  145.00   15)  143.00   16)  138.00   17)  130.00   18)  122.00
  19)  115.00   20)  115.00   21)  123.00   22)  127.00   23)  130.00   24)  135.00   25)  137.00   26)   70.00   27)   70.00
  28)   70.00
Y=  19
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)  142.00
  10)  143.00   11)  144.00   12)  143.00   13)  142.00   14)  140.00   15)  136.00   16)  130.00   17)  125.00   18)  117.00
  19)  110.00   20)  116.00   21)  125.00   22)  127.00   23)  130.00   24)  133.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  18
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)  138.00   11)  138.00   12)  136.00   13)  135.00   14)  130.00   15)  126.00   16)  120.00   17)  115.00   18)  110.00
  19)  115.00   20)  120.00   21)  125.00   22)  128.00   23)  130.00   24)  133.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  17
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)  130.00   12)  127.00   13)  125.00   14)  123.00   15)  120.00   16)  113.00   17)  107.00   18)  113.00
  19)  120.00   20)  123.00   21)  125.00   22)  127.00   23)  132.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  16
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  120.00   13)  112.00   14)  110.00   15)  105.00   16)  112.00   17)  118.00   18)  121.00
  19)  123.00   20)  125.00   21)  127.00   22)  131.00   23)  133.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  15
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  110.00   13)  114.00   14)  116.00   15)  120.00   16)  122.00   17)  123.00   18)  125.00
  19)  128.00   20)  130.00   21)  132.00   22)  134.00   23)  136.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  14
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  120.00   13)  122.00   14)  124.00   15)  126.00   16)  127.00   17)  128.00   18)  129.00
  19)  130.00   20)  132.00   21)  134.00   22)  136.00   23)  137.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  13
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  123.00   13)  124.00   14)  125.00   15)  126.00   16)  127.00   17)  128.00   18)  129.00
  19)  131.00   20)  133.00   21)  135.00   22)  137.00   23)  138.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  12
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  125.00   13)  126.00   14)  127.00   15)  128.00   16)  129.00   17)  132.00   18)  133.00
  19)  135.00   20)  137.00   21)  138.00   22)  139.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  11
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)  128.00   12)  129.00   13)  129.00   14)  130.00   15)  132.00   16)  133.00   17)  134.00   18)  135.00
  19)  136.00   20)  138.00   21)  139.00   22)  142.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=  10
```

```
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  130.00   13)  131.00   14)  132.00   15)  133.00   16)  134.00   17)  135.00   18)  137.00
  19)  138.00   20)  141.00   21)  142.00   22)  143.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    9
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  132.00   13)  133.00   14)  134.00   15)  135.00   16)  137.00   17)  138.00   18)  140.00
  19)  142.00   20)  144.00   21)   70.00   22)   70.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    8
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)   70.00   13)  134.00   14)  135.00   15)  137.00   16)  139.00   17)  141.00   18)  142.00
  19)  143.00   20)   70.00   21)   70.00   22)   70.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    7
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  137.00   13)   70.00   14)  138.00   15)  140.00   16)  142.00   17)  143.00   18)  144.00
  19)   70.00   20)   70.00   21)   70.00   22)   70.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    6
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)  139.00   13)   70.00   14)   70.00   15)  143.00   16)  144.00   17)  145.00   18)  146.00
  19)  147.00   20)  148.00   21)  149.00   22)   70.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    5
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)   70.00   13)   70.00   14)   70.00   15)   70.00   16)   70.00   17)  147.00   18)  148.00
  19)  149.00   20)  150.00   21)  151.00   22)  152.00   23)  153.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    4
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)   70.00   13)   70.00   14)   70.00   15)   70.00   16)   70.00   17)   70.00   18)  148.00
  19)  150.00   20)  151.00   21)  152.00   22)  153.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    3
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)   70.00   13)   70.00   14)   70.00   15)   70.00   16)   70.00   17)   70.00   18)  150.00
  19)   70.00   20)   70.00   21)   70.00   22)   70.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    2
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)   70.00   13)   70.00   14)   70.00   15)   70.00   16)   70.00   17)   70.00   18)   70.00
  19)   70.00   20)   70.00   21)   70.00   22)   70.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
Y=    1
   1)   70.00    2)   70.00    3)   70.00    4)   70.00    5)   70.00    6)   70.00    7)   70.00    8)   70.00    9)   70.00
  10)   70.00   11)   70.00   12)   70.00   13)   70.00   14)   70.00   15)   70.00   16)   70.00   17)   70.00   18)   70.00
  19)   70.00   20)   70.00   21)   70.00   22)   70.00   23)   70.00   24)   70.00   25)   70.00   26)   70.00   27)   70.00
  28)   70.00
```

```
     SIMULATION INITIALIZED BY RESTART FILE :      EXXON-CRANDON      CALIB.CALIBRATION DATA.  REVISED 10/8/81 (BRACKETT)

     RESTART CONDITIONS :
       TIME TO BEGIN SIMULATION =          0.000 DAYS
       NUMBER OF PARTICLES      =          0
       HEADS IN FEET AT TIME        0.000 DAYS :

 Y=   1
    1) 1596.61     2) 1595.85     3) 1594.35     4) 1592.12     5) 1589.19     6) 1585.63     7) 1581.50     8) 1576.91     9) 1572.00
   10) 1566.95    11) 1561.95    12) 1557.14    13) 1552.58    14) 1548.28    15) 1544.26    16) 1540.54    17) 1537.25    18) 1536.10
   19) 1535.94    20) 1536.63    21) 1537.38    22) 1538.22    23) 1539.39    24) 1541.23    25) 1543.99    26) 1546.70    27) 1548.75
   28) 1549.83
 Y=   2
    1) 1596.26     2) 1595.50     3) 1593.97     4) 1591.71     5) 1588.73     6) 1585.09     7) 1580.86     8) 1576.12     9) 1571.04
   10) 1565.81    11) 1560.66    12) 1555.79    13) 1551.22    14) 1546.90    15) 1542.87    16) 1539.02    17) 1534.00    18) 1534.00
   19) 1534.00    20) 1535.48    21) 1536.19    22) 1536.78    23) 1537.62    24) 1539.22    25) 1542.93    26) 1546.26    27) 1548.61
   28) 1549.82
 Y=   3
    1) 1595.58     2) 1594.80     3) 1593.24     4) 1590.91     5) 1587.84     6) 1584.05     7) 1579.61     8) 1574.59     9) 1569.13
   10) 1563.48    11) 1557.98    12) 1553.04    13) 1548.50    14) 1544.15    15) 1540.17    16) 1537.57    17) 1535.00    18) 1535.21
   19) 1534.00    20) 1534.00    21) 1534.00    22) 1534.00    23) 1534.00    24) 1534.00    25) 1541.15    26) 1545.69    27) 1548.53
   28) 1549.91
 Y=   4
    1) 1594.59     2) 1593.78     3) 1592.17     4) 1589.76     5) 1586.56     6) 1582.58     7) 1577.84     8) 1572.39     9) 1566.32
   10) 1559.88    11) 1553.66    12) 1548.78    13) 1544.48    14) 1539.93    15) 1535.00    16) 1535.00    17) 1535.00    18) 1536.58
   19) 1536.53    20) 1536.02    21) 1535.36    22) 1534.90    23) 1534.59    24) 1534.00    25) 1540.88    26) 1545.73    27) 1548.79
   28) 1550.28
 Y=   5
    1) 1593.30     2) 1592.47     3) 1590.80     4) 1588.29     5) 1584.95     6) 1580.75     7) 1575.68     8) 1569.71     9) 1562.79
   10) 1554.97    11) 1546.89    12) 1542.84    13) 1539.61    14) 1535.00    15) 1535.00    16) 1537.40    17) 1538.42    18) 1538.24
   19) 1537.66    20) 1536.59    21) 1535.28    22) 1534.67    23) 1534.00    24) 1534.00    25) 1541.53    26) 1546.45    27) 1549.54
   28) 1551.04
 Y=   6
    1) 1591.74     2) 1590.88     3) 1589.16     4) 1586.57     5) 1583.09     6) 1578.70     7) 1573.33     8) 1566.87     9) 1559.06
   10) 1549.20    11) 1535.00    12) 1535.00    13) 1535.00    14) 1535.00    15) 1538.94    16) 1540.08    17) 1540.19    18) 1539.79
   19) 1538.77    20) 1536.89    21) 1534.00    22) 1534.00    23) 1534.00    24) 1538.52    25) 1543.69    26) 1547.98    27) 1550.76
   28) 1552.21
 Y=   7
```

```
   1) 1589.94    2) 1589.06    3) 1587.30    4) 1584.64    5) 1581.06    6) 1576.52    7) 1570.96    8) 1564.28    9) 1556.30
  10) 1546.67   11) 1535.00   12) 1536.96   13) 1538.21   14) 1540.10   15) 1541.13   16) 1541.87   17) 1541.97   18) 1541.45
  19) 1540.22   20) 1537.72   21) 1534.00   22) 1535.51   23) 1537.37   24) 1541.28   25) 1545.73   26) 1549.58   27) 1552.32
  28) 1553.72
Y=  8
   1) 1587.92    2) 1587.03    3) 1585.23    4) 1582.52    5) 1578.87    6) 1574.25    7) 1568.62    8) 1561.90    9) 1554.06
  10) 1545.09   11) 1535.00   12) 1538.13   13) 1540.86   14) 1542.05   15) 1543.09   16) 1543.75   17) 1543.86   18) 1543.32
  19) 1542.13   20) 1539.60   21) 1534.00   22) 1535.55   23) 1537.61   24) 1542.39   25) 1547.26   26) 1551.29   27) 1554.10
  28) 1555.53
Y=  9
   1) 1585.70    2) 1584.79    3) 1582.98    4) 1580.24    5) 1576.56    6) 1571.91    7) 1566.24    8) 1559.54    9) 1551.87
  10) 1543.51   11) 1535.00   12) 1539.71   13) 1541.92   14) 1543.62   15) 1544.89   16) 1545.68   17) 1545.87   18) 1545.34
  19) 1543.86   20) 1540.80   21) 1534.00   22) 1534.00   23) 1534.00   24) 1542.33   25) 1548.54   26) 1553.12   27) 1556.15
  28) 1557.67
Y= 10
   1) 1583.28    2) 1582.37    3) 1580.55    4) 1577.81    5) 1574.13    6) 1569.48    7) 1563.80    8) 1557.06    9) 1549.28
  10) 1540.97   11) 1535.00   12) 1540.25   13) 1542.91   14) 1545.03   15) 1546.63   16) 1547.66   17) 1548.08   18) 1547.79
  19) 1546.68   20) 1544.64   21) 1542.11   22) 1538.87   23) 1534.00   24) 1543.28   25) 1550.34   26) 1555.38   27) 1558.63
  28) 1560.23
Y= 11
   1) 1580.66    2) 1579.75    3) 1577.94    4) 1575.21    5) 1571.57    6) 1566.96    7) 1561.33    8) 1554.51    9) 1546.12
  10) 1535.00   11) 1535.00   12) 1540.38   13) 1543.82   14) 1546.40   15) 1548.36   16) 1549.71   17) 1550.47   18) 1550.57
  19) 1549.95   20) 1548.55   21) 1546.28   22) 1542.38   23) 1534.00   24) 1545.36   25) 1553.07   26) 1558.34   27) 1561.66
  28) 1563.28
Y= 12
   1) 1577.85    2) 1576.94    3) 1575.14    4) 1572.44    5) 1568.86    6) 1564.38    7) 1558.94    8) 1552.43    9) 1544.57
  10) 1535.00   11) 1536.64   12) 1541.81   13) 1545.02   14) 1547.81   15) 1550.08   16) 1551.80   17) 1552.96   18) 1553.52
  19) 1553.50   20) 1552.86   21) 1551.66   22) 1549.91   23) 1548.42   24) 1550.00   25) 1557.12   26) 1562.14   27) 1565.31
  28) 1566.84
Y= 13
   1) 1574.85    2) 1573.94    3) 1572.13    4) 1569.46    5) 1565.95    6) 1561.64    7) 1556.54    8) 1550.60    9) 1543.64
  10) 1535.00   11) 1535.00   12) 1542.36   13) 1546.01   14) 1549.16   15) 1551.79   16) 1553.89   17) 1555.46   18) 1556.53
  19) 1557.10   20) 1557.23   21) 1557.06   22) 1556.83   23) 1557.19   24) 1555.00   25) 1562.18   26) 1566.70   27) 1569.49
  28) 1570.83
Y= 14
   1) 1571.65    2) 1570.72    3) 1568.89    4) 1566.20    5) 1562.74    6) 1558.60    7) 1553.87    8) 1548.69    9) 1543.28
  10) 1538.02   11) 1535.00   12) 1542.83   13) 1546.89   14) 1550.40   15) 1553.41   16) 1555.92   17) 1557.95   18) 1559.52
  19) 1560.66   20) 1561.46   21) 1562.06   22) 1562.69   23) 1563.63   24) 1565.00   25) 1568.79   26) 1571.90   27) 1574.00
  28) 1575.06
Y= 15
   1) 1568.28    2) 1567.31    3) 1565.40    4) 1562.63    5) 1559.12    6) 1555.04    7) 1550.54    8) 1545.93    9) 1541.65
  10) 1537.69   11) 1535.00   12) 1543.18   13) 1547.61   14) 1551.48   15) 1554.88   16) 1557.81   17) 1560.28   18) 1562.32
  19) 1563.98   20) 1565.33   21) 1566.51   22) 1567.69   23) 1569.11   24) 1571.00   25) 1575.00   26) 1576.99   27) 1578.47
  28) 1579.26
Y= 16
   1) 1564.79    2) 1563.74    3) 1561.66    4) 1558.68    5) 1554.98    6) 1550.79    7) 1546.24    8) 1541.72    9) 1538.62
  10) 1535.00   11) 1535.00   12) 1543.62   13) 1548.13   14) 1552.37   15) 1556.14   16) 1559.56   17) 1562.47   18) 1564.94
  19) 1567.04   20) 1568.82   21) 1570.40   22) 1571.94   23) 1573.58   24) 1575.59   25) 1580.00   26) 1581.48   27) 1582.54
  28) 1583.13
Y= 17
   1) 1561.26    2) 1560.07    3) 1557.74    4) 1554.36    5) 1550.22    6) 1545.82    7) 1540.79    8) 1535.00    9) 1535.00
  10) 1535.00   11) 1539.33   12) 1543.89   13) 1548.59   14) 1553.15   15) 1557.36   16) 1561.09   17) 1564.39   18) 1567.34
  19) 1569.86   20) 1571.99   21) 1573.87   22) 1575.56   23) 1577.17   24) 1578.49   25) 1579.24   26) 1585.28   27) 1585.99
  28) 1586.50
Y= 18
   1) 1557.82    2) 1556.46    3) 1553.75    4) 1549.71    5) 1544.60    6) 1540.38    7) 1535.00    8) 1535.00    9) 1535.92
  10) 1535.00   11) 1538.84   12) 1543.51   13) 1548.58   14) 1553.64   15) 1558.37   16) 1562.59   17) 1566.31   18) 1569.51
  19) 1572.35   20) 1574.80   21) 1576.92   22) 1578.76   23) 1580.43   24) 1582.02   25) 1582.02   26) 1587.29   27) 1588.52
  28) 1589.27
Y= 19
```

```
   1) 1554.62    2) 1553.10    3) 1550.00    4) 1545.02    5) 1537.00    6) 1535.00    7) 1535.00    8) 1535.00    9) 1537.57
  10) 1537.72   11) 1537.00   12) 1542.25   13) 1548.07   14) 1554.02   15) 1559.40   16) 1564.07   17) 1568.10   18) 1571.55
  19) 1574.55   20) 1577.26   21) 1579.55   22) 1581.46   23) 1583.19   24) 1584.85   25) 1586.62   26) 1586.95   27) 1590.45
  28) 1591.69
Y= 20
   1) 1551.85    2) 1550.23    3) 1547.00    4) 1542.28    5) 1537.00    6) 1538.80    7) 1538.85    8) 1537.00    9) 1538.97
  10) 1540.67   11) 1541.08   12) 1540.00   13) 1546.95   14) 1554.46   15) 1560.66   16) 1565.69   17) 1569.88   18) 1573.49
  19) 1576.63   20) 1579.41   21) 1591.78   22) 1583.72   23) 1585.40   24) 1586.96   25) 1588.54   26) 1589.60   27) 1590.02
  28) 1594.26
Y= 21
   1) 1549.60    2) 1547.87    3) 1544.41    4) 1539.00    5) 1536.00    6) 1541.08    7) 1542.10    8) 1541.67    9) 1540.00
  10) 1544.21   11) 1545.91   12) 1546.19   13) 1545.00   14) 1555.78   15) 1562.59   16) 1567.66   17) 1571.86   18) 1575.41
  19) 1578.51   20) 1581.32   21) 1583.71   22) 1585.56   23) 1587.10   24) 1588.39   25) 1589.46   26) 1590.15   27) 1590.15
  28) 1595.73
Y= 22
   1) 1547.99    2) 1546.13    3) 1542.66    4) 1539.00    5) 1542.06    6) 1544.46    7) 1546.01    8) 1546.77    9) 1547.47
  10) 1549.64   11) 1551.52   12) 1553.17   13) 1555.34   14) 1560.65   15) 1565.75   16) 1570.14   17) 1574.00   18) 1577.37
  19) 1580.33   20) 1582.99   21) 1585.34   22) 1587.06   23) 1588.42   24) 1589.44   25) 1590.15   26) 1590.54   27) 1590.54
  28) 1596.10
Y= 23
   1) 1547.13    2) 1544.90    3) 1540.00    4) 1540.00    5) 1544.86    6) 1547.77    7) 1549.74    8) 1551.25    9) 1552.74
  10) 1554.63   11) 1556.65   12) 1558.81   13) 1561.47   14) 1565.14   15) 1569.05   16) 1572.76   17) 1576.20   18) 1579.29
  19) 1582.09   20) 1584.57   21) 1586.71   22) 1588.29   23) 1589.42   24) 1590.18   25) 1590.60   26) 1590.76   27) 1590.76
  28) 1595.37
Y= 24
   1) 1547.41    2) 1545.23    3) 1540.00    4) 1544.66    5) 1548.20    6) 1551.02    7) 1553.18    8) 1555.11    9) 1556.98
  10) 1558.90   11) 1560.97   12) 1563.23   13) 1565.82   14) 1568.83   15) 1572.08   16) 1575.26   17) 1578.34   18) 1581.20
  19) 1583.76   20) 1586.02   21) 1587.90   22) 1589.30   23) 1590.20   24) 1590.64   25) 1590.72   26) 1590.65   27) 1590.65
  28) 1593.54
Y= 25
   1) 1548.76    2) 1547.52    3) 1545.00    4) 1548.52    5) 1551.44    6) 1554.03    7) 1556.36    8) 1558.47    9) 1560.54
  10) 1562.54   11) 1564.63   12) 1566.86   13) 1569.29   14) 1571.94   15) 1574.79   16) 1577.64   17) 1580.41   18) 1583.00
  19) 1585.30   20) 1587.33   21) 1588.97   22) 1590.13   23) 1590.78   24) 1590.88   25) 1590.56   26) 1590.10   27) 1590.00
  28) 1590.61
Y= 26
   1) 1550.26    2) 1550.00    3) 1550.01    4) 1552.06    5) 1554.50    6) 1556.80    7) 1559.06    8) 1561.28    9) 1563.38
  10) 1565.49   11) 1567.67   12) 1569.86   13) 1572.12   14) 1574.58   15) 1577.19   16) 1579.80   17) 1582.33   18) 1584.67
  19) 1586.75   20) 1588.52   21) 1589.90   22) 1590.87   23) 1591.25   24) 1590.96   25) 1590.07   26) 1588.80   27) 1587.00
  28) 1588.35
Y= 27
   1) 1550.91    2) 1550.00    3) 1552.28    4) 1554.50    5) 1556.87    6) 1559.16    7) 1561.35    8) 1563.59    9) 1565.78
  10) 1567.93   11) 1570.16   12) 1572.27   13) 1574.44   14) 1576.79   15) 1579.27   16) 1581.71   17) 1584.03   18) 1586.16
  19) 1588.04   20) 1589.58   21) 1590.79   22) 1591.55   23) 1591.72   24) 1591.02   25) 1589.58   26) 1587.50   27) 1585.00
  28) 1586.34
Y= 28
   1) 1551.36    2) 1551.00    3) 1553.53    4) 1555.94    5) 1558.39    6) 1560.79    7) 1563.12    8) 1565.35    9) 1567.74
  10) 1570.00   11) 1572.15   12) 1574.15   13) 1576.29   14) 1578.61   15) 1581.00   16) 1583.32   17) 1585.48   18) 1587.46
  19) 1589.11   20) 1590.44   21) 1591.47   22) 1592.17   23) 1592.13   24) 1590.94   25) 1588.80   26) 1586.33   27) 1583.00
  28) 1584.57
Y= 29
   1) 1551.08    2) 1551.00    3) 1553.70    4) 1556.36    5) 1559.00    6) 1561.58    7) 1564.07    8) 1566.39    9) 1569.07
  10) 1571.34   11) 1573.40   12) 1575.47   13) 1577.66   14) 1580.01   15) 1582.34   16) 1584.62   17) 1586.66   18) 1588.49
  19) 1590.00   20) 1591.16   21) 1592.12   22) 1592.66   23) 1592.34   24) 1590.60   25) 1587.84   26) 1585.11   27) 1582.00
  28) 1583.27
Y= 30
   1) 1549.77    2) 1550.00    3) 1552.74    4) 1555.73    5) 1558.63    6) 1561.43    7) 1564.12    8) 1566.67    9) 1569.56
  10) 1571.93   11) 1574.06   12) 1576.18   13) 1578.48   14) 1580.94   15) 1583.29   16) 1585.58   17) 1587.61   18) 1589.28
  19) 1590.69   20) 1591.81   21) 1592.58   22) 1592.91   23) 1592.37   24) 1590.19   25) 1586.54   26) 1583.28   27) 1580.00
  28) 1582.15
Y= 31
```

```
   1) 1547.13    2) 1545.00    3) 1550.34    4) 1554.06    5) 1557.24    6) 1560.28    7) 1563.24    8) 1566.06    9) 1569.03
  10) 1571.74   11) 1574.02   12) 1576.33   13) 1578.74   14) 1581.25   15) 1583.74   16) 1586.17   17) 1588.28   18) 1589.94
  19) 1591.28   20) 1592.32   21) 1592.88   22) 1592.87   23) 1591.87   24) 1589.12   25) 1584.82   26) 1580.00   27) 1580.00
  28) 1582.06
Y=  32
   1) 1545.53    2) 1544.00    3) 1548.22    4) 1551.61    5) 1554.78    6) 1558.08    7) 1561.35    8) 1564.49    9) 1567.57
  10) 1570.52   11) 1573.14   12) 1575.68   13) 1578.29   14) 1500.00   15) 1500.00   16) 1500.00   17) 1500.00   18) 1590.54
  19) 1591.92   20) 1592.79   21) 1593.06   22) 1592.55   23) 1590.67   24) 1587.66   25) 1583.92   26) 1580.00   27) 1581.69
  28) 1582.95
Y=  33
   1) 1544.34    2) 1543.00    3) 1545.52    4) 1547.98    5) 1550.86    6) 1554.58    7) 1558.37    8) 1561.93    9) 1565.25
  10) 1568.44   11) 1571.37   12) 1574.17   13) 1577.00   14) 1579.94   15) 1582.95   16) 1586.19   17) 1589.06   18) 1591.09
  19) 1592.52   20) 1593.25   21) 1593.22   22) 1592.15   23) 1589.81   24) 1586.37   25) 1582.50   26) 1580.00   27) 1582.71
  28) 1583.99
Y=  34
   1) 1543.40    2) 1542.00    3) 1541.36    4) 1542.42    5) 1544.68    6) 1549.61    7) 1554.25    8) 1558.19    9) 1561.69
  10) 1565.12   11) 1568.40   12) 1571.57   13) 1574.71   14) 1577.96   15) 1581.58   16) 1585.46   17) 1588.72   18) 1591.06
  19) 1592.70   20) 1593.45   21) 1593.12   22) 1591.50   23) 1568.56   24) 1584.42   25) 1579.00   26) 1581.80   27) 1584.05
  28) 1585.21
Y=  35
   1) 1542.77    2) 1540.00    3) 1534.00    4) 1534.00    5) 1534.00    6) 1543.19    7) 1549.16    8) 1553.27    9) 1556.71
  10) 1560.34   11) 1563.87   12) 1567.37   13) 1570.98   14) 1574.67   15) 1578.93   16) 1583.45   17) 1587.09   18) 1589.51
  19) 1591.78   20) 1592.69   21) 1592.54   22) 1590.63   23) 1587.20   24) 1582.41   25) 1579.00   26) 1583.03   27) 1585.38
  28) 1586.50
Y=  36
   1) 1543.81    2) 1540.00    3) 1534.00    4) 1590.00    5) 1535.00    6) 1539.87    7) 1543.95    8) 1546.97    9) 1549.59
  10) 1553.55   11) 1557.21   12) 1560.73   13) 1564.69   14) 1569.47   15) 1574.69   16) 1580.15   17) 1584.05   18) 1585.00
  19) 1589.28   20) 1591.39   21) 1591.51   22) 1589.45   23) 1585.63   24) 1580.00   25) 1582.17   26) 1584.86   27) 1586.82
  28) 1587.82
Y=  37
   1) 1547.55    2) 1546.70    3) 1547.33    4) 1556.52    5) 1536.00    6) 1537.00    7) 1538.00    8) 1539.00    9) 1539.00
  10) 1545.00   11) 1548.75   12) 1551.89   13) 1555.37   14) 1561.99   15) 1568.31   16) 1575.52   17) 1580.68   18) 1580.00
  19) 1585.00   20) 1588.42   21) 1589.89   22) 1587.98   23) 1583.91   24) 1580.00   25) 1583.70   26) 1586.33   27) 1588.12
  28) 1589.03
Y=  38
   1) 1551.03    2) 1550.82    3) 1551.00    4) 1551.64    5) 1545.58    6) 1543.75    7) 1543.15    8) 1542.63    9) 1541.00
  10) 1538.00   11) 1538.00   12) 1539.00   13) 1540.00   14) 1552.84   15) 1558.97   16) 1569.51   17) 1577.95   18) 1578.00
  19) 1580.00   20) 1582.00   21) 1587.73   22) 1585.79   23) 1580.00   24) 1582.64   25) 1585.21   26) 1587.54   27) 1589.21
  28) 1590.06
Y=  39
   1) 1553.63    2) 1553.44    3) 1553.12    4) 1552.34    5) 1549.85    6) 1548.17    7) 1547.12    8) 1546.28    9) 1545.26
  10) 1544.31   11) 1544.72   12) 1546.61   13) 1551.00   14) 1554.00   15) 1555.00   16) 1560.00   17) 1565.00   18) 1576.00
  19) 1577.00   20) 1579.00   21) 1585.21   22) 1583.08   23) 1578.00   24) 1582.54   25) 1585.85   26) 1588.33   27) 1590.00
  28) 1590.84
Y=  40
   1) 1555.33    2) 1555.09    3) 1554.58    4) 1553.67    5) 1552.19    6) 1550.85    7) 1549.80    8) 1548.98    9) 1548.37
  10) 1548.16   11) 1548.86   12) 1550.63   13) 1553.47   14) 1556.27   15) 1558.91   16) 1562.72   17) 1566.88   18) 1571.00
  19) 1572.00   20) 1574.00   21) 1575.00   22) 1576.00   23) 1577.00   24) 1582.56   25) 1586.24   26) 1588.82   27) 1590.51
  28) 1591.35
Y=  41
   1) 1556.17    2) 1555.90    3) 1555.35    4) 1554.48    5) 1553.30    6) 1552.13    7) 1551.14    8) 1550.39    9) 1549.96
  10) 1550.01   11) 1550.81   12) 1552.47   13) 1554.88   14) 1557.60   15) 1560.54   16) 1564.01   17) 1567.68   18) 1571.04
  19) 1573.34   20) 1575.88   21) 1577.46   22) 1578.14   23) 1579.88   24) 1583.38   25) 1586.61   26) 1589.10   27) 1590.78
  28) 1591.62
```

```
** START HEAD SOLUTION - TIME :  18615.0 DAYS        **


ITERATION NO.     1  EPSILON =              .7366E+00 EMAX =            .2417E-02
ITERATION NO.     2  EPSILON =              .5536E+00 EMAX =            .1629E-02
ITERATION NO.     3  EPSILON =              .4810E+00 EMAX =            .1452E-02

** TIME =     18615.00      NO. OF PARTICLES GENERATED =      106      TOTAL PARTICLES =     2933
```

```
              EXXON-CRANDON      PROJECT REPORT    9.2 EXAMPLE CASE

         **** HEADS (FEET) AT TIME = 18615.0000 DAYS ****

              NO. OF ITERATIONS =     3  EPSILON =      .481  EMAX =      .001

                                           HEADS IN X DIRECTION (FROM 1500 FT. DATUM)

        1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25

  Y
DIREC
-----

41 56.2 55.9 55.4 54.5 53.3 52.1 51.1 50.4 50.0 50.0 50.8 52.5 54.9 57.6 60.5 64.0 67.7 71.0 73.3 75.9 77.5 78.1 79.9 83.4 86.6

40 55.3 55.1 54.6 53.7 52.2 50.8 49.8 49.0 48.4 48.2 48.9 50.6 53.5 56.3 58.9 62.7 66.9 71.0 72.0 74.0 75.0 76.0 77.0 82.6 86.2

39 53.6 53.4 53.1 52.3 49.8 48.2 47.1 46.3 45.3 44.3 44.7 46.6 51.0 54.0 55.0 60.0 65.0 76.0 77.0 79.0 85.2 83.1 78.0 82.5 85.9

38 51.0 50.8 51.0 51.6 45.6 43.8 43.2 42.6 41.0 38.0 38.0 39.0 40.0 52.8 58.9 69.5 77.9 78.0 80.0 82.0 87.7 85.7 80.0 82.6 85.2

37 47.5 46.7 47.3 56.5 36.0 37.0 38.0 39.0 39.0 45.0 48.7 51.8 55.3 61.9 68.2 75.4 80.6 80.0 85.0 88.3 89.8 87.9 83.9 80.0 83.7

36 43.8 40.0 34.0 90.0 35.0 39.9 43.9 46.9 49.5 53.5 57.1 60.6 64.6 69.4 74.6 80.0 83.9 85.0 89.2 91.2 91.3 89.3 85.5 80.0 82.2

35 42.8 40.0 34.0 34.0 34.0 43.2 49.1 53.2 56.6 60.3 63.8 67.2 70.8 74.5 78.7 83.2 86.9 89.3 91.5 92.6 92.3 90.4 87.1 82.4 79.0

34 43.4 42.0 41.4 42.4 44.7 49.6 54.2 58.1 61.6 65.0 68.3 71.4 74.5 77.7 81.3 85.2 88.4 90.7 92.3 93.1 92.8 91.2 88.3 84.3 79.0

33 44.3 43.0 45.5 48.0 50.8 54.5 58.3 61.8 65.1 68.3 71.2 74.0 76.8 79.7 82.7 85.9 88.7 90.7 92.1 92.8 92.8 91.7 89.5 86.2 82.4

32 45.5 44.0 48.2 51.6 54.7 58.0 61.3 64.4 67.5 70.4 73.0 75.5 78.1 80.7 83.3 85.9 88.3 90.1 91.4 92.2 92.5 92.0 90.2 87.4 83.8

31 47.1 45.0 50.3 54.0 57.2 60.2 63.2 66.0 68.9 71.6 73.8 76.1 78.5 81.0 83.4 85.8 87.8 89.4 90.7 91.7 92.2 92.1 91.2 88.6 84.6

30 49.8 50.0 52.7 55.7 58.6 61.4 64.0 66.6 69.4 71.8 73.9 76.0 78.2 80.6 82.9 85.2 87.1 88.7 90.1 91.1 91.7 91.9 91.4 89.5 86.2

29 51.1 51.0 53.7 56.3 59.0 61.5 64.0 66.3 68.9 71.2 73.2 75.2 77.4 79.7 82.0 84.2 86.2 87.9 89.3 90.3 91.0 91.1 90.8 89.7 87.4

28 51.4 51.0 53.5 55.9 58.3 60.7 63.0 65.2 67.6 69.8 72.0 73.9 76.0 78.3 80.7 82.9 85.0 86.9 88.4 89.5 90.3 90.4 90.4 89.9 88.3
```

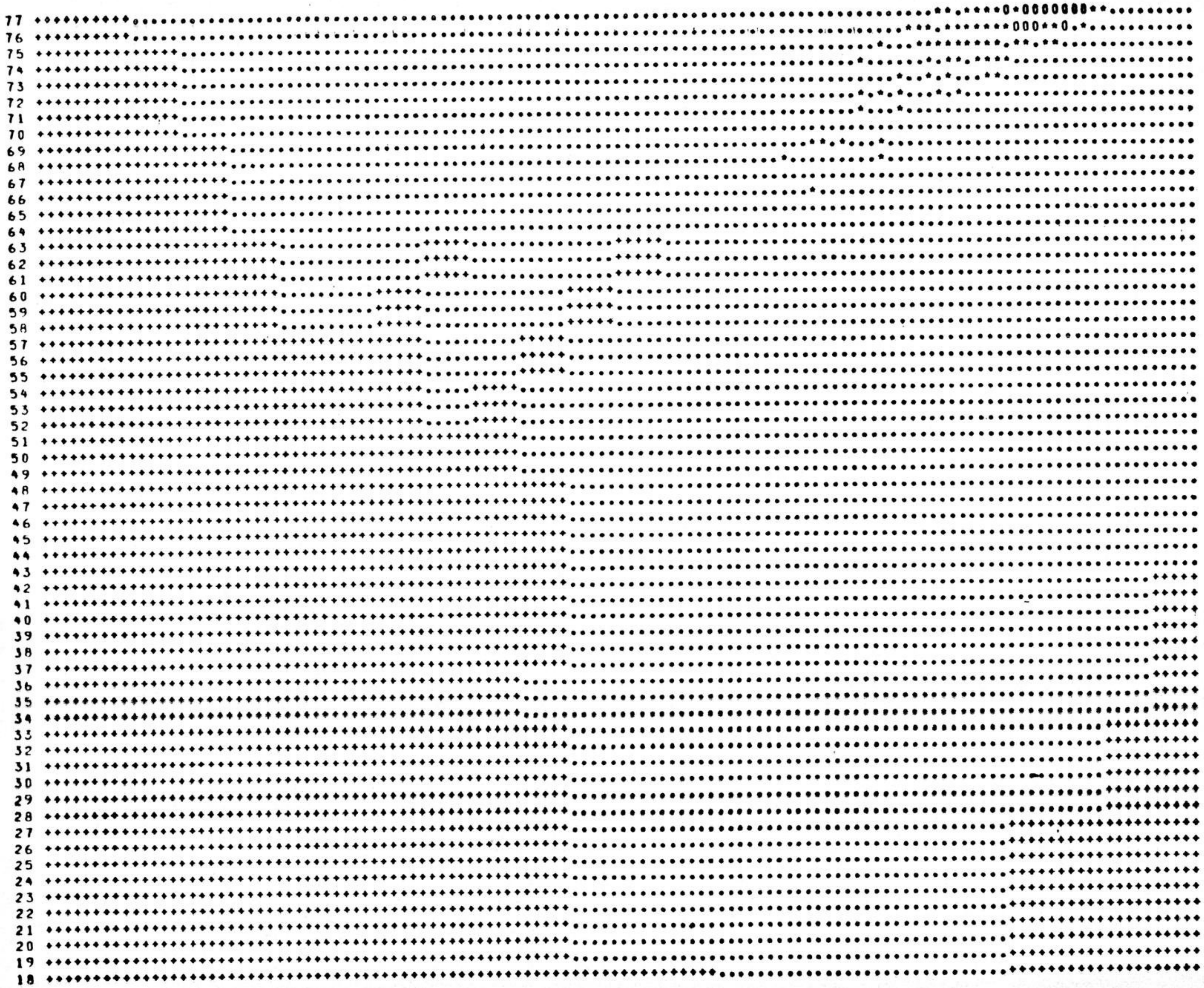
```
27 50.9 50.0 52.3 54.5 56.8 59.1 61.3 63.5 65.7 67.8 70.0 72.1 74.2 76.5 78.9 81.3 83.6 85.6 87.3 88.7 89.7 90.0 90.3 90.1 89.1

26 50.3 50.0 50.0 52.0 54.5 56.7 59.0 61.2 63.3 65.4 67.5 69.7 71.9 74.3 76.9 79.4 81.9 84.1 86.1 87.8 89.0 89.8 90.3 90.3 89.6

25 48.8 47.5 45.0 48.5 51.4 54.0 56.3 58.4 60.4 62.4 64.5 66.7 69.1 71.7 74.5 77.3 80.0 82.5 84.8 86.7 88.2 89.4 90.1 90.3 90.2

24 47.4 45.2 40.0 44.7 48.2 51.0 53.1 55.1 56.9 58.8 60.9 63.1 65.7 68.6 71.8 75.0 78.0 80.8 83.3 85.5 87.3 88.7 89.6 90.2 90.3

23 47.1 44.9 40.0 40.0 44.8 47.7 49.7 51.2 52.7 54.6 56.6 58.7 61.3 65.0 68.8 72.5 75.9 78.9 81.7 84.1 86.2 87.8 89.0 89.8 90.2

22 48.0 46.1 42.7 39.0 42.1 44.4 46.0 46.7 47.4 49.6 51.5 53.1 55.3 60.5 65.6 69.9 73.7 77.1 80.0 82.6 84.9 86.7 88.0 89.1 89.8

21 49.6 47.9 44.4 39.0 38.0 41.1 42.1 41.7 40.0 44.2 45.9 46.2 45.0 55.7 62.4 67.5 71.6 75.1 78.2 81.0 83.4 85.2 86.8 88.1 89.1

20 51.9 50.2 47.0 42.3 37.0 38.8 38.8 37.0 39.0 40.7 41.1 40.0 46.9 54.4 60.5 65.5 69.7 73.3 76.4 79.1 81.5 83.4 85.1 86.7 88.2

19 54.6 53.1 50.0 45.0 37.0 35.0 35.0 35.0 37.6 37.7 37.0 42.2 48.0 53.9 59.3 63.9 67.9 71.4 74.3 77.0 79.3 81.2 83.0 84.6 86.4

18 57.8 56.5 53.7 49.7 44.6 40.4 35.0 35.0 35.9 35.0 38.8 43.5 48.5 53.6 58.3 62.5 66.2 69.4 72.2 74.6 76.7 78.6 80.2 81.8 81.8

17 61.3 60.1 57.7 54.4 50.2 45.6 40.8 35.0 35.0 35.0 39.3 43.9 48.5 53.1 57.3 61.0 64.3 67.2 69.7 71.8 73.7 75.4 77.0 78.4 79.2

16 64.8 63.7 61.7 58.7 55.0 50.8 46.2 41.7 38.6 35.0 35.0 43.6 48.1 52.3 56.1 59.5 62.4 64.8 66.9 68.7 70.3 71.8 73.5 75.5 80.0

15 68.3 67.3 65.4 62.6 59.1 55.0 50.5 45.9 41.7 37.7 35.0 43.2 47.6 51.4 54.8 57.7 60.2 62.2 63.9 65.2 66.4 67.6 69.1 71.0 75.0

14 71.6 70.7 68.9 66.2 62.7 58.6 53.9 48.7 43.3 38.0 35.0 42.8 46.9 50.4 53.4 55.9 57.9 59.5 60.6 61.4 62.0 62.6 63.6 65.0 68.8

13 74.8 73.9 72.1 69.5 65.9 61.6 56.5 50.6 43.6 35.0 35.0 42.3 46.0 49.1 51.7 53.8 55.4 56.5 57.1 57.2 57.0 56.8 57.2 55.0 62.2

12 77.8 76.9 75.1 72.4 68.9 64.4 58.9 52.4 44.6 35.0 36.6 41.8 45.0 47.8 50.0 51.8 52.9 53.5 53.5 52.8 51.6 49.9 48.4 50.0 57.1

11 80.7 79.7 77.9 75.2 71.6 67.0 61.3 54.5 46.1 35.0 35.0 40.4 43.8 46.4 48.3 49.7 50.4 50.5 49.9 48.5 46.3 42.4 34.0 45.4 53.1

10 83.3 82.4 80.5 77.8 74.1 69.5 63.8 57.1 49.3 41.0 35.0 40.2 42.9 45.0 46.6 47.6 48.1 47.8 46.7 44.6 42.1 38.9 34.0 43.3 50.3

 9 85.7 84.8 83.0 80.2 76.6 71.9 66.2 59.5 51.9 43.5 35.0 39.7 41.9 43.6 44.9 45.7 45.9 45.3 43.9 40.8 34.0 34.0 34.0 42.3 48.5

 8 87.9 87.0 85.2 82.5 78.9 74.2 68.6 61.9 54.1 45.1 35.0 38.1 40.9 42.0 43.1 43.7 43.8 43.3 42.1 39.6 34.0 35.6 37.6 42.4 47.3
```

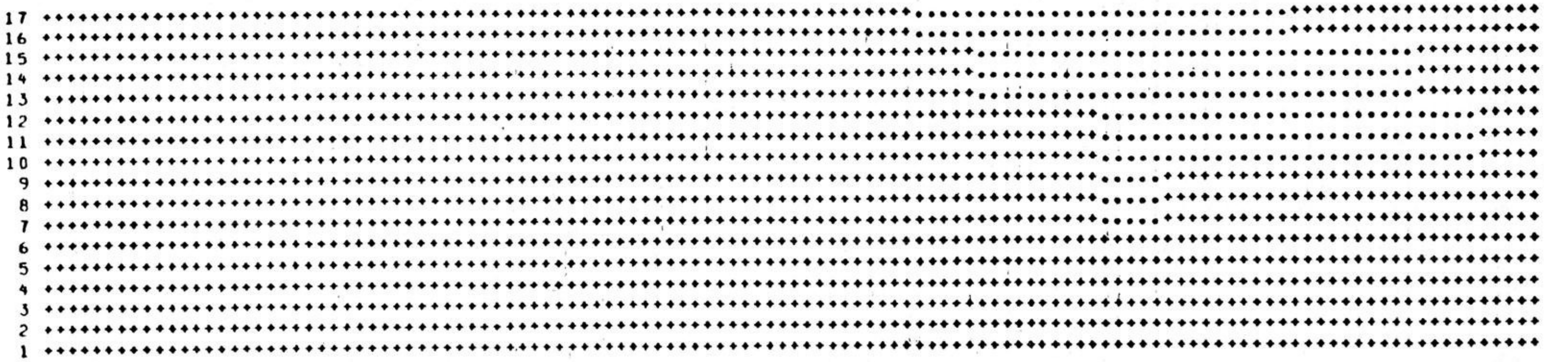
```
7 89.9 89.1 87.3 84.6 81.0 76.5 71.0 64.3 56.3 46.7 35.0 37.0 38.2 40.1 41.1 41.9 42.0 41.4 40.2 37.7 34.0 35.5 37.4 41.3 45.7

6 91.7 90.9 89.2 86.6 83.1 78.7 73.3 66.9 59.1 49.2 35.0 35.0 35.0 35.0 38.9 40.1 40.2 39.8 38.8 36.9 34.0 34.0 34.0 38.5 43.7

5 93.3 92.5 90.8 88.3 84.9 80.7 75.7 69.7 62.8 55.0 46.9 42.8 39.6 35.0 35.0 37.4 38.4 38.2 37.7 36.6 35.3 34.7 34.0 34.0 41.5

4 94.6 93.8 92.2 89.7 86.5 82.6 77.8 72.4 66.3 59.9 53.7 48.8 44.5 39.9 35.0 35.0 35.0 36.6 36.5 36.0 35.4 34.9 34.6 34.0 40.9

3 95.6 94.8 93.2 90.9 87.8 84.0 79.6 74.6 69.1 63.5 58.0 53.0 48.5 44.2 40.2 37.6 35.0 35.2 34.0 34.0 34.0 34.0 34.0 34.0 41.1

2 96.3 95.5 94.0 91.7 86.7 85.1 80.8 76.1 71.0 65.8 60.7 55.8 51.2 46.9 42.9 39.0 34.0 34.0 34.0 35.5 36.2 36.8 37.6 39.2 42.9

1 96.6 95.8 94.3 92.1 89.2 85.6 81.5 76.9 72.0 66.9 61.9 57.1 52.6 48.3 44.3 40.5 37.2 36.1 35.9 36.6 37.4 38.2 39.4 41.2 44.0
```

```
SLICE NUMBER      2     ITERATION #        3     TIME =  18615.000 DAYS


                                        HEADS IN X DIRECTION (FROM 1500 FT. DATUM)

     26    27    28

   Y
 DIREC
 -----

  41 89.1 90.8 91.6

  40 88.8 90.5 91.4

  39 88.3 90.0 90.8

  38 87.5 89.2 90.1

  37 86.3 88.1 89.0

  36 84.9 86.8 87.8

  35 83.0 85.4 86.5

  34 81.8 84.0 85.2

  33 80.0 82.7 84.0

  32 80.0 81.7 82.9

  31 80.0 80.0 82.1

  30 83.1 80.0 82.1

  29 84.9 82.0 83.3

  28 86.1 83.0 84.6

  27 87.3 85.0 86.3
```

```
26 [illegible] 87.6 [illegible]
25 89.9 90.0 90.6
24 90.3 90.3 93.5
23 90.4 90.4 95.3
22 90.2 90.2 96.0
21 89.8 89.8 95.6
20 89.3 89.8 94.2
19 86.8 90.3 91.6
18 87.2 88.4 89.2
17 85.2 85.9 86.4
16 81.4 82.5 83.1
15 77.0 78.4 79.2
14 71.9 74.0 75.0
13 66.7 69.5 70.8
12 62.1 65.3 66.8
11 58.3 61.7 63.3
10 55.4 58.6 60.2
 9 53.1 56.1 57.7
 8 51.3 54.1 55.5
 7 49.6 52.3 53.7
 6 47.9 50.8 52.2
 5 46.4 49.5 51.0
 4 45.7 48.8 50.3
 3 45.7 48.5 49.9
 2 46.3 48.6 49.8
 1 46.7 48.7 49.8
```

```
          EXXON-CRANDON      PROJECT REPORT    9.2 EXAMPLE CASE
      **** CONCENTRATIONS (AS PERCENT POND LEAKAGE) AT TIME =18615.0000 DAYS ****
          NO. OF ITERATIONS =     3  EPSILON =     .481  EMAX =     .001

                                                               X
                                                                                                       1         1         1
             1         2         3         4         5         6         7         8         9         0         1         2
  Y 123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890

123 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
122 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
121 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
120 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
119 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
118 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
117 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++..........++++++++++
116 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++..........++++++++++
115 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++..........++++++++++
114 +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++....................+++++++++++++++..........++++++++++
113 +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++....................+++++++++++++++..........++++++++++
112 +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++....................+++++++++++++++..........++++++++++
111 +++++++++++++++++++++++++++++++++++++++++++++........................................++++++++++....................+++++
110 +++++++++++++++++++++++++++++++++++++++++++++........................................++++++++++....................+++++
109 +++++++++++++++++++++++++++++++++++++++++++++........................................++++++++++....................+++++
108 +++++++++++++++++++++++++............................................................+++++.........................+++++
107 +++++++++++++++++++++++++............................................................+++++.........................+++++
106 +++++++++++++++++++++++++............................................................+++++.........................+++++
105 +++++++++++++++++++++++++...............................................................................................
104 +++++++++++++++++++++++++...............................................................................................
103 +++++++++++++++++++++++++...............................................................................................
102 ++++++++++..............................................................................................................
101 ++++++++++..............................................................................................................
100 ++++++++++..............................................................................................................
 99 ++++++++++..............................................................................................................
 98 ++++++++++..............................................................................................................
 97 ++++++++++..............................................................................................................
 96 ++++++++++..............................................................................................................
 95 ++++++++++..............................................................................................................
 94 ++++++++++..............................................................................................................
 93 ++++++++++..............................................................................................................
 92 ++++++++++..............................................................................................................
 91 ++++++++++..............................................................................................................
 90 ++++++++++..............................................................................................................
 89 ++++++++++..............................................................................................................
 88 ++++++++++................................................................................................****..........
 87 ++++++++++................................................................................................0*000***......
 86 ++++++++++...............................................................................................*0000000*..*...
 85 ++++++++++.............................................................................................**0000000000*0000
 84 ++++++++++..............................................................................................*00001000100*00*
 83 ++++++++++............................................................................................*0000100001110**0*
 82 ++++++++++..........................................................................................***000100000001000**
 81 ++++++++++.........................................................................................**00000110011111*0***
 80 ++++++++++........................................................................................*.000001000011010**.*.
 79 ++++++++++.....................................................................................**.**00000000001000*.....
 78 ++++++++++...................................................................................*.*0***00000000000*........
```


77
76
75
74
73
72
71
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18



```
                *** SCALE ***
       .   0   1   2   3   4   5   6   7   8   9
     0.0 1.0 10. 20. 30. 40. 50. 60. 70. 80. 90. 100

VALUES LESS THAN 0.0 DENOTED BY  ?.  VALUES GREATER THAN 100. DENOTED BY  X
```

```
                    SLICE NUMBER      2     ITERATION #        3     TIME =  18615.000 DAYS


                X
      1         1        1
      2         3        4
 Y    12345678901234567890

123   ++++++++++++++++++++
122   ++++++++++++++++++++
121   ++++++++++++++++++++
120   ++++++++++++++++++++
119   ++++++++++++++++++++
118   ++++++++++++++++++++
117   ++++++++++++++++++++
116   ++++++++++++++++++++
115   ++++++++++++++++++++
114   ++++++++++++++++++++
113   ++++++++++++++++++++
112   ++++++++++++++++++++
111   ++++++++++++++++++++
110   ++++++++++++++++++++
109   ++++++++++++++++++++
108   ++++++++++++++++++++
107   ++++++++++++++++++++
106   ++++++++++++++++++++
105   ++++++++++++++++++++
104   ++++++++++++++++++++
103   ++++++++++++++++++++
102   ++++++++++++++++++++
101   ++++++++++++++++++++
100   ++++++++++++++++++++
 99   .....+++++++++++++++
 98   .....+++++++++++++++
 97   .....+++++++++++++++
 96   .....+++++++++++++++
 95   .....+++++++++++++++
 94   .....+++++++++++++++
 93   .....+++++++++++++++
 92   .....+++++++++++++++
 91   .....+++++++++++++++
 90   ..........++++++++++
 89   .......*..++++++++++
 88   ..........++++++++++
 87   ..*..**...++++++++++
 86   ..***.....++++++++++
 85   .****.*.*.++++++++++
 84   *.*.*.****++++++++++
 83   *.0*.*....++++++++++
 82   .*.*.*....++++++++++
 81   ..........++++++++++
 80   ..........++++++++++
 79   ..........++++++++++
 78   ..........++++++++++
 77   ..........++++++++++
 76   ..........++++++++++
```

```
75 ..........++++++++++
74 ..........++++++++++
73 ..........++++++++++
72 ..........++++++++++
71 ..........++++++++++
70 ..........++++++++++
69 ..........++++++++++
68 ..........++++++++++
67 ..........++++++++++
66 ..........++++++++++
65 ..........++++++++++
64 ..........++++++++++
63 ..........++++++++++
62 ..........++++++++++
61 ..........++++++++++
60 ..........++++++++++
59 ..........++++++++++
58 ..........++++++++++
57 .....+++++++++++++++
56 .....+++++++++++++++
55 .....+++++++++++++++
54 ++++++++++++++++++++
53 ++++++++++++++++++++
52 ++++++++++++++++++++
51 ++++++++++++++++++++
50 ++++++++++++++++++++
49 ++++++++++++++++++++
48 ++++++++++++++++++++
47 ++++++++++++++++++++
46 ++++++++++++++++++++
45 ++++++++++++++++++++
44 ++++++++++++++++++++
43 ++++++++++++++++++++
42 ++++++++++++++++++++
41 ++++++++++++++++++++
40 ++++++++++++++++++++
39 ++++++++++++++++++++
38 ++++++++++++++++++++
37 ++++++++++++++++++++
36 ++++++++++++++++++++
35 ++++++++++++++++++++
34 ++++++++++++++++++++
33 ++++++++++++++++++++
32 ++++++++++++++++++++
31 ++++++++++++++++++++
30 ++++++++++++++++++++
29 ++++++++++++++++++++
28 ++++++++++++++++++++
27 ++++++++++++++++++++
26 ++++++++++++++++++++
25 ++++++++++++++++++++
24 ++++++++++++++++++++
23 ++++++++++++++++++++
22 ++++++++++++++++++++
21 ++++++++++++++++++++
20 ++++++++++++++++++++
19 ++++++++++++++++++++
18 ++++++++++++++++++++
17 ++++++++++++++++++++
16 ++++++++++++++++++++
```

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


                                     *** SCALE ***
                           *    0    1    2    3    4    5    6    7    8    9
                         0.0  1.0  10.  20.  30.  40.  50.  60.  70.  80.  90.  100

           VALUES LESS THAN 0.0 DENOTED BY  ?.  VALUES GREATER THAN 100. DENOTED BY  X
```

APPENDIX C

Program Listing

```
      PROGRAM RANWLK(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     1                 DEBUG=OUTPUT,TAPE10,TAPE11,TAPE12,TAPE13)
C C$      ARRAYS
C C$       CALLS
C C$      TRACE
C
C**************************************************************
C
C      ***  GOLDER ASSOCIATES GROUNDWATER COMPUTING SYSTEM  ***
C
C               VERSION 6.1         04 DECEMBER 1981
C
C            ( COMBINED IADI AND PARTICLE PUSHER MODELS )
C
C      THIS VERSION IS A COMBINATION OF THE FINITE DIFFERENCE
C      HEAD SOLVER PROGRAM AND THE RANDOM WALK SOLUTE TRANSPORT
C      MODEL.
C
C      HEADS ARE COMPUTED BY SOLVING THE TRANSIENT EQUATION OF
C      GROUNDWATER PRESSURE DISTRIBUTION USING A FINITE
C       DIFERENCE APPROXIMATION. THE GOVERNING EQUATION
C       AND SOLUTION METHODOLOGY ARE  DOCUMENTED
C       IN:
C         "SELECTED DIGITAL COMPUTER TECHNIQUES FOR GROUND-
C          WATER RESOURCE EVALUATION"
C          T.A. PRICKETT AND C.G. LONNQUIST
C          ILLINOIS STATE WATER SURVEY BULLETIN 55
C          1971
C
C
C      THE RANDOM WALK MODEL TRACKS A MASS OF SOLUTE WHICH IS
C      IDEALIZED AS PARTICLES.TRANSPORT IS MODELED BY COMPUTING
C      THE X,Y COORDINATES OF EACH PARTICLE AS THEY ARE MOVED
C      BY BOTH GRADIENT INDUCED MOTION AND DISPERSIVE MOTION.
C
C      VERSION 6.1 INCLUDES THE FOLLOWING OPTIONS:
C
C        - SEPERATE HEAD AND PARTICLE GRID SPACING
C        - NODE BY NODE INPUT OF LEAKAGE PONDS
C        - VARIABLE THICKNESS ARRAY
C        - ONE LAYER MODEL (REMNANTS OF 2 LAYER MODEL REMAIN)
C        - RESTART FILES (INPUT AND OUTPUT)
C        - SINGLE CHARACTER OUTPUT MATRIX AT 1 IN. TO 2000 FT.
C          SCALE FOR 200 X 333.33 FT. PARTICLE GRIDS
C
C**************************************************************
*
C
C
       COMMON/PARMS/HEAD(28,41),HOLD(28,41),BOT(28,41),
     1              T(28,41,2),R(28,41),MATL(28,41),
     2              GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
       COMMON/CONTRL/TSTEP,NX,NY,DX,DY,TIMMAX,OUTFRQ,NDATPR(10),LUNIT,
     1              TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
     2              IHEDIN,IHEDOT,ISEED
C
```

```
      COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KELIM
C
      COMMON/MATER/ NMAT,DL(20),DT(20),A(20),K(20),S(20),RE(20),POR(20)
C
      COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),TM(20,20),RATE(20,20),
     1             NODES(20,100,2)
C
      COMMON/ERROR/ERRCOD,ERRARG(10)
C
      REAL DX,K,TSTEP,ALPHA,TOL,ERRARG,TIMMAX
C
      INTEGER NX,NY,NUMIT,TUNIT,LUNIT,OUTFRG,OUTKNT,ERRCOD
      INTEGER MAXIT
      INTEGER TITLE
C
C      GET DATE AND TIME
C
      CALL CLOCK(ITIME)
      CALL DATE(IDATE)
        TIME = 0.0
C
C     READ IN DATA AND ECHO BACK TO PRINTER
C
      ERRCOD = 0
      CALL INPUT(ITIME,IDATE)
       IF(ERRCOD.LE.0)GO TO 84
         CALL  ERPROC
         IF(ERRCOD.GE.100) GO TO 900
   84 CONTINUE
C
C
C       INITIALIZE VARIABLES
      DTFAC = 1.
      DTMAX = TSTEP
      NTOTAL = 0
C
C     READ HEADS FROM RESTART FILE
C
      IF(IHEDIN .LE. 0) GOTO 85
        ERRCOD = 0
        CALL HEDIN(TITLE,IHEDIN,NX,NY,HEAD,TIME,TUNIT,LUNIT,X,Y,
     1            NTOTAL)
         IF(ERRCOD .LE. 0) GOTO 85
           CALL ERPROC
           IF(ERRCOD .GE. 100) GOTO 900
   85 CONTINUE
C
      IF(ERRCOD .LE. 0) GOTO 90
        CALL ERPROC
        IF(ERRCOD .GE. 100) GOTO 900
   90 CONTINUE
C     INITIALIZE ARRAYS
      DO 100 I=1,NXPAR
        DO 95 J=1,NYPAR
          NOUT(I,J)=0
   95   CONTINUE
```

```
  100 CONTINUE
      DO 110 I = 1,NX
        DO 105 J=1,NY
          HOLD(I,J) = HEAD(I,J)
  105   CONTINUE
  110 CONTINUE
C***PLACE RESTART PARTICLES***
C
      IF(IHEDIN.EQ.0) GO TO 111
      DO 112 NP = 1,NTOTAL
      CALL FIND(X(NP),Y(NP),DXPAR,DYPAR,NXPAR,NYPAR,NS,MS)
      NOUT(NS,MS)=NOUT(NS,MS)+1
112   CONTINUE
111   CONTINUE
C     INITIALIZE COUNTER FOR OUTPUTTING HEADS EVERY "OUTFRQ" TIMESTEPS
      OUTKNT = 1
C
C **** START TIME STEP LOOP ****
C
      NT=0
  120 CONTINUE
        TIME = TIME + TSTEP
        NT=NT+1
        IF(MTYPE .EQ. 3) GO TO 140
C
C       SOLVE FOR HEADS IN UPPER LAYER
C
        ERRCOD = 0
        L = 1
        CALL IADI(L,NT,TIME,NUMIT,E,EMAX)
C
        IF(ERRCOD .LE. 0) GOTO 130
          CALL ERPROC
          IF(ERRCOD .GE. 100) GOTO 900
  130   CONTINUE
  140   CONTINUE
        IF(MTYPE .EQ. 2) GOTO 150
C
C       SOLVE FOR LOWER LAYER HEADS
C
        ERRCOD = 0
        L = 2
        CALL IADI(L,NT,TIME,NUMIT,E,EMAX)
        IF(ERRCOD .LE. 0) GOTO 150
          CALL ERPROC
          IF(ERRCOD .GE. 100) GOTO 900
  150   CONTINUE
C
C       COMPUTE INTER-LAYER LEAKAGE
C
        IF(MTYPE .NE. 1) GOTO 160
          ERRCOD = 0
          CALL LEAK
          IF(ERRCOD .LE. 0) GOTO 160
            CALL ERPROC
            IF(ERRCOD .GE. 100) GOTO 900
  160   CONTINUE
```

```
C
C      SOLVE FOR SOLUTE TRANSPORT IF PARTICLE VOLUME > 0
C
       IF(PARTVL.LE.0) GOTO 800
C
C      GENERATE NEW PARTICLES
C
       ERRCOD=0
       CALL GENERAT(TIME,NTOTAL)
      IF(ERRCOD.LE.0) GO TO 162
      CALL ERPROC
      IF(ERRCOD.GE.100.) GO TO 900
162   CONTINUE
C
C      SOLVE FOR SOLUTE TRANSPORT IF NO. OF PARTICLES > 0
C
       IF(NTOTAL.LE.0) GOTO 800
C
C     COMPUTE NEW GRADIENTS
C
      ERRCOD = 0
      CALL GRADNT
      IF(ERRCOD.LE.0) GOTO 165
        CALL ERPROC
        IF(ERRCOD.GE.100) GOTO 900
  165 CONTINUE
C
       DO 180 NP=1,NTOTAL
C
C      FIND THE HEAD SOLUTION CELL THE PARTICLE IS IN
C
       CALL FIND(X(NP),Y(NP),DX,DY,NX,NY,NN,MM)
       MAT=MATL(NN,MM)
C
C      IF POROSITY OF CELL IS ZERO, DO NOT MOVE PARTICLE
C
       IF(A(MAT).LE.0.0) GOTO 180
C
C     FIND THE SOLUTE TRANS. CELL THAT PARTICLE IS IN
C
      CALL FIND(X(NP),Y(NP),DXPAR,DYPAR,NXPAR,NYPAR,NS,MS)
C
C      DECREMENT OUTPUT MATRIX PARTICLE COUNTER
C
       NOUT(NS,MS)=NOUT(NS,MS)-1
C
C      MOVE PARTICLE
C     WRITE(6,9993) NP,X(NP),Y(NP),MAT,DL(MAT),DT(MAT),A(MAT),
C    I            GX(NN,MM),GY(NN,MM)
C9993 FORMAT(5X,"NP=",I5," X=",F8.2," Y=",F8.2," MAT=",I5,
C    1       " DL=",F8.2," DT=",F8.2," A=",F8.2," GX=",F10.5,
C    2       " GY=",F10.5)
C
       CALL MOVE(X(NP),Y(NP),DL(MAT),DT(MAT),A(MAT),HYP(NN,MM),
     1          GX(NN,MM),GY(NN,MM),ISEED)
C
C      FIND CELL THAT PARTICLE HAS MOVED TO
```

```
C
      CALL FIND(X(NP),Y(NP),DXPAR,DYPAR,NXPAR,NYPAR,NS,MS)
C
C      INCREMENT OUTPUT PARTICLE MATRIX COUNTER
C
       NOUT(NS,MS)=NOUT(NS,MS)+1
  180  CONTINUE
C
C       OUTPUT RESULTS IF DESIRED
C
 800    CONTINUE
        IF(NT .NE. 1 .AND. NT .NE. OUTKNT) GOTO 810
          OUTKNT = OUTKNT + OUTFRQ
C    WRITE(6,9990) NDATPR
C9990     FORMAT(//5X,"I GOT INTO PRINT SECT.",10I1)
          IFLAG = 0
          IF(NDATPR(3).GE.1)CALL OUTPUT(TIME,NUMIT,E,EMAX)
          IF(NDATPR(4).GE.1)CALL OUT2K(1,TIME,NUMIT,E,EMAX)
          IF(NDATPR(5).GE.1.AND.NTOTAL.GT.0) CALL OUT2K(2,TIME,NUMIT,
     1        E,EMAX)
          IF(NDATPR(6).GE.1.AND.NTOTAL.GT.0)CALL PLOT3(NXPAR,NYPAR,
     1     NOUT,TIME)
          IF(NDATPR(7).GE.1.AND.NTOTAL.GT.0) IFLAG = 7
          IF(IFLAG .NE. 7)  GOTO 807
            WRITE(6,2010) TIME
 2010       FORMAT(1H1,/5X,"** PARTICLE COUNT AT TIME = ",F12.2,
     1              " **"//)
            CALL PLOT
  807    CONTINUE
C
          IF(NDATPR(8) .LE. 0) GOTO 808
            WRITE(6,2015) TIME
 2015     FORMAT(1H1,/5X,"** GRADIENTS AT TIME = ",F12.2,
     1            " **"//10X,"-- GX --"//)
          CALL PLOTR(GX,NX,NY)
          WRITE(6,2020)
 2020     FORMAT(///5X,"-- GY --"//)
          CALL PLOTR(GY,NX,NY)
          WRITE(6,2025)
 2025     FORMAT(///5X,"-- HYP --"//)
        CALL PLOTR(HYP,NX,NY)
  808   CONTINUE
      IF(NDATPR(10).GE.1)CALL OUT3K(TIME,NUMIT,E,EMAX)
C
C       ELIMINATE INACTIVE PARTICLES AFTER EACH PRINTING
C
          IF(NTOTAL.GT.0) CALL ELIM(DX,DY,NX,NY,NTOTAL)
  810   CONTINUE
      IF(KELIM.EQ.1.AND.NTOTAL.GT.0)CALL ELIM (DX,DY,NX,NY,NTOTAL)
C     WRITE(6,9991) NDATPR
C9991  FORMAT(/5X,"I GOT PAST PRINT SECTION  ",10I1/)
C
C        ADJUST TIME STEP
C
         TSTEP = TSTEP * DTFAC
         IF(TSTEP .GT. DTMAX) TSTEP = DTMAX
C
```

```
C **** END TIME STEP LOOP ****
C
      IF(TIME.LE.TIMMAX) GO TO 120
C
C      CHECK FOR OUTPUTTING RESTART FILE
C
      IF(IHEDOT .LE. 0) GOTO 820
        ERRCOD = 0
        CALL HEDOUT(TITLE,IHEDOT,NX,NY,HEAD,TIME,TUNIT,LUNIT,X,Y,NTOTAL)
        IF(ERRCOD .LE. 0) GOTO 820
          CALL ERPROC
          IF(ERRCOD .GE. 100) GOTO 900
  820 CONTINUE
C
C     END RUN
C
      WRITE(6,2000)
 2000 FORMAT(//" **** END PROGRAM ****"//)
C
  900 STOP
      END
```

```
      SUBROUTINE INPUT(ITIME,IDATE)
C C$     ARRAYS
C C$      TRACE
C C$       CALLS
C
C*************************************************************************
C
C    FUNCTION - THIS SUBROUTINE READS IN THE REQUIRED DATA TO MODEL
C                A GIVEN PROBLEM. THE PARAMETERS ARE INPUT ACCORDING
C                TO FIXED FORMAT, ALL FIELDS ARE 10 CHARACTERS WIDE.
C                THE DATA IS ECHOED BACK TO THE PRINTER FILE AFTER
C                EACH LINE IS READ.
C
C   PARAMETERS-      SEE MANUAL
C
C*************************************************************************
C
      COMMON/PARMS/HEAD(28,41),HOLC(28,41),BOT(28,41),
     1             T(28,41,2),R(28,41),MATL(28,41),
     2             GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
      COMMON/CONTRL/TSTEP,NX,NY,DX,DY,TIMMAX,OUTFRG,NDATPR(10),LUNIT,
     1              TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
     2              IHEDIN,IHEDOT,ISEED
C
      COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KFLIM
C
      COMMON/MATER/ NMAT,DL(20),DT(20),A(20),K(20),S(20),RE(20),POR(20)
C
      COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),TM(20,20),RATE(20,20),
     1             NODES(20,100,2)
C
      COMMON/ERROR/ERRCOD,ERRARG(10)
C
      REAL K,LAYER,PTEMP(50)
C
      INTEGER ERRCOD,LUNIT,MAXIT,NX,NY,OUTFRG,TITLE
      INTEGER TUNIT,ITEMP(50)
      CHARACTER*5 NANS(10),MTD(3)*25
      DATA MTD/'LEAKY TWO LAYER','UNCONFINED ONE LAYER',
     *         'CONFINED ONE LAYER'/
C
C   FORCE 1 LAYER MODEL
C
      NL = 1
C
C     READ TITLE,UNITS AND SINGLE VALUE PARAMETERS
C
      READ(5,1010) TITLE
 1010 FORMAT(8A10)
      IF(EOF(5) .NE. 0)GOTO 900
      WRITE(6,2010) ITIME,IDATE,TITLE
 2010 FORMAT("1",//5X,82("*")/5X,"*",80X,"*"/5X,"*",17X,
     1"GOLDER ASSOCIATES GROUNDWATER COMPUTING SYSTEM",17X,"*"/
     25X,"*",80X,"*"/5X,"*",25X,"EXXON MINERALS CRANDON PROJECT",25X
     3,"*"/5X,"*",80X,"*"/5X,"*",23X,"GROUNDWATER IMPACT SCREENING MOD",
```

```
     4"EL",23X,"*"/5X,"*",80X,"*"/
     65X,"*",23X,"MODIFICATION 6.1  03 DECEMBER 1981",23X,"*"/
     I 5X,"*",80X,"*"/5X,"*",18X,"RUN TIME: ",A10,
     I 5X,"RUN DATE: ",A10,17X,"*"/
     75X,"*",80X,"*"/5X,82("*")/5X,"*",80X,"*"/5X,"*",8A10,"*"/
     85X,"*",80X,"*"/5X,82("*")/)
C
      READ(5,1015) TUNIT,LUNIT
 1015 FORMAT(A4,6X,A4)
      IF(EOF(5) .NE. 0) GOTO 900
      WRITE(6,2015) TUNIT,LUNIT
 2015 FORMAT(/17X,"--- UNITS ---"//
     1     5X,"TIME UNITS = ",A4,5X,"LENGTH UNITS = ",A4/)
C
      READ(5,1020) DX,DY,NX,NY,TSTEP,TIMMAX,PARTVL
 1020 FORMAT(2F10.0,2I10,3F10.0)
      IF(EOF(5) .NE. 0) GOTO 900
      WRITE(6,2020) LUNIT,DX,LUNIT,DY,NX,NY,TUNIT,TSTEP,TUNIT,
     *                   TIMMAX,LUNIT,PARTVL
 2020 FORMAT(/19X,"---  PROBLEM DEFINITION  ---"//
     *  5X,'GRID SPACING IN X DIRECTION (',A4,')',15X,'DX =',F10.2/
     *  5X,'GRID SPACING IN Y DIRECTION (',A4,')',15X,'DY =',F10.2/
     *  5X,'NUMBER OF NODES IN X DIRECTION',19X,'NX =',I10/
     *  5X,'NUMBER OF NODES IN Y DIRECTION',19X,'NY =',I10/
     *  5X,'TIME STEP (',A4,')',30X,'TSTEP =',F10.2/
     *  5X,'MAXIMUM RUN TIME(',A4,')',23X,'TIMMAX =',F10.2/
     *  5X,'PARTICLE VOLUME (CU.',A4,')',20X,'PARTVL =',F10.4)
      READ(5,1021)DXPAR,DYPAR,NXPAR,NYPAR,KELIM
1021  FORMAT(2F10.0,2I10,I2)
      WRITE(6,2021)LUNIT,DXPAR,LUNIT,DYPAR,NXPAR,NYPAR
 2021 FORMAT(/
     *  5X,'SUBGRID SPACING IN X DIRECTION (',A4,')',9X,'DXPAR =',F10.0/
     *  5X,'SUBGRID SPACING IN Y DIRECTION (',A4,')',9X,'DYPAR =',F10.0/
     *  5X,'NUMBER OF NODES IN SUBGRID X DIRECTION',8X,'NXPAR =',I10/
     *  5X,'NUMBER OF NODES IN SUBGRID Y DIRECTION',8X,'NYPAR =',I10)
      IF(KELIM.LE.0) GO TO 70
      WRITE (6,2022) KELIM
      GO TO 75
   70 WRITE(6,2023) KELIM
 2023 FORMAT(5X,'PARTICLES ELIMINATED ON PRINT STEP',12X,'KELIM =',I10/)
 2022 FORMAT(5X,'PARTICLES ELIMINATED ON TIME STEP',13X,'KELIM =',I10/)
   75 READ(5,1025)ISEED,MTYPE, MAXIT,TOL,OUTFRQ,(NDATPR(I),I=1,10),
     1               IHEDIN,IHEDOT
 1025 FORMAT(3I10,F10.0,1I10,10I1,2I10)
      IF(EOF(5) .NE. 0) GOTO 900
      IF(MTYPE .EQ. 0.OR. MTYPE .EQ. 1) GOTO 920
      WRITE(6,2025)ISEED,MTD(MTYPE),MTYPE,MAXIT,LUNIT,TOL,OUTFRQ,
     1               (NDATPR(I),I=1,10),IHEDIN,IHEDOT
 2025 FORMAT(
     *  5X,'RANDOM NUMBER',33X,'ISEED =',I10/
     *  5X,'MODEL TYPE :  ',A,7X,'MTYPE =',I10/
     *  5X,'MAXIMUM INTERATIONS PER TIME STEP',13X,'MAXIT =',I10/
     *  5X,'ITERATION TOLERANCE (',A4,')',22X,'TOL =',F10.0/
     *  5X,'FREQUENCY OF OUTPUT (NO. OF TIMESTEPS)',7X,'OUTFRQ =',I10/
     *  5X,'PRINTOUT OPTIONS (SEE DETAILS BELOW)',9X,'NDATPR =',10I1/
     *  5X,'RESTART CONDITION READ FROM FILE NUMBER',6X,'IHEDIN =',I10/
     *  5X,'RESTART CONDTITON WRITTEN TO FILE NUMBER     IHEDOT =',I10/)
```

```
      WRITE(6,2200)
 2200 FORMAT(/5X,'--- PRINTOUT OPTIONS ---',30X,'SELECTED?')
      DO 130 NPROPT=1,10
        NANS(NPROPT)='NO '
        IF(NDATPR(NPROPT).GE.1) NANS(NPROPT)='YES'
  130 CONTINUE
      WRITE(6,2210) (NANS(NPROPT),NPROPT=1,10)
 2210 FORMAT(/
     .5X,'DUMP HEAD, BOTTOM AND MATERIAL TYPE ARRAY              ',6X,A/
     .5X,'DUMP HEAD ARRAY ON PROGRAM GENERATED ABORT             ',6X,A/
     .5X,'PLOT HEAD MATPIX, 20 COLUMNS PER PAGE                  ',6X,A/
     .5X,'PLOT HEAD MATRIX, 1 INCH TO 2000 FEET SCALE            ',6X,A/
     .5X,'PLOT CONCENTRATION MATRIX, 1 INCH TO 2000 FEET SCALE',6X,A/
     .5X,'PLOT SYMBOLIC ACTIVE AND BOUNDARY PARTICLE SUMMARY   ',6X,A/
     .5X,'PRINT DETAILED PARTICLE COUNT BY CELL                  ',6X,A/
     .5X,'PRINT DETAILED GRADIENTS BY CELL                       ',6X,A/
     .5X,'PRINT ITERATION INFORMATION FOR FINITE DIFFERENCE    ',6X,A/
     .5X,'PRINT SYMBOLIC CONCENTRATION CONTOURS (SUBGRID)       ',6X,A/)
C
C     READ DEFAULT VALUES
C
      WRITE(6,2026)
 2026 FORMAT(//5X,"---  DEFAULT VALUES  ---")
      READ(5,1027) HEAD(1,1),BOT(1,1),MATL(1,1),THICK(1,1)
 1027 FORMAT(2F10.0,I10,F10.3)
      IF(EOF(5).NE.0) GOTO 900
      WRITE(6,2027) HEAD(1,1),LUNIT,BOT(1,1),LUNIT,MATL(1,1),
     .  THICK(1,1),LUNIT
 2027 FORMAT(//
     .  5X,'GROUNDWATER HEAD ELEVATION    =',F10.0,1X,A4/
     .  5X,'BASE OF AQUIFER ELEVATION     =',F10.0,1X,A4/
     .  5X,'MATERIAL TYPE                 =',I10/
     .  5X,'AQUIFER THICKNESS             =',F10.3,1X,A4)
C
C
C     FILL IN DEFAULT VALUES IN ARRAYS
C
      DO 15 I=1,NX
        DO 10 J=1,NY
        DO 8 L=1,NL
          HEAD(I,J)=HEAD(1,1)
          BOT(I,J)=BOT(1,1)
          MATL(I,J)=MATL(1,1)
          THICK(I,J)=THICK(1,1)
    8   CONTINUE
   10   CONTINUE
   15 CONTINUE
C
C      READ INPUT BLOCKS
C
   30 CONTINUE
      READ(5,2033) DBLOCK
 2033 FORMAT(A4)
      IF(EOF(5).NE.0) GOTO 900
C     SEARCH FOR PROPER BLOCK
      IF(DBLOCK .EQ. "HEAD") GOTO 45
      IF(DBLOCK .EQ. "BOTT") GOTO 160
```

```
      IF(DBLOCK .EQ. "MATE") GOTO 300
      IF(DBLOCK .EQ. "LEAK") GOTO 250
      IF(DBLOCK .EQ. "TYPE") GOTO 200
      IF(DBLOCK .EQ. "THIC") GOTO 400
      IF(DBLOCK .EQ. "END ") GOTO 800
C     UNKNOWN BLOCK NAME
      ERRCOD = 104
      GOTO 910
C
C--------------------------------------------------
C
C
C     READ INITIAL HEAD VALUES
C
   45 CONTINUE
      WRITE(6,2034)
 2034 FORMAT(//5X,"--- INITIAL HEAD VALUES ---"/)
C
      L=0
      IF(MTYPE .NE. 1) GOTO 47
      READ(5,1036) LAYER
 1036 FORMAT(A5)
      IF(LAYER .EQ. "UPPER") L=1
      IF(LAYER .EQ. "LOWER") L=2
      IF(L .NE. 0) GOTO 47
C     UNKNOWN LAYER
        ERRCOD = 105
        GOTO 910
   47  CONTINUE
           IF(L .EQ. 0) L=MTYPE-1
        IF(MTYPE .EQ. 1) WRITE(6,2036) LAYER
 2036   FORMAT(/5X,"--- ",A5," LAYER ---"/)
C
      J=NY
   50 CONTINUE
      IF(J.LT.1) GO TO 60
          READ(5,1035) (PTEMP(I),I=1,NX)
 1035     FORMAT(8F10.0)
          IF(EOF(5) .NE. 0) GOTO 900
          DO 55 I=1,NX
            IF(PTEMP(I).NE.0) HEAD(I,J)=PTEMP(I)
   55     CONTINUE
          WRITE(6,2035) (HEAD(II,J),II=1,NX)
 2035     FORMAT((5X,15F8.2)/)
C
        J=J-1
        GO TO 50
   60 CONTINUE
      GO TO 30
  100 CONTINUE
C
C     READ BOTTOM VALUES
C
  160 CONTINUE
      WRITE(6,2060)
 2060 FORMAT(//5X,"--- BOTTOM ELEVATIONS ---"/)
C
```

```
      L=0
      IF(MTYPE .NE. 1) GOTO 162
      READ(5,1036) LAYER
      IF(LAYER .EQ. "UPPER") L = 1
      IF(LAYER .EQ. "LOWER") L = 2
      IF(L .NE. 0) GOTO 162
        ERRCOD = 105
        GOTO 910
  162 CONTINUE
      IF(L .EQ. 0) L =  MTYPE -1
      IF(MTYPE .EQ. 1) WRITE(6,2036) LAYER
      J=NY
  165 CONTINUE
      IF(J.LT.1) GOTO 170
        READ(5,1065) (PTEMP(I),I=1,NX)
 1065   FORMAT(8F10.0)
        IF(EOF(5).NE.0) GOTO 900
        DO 167 I=1,NX
          IF(PTEMP(I).NE.0) BOT(I,J)=PTEMP(I)
  167   CONTINUE
        WRITE(6,2065) (BOT(II,J),II=1,NX)
 2065   FORMAT((5X,15F8.2)/)
      J=J-1
      GOTO 165
  170 CONTINUE
      GOTO 30
C
C     READ MATERIAL TYPE MATRIX
C
  200 CONTINUE
      WRITE(6,2075)
 2075 FORMAT(//,5X,"---  MATERIAL TYPE MATRIX ---"//
     133X,'CELL NUMPER IN X DIRECTION'/
     21X,'CELL NUMBER',26X,'1',19X,'2'/
     31X,'Y DIRECTION',7X,2(' 1 2 3 4 5 6 7 8 9 0'),' 1 2 3 4 5 6 7 8'/
     41X,11('-'),8X,55('-')/)
C
      L=0
      IF(MTYPE .NE. 1) GOTO 205
      READ(5,1036) LAYER
      IF(LAYER .EQ. "UPPER") L=1
      IF(LAYER .EQ. "LOWER") L=2
      IF(L .NE. 0) GOTO 205
        ERRCOD = 105
        GOTO 910
  205 CONTINUE
      IF(L .EQ. 0) L=MTYPE-1
      IF(MTYPE .EQ. 1) WRITE(6,2036) LAYER
      J=NY
  210 CONTINUE
      IF(J.LT.1) GOTO 220
        READ(5,1080) (ITEMP(I),I=1,NX)
 1080   FORMAT(80I1)
        IF(EOF(5) .NE. 0) GOTO 900
        DO 215 I=1,NX
          IF(ITEMP(I).NE, 0) MATL(I,J)=(ITEMP(I))
  215   CONTINUE
```

```
           WRITE(6,2080) J,(MATL(II,J),II=1,NX)
 2080      FORMAT(4X,I2,14X,28I2)
      J=J-1
      GOTO 210
  220 CONTINUE
      GOTO 30
C
C     READ LEAKAGE HISTORIES
C
  250 CONTINUE
      WRITE(6,2085)
 2085 FORMAT(//5X,"--- LEAKAGE HISTORIES ---"/)
C
      NLEAK = 1
C
C     START LEAKAGE HISTORY LOOP
C
  255 CONTINUE
      READ(5,1090) NUM,NLPT(NLEAK),NNODES(NLEAK)
      IF(EOF(5) .NE. 0) GOTO 900
 1090 FORMAT(3I10)
      IF(NUM .LE. 0.) GOTO 270
      NN = NNODES(NLEAK)
      WRITE(6,2090) NUM,NLPT(NLEAK),NNODES(NLEAK)
 2090 FORMAT(//,5X,"HISTORY NO.",I5,5X,"NO. OF LEAKAGE CURVE POINTS =",
     1        I5,5X,"NO. OF NODES =",I5,/)
C
      NLP=NLPT(NLEAK)
      READ(5,1092)(TM(NLEAK,IR),RATE(NLEAK,IR),IR=1,NLP)
 1092 FORMAT(2F10.0)
      IF(EOF(5).NE.0)GO TO 900
C
      WRITE(6,2092)TUNIT,LUNIT,TUNIT,(TM(NLEAK,IR),RATE(NLEAK,IR),
     *               IR=1,NLP)
 2092 FORMAT(16X,"LEAKAGE CURVE"/5X,34('-')/10X,"TIME",16X,"RATE"/
     1        9X,'(',A4,')',10X,'(CU.',A4,'/',A4,')'/
     2        (5X,F10.2,11X,F10.2))
C
      READ(5,1095) (NODES(NLEAK,I,1),NODES(NLEAK,I,2),I=1,NN)
 1095 FORMAT(20I4)
      IF(EOF(5) .NE. 0) GOTO 900
      WRITE(6,2095)NUM,(NODES(NLEAK,I,1),NODES(NLEAK,I,2),I=1,NN)
 2095 FORMAT(41X,'NODAL COORDINATES OF LEAKAGE FROM SOURCE',I5//
     *        5X,12(' X , Y     ')/
     *        (5X,12(I3,',',I3,3X)))
C     CHECK FOR VALID LEAKAGE HISTORY
       DO 260 NLK=1,NLP
       IF(NLK.EQ.1)GO TO 260
       MLK = NLK-1
      IF(TM(NLEAK,NLK).GT.TM(NLEAK,MLK))GO TO 260
       WRITE(6,2096)
 2096  FORMAT(15X,"*FATAL ERROR LEAKAGE CURVE
     1        TIME AXIS ERROR**"/)
C
  260  CONTINUE
C
C
```

```
      NLEAK = NLEAK + 1
      GOTO 255
C
C     END INPUT LOOP
C
  270 CONTINUE
      NLEAK = NLEAK - 1
      GOTO 30
C
C    READ MATERIAL TYPE DEFINITION
C
  300 CONTINUE
      WRITE(6,2300)LUNIT,TUNIT,LUNIT,TUNIT,LUNIT,LUNIT
 2300 FORMAT(//5X,"--- MATERIAL TYPE DEFINITION ---"//
     *  77X,'LONGITUDINAL       TRANSVERSE'/
     *  19X,'PERMEABILITY',20X,'RECHARGE',18X,
     *  'DISPERSIVITY    DISPERSIVITY'/
     *  9X,'NUMBER       (',A4,'/',A4,')     STORATIVITY  (CU.',
     *  A4,'/',A4,')     POROSITY        (',A4,')',10X,'(',
     *  A4,')         RETARDATION'/)
C
      NMAT = 1
  310 CONTINUE
      READ(5,1310) NUM,K(NMAT),S(NMAT),RE(NMAT),POR(NMAT),DL(NMAT),
     *               DT(NMAT),RT
 1310 FORMAT(I10,7E10.3)
      IF(EOF(5) .NE. 0) GOTO 900
      IF(NUM .EQ. 0) GOTO 350
C
      IF(RT.LE.0.0) RT=1.0
C
      WRITE(6,2310) NUM,K(NMAT),S(NMAT),RE(NMAT),POR(NMAT),DL(NMAT),
     1               DT(NMAT),RT
 2310 FORMAT(5X,I10,3(5X,E10.2),2(4X,E10.3),6X,E10.3,5X,E10.3)
C
      A(NMAT) = 0.0
      IF(POR(NMAT) .GT. 0) A(NMAT) = K(NMAT)*TSTEP/(POR(NMAT)*RT)
C
      NMAT = NMAT + 1
      GOTO 310
C
  350 CONTINUE
      NMAT = NMAT - 1
      GOTO 30
C
C     READ IN THICKNESS ARRAY
C
  400 CONTINUE
      WRITE(6,2410) LUNIT
 2410 FORMAT(//5X,"---AQUIFER THICKNESS (",A4,")---")
C
      J=NY
  405 CONTINUE
      IF(J.LE.0)GO TO 450
      READ(5,1420)(PTEMP(I),I=1,NX)
 1420 FORMAT(8F10.0)
       IF(EOF(5).NE.0)GO TO 900
```

```
      DO 410 I=1,NX
      IF(PTEMP(I).GT.0.0)THICK(I,J)=PTEMP(I)
  410 CONTINUE
      WRITE(6,2430)J,(I,THICK(I,J),I=1,NX)
 2430 FORMAT(1X,'Y= ',I3/(9(2X,I3,')',F8.2)))
C
      J=J-1
      GO TO 405
  450 CONTINUE
      GO TO 30
C
C
C     COMPUTE TRANSMISSIVITIES
C
  800 CONTINUE
      IF(MTYPE .EQ. 2) GOTO 890
      DO 810 I=1,NX
        DO 810 J=1,NY
          MAT = MATL(I,J)
          IF(MTYPE .EQ. 1) T(I,J,1) = K(MAT)*(TOP(I,J)-BOT(I,J))
          IF(MTYPE .EQ. 3) T(I,J,1)=K(MAT)*THICK(I,J)
        T(I,J,2) = T(I,J,1)
  810 CONTINUE
C
  890 CONTINUE
      WRITE(6,2165)
 2165 FORMAT(//5X,"**** INPUT COMPLETE ****"//)
      GOTO 950
C
C     SET ERROR CODE
C
  900 CONTINUE
      ERRCOD = 102
  910 CONTINUE
      WRITE(6,2070)
 2070 FORMAT(//5X,"**** ERROR - INPUT INCOMPLETE ****"//)
C    SIGNAL INVALID MTYPE, MUST BE 1 LAYER ONLY IN THIS VERSION
  920 CONTINUE
      ERRCOD = 105
      ERRARG(1) = 0
C
C     NORMAL EXIT
C
  950 CONTINUE
C
C   CHECK FOR ARRAY DUMP
      IF(NDATPR(1) .EQ. 0) GO TO 9000
C
C     DUMP ARRAYS (REVERSED FROM INPUT)
C
      WRITE(6,2176)
C DUMP THE HEAD ARRAY
      WRITE(6,2171)
      DO 955 L=1,NL
      DO 955 J=1,NY
      WRITE(6,2174)(HEAD(I,J),I=1,NX)
  955 CONTINUE
```

```
C      DUMP BOTTOM ARRAY
       WRITE(6,2177)
       DO 958 L=1,NL
       DO 958 J=1,NY
         WRITE(6,2174)(BOT(I,J),I=1,NX)
  958 CONTINUE
C DUMP THE "MATERIAL TYPE" ARRAY
       WRITE(6,2172)
       DO 960 L=1,NL
       DO 960 J=1,NY
       WRITE(6,2178) (MATL(I,J),I=1,NX)
  960 CONTINUE
C
 2171      FORMAT(/,5X,"HEADS",/)
 2172      FORMAT(/,5X,"MATERIAL TYPE",/)
 2173      FORMAT(/5X,"PERMEABILITY"/)
 2174      FORMAT(5X,10E11.4)
 2175      FORMAT(/5X,"STORAGE COEFFICIENTS"/)
 2176      FORMAT(//5X,"ARRAY DUMP - UP-SIDE-DOWN FROM INPUT"/)
 2177      FORMAT(/5X,"BOTTOM"/)
 2178      FORMAT(5X,30I4)
 9000 CONTINUE
C
       RETURN
       END
```

```
C
C
            SUBROUTINE IADI(L,NT,TIME,NUMIT,E,EMAX)
C C$      ARRAYS
C C$      CALLS
C C$      TRACE
C
C*********************************************************************
C
C  FUNCTION - THIS SUBROUTINE SOLVES FOR THE DISTRIBUTION OF HEADS
C             ACROSS THE FINITE DIFFERENCE GRID USING THE ITERATIVE
C             ALTERNATING DIRECTION IMPLICIT (IADI) SOLUTION TECH-
C             NIQUE. CORRECTION FOR TRANSMISSIVITY IN UNCONFINED
C             AQIFER SIMULATION IS CONTROLLED BY THE PARAMETER "L":
C
C                L = 1  -  UNCONFINED AQUIFER, CORRECT TRANSMISSIVITY
C                L = 2  -  CONFINED AQUIFER, CONSTANT TRANSMISSIVITY
C
C*********************************************************************
C
      COMMON/PARMS/HEAD(28,41),HOLD(28,41),BOT(28,41),
     1             T(28,41,2),R(28,41),MATL(28,41),
     2             GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
      COMMON/CONTRL/TSTEP,NX,NY,DX,DY,TIMMAX,OUTFRQ,NDATPR(10),LUNIT,
     1              TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
     2              IHECIN,IHEDOT,ISEED
C
      COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KELIM
C
      COMMON/MATER/ NMAT,DL(20),DT(20),A(20),K(20),S(20),RE(20),POR(20)
C
      COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),TM(20,20),RATE(20,20),
     1             NODES(20,100,2)
C
      COMMON/ERROR/ERRCOD,ERRARG(10)
C
      REAL B(50),G(50),DLAST(28,41),K
C
      INTEGER ERRCOD,TITLE,TUNIT,LUNIT
C     WRITE(6,10)L,NT,TIME
C 10  FORMAT("* * * ARRIVED IN IADI * * *"/
C    1       "L =",I10,"NT=",I10,"TIME=",F10.2)
C     WRITE(6,9000)((T(I,J,2),I=1,NX),J=1,NY)
C9000 FORMAT(10F12.1)
C
      IF(NDATPR(9).LE.0) GO TO 20
      WRITE(6,2002) TIME,TUNIT
 2002 FORMAT(1H1,/5X,"** START HEAD SOLUTION - TIME :",F9.1,
     1       1X,A10," **"//)
   20 CONTINUE
C
C     LOAD RECHARGE ARRAY
C
      DO 80 I=1,NX
        DO 70 J=1,NY
```

```
          MAT=MATL(I,J)
          R(I,J) = RE(MAT)
   70   CONTINUE
   80 CONTINUE
C     WRITE(6,2003)
C2003 FORMAT(5X,"FLAG 1 "/)
C
      IF(NLEAK.EQ.0)GO TO 87
      DO 86 M=1,NLEAK
        NLP=NLPT(M)
        IF(TIME.LT.TM(M,1).OR.TIME.GT.TM(M,NLP)) GOTO 88
        NNK = NNODES(M)
C       FIND LEAK RATE
C     WRITE(6,2004)
C2004 FORMAT(5X,"FLAG 2"/)
        CALL INTERP(M,TIME,Q,TSTEP)
        XRATIO = DX/DXPAR
        YRATIO = DY/DYPAR
        GRATIO = XRATIO*YRATIO
        UNITQ = Q/FLOAT(NNK)
          DO 84 NN=1,NNK
            IN = NODES(M,NN,1)
            JN = NODES(M,NN,2)
            XTEM=(IN-1)*DXPAR+DXPAR/2.
            YTEM=(JN-1)*DYPAR+DYPAR/2.
            CALL FIND(XTEM,YTEM,DX,DY,NX,NY,IN1,JN1)
C            PRORATE RECHARGE ARRAY WITH POND LEAKAGES
            MAT = MATL(IN1,JN1)
            R(IN1,JN1) = R(IN1,JN1)-(RE(MAT)/GRATIO)+UNITQ
   84     CONTINUE
   88  CONTINUE
   86 CONTINUE
87    CONTINUE
C   PREDICT HEADS
C
      DO 110 I=1,NX
        DO 100 J=1,NY
          D=HEAD(I,J)-HOLD(I,J)
          HOLD(I,J)=HEAD(I,J)
          F=1.0
          IF(NT.LE.2) GOTO 90
          IF(DLAST(I,J).EQ.0.0) GOTO 90
          F=D/DLAST(I,J)
          IF(F.GT.5.) F=5.0
          IF(F.LT.0.0) F=0.0
   90     CONTINUE
          DLAST(I,J)=D
          HEAD(I,J) = HEAD(I,J) +D*F
          IF(HEAD(I,J).LE.BOT(I,J))HEAD(I,J)=BOT(I,J)+0.01
  100   CONTINUE
  110 CONTINUE
C     WRITE(6,2005)
C2005 FORMAT(5X,"FLAG3"/)
C
C     REFINE ESTIMATE OF HEADS BY IADI METHOD
C
      NUMIT = 0
```

```
  115 CONTINUE
      E=0.0
      EMAX=0.0
      NUMIT=NUMIT + 1
C
C     EXTRA CHECK FOR WATER LEVEL BELOW BOTTOM
C
C     DO 101 I=1,NX
C       DO 102 J=1,NY
C         XX=HEAD(I,J)-BOT(I,J)
C         YY=HEAD(I+1,J)-BOT(I+1,J)
C         IF(XX.LT.0.OR. YY.LT.0) WRITE(6,9999) I,J,XX,HEAD(I,J),
C    1      BOT(I,J),YY,HEAD(I+1,J),BOT(I+1,J)
C9999     FORMAT(5X,2I10,6F10.3)
C 102   CONTINUE
C 101 CONTINUE
C
C
C     ADJUST TRANSMISSIVITIES IF AQUIFER IS UNCONFINED
C
      IF(L .EQ. 2) GOTO 135
      DO 130 I=1,NX
        DO 120 J=1,NY
          MAT = MATL(I,J)
          IF(I.LT.NX) T(I,J,2)=K(MAT) * SQRT((HEAD(I,J)-
     1    BOT(I,J))*(HEAD(I+1,J)-BOT(I+1,J)))
          IF(J.LT.NY) T(I,J,1)=K(MAT)*SQRT((HEAD(I,J)-
     1    BOT(I,J))*(HEAD(I,J+1)-BOT(I,J+1)))
          IF(I.EQ.NX) T(I,J,2) = (HEAD(I,J)-BOT(I,J)) * K(MAT)
          IF(J.EQ.NY) T(I,J,1) = (HEAD(I,J)-BOT(I,J)) * K(MAT)
  120   CONTINUE
  130 CONTINUE
  135 CONTINUE
C
C     DO COLUMN CALCULATIONS
C
      DXX=DX * DY
      DO 250 II=1,NX
      I=II
C     CHECK FOR DIRECTION ALTERATION
      NTT=NT+NUMIT
      IF(MOD(NTT,2).EQ.1) I=NX-I+1
C
C     CALCULATE B AND G ARRAYS
C
      DO 220 J=1,NY
        MAT = MATL(I,J)
        BB=S(MAT)*DXX/TSTEP
        DD=(HOLD(I,J)*S(MAT)*DXX/TSTEP)+R(I,J)
        AA=0.0
        CC=0.0
        IF(J.EQ.1) GOTO 150
          AA=-T(I,J-1,1)
          BB=BB+T(I,J-1,1)
  150   CONTINUE
        IF(J.EQ.NY) GOTO 160
          CC=-T(I,J,1)
```

```
          BB=BB+T(I,J,1)
  160   CONTINUE
        IF(I.EQ.1) GOTO 170
          BB=BB+T(I-1,J,2)
          DD=DD+HEAD(I-1,J)*T(I-1,J,2)
  170   CONTINUE
        IF(I.EQ.NX) GOTO 180
          BB=BB+T(I,J,2)
          DD=DD+HEAD(I+1,J)*T(I,J,2)
  180   CONTINUE
        IF(J.GT.1)W=BB-AA*B(J-1)
        IF(J.EQ.1)W=BB
        B(J)=CC/W
        IF(J.GT.1)G(J)=(DD-AA*G(J-1))/W
        IF(J.EQ.1)G(J)=DD/W
  220 CONTINUE
C
C     RE-ESTIMATE HEADS
C
      DH =ABS(HEAD(I,NY)-G(NY))
      E=E+DH
      IF(DH.GT.EMAX) EMAX=DH
      HEAD(I,NY) = G(NY)
      N = NY-1
  230 CONTINUE
      HA=G(N)-B(N)*HEAD(I,N+1)
      DH = ABS(HA-HEAD(I,N))
      E = E + DH
      IF(DH .GT. EMAX) EMAX = DH
      HEAD(I,N)=HA
      N=N-1
      IF(N.GT.0) GOTO 230
C
      DO 240 N=1,NY
        IF(HEAD(I,N).GT.BOT(I,N)) GOTO 240
        E=E+BOT(I,N)+0.01 - HEAD(I,N)
        HEAD(I,N)=BOT(I,N)+0.01
  240 CONTINUE
C
  250 CONTINUE
C
C     READJUST TRANSMISSIVITY IF AQUIFER IS UNCONFINED
C
      IF(L .EQ. 2) GOTO 275
      DO 270 J=1,NY
        DO 260 I=1,NX
          MAT = MATL(I,J)
          IF(I.LT.NX) T(I,J,2)=K(MAT)*SQRT((HEAD(I,J)-BOT(I,J))
     1    *(HEAD(I+1,J)-BOT(I+1,J)))
          IF(J.LT.NY) T(I,J,1)=K(MAT)*SQRT((HEAD(I,J)-BOT(I,J))
     1      *(HEAD(I,J+1)-BOT(I,J+1)))
          IF(I.EQ.NX) T(I,J,2)=K(MAT)*(HEAD(I,J)-BOT(I,J))
          IF(J.EQ.NY) T(I,J,1)=K(MAT)*(HEAD(I,J)-BOT(I,J))
  260   CONTINUE
  270 CONTINUE
  275 CONTINUE
C
```

```
C       DO ROW CALCULATIONS
C
        DO 400 JJ=1,NY
          J=JJ
          IF(MOD(NT+NUMIT,2).EQ.1) J=NY-J+1
          DO 330 I=1,NX
            MAT = MATL(I,J)
            BB=S(MAT)*DXX/TSTEP
            DD=(HOLD(I,J)*S(MAT)*DXX/TSTEP)+R(I,J)
            AA=0.0
            CC=0.0
            IF(J.EQ.1) GOTO 280
              BB=BB+T(I,J-1,1)
              DD=DD+HEAD(I,J-1)*T(I,J-1,1)
  280       CONTINUE
            IF(J.EQ.NY) GOTO 290
              DD=DD+HEAD(I,J+1)*T(I,J,1)
              BB=BB+T(I,J,1)
  290       CONTINUE
            IF(I.EQ.1) GOTO 300
              BB=BB+T(I-1,J,2)
              AA=-T(I-1,J,2)
  300       CONTINUE
            IF(I.EQ.NX) GOTO 310
              BB=BB+T(I,J,2)
              CC=-T(I,J,2)
  310       CONTINUE
            IF(I.GT.1)W=BB-AA*B(I-1)
            IF(I.EQ.1)W=BB
            B(I)=CC/W
            IF(I.EQ.1)G(I)=DD/W
            IF(I.GT.1)G(I)=(DD-AA*G(I-1))/W
  330     CONTINUE
C
C         RE-ESTIMATE HEADS
C
          DH = ABS(HEAD(NX,J)-G(NX))
        E = E + DH
        IF(DH .GT. EMAX) EMAX = DH
          HEAD(NX,J)=G(NX)
          N=NX-1
  340     CONTINUE
            HA=G(N)-B(N)*HEAD(N+1,J)
            DH =ABS(HEAD(N,J)-HA)
        E= E + DH
        IF(DH .GT. EMAX) EMAX = DH
            HEAD(N,J)=HA
            N=N-1
          IF(N.GT.0) GOTO 340
          DO 350 N=1,NX
            IF(HEAD(N,J) .GT. BOT(N,J)) GOTO 350
            E=E+BOT(N,J)+0.01-HEAD(N,J)
            HEAD(N,J)=BOT(N,J)+0.01
            WRITE(6,2007) HEAD(N,J),BOT(N,J),N,J
 2007       FORMAT(//5X,"HEAD OF",F12.2," WENT BELOW BOTTOM",F12.2,
     1             " AT NODE",2I5/)
  350     CONTINUE
```

```
C
  400 CONTINUE
C
C     PRINT ITERATION INFO
C
      IF(NDATPR(9).LE.0) GOTO 450
      WRITE(6,2010) NUMIT,E,EMAX
 2010 FORMAT(5X,"ITERATION NO.",I5,"  EPSILON = ",E20.4," EMAX =",E20.4)
      ERRCOD = 0
      IF(NUMIT.LT.MAXIT) GOTO 450
        ERRCOD = 101
        GOTO 901
  450 CONTINUE
C
C     CHECK FOR CONVERGENCE, PASS THRU AGAIN IF NOT CLOSED
C
      IF(E.GT.TOL) GOTO 115
C     NORMAL EXIT
  900 RETURN
C    ITERATION LOOP ERROR
901   STOP
      END
```

```
C
C
C
      SUBROUTINE LEAK
C C$      ARRAYS
C C$      CALLS
C C$      TRACE
C
C*************************************************************
C
C   FUNCTION - THIS SUBROUTINE COMPUTES THE INTERLAYER LEAKAGE BETWEEN
C              TWO AGUIFER LAYERS AS A FUNCTION OF THE DIFFERENCE
C              IN THE HEADS IN THE LAYERS, THE PERMEABILITY OF THE
C              UPPER LAER AND THE SATURATED DEPTH OF THE UPPER LAYER.
C
C*************************************************************
C
      COMMON/PARMS/HEAD(28,41),HOLD(28,41),BOT(28,41),
     1             T(28,41,2),R(28,41),MATL(28,41),
     2             GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
      COMMON/CONTRL/TSTEP,NX,NY,DX,DY,TIMMAX,OUTFRQ,NDATPR(10),LUNIT,
     1              TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
     2              IHEDIN,IHEDOT,ISEED
C
      COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KELIM
C
      COMMON/MATER/ NMAT,DL(20),DT(20),A(20),K(20),S(20),RE(20),POR(20)
C
      COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),TM(20,20),RATE(20,20),
     1             NODES(20,100,2)
C
      COMMON/ERROR/ERRCOD,ERRARG(10)
C
      REAL K
      INTEGER ERRCOD,OUTFRQ,TITLE,TUNIT
C     WRITE(6,10)
C 10  FORMAT("* * * ARRIVED IN LEAK * * *")
C
      DXX = DX * DY
      DO 50 J=1,NY
        DO 40 I=1,NX
          DH = HEAD(I,J)-HEAD(I,J)
          DLEN = HEAD(I,J)-BOT(I,J)
          IF(DLEN .GT. 0.) GOTO 30
            ERRCOD=103
            GOTO 900
   30   CONTINUE
        MAT = MATL(I,J)
        XLEAK = DXX * (DH/DLEN) * K(MAT)
        R(I,J) = R(I,J) + XLEAK
        R(I,J) = R(I,J) - XLEAK
   40 CONTINUE
   50 CONTINUE
C
  900 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OUTPUT(TIME,NUMIT,E,EMAX)
C C$      ARRAYS
C C$      CALLS
C C$      TRACE
C
C*************************************************************************
C
C
C   FUNCTION: PRINTS THE HEAD MATRIX VALUES IN BLOCK FORM.
C             THE ORIGIN (NODE 1,1) IS PRINTED IN THE LOWER
C             LEFT CORNER. PROBLEMS WITH MORE THAN 20 COLUMNS
C             ARE PRINTED IN STRIPS, 20 COLUMNS PER PAGE.
C
C
C*************************************************************************
C
C
      COMMON/PARMS/HEAD(28,41),HOLD(28,41),DOT(28,41),
     1             T(28,41,2),R(28,41),MATL(28,41),
     2             GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
      COMMON/CONTRL/TSTEP,NX,NY,DX,DY,TIMMAX,OUTFRG,NCATPR(10),LUNIT,
     1              TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
     2              IHEDIN,IHEDOT,ISEED
C
      COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KELIM
C
      COMMON/MATER/ NMAT,DL(20),DT(20),A(20),K(20),S(20),RE(20),POR(20)
C
      COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),TY(20,20),RATE(20,20),
     1             NODES(20,100,2)
C
      COMMON/ERROR/ERRCOD,ERRARG(10)
C
      INTEGER TITLE,TUNIT,LUNIT,NX,NY,COLLP,COLPP,ERRCOD
      REAL K
C     WRITE(6,10)TIME,NUMIT
C  10 FORMAT("* * * ARRIVED IN OUTPUT * * *"/
C    1        "TIME=",F10.2,"NUMIT=",I10)
      WRITE(6,2010) TITLE
 2010 FORMAT("1",5X,8A10)
C
      WRITE(6,2015) LUNIT,TIME,TUNIT,NUMIT,TSTEP
 2015 FORMAT(/5X,"**** HEADS (",A4,") AT TIME = ",F10.4,1X,A4," ****"
     1        //5X,"NUMBER OF ITERATIONS =",I5,
     2        "  TSTEP =",F10.4//)
C
C     COMPUTE NUMBER OF SLICES REQD TO PRINT MATRIX
C
      LA = 1
      IF(MTYPE .EQ. 3) LA = 2
      LAYER = " "
  105 CONTINUE
      IF(MTYPE .EQ. 1 .AND. LA .EQ. 1) LAYER = "UPPER"
      IF(MTYPE .EQ. 1 .AND. LA .EQ. 2) LAYER = "LOWER"
      IF(LAYER .NE. " ") WRITE(6,2017) LAYER
```

```
 2017 FORMAT(/10X,"*** ",A5," LAYER ***"//)
C
      COLPP = 20
      NSLICE = 1
  110 CONTINUE
        NCOLS = COLPP * NSLICE
        IF(NX .LE. NCOLS) GOTO 120
        NSLICE = NSLICE + 1
      GOTO 110
  120 CONTINUE
C
C     COMPUTE NUMBER OF COLUMNS IN LAST SLICE
C
      COLLP = NX - (COLPP*(NSLICE - 1))
C
C     PRINT MATRIX IN SLICES OF "COLPP" COLUMNS PER PAGE
C
      NPAGE = 0
      DO 200 NSL = 1,NSLICE
        NPAGE = NPAGE + 1
        IF(NSL .GT. 1) WRITE(6,2020) NSL,NUMIT,TIME,TUNIT
 2020   FORMAT("1",/5X," SLICE NUMBER ",I5,5X,"ITERATION #",
     1        I5,5X,"TIME = ",F10.3,1X,A10/////)
        KI = ((NSL - 1) * COLPP) + 1
        L = NSL * COLPP
        IF(NPAGE .EQ. NSLICE) L = NX
C
       J=NY
  140  CONTINUE
       IF(J.LT.1) GO TO 150
          WRITE(6,2025) (HEAD(I,J),I=KI,L)
 2025     FORMAT(5X,20F6.1)
          J=J-1
          GO TO 140
  150   CONTINUE
C
  200 CONTINUE
      WRITE(6,2030)
 2030 FORMAT("1")
      IF(LA .EQ. 2) GOTO 900
      IF(MTYPE .NE. 1) GOTO 900
        LA = LA + 1
        GOTO 105
  900 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE OUT2K(ITYPE,TIME,NUMIT,E,EMAX)
C C$       ARRAYS
C C$       CALLS
C C$       TRACE
C
C*****************************************************************
C
C
C   FUNCTION: PRINTS THE HEAD OR CONCENTRATION MATRIX VALUES IN BLOCK
C             FORM. THE ORIGIN (NODE 1,1) IS PRINTED IN THE LOWER
C             LEFT CORNER. PROBLEMS WITH MORE THAN 25 COLUMNS
C             ARE PRINTED IN STRIPS, 25 COLUMNS PER PAGE.
C
C ARGUMENTS:
C     ITYPE - SELECTS TYPE OF OUTPUT
C             1 = PRINTS HEADS
C             2 = PRINTS CONCENTRATIONS
C
C      TIME - TIME SINCE SIMULATION BEGAN
C
C     NUMIT - NUMBER OF ITERATIONS
C
C*****************************************************************
C
C
      COMMON/PARMS/HEAD(28,41),HOLD(28,41),BOT(28,41),
     1             T(28,41,2),R(28,41),MATL(28,41),
     2             GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
      COMMON/CONTRL/ISTEP,NX,NY,DX,DY,TIMMAX,OUTFRQ,NDATPR(10),LUNIT,
     1              TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
     2              IBEGIN,IHEDOT,ISEED
C
      COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KELIM
C
      COMMON/MATER/ NMAT,DL(20),DT(20),A(20),K(20),S(20),RE(20),POR(20)
C
      COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),TM(20,20),RATE(20,20),
     1             NODES(20,100,2)
C
      COMMON/ERROR/ERRCOD,ERRARG(10)
C
      INTEGER TITLE,TUNIT,LUNIT,NX,NY,COLLP,COLPP,OUTFRQ
C
      REAL HP(28),K
C
C      WRITE(6,9992) ITYPE,TIME,NUMIT
C9992 FORMAT(//5X,"I GOT INTO OUT2K ",I10,F10.2,I10/)
      WRITE(6,2010) TITLE
 2010 FORMAT("1"//5X,8A10)
C
      IF(ITYPE .NE. 1) GOTO 90
      WRITE(6,2015) LUNIT,TIME,TUNIT,NUMIT,E,EMAX
 2015 FORMAT(/10X,"**** HEADS (",A4,") AT TIME = ",F10.4,1X,A4,
     1      " ****"//15X,"NO. OF ITERATIONS =",I5,"  EPSILON = ",F8.3,
     2      "  EMAX =",F8.3//)
```

```
   90 CONTINUE
C
      IF(ITYPE .NE. 2) GOTO 100
      WRITE(6,2016) TIME,TUNIT,NUMIT,E,EMAX
 2016 FORMAT(/10X,"**** CONCENTRATIONS (AS PERCENT POND LEAKAGE)",
     1     " AT TIME =",F10.4,1X,A4," ****"//,15X,"NO. OF ITERATIONS =",
     2          I5,"  EPSILON =",F8.2,"  EMAX =",F9.3//)
  100 CONTINUE
C
C     COMPUTE NUMBER OF SLICES REQD TO PRINT MATRIX
C
      LA = 1
      IF(MTYPE .EQ. 3) LA = 2
      LAYER = " "
  105 CONTINUE
      IF(MTYPE .EQ. 1 .AND. LA .EQ. 1) LAYER = "UPPER"
      IF(MTYPE .EQ. 1 .AND. LA .EQ. 2) LAYER = "LOWER"
      IF(LAYER .NE. " ") WRITE(6,2017) LAYER
 2017 FORMAT(/10X,"*** ",A5," LAYER ***"//)
C
      COLPP = 25
      NSLICE = 1
  110 CONTINUE
        NCOLS = COLPP * NSLICE
        IF(NX .LE. NCOLS) GOTO 120
        NSLICE = NSLICE + 1
      GOTO 110
 120  CONTINUE
C
C     COMPUTE NUMBER OF COLUMNS IN LAST SLICE
C
      COLLP = NX - (COLPP*(NSLICE - 1))
C
C     PRINT MATRIX IN SLICES OF "COLPP" COLUMNS PER PAGE
C
      NPAGE = 0
C     WRITE(6,9990) NSLICE,COLPP,COLLP,NX
C9990 FORMAT(5X,"STARTING SLICE LOOP - NSLICE,COLPP,COLLP,NX=",4I10)
      DO 200 NSL = 1,NSLICE
        IF(NSL .LE. 2) GOTO 125
        XNSL = FLOAT(NSL)
        WRITE(6,9991) XNSL
 9991   FORMAT(5X,"ERROR - NSL =",F20.5)
        GO TO 900
 125    CONTINUE
        NPAGE = NPAGE + 1
        IF(NSL .GT. 1) WRITE(6,2020) NSL,NUMIT,TIME,TUNIT
 2020   FORMAT("1",/5X," SLICE NUMBER ",I5,5X,"ITERATION #",
     1          I6,5X,"TIME = ",F10.3,1X,A4////)
        KT = ((NSL - 1) * COLPP) + 1
        L = NSL * COLPP
        IF(NPAGE .EQ. NSLICE) L = NX
C
      WRITE(6,2027)
 2027 FORMAT(45X,*HEADS IN X DIRECTION (FROM 1500 FT. DATUM)*)
        IF(NPAGE.GT.1) GO TO 130
        WRITE(6,2022)
```

```
            GO TO 132
      130   WRITE(6,2023)
      132   CONTINUE
     2023   FORMAT(/4X,'    26    27    28'/)
     2022   FORMAT(/5X,"    1     2     3     4     5     6     7     8 ",
     1                 "    9    10    11    12    13    14    15    16 ",
     2                 "   17    18    19    20    21    22    23    24 ",
     3                 "   25"/)
           WRITE(6,2029)
     2029  FORMAT(4X,'Y'/2X,'DIREC'/2X,'-----')
            J=NY
      140   CONTINUE
            IF(J.LT.1) GO TO 150
            CFAC = (PARTVL*100.)/(DX*DY)
            DO 145 IH=KI,L
              MAT = MATL(IH,J)
              IF(ITYPE.EQ.1) HP(IH) = HEAD(IH,J)-1500.
              IF(ITYPE.EQ.2) HP(IH) = (CFAC/THICK(IH,J)) * NOUT(IH,J)/POR
      1          (MAT)
      145   CONTINUE
               IF(ITYPE.EQ.1) WRITE(6,2024) J,(HP(IH),IH=KI,L)
               IF(ITYPE.EQ.2) WRITE(6,2025) J,(HP(IH),IH=KI,L)
     2024      FORMAT(//2X,I3,25F5.1)
     2025      FORMAT(//2X,I3,25F5.2)
               J=J-1
               GO TO 140
      150    CONTINUE
     C
     C         WRITE(6,9994) NSL
     C9994     FORMAT(5X,"END PRINT LOOP, NSL =",I30)
       200 CONTINUE
           WRITE(6,2030)
      2030 FORMAT("1")
           IF(LA .EQ. 2) GOTO 900
           IF(MTYPE .NE. 1) GOTO 900
             LA = LA + 1
             GOTO 105
       900 CONTINUE
     C
           RETURN
           END
```

```
      SUBROUTINE GRADNT
C C$       ARRAYS
C C$       CALLS
C C$       TRACE
C
C***************************************************************
C
C
C     THIS SUBROUTINE COMPUTES THE X AND Y GRADIENTS AT
C     EACH NODE FROM THE HEAD DISTRIBUTION COMPUTED BY THE
C     FINITE DIFFERERENCES GROUNDWATER SOLUTION
C
C***************************************************************
C
      COMMON/PARMS/HEAD(28,41),HOLD(28,41),DOT(28,41),
     1            T(28,41,2),R(28,41),MATL(28,41),
     2            GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
      COMMON/CONTRL/TSTEP,NX,NY,DX,DY,TIMMAX,OUTFRQ,NDATPR(10),LUNIT,
     1             TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
     2             IHEDIN,IHEDOT,ISEED
C
      COMMON/LEAK/ NLEAK,NHOLES(20),NLPT(20),IN(20,20),RATE(20,20),
     1            HOLES(20,100,2)
C
      COMMON/ERROR/ERRCOD,ERRARG(10)
C
      INTEGER TITLE,LUNIT,TUNIT,OUTFRQ
C     WRITE(6,10)
C 10  FORMAT("* * * ARRIVED IN GRADNT * * *"/)
C
C     SET MATRICES TO ZERO
C
      DO 50 I=1,NX
        DO 40 J=1,NY
          HYP(I,J)=0.0
          GX(I,J)=0.0
          GY(I,J)=0.0
   40   CONTINUE
   50 CONTINUE
C
C     COMPUTE GRADIENTS AT EDGES OF MATRIX
C
      DO 60 I=1,NX
        GY(I,1)=(HEAD(I,1)-HEAD(I,2))/DY
        GY(I,NY)=(HEAD(I,NY-1)-HEAD(I,NY))/DY
   60 CONTINUE
C
      DO 70 J=1,NY
        GX(1,J)=(HEAD(1,J)-HEAD(2,J))/DX
        GX(NX,J)=(HEAD(NX-1,J)-HEAD(NX,J))/DX
   70 CONTINUE
C
C     COMPUTE INTERIOR MATRIX GUADRENTS
C
      NX1=NX-1
      NY1=NY-1
```

```
                  DO 100 I=2,NX1
                    DO 90 J=2,NY1
                      GX(I,J)=(HEAD(I-1,J)-HEAD(I+1,J))/(2*DX)
                      GY(I,J)=(HEAD(I,J-1)-HEAD(I,J+1))/(2*DY)
             90     CONTINUE
            100   CONTINUE
          C
          C       COMPUTE HYPOTENUS FOR LATER USE
          C
                  DO 120 I=1,NX
                    DO 110 J=1,NY
                      HYP(I,J)=SQRT(GX(I,J)*GX(I,J)+GY(I,J)*GY(I,J))
            110     CONTINUE
            120   CONTINUE
                  RETURN
                  END
```

```
      SUBROUTINE HEDIN(TITLE,IHEDIN,NX,NY,HEAD,TIME,TUNIT,LUNIT,X,Y,
     1          NTOTAL)
C C$      ARRAYS
C C$      CALLS
C C$      TRACE
C
C*********************************************************************
C
C   FUNCTION -  THIS ROUTINE LOADS THE HEAD ARRAY FROM A RESTART
C               FILE.
C
C  PARAMETERS -
C       TITLE -  TITLE OF RUN WHICH CREATED THE RESTART FILE,
C                READ FOR INFORMATION PURPOSES ONLY.
C      IHEDIN -  FILE NUMBER THAT RESTART FILE IS ON.
C          NX -  NUMBER OF VALUES IN THE X DIRECTION
C          NY -  NUMBER OF VALUES IN THE Y DIRECTION
C        HEAD -  HEAD ARRAY TO BE LOADED
C
C***********************************************************************
C
      COMMON/ERROR/ERRCOD,ERRARG(10)
      REAL HEAD(28,41),X(20000),Y(20000)
      INTEGER TITLE(8),ERRCOD,TUNIT,LUNIT,TITLE1(8)
C     WRITE(6,10)TITLE,IHEDIN,NX,NY
C 10  FORMAT("* * * ARRIVED IN HEDIN * * *"/
C    1         "TITLE=",8A10/"IHEDIN=",I5,"NX=",I10,
C    2         "NY=",I10)
C
C
      READ(IHEDIN,1015) TITLE1
 1015 FORMAT(8A10)
      IF(EOF(IHEDIN) .NE. 0) GOTO 900
      READ(IHEDIN,1017)TIME,ITUNIT,ILUNIT,NNX,NNY,NTOTAL
 1017 FORMAT(F10.0,6X,A4,6X,A4,3I10)
C          CHECK FOR PARAMETER MATCH
      IF(ITUNIT.EQ.TUNIT)GO TO 20
      WRITE(6,2016)ITUNIT,TUNIT
 2016 FORMAT(/,5X,"** ERROR: TIME UNIT MISMATCH:",
     1         " TIME UNIT ON RESTART FILE-",A10,2X,
     2         " TIME UNIT ON INPUT FILE-",A10," **"/)
      GO TO 920
 20   CONTINUE
C
      IF(ILUNIT.EQ.LUNIT)GO TO 25
      WRITE(6,2017)ILUNIT,LUNIT
 2017 FORMAT(/,5X,"** ERROR:LENGTH UNIT MISMATCH:",
     1         " LENGTH UNIT ON RESTART FILE-",A10,2X,
     2         " LENGTH UNIT ON INPUT FILE -",A10," **"/)
       GO TO 930
 25   CONTINUE
C
      IF(NNX.EQ.NX.AND.NNY.EQ.NY)GO TO 30
      WRITE(6,2018)NNX,NNY,NX,NY
 2018 FORMAT(/,5X,"**ERROR-GRID SPACING MISMATCH : NX,NY ON RESTART
     1          FILE-",
     2       2I5,2X,"NX,NY ON INPUT FILE-",
```

```
                3     2I5,2X,"**"/)
              GO TO 940
         50   CONTINUE
      C
      C
      C     WRITE TIME & PARTICLE COUNT
      C
            WRITE(6,2015)TITLE1,TIME,TUNIT,NTOTAL,LUNIT,TIME,TUNIT
       2015 FORMAT(5X,*SIMULATION INITIALIZED BY RESTART FILE : *,6A10//
           .  5X,*RESTART CONDITIONS :*/
           .  7X,*TIME TO BEGIN SIMULATION =*,2X,F10.3,1X,A4/
           .  7X,*NUMBER OF PARTICLES       =*,I8/
           .  7X,*HEADS IN *,A4,* AT TIME *,F10.3,1X,A4,1X,*:*/)
      C
            DO 100 J=1,NY
              READ(IREDIN,1020)(HEAD(I,J),I=1,NX)
              IF(EOF(IREDIN) .NE. 0) GOTO 910
       1020   FORMAT(8F10.0)
      C
            WRITE(6,2020)J,(I,HEAD(I,J),I=1,NX)
       2020 FORMAT(1X,*Y=*,I3/(5(2X,I3,*)*,F8.2)))
      C
        100 CONTINUE
      C
      C      READ IN PARTICLE LOCATIONS
      C
            READ(IREDIN,1025)(X(N),Y(N),N=1,NTOTAL)
       1025 FORMAT(8F10.2)
      C
      C     INPUT COMPLETE
      C
            GOTO 999
        900 CONTINUE
      C     SIGNAL EMPTY RESTART FILE
            ERRCOD = 105
            ERRARG(1) = 1
            ERRARG(2) = IREDIN
            GOTO 999
      C
        910 CONTINUE
      C     SIGNAL REACHED END OF FILE BEFORE COMPLETED LOAD
            ERRCOD = 106
            ERRARG(1) = 2
            ERRARG(2) = I
            ERRARG(3) = J
            GOTO 999
        920  CONTINUE
            ERRCOD = 107
            GO TO 999
        930 CONTINUE
            ERRCOD = 108
            GO TO 999
        940 CONTINUE
            ERRCOD = 109
      C
        999 CONTINUE
            RETURN
            END
```

```
      C
            SUBROUTINE HEDOUT(TITLE,IHEDOT,NX,NY,HEAD,TIME,TUNIT,LUNIT,X,Y,
           1      NTOTAL)
      C C$       ARRAYS
      C C$       CALLS
      C C$       TRACE
      C
      C*****************************************************************
      C
      C FUNCTION - THIS ROUTINE WRITES A RESTART FILE FROM THE HEAD ARRAY
      C            AT THE END OF A RUN.
      C
      C PARAMETERS:
      C
      C     TITLE - TITLE OF RUN WHICH IS WRITING THE RESTART FILE, FOR
      C             INFORMATION PURPOSES ONLY
      C    IHEDOT - FILE NUMBER ON WHICH TO WRITE RESTART FILE.
      C        NX - NUMBER OF VALUES IN THE X-DIRECTION.
      C        NY - NUMBER OF VALUES IN THE Y-DIRECTION
      C      HEAD - HEAD ARRAY TO BE WRITTEN TO THE RESTART FILE.
      C
      C*****************************************************************
      C
            REAL HEAD(28,41),X(25000),Y(25000)
            INTEGER TITLE(8)
      C     WRITE(6,10)
      C 10  FORMAT("* * * ARRIVED IN HEDOUT * * *")
      C
            WRITE(6,2010) IHEDOT
       2010 FORMAT(//5X,"** HEADS BEING WRITTEN TO FILE # ",I5,"  **"//)
      C
            WRITE(IHEDOT,2020) TITLE
       2020 FORMAT(8A10)
            WRITE(IHEDOT,2025)TIME,TUNIT,LUNIT,NX,NY,NTOTAL
       2025 FORMAT(F10.2,6X,A4,6X,A4,3I10)
            DO 100 J=1,NY
            WRITE(IHEDOT,2030) (HEAD(I,J),I=1,NX)
       2030 FORMAT(8F10.2)
      C
      100   CONTINUE
            WRITE(IHEDOT,2035)(X(I),Y(I),I=1,NTOTAL)
       2035 FORMAT(8F10.2)
            RETURN
            END
```

```
C
      SUBROUTINE  INTERP(M,TIME,G,TSTEP)
C C$       ARRAYS
C C$       CALLS
C C$       TRACE
C
C*****************************************************************
C
C  FUNCTION - THIS ROUTINE INTERPOLATES A LEAKAGE RATE AT A GIVEN
C             TIME FROM THE TIME-RATE CURVE INPUT FOR EACH LEAKAGE
C             HISTORY.
C
C PARAMETERS:
C
C          M - IDENTIFICATION NUMBER OF THE LEAKAGE HISTORY
C       TIME - TIME VALUE FOR WHICH A LEAKAGE RATE IS NEEDED
C          G - LEAKAGE RATE WHICH CORRESPONDS TO "TIME"
C      TSTEP - TIME STEP OF RUN
C
C*****************************************************************
C
      COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),TM(20,20),RATE(20,20),
     1             NODES(20,100,2)
C
C     WRITE(6,10)
C 10  FORMAT("* * * ARRIVED IN INTERP * * *")
      G = 0.0
      TIMC = TIME + (TSTEP/2.0)
C     WRITE(6,9998) TIMC,TSTEP,NLPT(M),RATE(M,1),TM(M,1)
C9998 FORMAT(5X,"TIMC=",F10.2," TSTEP=",F10.2, " NLP=",I10,
C    1       " RATE(M,1)=",F10.2," TIM(M,1)=",F10.2)
C    CHECK IF VALUE IS IN BOUNDS
      IF(TIMC .LT. TM(M,1)) GOTO 900
      NLP = NLPT(M)
      IF(TIMC .GT. TM(M,NLP)) GOTO 900
C     INTERPOLATE LEAKAGE RATE
      DO 100 IR=1,NLP
        IF(TIMC .GT. TM(M,IR)) GOTO 100
        IF(TIMC .EQ. TM(M,IR)) GOTO 110
        JR = IR - 1
        DELR = RATE(M,IR) - RATE(M,JR)
        DELT = TM(M,IR) - TM(M,JR)
        G = RATE(M,JR) + ((DELR/DELT)*(TIMC-TM(M,JR)))
        GOTO 120
  100 CONTINUE
      GO TO 900
  110 CONTINUE
C     TIME IS EQUAL TO A SPECIFIED VALUE ON CURVE
      G = RATE(M,IR)
  120 CONTINUE
C
  900 CONTINUE
C     WRITE(6,2010) M,TIME,G
C2010 FORMAT(/5X,"M,TIME & G =",I10,2F10.2)
      RETURN
      END
```

```
      C
            SUBROUTINE GENERAT(TIME,NTOTAL)
      C C$       ARRAYS
      C C$       CALLS
      C C$       TRACE
      C
      C*******************************************************************
      C
      C FUNCTION - THIS ROUTINE GENERATES PARTICLES IN THE TIMESTEP IN
      C            QUESTION AND ADDS THEM TO THE LIST OF PARTICLES.
      C
      C
      C PARAMETERRS :
      C
      C      ISEED - SEED VALUE FOR THE RANDOM NUMBER GENERATOR, WHICH
      C              IS USED TO DISTRIBUTE THE INITIAL PARTICLE LOCATION.
      C       TIME - TIME OF THE SIMULATION.
      C     NTOTAL - POINTER WHICH INDICATES TOTAL NUMBER OF PARTICLES
      C              THAT ARE IN SYSTEM. UPDATED FOR GENERATED PARTICLES
      C
      C
      C*****************************************************************
      C
      C
            COMMON/PARMS/HEAD(28,41),HOLD(28,41),BOT(28,41),
           1             T(28,41,2),R(28,41),MATL(28,41),
           2             GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
      C
            COMMON/CONTRL/TSTEP,NX,NY,DX,DY,TIMMAX,OUTFRQ,NDATPR(10),LUNIT,
           1              TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
           2              IHEDIR,IHEDOT,ISEED
      C
            COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
           1 NXPAR,NYPAR,RELIM
      C
            COMMON/MATER/ NMAT,SL(20),ST(20),A(20),K(20),S(20),RE(20),POR(20)
      C
            COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),TM(20,20),RATE(20,20),
           1             NOPTS(20,100,2)
      C
            COMMON/ERROR/ERRCOD,ERRARG(10)
      C
            INTEGER TITLE,LUNIT,TUNIT,OUTFRQ
            REAL U(5)
      C     WRITE(6,10)
      C 10  FORMAT("* * * ARRIVED IN GENERAT * * *")
      C
            NIN = 0
      C     CYCLE THRU LEAKAGE HISTORIES
            DO 100 N = 1,NLEAK
              NLP = NLPT(N)
              IF(TIME.LT.TM(N,1) .OR. TIME.GT.TM(N,NLP)) GOTO 100
      C       DETERMINE LEAK RATE
              CALL INTERP(N,TIME,G,TSTEP)
              NPP = INT((G*TSTEP/PARTVL)+0.5)
      C      WRITE(6,9995) NPP,PARTVL
      C9995 FORMAT(5X,"NPP=",I10," PARTVL=",F15.2)
               IF(NPP .LT. 0) GOTO 100
               NIN = NIN + NPP
```

```
C        CYCLE THRU PARTICLES
         DO 80 NP = 1,NPP
C          SELECT NODE IN WHICH TO LEAK PARTICLE
           NTOTAL = NTOTAL + 1
           IF(NTOTAL .GT. 25000) GOTO 900
           CALL RAND(ISEED,16777215,0,3,U)
           INODE = INT(1+(U(1)*NNODES(N)))
           XX = (FLOAT(NODES(N,INODE,1))*DXPAR)-(1.5*DXPAR)
           YY = (FLOAT(NODES(N,INODE,2))*DYPAR)-(1.5*DYPAR)
           X(NTOTAL) = XX + (DXPAR*U(2)-0.5)
           Y(NTOTAL) = YY + (DYPAR*U(3)-0.5)
C      WRITE(6,2005)TIME,NLEAK,NP,X(NTOTAL),Y(NTOTAL),INODE
C2005 FORMAT(5X,"TIME=",F10.2," NLEAK=",I5," PART. #",I5,
C    1          " X=",F10.2," Y=",F10.2," NODE #",I5)
           CALL FIND(X(NTOTAL),Y(NTOTAL),DXPAR,DYPAR,NXPAR,NYPAR,NN,MM)
           NOUT(NN,MM) = NOUT(NN,MM) + 1
   80    CONTINUE
  100 CONTINUE
      WRITE(6,2010) TIME,NIN,NTOTAL
 2010 FORMAT(/5X,"** TIME =",F12.2,5X,"NO. OF PARTICLES",
     1          " GENERATED =",I8,5X,"TOTAL PARTICLES =",I8)
C
C       NORMAL FINISH
C
        GOTO 999
C
C        SIGNAL PARTICLE COUNT OVERFLOW
C
  900 CONTINUE
C
        ERRCOD = 107
        ERRARG(1) = 2
        ERRARG(2) = NTOTAL
        ERRARG(3) = TIME
C
  999 CONTINUE
        RETURN
        END
```

```
      C
      C*****************************************************************
      C
      C
      C
            SUBROUTINE FIND(X,Y,DX,DY,NX,NY,NN,MM)
      C C$       ARRAYS
      C C$       CALLS
      C C$       TRACE
      C     THIS SUBROUTINE FINDS WHICH CELL THE PARTICLES IS IN.
      C     IF IT IS OUTSIDE THE AREA IT IS MOVED BACK TO THE NEAREST
      C      SIDE CELL.
      C
      C*****************************************************************
      C     WRITE(6,10)
      C 10  FORMAT("* * * ARRIVED IN FIND * * *")
      C
            NN=INT((X/DX)+1.0)
            MM=INT((Y/DY)+1.0)
            IF(NN.LT.1) NN=1
            IF(NN.GT.NX) NN=NX
            IF(MM.LT.1) MM=1
            IF(MM.GT.NY) MM=NY
      C     WRITE(6,9990) X,Y,NN,MM
      C9990 FORMAT(5X," FIND: X,Y",2F12.2,5X,"NN,MM =",2I10)
            RETURN
            END
```

```
C
      SUBROUTINE MOVE(X,Y,DL,DT,A,HYP,GX,GY,ISEED)
C C$      ARRAYS
C C$      CALLS
C C$      TRACE
C
C*****************************************************************
C
C      THIS SUBROUTINE MOVES THE PARTICLES TO THEIR NEW
C      POSITION ACCORDING TO SOLUTE TRANSPORT THEORY.
C      THE THEORY USED MOVES THE PARTICLE A DETERMINISTIC DISTANCE
C      DOWN GRADIENT, THEN MOVES IT A RANDOM AMOUNT ABOUT THAT NEW
C      CENTROID POINT.  THE DETERMINISTIC MOVEMENT IS GIVEN BY:
C
C                                 (HYD.CON.*TIMESTEP SIZE)
C          DC = (MAX. GRADIENT)*------------------------
C                                 (POROSITY*RETARDATION)
C
C      THE LONGITUDINAL MOVEMENT OF THE PARTICLE IS THEN GIVEN BY:
C
C          DLONG = DC + SQRT(2*DC*LONGIT. DISPERSIVITY)*RAND. NORM #1
C
C      SIMILARLY, THE TRANSVERSE MOVEMENT IS GIVEN BY:
C
C          DTRAN = SQRT(2*DC*TRANSVERSE DISPERSIVITY)*RAND. NORM #2
C
C      THE PROGRAM THEN RESOLVES THE MOVEMENT VECTOR INTO X AND Y
C      COMPONENTS, AND ADDS THEM TO THE ORIGINAL VALUES TO GIVE
C      THE FINAL LOCATION OF THE PARTICLE.
C
C      **NOTE** THERE IS NO UNIVERSAL AGREEMENT IN THE METHOD USED
C               TO COMPUTE THE LONGITUDINAL AND TRANSVERSE
C               MOVEMENT OF PARTICLES.
C
C
C*****************************************************************
C
      DIMENSION U(2)
C     WRITE(6,5)
C   5 FORMAT("* * * ARRIVED IN MOVE * * *")
      XO=X
      YO=Y
      IF(HYP.EQ.0)GOTO 10
      CALL RAND(ISEED,16777213,1,2,U)
      DC=HYP*A
      DLONG=U(1)*SQRT(2*DL*DC)+DC
      DTRAN=U(2)*SQRT(2*DT*DC)
      X=X+(GX*DLONG-GY*DTRAN)/HYP
      Y=Y+(GY*DLONG+GX*DTRAN)/HYP
   10 CONTINUE
C     WRITE(6,9990) X,Y,U(1),U(2)
C9990 FORMAT(5X,"X=",F10.2," Y=",F10.2," U1=",F8.2," U2=",F8.2)
      RETURN
      END
```

```
C
C
      SUBROUTINE ELIM(DX,DY,NX,NY,NTOTAL)
C C$       ARRAYS
C C$       CALLS
C C$       TRACE
C
C*************************************************************
C
C     THIS SUBROUTINE SETS ALL BOUNDARY AREAS TO ZERO AFTER EACH PRINT
C     CYCLE SO THAT BOUNDARIES WILL INDICATE PARTICLES LOST PER PRINT
C     STEP ON EACH PRINTING.  IN ADDITION THE LIST OF PARTICLES IS
C      REDUCED TO ACTIVE PARTICLES BY ELIMINATING THOSE IN
C      BOUNDARY AREAS.
C
C***********************************************************
C
      COMMON/PARMS/HEAD(28,41),HOLD(28,41),POT(28,41),
     1             T(28,41,2),R(28,41),MATL(28,41),
     2             GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
      COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KELIM
C
      COMMON/MATER/ NMAT,DL(20),DT(20),A(20),K(20),S(20),FE(20),POR(20)
C     WRITE(6,5)
C   5 FORMAT("* * * ARRIVED IN ELIM * * *")
C
C
      NBDY=0
      KK=0
   10 CONTINUE
      KK=KK+1
      IF(KK.GT.NTOTAL)GO TO 20
C     FIND WHICH MATERIAL CELL PARTICLE IS IN
      CALL FIND(X(KK),Y(KK),DX,DY,NX,NY,NN,MM)
      MAT=MATL(NN,MM)
      IF(A(MAT).GT.0.)GO TO 10
C
C     SWAP LAST PARTICLE IN LIST WITH STALLED PARTICLE
C
C     FIND WHICH SOLUTE CELL THE PARTICLE IS IN
      CALL FIND(X(KK),Y(KK),DXPAR,DYPAR,NXPAR,NYPAR,NN,MM)
      X(KK)=X(NTOTAL)
      Y(KK)=Y(NTOTAL)
      NTOTAL=NTOTAL-1
      NBDY=NBDY+1
      KK=KK-1
C
C     DECREMENT BOUNDARY PARTICLE MATRIX
C
      NOUT(NN,MM)=NOUT(NN,MM)-1
      GO TO 10
   20 CONTINUE
      WRITE(6,2000)NBDY,NTOTAL
 2000 FORMAT(///5X,"BOUNDARY PARTICLES ELIMINATED IN THIS TIME STEP =",
     1            I5,"  TOTAL NOW =",I5)
      RETURN
      END
```

```
C
C
C
      SUBROUTINE PLOT
C C$      ARRAYS
C C$      CALLS
C C$      TRACE
      COMMON/PARTIC/X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KELIM
C
C
C     THIS IS A QUICKIE PLOT ROUTINE WHICH PRINTS THE MATRIX
C
      WRITE(6,2001)
 2001 FORMAT(1X,' Y ',63X,'X'/1X,'---','   1   2   3   4   5   6   7   8
     1   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25
     2  26  27  28  29  30  31  32'/
     31X,'---')
      DO 10 K=1,NYPAR
        J=NYPAR-K+1
        WRITE(6,2002) J,(NOUT(I,J),I=1,NXPAR)
 2002   FORMAT(1X,I3,32I4)
   10 CONTINUE
      RETURN
      END
```

```
SUBROUTINE PLOTR      74/175  OPT=0                    FTN 5.0+508        81/12/07. 12.15.58       PAGE      1

                SUBROUTINE PLOTR(XV,NX,NY)
          C C$      ARRAYS
          C C$      CALLS
          C C$      TRACE
                DIMENSION XV(28,41)
          C
          C
          C     THIS IS A QUICKIE PLOT ROUTINE WHICH PRINTS THE MATRIX
          C
                DO 10 K=1,NY
                J=NY-K+1
                WRITE(6,2002)J
           2002 FORMAT(1H ,"NY ROW = ",I5)
                WRITE(6,2000)(XV(I,J),I=1,NX)
           2000 FORMAT(1H ,20F6.4)
             10 CONTINUE
                RETURN
                END
```

```
C
C
C
C
      SUBROUTINE PLOT3(NX,NY,NOUT,TIME)
C C$      ARRAYS
C C$      CALLS
C C$      TRACE
C
C*****************************************************************
C
C     PLOTS THE ACTIVE PARTICLES AND THE BOUNDARY PARTICLES USING
C     A SINGLE DIGIT ALGORITHM
C
C*****************************************************************
C
      COMMON/PARMS/HEAD(28,41),HOLD(28,41),BOT(28,41),
     1             T(28,41,2),R(28,41),MATL(28,41),
     2             GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
      COMMON/MATER/ NMAT,EL(20),DT(20),A(20),K(20),S(20),RF(20),POR(20)
C
      DIMENSION NOUT(150,150)
      DIMENSION LINE(150),INUM(11),ISYM(11),IAXIS(100)
      DATA INUM/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H*/
      DATA ISYM/1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HJ,1HK,1HZ/
C     WRITE(6,5)
C   5 FORMAT("* * * ARRIVED IN PLOT3 * * *")
C
C     SET UP AXIS LABEL
C
      DO 1 I=1,100
      IAXIS(I)=1H.
    1 CONTINUE
      DO 2 I=10,90,10
      J=(I/10)+1
      IAXIS(I)=INUM(J)
    2 CONTINUE
      IAXIS(100)=1H0
      DO 3 I=5,95,10
      IAXIS(I)=1H*
    3 CONTINUE
C
C     SET SCALES FOR ANALYSIS
C
      MAXPAR=0
      MAXBDY=0
      DO 10 I=1,NX
      DO 10 J=1,NY
      IF(MATL(I,J).EQ.0)GO TO 15
      IF(NOUT(I,J).GT.MAXPAR)MAXPAR=NOUT(I,J)
      GO TO 10
   15 CONTINUE
      IF(NOUT(I,J).GT.MAXBDY)MAXBDY=NOUT(I,J)
   10 CONTINUE
      MAXPAR=(MAXPAR/10+1)*10
      MAXBDY=(MAXBDY/10+1)*10
```

```
            SCALE1=(FLOAT(MAXPAR))/10.0*0.99999
            SCALE2=(FLOAT(MAXBDY))/10.0*0.99999
            IF(SCALE1.LE.1.0)SCALE1=1.0
            IF(SCALE2.LE.1.0)SCALE2=1.0
      C
      C     WRITE HEADER FOR PLOT
      C
            WRITE(6,2005)
            IFSP=0.5+10.0*SCALE1
            IFSB=0.5+10.0*SCALE2
            WRITE(6,2000)IFSP,IFSB
       2000 FORMAT(1H ,/5X,78(1H*),/5X,1H*,76X,1H*,/,5X,
           1        1H*,19X,"SYMBOLIC PLOT OF PARTICLE DISTRIBUTION",19X,1H*,
           2        /5X,1H*,76X,1H*,/5X,78(1H*),/5X,1H*,76X,1H*,/5X,
           3        "* PERCENT OF FULL SCALE      0  10 20 30 40",
           4        " 50 60 70 80 90 100   FULL SCALE = *",/5X,
           5        "* ACTIVE PARTICLE SYMBOLS   . 0  1  2  3  4  5  6  ",
           6        "7  8  9   ",I5," PARTICLES *",/5X,
           7        "* BOUNDARY PARTICLE SYMBOLS / A  B  C  D  E  F  G  ",
           8   "H  J  K   ",I5," PARTICLES *",/5X,1H*,76X,1H*,/5X,78(1H*),/)
            WRITE(6,2001) TIME
       2001 FORMAT(/5X,*PARTICLE DISTRIBUTION AT TIME = *,F10.4)
            WRITE(6,2004)
       2004 FORMAT(1H )
            IF(NY .GT. 50) WRITE(6,2005)
       2005 FORMAT(1H1)
            WRITE(6,2003)(IAXIS(I),I=1,NX)
            WRITE(6,2004)
      C
      C     PLOT EACH POINT IN LINE MATRIX
      C
            DO 20 KK=1,NY
            J=NY-KK+1
            DO 30 I=1,NX
            MAT=MATL(I,J)
            NUM=NOUT(I,J)
            FNUM=FLOAT(NUM)
            IF(MAT.EQ.0)GO TO 25
            LL=1H.
            IF(NUM.EQ.0)GO TO 28
            IVAL=INT(FNUM/SCALE1)+1
            LL=INUM(IVAL)
            GO TO 28
         25 CONTINUE
            LL=1H/
            IF(NUM.EQ.0)GO TO 28
            IVAL=INT(FNUM/SCALE2)+1
            LL=ISYM(IVAL)
         28 CONTINUE
            LINE(I)=LL
         30 CONTINUE
            WRITE(6,2002)IAXIS(J),(LINE(I),I=1,NX)
       2002 FORMAT(1H ,A1,2X,100A1)
         20 CONTINUE
            WRITE(6,2004)
            WRITE(6,2003)(IAXIS(I),I=1,NX)
       2003 FORMAT(1H ,3X,100A1)
            WRITE(6,2004)
            RETURN
            END
```

```
C
C
      SUBROUTINE ERPROC
C C$        ARRAYS
C C$        CALLS
C C$        TRACE
C
C*************************************************************************
C
C     FUNCTION - THIS SUBROUTINE HANDLES ERROR PROCESSING. THE
C                ERROR CODES ARE PASSED THRU THE PARAMETER
C                ERRCOD. ERROR CODES RANGING FROM 1-99 ARE NON-
C                FATAL INFORMATIONAL ERRORS. ERROR CODES GREATER
C                THAN 100 ARE FATAL AND RESULT IN THE TERMINATION
C                OF THE PROGRAM EXECUTION.
C                IN ADDITION, PARAMETERS OF INTEREST ARE
C                ALSO PASSED FOR PRINTING VIA "ARG",WITH
C                - ARG       =THE ARGUMENT ARRAY
C                - ARG(1)    =NUMBER OF ARGUMENTS
C                - ARG(2-10)=REAL ARGUMENTS
C
C*************************************************************************
C
C
       COMMON/PARMS/HEAD(28,41),HOLD(28,41),DOT(28,41),
     1              T(28,41,2),R(28,41),MATL(28,41),
     2              GX(28,41),GY(28,41),HYP(28,41),THICK(28,41)
C
       COMMON/CONTRL/ISTEP,NX,NY,DX,DY,TIMMAX,OUTFRQ,NDATPR(10),LUNIT,
     1               TUNIT,TITLE(8),TOL,MAXIT,NTYPE,NL,PARTVL,
     2               THESIG,THEDOT,ISEED
C
       COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR,
     1 NXPAR,NYPAR,KELIM
C
       COMMON/MATER/ NMAT,EL(20),DT(20),A(20),K(20),S(20),RE(20),PCR(20)
C
       COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),IR(20,20),RATE(20,20),
     1              NODES(20,100,2)
C
       COMMON/ERROR/ERRCOD,ERRARG(10)
C
       INTEGER ERRCOD,TITLE,TUNIT,OUTFRQ
       REAL ERRARG,HEAD,K
C      WRITE(6,10)
C 10   FORMAT("* * * ARRIVED IN ERPROC * * *")
C
       NARG=ERRARG(1)+1
       IF(ERRCOD .EQ. 100) WRITE(6,2100)
 2100 FORMAT(//5X,"** FATAL ERROR #100 - NO FLOW BOUNDARY MATCH",
     1          " NODE IS OUTSIDE GRID **"/)
C
       IF(ERRCOD .EQ. 101) WRITE(6,2101)
 2101 FORMAT(//5X,"** FATAL ERROR #101 - SOLUTION OF HEADS DID NOT ",
     1          "CONVERGE IN MAXIMUM ALLOWED NUMBER OF  ITERATIONS **"/)
C
       IF(ERRCOD .EQ. 102) WRITE(6,2102)
```

```
            CALL FIND(XX,YY,DX,DY,NX,NY,NHEAD,MHEAD)
               MAT = MATL(NHEAD,MHEAD)
            IF(POR(MAT).LE.0.0)HP(KOUNT)="+"
            IF(POR(MAT).LE.0.0) GO TO 144
             CONC = CFAC * NOUT(IH,J)/(POR(MAT)*THICK(NHEAD,MHEAD))
            IF(CONC.GT.100.OR.CONC.LE.0) GO TO 141
            IF(CONC.GT.0.0.AND.CONC.LT.1.0)HP(KOUNT)="+"
            IF(CONC.GE.1.0.AND.CONC.LT.10.0)HP(KOUNT)="0"
            IF(CONC.GE.10.0.AND.CONC.LT.20.0)HP(KOUNT)="1"
            IF(CONC.GE.20.AND.CONC.LT.30) HP(KOUNT)="2"
            IF(CONC.GE.30.AND.CONC.LT.40.)HP(KOUNT)="3"
            IF(CONC.GE.40.AND.CONC.LT.50.)HP(KOUNT)="4"
            IF(CONC.GE.50.AND.CONC.LT.60.)HP(KOUNT)="5"
            IF(CONC.GE.60.AND.CONC.LT.70.)HP(KOUNT)="6"
            IF(CONC.GE.70.AND.CONC.LT.80.)HP(KOUNT)="7"
            IF(CONC.GE.80.AND.CONC.LT.90.)HP(KOUNT)="8"
            IF(CONC.GE.90.AND.CONC.LT.100.)HP(KOUNT)="9"
      141   CONTINUE
            IF(CONC.LT.0.0)HP(KOUNT)="?"
            IF(CONC.GE.100)HP(KOUNT)="X"
            IF(CONC.EQ.0.0)HP(KOUNT)= "."
      144   KOUNT=KOUNT+1
        145  CONTINUE
            IF(NPAGE.EQ.NSLICE)COLPP=COLLP
            WRITE(6,2025)J,(HP(II),II=1,COLPP)
      2025  FORMAT(2X,I3,1X,120(A1))
               J=J-1
               GO TO 140
        150   CONTINUE
            WRITE(6,2026)
      2026  FORMAT(//41X,"*** SCALE ***",/26X,"   +   0   1   2   3   4   5"
           1 ,"   6   7   8   9",/26X,
           2"0.0 1.0 10. 20. 30. 40. 50. 60. 70. 80. 90. 100"
           3 //13X,"VALUES LESS THAN 0.0 DENOTED BY  ?.  VALUES GREATER THAN",
           3 " 100. DENOTED BY  X")
      C
      C        WRITE(6,9994) NSL
      C9994    FORMAT(5X,"END PRINT LOOP, NSL =",I10)
        200 CONTINUE
            WRITE(6,2030)
       2030 FORMAT("1")
            IF(LA .EQ. 2) GOTO 900
            IF(MTYPE .NE. 1) GOTO 900
              LA = LA + 1
              GOTO 105
        900 CONTINUE
      C
            RETURN
            END
```

```
 2102 FORMAT(//5X,"** FATAL ERROR #102 - NOT ENOUGH INPUT DATA **"/)
C
      IF(ERRCOD.EQ.103) WRITE(6,2103)(ERRARG(I),I=2,NARG)
 2103 FORMAT(//5X,"** FATAL ERROR #103 - PROBLEM DEFINITION RESULTS",
     1         " IN NEGATIVE HEAD VALUES , RESTART FILE CREATED **",
     2         /5X,"HEAD = ",F10.2,5X,"I,J = ",2F4.0)
C
      IF(ERRCOD .EQ. 104) WRITE(6,2104)
 2104 FORMAT(//5X,"** FATAL ERROR #104 - UNRECOGNIZABLE DATA BLOCK",
     1         " NAME IN INPUT **"/)
C
      IF(ERRCOD.EQ.105)WRITE(6,2105)(ERRARG(I),I=2,NARG)
 2105 FORMAT(//5X,"** FATAL ERROR #105 - RESTART FILE ON UNIT
     1         NO.",I5," IS EMPTY **"/)
C
      IF(ERRCOD.EQ.106)WRITE(6,2106)(ERRARG(I),I=2,NARG)
 2106 FORMAT(//5X,"** FATAL ERROR #106 - RESTART FILE HAS
     1         INSUFFICIENT DATA - I=",I4," J=",I4," **"/)
C
      IF(ERRCOD.EQ.107) WRITE(6,2107)(ERRARG(I),I=2,NARG)
 2107 FORMAT(//5X,"** FATAL ERROR #107 - TOO MANY PARTICLES,
     1      NTOTAL =",I8," A TIME =",F10.2,"RESTART FILE CREATED"," **"/)
C
C     CHECK FOR  FATAL  ERROR
C
      IF(ERRCOD .GE. 100) WRITE(6,2200)
 2200 FORMAT(//5X,"** PROGRAM ABORTED **"/)
C
C     CHECK FOR ARRAY DUMP OPTION
      IF(NDATPR(2) .EQ. 0) GOTO 900
C     ARRAY DUMP WILL PUT NX VALUES OF X ON 1 LINE
C     FOR NY LINES OF Y
C     WITH A MAXIMUM NX=20 (NO MAX. NY)
C
      WRITE(6,1000)
C
C
      DO 160 L=1,NL
      DO 160 J=1,NY
      WRITE(6,1001) (HEAD(I,J),I=1,NX)
  160 CONTINUE
 1000 FORMAT(/5X,"HEAD ARRAY DUMP - UP-SIDE-DOWN"/)
 1001 FORMAT(5X,20F6.1)
  900 CONTINUE
      RETURN
      END
```

```
      IF(MTYPE .EQ. 3) LA = 2
      LAYER = " "
  105 CONTINUE
      IF(MTYPE .EQ. 1 .AND. LA .EQ. 1) LAYER = "UPPER"
      IF(MTYPE .EQ. 1 .AND. LA .EQ. 2) LAYER = "LOWER"
      IF(LAYER .NE. " ") WRITE(6,2017) LAYER
 2017 FORMAT(/10X,"*** ",A5," LAYER ***"//)
C
      COLPP = 120
      NSLICE = 1
  110 CONTINUE
        NCOLS = COLPP * NSLICE
        IF(NXPAR .LE. NCOLS) GOTO 120
        NSLICE = NSLICE + 1
      GOTO 110
  120 CONTINUE
C
C     COMPUTE NUMBER OF COLUMNS IN LAST SLICE
C
      COLLP = NXPAR - (COLPP*(NSLICE - 1))
C
C     PRINT MATRIX IN SLICES OF "COLPP" COLUMNS PER PAGE
C
      NPAGE = 0
C     WRITE(6,9990) NSLICE,COLPP,COLLP,NXPAR
C9990 FORMAT(5X,"STARTING SLICE LOOP - NSLICE,COLPP,COLLP,NXPAR=",4I10)
      DO 200 NSL = 1,NSLICE
        IF(NSL .LE. 2) GOTO 125
        XNSL = FLOAT(NSL)
        WRITE(6,9991) XNSL
 9991   FORMAT(5X,"ERROR - NSL =",E20.5)
        GO TO 900
  125   CONTINUE
        NPAGE = NPAGE + 1
        IF(NSL .GT. 1) WRITE(6,2020) NSL,NUMIT,TIME,TUNIT
 2020   FORMAT("1",/5X," SLICE NUMBER ",I5,5X,"ITERATION #",
     1          I8,5X,"TIME = ",F10.3,1X,A4/////)
       IF(NSL.EQ.1)WRITE(6,2024)
       IF(NSL.EQ.2)WRITE(6,2023)
 2023 FORMAT(15X,'X'/6X,'1                   1                   1'/
     *  6X,'2',8X,'3',9X,'4'/
     *  3X,'Y',2X,2('1234567890')/)
 2024 FORMAT(63X,'X'/105X,"1                   1                   1",/6X,
     1 9X,"1",9X,"2",9X,"3",9X,"4",9X,"5",9X,"6",9X,"7",9X,"8",9X,"9",9X
     2 ,"0",9X,"1",9X,"2"/3X,'Y',2X,12('1234567890')/)
       KI=((NSL-1)*COLPP) + 1
        L = NSL * COLPP
        IF(NPAGE .EQ. NSLICE) L = NXPAR
C
        J=NYPAR
  140   CONTINUE
       KOUNT=1
        IF(J.LT.1) GO TO 150
         CFAC = (PARTVL*100.)/(DXPAR*DYPAR)
        DO 145 IH=KI,L
       XX=(IH-1)*DXPAR+DXPAR/2.
       YY=(J-1)*DYPAR+DYPAR/2.
```

```
      C
            SUBROUTINE OUT3K(TIME,NUMIT,E,EMAX)
      C C$       ARRAYS
      C C$       CALLS
      C C$       TRACE
      C
      C****************************************************************
      C
      C
      C   FUNCTION: PRINTS THE  CONCENTRATION MATRIX VALUES IN BLOCK
      C              FORM. THE ORIGIN (NODE 1,1) IS PRINTED IN THE LOWER
      C              LEFT CORNER.
      C
      C ARGUMENTS:
      C
      C      TIME - TIME SINCE SIMULATION BEGAN
      C
      C     NUMIT - NUMBER OF ITERATIONS
      C
      C****************************************************************
      C
      C
            COMMON/PARMS/HEAD(28,41),HOLD(28,41),SOT(28,41),
           1              T(28,41,2),R(28,41),MATL(28,41),
           2              CX(28,41),CY(28,41),HYP(28,41),THICK(28,41)
      C
            COMMON/CONTRL/ISTEP,NX,NY,DX,DY,TIMMAX,OUTFRQ,NDATPR(10),LUNIT,
           1              TUNIT,TITLE(8),TOL,MAXIT,MTYPE,NL,PARTVL,
           2              IBEGIN,IBEDOT,ISEED
      C
            COMMON/PARTIC/ X(25000),Y(25000),NOUT(150,150),DXPAR,DYPAR
           1 ,NXPAR,NYPAR,RECLIM
      C
            COMMON/MATER/ NMAT,EL(20),DT(20),A(20),K(20),S(20),RF(20),POR(20)
      C
            COMMON/LEAK/ NLEAK,NNODES(20),NLPT(20),IM(20,20),RATE(20,20),
           1             NODES(20,100,2)
      C
            COMMON/ERROR/ERRCOD,ERRARG(10)
      C
            INTEGER TITLE,TUNIT,LUNIT,NX,NY,COLLP,COLPP,OUTFRQ,HP(120)
      C
      C
      C      WRITE(6,9992) ITYPE,TIME,NUMIT
      C9992 FORMAT(//5X,"I GOT INTO OUT3K ",I10,F10.2,I10/)
            WRITE(6,2010) TITLE
       2010 FORMAT("1"//5X,8A10)
      C
            WRITE(6,2016) TIME,TUNIT,NUMIT,E,EMAX
       2016 FORMAT(/10X,"**** CONCENTRATIONS (AS PERCENT POND LEAKAGE)",
           1     " AT TIME =",F10.4,1X,A4," ****"//,15X,"NO. OF ITERATIONS =",
           2       I5,"  EPSILON =",F8.3,"  EMAX =",F8.3//)
      C
      C     COMPUTE NUMBER OF SLICES REQD TO PRINT MATRIX
      C
            LA = 1
            MTYPE=3
```

```
75 ..........++++++++++
74 ..........++++++++++
73 ..........++++++++++
72 ..........++++++++++
71 ..........++++++++++
70 ..........++++++++++
69 ..........++++++++++
68 ..........++++++++++
67 ..........++++++++++
66 ..........++++++++++
65 ..........++++++++++
64 ..........++++++++++
63 ..........++++++++++
62 ..........++++++++++
61 ..........++++++++++
60 ..........++++++++++
59 ..........++++++++++
58 ..........++++++++++
57 .....+++++++++++++++
56 .....+++++++++++++++
55 .....+++++++++++++++
54 ++++++++++++++++++++
53 ++++++++++++++++++++
52 ++++++++++++++++++++
51 ++++++++++++++++++++
50 ++++++++++++++++++++
49 ++++++++++++++++++++
48 ++++++++++++++++++++
47 ++++++++++++++++++++
46 ++++++++++++++++++++
45 ++++++++++++++++++++
44 ++++++++++++++++++++
43 ++++++++++++++++++++
42 ++++++++++++++++++++
41 ++++++++++++++++++++
40 ++++++++++++++++++++
39 ++++++++++++++++++++
38 ++++++++++++++++++++
37 ++++++++++++++++++++
36 ++++++++++++++++++++
35 ++++++++++++++++++++
34 ++++++++++++++++++++
33 ++++++++++++++++++++
32 ++++++++++++++++++++
31 ++++++++++++++++++++
30 ++++++++++++++++++++
29 ++++++++++++++++++++
28 ++++++++++++++++++++
27 ++++++++++++++++++++
26 ++++++++++++++++++++
25 ++++++++++++++++++++
24 ++++++++++++++++++++
23 ++++++++++++++++++++
22 ++++++++++++++++++++
21 ++++++++++++++++++++
20 ++++++++++++++++++++
19 ++++++++++++++++++++
18 ++++++++++++++++++++
17 ++++++++++++++++++++
16 ++++++++++++++++++++
```