GROUND WATER AND CONTAMINANT TRANSPORT MODELING: GARBER-WELLINGTON AQUIFER IN OKLAHOMA

Project Completion Report

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INTRODUCTION

In establishing the National Center for Ground Water Research (NCGWR), the United States Environmental Protection Agency recognized that an effective way to approach long-range ground water management problems was to develop an exploratory research program in conjunction with applied research efforts which were mission oriented. One applied project to be addressed by the NCGWR in cooperation with the Environmental Protection Agency, the State of Oklahoma, and the Association of Central Oklahoma Governments was the development of an implementable plan for the protection, development, and management of the Garber-Wellington Aquifer in Oklahoma.

The project described in this report was an integral part of Objective 600 of the work plan developed jointly by the Association of Central Oklahoma Governments' Garber-Wellington Association and the Environmental Protection Agency's Robert S. Kerr Environmental Research Laboratory (ACOG-GWA and EPA, 1980). Objective 600 was to evaluate present and potential man-caused pollution sources in the Garber-Wellington Aquifer, and Objective 606, in particular, was to develop submodels for pollutant transport. The specific problems which were addressed include (1) transport and fate of pollutants from major sources, and (2) salt water upconing and the lateral movement of salt water in a local well setting. This latter objective (606) was addressed in this project and will partially fulfill the National Center for Ground Water Research commitments to the Garber-Wellington Study.

METHODS

The project focused on the implementation and/or modification of existing mathematical models which could be applied to the Garber-Wellington Aquifer in Oklahoma.

Computer based literature surveys were conducted and an initial set of mathematical models for ground-water flow and chemical transport was selected for potential applications to NCGWR projects. These models are summarized in Table 1. The rational used in the initial selection of numerical models was based on model availability, documentation, and previous applications, as well as the experience of NCGWR personnel in the coding and/or use of a specific model or numerical method.

The data requirements for several of the numerical models were summarized and the availability of computer codes was assessed. If the code for a given model was not available in the form of cards, magnetic tape, or disc files, the model was not considered for application to the Garber-Wellington Aquifer.

The Trescott-Pinder Larson (1976) potentiometric head model and the Konikow-Bredehoeft (1978) solute transport model were selected for use on the Garber-Wellington aquifer since these computer codes are well maintained by the U. S. Geological Survey and the documentation is complete and well written. The two models have been used to simulate changes in the piezometric surface in the Yukon Well Field. The Konikow-Bredehoeft solute transport model was also used to simulate the movement of contaminants from a variety of hypothetical sources of pollution. The examples have been documented to include the development of aquifer parameters and

TABLE I

SELECTED MATHEMATICAL MODELS FOR
FLUID FLOW AND CONTAMINANT TRANSPORT

Model Reference	Description/Comments
Cleary-Ungs (1978)	Ten analytical models for fluid flow and solute transport; documentation and code availble.
Green-Cox (1966)	Two-dimensional finite-difference/method-of-characteristics model for miscible displacement in a vertical plane; documentation available, but code not readily accessible.
Gupta, et. al. (1975)	Three-dimensional finite-element model for fluid flow and solute transport; documentation not readily accessible and code not available.
Konikow-Bredehoeft (1978)	Two-dimensional finite-difference/method-of-characteristics model for solute transport in a horizontal plane; documentation and code readily available and well maintained.
Lyla (1980)	Two-dimensional finite element model for immiscible displacement of a salt-water/fresh-waterinterface; documentation and code available but contain many errors.
Prickett-Lonnquist (1971)	Finite-difference model for one- two-, or three-dimensional fluid flow; documentation and readily available.
Schmorak-Mercado (1969)	Analytical solution for salt-water upconing beneath a partially penetrating well in a confined aquifer.
Trescott (1975)	Three-dimensional finite-difference fluid-flow model; documentation and code available.
Trescott-Pinder-Larson (1976)	Two-dimensional finite-difference model for fluid flow in a horizontal plane; documentation and code readily available and well maintained.
Willhite-Wagner (1974)	Three-dimensional finite-difference model for fluid-flow and heat transport; documentation and code available.

preparation of input data, as well as model calibration and interpretation of the results. The application of these models to the Yukon Well Field are presented in detail in Part I of this report.

The Willhite-Wagner (1974) model was selected for implementation of a three-dimensional model since one of the principal investigators had been involved in the development of the computer code and was therefore familiar with the structure and use of the model. The model was originally developed for heat-transport in heterogeneous, anisotropic confined or leaky aquifers. The code and documentation were modified to convert the model to a solute transport model for this project. The mathematical development and documentation of the computer code are discussed in Part II of this project completion report.

The Schmorak-Mercado (1969) analytical solution for salt-water upconing beneath a partially penetrating well in a confined aquifer was used as the basis for an analytical model to predict the rise in elevation of an abrupt salt-water/fresh-water interface beneath a pumped well. Dispersion effects were superimposed on the rise of the interface elevation to yield the concentration profile across the transition zone and to estimate the salinity of the pumped water. The potential for salt-water upconing in the Garber-Wellington Aquifer was evaluated using this model in conjunction with the field data for the Yukon Well Field. This work is summarized as Part III of the report.

SUMMARY

The major portion of this project completion report has been divided into the following parts:

I. Potentiometric Head and Solute Transport Models for the Yukon Well Field, Garber-Wellington Aquifer,

II. Numerical Model for Three-Dimensional Fluid Flow and Solute Transport in Ground-Water Systems, and

III. Potential for Salt-Water Upconing in the Yukon Well Field.

Each of these parts of the report have been written as "stand alone" documents. This choice of format was based on the broad scope and the specific objectives of the project in relation to the overall work plan for the Garber-Wellington Study.

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GROUND-WATER AND CONTAMINANT TRANSPORT MODELING: GARBER-WELLINGTON AQUIFER IN OKLAHOMA

PART I

POTENTIOMETRIC HEAD AND SOLUTE TRANSPORT MODELS FOR THE YUKON WELL FIELD, GARBER-WELLINGTON AQUIFER

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SECTION I

ABSTRACT

Personnel at the Association of Central Oklahoma Governments, Garber-Wellington Association (ACOG-GWA) requested the transfer of technology on the use of selected mathematical models that may be applied to the fresh water zone of the Garber-Wellington Aquifer. This research is part of a project funded by the National Center for Ground-Water Research. Two numerical models by the U. S. Geological Survey (1976, 1978) and an analytical model by Cleary and Ungs (1978) were selected. The well field used by the City of Yukon, Oklahoma was selected because there were more detailed records concerning aquifer properties, well construction and pumping rates. Most of these parameters were averaged and entered into data sets for the various models. Calibration was completed on all three models. Several examples were set up to demonstrate how to simulate the piezometric head, drawdown and contaminant migration with detailed explanations on the source of information and a reason for each example.

SECTION II

INTRODUCTION

Purpose

This report addresses technology transfer of selected analytical and numerical models to users for simulating changes of piezometric head, drawdown and contaminant migration in an aquifer or a well field within an aquifer. This is part of Objective 600 and 606 work plan developed by the Association of Central Oklahoma Governments, Garber-Wellington Association (ACOG-GWA) and the Environmental Protection Agency's Robert S. Kerr Research Laboratory (EPA). Objective 600 is to evaluate present and potential man-caused pollution sources in the Garber-Wellington Aquifer and Objective 606, in particular, is to develop submodels of pollution transport. Potential users would include personnel at ACOG-GWA who plan to use these models to protect, develop and manage the Garber-Wellington Aquifer in Oklahoma.

Previous Investigations

Introduction

Jacobsen and Reed (1944,1949) first reported the use of Permian red beds (Wellington Formation) as a source of usable ground water. Wood and Burton (1968) described the ground-water resources in Cleveland and Oklahoma Counties. They also discussed the thickness of the fresh water overlying the salt water. Wickersham (1976) prepared a hydrologic atlas on the ground-water resources and chemical parameters for the southern regions of the Garber-Wellington Aquifer. Carr and Marcher (1977) prepared a report on the ground-water resources and chemical parameters in the northern regions of the

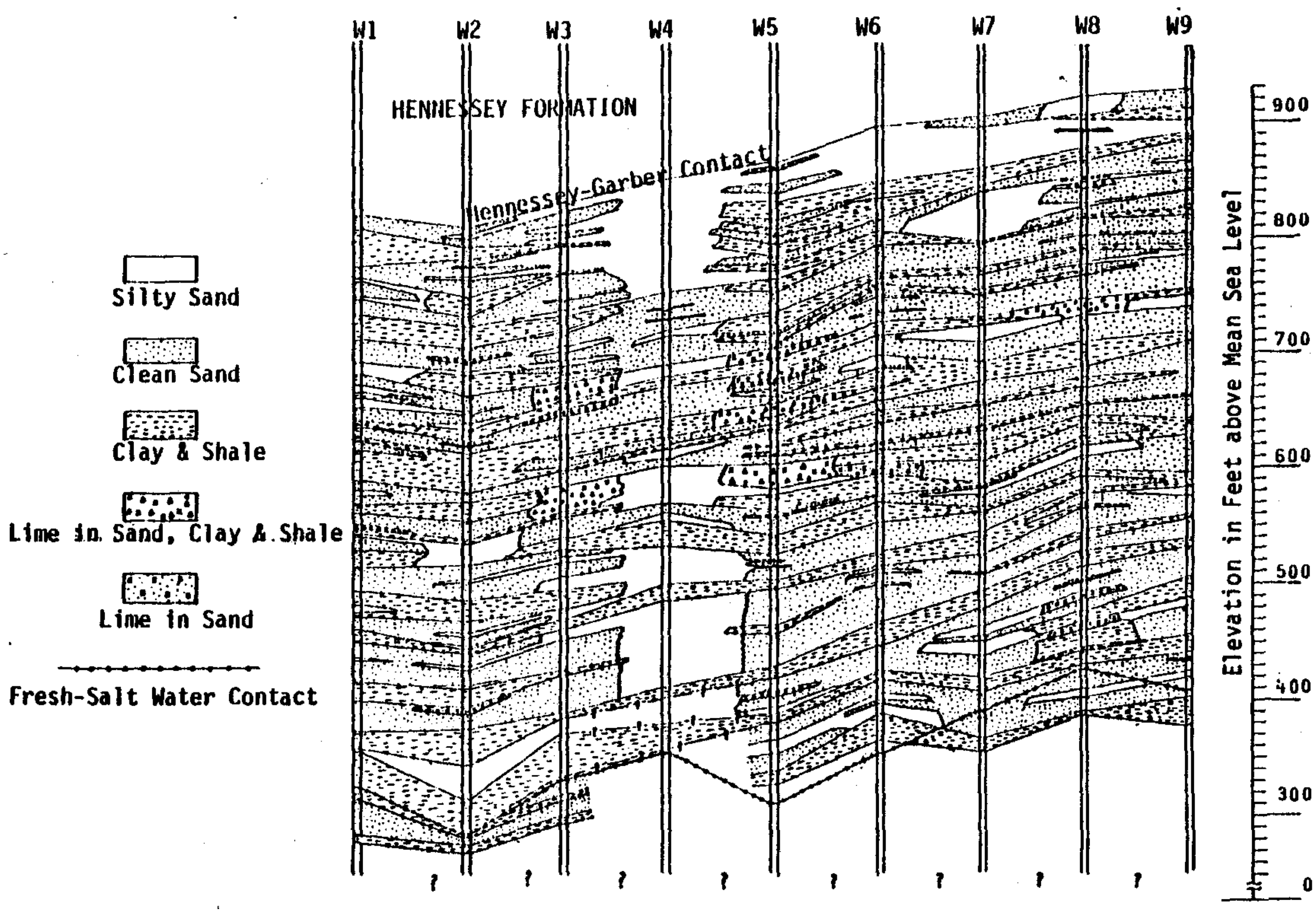
Garber-Wellington Aquifer. In addition, Wickersham, Carr and Marcher reported the elevations of the top and base of the fresh water zone. Engineering Enterprises (1979) constructed a well field for the City of Yukon which included detailed well logs, aquifer tests and water level measurements. ACOG-GWA (1981) has continuous records on ground water levels, quality and pumping rates for nine wells in the Yukon Well Field.

Analytical and Numerical Models

Cleary and Ungs (1978) (Model Number 9) prepared several analytical solutions capable of predicting drawdown at specified observation points. Trescott, et. al. (1976) (Trescott Model) developed a finite difference model that simulates ground water flow in 2-dimensions. Konikow and Bredehoeft (1978) (Konikow Model) developed a finite difference model capable of predicting the migration of solute transport in 2-dimensions.

Hydrogeology

The Garber-Wellington Aquifer is a confined multistoried sandstone aquifer which is overlayed by the Hennessey Shale. Based on correlated well logs from the Yukon Well Field, many of the sand layers are continuous between all nine wells; whereas, others pinch out or grade into silty sand, clay or shale (see figure 1). Each sand layer may have a different piezometric level, transmissivity, porosity, storativity, etc. As each sand layer is dewatered at the pumping well, these properties may change. This causes difficulty in calibrating 2-dimensional models.



GEOLOGIC CROSS-SECTIONAL

Figure 1

SECTION III

HYDROLOGIC DATA REQUIREMENTS FOR THE MODELS

Introduction

There are five major data input sets for the Trescott and Konikow Models. The data sets are: starting head, storage coefficient, transmissivity, recharge and pumping wells. Storage coefficients, transmissivities, recharge rates and permeabilities of the individual sand and silt layers are unkown. Therefore, average values were used for data inputs. Results of averaging the values for the different parameters are shown in the generalize cross section in figure 2. These average values were used for most data inputs of the models, i.e., storage coefficients, transmissivity, recharge, etc.

Piezometric Surface

Starting head represents the water level or the piezometric surface measured at the well. This data should be measured when the well was completed and then on a continual basis to aid in calibration. Piezometric surface measurements made in 1978 were plotted and contoured (see figure 3).

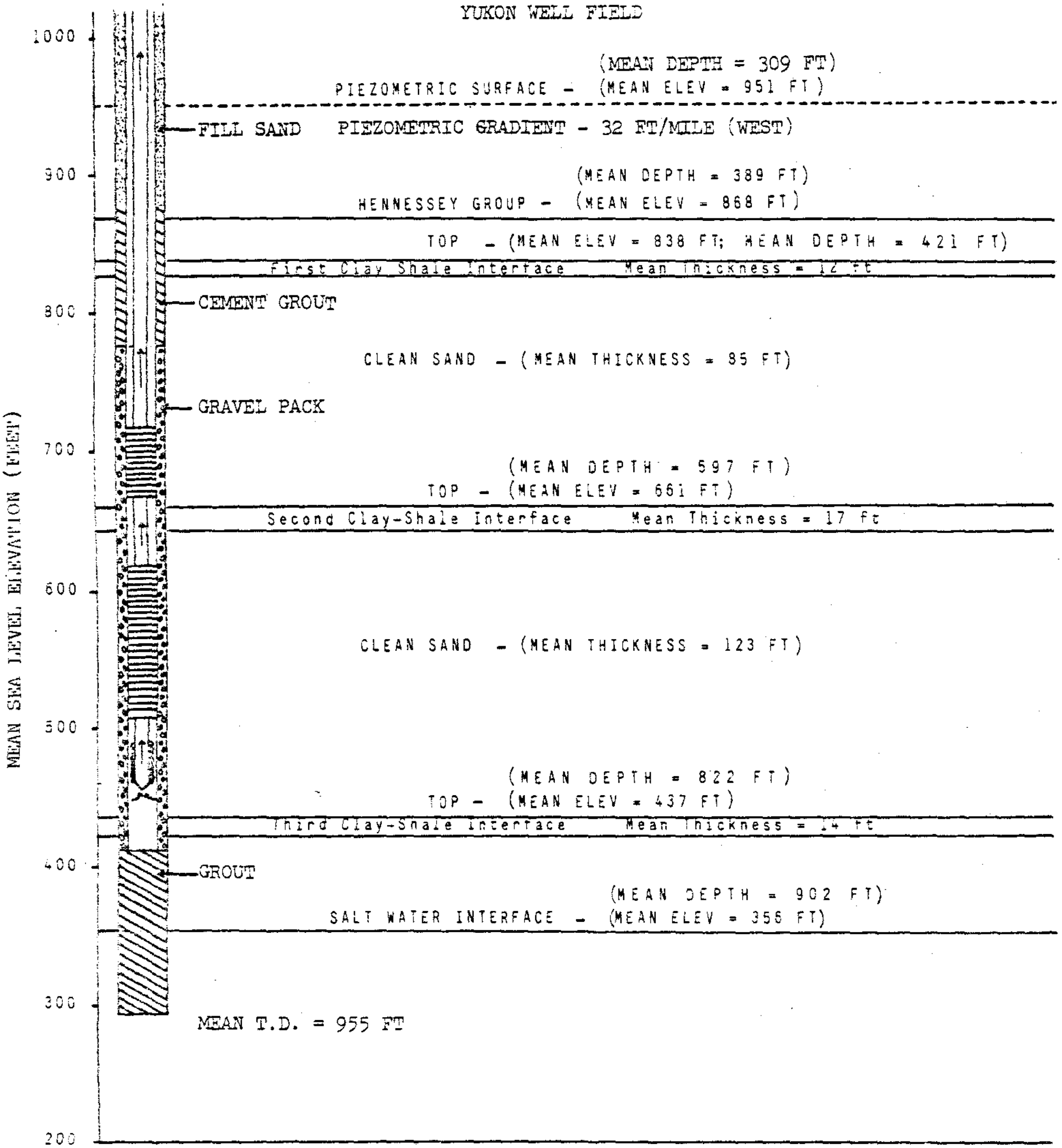
Storage Coefficient

Storage coefficient values obtained by Engineering Enterprises for well Y-P-4 were from 0.0005 to 0.0007. These are close to values reported by Wood and Burton (1968) (from 0.0001 to 0.0004). An average constant value of 0.0006 was used for the models.

Transmissivity

The transmissivity may vary from one area to another in an aquifer. To obtain reliable data, a transmissivity should be calculated for each well. The transmissivity values for the Yukon

GENERALIZED CROSS SECTION USING MEAN VALUES
GARBER-WELLINGTON AQUIFER
YUKON WELL FIELD



MEAN THICKNESS OF GRAVEL PACK = 364 FT

$\bar{T}$ = 2752 K = 13 GPD/FT^2

(Net Clean Sand = 208 FT)

Figure 2

PIEZOMETRIC SURFACE

ROWS	COLUMNS 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	26	27	28	29	30	31	32
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	957	956	955	954	953	952	951	952	954	956	958	960	961	962	964	966	968	970	971	972	974	976	978	980	981	982	984	986	988	990	0
3	0	957	956	955	954	952	951	950	951	953	955	956	958	959	960	962	963	965	968	969	970	972	974	976	978	979	980	982	984	986	989	0
4	0	956	955	954	952	951	950	949	950	951	953	954	956	957	958	959	961	962	964	965	969	970	972	974	976	977	978	980	982	984	987	0
5	0	957	953	952	951	950	949	949	949	950	951	952	954	955	956	956	957	959	960	962	965	968	970	972	974	975	976	978	980	983	986	0
6	0	953	952	951	951	950	949	948	948	949	950	950	952	953	953	953	954	956	957	960	961	964	966	969	970	972	974	976	979	982	985	0
7	0	952	951	950	950	949	948	947	947	948	948	949	950	950	950	950	952	953	954	957	959	961	963	965	967	969	971	974	977	980	983	0
8	0	953	952	951	950	949	948	947	947	947	948	948	949	949	949	949	950	950	952	954	957	95[illegible]	961	962	964	966	[illegible]	971	974	978	981	0
9	0	952	951	950	949	948	947	947	947	947	947	948	948	948	948	947	948	949	950	951	955	957	959	961	963	965	967	[illegible]	972	976	979	0
10	0	949	948	948	948	947	946	946	946	946	946	946	946	946	946	945	945	947	949	950	953	956	960	961	963	965	967	969	972	975	977	0
11	0	948	947	947	947	946	946	946	946	946	945	945	944	943	943	943	943	945	949	953	956	959	960	962	963	965	967	969	972	974	976	0
12	0	947	946	946	946	945	945	945	944	944	944	944	943	942	942	942	942	944	947	951	956	960	961	962	963	965	967	969	972	973	975	0
13	0	945	944	944	944	942	942	942	941	941	942	942	942	943	943	943	944	946	948	952	956	958	961	962	963	965	967	969	971	973	975	0
14	0	943	943	942	941	940	940	939	939	940	942	943	944	945	946	947	948	950	952	953	955	957	959	962	963	965	967	969	971	973	975	0
15	0	941	941	939	939	938	937	937	937	939	940	942	943	944	945	946	947	949	950	952	954	956	958	960	963	965	967	969	971	972	975	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	957	958	959	961	963	966	969	970	973	975	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	956	957	958	960	961	965	969	971	973	975	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	954	955	956	958	959	962	965	968	971	974	0
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20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
32	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

CONTOUR INTERVAL: 10 FEET

Figure 3

Well Field were similar to each other except for well Y-4-P, where the value was lower.

Recharge

Estimates of recharge and discharge are required to simulate the flow of ground water at the edge of a confined aquifer (boundary nodes). Recharge rates can be entered into the models in several ways: 1) constant head; the piezometric surfaces of the constant head nodes do not change during the simulation. 2) injection wells; this is a form of artifical recharge where a fluid is injected into the aquifer. 3) constant flux; the fluid is flowing into a node at a specific rate. 4) recharge matrix; a volume of fluid entering a node due to the piezometric gradient. To calculate a recharge rate, a flow net analysis was used, similar to the method described by Walton (1962).

To calculate the amount of recharge and discharge rates for the recharge matrix, the following equation was used:

$$q_v/A_v=K(dH/dL) \quad (1)$$

where

q_v/A_v = boundary recharge rate

K = coefficient of permeability (average between adjacent nodes)

dH = head difference between nodes

dL = length between nodes

when using transmissivity (T) where

$$T = Km \quad (2)$$

where

K = coefficient of permeability

m = thickness of the aquifer

equation (1) can be rewritten as:

$$q_v = TW(dH/dL) \quad (3)$$

where

q_v = boundary recharge (Ft^3/sec)

T = transmissivity

W = width of a node (Δx)

dH = head difference between nodes

dL = length between nodes (Δy)

therefore, by rotating recharge (q_v) from a vertical cross section into a horizontal plane and setting it to a recharge rate per node (QRE(I,J))

$$QRE(I,J) = q_v/(W)(dL) \quad (4)$$

(or)

$$QRE(I,J) = q_v/\Delta x \Delta y \quad (5)$$

Values of QRE(I,J) are computed for each node inside boundary node. Recharge values can be used as discharge values for the nodes which are down-gradient by changing the sign of QRE(I,J). The units of QRE(I,J) are in L/seconds.

Wells

The last major data input are pumping and/or injection wells. The source of these data must be from accurate records of pumping rates for individual wells. These data are necessary for model simulation and calibration. Since individual wells are not pumped continuously, the weighted average pumping rate was calculated for the entire well field on a monthly basis using individual pumping rate schedules. Monthly would facilitate comparison with the quantity pumped shown in the mass balance of the model output. In addition, each model is capable of handling multiple pumping periods of variable length (i.e., hours, days, months, years). As daily or monthly pumping rates change, these changes can be simulated.

SECTION IV

MODEL APPLICATIONS

Analytical Model

Model Number 9 is one of the 10 analytical solutions developed by Cleary and Ungs (1978). This particular model was developed to simulate a confined aquifer with one recharge boundary (constant head) and three impermeable boundaries (see figure 4). This model design is best suited for the hydrogeologic setting of the Yukon Well Field. Model Number 9 was used as an aid in calibrating the Trescott and Konikow Models.

Trescott Model

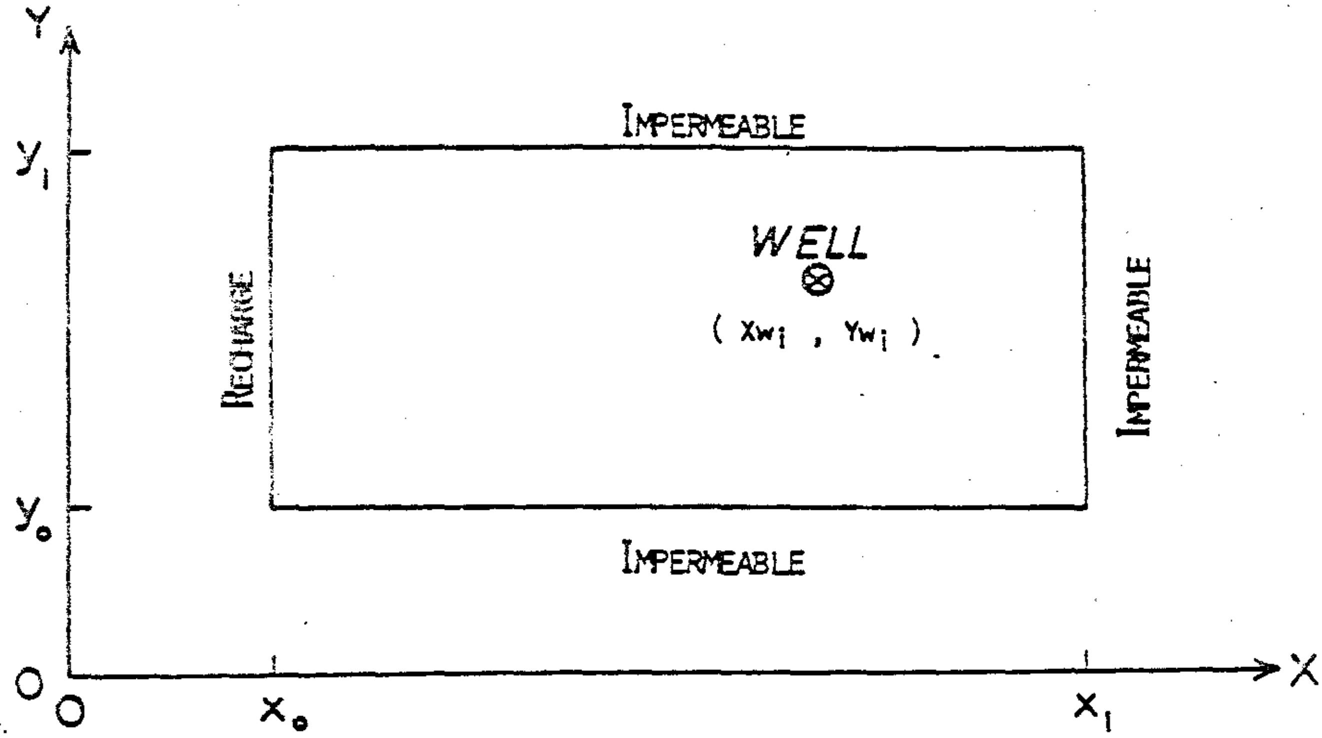
The Trescott Model was originally used to simulate the changes in the piezometric surface within the well field due to pumping. The ADIP iterative solution is used. Simulation results were compared and calibrated with observed piezometric surface and drawdown measurements. The hydrogeologic data inputs for the Trescott Model were transferred to the Konikow Model. The advantages of initially using the Trescott Model are: 1) it is easier to calibrate the Trescott Model because it computes a piezometric surface; 2) a cumulative mass balance is produced for each time step; 3) the cost of a simulation is significantly less.

Konikow Model

The Konikow Model was used to predict a path and rate of migration of a conservative contaminant from a hypothetical source. This model only uses the ADIP iterative solution. The model was originally written to handle a maximum grid size of 20 rows by 20 columns. To accommodate larger grid sizes, all the common and

TWO-DIMENSIONAL GROUNDWATER FLOW

(FINITE DIMENSIONS)



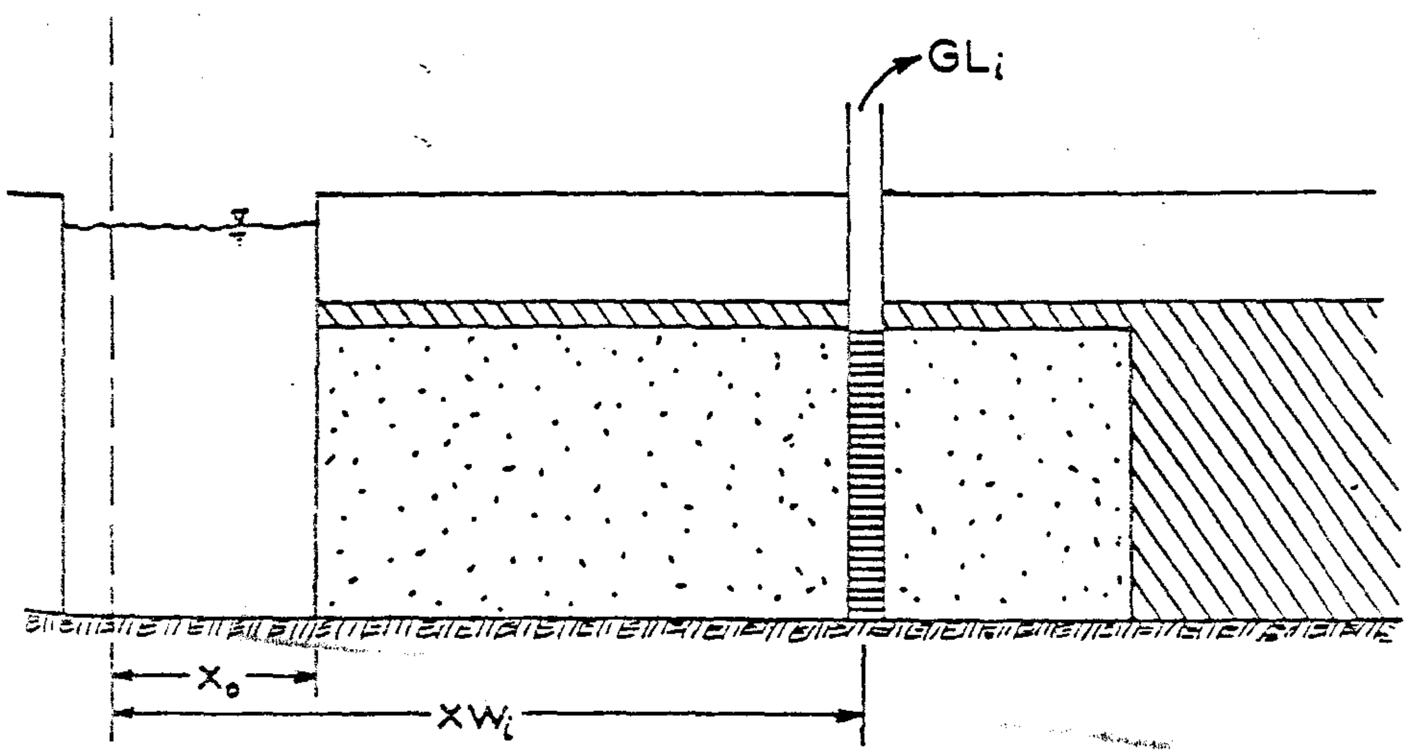


Figure 4, (After Cleary and Ungs, 1978)

dimension statements are changed in the source code. It is strongly recommended that if any changes are made, these statements should be changed to the same dimensions; otherwise, the solution may produce erroneous answers. In addition to the hydrogeologic data inputs from the Trescott Model, parameters used to characterize chemical transport were added. Since there is no documented contamination in the Yukon Well Field, assumed values were used for chemical transport parameters to demonstrate how the solute transport model can be used to simulate contaminant movement.

The Matrix Grid

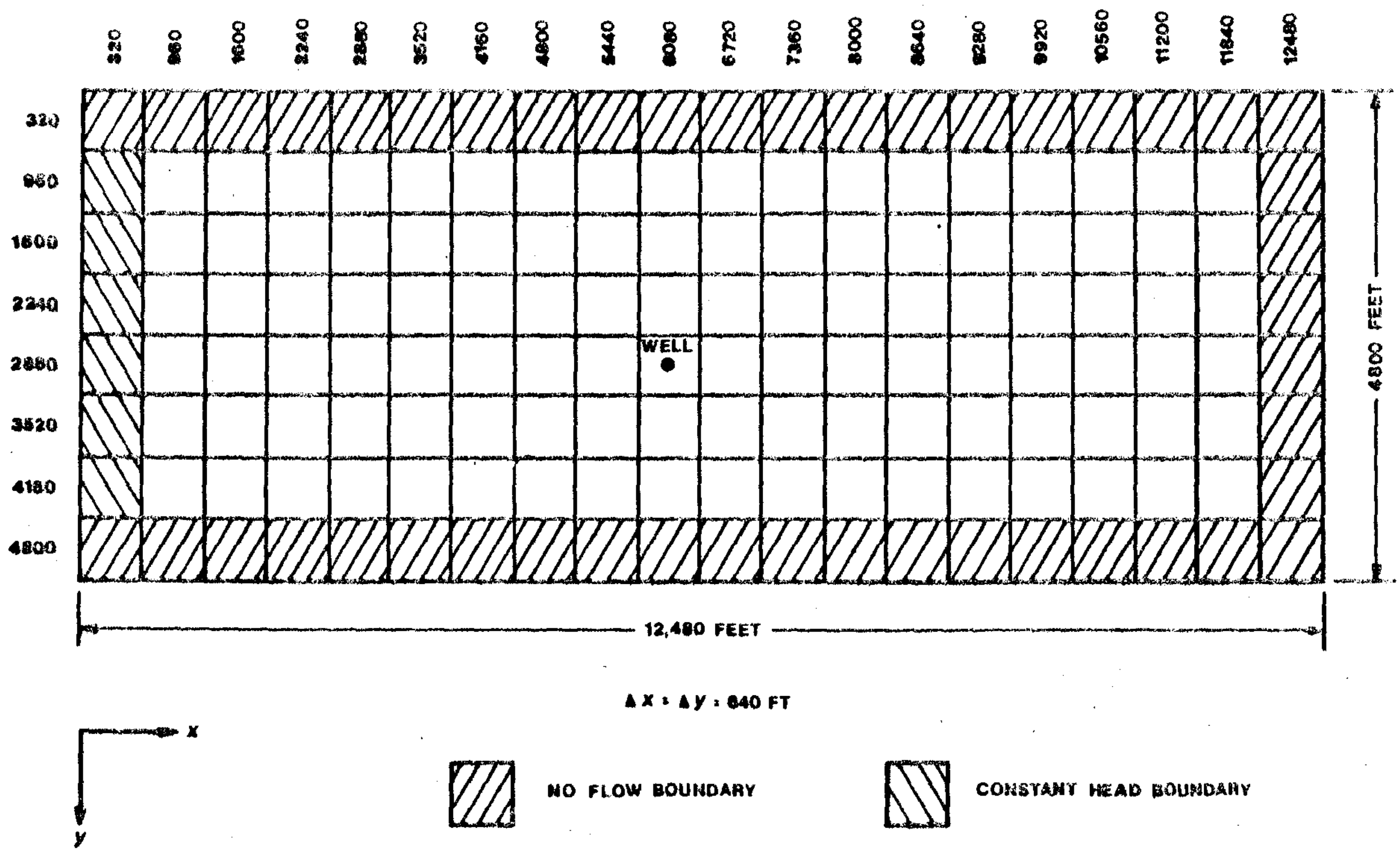
Analytical Model

Because Model Number 9 is an analytical model, finite dimensions are used. Points are specified according to their position in the X and Y direction on the surface plane. In order to facilitate comparison of results between analytical and numerical solutions, the position of the points were located to correspond to the center of each node in the finite difference grid (see figure 5) which is used for the numerical models.

Numerical Models

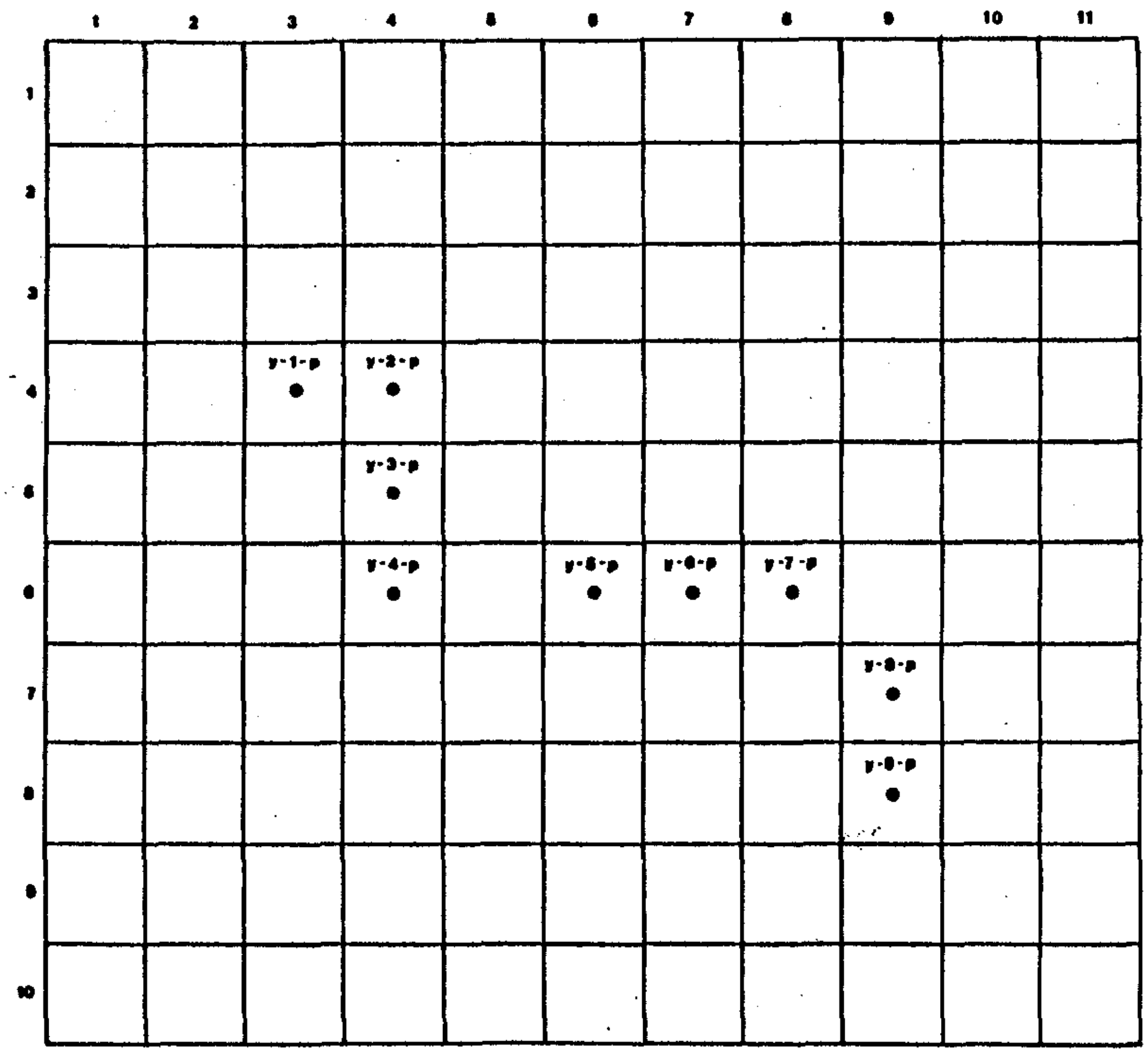
The grid can be developed in several forms for the two numerical models. For this particular study, two finite difference grids were developed. One grid was a spacing of 660 feet by 660 feet or 64 nodes per square mile (see figure 6). The second grid was a spacing of 2640 feet by 2640 feet or 4 nodes per square mile (see figure 7). Selection of the grid size will depend on the degree of detail desired, the density of data control, and the cost for a simulation run. The costs are much higher for a smaller grid spacing.

SCHEMATIC DESIGN FOR MODEL NO. 9



ure

SCHEMATIC DESIGN FOR THE TRESCOTT AND KONIKOW MODELS
YUKON WELL FIELD



Grid size: 2640 ft x 2640 ft

Figure 6

SCHEMATIC DESIGN FOR THE TRESCOTT AND KONIKOW MODELS
YUKON WELL FIELD

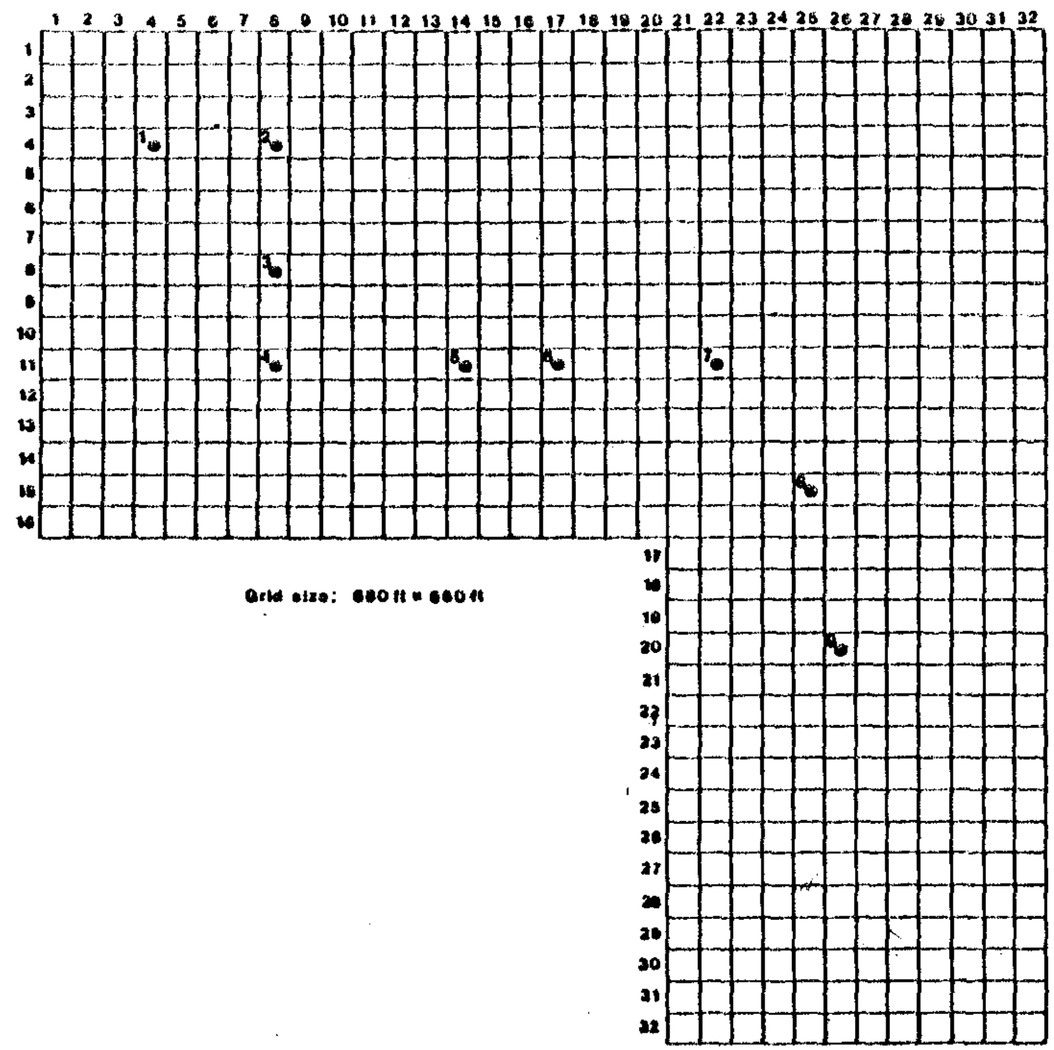


Figure 7

Simulation Examples

Several examples are designed to demonstrate the capabilities of each model. A complete summary of different examples used for Model Number 9, Trescott and Konikow Models are tabulated in Tables I, II and III, respectively. The cost of a simulation after the source code was compiled for each model and the length of a simulation is tabulated in Table IV.

TABLE I

SIMULATION EXAMPLE USING THE
TWO-DIMENSIONAL GROUNDWATER FLOW
(FINITE DIMENSIONS)
by CLEARY AND UNGS

SIMULATION TIME	PARAMETERS
28 days	Grid size: 20 x 8; node dimensions: 640 x 640 feet; transmissivity: 368.064 Ft^2/Day; One pumping well: 25920 Ft^3/Day.

TABLE II

SIMULATION EXAMPLES USING THE
FINITE-DIFFERENCE MODEL By TRESCOTT, PINDER, AND LARSON
FOR AQUIFER SIMULATION IN TWO DIMENSIONS

SIMULATION TIME PER PUMPING PERIOD	OPTIONS SELECTED	PARAMETERS
28 days	ADI, CHEC, NUME, HEAD	Grid size: 13 x 22; node dimensions: 640 x 640 feet; constant head; storage coefficient: 0.0006; transmissivity: 0.00426 Ft^2/Day; one pumping period; one pumping well at 0.30 Ft^3/Sec; time step: 24 hours.
30 min., 25 min., 8 min., 3 min., 3 min.	ADI, CHEC, NUME, HEAD	Grid size: 32 x 32; node dimensions: 660 x 660 feet; constant head; contoured head; storage coefficient: 0.0006; transmissivity: 0.0038 Ft^2/Day; one pumping well; time step: 0.0208 hours, 0.0174 hours, 0.0055 hours, 0.0021 hours, 0.0021 hours; five pumping periods.
28 days, 31 days, 30 days, 31 days, 30 days, 31 days,	RECH, ADI, CHEC, NUME, HEAD	Grid size: 10 x 11; node dimensions: 2640 x 2640 feet; starting head: 952 feet; storage coefficient: 0.0006; transmissivity: 0.00426 Ft^2/Day; recharge rate: 1.85 x 10^{-8} Ft/Sec per node; nine pumping wells; time step: 24 hours; six pumping periods each pumping period representing a month in 1981 starting with February.
31 days, 30 days, 2 days, 2 days	RECH, ADI, CHEC, NUME, HEAD	Grid size: 10 x 11; node dimensions: 2640 x 2640 feet; starting head: 952 feet; storage coefficient: 0.0006; transmissivity: 0.00426 Ft^2/Day; recharge rate: 1.85 x 10^{-8} Ft/Sec per node; nine pumping wells. time step: 24 hours; four pumping periods; 9 pumping wells for the first two pumping periods, 4 wells for the third, 5 well for the fourth.

TABLE III

SIMULATION EXAMPLES USING THE
COMPUTER MODEL (KONIKOW AND BREDEHOFT) OF
TWO-DIMENSIONAL SOLUTE TRANSPORT
AND DISPERSION IN GROUND WATER

SIMULATION TIME PER PUMPING PERIOD	SIMULATION EXAMPLE	PARAMETERS
28 days, 31 days, 30 days, 31 days, 30 days, 31 days, 1.58 years	Landfill	Grid size: 32 x 32; node dimensions: 660 x 660 feet; starting head: 958 feet; storage coefficient: 0.0006; transmissivity: 0.00426 Ft^2/Day; recharge rate: 3.90 x 10^{-9} Ft/Sec per node; nine pumping wells.
180 days	Injection well	Grid size: 32 x 32; node dimensions: 660 x 660 feet; starting head: 958 feet; storage coefficient: 0.0006; transmissivity: 0.00426 Ft^2/Day; recharge rate: 3.90 x 10^{-9} Ft/Sec per node; nine pumping wells.
180 days	Boundary source	Grid size: 32 x 32; node dimensions: 660 x 660 feet; starting head: 958 feet; storage coefficient: 0.0006; transmissivity: 0.00426 Ft^2/Day; recharge rate; 3.90 x 10^{-9} Ft/Sec per node; nine pumping wells.

TABLE IV

APPROXIMATE COST* OF A SIMULATION AND CPU PROCESSOR TIME

GRID° SIZE	SIMULATION TIME PER PUMPING PERIOD	OPTIONS°°	MODEL		
			MODEL 9	TRESCOTT	KONIKOW
32 x 32	180 days	RECH, CHEC, NUME, HEAD, ADI, 1 puming period, injection well, time step multiplier.	----	$5.57 proc. time = 0.0052 hr.	$14.96 proc. time = 0.01361 hr.
10 x 11	180 days	RECH, CHEC, NUME, HEAD, ADI, 1 pumping period, injection well, time step multiplier.	----	$0.68 proc. time = 0.00058 hr.	$2.91 proc. time = 0.00227 hr.
32 x 32	180 days	ADI, 1 pumping period, boundary source, time step multiplier	----	----	$13.78 proc. time = 0.0125 hr.
32 x 32	28 days, 31 days, 30 days, 31 days, 30 days, 31 days	RECH, CHEC, NUME, HEAD, ADI, 6 pumping periods, landfill	----	$4.60 proc. time= 0.00492 hr.	$75.82 proc. time = 0.071 hr.
20 x 8	28 days	CHEC, NUME, HEAD, ADI, 1 pumping period, constant head	$79.85**	$0.55 proc. time= 0.00064 hr.	----
10 x 11	31 days, 30 days, 2 days, 2 days	RECH, CHEC, NUME, HEAD, ADI, 4 pumping periods	----	$1.07 proc. time = 0.00095 hr.	----

* The cost is the total of all of the following:

Processor time ---------------------------- cpu hours at $700.00
Processor storage ------------------------- K bytes hours at $0.60
Disk excps -------------------------------- at $0.36 per 1000 -----
I/O cost (excluding printer/reader/punch)
Connect ----------------------------------- hours at $1.50

° The number of rows and columns in the grid.

°° Some options may pertain to one or more models and not to other models.

** Includes connection time of 0.349 hours.

SECTION V

CALIBRATION

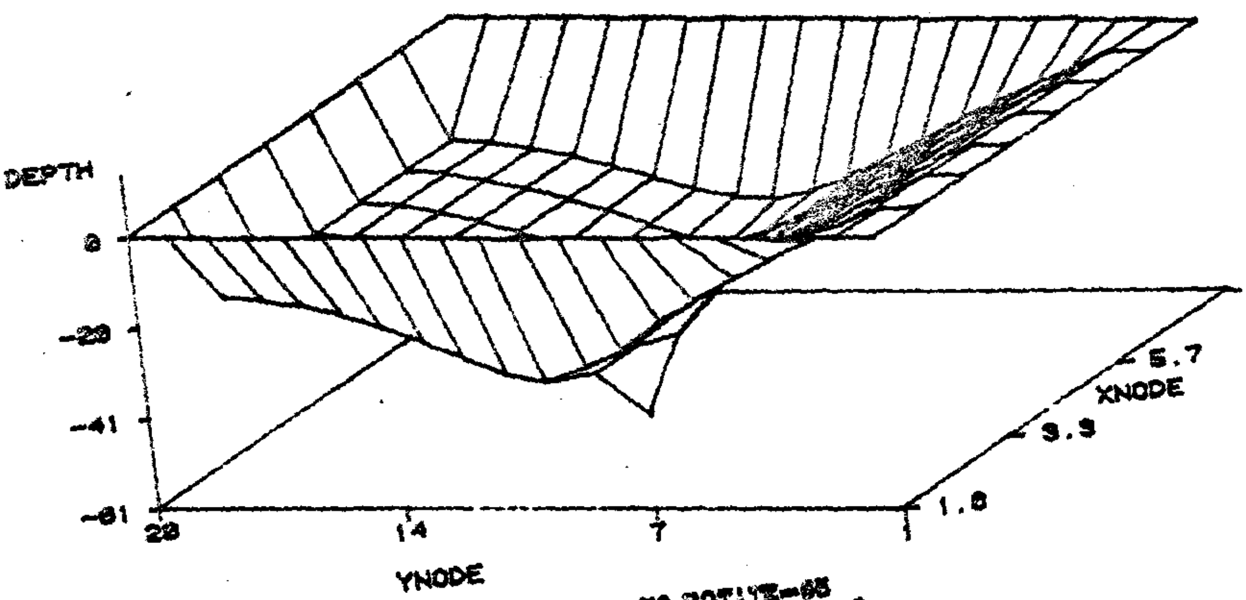
Introduction

Calibration is critical for any type of simulation. The calibration was conducted in two phases: 1) comparison of an analytical solution to a numerical solution and 2) comparison of field data with predictions made by the model. Comparison of the analytical solution to the numerical solution should reveal similar results. The error associated with an analytical solution involves a computation of drawdown at a positional point; whereas, the numerical solution involves a computation of head and drawdown for a node area.

Analytical vs. Numerical Solution

The data input for comparing an analytical with a numerical model were organized into a matrix grid consisting of 8 columns by 20 rows with 1 well pumping for 28 days. In both models, the area simulated was 2.15 square miles using constant head ('x' side of figures 8 and 9). The cone of depression extended over a large area of 1 mile or more (see figures 8 and 9). The drawdown values in both models are comparable. The values located at nodes further from the pumping well represented a difference in drawdown of about 6 feet. The difference in drawdown at the pumping well was 16 feet. In the numerical solution, the boundary nodes (no flow boundary) show an effect on the cone of depression, as illustrated in figure 8, but the shape of the cone inside the boundary nodes have the same shape as the analytical solution. Even though the differences appear large, it was felt that the available data is accurate enough to approximate the hydrogeologic characteristics of this aquifer.

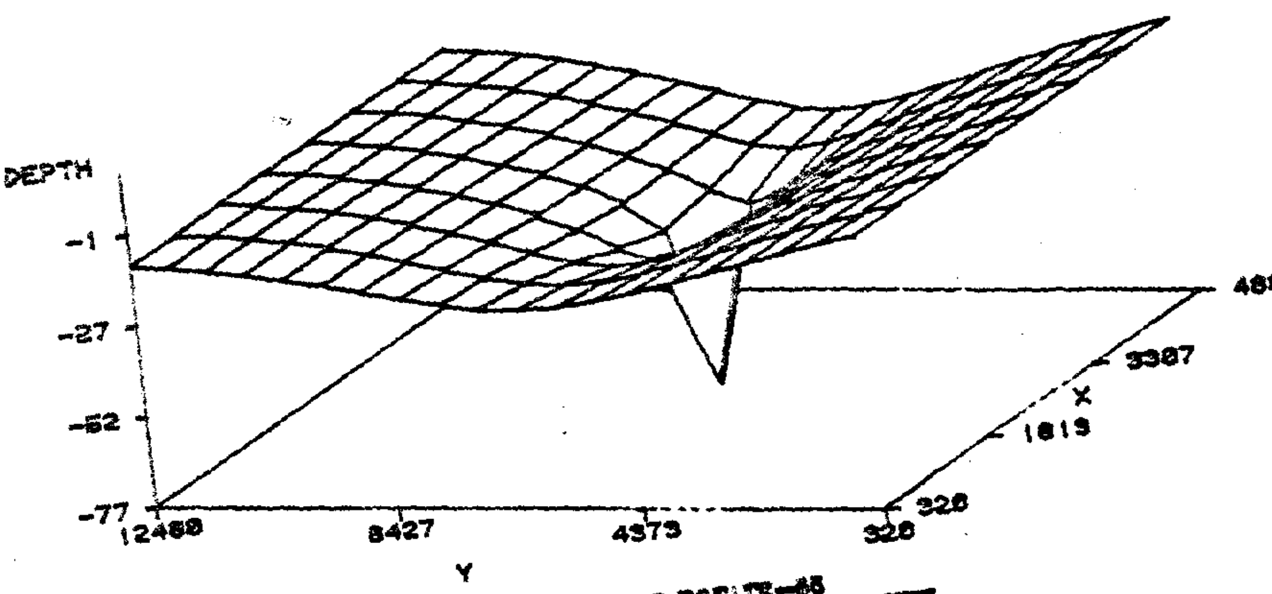
NUMERICAL MODEL (28 DAYS)
DRAWDOWN



TILT=70 ROTATE=65
(EACH NODE = 840 FEET)

FIGURE 8

ANALYTICAL MODEL 9 (28 DAYS)
DRAWDOWN



TILT=70 ROTATE=65
X, Y, AND DEPTH UNITS ARE IN FEET

FIGURE 9

Trescott Model

A simulation test of drawdown at a pumping well was set up to simulate a pump efficiency test. The pumping rates were changed during the field test which caused a change in head and corresponding drawdown. The different pumping rates were entered and the simulation run was performed. As time progressed in the simulation, the differences in observed and calculated values were decreasing to a difference of 9 feet. These differences may be attributed to two factors: 1) it was unknown how long the pump was off before the static water level measurements were made; it is possible that the cone of depression had not fully recovered when the static water level was measured; and 2) the radius of influence from adjacent wells may have affected the drawdown measurements at this well. Therefore, it was concluded that the weighted average rates were accurate enough to simulate the observed data from the pump efficiency test.

Konikow Model

Data input for the Trescott Model were transferred to the Konikow Model and resulting piezometric head changes were compared. Hypothetical examples of potential chemical contamination were used in subsequent simulation runs of the Konikow Model. Each example demonstrated the ability of the Konikow Model to move a contaminant plume from a point source, i.e., landfills, injection well(s) or a line source toward a sink such as a pumping well. There is no reported evidence of contaminants entering the ground water from the surface or subsurface in the Yukon Well Field. Therefore, the shape and location of a contaminant plume produced by the model could not be calibrated using actual field data.

SECTION VI

CONCLUSIONS

Overall, it was possible to model the Garber-Wellington Aquifer with numerical 2-dimensional models. Based on available data, the drawdown results of the simulation for all models were similar to the observed results. In order to achieve a higher degree of accuracy, pumping schedules and corresponding water-level measurements need to be obtained from wells in the Yukon Well Field and surrounding areas. Furthermore, hydrogeologic parameters, i.e., piezometric head, permeability, porosity, etc., are needed for individual sand layers of the confined aquifer. These are necessary if more accurate results are required or if a 3-dimensional model is to be used to simulate the aquifer.

To show what each model is capable of performing, several examples have been run. The data set and selected results of each simulation are included in the Appendices. The input parameters that have been changed for each simulation are shown in Tables 2, 3 and 4.

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APPENDIX I

USER'S MANUAL FOR THE TRESCOTT MODEL

DATA DECK INSTRUCTIONS

Introduction

There are four groups of data input for the Trescott Model. Each group will be addressed individually. The format presented by Trescott, et. al. (1976) is presented here with a more detailed explanation of each option and input parameter used. This will include source of data and calculation of input data. Field locations and matricies of input data formats as well as a complete listing of several data sets in the proper formats are included in the figures and appendices.

The simulation example data sets in Appendices VI, VIII, X and XII have dashed lines and comments which are included in the right margin of the data sets. These are only comments used for clarification in this report and are not to be included in the data set when the job is submitted.

Group I

Cards 1 and 2

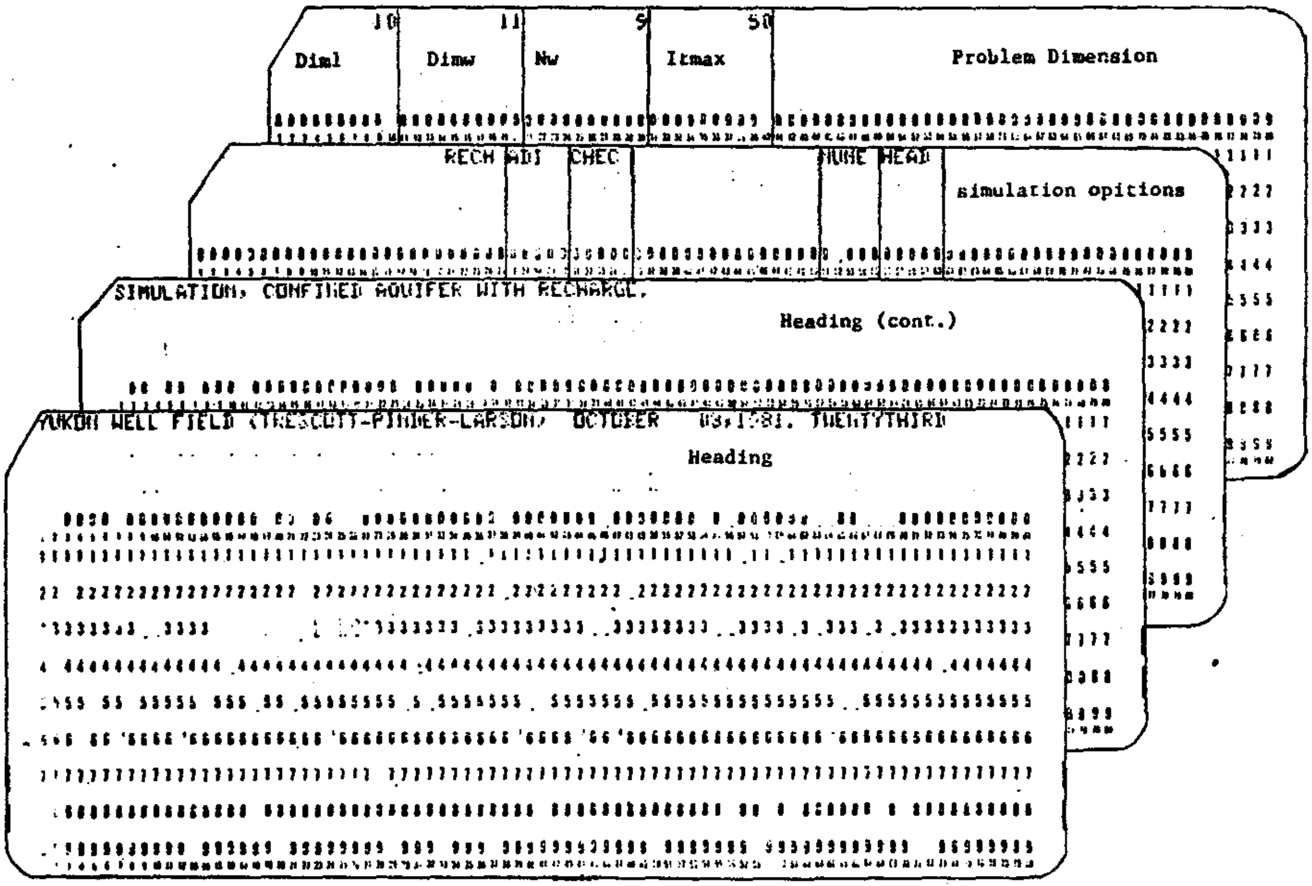
Cards 1 and 2 provide the heading (see figure 10). This can be any title that the user wishes. In the test runs that were made, the descriptive titles were used to help identify the simulation run.

Card 3

Card 3 selects which ever options the user wishes to use.

Option RECH

The option RECH can be used to enter a recharge rate in the model area as a matrix. Other ways which the recharge rate can be entered to the data set include the use of constant head or injection wells. If the recharge rate is to be entered in using injection wells or there is an injection well in the area under study, the injection rate



Group I

Figure 10

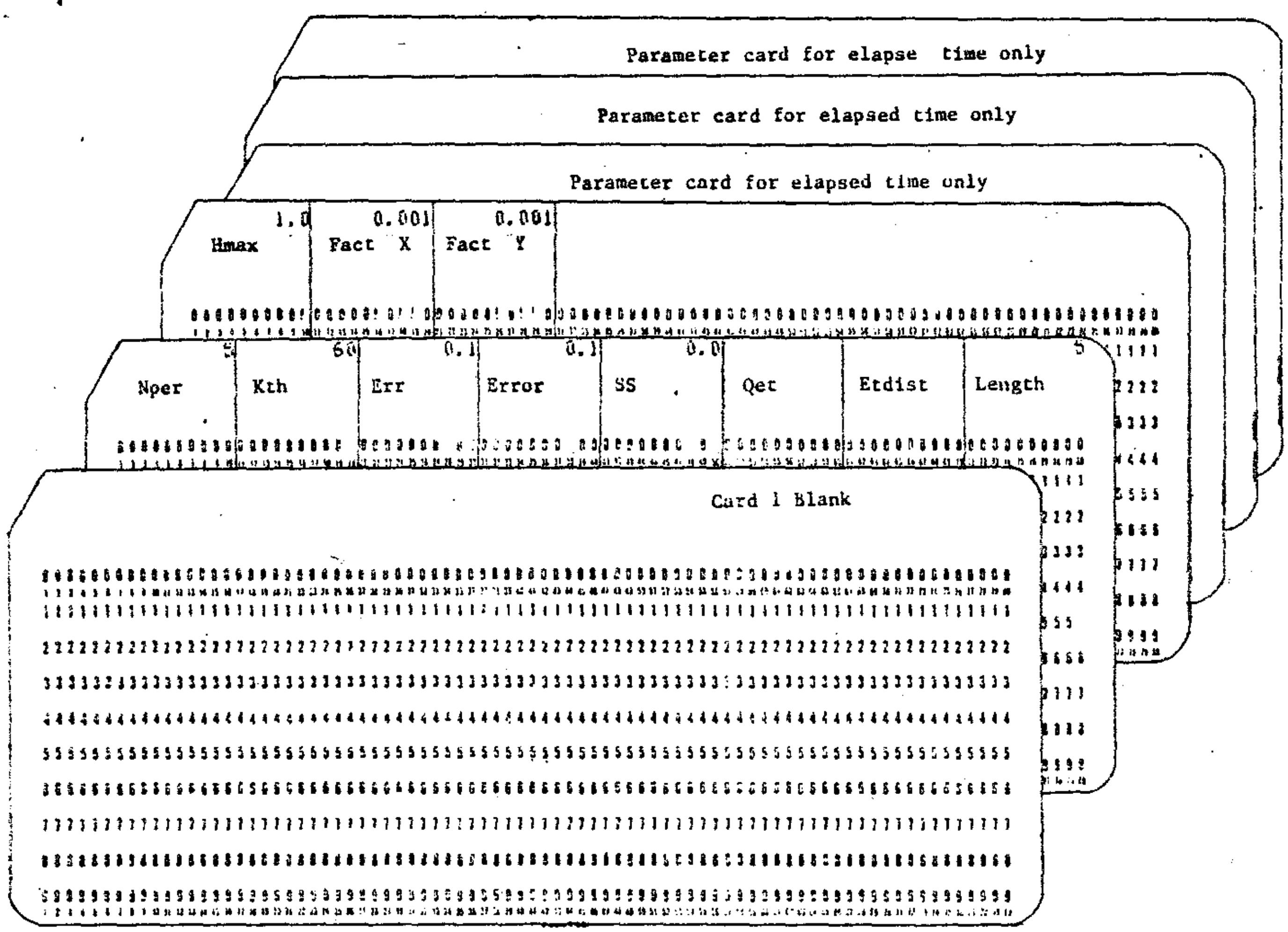
is entered in the pumping well matrix. The injection rate is a positive value. If constant head or injection wells are used, then option RECH is not used or flagged. The first rows and columns inside the boundary nodes are set as recharge nodes. <u>ADI</u> was used as mentioned earlier. Option <u>CHEC</u> was used to compute a mass balance for calibration purposes. Option <u>NUME</u> was used to print a numeric map of the drawdown. Option <u>HEAD</u> was used to print the head matrix so the user could observe what value was being read into the model.

Card 4

Card 4 is used to define dimensions. This includes the number of rows, the number of columns and the number of pumping wells with real well radius. The real well radius is used to calculate the drawdown for each well. Maximum number of iterations was set at 50 to obtain steady-state simulation.

Group II

This group of cards are used to establish the scalar parameters.



Group II

Figure 11

In this group, all the cards that are underlined are required for data input. The remainder of the cards are not required and can be eliminated, depending on which options are selected.

Cards 1 and 2

In this case, Card 1 was a blank card (see figure 11) because the drawdown was printed in numeric form. Card 2 contains some control parameters. The first one is the number of pumping periods. This can be 1 or more. The next field is the number of time steps that must be generated before head and drawdown maps are printed. The next field is the error closure criterion. This depends on the degree of accuracy that the user wishes. A value of 0.1 was used. The next field used is the steady-state criterion. Once again, this depends on the user. A value of 0.1 was used in this simulation. Because information was either unavailable or the data input was not required to simulate the Yukon Well Field, the next three fields were zero. The last field input is required for a specific type of numerical solution; in this case ADI was choosen and a value of 5 was selected. This number can be obtained from figure 16 in the Trescott manual (Trescott, etal., 1976).

Card 3

Card 3 data input for HMAX was set to 1.0. The multiplication factor for transmissivity was assumed to be equal in both directions and the value assigned was 1.0. This factor is multiplied with the multiplication factor on the transmissivity matrix.

Cards 4, 5 and 6

Cards 4,5 and 6 were left blank since this run was initiated using an initial starting head matrix. In the event that an initial run is made and the cumulative volumes for mass balance are stored, then these cards (4, 5 and 6) must be added to initialize a subsequent simulation run.

Group III

Introduction

The data on this group of cards is known as the Array Data. The data can be entered in two ways. One way is by entering one number that is constant throughout the entire area, i.e., starting head has the same elevation throughout the entire area of study. The other way is in the form of a matrix. A parameter card is placed before each data matrix (see figures 12 - 14).

Parameter Card

The multiplication factor of the numbers used in the matrix are entered in field 1 - 10 on the parameter card. 1 or 0 is used as flags in the other fields; field 11-20 is marked if a matrix is to be read, field 21-30 is marked with a 1 if the matrix is to be printed. It is strongly recommended that the martix be printed to make sure that the data array is being read properly. Field 31-40 is used to identify the source of the data array, i.e., cards or disk, Field 41-50 is used to indicate whether or not the matrix is to be stored on disk. This information must precede every matrix. In all examples, the matrices were read from cards and were not stored on disks.

Card 1

Card 1 is used only if there is a previous run for which the head values have been computed. If an initial simulation is made, as in the case of the Yukon Well Field study, this card is omitted. If subsequent simulations are made, this card must be added as well as

GROUP III

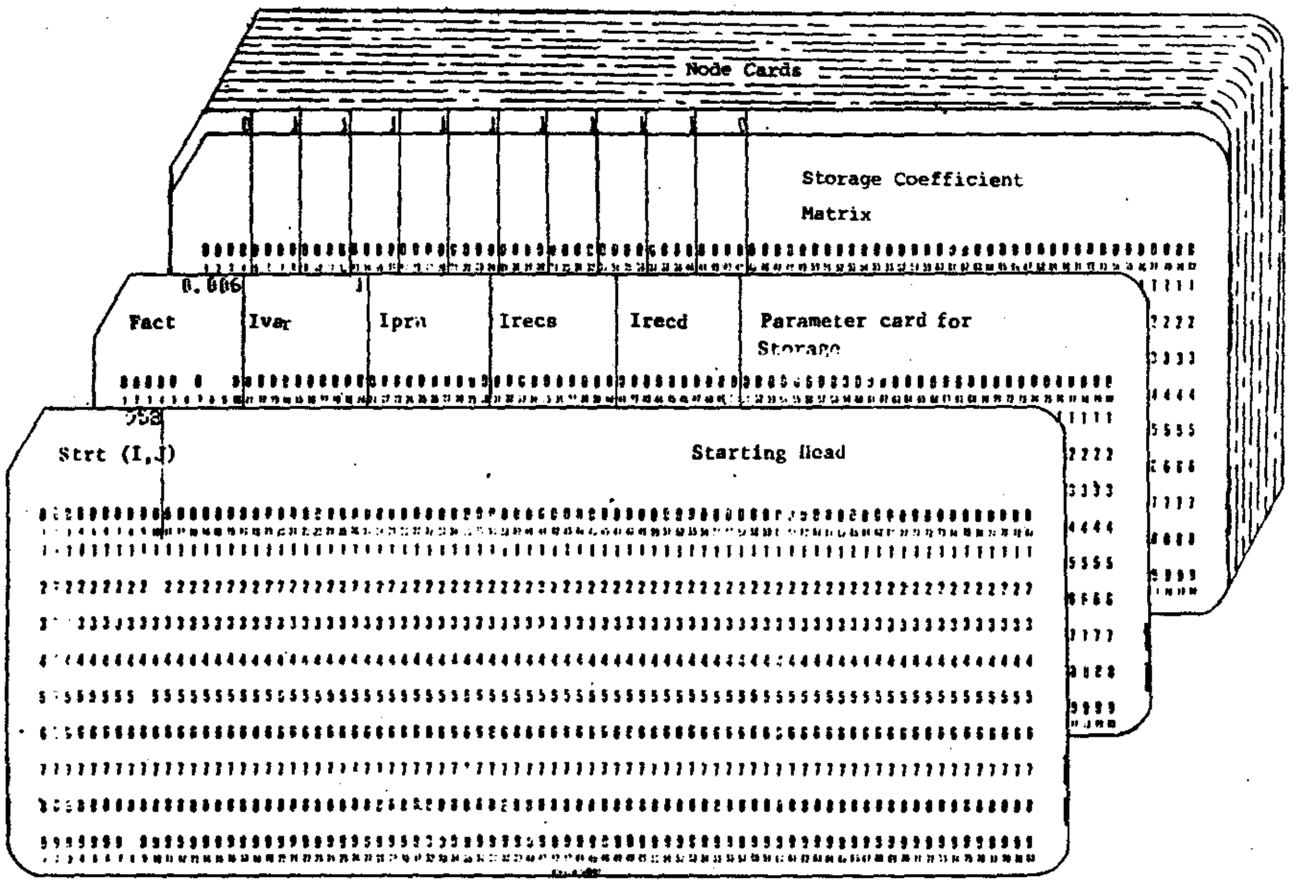


Figure 12

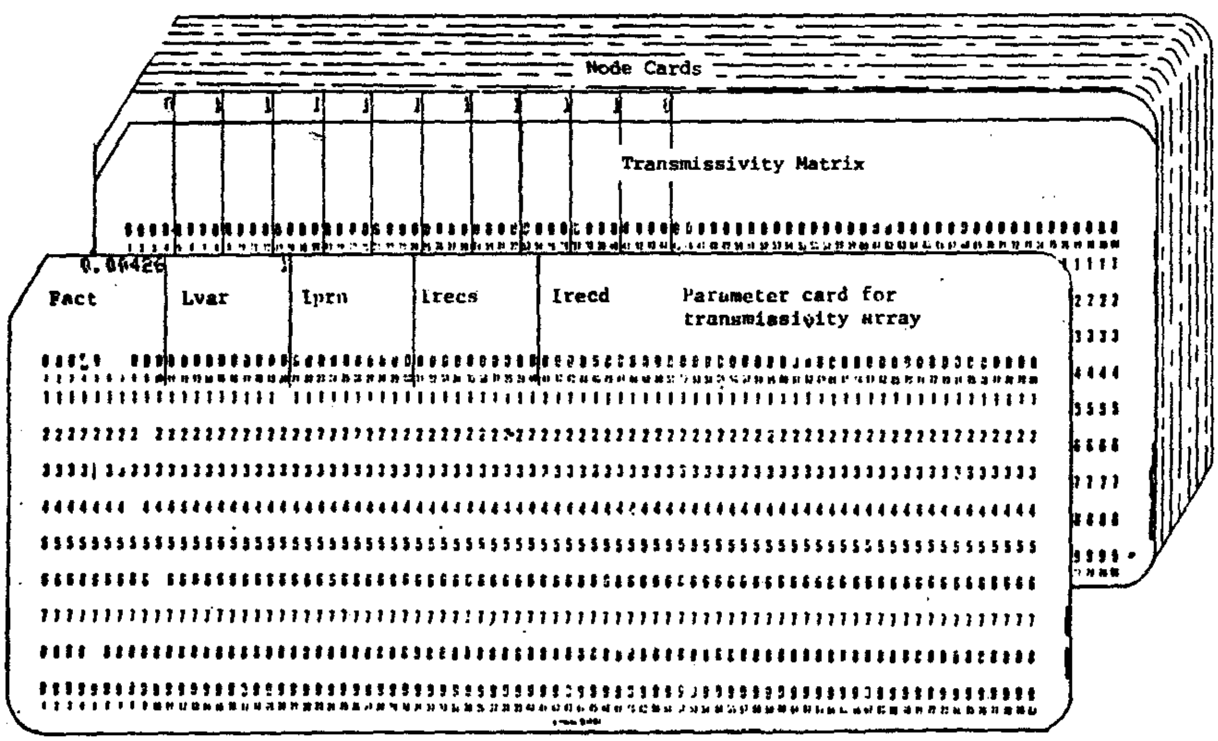


Figure 13

Cards 4,5 and 6 from group II.

Card 2

Card 2 is used for the starting head matrix. Where the head values are constant, a matrix is not needed and the value is simply added to the first field. However, where a gradient is described by a contoured piezometric surface (see figure 15, 16 and 17), a matrix will be required. A matrix for the head starting was used in some examples for the Yukon Well Field.

Card 3

Card 3 is used for the storage coefficient. The value of the storage coefficient was assumed to be constant across the entire Yukon Well Field area. A value of 0.0006 was reported for well Y-P-4 and subsequently used in the model. The first card is the parameter card. The first and last rows and columns are used to establish the boundary conditions. If a constant head is used, then the nodes which are to remain constant need to be flagged in the storage coefficient matrix by placing a minus sign in front of each constant head node.

Card 4

Card 4 is used to input the transmissivity. A martix format is chosen and the first card is the parameter card followed by the matrix. The value of transmissivity must be in units of L^2/second.

Cards 5,6,7,8,9,10,11 and 12

Cards 5,6,7,8,9,10,11 and 12 are omitted since the Yukon Well Field is treated as a confined aquifer and there is no evapotranspiration.

Card 13

Card 13 is used for recharge. This card is used only when the

GROUP III

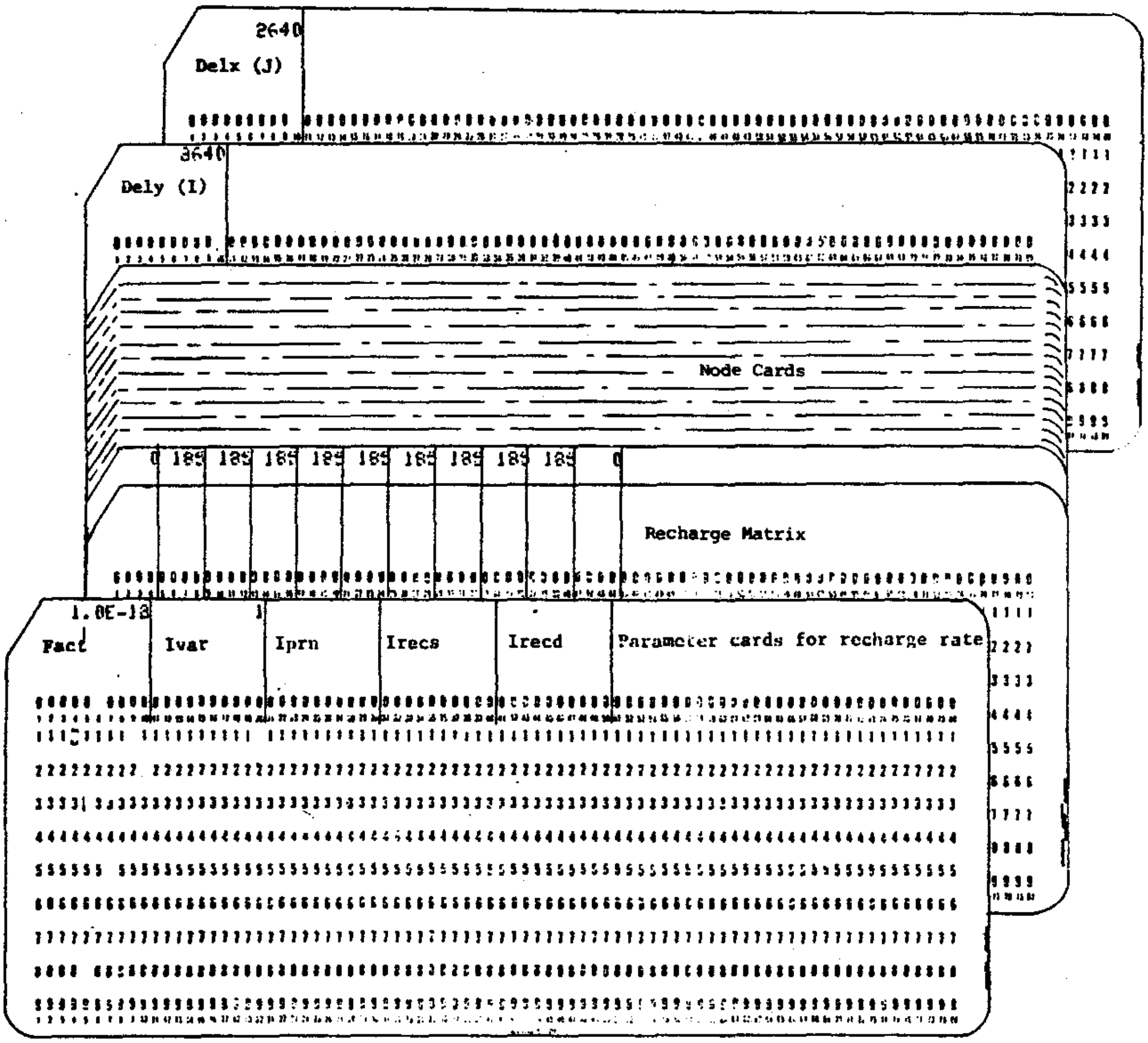


Figure 14

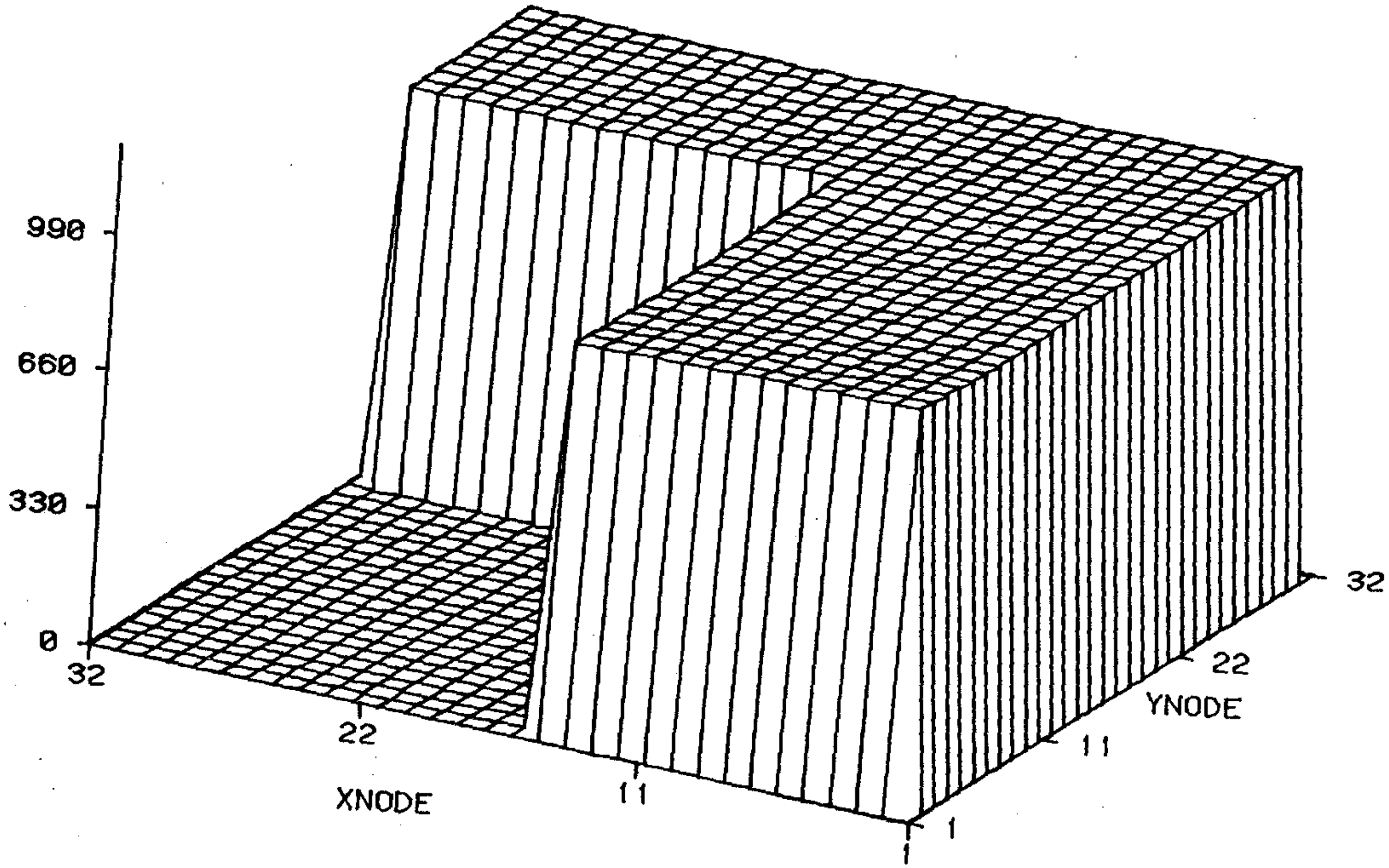
PIEZOMETRIC SURFACE

COLUMNS

ROWS	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	26	27	28	29	30	31	32
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	957	956	955	954	953	952	951	952	954	956	958	960	961	962	964	966	968	970	971	972	974	976	978	980	981	982	984	986	988	990	0
3	0	957	956	955	954	952	951	950	951	953	955	956	958	959	960	962	963	965	968	969	970	972	974	976	978	979	980	982	984	986	989	0
4	0	956	955	954	952	951	950	949	950	951	953	954	956	957	958	959	961	962	964	965	969	970	972	974	976	977	978	980	982	984	987	0
5	0	957	953	952	951	950	949	949	949	950	951	952	954	955	956	956	957	959	960	962	965	968	970	972	974	975	976	978	980	983	986	0
6	0	953	952	951	951	950	949	948	948	949	950	950	952	953	953	953	954	956	957	960	961	964	966	969	970	972	974	976	979	982	985	0
7	0	952	951	950	950	949	948	947	947	948	948	949	950	950	950	950	952	953	954	957	959	961	963	965	967	969	971	974	977	980	983	0
8	0	953	952	951	950	949	948	947	947	947	948	948	949	949	949	949	950	950	952	954	957	959	961	962	964	966	969	971	974	978	981	0
9	0	952	951	950	949	948	947	947	947	947	947	948	948	948	948	947	948	949	950	951	955	957	959	961	963	965	967	969	972	976	979	0
10	0	949	948	948	948	947	946	946	946	946	946	946	946	946	946	945	945	947	949	950	953	956	960	961	963	965	967	969	972	975	977	0
11	0	948	947	947	947	946	946	946	946	946	945	945	944	943	943	943	943	945	949	953	956	959	960	962	963	965	967	969	972	974	976	0
12	0	947	946	946	946	945	945	945	944	944	944	944	943	942	942	942	942	944	947	951	956	960	961	962	963	965	967	969	972	973	975	0
13	0	945	944	944	944	942	942	942	941	941	942	942	942	943	943	943	944	946	948	952	956	958	961	962	963	965	967	969	971	973	975	0
14	0	943	943	942	941	940	940	939	939	940	942	943	944	945	946	947	948	950	952	953	955	957	959	962	963	965	967	969	971	973	975	0
15	0	941	941	939	939	938	937	937	937	939	940	942	943	944	945	946	947	949	950	952	954	956	958	960	963	965	967	969	971	972	975	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	957	958	959	961	963	966	969	970	973	975	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	956	957	958	960	961	965	969	971	973	975	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	954	955	956	958	959	962	965	968	971	974	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	952	953	954	956	957	960	963	966	969	972	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	951	952	953	955	956	960	963	966	969	972	0
32	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

Figure 15

INITIAL PIEZOMETRIC HEAD (1978)



TILT=70 ROTATE=65

(INVERSE IMAGE)

Figure 16

INITIAL PIEZOMETRIC HEAD (1978)

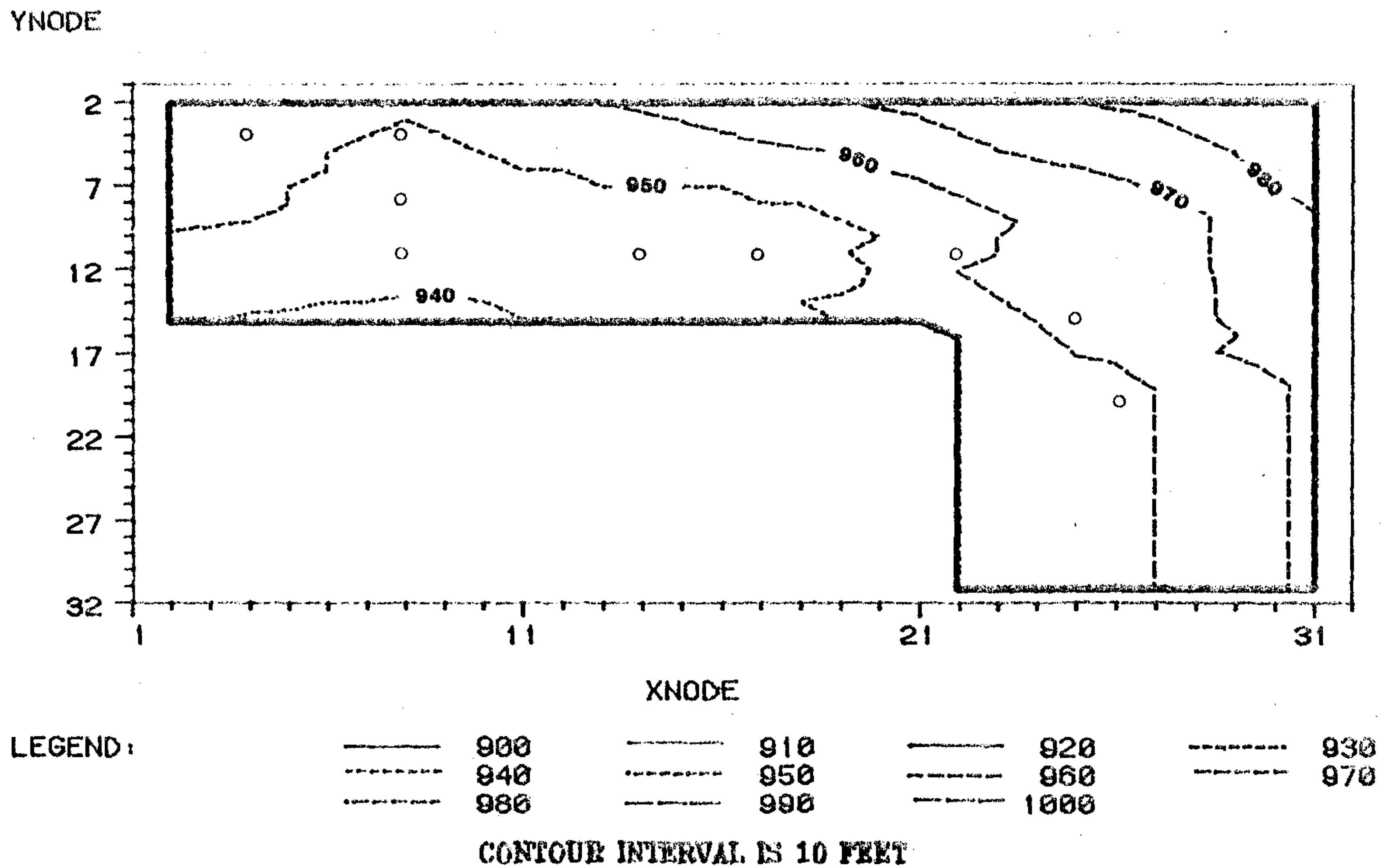


Figure 17

RECH option is used. If RECH is not used, then this card is omitted.

It was decided for this study that the recharge values be entered in the form of a matrix using the first nodes inside of the boundary nodes. Positive numbers are used where the ground water enters the study area and negative numbers are used for nodes where the ground water leaves the study area. Positive and negative values are determined based on the direction of the piezometric gradient (see figures 15 and 17).

Cards 14 and 15

Card 14 is used to set the grid spacing in the x direction and card 15 is used to set the grid spacing in the y direction.

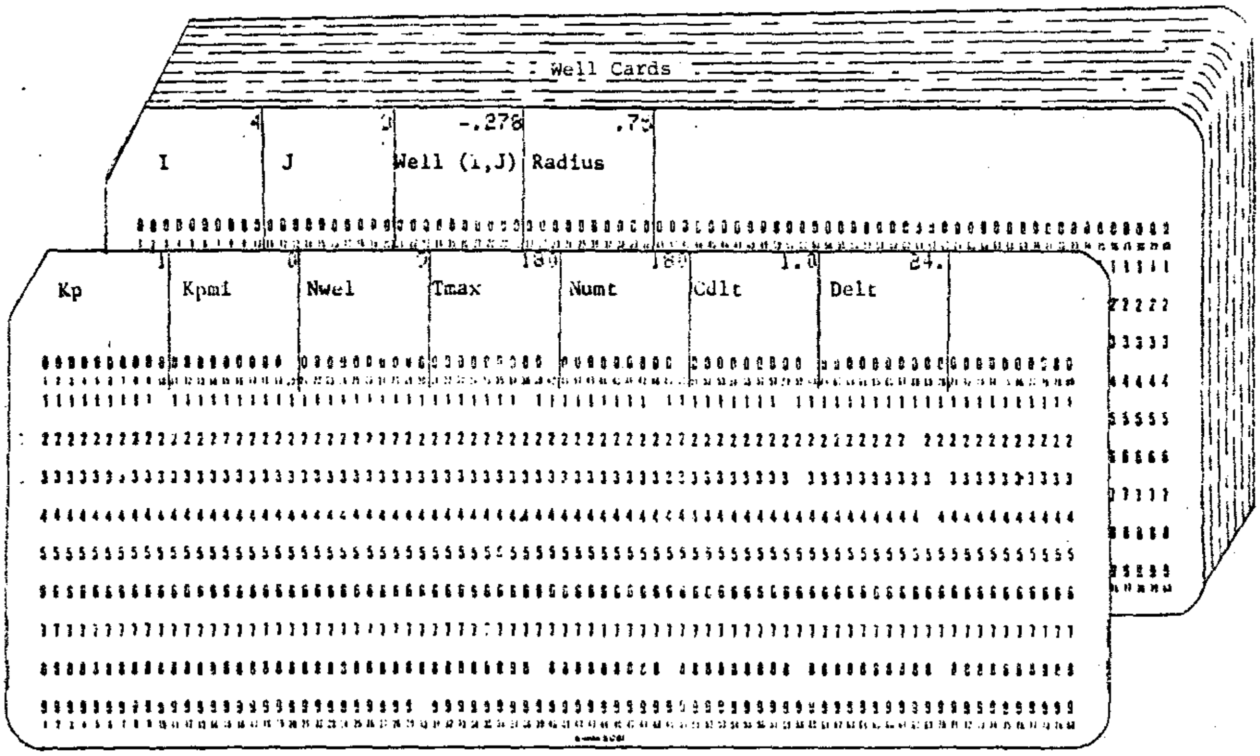
Group IV

Introduction

This group includes the parameter cards used to establish pumping rates for corresponding pumping periods.

Card 1

Field 1-10, on card 1 (see figure 18), is used for the sequence number of the pumping period, ie. pumping period number 2, pumping period number 3 etc.. Field 11-20 is used for the sequence number of the previous pumping period. If the user decides to use this numbering scheme, then card 1 of the group III must be entered at that particular location of the data set. If the present pumping period number is the same as the previous pumping period number, then card 1 of group III is not needed (see Trescott and etals, 1976). This was done in all simulations using multiple pumping periods. Field 21-30 is used to specify the number of wells. If zero wells are used then



Group IV

Figure 18

this number is zero; if there are to be 9 wells pumping during the simulation, then the number 9 is entered. Field 31-40 is used to represent the number of days that these wells will be pumped at a specified pumping rate. Field 41-50 is used to signify the number of time steps for a particular pumping period. This term is referred to as delt. This is dependent on the size of the initial time step in hours. For example, if the time step, is 24 hours, then 30 time steps would represent a pumping period of 30 days. Field 51-60 is used to represent a multiplication factor for delt. This factor is recommended for simulation longer than 180 days. To increase the time step exponentially, values from 1.1 to 1.5 should be used. Field 61-70 is used to represent the initial time step.

Data Set 1

This data set describes the location of the well by x and y coordinates of each pumping node (see figure 18) and the corresponding pumping rate (negative value) in L^3/second. If the drawdown is to be computed at the well, a real well radius is entered which represents the radius of the well.

In appendix XII is an example to demonstrate how multiple pumping periods can be entered and how selected wells can be turned on and off. Various options which can be used in the Trescott and Konikow Models are shown in Tables II and III, respectively.

APPENDIX II

USER'S MANUAL FOR THE KONIKOW MODEL

DATA DECK INSTRUCTIONS

Introduction

The hydrogeologic data input for the Konikow Model are similar to the Trescott Model. The only difference is that the Konikow Model requires chemical transport parameters.

The data input format in the publication by Konikow and Bredehoeft (1978) is presented herein with a more detailed explanation of each input parameter. Field location and matricies of input data formats as well as a complete listing of several data sets in the proper formats are included in the figures and appendices.

Simulation example data sets in appendix XIV, XVI and XVIII have dashed lines and comments which are included in the right margin of the data sets. These are comments used only for clarification in this report and are not to be included in the data set when submitted for execution.

Card 1

<u>Title</u>

This is the title card (see figure 19). This can be any title the user wishes. In the test runs that were made, a descriptive title was used to identify the simulation.

Card 2

This card is used to select options for the desired simulation (see figure 19). The range of the selected options are set in this card.

<u>NTIM</u>

This is in field 1-4. It sets the number of time steps in the pumping period. If the transient solution is used, a simulation larger than 100 times the initial time step will require the use of a time step multiplier in card 3. For example, when the initial time step is 86400 seconds (1 day) and the length of a simulation is 365.25 days (1 year), a time step multiplier is needed. If the time step multiplier is not used, the simulation will end at 100 days instead of 365.25 days.

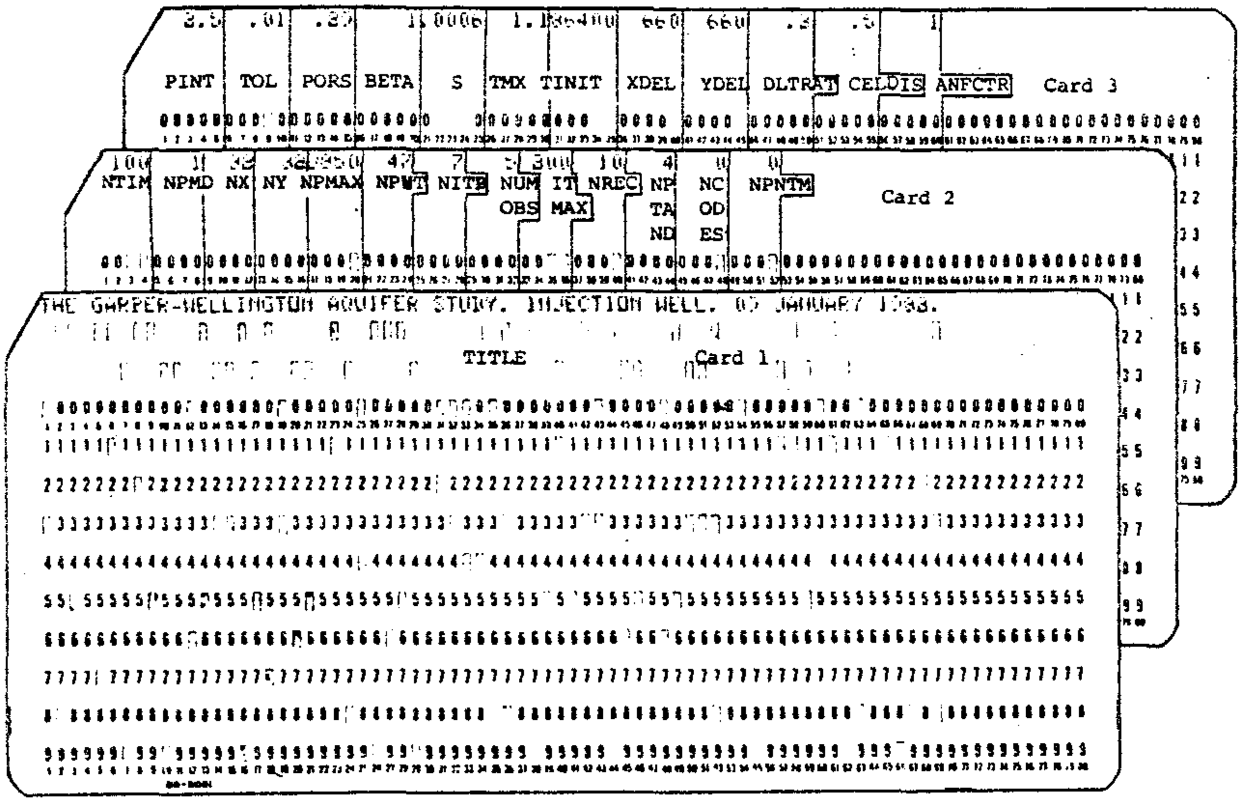


Figure 19. Cards 1, 2 and 3

NPMP

This is in field 5-8. This sets the number of pumping periods. If more than 1 pumping period is used, data set 10 must be completed. Data set 10 starts the second pumping period and subsequent periods thereafter.

NX

This is in field 9-12. It sets the number of nodes in the x direction. If the matrix is larger than 20 nodes, this limit may be increased in the source code by changing all common and dimension statements.

NY

This is in field 13-16. It sets the number of nodes in the y direction. If the matrix is larger than 20 nodes, this limit may be increased in the source code by changing all common and dimension statements.

NPMAX

This is in field 17-20. This sets the maximum number of particles that are to be used in the simulation. The maximum number of particles for the area being simulated can be calculated by using equation 71 in Konikow and Bredehoeft (1978):

$$NPMAX = (NX-2)(NY-2)(NPTPND) + (N_s)(NPTPND) + 250$$

where

NX is the number of nodes in the X direction

NY is the number of nodes in the Y direction

NPTPND is the number of particles per node

N_s is the number of nodes that represent fluid sources, either at wells or at constant head cells, ie. the number of nodes that a landfill occupies.

If the value for NPMAX is larger than 3200, all common and dimension statements in the source code must be changed to accommodate larger values of NPMAX.

NPNT

This is in field 21-24. It specifies the number of times steps before a complete print out of hydraulic and chemical and parameters is printed.

NITP

This is in field 25-28. This sets the number of iterations per time step. The general range is from 4 through 7.

NUMOBS

This is in field 29-32. This specifies the number of observation points where the head, concentration and time are tabulated. This shows how the concentration in a contaminant plume changes for each time step if the observation point is located in the direction of the contaminant plume. These points can be located in any desired node. The source code has a limit of 5 observation points. If more observation points are desired, this limit may be changed in the source code.

ITMAX

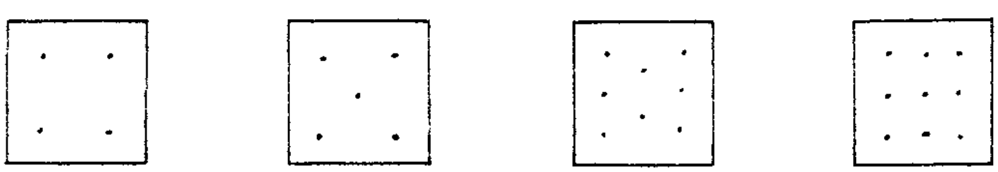
This is in field 33-36. It is the maximum allowable number of iterations in ADIP. The range is usually from 100 through 200.

NREC

This is in field 37-40. It is the number of pumping or injection wells to be specified in data set 2.

NPTPND

This is in field 41-44. It is the number of particles per node. This is part of the method of characteristics which is placing a traceable particle in a node. This particle is moved base on time and velocity of the fluid for each time step. Schematic diagrams for various numbers of particles in each node are shown below:



4 5 8 9

NCODES

This is in field 45-48. It is the number of identification codes. These are used to flag which nodes have a contaminant source and a known concentration rate which is leaching into the aquifer. These nodes are treated as constant head (see appendix XVII, drawdown map, figure40). If there are more than one contaminant source with different concentrations entering the aquifer, these can be entered by assigning two or more codes. The limit is 10 codes (0 - 9). If more than 10 NODEID's are needed, this limit may be increased by changing all common and dimension statements in the source code.

NPNTMV

This is in field 49-52. This is the particle movement interval (IMOV) option to have all chemical paramters printed at the end of a specified time step. 0 specifies to print at the end of each time step.

NPNTVL

This is in field 53-56. This is the option for printing computed velocities at the end of a time step. 0 = do not print; 1 = print for the first time step and 2 = print for all time steps.

NPNTD

This is in field 57-60. This is the option for printing computed dispersion equation coefficients. The option definition is the same for NPNTVL.

NPDELC

This is in field 61-64. This is the option for printing computed changes in concentration. Specify 0 for do not print; 1 to print concentration.

NPNCHV

This is in field 65-68. This is the option to punch velocity data on cards. The option definitions are the same for NPNTVL.

Card 3

This card selects options to be used for a desired simulation (see figure 19). The range of selected options is set in this card.

PINT

This is in field 1-5. This sets the length of a pumping period in years.

TOL

This is in field 6-10. It is the convergence criteria in ADIP. The range is usually TOL ≤ 0.01.

POROS

This is in field 11-15. It is the effective porosity of the aquifer.

BETA

This is in field 16-20. This is the longitudinal dispersivity or characteristic length of the contaminant plume in feet.

S

This is in field 21-25. It is the storage coefficient of the area being simulated. If the transient solution is used, a storage coefficient value is entered. If the steady flow solution is used, then the storage coefficient is set to zero.

TIMX

This is in field 26-30. This is the time increment multiplier for transient flow problems. TIMX is disregarded if the storage coefficient is zero.

TINIT

This is in field 31-35. This sets the size of the initial time step in seconds. TINIT is disregarded if the storage coefficient is set to zero.

XDEL

This is in field 36-40. This sets the width of the finite difference cell in the x direction in units of feet.

YDEL

This is in field 41-45. This sets the width of the finite difference cell in the y direction in units of feet.

DLTRAT

This is in field 46-50. This sets the ratio of the transverse to longitudinal dispersivity.

CELDIS

This is in field 51-55. This is the maximum cell distance per particle move. The range is from 0 to 1.0.

ANFCTR

This is in field 56-60. This is the ratio of the transmissivity in the y direction to the transmissivity in the x direction.

Data Set 1

Value of NUMOBS

This data set is for the location of the observation wells (for field locations, see figure 20). It is the x and y coordinates of observation points. This data set is eliminated if NUMOBS in card 2 is 0 (zero). The maximum number of observation points for this source code is 5. If more than 5 observation points are needed, the common and dimension statements in the source code may be changed.

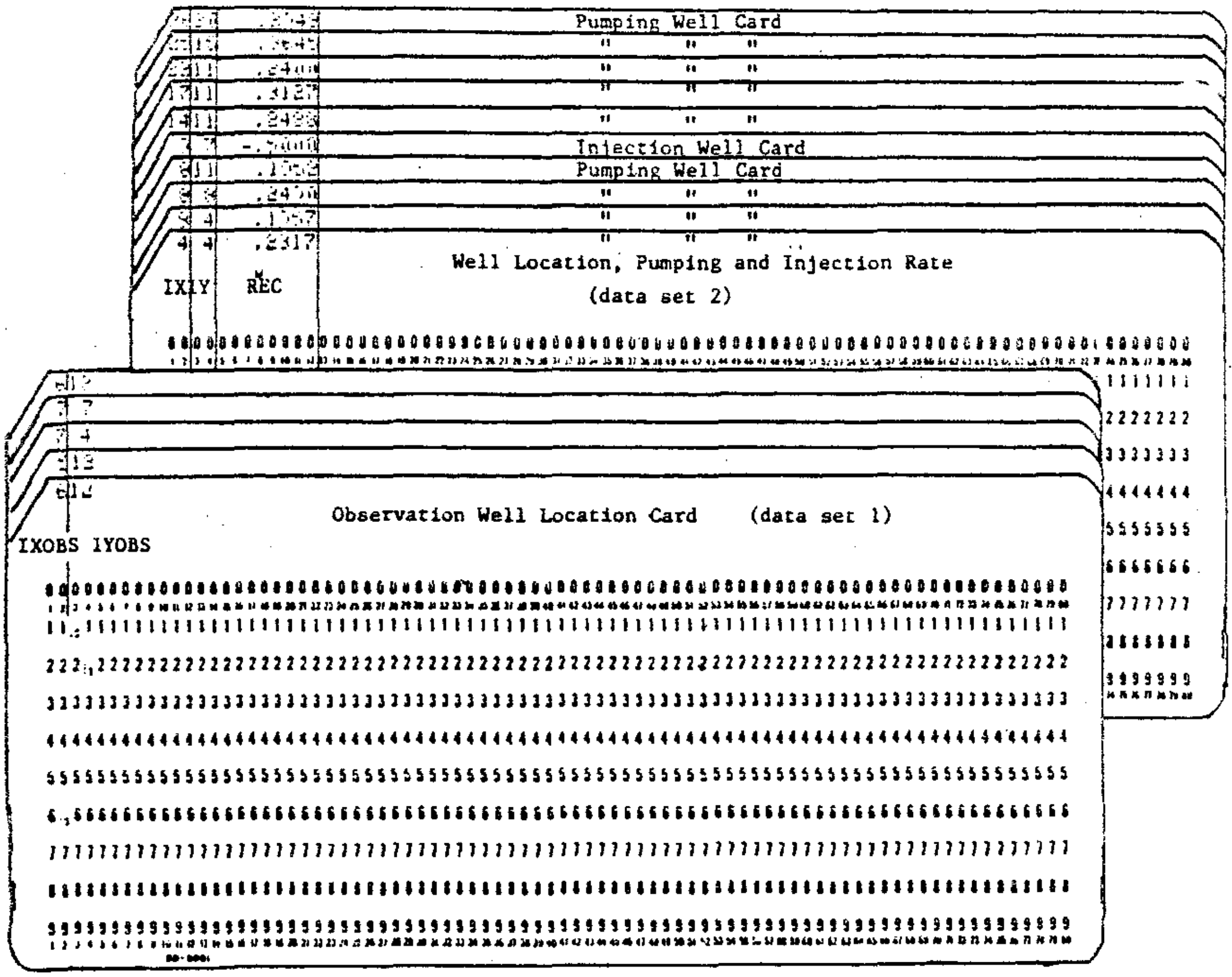


Figure 20. Data Sets 1 and 2

Data Set 2

Value of NREC

This data set is used to provide x and y coordinates of pumping and/or injection wells (for field locations, see figure 20). The pumping rate is a positive value (+) and the injection rate is negative (-) in units of Ft^3/sec.. If an injection well is used, the concentration of the fluid is entered on the same card.

Data Set 3

Transmissivity

This data set is an array for temporary storage of transmissivity data in ft^2/sec. (for field locations, see figure 21). For an anisotropic aquifer, an input value of T_{xx} is used and the program will adjust for anisotropy by multipling T_{yy} by ANFCTR.

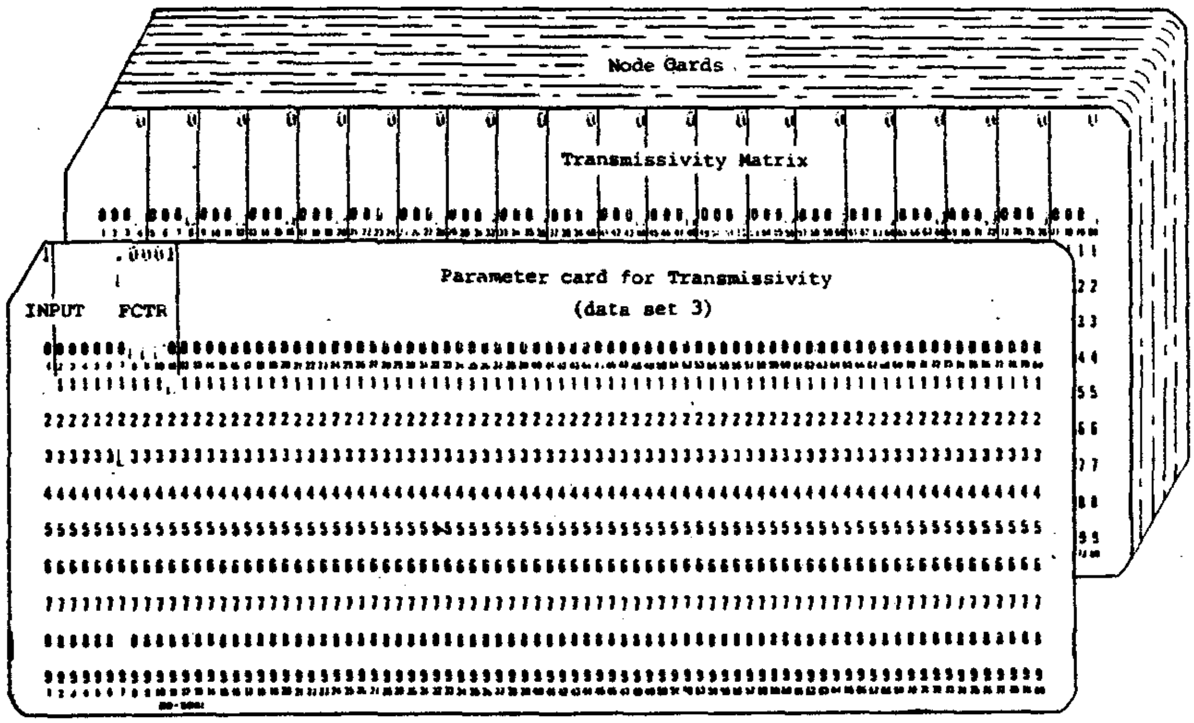


Figure 21. Data Set 3

Data Set 4

__Thickness__

This is the data set for saturated thickness of the aquifer, in feet (for field locations, see figure 22). For the Garber-Wellington Aquifer, this was an average thickness of the fresh water zone within the confined interval.

Data Set 5

__Recharge__

This data set is for the recharge of the aquifer per node (for

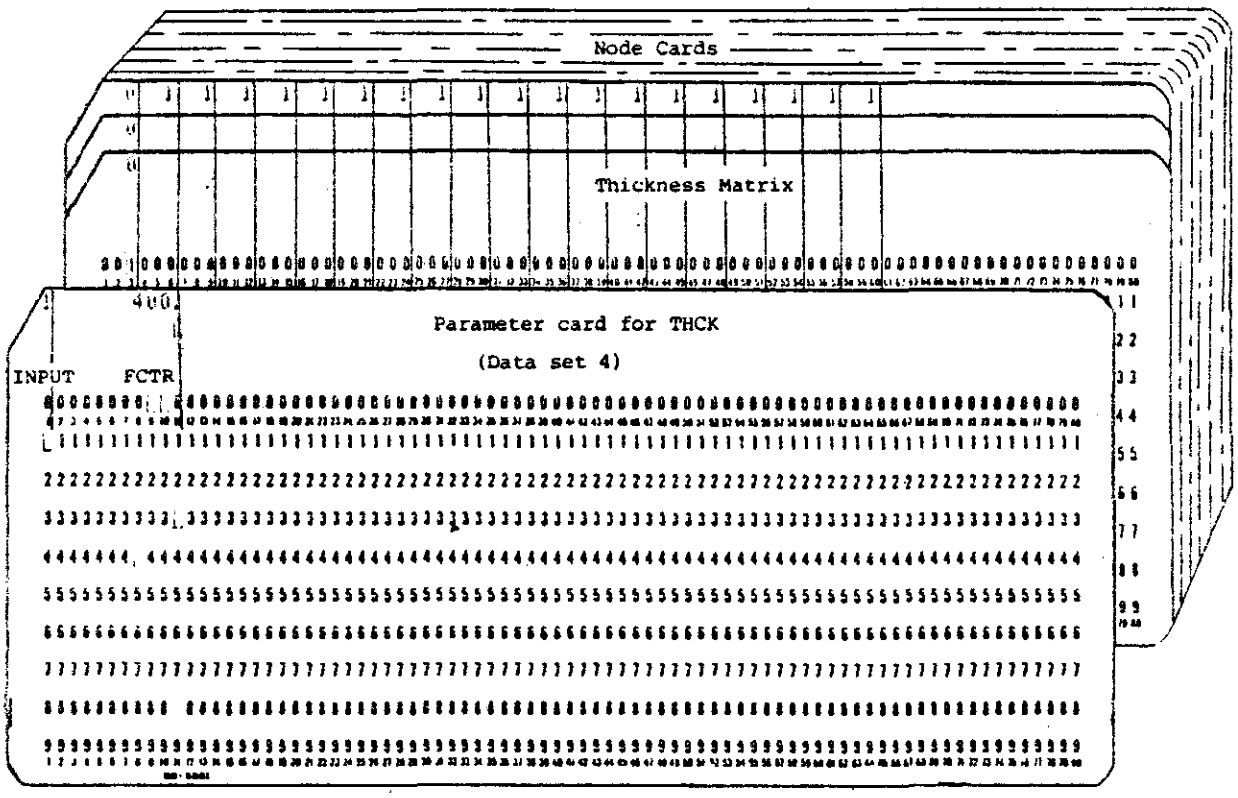


Figure 22. Data Set 4

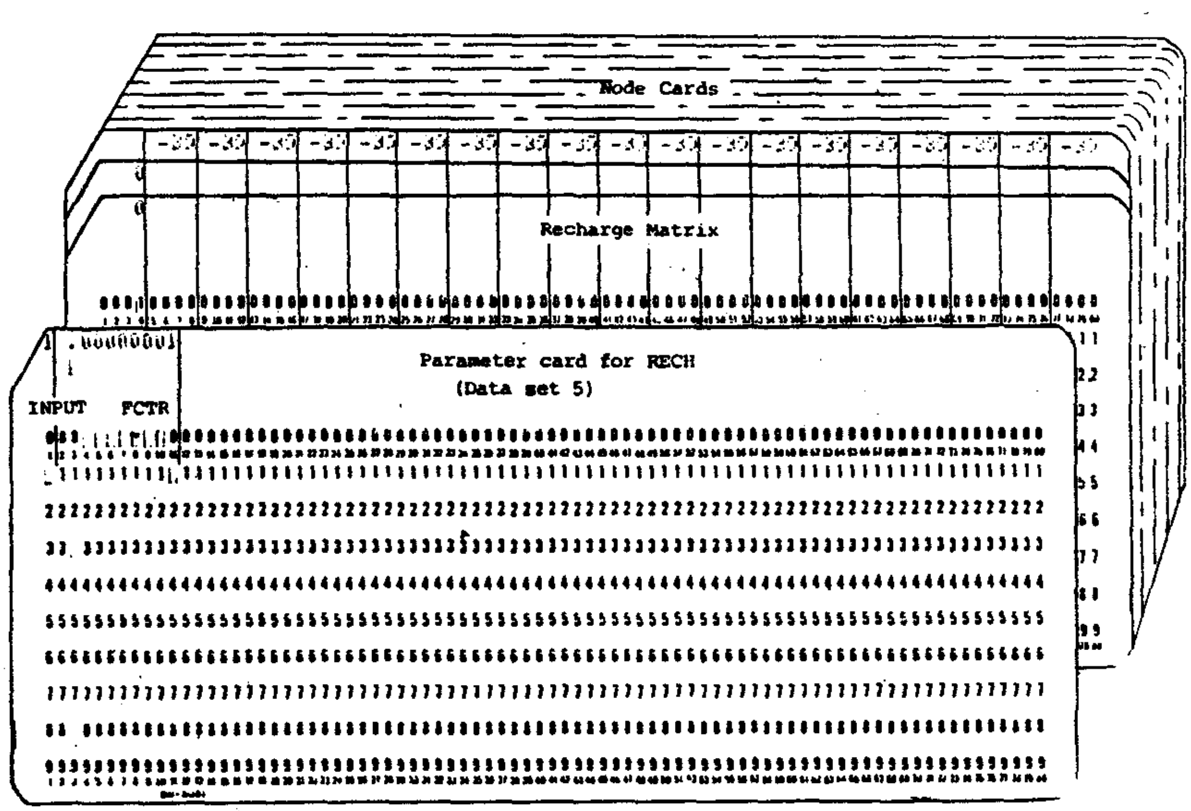


Figure 23. Data Set 5

field locations, see figure 23). Calculation of a recharge rate is discussed earlier in the recharge section. The volume of water entering the simulated area has a negative value (-) where the discharged water has a positive value (+).

Data Set 6

NODEID

This is the node identification matrix (for field locations, see figure 24). This is used to define constant head nodes, other boundary conditions and stresses. This data set was used to describe point sources of contaminants.

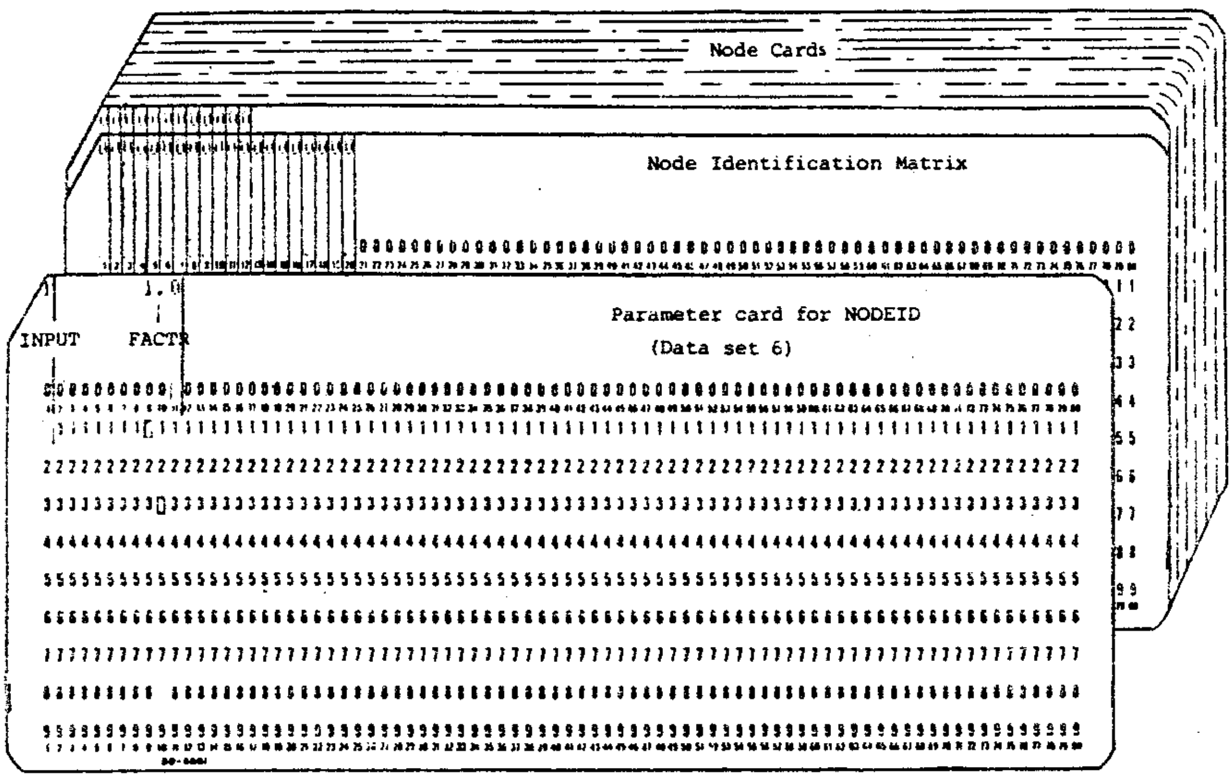


Figure 24. Data Set 6

Data Set 7

Value of NCODES

This data set is used to define the value of NODEID (for field locations, see figure 25). This data set is used only when NCODES in card 2 is greater than 0 (zero). The value of NODEID is equal to ICODE. NODEID values range from 0 through 9. The program sets leakance to equal FCTR1. The concentration of the contaminant entering the ground water (CNRECH) is equal to FCTR3. If OVERRD is nonzero, then RECH is equal to FCTR3. If OVERRD is zero, then RECH in data set 5 is preserved.

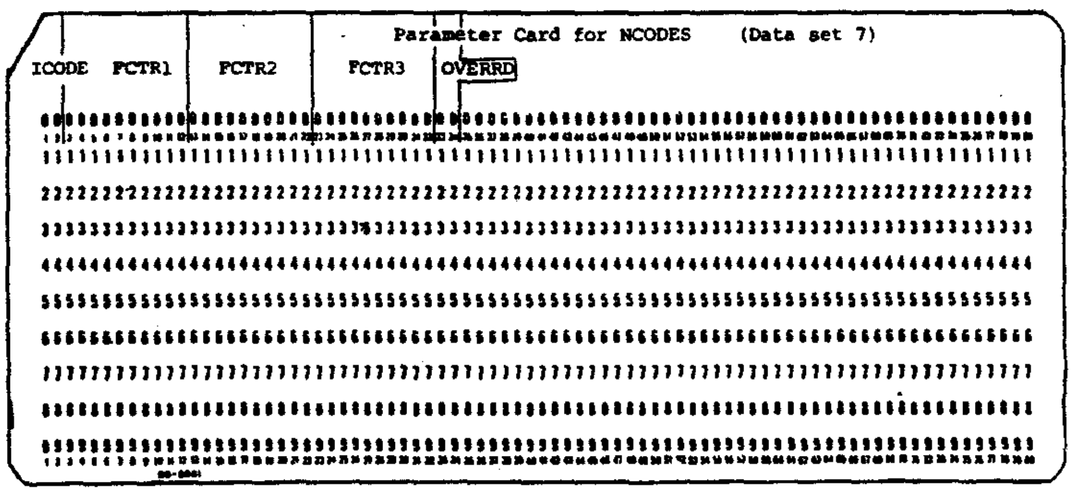


Figure 25. Data Set 7

Data Set 8

Piezometric Surface

This data set is used to describe the initial water table or piezometric surface (for field locations, see figure 26). It also can be used to set a constant head in a stream or source bed. The units are in feet.

Data Set 9

Initial Concentration

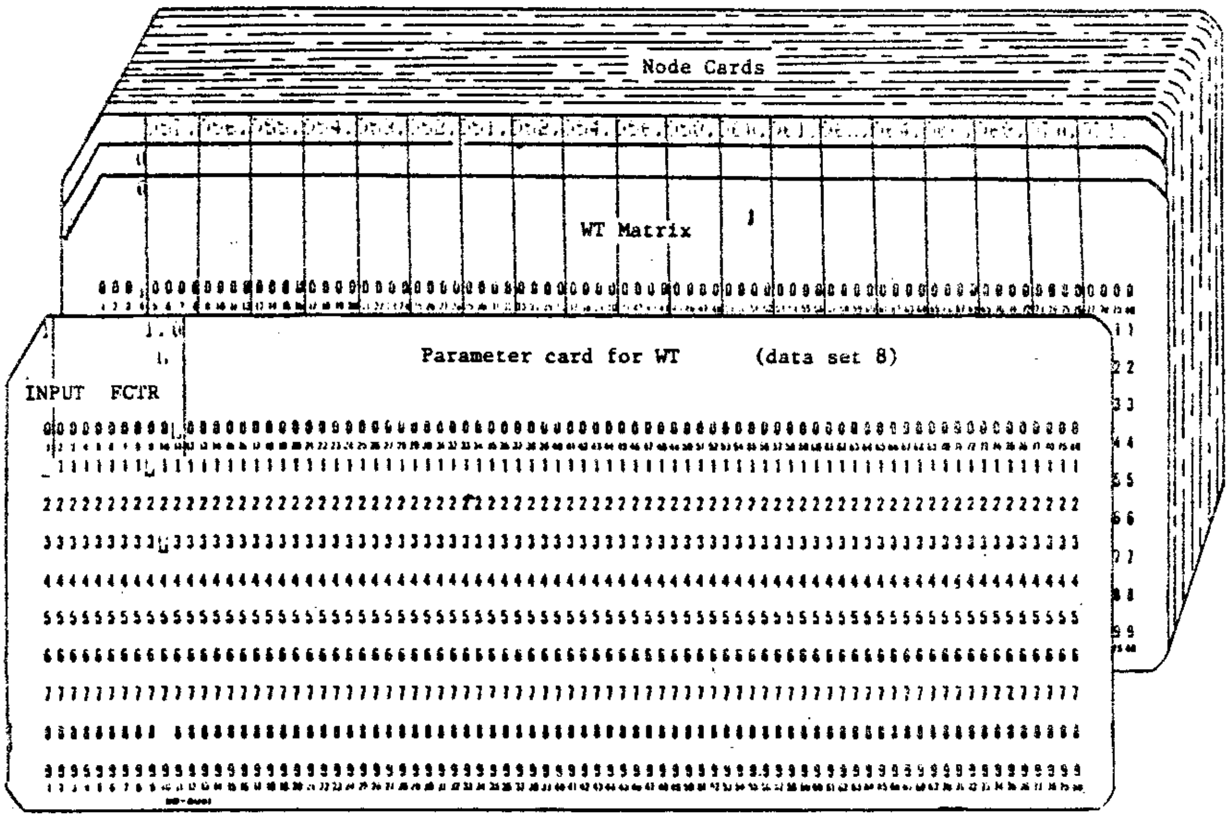


Figure 26. Data Set 8

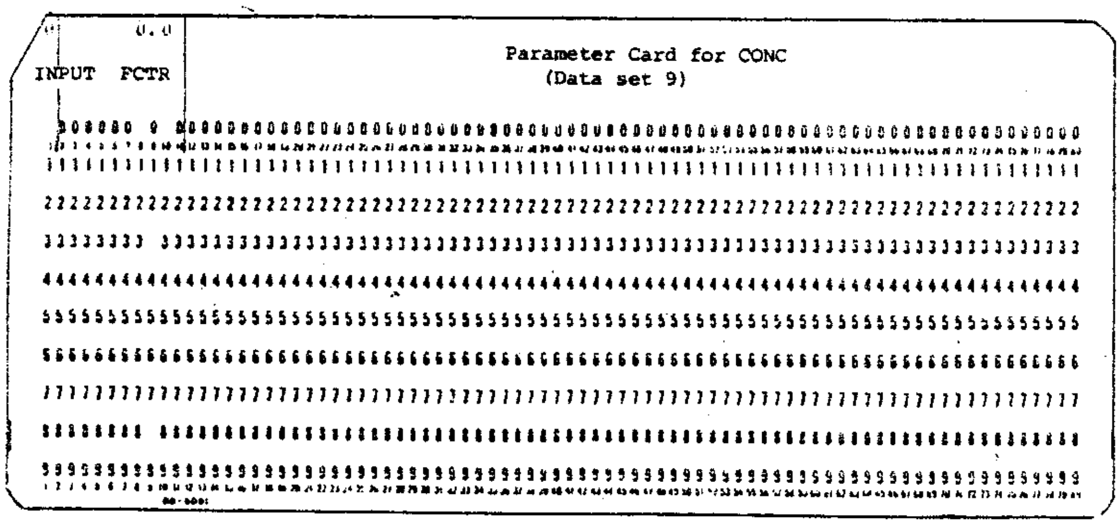


Figure 27. Data Set 9

This data set is used to set the initial concentration of the aquifer (for field locations, see figure 27).

Data Set 10

Revision of NPMP

This data set is used for pumping periods greater than 1 (for field locations, see figure 28). This allows time step parameters, print options and pumpage rates to be modified for each pumping period of the simulation.

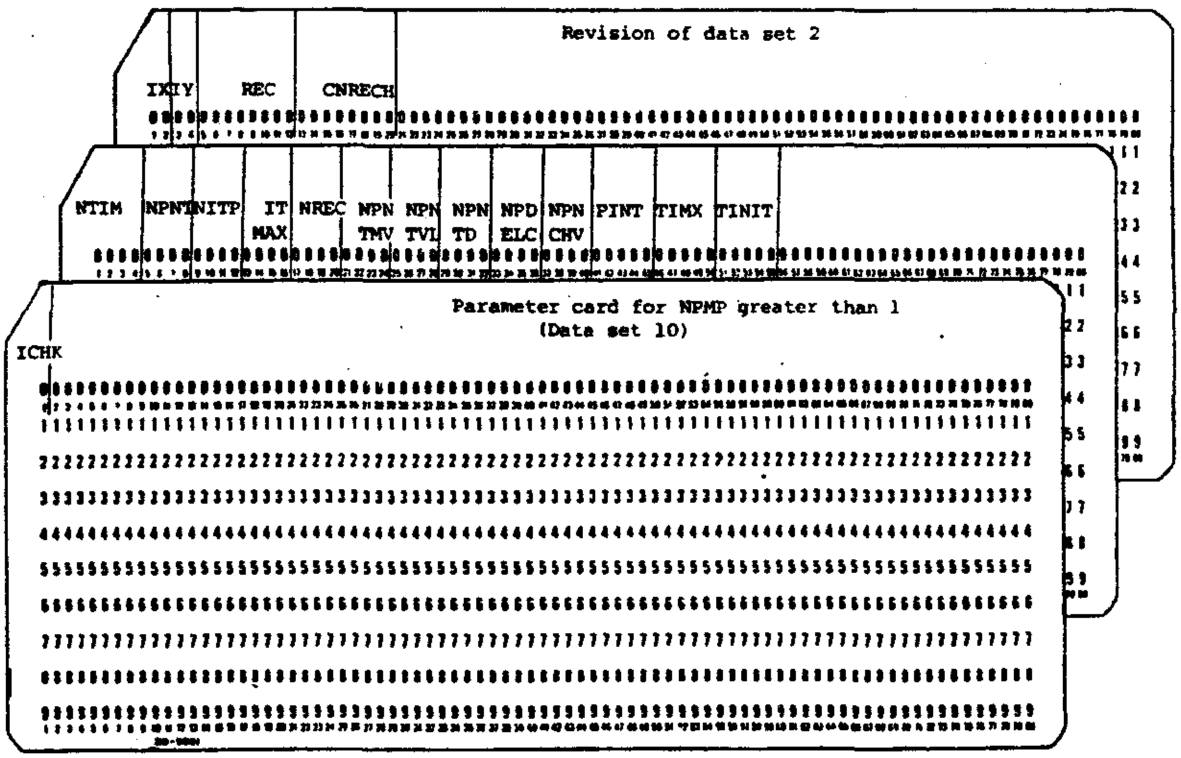


Figure 28. Data Set 10

APPENDIX III

COMPARISION OF SIMULATION EXAMPLE'S

FOR THE KONIKOW MODEL

TABLE V

INPUT PARAMETERS
FOR KONIKOW MODEL

CARD NUMBER	VARIABLE NAME	VALUE SIMULATION INJ.	LANDFILL	BOUNDARY	COMMENTS
1	TITLE				This can be any description the user decides to use.
2	NTIM	100			It is advised to set this to the maximum value if a simulation is longer than 100 days with an initial time step of 86400 seconds.
	NX	32			
	NY	32			All common statements were changed from 20 to 32.
	NPMAX	3850			This limit was changed too.
	NPNT	30	28		Arbitrarily chosen parameter.
	NITP	7			
	NUMOBS	5			
	ITMAX	200			
	NREC	10	9	9	9 pumping wells for no. 1, 9 pumping and 1 injection well for no. 2, 9 pumping wells for no. 3.
	NPTPND	4			
	NCODES	0	1	1	Landfill for no. 1 and boundary source for no. 3.
	NPNTMV	0			
	NPNTVL	0			
	NPNTD	0			
	NPDELC	0			
	NPNCHV	0			
3	PINT	0.5	0.077	0.5	Changes with multiple pumping period
	TOL	0.01			
	POROS	.29			
	BETA	1	100		
	S	.0006			
	TIMX	1.1	1.0	1.1	This increases the time step exponentially.
	TINIT	86400			1 day.
	XDEL	660			
	YDEL	600			Dimensions of each node.
	DLTRAT	0.3			
	CELDIS	0.5	0.5	1.0	
	ANFCTR	1.0			
data set 1	IXOBS, IYOBS				These can be placed in any location and even in nodes that a pumping well.
data set 2	IX,IY, REC, CNRECH				See data for the Trescott Model.
data set 3	INPUT,FCTR, VPRM				See data for the Trescott Model.
data set 4	INPUT,FCTR, VPRM	400			Average fresh water thickness.

TABLE Va

INPUT PARAMETERS
FOR KONIKOW MODEL (cont.)

CARD NUMBER	VARIBLE NAME	VALUE SIMULATION INJ.	LANDFILL	BOUNDARY	COMMENTS
data set 5	INPUT,FCTR, RECH				See data for the Trescott Model.
data set 6	INPUT,FCTR, NODEID	0	1	2	1 is for the landfill, 0 no sources and 2 is for a boundary source.
data set 7	ICODE,FCTR1, FCTR2,FCTR3, OVERRD				Defining the nodeid.
data set 8	INPUT,FCTR, WT				The contoured piezometric surface.
data set 9	INPUT,FCTR, CONC	0			Initial concentration of the aquifer.
data set10					For multiple pumping periods.

APPENDIX IV

MODEL NUMBER 9 DATA SET FOR COMPARISION TO A

NUMERICAL SOLUTION (TRESCOTT MODEL)

```
 ENTER TITLE ?
COMPARISION OF ANALYTICAL  TO NUMRRICALL SOLUTION AT WELL Y-P-6
 ENTER MODEL NUMBER ?
?
9
 ENTER UNITS FOR LENGTH ? ( 2 CHARACTERS)
FT
 ENTER UNITS FOR TIME ? (2 CHARACTERS)
!
READY
CALL 'U11224B.GWTRP.LOAD'
TEMPNAME ASSUMED AS MEMBERNAME

 ENTER TITLE ?
COMPARISION OF AN ANALYTICAL SOLUTION TO THE NUMERICAL SOLUTION
 ENTER MODEL NUMBER ?
?
9
 ENTER UNITS FOR LENGTH ? ( 2 CHARACTERS)
FT
 ENTER UNITS FOR TIME ? (2 CHARACTERS)
DY
 ENTER NUMBER OF X-POSITION POINTS ?
?
[illegible]
 ENTER 20 X-POSITIONS ?(FT)
?

320 960 1600 2240 2880 3520 4160 4800 5440 6080 6720 7360
?
8000 8640 9280 9920 10560 11200 11840 12480
 ENTER NUMBER OF Y-POSITION POINTS ?
?
8
 ENTER  8 Y-POSITIONS ?(FT)
?
320 960 1600 2240 2880 3520 4160 4800
```

```
 ENTER NUMBER OF TIME VARIABLES ?
?
1
 ENTER  1 TIME VARIABLES ?(DY)
?
28
 ENTER NUMBER OF WELLS ?
?
1
 ENTER  1 X-POSITIONS OF WELLS ?(FT)
?
6080
 ENTER  1 Y-POSITIONS OF WELLS ?(FT)
?
2880
 ENTER  1 CHARGE RATES OF WELLS ?(FT**3/DY)
?
25920
 ENTER X-DIRECTION TRANSMISSIVITY TXX= ?(FT**2/DY)
?
368.064
 ENTER Y-DIRECTION TRANSMISSIVITY TYY= ?(FT**2/DY)
?
368.064
 ENTER  STORAGE COEFFICIENT ST = ?
?
.0006
 ENTER X-CORNER NODES OF AQUIFER  X0, X1 = ?(FT X0 <X1)
?
0 12800
 ENTER Y-CORNER NODES OF AQUIFER  Y0, Y1 = ?(FT Y0 <Y1)
?
0 5120
 ENTER INITIAL PIEZOMETRIC HEAD H0= ?(FT)
?
958
 ENTER NUMBER OF SUMMATIONS NMAX =?
?
195
```

APPENDIX V

MODEL NUMBER 9 OUTPUT FOR COMPARISION TO A

NUMERICAL SOLUTION (TRESCOTT MODEL)

COMPARISION OF AN ANALYTICAL SOLUTION TO THE NUMERICAL SOLUTION

```
                    ANALYTIC SOLUTION TO THE UNSTEADY STATE
                 TWO-DIMENSIONAL FLOW EQUATION FOR A CONFINED AQUIFER
            WITH FINITE DIMENSIONS, ONE RECHARGE BOUNDARY AND THREE
                            ZERO FLUX BOUNNDARIES

                             SYSTEM PARAMETERS
                           (UNITS OF FT AND DY)


NUMBER OF SUMMATIONS USED PER SERIES :NMAX = 195
                 STORAGE COEFFICIENT :  ST =  0.600000D-03
  TRANSMISSIVITY IN THE X DIRECTION : TXX =  0.368064D+03 (SQ FT/DY)
  TRANSMISSIVITY IN THE Y DIRECTION : TYY =  0.368064D+03 (SQ FT/DY)
          INITIAL PIEZOMETRIC HEAD :  HO =  0.958000D+03 (FT)


          X-CORNER NODES OF AQUIFER :  X0 =  0.0          (FT)
                                       X1 =  0.128000D+05 (FT)
          Y-CORNER NODES OF AQUIFER :  Y0 =  0.0          (FT)
                                       Y1 =  0.512000D+04 (FT)

         HENCE, THE CONFINED AQUIFER IS RECTANGULAR IN SHAPE, DEFINED
 ALONG SIDE (X0,Y0) - (X0,Y1)   RECHARGE  BOUNDARY(I.E.,DRAWDOWN = 0)
 ALONG      (X0,Y1) - (X1,Y1)   ZERO FLUX
 ALONG      (X1,Y1) - (X1,Y0)   ZERO FLUX
 ALONG      (X1,Y0) - (X0,Y0)   ZERO FLUX


               TOTAL NUMBER OF WELLS: NW =    1

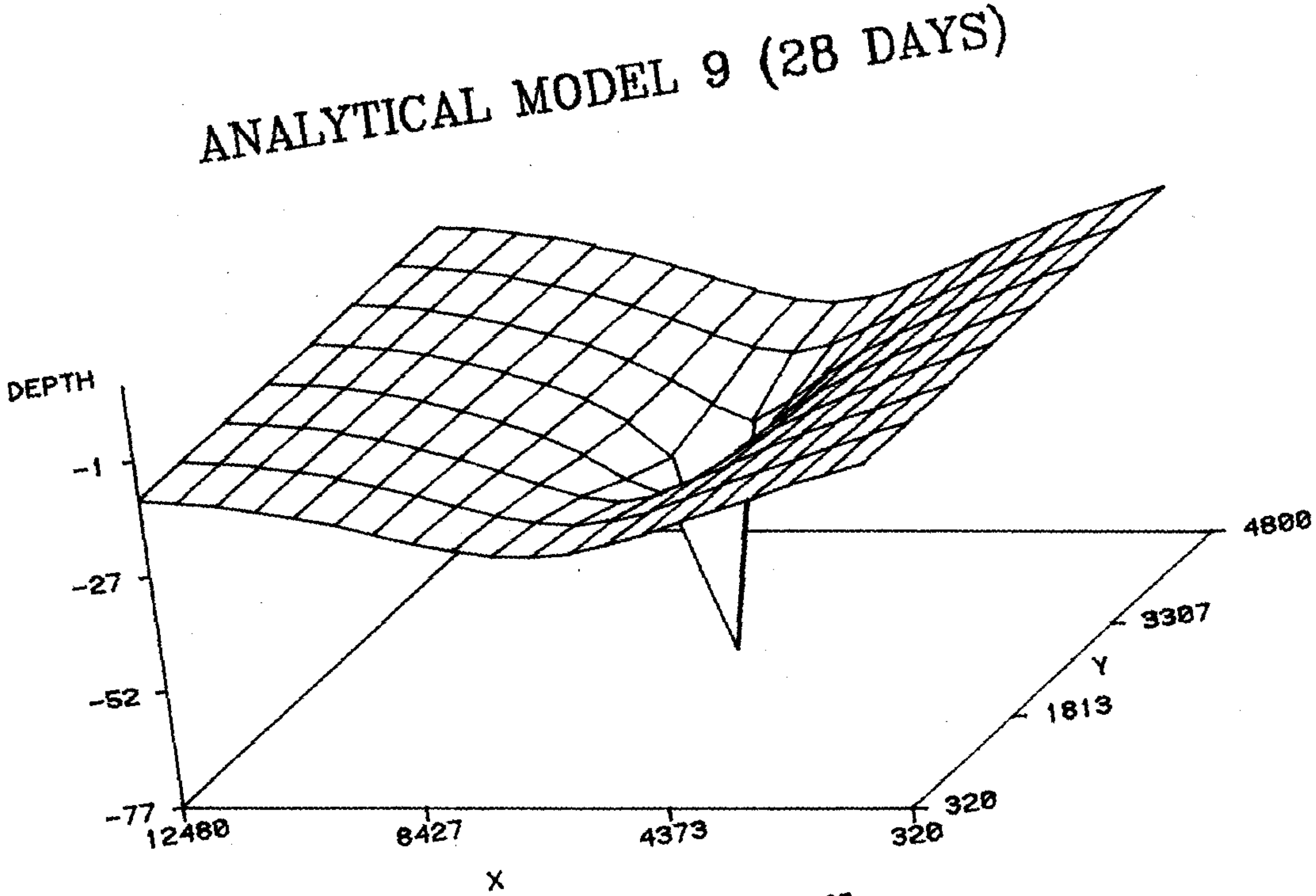
            WELL LOCATION AND ITS PUMPING(-) OR RECHARGE(+) RATE
            I      XW(I)  (FT)    YW(I)  (FT)    GL(I)   (FT**3/DY)

            1      0.6080D+04     0.2880D+04     0.2592D+05



                        TIME =       28.000  DY
                        PLOTTING DRAWDOWN(FT)
```

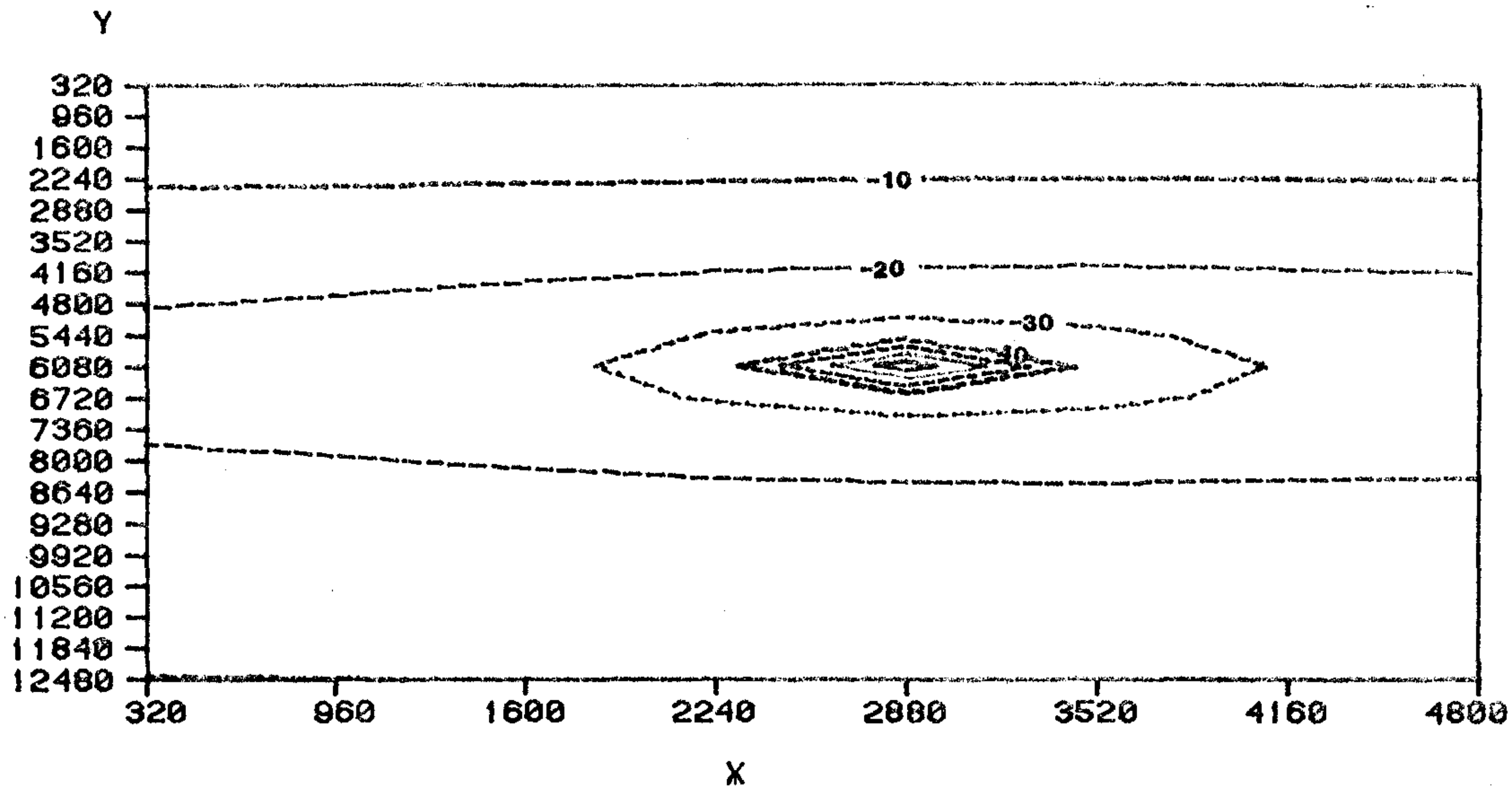
	DISTANCE (FT)							
DISTANCE DOWN (FT) X	320.0	960.0	1600.0	2240.0	2880.0	3520.0	4160.0	4800.0 →Y
320.0	-1.271	-1.287	-1.30[illegible]	-1.320	-1.335	-1.348	-1.356	-1.360
960.0	-3.852	-3.881	-3.930	-3.987	-4.034	-4.076	-4.098	-4.108
1600.0	-6.4[illegible]3	-6.530	-6.627	-6.737	-6.825	-6.896	-6.930	-6.942
2240.0	-9.160	-9.264	-9.459	-9.650	-9.767	-9.876	-9.909	-9.914
2880.0	-11.911	-12.076	-12.407	-12.739	-12.952	-13.091	-13.090	-13.059
3520.0	-14.683	-15.012	-15.571	-16.161	-16.506	-16.640	-16.514	-16.380
4160.0	-17.365	-17.958	-18.950	-20.058	-20.664	-20.676	-20.191	-19.799
4800.0	-19.747	-20.632	-22.479	-24.712	-25.987	-25.463	-24.013	-23.068
5440.0	-21.510	-22.843	-25.720	-30.426	-34.332	-31.277	-27.481	-25.661
6080.0	-22.333	-23.825	-27.[illegible]	-34.725	-76.961	-35.597	-29.196	-26.831
6720.0	-22.040	-23.373	-26.251	-30.960	-34.848	-31.811	-28.015	-26.196
7360.0	-20.841	-21.777	-23.575	-25.811	-27.056	-26.565	-25.118	-24.174
8000.0	-19.090	-19.665	-20.680	-21.792	-22.363	-22.417	-21.934	-21.544
8640.0	-17.143	-17.475	-18.038	-18.635	-18.947	-19.126	-19.005	-18.873
9280.0	-15.247	-15.437	-15.755	-16.095	-16.290	-16.466	-16.472	-16.445
9920.0	-13.552	-13.662	-13.847	-14.053	-14.192	-14.326	-14.370	-14.379
10560.0	-12.141	-12.207	-12.320	-12.451	-12.566	-12.651	-12.700	-12.720
11200.0	-11.058	-11.100	-11.174	-11.262	-11.371	-11.413	-11.456	-11.477
11840.0	-10.327	-10.357	-10.410	-10.475	-10.584	-10.594	-10.632	-10.651
12480.0	-9.959	-9.984	-10.027	-10.082	-10.194	-10.186	-10.221	-10.239



TILT=70 ROTATE=65

Figure 29

ANALYTICAL MODEL 9 (28 DAYS)



LEGEND: DEPTH

-80	-70	-60
-50	-40	-30
-20	-10	0

CONTOUR INTERVAL IS 10 FEET

Figure 30

APPENDIX VI

TRESCOTT MODEL'S DATA SET FOR COMPARISON TO ANALYTICAL SOLUTION NUMBER 9

A BRIEF DESCRIPTION ABOUT THE DATA SETS AND OUTPUT IN THE APPENDICES

Each data set was divided into several groups separated by dashed lines. The comments on the right side identifies the group number or name. These dashed lines and comments must be removed if a simulation is to be run.

Only selected output from each data set is included in this report. The drawdown maps are represented as 3-D plots and contoured maps. In order to enhance the 3-D effect, the 3-D plots are inverted (except for 3-D plots on Model Number 9).

In the Konikow output, the drawdown and concentration maps were modified in order to specially correct the data location by column and rows in the actual format. In the actual format, each row is printed in two lines.

Squares are used to highlight the position of pumping wells on the drawdown maps.

```
//G11370F  JOB (?????,GHD-TR-TRES),'GHD:SUBTRESC',TIME=(5,0),CLASS=K,
//  MSGCLASS=X,NOTIFY=*
/*PASSWORD ?
//TRES    EXEC PGM=TRES1,REGION=600K        PARM=PARMS                         JCL USED AT OSU
//STEPLIB  DD  DISP=SHR,DSNAME=U11370F.TRESCOTT.LOAD
//*T06F001 DD SYSOUT=A
//FT06F001 DD DISP=OLD,DSN=U11370F.TR16TRES.OUTLIST
//FT05F001 DD *
------------------------------------------------------------------------------------------------
                          ---------------  TEST PROBLEM  -----------              GROUP I
                                                                         TITLE AND OPTIONS SELECTED
                     ADI  CHEC                 NUME HEAD
------------------------------------------------------------------------------------------------
      20         8         1        50
                                                                         GROUP II: SCALAR PARAMETERS
       1         7       .01       .01                              5
      1.        1.        1.
------------------------------------------------------------------------------------------------

                                                                         BLANK CARDS

-------------------------------------------------------------------------- GROUP III :ARRAY DATA  ---
     958.                                                                STARTING HEAD (CONSTANT)
------------------------------------------------------------------------------------------------
    .0006        1

  0  -1  -1  -1  -1  -1  -1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0                                          STORAGE COEFFICIENT
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0                                              MATRIX
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0
  0   1   1   1   1   1   1   0

------------------------------------------------------------------------------------------------
  0.00426                                                                TRANSMISSIVITY (CONSTANT)
------------------------------------------------------------------------------------------------
     640.                                                                GRID SPACING
     640.
------------------------------------------------------------------------------------------------
       1         0         1        30        28        1.       24.     GROUP IV
      11         4       -.3        1.                                   PARAMETERS FOR PUMPING
//                                                                       PERIODS
```

APPENDIX VII

SELECTED OUTPUT FOR COMPARISON TO

ANALYTICAL MODEL NUMBER 9

U. S. G. S.

FINITE-DIFFERENCE MODEL
FOR
SIMULATION OF GROUND-WATER FLOW

JANUARY, 1975

****

--------------- TEST PROBLEM -----------

****

SIMULATION OPTIONS: ADI CHEC NUME HEAD

```
                                                   NUMBER OF ROWS =   20
                                                NUMBER OF COLUMNS =    8
NUMBER OF WELLS FOR WHICH DRAWDOWN IS COMPUTED AT A SPECIFIED RADIUS =    1
                          MAXIMUM PERMITTED NUMBER OF ITERATIONS =   50

                                           WORDS OF Y VECTOR USED =   2532

                                        NUMBER OF PUMPING PERIODS =    1
                                     TIME STEPS BETWEEN PRINTOUTS =    7

                                     ERROR CRITERION FOR CLOSURE =    .1000000E-01
                                    STEADY STATE ERROR CRITERION =    .1000000E-01

                                  SPECIFIC STORAGE OF CONFINING BED =   .0
                                         EVAPOTRANSPIRATION RATE =   .0
                                           EFFECTIVE DEPTH OF ET =   1.000000

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

                                                   STARTING HEAD =   958.0000
```

STORAGE COEFFICIENT
MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	0.0
3	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
4	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
5	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
6	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
7	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
8	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
9	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
10	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
11	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
12	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
13	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
14	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
15	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
16	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
17	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
18	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
19	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSMISSIVITY = .4260000E-02

DELX = 640.0000

DELY = 640.0000

SOLUTION BY THE ALTERNATING DIRECTION IMPLICIT PROCEDURE

5 ITERATION PARAMETERS: 0.761D-02 0.258D-01 0.873D-01 0.295D+00 0.100D+01

PUMPING PERIOD NO. 1: 30.00 DAYS

NUMBER OF TIME STEPS= 28

DELT IN HOURS = 24.000

MULTIPLIER FOR DELT = 1.000

1 WELLS

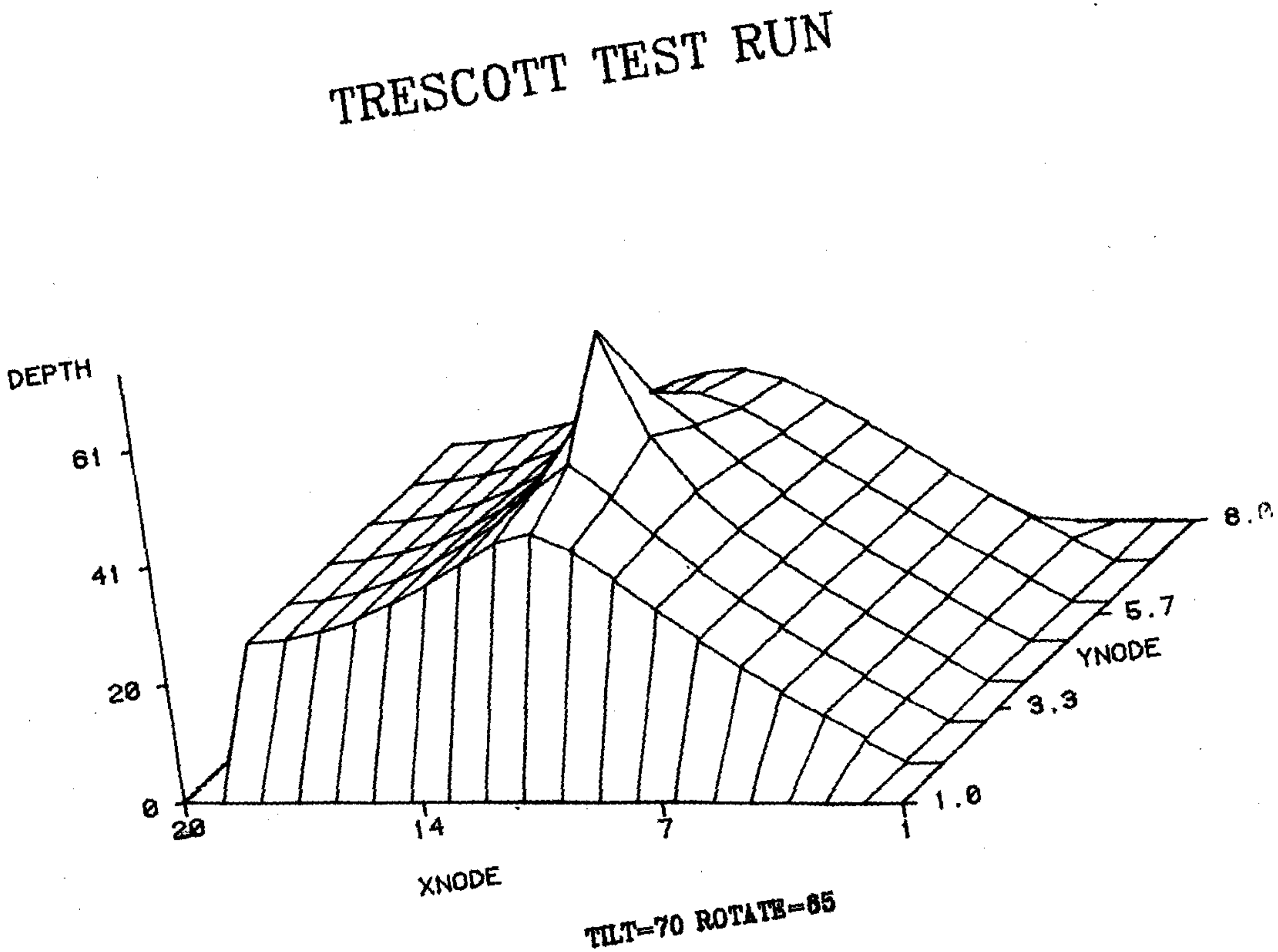
I	J	PUMPING RATE	WELL RADIUS
11	4	-0.30	1.00

DRAWDOWN

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	3.9	3.9	3.9	3.8	3.8	3.8	0.0
4	0.0	7.9	7.8	7.8	7.7	7.7	7.6	0.0
5	0.0	12.0	12.0	11.9	11.8	11.6	11.5	0.0
6	0.0	16.4	16.4	16.3	16.0	15.8	15.6	0.0
7	0.0	21.2	21.2	21.0	20.6	20.1	19.8	0.0
8	0.0	26.3	26.5	26.4	25.6	24.6	24.0	0.0
9	0.0	31.6	32.4	33.0	31.2	29.2	28.0	0.0
10	0.0	36.5	38.9	42.5	37.4	33.4	31.4	0.0
11	0.0	39.6	44.8	61.0	43.2	36.0	33.2	0.0
12	0.0	37.9	40.3	43.8	38.8	34.7	32.7	0.0
13	0.0	34.3	35.1	35.8	34.0	32.0	30.8	0.0
14	0.0	30.6	30.8	30.7	29.9	28.9	28.3	0.0
15	0.0	27.3	27.3	27.1	26.7	26.2	25.9	0.0
16	0.0	24.5	24.5	24.4	24.1	23.8	23.7	0.0
17	0.0	22.5	22.5	22.4	22.2	22.0	22.0	0.0
18	0.0	21.1	21.1	21.0	20.9	20.8	20.8	0.0
19	0.0	20.5	20.4	20.4	20.3	20.2	20.2	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
11	4	1.00	842.14	115.86



(Inverted Image)

Figure 31

TRESCOTT TEST RUN

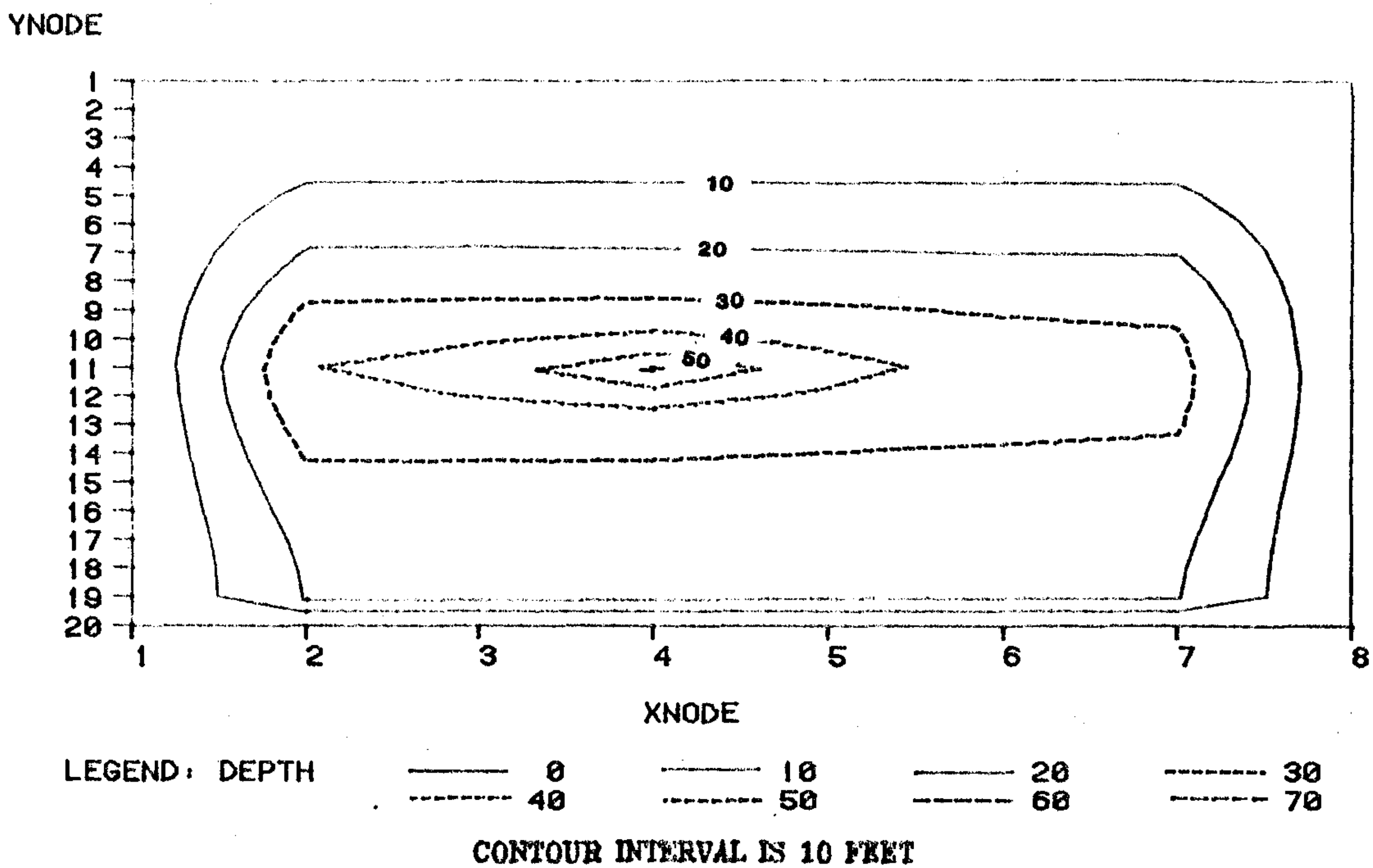


Figure 32

APPENDIX VIII

DATA SET FOR CALIBRATING THE TRESCOTT MODEL

AT WELL Y-6-P

```
//G11370F  JOB (?????,GHD-TR-TRES),'GHD:SUBTRESC',TIME=(5,0),CLASS=K,
//  MSGCLASS=X,NOTIFY=*
/*PASSWORD ?
//TRES  EXEC PGM=LOADER,PARM='SIZE=600K',REGION=600K
//SYSLIB DD DISP=SHR,DSN=SYS1.FORTLIB                                      JCL USED AT OSU
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,DSN=U11370F.TRESCOTT.OBJ
//*T06F001 DD SYSOUT=A
//FT06F001 DD DISP=OLD,DSN=U11370F.TR7TRES.OUTLIST
//FT05F001 DD *
---------------------------------------------------------------------  -------------------------
THE GARBER-WELLINGTON STUDY.  13 JANUARY 1981.
CONFINED AQUIFER WITH CONSTANT HEAD.                                    TITLE AND OPTIONS SELECTED
                         ADI  CHEC                  NUME HEAD
---------------------------------------------------------------------  -------------------------
       32       32        1       50
                                                                        GROUP II
        5        2      0.1      0.1      0.0                        5  SCALAR PARAMETERS
      1.0        1        1
---------------------------------------------------------------------  -------------------------

                                                                        BLANK CARDS

---------------------------------------------------------------------  -------------------------
    10000        1
        0        0        0        0        0        0        0        0      GROUP III
        0        0        0        0        0        0        0        0
        0        0        0        0        0        0        0        0     ARRAY DATA
        0        0        0        0        0        0        0        0
        0      957      956      955      954      953      952      951
      952      954      956      958      960      961      962      964
      966      968      970      971      972      974      976      978
      980      981      982      984      986      988      990        0
        0      957      956      955      954      952      951      950
      951      953      955      956      958      959      960      962
      963      965      968      969      969      970      972      974
      976      977      978      980      982      984      987        0
        0      956      955      954      952      951      950      949
      950      951      953      954      956      957      958      959
      961      962      964      965      969      970      972      974
      976      977      978      980      982      984      987        0
        0      957      953      952      951      950      949      949
      949      950      951      952      954      955      956      956
      957      959      960      962      965      968      970      972
      974      975      976      978      980      983      986        0
        0      953      952      951      951      950      949      948
      948      949      950      950      952      953      953      953
      954      956      957      960      961      964      966      969
      970      972      974      976      979      982      985        0
        0      952      951      950      950      949      948      947
      947      948      948      949      950      950      950      950
      952      953      954      957      959      961      963      965
      967      969      971      974      977      980      983        0
        0      953      952      951      950      949      948      947
      947      947      948      948      949      949      949      949
      950      950      952      954      957      959      961      962
      964      966      969      971      974      978      981        0
        0      952      951      950      949      948      947      947
      947      947      947      948      948      948      948      947
      947      949      950      951      955      957      959      961
      963      965      967      969      972      976      979        0
        0      949      948      948      948      948      946      946
      946      946      946      946      946      946      946      945
      945      947      949      950      953      956      960      961
      963      965      967      969      972      975      977        0
```

STARTING HEAD MATRIX

0	948	947	947	947	946	946	946
946	946	945	945	944	943	943	943
943	945	949	953	956	959	960	962
963	965	967	969	972	974	976	0
0	947	946	946	946	945	945	945
944	944	944	944	943	942	942	942
942	944	947	951	956	960	961	962
963	965	967	969	972	973	975	0
0	945	944	944	944	942	942	942
941	941	942	942	942	943	943	943
944	946	948	952	956	958	961	962
963	965	967	969	971	973	975	0
0	943	943	942	941	940	940	939
939	940	942	943	944	945	946	947
948	950	952	953	955	957	959	962
963	965	967	969	971	973	975	0
0	941	941	939	939	938	937	937
937	939	940	942	943	944	945	946
947	947	950	952	954	956	958	960
963	965	967	969	971	972	975	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	959
961	963	966	969	970	973	975	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	958
960	961	966	969	971	973	975	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	956
958	959	962	965	968	971	974	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	954
956	957	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	953
955	956	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	951
955	956	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	969	972	0
0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	966	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	969	972	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	950
953	957	960	963	966	969	972	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

0.0006 1

0	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	-1	0								
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	-1	0								
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	-1	0								
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	-1	0								
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	-1	0								
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	-1	0								

STORAGE COEFFICIENT

MATRIX

```
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1  -1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1  -1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1  -1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1  -1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1  -1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1  -1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1  -1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1   1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1   1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1   1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   1   1   1   1   1   1   1   1   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0
-------------------------------------------------------------------------------   ----------------------
  0.0001       1

 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0      TRANSMISSIVITY
 0  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38  38
38  38  38  38  38  38  38  38  38  38  38   0           MATRIX
 0
 0   0   0  38  38  38  38  38  38  38  38   0
 0
 0   0   0  38  38  38  38  38  38  38  38   0
 0
 0   0   0  38  38  38  38  38  38  38  38   0
 0
 0   0   0  38  38  38  38  38  38  38  38   0
 0
```

```
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
      0
      0   0   0  38  38  38  38  38  38  38  38   0
   0
   0
-------------------------------------------------------------------------------   ------------------------
        660.                                                                        GRID SPACING
        660.
-------------------------------------------------------------------------------   ------------------------
           1          0          1       .021          2        1.0         .5
          11         14     -.7532        .75
           2          2          1       .017          2        1.0        .42      GROUP IV
          11         14     -.7397        .75                                       PARAMETERS THAT CHANGE
           3          3          1     .00556          2        1.0       .133      WITH EACH PUMPING PERIOD
          11         14     -.6795        .75
           4          4          1     .00208          2        1.0        .05
          11         14     -.5838        .75
           5          5          1     .00208          2        1.0        .05
          11         14     -.5280        .75
```

APPENDIX IX

SELECTED OUTPUT FOR CALIBRATING THE TRESCOTT MODEL

AT WELL Y-6-P

U. S. G. S.

FINITE-DIFFERENCE MODEL
FOR
SIMULATION OF GROUND-WATER FLOW

JANUARY, 1975

****

THE GARBER-WELLINGTON STUDY. 13 JANUARY 1981. CONFINED AQUIFER WITH CONSTANT HEAD.

****

SIMULATION OPTIONS: ADI CHEC NUME HEAD

NUMBER OF ROWS = 32
NUMBER OF COLUMNS = 32
NUMBER OF WELLS FOR WHICH DRAWDOWN IS COMPUTED AT A SPECIFIED RADIUS = 1
MAXIMUM PERMITTED NUMBER OF ITERATIONS = 50

WORDS OF Y VECTOR USED = 14820

NUMBER OF PUMPING PERIODS = 5
TIME STEPS BETWEEN PRINTOUTS = 2

ERROR CRITERION FOR CLOSURE = .1000000
STEADY STATE ERROR CRITERION = .1000000

SPECIFIC STORAGE OF CONFINING BED = .0
EVAPOTRANSPIRATION RATE = .0
EFFECTIVE DEPTH OF ET = 1.000000

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

STARTING HEAD MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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								
2	0.0	957.0	956.0	955.0	954.0	953.0	952.0	951.0	952.0	954.0	956.0	958.0	960.0	961.0	962.0	964.0	966.0	968.0	970.0	971.0
	972.0	974.0	976.0	978.0	980.0	981.0	982.0	984.0	986.0	988.0	990.0	0.0								
3	0.0	957.0	956.0	955.0	954.0	952.0	951.0	950.0	951.0	953.0	955.0	956.0	958.0	959.0	960.0	962.0	963.0	965.0	968.0	969.0
	969.0	970.0	972.0	974.0	976.0	977.0	978.0	980.0	982.0	984.0	987.0	0.0								
4	0.0	956.0	955.0	954.0	952.0	951.0	950.0	949.0	950.0	951.0	953.0	954.0	956.0	957.0	958.0	959.0	961.0	962.0	964.0	965.0
	969.0	970.0	972.0	974.0	976.0	977.0	978.0	980.0	982.0	984.0	987.0	0.0								
5	0.0	957.0	953.0	952.0	951.0	950.0	949.0	949.0	949.0	950.0	951.0	952.0	954.0	955.0	956.0	956.0	957.0	959.0	960.0	962.0
	965.0	968.0	970.0	972.0	974.0	975.0	976.0	978.0	980.0	983.0	986.0	0.0								
6	0.0	953.0	952.0	951.0	951.0	950.0	949.0	948.0	948.0	949.0	950.0	950.0	952.0	953.0	953.0	953.0	954.0	956.0	957.0	960.0
	961.0	964.0	966.0	969.0	970.0	972.0	974.0	976.0	979.0	982.0	985.0	0.0								
7	0.0	952.0	951.0	950.0	950.0	949.0	948.0	947.0	947.0	948.0	948.0	949.0	950.0	950.0	950.0	950.0	952.0	953.0	954.0	957.0
	959.0	961.0	963.0	965.0	967.0	969.0	971.0	974.0	977.0	980.0	983.0	0.0								
8	0.0	953.0	952.0	951.0	950.0	949.0	948.0	947.0	947.0	947.0	948.0	948.0	949.0	949.0	949.0	949.0	950.0	950.0	952.0	954.0
	957.0	959.0	961.0	962.0	964.0	966.0	969.0	971.0	974.0	978.0	981.0	0.0								
9	0.0	952.0	951.0	950.0	949.0	948.0	947.0	947.0	947.0	947.0	947.0	948.0	948.0	948.0	948.0	947.0	947.0	949.0	950.0	951.0
	955.0	957.0	959.0	961.0	963.0	965.0	967.0	969.0	972.0	976.0	979.0	0.0								
10	0.0	949.0	948.0	948.0	948.0	948.0	946.0	946.0	946.0	946.0	946.0	946.0	946.0	946.0	946.0	945.0	945.0	947.0	949.0	950.0
	953.0	956.0	960.0	961.0	963.0	965.0	967.0	969.0	972.0	975.0	977.0	0.0								
11	0.0	948.0	947.0	947.0	947.0	946.0	946.0	946.0	946.0	946.0	945.0	945.0	944.0	943.0	943.0	943.0	943.0	945.0	949.0	953.0
	956.0	959.0	960.0	962.0	963.0	965.0	967.0	969.0	972.0	974.0	976.0	0.0								
12	0.0	947.0	946.0	946.0	946.0	945.0	945.0	945.0	944.0	944.0	944.0	944.0	943.0	942.0	942.0	942.0	942.0	944.0	947.0	951.0
	956.0	960.0	961.0	962.0	963.0	965.0	967.0	969.0	972.0	973.0	975.0	0.0								
13	0.0	945.0	944.0	944.0	944.0	942.0	942.0	942.0	941.0	941.0	942.0	942.0	942.0	943.0	943.0	943.0	944.0	946.0	948.0	952.0
	956.0	958.0	961.0	962.0	963.0	965.0	967.0	969.0	971.0	973.0	975.0	0.0								
14	0.0	943.0	943.0	942.0	941.0	940.0	940.0	939.0	939.0	940.0	942.0	943.0	944.0	945.0	946.0	947.0	948.0	950.0	952.0	953.0
	955.0	957.0	959.0	962.0	963.0	965.0	967.0	969.0	971.0	973.0	975.0	0.0								
15	0.0	941.0	941.0	939.0	939.0	938.0	937.0	937.0	937.0	939.0	940.0	942.0	943.0	944.0	945.0	946.0	947.0	947.0	950.0	952.0
	954.0	956.0	958.0	960.0	963.0	965.0	967.0	969.0	971.0	972.0	975.0	0.0								
16	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	959.0	961.0	963.0	966.0	969.0	970.0	973.0	975.0	0.0								
17	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	958.0	960.0	961.0	966.0	969.0	971.0	973.0	975.0	0.0								
18	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	956.0	958.0	959.0	962.0	965.0	968.0	971.0	974.0	0.0								
19	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	954.0	956.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
20	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	953.0	955.0	956.0	960.0	963.0	966.0	969.0	972.0	0.0								
21	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	951.0	955.0	956.0	960.0	963.0	966.0	969.0	972.0	0.0								

22	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
23	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
24	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
25	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
26	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
27	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	950.0	953.0	957.0	960.0	963.0	966.0	966.0	972.0	0.0								
28	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
29	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
30	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
31	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	950.0	953.0	957.0	960.0	963.0	966.0	969.0	972.0	0.0								
32	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								

STORAGE COEFFICIENT MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	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										
2	0.0	0.00060	0.00060	0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060
	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060	-0.00060
	-0.00060	-0.00060	-0.00060	0.0										
3	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
4	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
5	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
6	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
7	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
8	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
9	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
10	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
11	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
12	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
13	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
14	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
15	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
16	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
17	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
18	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
19	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
20	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
21	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
22	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
23	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
24	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
25	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
26	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
27	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	-0.00060	0.0										
28	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.0										
29	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.0										
30	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	0.00060	0.00060	0.00060	0.00060	0.00060
	0.00060	0.00060	0.00060	0.0										
31	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	0.00060	0.00060	0.00060	0.000 0	0.00060
	0.00060	0.00060	0.00060	0.0										
32	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

TRANSMISSIVITY MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	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										
2	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
3	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
4	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
5	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
6	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
7	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
8	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
9	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
10	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
11	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
12	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
13	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
14	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
15	0.0	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	[illegible]	0.00380
	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
16	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
17	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
18	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
19	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
20	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
21	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
22	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
23	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
24	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
25	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
26	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
27	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
28	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
29	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
30	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
31	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	0.00380	0.00380	0.00380	0.00380	0.00380
	0.00380	0.00380	0.00380	0.0										
32	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

DELX = 660.0000

DELY = 660.0000

SOLUTION BY THE ALTERNATING DIRECTION IMPLICIT PROCEDURE

5 ITERATION PARAMETERS: 0.274D-02 0.120D-01 0.524D-01 0.229D+00 0.100D+01

PUMPING PERIOD NO. 1: 0.02 DAYS

NUMBER OF TIME STEPS= 2

DELT IN HOURS = 0.252

MULTIPLIER FOR DELT = 1.000

1 WELLS

I	J	PUMPING RATE	WELL RADIUS
11	14	-0.75	0.75

DRAWDOWN

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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								
2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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								
3	0.0	0.1	0.1	0.1	0.2	-0.0	-0.0	-0.1	-0.1	0.1	0.1	-0.0	0.1	0.0	-0.0	0.1	-0.1	-0.0	0.2	0.2
	-0.2	-0.3	-0.2	-0.2	-0.2	-0.2	-0.3	-0.2	-0.2	-0.3	0.0	0.0								
4	0.0	-0.0	0.1	0.1	-0.1	-0.0	-0.0	-0.2	-0.0	-0.1	0.0	-0.1	0.1	0.0	0.0	-0.0	0.1	-0.0	0.0	-0.2
	0.4	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.1	-0.0	0.0	0.0								
5	0.0	0.5	-0.2	-0.1	-0.1	-0.1	-0.1	0.0	-0.1	-0.0	-0.0	-0.1	0.1	0.0	0.1	-0.1	-0.1	0.0	-0.1	-0.1
	0.0	0.2	0.1	0.1	0.2	0.1	-0.0	-0.0	-0.1	-0.0	0.0	0.0								
6	0.0	-0.1	-0.0	-0.1	0.1	0.1	0.0	-0.1	-0.1	0.0	0.1	-0.2	0.1	0.1	0.0	-0.1	-0.1	0.0	-0.1	0.1
	-0.2	-0.0	-0.1	0.2	-0.1	0.0	0.0	-0.0	0.1	0.1	0.0	0.0								
7	0.0	-0.1	-0.1	-0.2	-0.0	-0.0	-0.1	-0.1	-0.1	0.0	-0.1	-0.0	-0.0	-0.1	-0.1	-0.2	0.0	-0.0	-0.2	0.1
	-0.0	-0.1	-0.1	-0.1	-0.0	-0.0	-0.1	0.0	0.1	0.0	0.0	0.0								
8	0.0	0.2	0.1	0.1	0.1	0.1	0.0	-0.1	-0.0	-0.1	0.1	-0.1	0.1	0.0	-0.0	-0.0	0.1	-0.2	-0.0	-0.1
	0.1	-0.0	0.0	-0.2	-0.1	-0.2	0.0	-0.1	-0.1	0.0	0.0	0.0								
9	0.0	0.2	0.1	0.1	0.0	-0.0	-0.1	0.0	0.1	0.0	-0.0	0.2	0.1	0.1	0.1	-0.1	-0.2	0.1	-0.1	-0.3
	0.1	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.0	0.0	0.0								
10	0.0	-0.1	-0.2	-0.1	0.0	0.2	-0.2	-0.1	-0.0	-0.0	-0.0	-0.0	0.0	0.4	0.1	-0.1	-0.1	-0.0	-0.0	-0.3
	-0.3	-0.3	0.2	-0.1	-0.0	-0.0	-0.0	-0.1	-0.0	0.1	0.0	0.0								
11	0.0	0.1	-0.1	0.0	0.1	-0.1	0.1	0.1	0.1	0.2	-0.0	0.1	0.3	9.7	0.2	-0.1	-0.2	-0.2	0.1	0.3
	0.2	0.2	-0.1	0.1	-0.1	-0.0	-0.0	-0.1	0.1	0.0	0.0	0.0								
12	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.0	0.1	0.1	0.1	0.0	0.2	-0.1	-0.1	-0.3	-0.2	-0.2	-0.2
	0.1	0.3	0.1	0.0	-0.1	-0.0	-0.0	-0.0	0.2	-0.1	0.0	0.0								
13	0.0	0.1	-0.1	0.0	0.2	-0.2	-0.0	0.0	-0.1	-0.2	-0.1	-0.2	-0.2	-0.0	-0.1	-0.2	-0.2	-0.1	-0.3	-0.0
	0.2	-0.1	0.2	0.0	-0.1	-0.0	0.0	-0.0	-0.0	-0.0	0.0	0.0								
14	0.0	0.0	0.1	0.0	-0.0	-0.1	0.1	-0.1	-0.1	-0.1	0.2	0.1	0.2	0.2	0.2	0.3	0.2	0.4	0.4	0.1
	0.0	-0.0	-0.1	0.2	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0								
15	0.0	-0.1	-0.0	-0.3	-0.1	-0.1	-0.2	-0.1	-0.2	-0.0	-0.2	-0.0	-0.0	-0.1	-0.0	-0.0	-0.0	-0.3	-0.1	-0.1
	-0.1	-0.1	-0.1	-0.1	0.2	0.1	0.1	0.0	0.1	-0.2	0.0	0.0								
16	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	-0.1	-0.0	-0.1	-0.0	0.1	-0.2	0.1	0.0	0.0								
17	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	-0.1	0.1	-0.2	0.3	0.3	0.2	0.1	0.0	0.0								
18	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	-0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.0	0.0	0.0								
19	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	-0.2	-0.0	-0.2	-0.1	-0.1	-0.1	-0.1	0.0	0.0								
20	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	-0.1	-0.0	-0.2	0.0	-0.0	-0.0	-0.0	0.0	0.0								
21	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	-0.3	0.2	-0.2	0.0	0.0	-0.0	-0.0	0.0	0.0								

22	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	-0.2	-0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0								
23	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	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0								
24	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	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0								
25	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	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0								
26	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	-0.2	-0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0								
27	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	-0.2	-0.1	0.1	0.0	0.0	0.1	-0.6	0.0	0.0								
28	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	-0.2	-0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.0								
29	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	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0								
30	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	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0								
31	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	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0								
32	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								

HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
11	14	0.75	818.08	124.92

APPENDIX X

TRESCOTT MODEL'S DATA SET TO DEMONSTRATE MULTIPLE PUMPING PERIODS

TRESCOTT MODEL

This data set has 6 pumping periods representing individual months beginning with February, 1981 through July, 1981

```
//G11370F  JOB (?????,GHD-TR-TRES),'GHD:SUBTRESC',TIME=(5,0),CLASS=K,
//  MSGCLASS=X,NOTIFY=*
/*PASSWORD ?
//TRES  EXEC PGM=LOADER,PARM='SIZE=600K',REGION=600K
//SYSLIB DD DISP=SHR,DSN=SYS1.FORTLIB                                   JCL USED AT OSU
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,DSN=U11370F.TRESCOTT.OBJ
/*FT06F001 DD SYSOUT=A
//FT06F001 DD DISP=OLD,DSN=U11370F.TR15TRES.OUTLIST
//FT05F001 DD *
------------------------------------------------------------------------------------------
YUKON WELL FIELD (TRESCOTT-PINDER-LARSON)  SEPTEMBER 26,1981. TWENTYTHIRD
SIMULATION, CONFINED AQUIFER WITH RECHARGE.                             TITLE AND OPTIONS USED
                RECH ADI  CHEC                NUME HEAD
------------------------------------------------------------------------------------------
       10        11        9       50
                                                                        GROUP II
        6        15        1       0.1       0.0                      5 SCALAR PARAMETERS
      1.0         1        1
------------------------------------------------------------------------------------------

                                                                        BLANK CARDS

--------------------------------------------------------------------------- GROUP III: ARRAY DATA -
      952                                                               STARTING HEAD (CONSTANT)
------------------------------------------------------------------------------------------
   0.0006         1

  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0                                       STORAGE COEFFICIENT
  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0                                           MATRIX
  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0

------------------------------------------------------------------------------------------
  0.00426         1

  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0                                       TRANSMISSIVITY
  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0                                          MATRIX
  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  0

------------------------------------------------------------------------------------------
  1.0E-11         1

  0 185 185 185 185 185 185 185 185 185  0
  0-185                             185  0                              RECHARGE  MATRIX
  0-185                             185  0
  0-185                             185  0
  0-185                             185  0
  0-185                             185  0
  0-185                             185  0
  0-185-185-185-185-185-185-185-185-185  0

------------------------------------------------------------------------------------------
     2640                                                               GRID SPACING
     2640
----------------------------------------------------------------------------GROUP IV: PUMPING-------
```

1	0	9	28	28	1.0	24.	
4	3	-.203	.75				
4	4	-.201	.75				
5	4	-.287	.75				PUMPING PERIOD 1
6	4	-.212	.75				
6	6	-.260	.75				
6	7	-.306	.75				
6	8	-.229	.75				
7	9	-.273	.75				
8	9	-.211	.75				

2	2	9	31	31	1.0	24.	
4	3	-.144	.75				
4	4	-.129	.75				
5	4	-.245	.75				
6	4	-.121	.75				PUMPING PERIOD 2
6	6	-.139	.75				
6	7	-.062	.75				
6	8	-.126	.75				
7	9	-.260	.75				
8	9	-.212	.75				

3	3	9	30	30	1.0	24.	
4	3	-.176	.75				
4	4	-.067	.75				
5	4	-.150	.75				
6	4	-.115	.75				
6	6	-.245	.75				PUMPING PERIOD 3
6	7	-.382	.75				
6	8	-.266	.75				
7	9	-.405	.75				
8	9	-.309	.75				

4	4	9	31	31	1.0	24.	
4	3	-.227	.75				
4	4	-.188	.75				
5	4	-.292	.75				
6	4	-.213	.75				PUMPING PERIOD 4
6	6	-.220	.75				
6	7	-.272	.75				
6	8	-.048	.75				
7	9	-.307	.75				
8	9	-.252	.75				

5	5	9	30	30	1.0	24.	
4	3	-.278	.75				
4	4	-.338	.75				
5	4	-.283	.75				
6	4	-.238	.75				PUMPING PERIOD 5
6	6	-.317	.75				
6	7	-.434	.75				
6	8	-.417	.75				
7	9	-.493	.75				
8	9	-.437	.75				

6	6	9	31	31	1.0	24.	
4	3	-.335	.75				
4	4	-.251	.75				
5	4	-.323	.75				
6	4	-.272	.75				
6	6	-.312	.75				PUMPING PERIOD 6
6	7	-.420	.75				
6	8	-.354	.75				
7	9	-.449	.75				
8	9	-.348	.75				

APPENDIX XI

SELECTED OUTPUT FROM THE TRESCOTT MODEL,

DEMONSTRATING MULTIPLE PUMPING PEROIDS

U. S. G. S.

FINITE-DIFFERENCE MODEL
FOR
SIMULATION OF GROUND-WATER FLOW

JANUARY, 1975

****

YUKON WELL FIELD (TRESCOTT-PINDER-LARSON) SEPTEMBER 26,1981. TWENTYTHIRD SIMULATION, CONFINED AQUIFER WITH RECHARGE.

****

SIMULATION OPTIONS: RECH ADI CHEC NUME HEAD

NUMBER OF ROWS = 10
NUMBER OF COLUMNS = 11
NUMBER OF WELLS FOR WHICH DRAWDOWN IS COMPUTED AT A SPECIFIED RADIUS = 9
MAXIMUM PERMITTED NUMBER OF ITERATIONS = 50

WORDS OF Y VECTOR USED = 1772

NUMBER OF PUMPING PERIODS = 6
TIME STEPS BETWEEN PRINTOUTS = 15

ERROR CRITERION FOR CLOSURE = 1.000000
STEADY STATE ERROR CRITERION = .1000000

SPECIFIC STORAGE OF CONFINING BED = .0
EVAPOTRANSPIRATION RATE = .0
EFFECTIVE DEPTH OF ET = 1.000000

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

STARTING HEAD = 952.0000

STORAGE COEFFICIENT
MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
3	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
4	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
5	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
6	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
7	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
8	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
9	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSMISSIVITY MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
3	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
4	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
5	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
6	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
7	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
8	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
9	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

AREAL RECHARGE RATE
MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.0
3	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
4	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
5	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
6	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
7	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
8	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
9	0.0	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DELX = 2640.000

DELY = 2640.000

SOLUTION BY THE ALTERNATING DIRECTION IMPLICIT PROCEDURE

5 ITERATION PARAMETERS: 0.305D-01 0.729D-01 0.175D+00 0.418D+00 0.100D+01

PUMPING PERIOD NO. 1: 28.00 DAYS

NUMBER OF TIME STEPS= 28

DELT IN HOURS = 24.000

MULTIPLIER FOR DELT = 1.000

9 WELLS

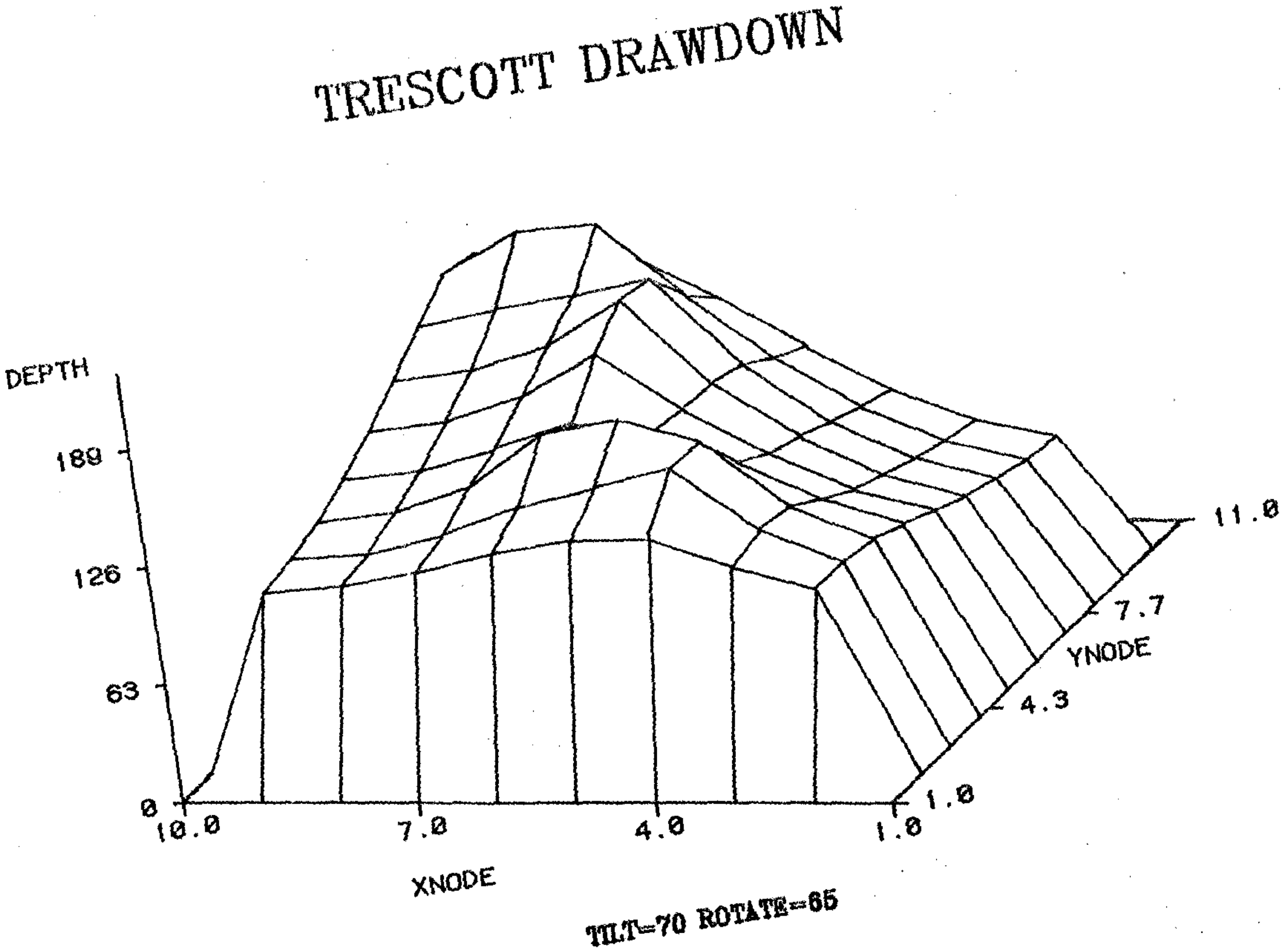
I	J	PUMPING RATE	WELL RADIUS
4	3	-0.20	0.75
4	4	-0.20	0.75
5	4	-0.29	0.75
6	4	-0.21	0.75
6	6	-0.26	0.75
6	7	-0.31	0.75
6	8	-0.23	0.75
7	9	-0.27	0.75
8	9	-0.21	0.75

DRAWDOWN

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	98.6	99.1	96.0	88.6	80.8	73.8	67.8	62.9	59.8	0.0
3	0.0	111.0	115.6	112.9	101.5	92.2	85.0	78.8	73.0	68.6	0.0
4	0.0	125.9	149.1	148.3	122.1	110.9	104.7	98.4	91.0	85.0	0.0
5	0.0	124.9	137.9	160.4	137.5	134.5	134.2	128.6	117.2	107.8	0.0
6	0.0	117.9	127.7	152.1	143.3	165.3	179.2	174.5	151.1	134.3	0.0
7	0.0	108.3	113.1	123.3	128.7	141.5	154.4	166.2	188.7	157.3	0.0
8	0.0	100.6	103.3	109.7	117.1	128.0	141.1	157.7	185.3	162.3	0.0
9	0.0	96.9	99.5	104.9	112.5	122.6	135.0	148.8	161.5	158.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
4	3	0.75	720.38	231.62
4	4	0.75	741.82	210.18
5	4	0.75	712.06	239.94
6	4	0.75	732.91	219.09
6	6	0.75	709.80	242.20
6	7	0.75	669.34	282.66
6	8	0.75	690.29	261.71
7	9	0.75	652.63	299.37
8	9	0.75	680.91	271.09



(Inverse Image)

Figure 33

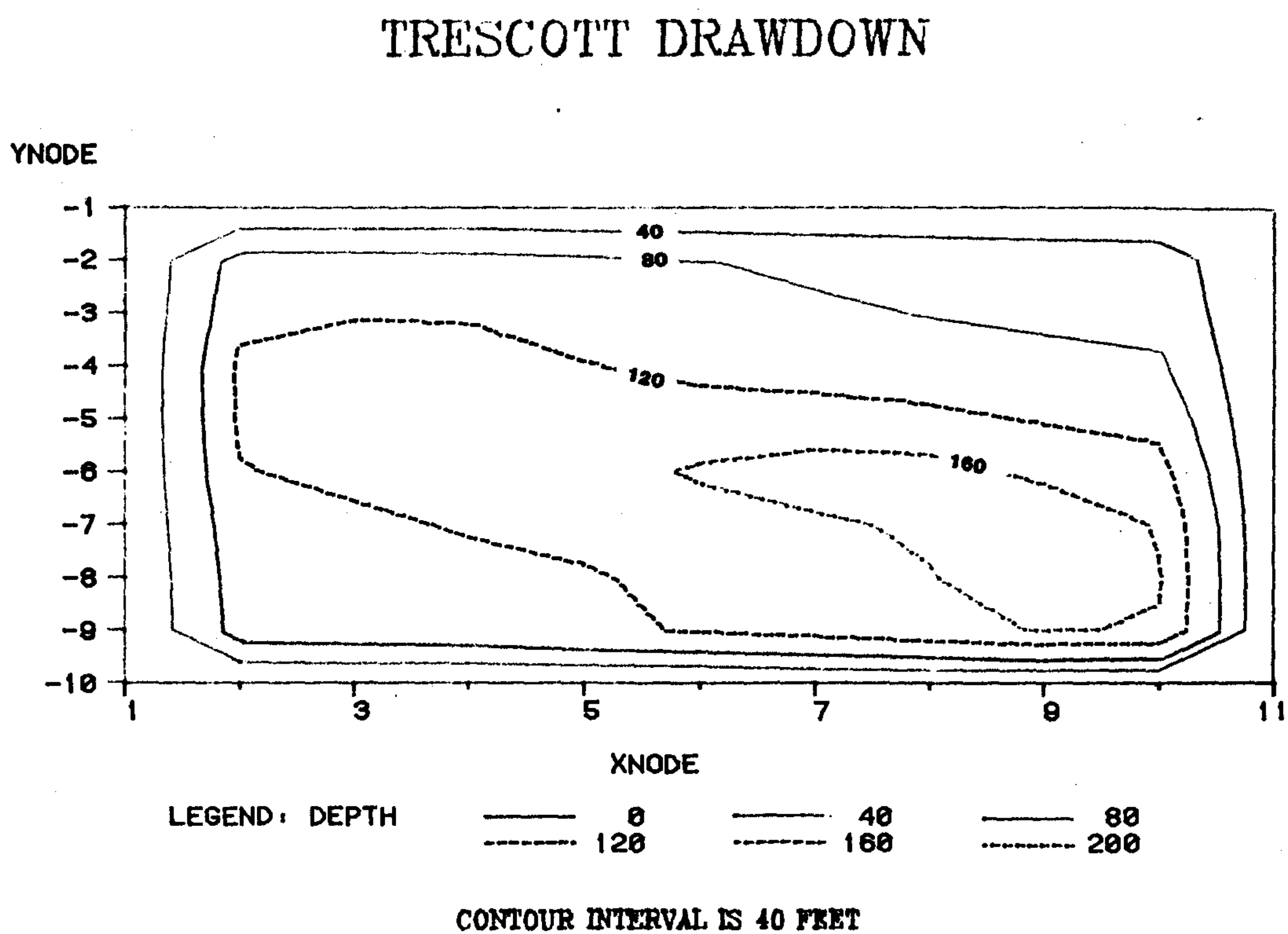

TRESCOTT DRAWDOWN
YNODE
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
40
80
120
160
1
3
5
7
9
11
XNODE
LEGEND: DEPTH
0
40
80
120
160
200
CONTOUR INTERVAL IS 40 FEET

Figure 34

APPENDIX XII

TRESCOTT MODEL'S DATA SET DEMONSTRATING

MULTIPLE PUMPING PERIODS

TRESCOTT MODEL

This data set has 4 pumping periods. The first two correspond to the months May, 1981 and June, 1981, respectively. The second two pumping periods demonstrate how to selectively turn pumping wells on and off in the simulation.

```
//G11370F  JOB (?????,GHD-TR-TRES),'GHD;SUBTRESC',TIME=(5,0),CLASS=K,
//  MSGCLASS=X,NOTIFY=*
/*PASSWORD ?
//TRES  EXEC PGM=LOADER,PARM='SIZE=600K',REGION=600K
//SYSLIB DD DISP=SHR,DSN=SYS1.FORTLIB                                     JCL USED AT OSU
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,DSN=U11370F.TRESCOTT.OBJ
/*FT06F001 DD SYSOUT=A
//FT06F001 DD DISP=OLD,DSN=U11370F.TR5TRES.OUTLIST
//FT05F001 DD *
------------------------------------------------------------------------------------------
YUKON WELL FIELD (TRESCOTT-PINDER-LARSON)  SEPTEMBER 26,1981. TWENTYTHIRD
SIMULATION, CONFINED AQUIFER WITH RECHARGE.                                TITLE AND OPTIONS SELECTED
                    RECH ADI  CHEC                 NUME HEAD
------------------------------------------------------------------------------------------
       10        11        9        50
                                                                          GROUP II
        4        15        1       0.1       0.0                        5 SCALAR PARAMETERS
      1.0         1        1
------------------------------------------------------------------------------------------

                                                                          BLANK CARDS

------------------------------------------------------------------------- GROUP III: ARRAY DATA -
      952                                                                 STARTING HEAD (CONSTANT)
------------------------------------------------------------------------------------------
   0.0006         1

   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0                            STORAGE COEFFICIENT
   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0                                MATRIX
   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0

------------------------------------------------------------------------------------------
   0.00426        1

   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0                            TRANSMISSIVITY
   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0                              MATRIX
   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0
   0   1   1   1   1   1   1   1   1   1   0

------------------------------------------------------------------------------------------
   1.0E-11        1

   0 185 185 185 185 185 185 185 185 185   0                            RECHARGE MATRIX
   0-185                               185   0
   0-185                               185   0
   0-185                               185   0
   0-185                               185   0
   0-185                               185   0
   0-185                               185   0
   0-185-185-185-185-185-185-185-185-185   0

------------------------------------------------------------------------------------------
     2640                                                                 GRID SPACING
     2640
---------------------------------------------------------------------------GROUP IV-----------
```

1	0	9	31	31	1.0	24.	
4	3	-.227	.75				PARAMETERS THAT CHANGE
4	4	-.188	.75				WITH PUMPING PERIODS
5	4	-.292	.75				
6	4	-.213	.75				
6	6	-.220	.75				PUMPING PERIOD 1
6	7	-.272	.75				
6	8	-.048	.75				
7	9	-.307	.75				
8	9	-.252	.75				
2	2	9	30	30	1.0	24.	
4	3	-.278	.75				
4	4	-.338	.75				
5	4	-.283	.75				
6	4	-.238	.75				PUMPING PERIOD 2
6	6	-.317	.75				
6	7	-.434	.75				
6	8	-.417	.75				
7	9	-.493	.75				
8	9	-.437	.75				
3	3	4	2	2	1.0	24.	
4	4	-.338	.75				PUMPING PERIOD 3
6	4	-.238	.75				
6	7	-.434	.75				
7	9	-.493	.75				
4	4	5	2	2	1.0	24.	
4	3	-.278	.75				
5	4	-.283	.75				PUMPING PERIOD 4
6	6	-.317	.75				
6	8	-.417	.75				
8	9	-.437	.75				

APPENDIX XIII

SELECTED OUTPUT FROM THE TRESCOTT MODEL,

DEMONSTRATING MULTIPLE PUMPING PERIODS

U. S. G. S.

FINITE-DIFFERENCE MODEL
FOR
SIMULATION OF GROUND-WATER FLOW

JANUARY, 1975

****

YUKON WELL FIELD (TRESCOTT-PINDER-LARSON) SEPTEMBER 26,1981. TWENTYTHIRD SIMULATION, CONFINED AQUIFER WITH RECHARGE.

****

SIMULATION OPTIONS: RECH ADI CHEC NUME HEAD

NUMBER OF ROWS =	10
NUMBER OF COLUMNS =	11
NUMBER OF WELLS FOR WHICH DRAWDOWN IS COMPUTED AT A SPECIFIED RADIUS =	9
MAXIMUM PERMITTED NUMBER OF ITERATIONS =	50
WORDS OF Y VECTOR USED =	1772
NUMBER OF PUMPING PERIODS =	4
TIME STEPS BETWEEN PRINTOUTS =	15
ERROR CRITERION FOR CLOSURE =	1.000000
STEADY STATE ERROR CRITERION =	.1000000
SPECIFIC STORAGE OF CONFINING BED =	.0
EVAPOTRANSPIRATION RATE =	.0
EFFECTIVE DEPTH OF ET =	1.000000
MULTIPLICATION FACTOR FOR TRANSMISSIVITY IN X DIRECTION =	1.000000
IN Y DIRECTION =	1.000000
STARTING HEAD =	952.0000

STORAGE COEFFICIENT
MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
3	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
4	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
5	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
6	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
7	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
8	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
9	0.0	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.00060	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSMISSIVITY
MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
3	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
4	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
5	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
6	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
7	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
8	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
9	0.0	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.00426	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

AREAL RECHARGE RATE
MATRIX

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.185E-08	0.0
3	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
4	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
5	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
6	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
7	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
8	0.0	-0.185E-08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.185E-08	0.0
9	0.0	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	-0.185E-08	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DELX = 2640.000

DELY = 2640.000

SOLUTION BY THE ALTERNATING DIRECTION IMPLICIT PROCEDURE

5 ITERATION PARAMETERS: 0.305D-01 0.729D-01 0.175D+00 0.418D+00 0.100D+01

PUMPING PERIOD NO. 1: 31.00 DAYS

NUMBER OF TIME STEPS= 31

DELT IN HOURS = 24.000

MULTIPLIER FOR DELT = 1.000

9 WELLS

I	J	PUMPING RATE	WELL RADIUS
4	3	-0.23	0.75
4	4	-0.19	0.75
5	4	-0.29	0.75
6	4	-0.21	0.75
6	6	-0.22	0.75
6	7	-0.27	0.75
6	8	-0.05	0.75
7	9	-0.31	0.75
8	9	-0.25	0.75

TIME STEP NUMBER = 30

SIZE OF TIME STEP IN SECONDS= 86400.00

TOTAL SIMULATION TIME IN SECONDS=	5270400.00
MINUTES=	87840.00
HOURS=	1464.00
DAYS=	61.00
YEARS=	0.17

DURATION OF CURRENT PUMPING PERIOD IN DAYS=	61.00
YEARS=	0.17

CUMULATIVE MASS BALANCE: L**3

SOURCES:	
STORAGE =	13792568.0
RECHARGE =	-3.42
CONSTANT FLUX =	0.0
CONSTANT HEAD =	0.0
LEAKAGE =	0.0
TOTAL SOURCES =	13792564.0
DISCHARGES:	
EVAPOTRANSPIRATION =	0.0
CONSTANT HEAD =	0.0
QUANTITY PUMPED =	13792763.0
LEAKAGE =	0.0
TOTAL DISCHARGE =	13792763.0
DISCHARGE-SOURCES =	199.00
PER CENT DIFFERENCE =	0.00

RATES FOR THIS TIME STEP: L**3/T

STORAGE =	3.2350
RECHARGE =	-0.0000
CONSTANT FLUX =	0.0
PUMPING =	-3.2350
EVAPOTRANSPIRATION =	0.0
CONSTANT HEAD:	
IN =	0.0
OUT =	0.0
LEAKAGE:	
FROM PREVIOUS PUMPING PERIOD =	0.0
TOTAL =	0.0
SUM OF RATES =	-0.0000

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

1.4600 0.0005

MAXIMUM CHANGE IN HEAD FOR THIS TIME STEP = 1.460

TIME STEP :	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	26	27	28	29	30
ITERATIONS:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

DRAWDOWN

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	28.8	29.9	28.2	22.1	15.7	10.4	6.2	2.7	0.4	0.0
3	0.0	39.8	44.5	44.3	33.3	24.7	18.7	13.8	9.3	5.5	0.0
4	0.0	52.3	73.6	80.2	51.0	39.3	33.5	28.0	21.2	15.4	0.0
5	0.0	50.2	61.9	82.8	61.1	58.0	57.8	52.7	40.7	30.9	0.0
6	0.0	43.2	51.3	72.1	63.8	85.3	99.3	96.6	69.7	50.9	0.0
7	0.0	34.4	37.7	45.1	48.1	58.4	69.6	81.3	105.1	69.4	0.0
8	0.0	27.7	28.8	32.4	36.4	43.5	53.7	69.4	100.4	71.3	0.0
9	0.0	24.6	25.7	28.1	31.8	37.7	46.3	57.7	69.6	63.7	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
4	3	0.75	809.92	142.08
4	4	0.75	788.48	163.52
5	4	0.75	799.46	152.54
6	4	0.75	821.26	130.74
6	6	0.75	788.60	163.40
6	7	0.75	745.73	206.27
6	8	0.75	752.64	199.36
7	9	0.75	725.39	226.61
8	9	0.75	743.90	208.10

PUMPING PERIOD NO. 3: 2.00 DAYS

NUMBER OF TIME STEPS= 2

DELT IN HOURS = 24.000

MULTIPLIER FOR DELT = 1.000

4 WELLS

I	J	PUMPING RATE	WELL RADIUS
4	4	-0.34	0.75
6	4	-0.24	0.75
6	7	-0.43	0.75
7	9	-0.49	0.75

TIME STEP NUMBER = 2

SIZE OF TIME STEP IN SECONDS= 86400.00

TOTAL SIMULATION TIME IN SECONDS=	5443200.00
MINUTES=	90720.00
HOURS=	1512.00
DAYS=	63.00
YEARS=	0.17

DURATION OF CURRENT PUMPING PERIOD IN DAYS=	63.00
YEARS=	0.17

CUMULATIVE MASS BALANCE:	L**3
SOURCES:	
STORAGE =	14052284.0
RECHARGE =	-3.53
CONSTANT FLUX =	0.0
CONSTANT HEAD =	0.0
LEAKAGE =	0.0
TOTAL SOURCES =	14052280.0
DISCHARGES:	
EVAPOTRANSPIRATION =	0.0
CONSTANT HEAD =	0.0
QUANTITY PUMPED =	14052481.0
LEAKAGE =	0.0
TOTAL DISCHARGE =	14052481.0
DISCHARGE-SOURCES =	201.00
PER CENT DIFFERENCE =	0.00

RATES FOR THIS TIME STEP:	L**3/T
STORAGE =	1.5030
RECHARGE =	-0.0000
CONSTANT FLUX =	0.0
PUMPING =	-1.5030
EVAPOTRANSPIRATION =	0.0
CONSTANT HEAD:	
IN =	0.0
OUT =	0.0
LEAKAGE:	
FROM PREVIOUS PUMPING PERIOD =	0.0
TOTAL =	0.0
SUM OF RATES =	-0.0000

MAXIMUM HEAD CHANGE FOR EACH ITERATION:

3.7502 0.0652

MAXIMUM CHANGE IN HEAD FOR THIS TIME STEP = 3.816

TIME STEP : 1 2

ITERATIONS: 1 1

DRAWDOWN

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	30.4	31.4	29.7	23.5	16.9	11.5	7.1	3.6	1.2	0.0
3	0.0	41.3	45.4	45.7	34.8	26.1	20.1	15.0	10.4	6.5	0.0
4	0.0	53.2	67.6	80.5	52.5	41.0	35.2	29.5	22.7	16.9	0.0
5	0.0	51.7	62.2	76.7	62.1	59.1	59.6	53.7	42.5	32.8	0.0
6	0.0	44.8	52.8	73.1	64.8	78.7	99.8	87.6	71.0	53.3	0.0
7	0.0	35.9	39.2	46.8	49.9	59.8	71.7	82.7	106.6	72.0	0.0
8	0.0	29.1	30.3	33.9	38.2	45.6	56.0	70.9	91.2	72.9	0.0
9	0.0	25.9	27.0	29.7	33.6	39.7	48.6	60.1	71.1	66.3	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
4	4	0.75	788.20	163.80
6	4	0.75	820.26	131.74
6	7	0.75	745.26	206.74
7	9	0.75	723.94	228.06

PUMPING PERIOD NO. 4: 2.00 DAYS

NUMBER OF TIME STEPS= 2

DELT IN HOURS = 24.000

MULTIPLIER FOR DELT = 1.000

5 WELLS

I	J	PUMPING RATE	WELL RADIUS
4	3	-0.28	0.75
5	4	-0.28	0.75
6	6	-0.32	0.75
6	8	-0.42	0.75
8	9	-0.44	0.75

```
--------------------------------------------------------------
|               TIME STEP NUMBER =          2                 |
--------------------------------------------------------------

     SIZE OF TIME STEP IN SECONDS=        86400.00

          TOTAL SIMULATION TIME IN SECONDS=     5616000.00
                                   MINUTES=       93600.00
                                     HOURS=        1560.00
                                      DAYS=          65.00
                                     YEARS=           0.18

DURATION OF CURRENT PUMPING PERIOD IN DAYS=          65.00
                                     YEARS=           0.18
```

```
CUMULATIVE MASS BALANCE:               L**3
------------------------

       SOURCES:
       --------
               STORAGE =          14351570.0
              RECHARGE =               -3.64
         CONSTANT FLUX =                0.0
         CONSTANT HEAD =                0.0
               LEAKAGE =                0.0
         TOTAL SOURCES =          14351566.0

       DISCHARGES:
       -----------
    EVAPOTRANSPIRATION =                0.0
         CONSTANT HEAD =                0.0
      QUANTITY PUMPED =           14351769.0
               LEAKAGE =                0.0
       TOTAL DISCHARGE =          14351769.0

     DISCHARGE-SOURCES =              203.00
    PER CENT DIFFERENCE =               0.00
```

```
RATES FOR THIS TIME STEP:                          L**3/T
-------------------------

                             STORAGE =             1.7320
                            RECHARGE =            -0.0000
                       CONSTANT FLUX =             0.0
                             PUMPING =            -1.7320
                  EVAPOTRANSPIRATION =             0.0
                      CONSTANT HEAD:
                                  IN =             0.0
                                 OUT =             0.0
                            LEAKAGE:
      FROM PREVIOUS PUMPING PERIOD =               0.0
                               TOTAL =             0.0

                        SUM OF RATES =            -0.0000
```

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

    4.7578      0.0959

MAXIMUM CHANGE IN HEAD FOR THIS TIME STEP =     4.841
-----------------------------------------------------

TIME STEP :  1  2
----------

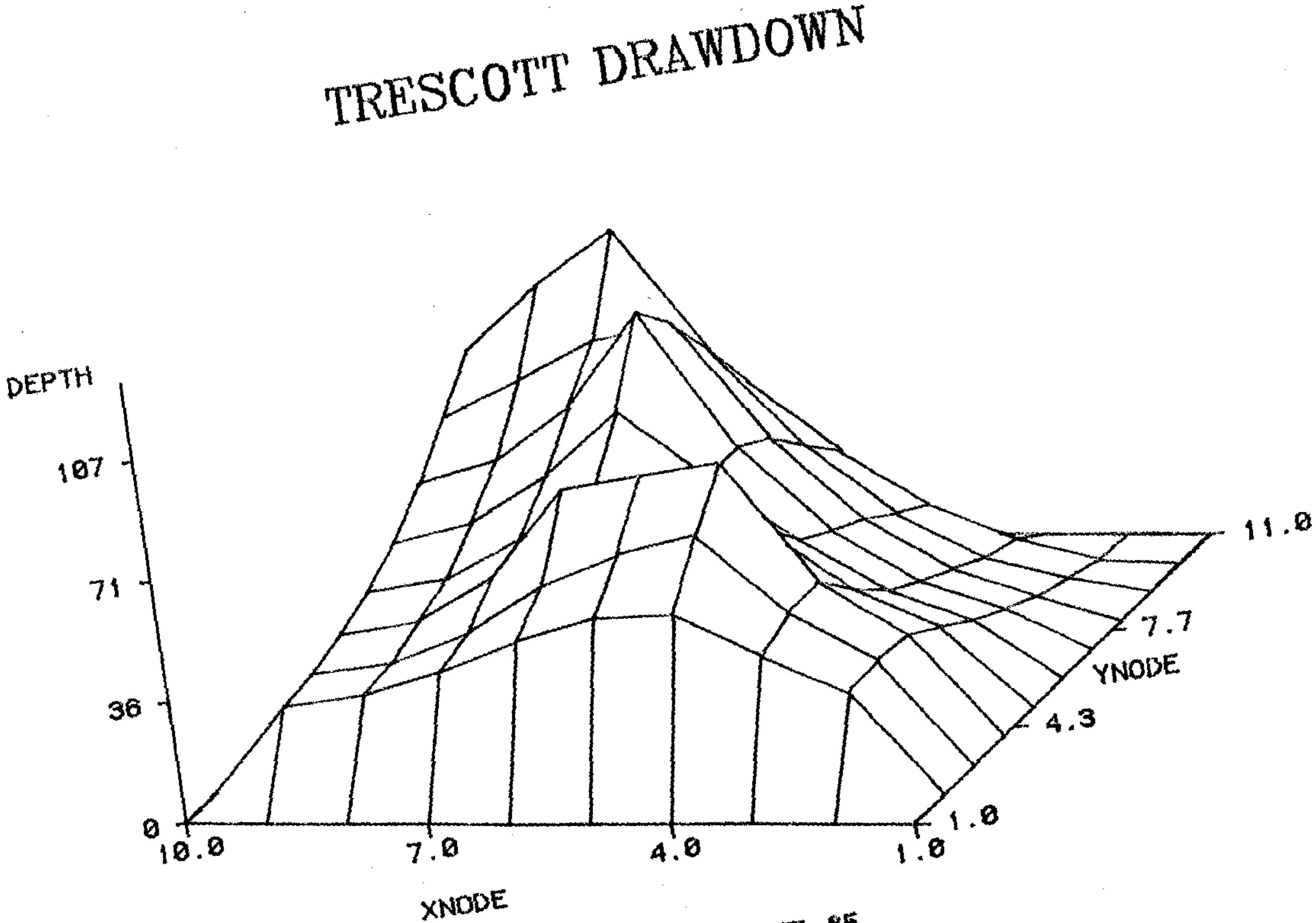
ITERATIONS:  1  1
----------
```

DRAWDOWN

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	31.9	32.8	31.1	24.9	18.2	12.7	8.2	4.5	2.1	0.0
3	0.0	42.7	46.5	46.1	36.1	27.6	21.4	16.3	11.5	7.6	0.0
4	0.0	54.3	71.2	72.2	53.0	42.4	36.7	31.0	24.2	18.4	0.0
5	0.0	53.1	63.1	79.9	63.2	60.3	60.1	55.1	44.1	34.7	0.0
6	0.0	46.3	53.6	67.8	65.5	82.9	89.3	93.0	71.4	55.2	0.0
7	0.0	37.4	40.6	47.7	51.5	61.3	72.4	83.0	94.9	72.9	0.0
8	0.0	30.5	31.7	35.5	40.0	47.5	58.0	72.6	97.3	74.9	0.0
9	0.0	27.2	28.4	31.2	35.3	41.8	50.8	62.4	73.1	68.7	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HEAD AND DRAWDOWN IN PUMPING WELLS

I	J	WELL RADIUS	HEAD	DRAWDOWN
4	3	0.75	812.34	139.66
5	4	0.75	802.39	149.61
6	6	0.75	790.99	161.01
6	8	0.75	756.26	195.74
8	9	0.75	746.98	205.02

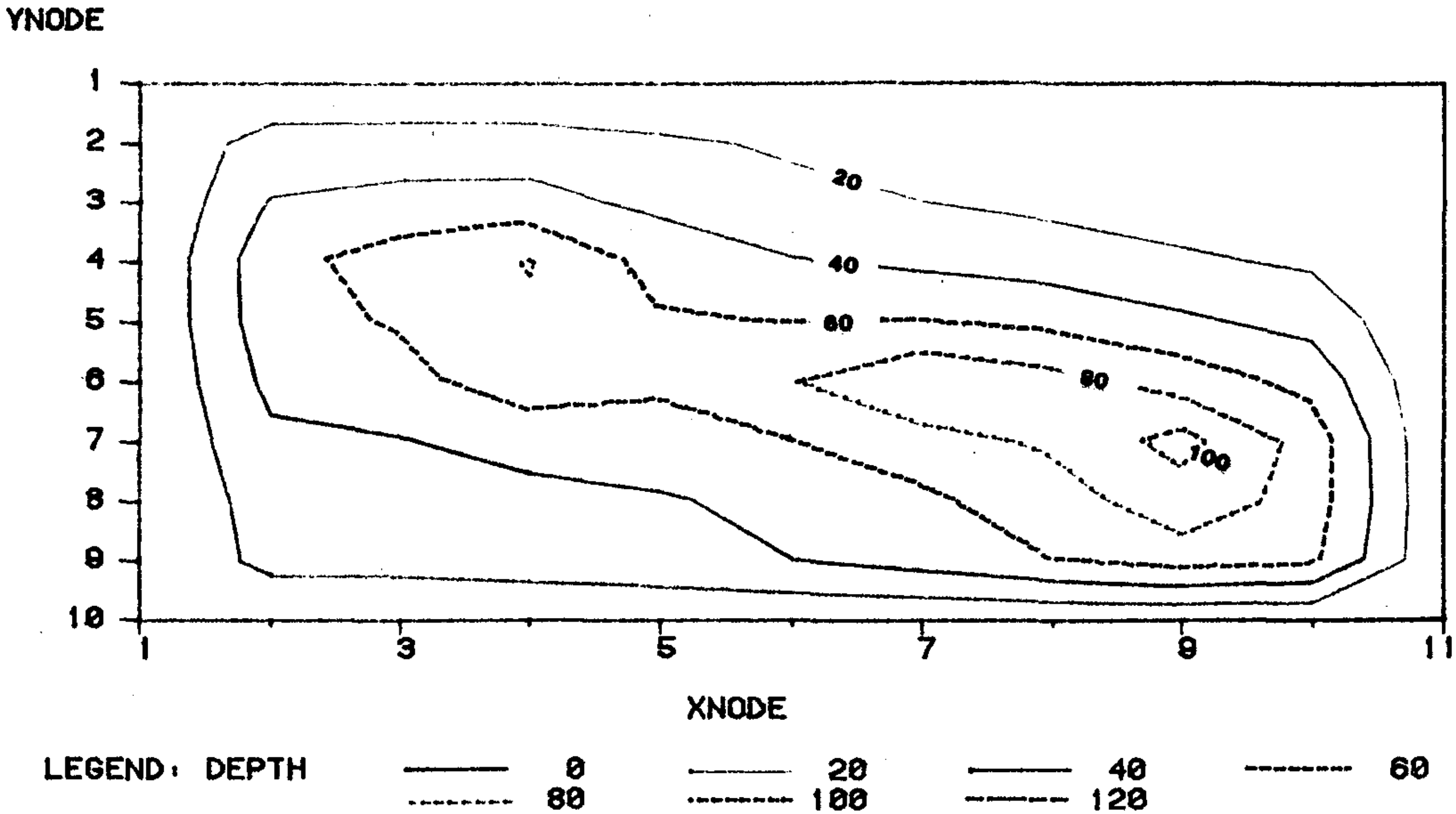


TILT=70 ROTATE=65

(Inverse image)

Figure 35

TRESCOTT DRAWDOWN



CONTOUR INTERVAL IS 20 FEET

Figure 36

APPENDIX XIV

KONIKOW MODEL'S DATA SET DEMONSTRATING AN

INJECTION WELL SIMULATION

```
//G11370F  JOB (?????,GHD-TR-KONI),'GHD:KONIKOW ',TIME=(5,0),CLASS=K,
//  MSGCLASS=X,NOTIFY=*
/*PASSWORD ?
//KONI  EXEC PGM=LOADER,PARM='SIZE=600K',REGION=600K
//SYSLIB DD DISP=SHR,DSN=SYS1.FORTLIB
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,DSN=U11370F.KONUPDAT.OBJ
//*T06F001 DD SYSOUT=A
//FT06F001 DD DISP=OLD,DSN=U11370F.TR20KON.OUTLIST
//FT05F001 DD *
```

JCL USED AT OSU

```
THE GARBER-WELLINGTON AQUIFER STUDY. INJECTION WELL. 09 JANUARY 1982.
 100   1  32  323850  30   7   5 200  10   4   0   0
   .5  .01  .29    1.0006  1.186400  660  660   .3   .5    1
```

TITLE AND SPECIFIED PARAMETERS

```
 612
 512
 7 4
 7 7
 618
```

LOCATION OF OBSERVATION WELLS

```
 4 4   .2317
 8 4   .1957
 8 8   .2490
 811   .1952
 9 7  -.5000
1411   .2488
1711   .3127
2211   .2400
2515   .3645
2620   .2948
```

NODE LOCATION OF WELLS AND PUMPING RATES OF WELLS

```
1      .0001
   0
   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0 426 426 426 426 426 426 426 426 426 426   0
```

TRANSMISSIVITY

MARTRIX

```
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426    0
0
0
```

```
1      400.
 0
 0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
```

THICKNESS
MATRIX

```
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
        1   1   1   1   1   1   1   1   1   1   0
    0
    0
------------------------------------------------------------------------------------------------------------
1 .00000001
   0
   0
        -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39
   -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39
         39
                                                 -39
         39
                                                 -39
         39
                                                 -39
         39
                                                 -39
         39
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         39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39
    39   39                                      -39
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RECHARGE RATE

MATRIX

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    39                                          -39
    39                                          -39
    39                                          -39
    39                                          -39
    39                                          -39
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    39   39   39   39   39   39   39   39   39 -39
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1        1.0
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NODE IDENTIFICATION

MATRIX

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1        1.0
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    957.956.955.954.953.952.951.952.954.956.958.960.961.962.964.966.968.970.971.
972.974.976.978.980.981.982.984.986.988.990.
    957.956.955.954.952.951.950.951.953.955.956.958.959.960.962.963.965.968.969.
970.972.974.976.978.979.980.982.984.986.989.
    956.955.954.952.951.950.949.950.951.953.954.956.957.958.959.961.962.964.965.
969.970.972.974.976.977.978.980.982.984.987.
    957.953.952.951.950.949.949.949.950.951.952.954.955.956.956.957.959.960.962.
965.968.970.972.974.975.976.978.980.983.986.
    953.952.951.951.950.949.948.948.949.950.950.952.953.953.953.954.956.957.960.
961.964.966.969.970.972.974.976.979.982.985.
    952.951.950.950.949.948.947.947.948.948.949.950.950.950.950.952.953.954.957.
959.961.963.965.967.969.971.974.977.980.983.
    953.952.951.950.949.948.947.947.947.948.948.949.949.949.949.950.950.952.954.
957.959.961.962.964.966.969.971.974.978.981.
    952.951.950.949.948.947.947.947.947.947.948.948.948.948.947.948.949.950.951.
955.957.959.961.963.965.967.969.972.976.979.
    949.948.948.948.947.946.946.946.946.946.946.946.946.946.945.945.947.949.950.
953.956.960.961.963.965.967.969.972.975.977.
    948.947.947.947.946.946.946.946.946.945.945.944.943.943.943.943.945.949.953.
956.959.960.962.963.965.967.969.972.974.976.
    947.946.946.946.945.945.945.944.944.944.944.943.942.942.942.942.944.947.951.
956.960.961.962.963.965.967.969.972.973.975.
    945.944.944.944.942.942.942.941.941.942.942.942.943.943.943.944.946.948.952.
956.958.961.962.963.965.967.969.971.973.975.
    943.943.942.941.940.940.939.939.940.942.943.944.945.946.947.948.950.952.953.
955.957.959.962.963.965.967.969.971.973.975.
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STARTING HEAD

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    941.941.939.939.938.937.937.937.939.940.942.943.944.945.946.947.949.950.952.      MATRIX
954.956.958.960.963.965.967.969.971.972.975.

    957.958.959.961.963.966.969.970.973.975.

    956.957.958.960.961.965.969.971.973.975.

    954.955.956.958.959.962.965.968.971.974.

    952.953.954.956.957.960.963.966.969.972.

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    951.952.953.955.956.960.963.966.969.972.
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0      0.0                                                                INITIAL CONCENTRATION OF
//                                                                        AQUIFER
```

APPENDIX XV

SELECTED OUTPUT FOR AN INJECTION WELL SIMULATION

U.S.G.S. METHOD-OF-CHARACTERISTICS MODEL FOR SOLUTE TRANSPORT IN GROUND WATER

THE GARBER-WELLINGTON AQUIFER STUDY. INJECTION WELL. 09 JANUARY 1982.

```
                    I N P U T    D A T A

                      GRID DESCRIPTORS

          NX     (NUMBER OF COLUMNS)  =     32
          NY     (NUMBER OF ROWS)     =     32
          XDEL   (X-DISTANCE IN FEET) =   660.0
          YDEL   (Y-DISTANCE IN FEET) =   660.0

                      TIME  PARAMETERS

          NTIM   (MAX. NO. OF TIME STEPS)        =     100
          NPMP   (NO. OF PUMPING PERIODS)        =       1
          PINT   (PUMPING PERIOD IN YEARS)       =       0.500
          TIMX   (TIME INCREMENT MULTIPLIER)     =       1.10
          TINIT  (INITIAL TIME STEP IN SEC.)     =   86400.

            HYDROLOGIC AND CHEMICAL PARAMETERS

          S        (STORAGE COEFFICIENT)        =      0.000600
          POROS    (EFFECTIVE POROSITY)         =      0.29
          BETA     (CHARACTERISTIC LENGTH)      =      1.0
          DLTRAT   (RATIO OF TRANSVERSE TO
                    LONGITUDINAL DISPERSIVITY)  =      0.30
          ANFCTR   (RATIO OF T-YY TO T-XX)      =      1.000000

                    EXECUTION PARAMETERS

          NITP   (NO. OF ITERATION PARAMETERS) =     7
          TOL    (CONVERGENCE CRITERIA - ADIP) =     0.0100
          ITMAX  (MAX.NO.OF ITERATIONS - ADIP) =   200
          CELDIS (MAX.CELL DISTANCE PER MOVE
                     OF PARTICLES - M.O.C.)    =     0.500
          NPMAX  (MAX. NO. OF PARTICLES)       =  3850
          NPTPND (NO. PARTICLES PER NODE)      =       4

                      PROGRAM OPTIONS

          NPNT   (TIME STEP INTERVAL FOR
                  COMPLETE PRINTOUT)        =    30
          NPNTMV (MOVE INTERVAL FOR CHEM.
                  CONCENTRATION PRINTOUT)   =     0
          NPNTVL (PRINT OPTION-VELOCITY
                  0=NO; 1=FIRST TIME STEP;
                  2=ALL TIME STEPS)         =     0
          NPNTD  (PRINT OPTION-DISP.COEF.
                  0=NO; 1=FIRST TIME STEP;
                  2=ALL TIME STEPS)         =     0
          NUMOBS (NO. OF OBSERVATION WELLS
                  FOR HYDROGRAPH PRINTOUT)  =     5
          NREC   (NO. OF PUMPING WELLS)     =    10
          NCODES (FOR NODE IDENT.)          =     0
          NPNCHV (PUNCH VELOCITIES)         =     0
          NPDELC (PRINT OPT.-CONC. CHANGE)  =     0
```

TIME INTERVALS (IN SECONDS)

86400.	95040.	.10454D+06	.11500D+06	.12650D+06	.13915D+06	.15306D+06	.16837D+06	.18521D+06	.20373D+06
.22410D+06	.24651D+06	.27116D+06	.29828D+06	.32810D+06	.36091D+06	.39701D+06	.43671D+06	.48038D+06	.52841D+06
.58126D+06	.63938D+06	.70332D+06	.77365D+06	.85102D+06	.93612D+06	.10297D+07	.11327D+07	.12460D+07	.13706D+07
.15076D+07	.16584D+07	.18242D+07	.20067D+07	.22073D+07	.24281D+07	.26709D+07	.29379D+07	.32317D+07	.35549D+07
.39104D+07	.43014D+07	.47316D+07	.52047D+07	.57252D+07	.62977D+07	.69275D+07	.76203D+07	.83823D+07	.92205D+07
.10143D+08	.11157D+08	.12273D+08	.13500D+08	.14850D+08	.16335D+08	.17968D+08	.19765D+08	.21741D+08	.23916D+08
.26307D+08	.28938D+08	.31832D+08	.35015D+08	.38516D+08	.42368D+08	.46605D+08	.51265D+08	.56392D+08	.62031D+08
.68234D+08	.75058D+08	.82563D+08	.90820D+08	.99902D+08	.10989D+09	.12088D+09	.13297D+09	.14627D+09	.16089D+09
.17698D+09	.19468D+09	.21415D+09	.23556D+09	.25912D+09	.28503D+09	.31353D+09	.34489D+09	.37938D+09	.41731D+09
.45905D+09	.50495D+09	.55544D+09	.61099D+09	.67209D+09	.73930D+09	.81323D+09	.89455D+09	.98400D+09	.10824D+10

LOCATION OF OBSERVATION WELLS

NO.	X	Y
1	6	12
2	5	12
3	7	4
4	7	7
5	6	18

LOCATION OF PUMPING WELLS

X	Y	RATE(IN CFS)	CONC.
4	4	0.2317	0.0
8	4	0.1957	0.0
8	8	0.2490	0.0
8	11	0.1952	0.0
9	7	-0.5000	0.0
14	11	0.2488	0.0
17	11	0.3127	0.0
22	11	0.2400	0.0
25	15	0.3645	0.0
26	20	0.2948	0.0

AREA OF ONE CELL = .4356D+06

X-Y SPACING:
660.00
660.00

DRAWDOWN

(Format Modified)

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	215	212	208	202	194	186	178	171	164	159	155	151	147	144	141	138	136	133	129	125	122	119	116	113	109	105	103	101	99	99	0
0	221	218	216	207	197	190	184	174	167	162	157	153	150	146	144	140	138	136	132	128	125	122	118	115	111	107	105	103	101	100	0
0	224	224	231	211	200	194	196	177	168	163	158	156	153	150	146	144	140	138	134	133	128	125	122	118	114	110	107	105	103	102	0
0	226	220	218	209	200	191	185	172	166	163	160	159	156	154	150	147	144	140	137	135	133	129	126	122	118	113	110	108	106	105	0
0	222	218	213	207	199	190	178	163	163	164	163	163	161	158	154	151	149	145	143	138	136	132	129	124	121	117	114	112	110	109	0
0	222	217	212	207	200	192	178	140	161	166	168	168	166	163	160	158	154	150	148	145	141	137	133	128	124	120	118	115	114	112	0
0	224	219	214	209	205	201	204	177	174	175	175	175	174	172	169	166	161	158	154	152	148	144	138	133	128	125	121	118	117	116	0
0	224	219	215	211	208	205	202	192	186	184	184	185	185	183	179	177	172	166	161	160	157	151	145	140	134	130	125	122	121	120	0
0	223	218	215	213	211	209	208	201	195	192	192	194	197	193	190	189	182	176	170	169	169	163	155	148	142	137	132	129	126	123	0
0	224	220	217	215	214	215	224	209	202	199	199	202	215	202	201	213	192	184	182	183	194	175	165	156	150	144	138	135	131	128	0
0	225	221	219	217	215	215	215	209	205	203	202	203	205	202	200	199	192	187	185	186	188	179	172	164	158	151	145	141	136	133	0
0	226	222	219	217	214	213	212	208	205	204	203	203	204	203	200	198	194	190	189	189	186	184	179	173	166	158	151	146	141	138	0
0	226	223	220	217	215	213	211	208	207	208	207	208	208	207	205	203	200	197	193	191	188	186	187	186	175	165	157	151	146	143	0
0	226	224	220	219	216	213	212	210	210	209	210	210	209	208	207	204	202	198	196	193	191	190	193	211	185	171	162	155	149	147	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	191	189	189	191	181	172	165	158	154	150	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	189	187	185	184	177	172	167	161	156	153	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	185	183	181	180	176	171	165	160	156	154	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	182	180	179	180	180	172	165	159	155	153	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	179	177	177	181	194	175	166	160	156	153	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176	174	173	175	175	170	163	158	155	153	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	174	171	169	169	166	164	160	157	154	152	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	171	168	166	164	161	160	157	155	152	151	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	169	166	163	161	158	157	155	153	151	150	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	167	164	161	159	156	155	154	152	150	149	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	166	163	160	158	154	154	153	151	150	149	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	165	162	159	157	154	154	153	151	150	149	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	165	162	160	158	155	154	153	152	150	149	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	166	163	161	159	156	156	154	153	152	150	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	167	165	163	161	158	158	157	155	153	152	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	168	167	165	164	161	161	160	158	156	153	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

CUMULATIVE MASS BALANCE -- (IN FT**3)

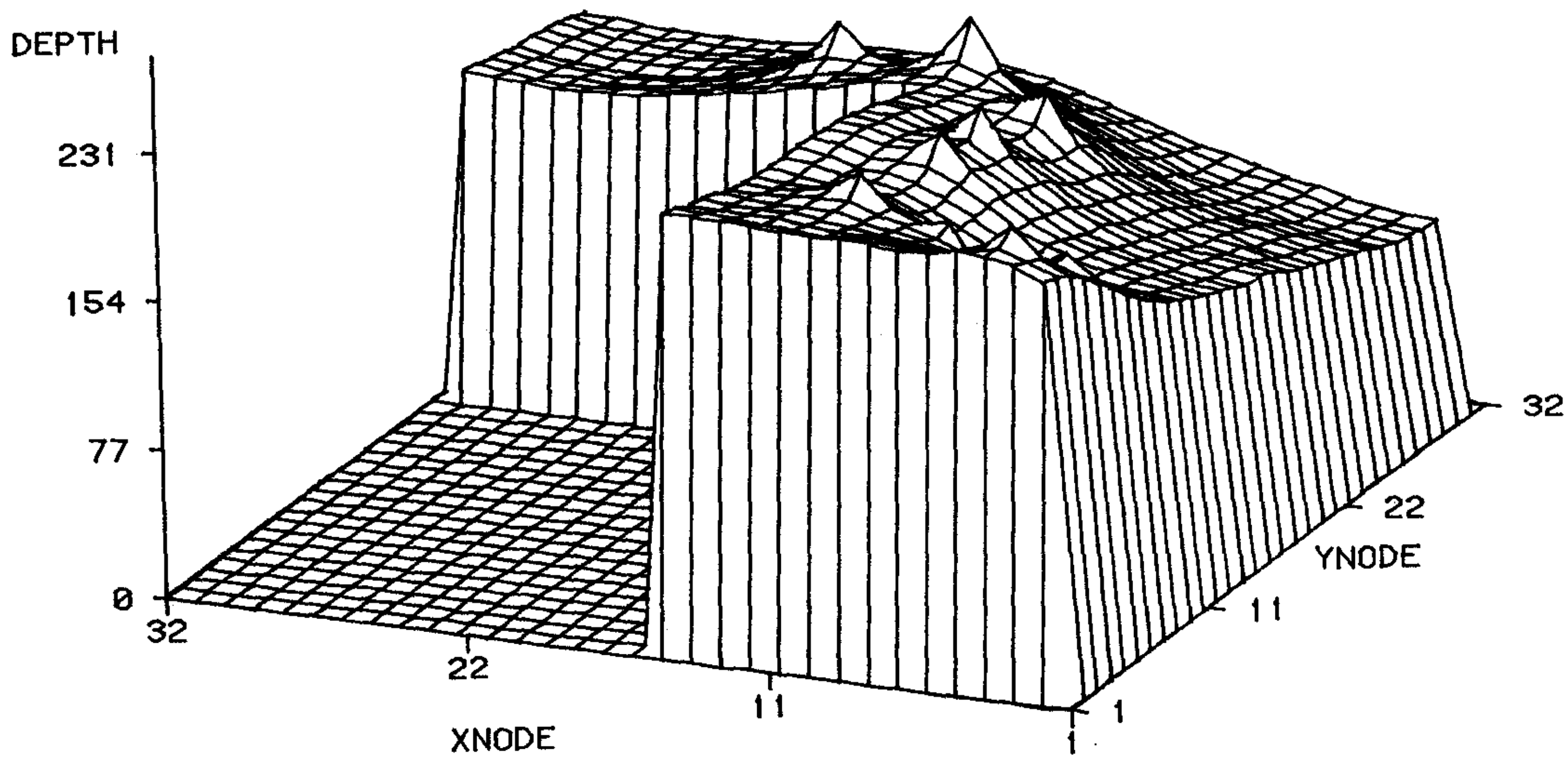
```
RECHARGE AND INJECTION        = -0.21351E+08
PUMPAGE AND E-T WITHDRAWAL    =  0.46910E+08
CUMULATIVE  NET  PUMPAGE      =  0.25559E+08
WATER RELEASE FROM STORAGE    =  0.25554E+08
LEAKAGE INTO AQUIFER          =  0.0
LEAKAGE OUT OF AQUIFER        =  0.0
CUMULATIVE  NET  LEAKAGE      =  0.0

     MASS BALANCE RESIDUAL    =  -5696.0
     ERROR  (AS PERCENT)      =  -.12143E-01
```

RATE MASS BALANCE -- (IN C.F.S.)

```
LEAKAGE INTO AQUIFER          =  0.0
LEAKAGE OUT OF AQUIFER        =  0.0
NET LEAKAGE      (QNET)       =  0.0
RECHARGE AND INJECTION        = -0.15023E+01
PUMPAGE AND E-T WITHDRAWAL    =  0.33007E+01
NET WITHDRAWAL    (TPUM)      =  0.33007E+01
```

DRAWDOWN (180 DAYS)

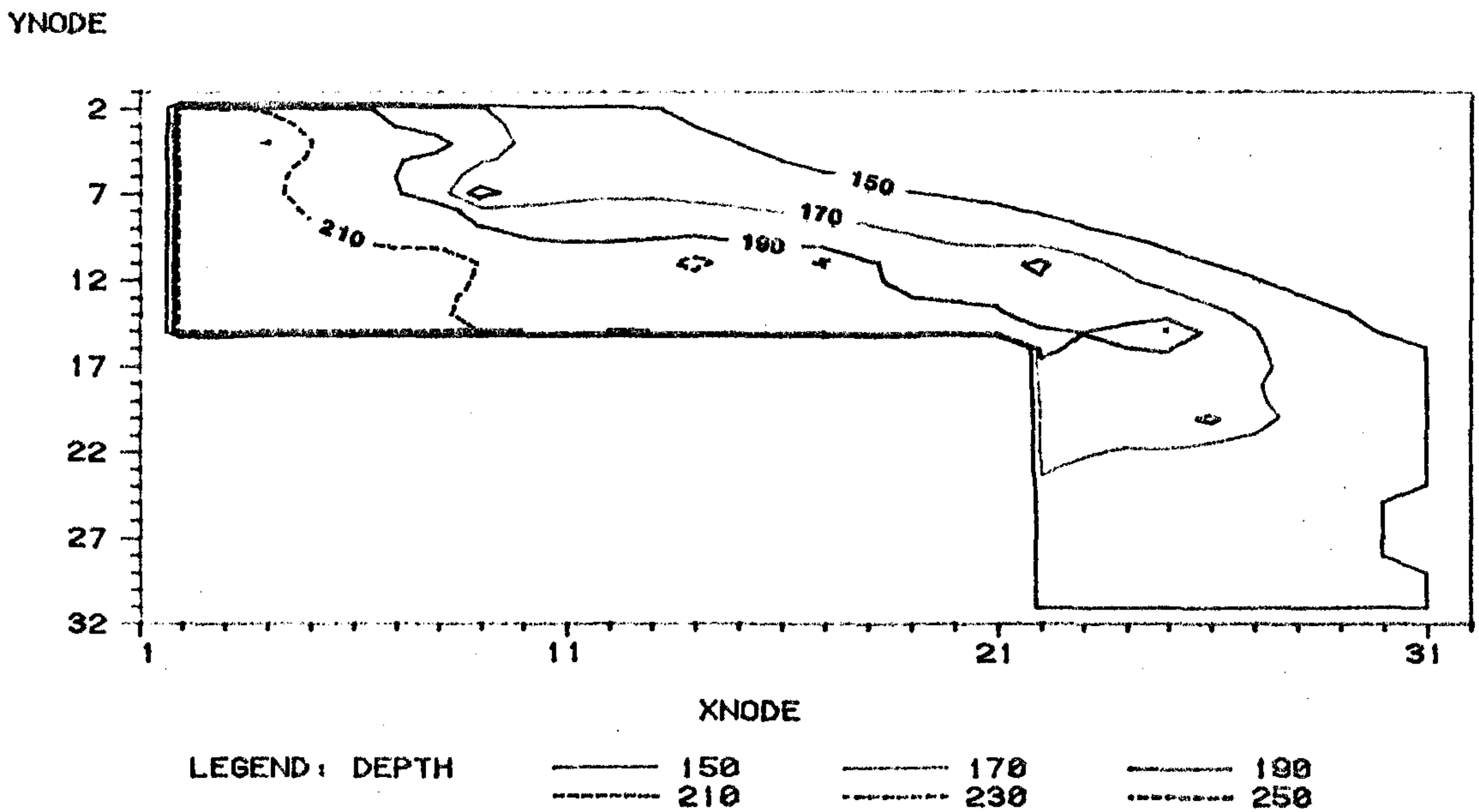


TILT=70 ROTATE=65

(Inverse Image)

Figure 38

DRAWDOWN (180 DAYS)



CONTOUR INTERVAL IS 20 FEET

CONCENTRATION

```
NUMBER OF TIME STEPS =     30
       DELTA T       =    .13706D+07
       TIME(SECONDS) =    .14212D+08
  CHEM.TIME(SECONDS) =  0.14212E+08
  CHEM.TIME(DAYS)    =  0.16449E+03
       TIME(YEARS)   =  0.45036E+00
  CHEM.TIME(YEARS)   =  0.45036E+00
 NO. MOVES COMPLETED =      1
```

CHEMICAL MASS BALANCE

```
       MASS IN BOUNDARIES      =  0.0
       MASS OUT BOUNDARIES     =  0.0
       MASS PUMPED IN          =  0.0
       MASS PUMPED OUT         =  0.0
       INFLOW MINUS OUTFLOW    =  0.0
       INITIAL MASS STORED     =  0.0
       PRESENT MASS STORED     =  0.0
       CHANGE MASS STORED      =  0.0
     COMPARE RESIDUAL WITH NET FLUX AND MASS ACCUMULATION:
       MASS BALANCE RESIDUAL   =  0.0
       ERROR  (AS PERCENT)     =  0.0
```

THE GARBER-WELLINGTON AQUIFER STUDY. INJECTION WELL, 09 JANUARY 1982.

TIME VERSUS HEAD AND CONCENTRATION AT SELECTED OBSERVATION POINTS

PUMPING PERIOD NO. 1

TRANSIENT SOLUTION

OBS.WELL NO.	X	Y
1	6	12

N	HEAD (FT)	CONC.(MG/L)	TIME (YEARS)
0	945.0	0.0	0.0
1	943.3	0.0	0.003
2	941.0	0.0	0.006
3	938.6	0.0	0.009
4	936.0	0.0	0.013
5	933.2	0.0	0.017
6	930.2	0.0	0.021
7	926.9	0.0	0.026
8	923.4	0.0	0.031
9	919.6	0.0	0.037
10	915.6	0.0	0.044
11	911.2	0.0	0.051
12	906.5	0.0	0.059
13	901.4	0.0	0.067
14	896.0	0.0	0.077
15	890.3	0.0	0.087
16	884.1	0.0	0.098
17	877.5	0.0	0.111
18	870.5	0.0	0.125
19	863.0	0.0	0.140
20	854.9	0.0	0.157
21	846.2	0.0	0.175
22	836.9	0.0	0.195
23	826.9	0.0	0.218
24	816.1	0.0	0.242
25	804.5	0.0	0.269
26	791.9	0.0	0.299
27	778.2	0.0	0.332
28	763.5	0.0	0.367
29	747.5	0.0	0.407
30	730.0	0.0	0.450
31	711.1	0.0	0.498
32	710.4	0.0	0.500

OBS.WELL NO.	X	Y
4	7	7

N	HEAD (FT)	CONC.(MG/L)	TIME (YEARS)
0	948.0	0.0	0.0
1	948.6	0.0	0.003
2	948.7	0.0	0.006
3	948.3	0.0	0.009
4	947.4	0.0	0.013
5	946.0	0.0	0.017
6	944.2	0.0	0.021
7	942.1	0.0	0.026
8	939.7	0.0	0.031
9	936.9	0.0	0.037
10	933.8	0.0	0.044
11	930.3	0.0	0.051
12	926.5	0.0	0.059
13	922.3	0.0	0.067
14	917.6	0.0	0.077
15	912.5	0.0	0.087
16	907.0	0.0	0.098
17	900.9	0.0	0.111
18	894.4	0.0	0.125
19	887.2	0.0	0.140
20	879.5	0.0	0.157
21	871.1	0.0	0.175
22	862.0	0.0	0.195
23	852.2	0.0	0.218
24	841.6	0.0	0.242
25	830.0	0.0	0.269
26	817.5	0.0	0.299
27	804.0	0.0	0.332
28	789.3	0.0	0.367
29	773.3	0.0	0.407
30	756.0	0.0	0.450
31	737.1	0.0	0.498
32	736.3	0.0	0.500

APPENDIX XVI

KONIKOW MODEL'S DATA SET DEMONSTRATING A

LANDFILL SIMULATION

```
//G11370F  JOB (?????,GHD-TR-KONI),'GHD:KONIKOW ',TIME=(5,0),CLASS=K,
//  MSGCLASS=X,NOTIFY=*
/*PASSWORD ?
//KONI  EXEC PGM=LOADER,PARM='SIZE=600K',REGION=600K
//SYSLIB DD DISP=SHR,DSN=SYS1.FORTLIB                                        JCL USED AT OSU
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,DSN=U11370F.KONUPDAT.OBJ
//*T06F001 DD SYSOUT=A
//FT06F001 DD DISP=OLD,DSN=U11370F.TR25KON.OUTLIST
//FT05F001 DD *
-------------------------------------------------------------------------------------------
THE GARBER-WELLINGTON AQUIFER STUDY, LANDFILL EXAMPLE. 09 JANUARY 1982      TITLE AND SPECIFIED
 100    6  32  323850  28    7    5 200   9    4    1    0                      PARAMETERS
 .077  .01  .29  100.0006     186400  660  660   .3   .5     1
-------------------------------------------------------------------------------------------
 9 6
 9 7                                                                         LOCATION OF OBSERVATION
 9 8                                                                                WELLS
 9 9
 8 8
-------------------------------------------------------------------------------------------
 4 4     .203
 4 8     .201
 8 8     .287                                                                NODE LOCATION OF WELLS
 811     .212                                                                AND PUMPING RATES
1411     .260
1711     .306
2211     .229
2515     .273
2620     .211
-------------------------------------------------------------------------------------------
1      .0001
  0
  0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
426 426 426 426 426 426 426 426 426 426 426   0                              TRANSMISSIVITY
  0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426     MATRIX
426 426 426 426 426 426 426 426 426 426 426   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0 426 426 426 426 426 426 426 426 426 426   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0
0
------------------------------------------------------------------------------------
1     400.
 0
 0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
 0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
 1  1  1  1  1  1  1  1  1  1  1  0
```

THICKNESS
MATRIX

```
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
    1  1  1  1  1  1  1  1  1  1  0
 0
 0
------------------------------------------------------------------------------------------
1 .00000001
  0
  0
   -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39
-39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39
    39
                                       -39
    39
                                       -39
    39
                                       -39
    39
                                       -39
    39
                                       -39
    39
                                       -39
    39
                                       -39
    39
                                       -39
    39
                                       -39
    39
                                       -39                           RECHARGE
    39                                                                MATRIX
                                       -39
    39
                                       -39
    39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39
 39 39                                 -39
```

```
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39                                        -39
      39   39   39   39   39   39   39   39   39 -39
   0
   0
----------------------------------------------------------------------------------------------------
1        1.0
00000000000000000000
000000000000
00000000000000000000
000000000000
00000000000000000000
000000000000
00000000000000000000
000000000000
00000000000000000000
000000000000
00000000000000000000
000000000000
00000000100000000000
000000000000
00000000000000000000
000000000000
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00000000000000000000
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00000000000000000000
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00000000000000000000
000000000000
00000000000000000000
000000000000
00000000000000000000
```

NODE IDENIFICATION
MATRIX

```
00000000000000000000
000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000

000000000000
 1         1.0   10000000
--------------------------------------------------------------------------------------------------------------
1         1.0
   0
   0
    957.956.955.954.953.952.951.952.954.956.958.960.961.962.964.966.968.970.971.
972.974.976.978.980.981.982.984.986.988.990.
    957.956.955.954.952.951.950.951.953.955.956.958.959.960.962.963.965.968.969.
970.972.974.976.978.979.980.982.984.986.989.
    956.955.954.952.951.950.949.950.951.953.954.956.957.958.959.961.962.964.965.
969.970.972.974.976.977.978.980.982.984.987.
    957.953.952.951.950.949.949.949.950.951.952.954.955.956.956.957.959.960.962.
965.968.970.972.974.975.976.978.980.983.986.
    953.952.951.951.950.949.948.948.949.950.950.952.953.953.953.954.956.957.960.
961.964.966.969.970.972.974.976.979.982.985.
    952.951.950.950.949.948.947.947.948.948.949.950.950.950.950.952.953.954.957.
959.961.963.965.967.969.971.974.977.980.983.
    953.952.951.950.949.948.947.947.947.948.948.949.949.949.949.950.950.952.954.
957.959.961.962.964.966.969.971.974.978.981.
    952.951.950.949.948.947.947.947.947.947.948.948.948.948.947.948.949.950.951.
955.957.959.961.963.965.967.969.972.976.979.
    949.948.948.948.947.946.946.946.946.946.946.946.946.946.945.945.947.949.950.
953.956.960.961.963.965.967.969.972.975.977.
    948.947.947.947.946.946.946.946.946.945.945.944.943.943.943.943.945.949.953.
956.959.960.962.963.965.967.969.972.974.976.
    947.946.946.946.945.945.945.944.944.944.944.943.942.942.942.942.944.947.951.
956.960.961.962.963.965.967.969.972.973.975.
    945.944.944.944.942.942.942.941.941.942.942.942.943.943.943.944.946.948.952.
956.958.961.962.963.965.967.969.971.973.975.
    943.943.942.941.940.940.939.939.940.942.943.944.945.946.947.948.950.952.953.
955.957.959.962.963.965.967.969.971.973.975.
```

```
    941.941.939.939.938.937.937.937.939.940.942.943.944.945.946.947.949.950.952.
 954.956.958.960.963.965.967.969.971.972.975.                              STARTING HEAD
                                                                              MATRIX
    957.958.959.961.963.966.969.970.973.975.

    956.957.958.960.961.965.969.971.973.975.

    954.955,956.958.959.962.965.968.971.974.

    952.953.954.956.957.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.

    951.952.953.955.956.960.963.966.969.972.
  0
  0
---------------------------------------------------------------------------INITIAL CONCENTRATION OF--
0      0.0                                                                 THE AQUIFER
-----------------------------------------------------------------------------------------------------
1
 100   31   7 200   9   0   0   0   0   0 .085     186400
 4 4     .144
 8 4     .129                                                              PUMPING PERIOD NO. 2
 8 8     .245
 811     .121
1411     .139
1711     .062
2211     .126
2515     .260
2620     .212
-----------------------------------------------------------------------------------------------------
1
 100   30   7 200   9   0   0   0   1   0 .082     186400
 4 4     .176
 8 4     .067
 8 8     .150                                                              PUMPING PERIOD NO. 3
 811     .115
1411     .245
1711     .382
2211     .266
2515     .405
2620     .309
-----------------------------------------------------------------------------------------------------
1
 100
```

```
 4 4     .227
 8 4     .188
 8 8     .292                                                                        PUMPING PERIOD NO. 4
 811     .213
1411     .220
1711     .272
2211     .048
2515     .307
2620     .252
-----------------------------------------------------------------------------------------------------------
1
 100  30   7 200   9   0   0   0   0   0 .082    186400
 4 4     .278
 8 4     .338
 8 8     .283                                                                        PUMPING PERIOD NO. 5
 811     .238
1411     .317
1711     .434
2211     .417
2515     .493
2620     .437
-----------------------------------------------------------------------------------------------------------
1
 100  42   7 200   9   0   0   0   0   0 1.58  1.186400
 4 4     .200
 8 4     .200
 8 8     .200                                                                        PUMPING PERIOD NO. 6
 811     .200
1411     .200
1711     .200
2211     .200
2515     .200
2620     .200
//
```

APPENDIX XVII

SELECTED OUTPUT FOR A LANDFILL SIMULATION

U.S.G.S. METHOD-OF-CHARACTERISTICS MODEL FOR SOLUTE TRANSPORT IN GROUND WATER

THE GARBER-WELLINGTON AQUIFER STUDY, LANDFILL EXAMPLE. 09 JANUARY 1982

```
                I N P U T     D A T A

                  GRID DESCRIPTORS

         NX    (NUMBER OF COLUMNS)  =    32
         NY    (NUMBER OF ROWS)     =    32
         XDEL  (X-DISTANCE IN FEET) =  660.0
         YDEL  (Y-DISTANCE IN FEET) =  660.0

                  TIME  PARAMETERS

         NTIM   (MAX. NO. OF TIME STEPS)       =    100
         NPMP   (NO. OF PUMPING PERIODS)       =      6
         PINT   (PUMPING PERIOD IN YEARS)      =      0.077
         TIMX   (TIME INCREMENT MULTIPLIER)    =      1.00
         TINIT  (INITIAL TIME STEP IN SEC.)    =  86400.

           HYDROLOGIC AND CHEMICAL PARAMETERS

         S       (STORAGE COEFFICIENT)        =      0.000600
         POROS   (EFFECTIVE POROSITY)         =      0.29
         BETA    (CHARACTERISTIC LENGTH)      =    100.0
         DLTRAT  (RATIO OF TRANSVERSE TO
                 LONGITUDINAL DISPERSIVITY)   =      0.30
         ANFCTR  (RATIO OF T-YY TO T-XX)      =      1.000000

                 EXECUTION PARAMETERS

         NITP    (NO. OF ITERATION PARAMETERS) =   7
         TOL     (CONVERGENCE CRITERIA - ADIP) =   0.0100
         ITMAX   (MAX.NO.OF ITERATIONS - ADIP) =  200
         CELDIS  (MAX.CELL DISTANCE PER MOVE
                     OF PARTICLES - M.O.C.)    =   0.500
         NPMAX   (MAX. NO. OF PARTICLES)       = 3850
         NPTPND  (NO. PARTICLES PER NODE)      =     4

                  PROGRAM OPTIONS

         NPNT    (TIME STEP INTERVAL FOR
                  COMPLETE PRINTOUT)      =    28
         NPNTMV  (MOVE INTERVAL FOR CHEM.
                  CONCENTRATION PRINTOUT) =     0
         NPNTVL  (PRINT OPTION-VELOCITY
                  0=NO; 1=FIRST TIME STEP;
                  2=ALL TIME STEPS)       =     0
         NPNTD   (PRINT OPTION-DISP.COEF.
                  0=NO; 1=FIRST TIME STEP;
                  2=ALL TIME STEPS)       =     0
         NUMOBS  (NO. OF OBSERVATION WELLS
                  FOR HYDROGRAPH PRINTOUT) =    5
         NREC    (NO. OF PUMPING WELLS)   =     9
         NCODES  (FOR NODE IDENT.)        =     1
         NPNCHV  (PUNCH VELOCITIES)       =     0
         NPDELC  (PRINT OPT.-CONC. CHANGE) =    0
```

TIME INTERVALS (IN SECONDS)

86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.
86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.	86400.

LOCATION OF OBSERVATION WELLS

NO.	X	Y
1	9	6
2	9	7
3	9	8
4	9	9
5	8	8

LOCATION OF PUMPING WELLS

X	Y	RATE(IN CFS)	CONC.
4	4	0.2030	0.0
4	8	0.2010	0.0
8	8	0.2870	0.0
8	11	0.2120	0.0
14	11	0.2600	0.0
17	11	0.3060	0.0
22	11	0.2290	0.0
25	15	0.2730	0.0
26	20	0.2110	0.0

AREA OF ONE CELL = .4356D+06

X-Y SPACING:
660.00
660.00

DRAWDOWN (FORMAT MODIFIED)

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	205	202	196	184	171	159	147	136	129	125	123	123	123	124	125	126	126	126	124	122	121	119	117	115	111	108	106	104	103	103	0
0	212	209	205	190	175	162	151	138	129	126	124	125	126	126	128	128	128	129	128	126	124	122	120	117	114	111	108	106	105	104	0
0	216	216	226	195	176	163	160	135	125	123	124	126	128	130	131	132	132	132	130	131	128	126	124	121	117	114	111	109	107	106	0
0	218	212	207	190	172	154	137	117	114	118	123	128	132	134	135	136	137	136	135	135	134	131	129	126	122	118	115	112	111	110	0
0	215	210	202	188	169	146	117	82	97	113	123	132	137	140	141	142	143	142	142	139	138	136	134	129	126	122	119	117	116	114	0
0	216	211	204	189	170	145	102	0	80	111	127	138	143	147	149	151	151	149	149	148	145	142	138	134	130	127	124	122	120	119	0
0	219	216	218	196	178	162	150	101	112	127	139	149	155	159	161	162	160	159	158	157	155	151	145	141	136.	132	128	126	125	123	0
0	218	214	209	197	185	173	162	143	141	146	155	162	169	173	174	176	173	170	168	168	167	161	155	149	144	138	134	131	129	128	0
0	215	210	206	199	191	185	180	167	162	163	169	177	187	188	189	193	187	182	179	181	184	177	167	159	153	147	142	138	136	133	0
0	215	210	206	202	197	197	206	186	178	177	181	191	212	200	204	225	201	194	193	198	216	191	179	169	162	155	150	146	141	138	0
0	216	211	208	204	200	199	199	191	186	186	188	194	201	201	203	207	200	197	197	201	205	196	187	179	171	164	157	153	147	144	0
0	216	211	208	205	201	199	197	192	190	190	192	195	200	202	203	204	202	200	201	203	202	200	195	190	181	173	165	159	154	150	0
0	216	213	209	205	202	200	197	194	194	195	195	200	204	206	207	208	208	207	205	204	204	203	205	205	193	181	172	165	159	156	0
0	215	214	209	207	203	200	198	196	197	198	201	203	205	208	209	209	209	208	207	207	207	207	213	235	204	188	177	170	163	160	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	208	207	208	211	199	189	181	172	168	164	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	206	204	203	202	195	189	183	176	171	167	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	202	200	199	198	194	188	181	175	171	168	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	198	196	196	197	198	189	181	174	170	167	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	194	193	193	199	215	193	181	174	170	167	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	191	189	189	191	192	185	178	172	169	166	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	188	185	184	183	181	178	174	170	167	165	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	184	181	179	178	175	173	170	167	165	163	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	181	178	175	173	170	169	167	165	163	161	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	178	175	172	170	167	167	165	163	161	160	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176	174	171	168	165	165	163	162	160	159	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	175	172	169	167	164	164	163	161	160	159	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	175	172	169	167	164	164	163	161	160	159	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176	173	170	168	165	165	164	162	161	159	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176	174	172	170	167	167	166	164	162	161	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	178	176	174	173	170	170	168	167	165	162	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

CUMULATIVE MASS BALANCE -- (IN FT**3)

```
RECHARGE AND INJECTION      = -0.15685E+08
PUMPAGE AND E-T WITHDRAWAL =  0.54435E+08
CUMULATIVE  NET  PUMPAGE    =  0.38750E+08
WATER RELEASE FROM STORAGE =  0.25289E+08
LEAKAGE INTO AQUIFER        =  0.13461E+08
LEAKAGE OUT OF AQUIFER      =  0.0
CUMULATIVE  NET  LEAKAGE    =  0.13461E+08

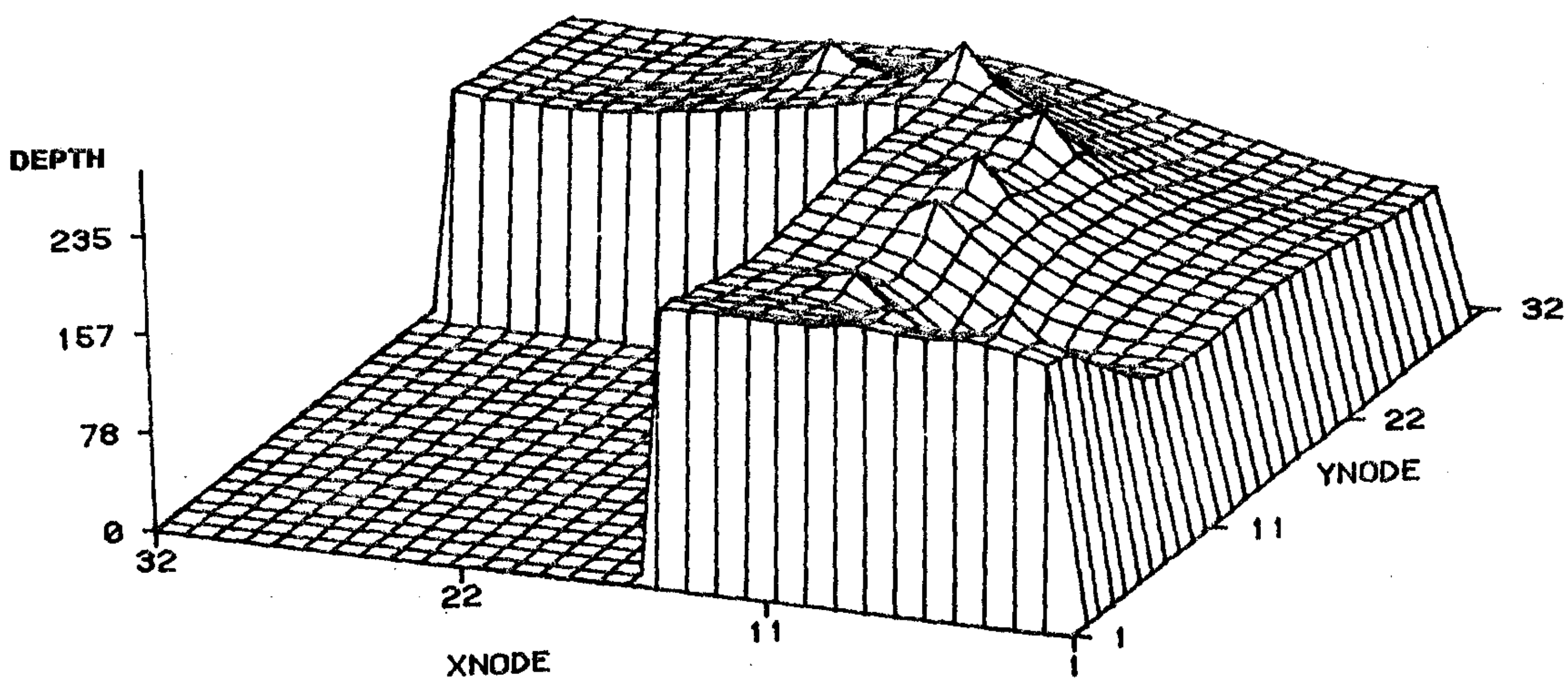
    MASS BALANCE RESIDUAL   =  -144.00
    ERROR  (AS PERCENT)     =  -.26454E-03
```

RATE MASS BALANCE -- (IN C.F.S.)

```
LEAKAGE INTO AQUIFER        =  0.15515E+01
LEAKAGE OUT OF AQUIFER      =  0.0
NET LEAKAGE    (QNET)       =  0.15515E+01
RECHARGE AND INJECTION      = -0.10023E+01
PUMPAGE AND E-T WITHDRAWAL =  0.42333E+01
NET WITHDRAWAL    (TPUM)    =  0.42333E+01
```

LANDFILL SIMULATION (180 DAYS)

DRAWDOWN

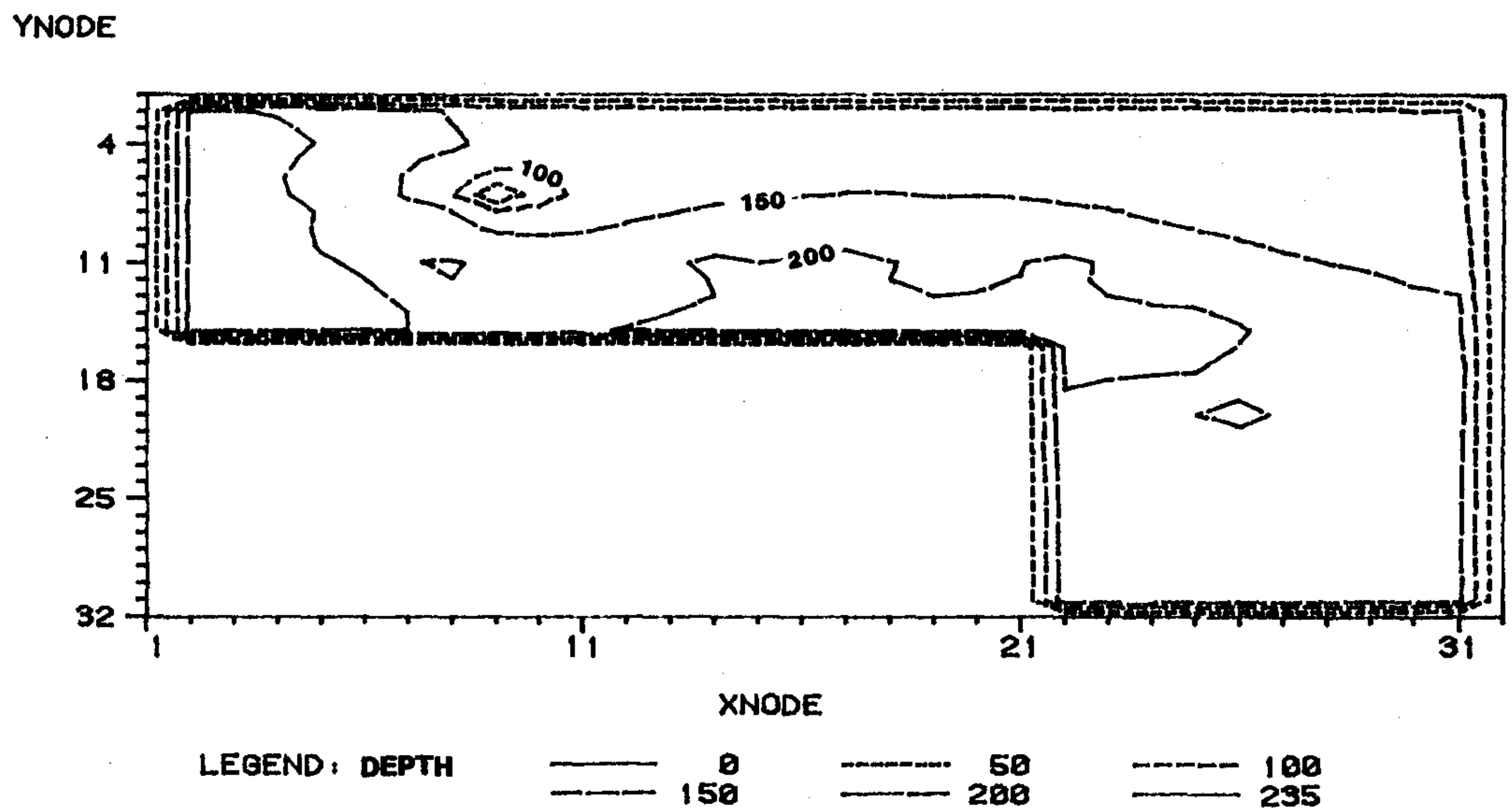


TILT=60 ROTATE=65
(1 NODE = 660 FEET)

Figure 39

LANDFILL SIMULATION (180 DAYS)

DRAWDOWN



CONTOUR INTERVAL IS 50 FEET
(1 NODE = 660 FEET)

Figure 40

CONCENTRATION

NUMBER OF TIME STEPS = 31
DELTA T = 86400.
TIME(SECONDS) = .15649D+08
CHEM.TIME(SECONDS) = 0.15649E+08
CHEM.TIME(DAYS) = 0.18112E+03
TIME(YEARS) = 0.49587E+00
CHEM.TIME(YEARS) = 0.49587E+00
NO. MOVES COMPLETED = 1

(FORMAT MODIFIED)

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	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	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	9	96	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	127	22965	92	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	18	125	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	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
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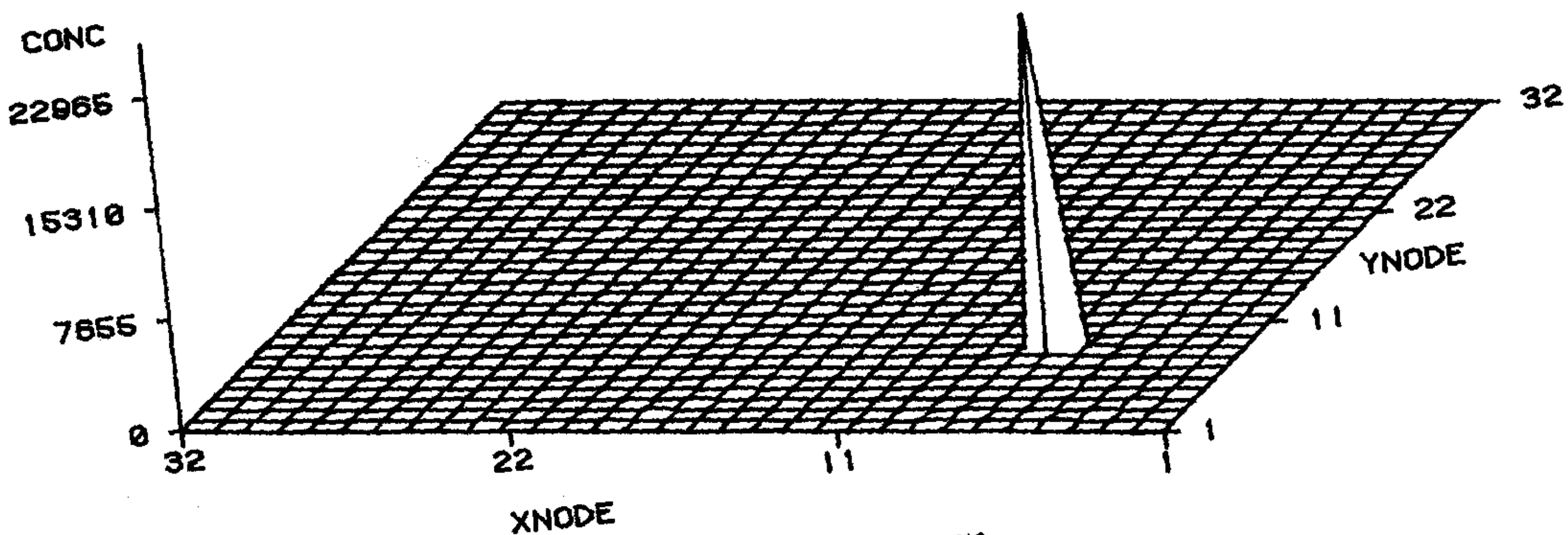
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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	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	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	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	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	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	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	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	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

CHEMICAL MASS BALANCE

MASS IN BOUNDARIES = 0.13461E+13
MASS OUT BOUNDARIES = 0.0
MASS PUMPED IN = 0.0
MASS PUMPED OUT = -0.19681E+08
INFLOW MINUS OUTFLOW = 0.13461E+13
INITIAL MASS STORED = 0.0
PRESENT MASS STORED = 0.11846E+13
CHANGE MASS STORED = 0.11846E+13
COMPARE RESIDUAL WITH NET FLUX AND MASS ACCUMULATION:
MASS BALANCE RESIDUAL = 0.16141E+12
ERROR (AS PERCENT) = 0.11991E+02

LANDFILL SIMULATION (180 DAYS)

CONTAMINATION PLUME



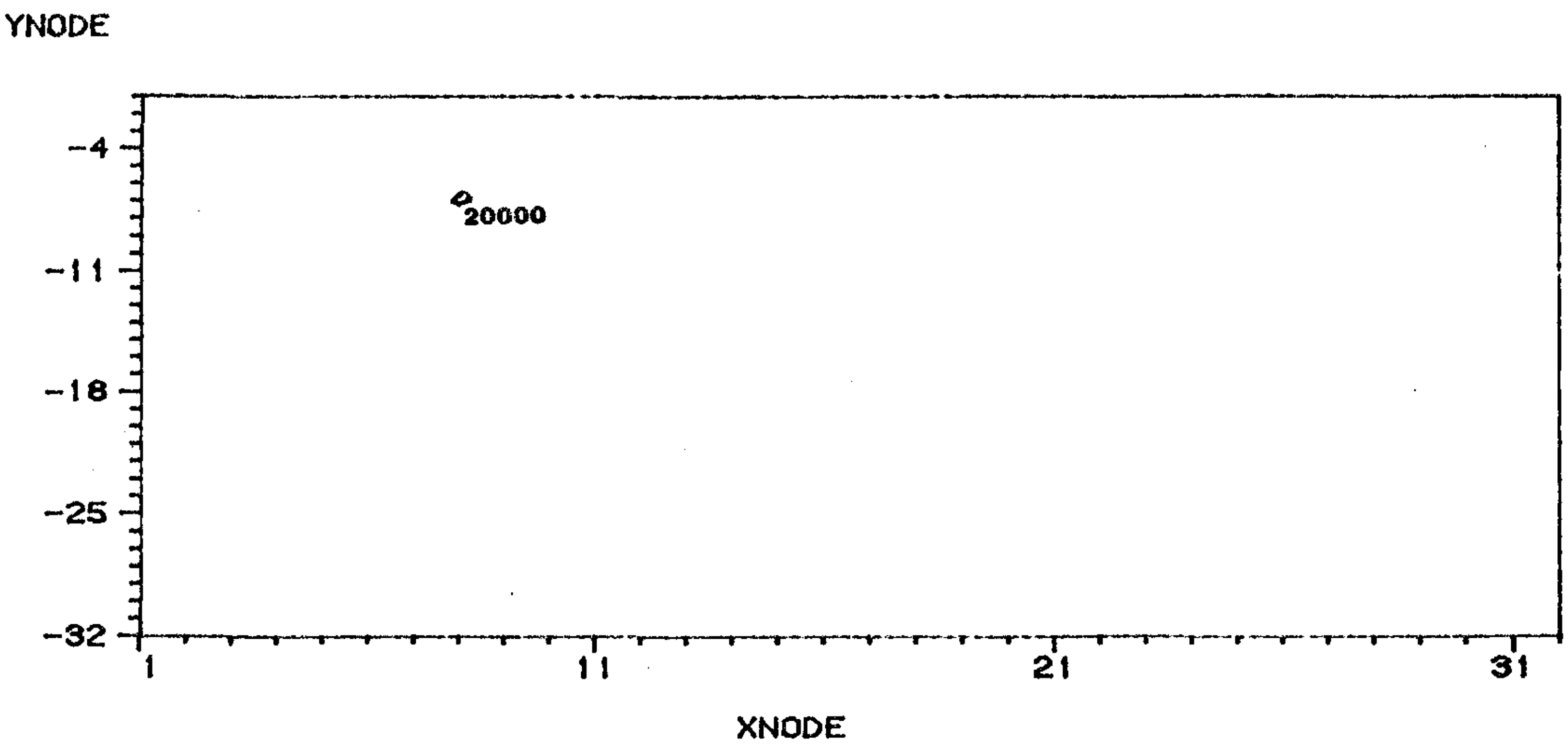
TILT=65 ROTATE=70
(1 NODE = 660 FEET)

(Inverse Image)

Figure 41

LANDFILL SIMULATION (180 DAYS)

CONTAMINATION PLUME



LEGEND: CONC 0 10000 20000 22965

CONTOUR INTERVAL IS 10000 MG/L
(1 NODE = 660 FEET)

Figure 42

DRAWDOWN (FORMAT MODIFIED)

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	213	209	203	194	184	174	166	160	158	160	165	172	178	185	193	200	206	212	216	220	223	226	228	230	230	230	230	231	231	230	0
0	219	215	211	199	186	176	168	160	158	161	165	173	180	187	195	201	208	215	219	222	226	229	231	233	233	233	233	233	232	233	0
0	224	221	224	202	187	176	173	155	151	157	164	173	182	190	197	205	211	216	221	227	229	232	234	236	236	236	236	235	235	234	0
0	228	220	214	200	183	166	151	134	138	149	162	174	184	193	200	207	214	219	224	229	234	237	239	240	240	239	239	238	238	238	0
0	228	222	214	200	181	158	128	95	118	142	160	176	188	197	204	211	218	223	229	233	237	240	242	243	243	243	243	243	243	242	0
0	231	226	219	204	183	155	109	0	97	139	163	181	193	202	210	218	224	229	235	239	242	245	246	247	247	247	247	247	247	246	0
0	237	234	236	212	193	173	154	111	132	156	174	190	202	211	219	226	231	236	241	246	249	251	251	252	251	252	251	251	251	251	0
0	239	235	229	216	202	188	175	160	165	176	190	203	214	222	229	236	240	244	248	254	258	259	259	259	258	257	256	256	256	255	0
0	239	234	229	221	212	204	198	189	189	195	204	216	228	234	239	247	250	253	257	264	270	271	269	268	267	265	264	263	262	260	0
0	241	236	232	226	221	219	225	211	208	210	218	228	247	244	250	265	259	263	269	278	293	283	280	277	275	273	271	270	268	266	0
0	244	239	235	231	227	225	225	220	219	221	227	234	243	247	253	259	262	267	274	283	291	290	288	286	284	282	279	278	275	273	0
0	245	241	237	234	230	228	227	224	224	228	232	238	246	251	256	262	267	272	280	288	293	296	297	296	293	290	287	285	282	280	0
0	246	243	240	236	233	231	229	229	230	234	239	245	252	258	264	269	275	281	286	292	299	302	307	308	304	299	295	292	289	287	0
0	247	245	241	238	235	233	232	232	234	238	243	249	254	260	266	272	278	283	290	297	306	310	315	327	314	308	303	299	295	294	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	318	318	319	321	317	313	310	305	303	300	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	325	324	323	323	319	318	316	312	309	306	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	329	327	326	326	324	321	318	315	313	311	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	333	331	330	331	331	326	322	318	316	314	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	336	334	334	337	345	333	327	323	320	318	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	340	338	336	337	337	334	329	326	324	322	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	343	340	338	337	335	334	331	329	327	325	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	345	342	340	338	336	335	333	331	330	328	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	347	344	342	340	337	337	335	334	332	331	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	349	346	344	342	339	339	337	336	335	333	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	352	349	346	344	341	341	340	338	337	336	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	354	351	348	346	343	343	342	341	340	338	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	356	354	351	349	346	346	345	343	342	341	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	359	356	353	352	349	349	348	346	345	344	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	361	359	356	355	352	352	351	349	348	346	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	363	362	360	358	356	356	354	353	351	348	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

CUMULATIVE MASS BALANCE -- (IN FT**3)

```
RECHARGE AND INJECTION       = -0.59559E+08
PUMPAGE AND E-T WITHDRAWAL =  0.18103E+09
CUMULATIVE  NET  PUMPAGE     =  0.12147E+09
WATER RELEASE FROM STORAGE =  0.39270E+08
LEAKAGE INTO AQUIFER         =  0.82331E+08
LEAKAGE OUT OF AQUIFER       =  0.0
CUMULATIVE  NET  LEAKAGE     =  0.82331E+08

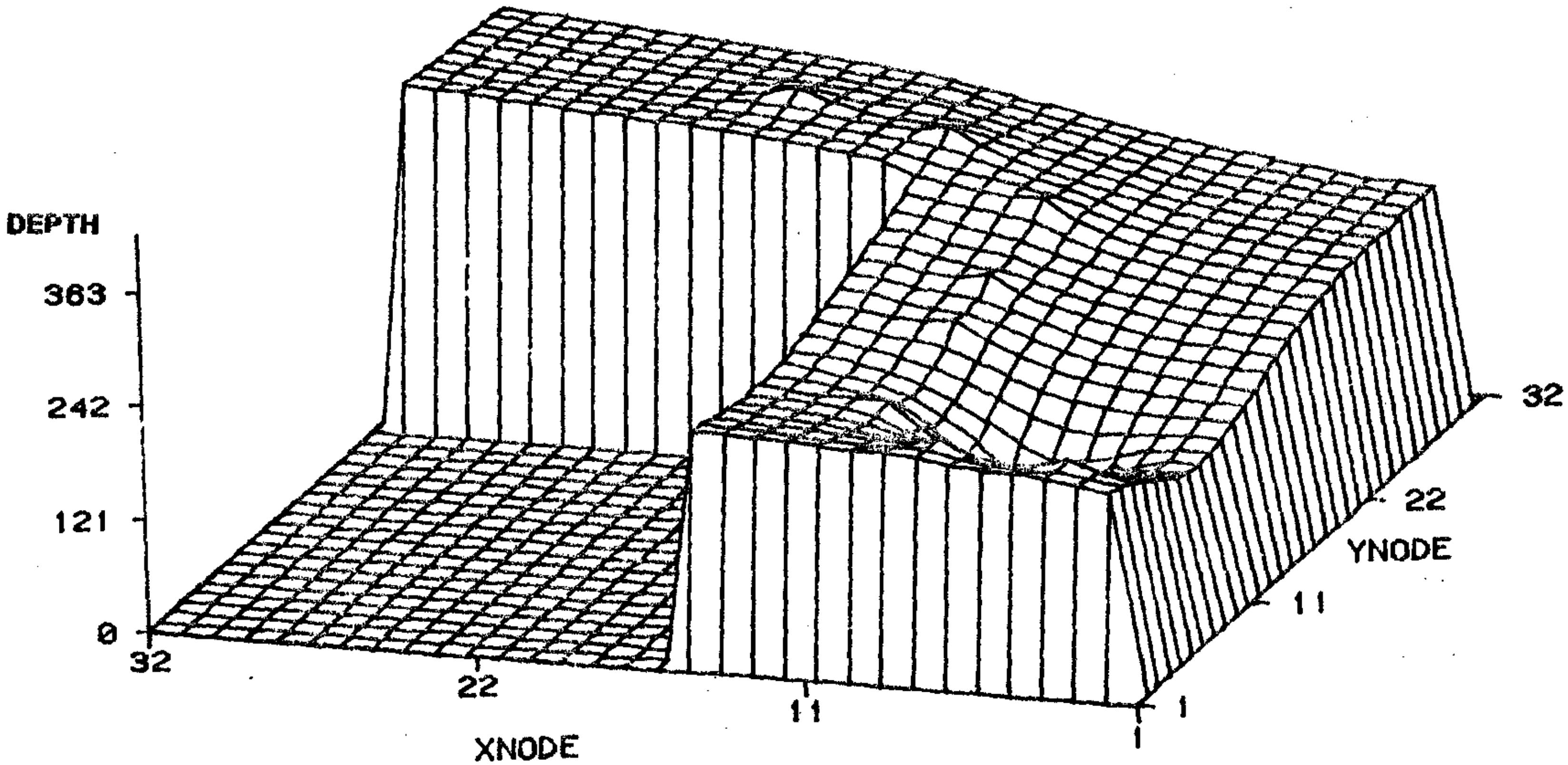
    MASS BALANCE RESIDUAL  =   .13362E+06
    ERROR  (AS PERCENT)    =   .73783E-01
```

RATE MASS BALANCE -- (IN C.F.S.)

```
LEAKAGE INTO AQUIFER         =  0.17488E+01
LEAKAGE OUT OF AQUIFER       =  0.0
NET LEAKAGE    (QNET)        =  0.17488E+01
RECHARGE AND INJECTION       = -0.10023E+01
PUMPAGE AND E-T WITHDRAWAL =  0.29693E+01
NET WITHDRAWAL    (TPUM)     =  0.29693E+01
```

LANDFILL SIMULATION (TWO YEARS)

DRAWDOWN



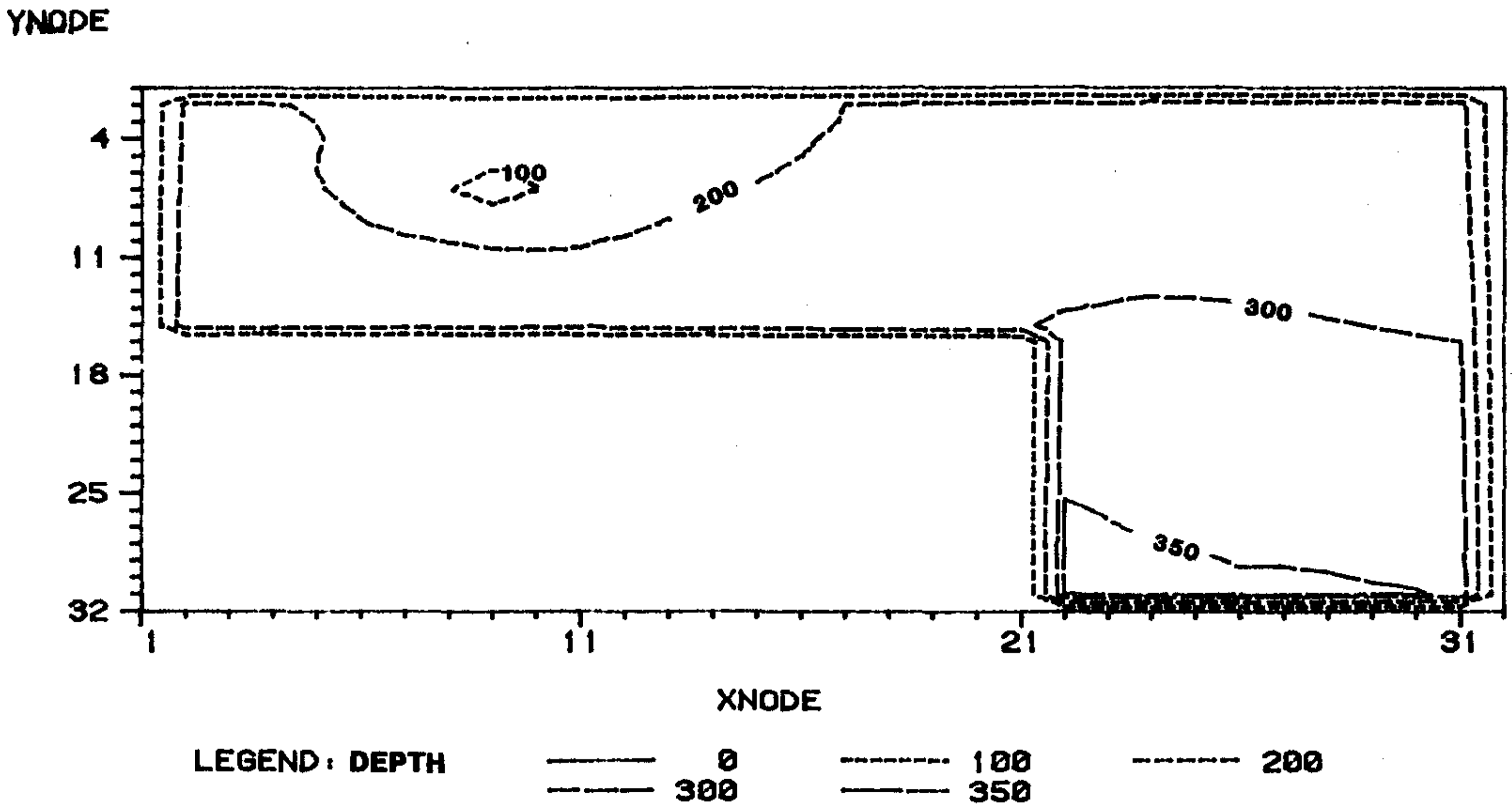
TILT=85 ROTATE=70
(1 NODE = 660 FEET)

(Inverse Image)

Figure 43

LANDFILL SIMULATION (TWO YEARS)

DRAWDOWN



CONTOUR INTERVAL IS 100 FEET
(1 NODE = 660 FEET)

Figure 44

CONCENTRATION

```
NUMBER OF TIME STEPS =     42
       DELTA T       =   .43014D+07
       TIME(SECONDS) =   .59422D+08
  CHEM.TIME(SECONDS) =  0.59422E+08
  CHEM.TIME(DAYS)    =  0.68775E+03
       TIME(YEARS)   =  0.18830E+01
  CHEM.TIME(YEARS)   =  0.18830E+01
 NO. MOVES COMPLETED =      1
```

(FORMAT MODIFIED)

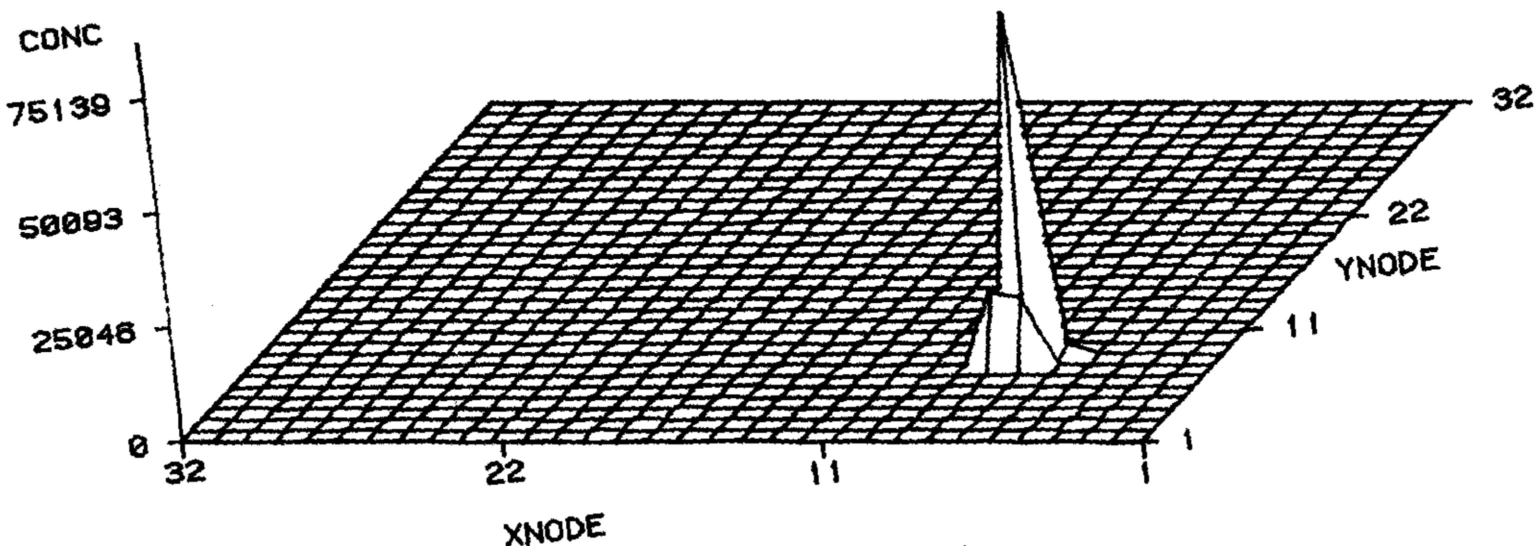
```
 0 0 0 0 0 0    0    0    0    0    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0    0    0    0    0    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0    0    0    0    0    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0    0    0    0    0    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0    0    4   17    2    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0    8  289 2316  197    2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 1011483575139 2347   18 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  611615614858  301    4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0   11   70  110    9    0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0    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    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    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 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 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 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 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 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 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 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 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 0 0 0 0
```

CHEMICAL MASS BALANCE

```
      MASS IN BOUNDARIES      =  0.82331E+13
      MASS OUT BOUNDARIES     =  0.0
      MASS PUMPED IN          =  0.0
      MASS PUMPED OUT         = -0.46455E+11
      INFLOW MINUS OUTFLOW    =  0.81866E+13
      INITIAL MASS STORED     =  0.0
      PRESENT MASS STORED     =  0.64099E+13
      CHANGE MASS STORED      =  0.64099E+13
    COMPARE RESIDUAL WITH NET FLUX AND MASS ACCUMULATION:
      MASS BALANCE RESIDUAL   =  0.17767E+13
      ERROR  (AS PERCENT)     =  0.21580E+02
```

LANDFILL SIMULATION (TWO YEARS)

CONTAMINATION PLUME

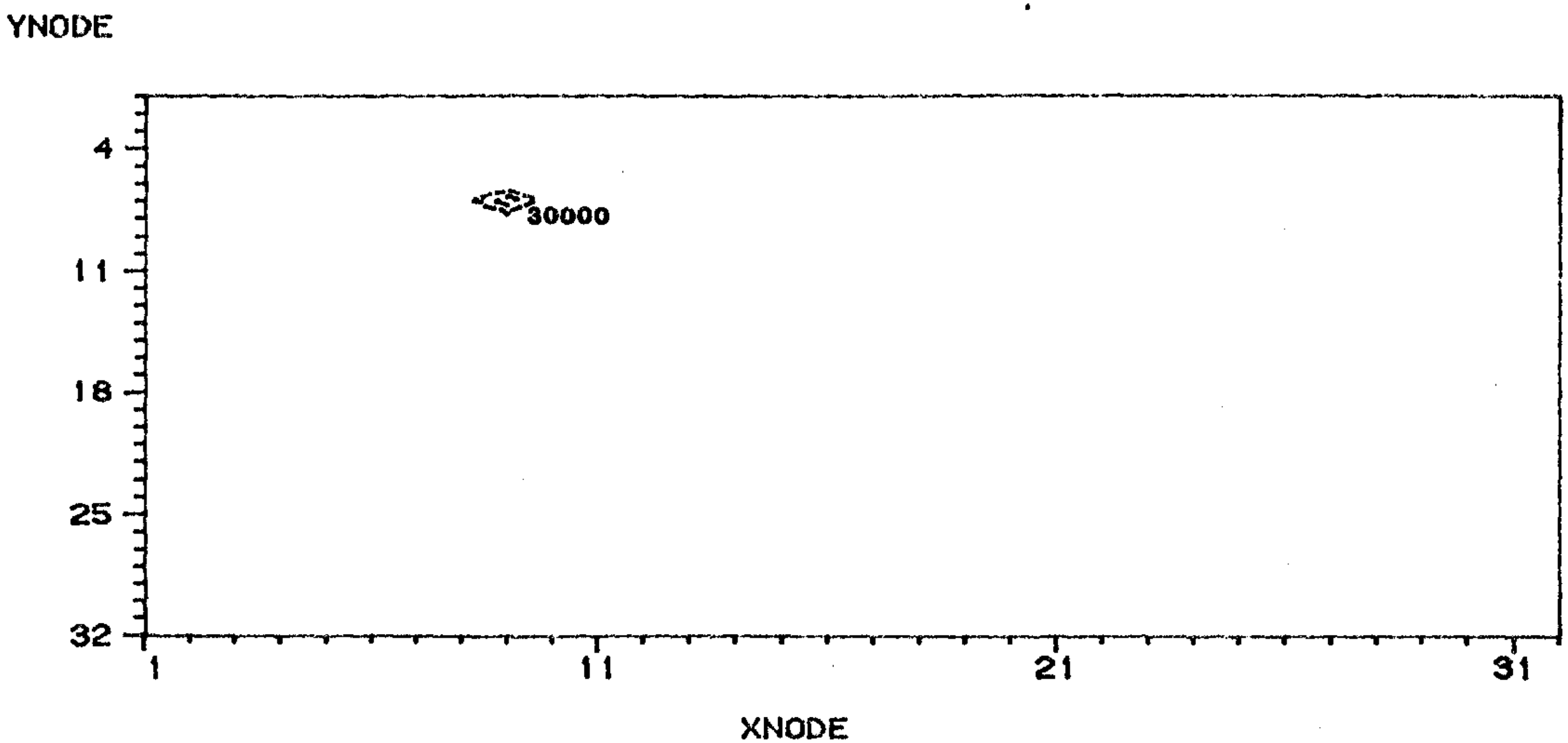


TILT=65 ROTATE=70
(1 NODE = 660 FEET)
(Inverse Image)

Figure 45

LANDFILL SIMULATION (TWO YEARS)

CONTAMINATION PLUME



LEGEND: CONC ——— 0 -------- 30000
------ 60000 ——— 75139

CONTOUR INTERVAL IS 30000 MG/L
(1 NODE = 660 FEET)

Figure 46

THE GARBER-WELLINGTON AQUIFER STUDY, LANDFILL EXAMPLE. 09 JANUARY 1982

TIME VERSUS HEAD AND CONCENTRATION AT SELECTED OBSERVATION POINTS

PUMPING PERIOD NO. 6

TRANSIENT SOLUTION

OBS.WELL NO.	X	Y
1	9	6

N	HEAD (FT)	CONC.(MG/L)	TIME (YEARS)
0	948.0	0.0	0.0
1	876.4	50.6	0.414
2	876.9	51.9	0.417
3	877.2	53.4	0.420
4	877.5	55.0	0.424
5	877.6	56.9	0.428
6	877.7	58.9	0.432
7	877.8	61.2	0.437
8	877.8	63.7	0.442
9	877.8	66.5	0.448
10	877.7	69.7	0.455
11	877.6	73.3	0.462
12	877.5	77.3	0.470
13	877.3	81.9	0.478
14	877.1	87.0	0.488
15	876.9	92.9	0.498
16	876.6	99.5	0.509
17	876.3	107.0	0.522
18	876.0	115.7	0.536
19	875.7	125.5	0.551
20	875.3	136.8	0.568
21	874.8	149.8	0.586
22	874.3	164.8	0.606
23	873.8	182.0	0.629
24	873.2	202.0	0.653
25	872.6	225.1	0.680
26	871.8	252.0	0.710
27	871.1	283.3	0.743
28	870.3	319.8	0.778
29	869.4	362.5	0.818
30	868.4	412.4	0.861
31	867.4	470.9	0.909
32	866.3	539.4	0.962
33	865.2	619.7	1.019
34	864.0	714.0	1.083
35	862.7	824.5	1.153
36	861.4	954.0	1.230
37	860.1	1105.6	1.315
38	858.7	1282.6	1.408
39	857.3	1487.4	1.510
40	855.9	1724.0	1.623
41	854.5	1998.5	1.747

42	853.1	2315.6	1.883
43	852.2	2584.2	1.991
44	852.2	2584.2	1.991

OBS.WELL NO.	X	Y
5	8	8

N	HEAD (FT)	CONC.(MG/L)	TIME (YEARS)
0	947.0	0.0	0.0
1	822.2	9.6	0.414
2	823.6	9.8	0.417
3	824.0	10.1	0.420
4	824.2	10.3	0.424
5	824.3	10.6	0.428
6	824.2	11.0	0.432
7	824.1	11.3	0.437
8	824.0	11.7	0.442
9	823.9	12.2	0.448
10	823.7	12.7	0.455
11	823.5	13.3	0.462
12	823.3	14.0	0.470
13	823.0	14.7	0.478
14	822.8	15.6	0.488
15	822.5	16.5	0.498
16	822.1	17.6	0.509
17	821.8	18.8	0.522
18	821.4	20.2	0.536
19	821.0	21.8	0.551
20	820.5	23.7	0.568
21	820.0	25.8	0.586
22	819.4	28.2	0.606
23	818.7	31.1	0.629
24	818.0	34.3	0.653
25	817.2	38.1	0.680
26	816.4	42.4	0.710
27	815.5	47.5	0.743
28	814.4	53.5	0.778
29	813.4	60.4	0.818
30	812.2	68.6	0.861
31	811.0	78.1	0.909
32	809.6	89.3	0.962
33	808.2	102.4	1.019
34	806.8	117.9	1.083
35	805.2	136.1	1.153
36	803.6	157.5	1.230
37	802.0	182.8	1.315
38	800.3	212.5	1.408
39	798.6	16126.6	1.510
40	796.8	16133.3	1.623
41	795.1	16143.0	1.747
42	793.4	16156.4	1.883
43	792.2	16169.2	1.991
44	792.2	16169.2	1.991

APPENDIX XVIII

KONIKOW MODEL'S DATA SET FOR A

BOUNDARY SOURCE SIMULATION

JCL USED AT OSU

```
//G11370F  JOB (?????,GHD-TR-KONI),'GHD:KONIKOW ',TIME=(5,0),CLASS=K,
//  MSGCLASS=X,NOTIFY=*
/*PASSWORD ?
//KONI  EXEC PGM=LOADER,PARM='SIZE=600K',REGION=600K
//SYSLIB DD DISP=SHR,DSN=SYS1.FORTLIB
//SYSLOUT DD SYSOUT=A
//SYSLIN DD DISP=SHR,DSN=U11370F.KONUPDAT.OBJ
//*T06F001 DD SYSOUT=A
//FT06F001 DD DISP=OLD,DSN=U11370F.TR5KON.OUTLIST
//FT05F001 DD *
```

TITLE AND SPECIFIED PARAMETERS

```
THE GARBER-WELLINGTON AQUIFER STUDY. BOUNDARY SOURCE. 09 JANUARY 1982.
 100   1  32  323850  30   7   5 200   9   4   1   0
   .5  .01  .29  100.0006  1.186400  660  660   .3    1    1
```

LOCATION OF OBSERVATION WELLS

```
 9 7
29 4
30 4
29 3
30 3
```

NODE LOCATION OF WELLS AND PUMPING RATES OF WELLS

```
 4 4   .2317
 8 4   .1957
 8 8   .2490
 811   .1952
1411   .2488
1711   .3127
2211   .2400
2515   .3645
2620   .2948
```

TRANSMISSIVITY MATRIX

```
1      .0001
   0
   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426 426
 426 426 426 426 426 426 426 426 426 426 426   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0 426 426 426 426 426 426 426 426 426 426   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0 426 426 426 426 426 426 426 426 426 426   0
0
0
-----------------------------------------------------------------------------
1      400.
  0
  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0
  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  0

     1  1  1  1  1  1  1  1  1  1  0
```

THICKNESS MATRIX

```
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
        1  1  1  1  1  1  1  1  1  1  0
  0
  0
---------------------------------------------------------------------------------------------------
1 .00000001
  0
  0
     -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39
 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39 -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39
      39
                                         -39                                    RECHARGE
      39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39  39
  39  39                                 -39                                     MATRIX
```

```
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39                                      -39
     39   39   39   39   39   39   39   39   39 -39
   0
   0
----------------------------------------------------------------------------------------------------
1         1.0
00000000000000000000
000000000000
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
00000000000000000000
000000000020
```

NODE IDENTIFICATION

MATRIX

```
000000000000000000000
000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000020

000000000000
 2         1.0   10000000
--------------------------------------------------------------------------------------------------------
1         1.0
   0
   0
    957.956.955.954.953.952.951.952.954.956.958.960.961.962.964.966.968.970.971.
972.974.976.978.980.981.982.984.986.988.990.
    957.956.955.954.952.951.950.951.953.955.956.958.959.960.962.963.965.968.969.
970.972.974.976.978.979.980.982.984.986.989.
    956.955.954.952.951.950.949.950.951.953.954.956.957.958.959.961.962.964.965.
969.970.972.974.976.977.978.980.982.984.987.
    957.953.952.951.950.949.949.949.950.951.952.954.955.956.956.957.959.960.962.
965.968.970.972.974.975.976.978.980.983.986.
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961.964.966.969.970.972.974.976.979.982.985.
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959.961.963.965.967.969.971.974.977.980.983.
    953.952.951.950.949.948.947.947.947.948.948.949.949.949.949.950.950.952.954.
957.959.961.962.964.966.969.971.974.978.981.
    952.951.950.949.948.947.947.947.947.947.948.948.948.948.947.948.949.950.951.
955.957.959.961.963.965.967.969.972.976.979.
    949.948.948.948.947.946.946.946.946.946.946.946.946.946.945.945.947.949.950.
953.956.960.961.963.965.967.969.972.975.977.
    948.947.947.947.946.946.946.946.946.945.945.944.943.943.943.943.945.949.953.
956.959.960.962.963.965.967.969.972.974.976.
    947.946.946.946.945.945.945.944.944.944.944.943.942.942.942.942.944.947.951.
956.960.961.962.963.965.967.969.972.973.975.
    945.944.944.944.942.942.942.941.941.942.942.942.943.943.943.944.946.948.952.
956.958.961.962.963.965.967.969.971.973.975.
    943.943.942.941.940.940.939.939.940.942.943.944.945.946.947.948.950.952.953.
955.957.959.962.963.965.967.969.971.973.975.
```

```
     941.941.939.939.938.937.937.937.939.940.942.943.944.945.946.947.949.950.952.    STARTING HEAD
954.956.958.960.963.965.967.969.971.972.975.
                                                                                     MATRIX
     957.958.959.961.963.966.969.970.973.975.

     956.957.958.960.961.965.969.971.973.975.

     954.955.956.958.959.962.965.968.971.974.

     952.953.954.956.957.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.

     951.952.953.955.956.960.963.966.969.972.
    0
    0
--------------------------------------------------------------------------------------------------------
0       0.0                                                                          INITIAL CONCENTRATION OF
//                                                                                   AQUIFER
```

APPENDIX XIX

SELECTED OUTPUT FOR A BOUNDARY SOURCE SIMULATION

```
U.S.G.S. METHOD-OF-CHARACTERISTICS MODEL FOR SOLUTE TRANSPORT IN GROUND WATER

THE GARBER-WELLINGTON AQUIFER STUDY. BOUNDARY SOURCE. 09 JANUARY 1982.

                    I N P U T     D A T A

                      GRID DESCRIPTORS

          NX     (NUMBER OF COLUMNS)  =     32
          NY     (NUMBER OF ROWS)     =     32
          XDEL   (X-DISTANCE IN FEET) =   660.0
          YDEL   (Y-DISTANCE IN FEET) =   660.0

                      TIME  PARAMETERS

          NTIM   (MAX. NO. OF TIME STEPS)        =     100
          NPMP   (NO. OF PUMPING PERIODS)        =       1
          PINT   (PUMPING PERIOD IN YEARS)       =       0.500
          TIMX   (TIME INCREMENT MULTIPLIER)     =       1.10
          TINIT  (INITIAL TIME STEP IN SEC.)     =   86400.

            HYDROLOGIC AND CHEMICAL PARAMETERS

          S        (STORAGE COEFFICIENT)         =       0.000600
          POROS    (EFFECTIVE POROSITY)          =       0.29
          BETA     (CHARACTERISTIC LENGTH)       =     100.0
          DLTRAT   (RATIO OF TRANSVERSE TO
                   LONGITUDINAL DISPERSIVITY)    =       0.30
          ANFCTR   (RATIO OF T-YY TO T-XX)       =       1.000000

                    EXECUTION PARAMETERS

          NITP   (NO. OF ITERATION PARAMETERS) =     7
          TOL    (CONVERGENCE CRITERIA - ADIP) =     0.0100
          ITMAX  (MAX.NO.OF ITERATIONS - ADIP) =   200
          CELDIS (MAX.CELL DISTANCE PER MOVE
                    OF PARTICLES - M.O.C.)     =     1.000
          NPMAX  (MAX. NO. OF PARTICLES)       =  3850
          NPTPND (NO. PARTICLES PER NODE)      =     4

                      PROGRAM OPTIONS

          NPNT   (TIME STEP INTERVAL FOR
                  COMPLETE PRINTOUT)         =     30
          NPNTMV (MOVE INTERVAL FOR CHEM.
                  CONCENTRATION PRINTOUT)    =      0
          NPNTVL (PRINT OPTION-VELOCITY
                  0=NO; 1=FIRST TIME STEP;
                  2=ALL TIME STEPS)          =      0
          NPNTD  (PRINT OPTION-DISP.COEF.
                  0=NO; 1=FIRST TIME STEP;
                  2=ALL TIME STEPS)          =      0
          NUMOBS (NO. OF OBSERVATION WELLS
                  FOR HYDROGRAPH PRINTOUT)   =      5
          NREC   (NO. OF PUMPING WELLS)      =      9
          NCODES (FOR NODE IDENT.)           =      1
          NPNCHV (PUNCH VELOCITIES)          =      0
          NPDELC (PRINT OPT.-CONC. CHANGE)   =      0
```

TIME INTERVALS (IN SECONDS)

86400.	95040.	.10454D+06	.11500D+06	.12650D+06	.13915D+06	.15306D+06	.16837D+06	.18521D+06	.20373D+06
.22410D+06	.24651D+06	.27116D+06	.29828D+06	.32810D+06	.36091D+06	.39701D+06	.43671D+06	.48038D+06	.52841D+06
.58126D+06	.63938D+06	.70332D+06	.77365D+06	.85102D+06	.93612D+06	.10297D+07	.11327D+07	.12460D+07	.13706D+07
.15076D+07	.16584D+07	.18242D+07	.20067D+07	.22073D+07	.24281D+07	.26709D+07	.29379D+07	.32317D+07	.35549D+07
.39104D+07	.43014D+07	.47316D+07	.52047D+07	.57252D+07	.62977D+07	.69275D+07	.76203D+07	.83823D+07	.92205D+07
.10143D+08	.11157D+08	.12273D+08	.13500D+08	.14850D+08	.16335D+08	.17968D+08	.19765D+08	.21741D+08	.23916D+08
.26307D+08	.28938D+08	.31832D+08	.35015D+08	.38516D+08	.42368D+08	.46605D+08	.51265D+08	.56392D+08	.62031D+08
.68234D+08	.75058D+08	.82563D+08	.90820D+08	.99902D+08	.10989D+09	.12088D+09	.13297D+09	.14627D+09	.16089D+09
.17698D+09	.19468D+09	.21415D+09	.23556D+09	.25912D+09	.28503D+09	.31353D+09	.34489D+09	.37938D+09	.41731D+09
.45905D+09	.50495D+09	.55544D+09	.61099D+09	.67209D+09	.73930D+09	.81323D+09	.89455D+09	.98400D+09	.10824D+10

LOCATION OF OBSERVATION WELLS

NO.	X	Y
1	9	7
2	29	4
3	30	4
4	29	3
5	30	3

LOCATION OF PUMPING WELLS

X	Y	RATE(IN CFS)	CONC.
4	4	0.2317	0.0
8	4	0.1957	0.0
8	8	0.2490	0.0
8	11	0.1952	0.0
14	11	0.2488	0.0
17	11	0.3127	0.0
22	11	0.2400	0.0
25	15	0.3645	0.0
26	20	0.2948	0.0

AREA OF ONE CELL = .4356D+06

X-Y SPACING:
660.00
660.00

CONCENTRATION
NUMBER OF TIME STEPS = 30
DELTA T = .13706D+07
TIME(SECONDS) = .14212D+08
CHEM.TIME(SECONDS) = 0.14212E+08
CHEM.TIME(DAYS) = 0.16449E+03
TIME(YEARS) = 0.45036E+00
CHEM.TIME(YEARS) = 0.45036E+00
NO. MOVES COMPLETED = 1

(Format Modified)

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	786	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	1	922	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	796	0
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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	1	1309	0
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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	2	1588	0
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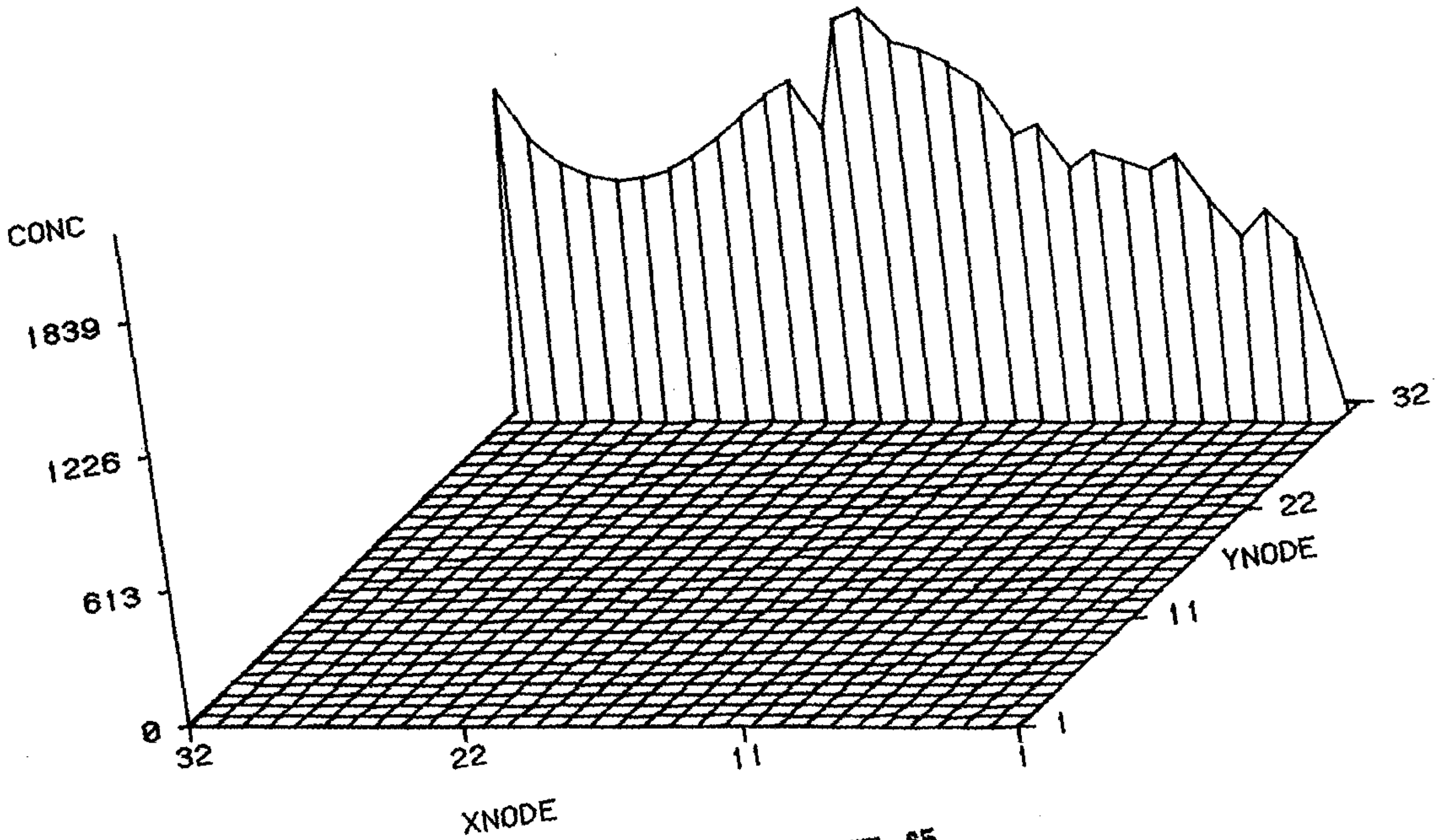
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1250	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1471	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHEMICAL MASS BALANCE

MASS IN BOUNDARIES = 0.12088E+13
MASS OUT BOUNDARIES = -0.11862E+08
MASS PUMPED IN = 0.72431E+12
MASS PUMPED OUT = -0.11774E+06
INFLOW MINUS OUTFLOW = 0.19331E+13
INITIAL MASS STORED = 0.0
PRESENT MASS STORED = 0.19213E+13
CHANGE MASS STORED = 0.19213E+13
COMPARE RESIDUAL WITH NET FLUX AND MASS ACCUMULATION:
MASS BALANCE RESIDUAL = 0.11866E+11
ERROR (AS PERCENT) = 0.61381E+00

BOUNDARY SOURCE (180 DAYS, MG/L)

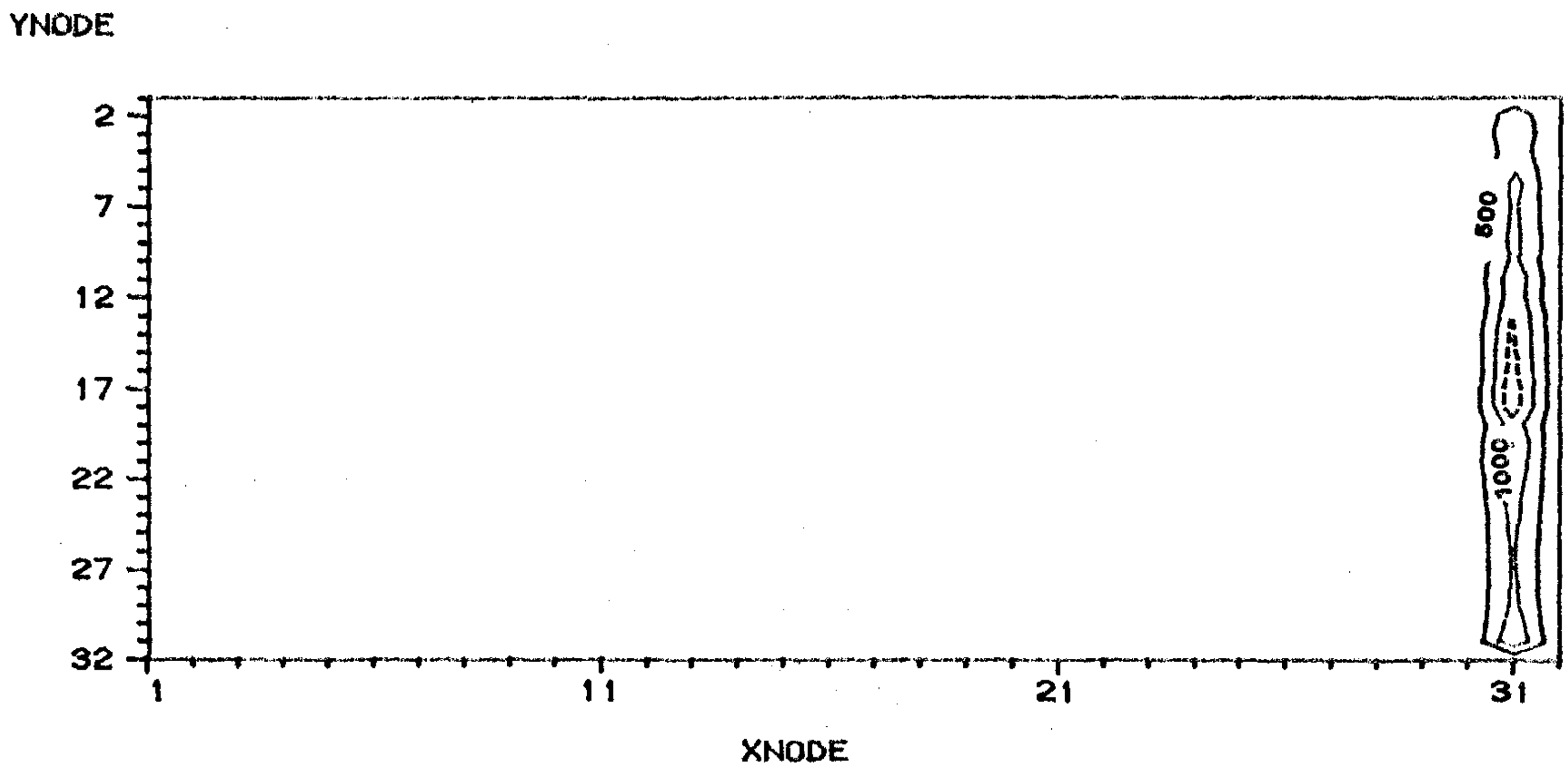


TILT=70 ROTATE=65

(Inverse Image)

Figure 47

BOUNDARY SOURCE (180 DAYS, MG/L)



LEGEND: CONC ——— 0 ——— 500 ——— 1000 -------- 1500 -------- 2000

CONTOUR INTERVAL IS 500 MG/L

Figure 48

THE GARBER-WELLINGTON AQUIFER STUDY. BOUNDARY SOURCE. 09 JANUARY 1982.

TIME VERSUS HEAD AND CONCENTRATION AT SELECTED OBSERVATION POINTS

PUMPING PERIOD NO. 1

TRANSIENT SOLUTION

OBS.WELL NO.	X	Y	N	HEAD (FT)	CONC.(MG/L)	TIME (YEARS)
1	9	7				
			0	947.0	0.0	0.0
			1	944.8	0.0	0.003
			2	941.7	0.0	0.006
			3	938.6	0.0	0.009
			4	935.5	0.0	0.013
			5	932.2	0.0	0.017
			6	928.8	0.0	0.021
			7	925.1	0.0	0.026
			8	921.2	0.0	0.031
			9	916.9	0.0	0.037
			10	912.1	0.0	0.044
			11	907.0	0.0	0.051
			12	901.3	0.0	0.059
			13	895.2	0.0	0.067
			14	888.4	0.0	0.077
			15	881.1	0.0	0.087
			16	873.1	0.0	0.098
			17	864.5	0.0	0.111
			18	855.2	0.0	0.125
			19	845.1	0.0	0.140
			20	834.3	0.0	0.157
			21	822.8	0.0	0.175
			22	810.5	0.0	0.195
			23	797.4	0.0	0.218
			24	783.5	0.0	0.242
			25	768.9	0.0	0.269
			26	753.5	0.0	0.299
			27	737.5	0.0	0.332
			28	720.8	0.0	0.367
			29	703.6	0.0	0.407
			30	685.9	0.0	0.450
			31	667.8	0.0	0.498
			32	667.1	0.0	0.500

OBS.WELL NO.	X	Y
3	30	4

N	HEAD (FT)	CONC.(MG/L)	TIME (YEARS)
0	984.0	0.0	0.0
1	984.8	0.0	0.003
2	985.2	0.0	0.006
3	985.5	0.0	0.009
4	985.7	0.0	0.013
5	985.9	0.0	0.017
6	986.0	0.0	0.021
7	986.1	0.0	0.026
8	986.1	0.0	0.031
9	986.1	0.0	0.037
10	986.0	0.0	0.044
11	985.9	0.0	0.051
12	985.7	0.0	0.059
13	985.5	0.0	0.067
14	985.3	0.0	0.077
15	984.9	0.0	0.087
16	984.6	0.0	0.098
17	984.1	0.0	0.111
18	983.7	0.0	0.125
19	983.1	0.0	0.140
20	982.6	0.0	0.157
21	982.0	0.0	0.175
22	981.3	0.0	0.195
23	980.6	0.0	0.218
24	979.9	0.1	0.242
25	979.1	0.1	0.269
26	978.3	0.1	0.299
27	977.4	0.2	0.332
28	976.5	0.2	0.367
29	975.6	0.3	0.407
30	974.7	0.5	0.450
31	973.7	0.7	0.498
32	973.7	0.7	0.500

GROUND-WATER AND CONTAMINANT TRANSPORT MODELING: GARBER-WELLINGTON AQUIFER IN OKLAHOMA

PART II

NUMERICAL MODEL FOR THREE-DIMENSIONAL FLUID FLOW AND SOLUTE TRANSPORT IN GROUND-WATER SYSTEMS

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March, 1982

INTRODUCTION

This document describes the revision of a numerical model for fluid flow and heat transfer in ground water systems (Willhite, et al., 1974a, 1974b) to solve the solute transport equations for a conservative tracer. The mathematical development of the partial differential equations describing solute transport is presented in Section A. This development parallels the development of the energy flow equations in Chapter 4, Volume I, of the Willhite, et al. (1974a) report.

Section B contains the formulation of the finite-difference equations for solute transport following an outline analogous to Sections 1.3.4 and 1.3.5, Volume II, (Willhite, et al., 1974b) which describe the formulation of the finite-difference equations for energy flow.

Section C is basically a user's manual for the numerical simulation of fluid flow and solute transport in ground water systems. This supplement includes a summary of the computer program and subprogram functions, and descriptions of the input data requirements and the computed results. The program listings are presented in Section D and example problems are summarized in Section E.

The authors must emphasize that this document should be used in conjunction with Volumes I and II of Willhite, et al. The purpose of this report is to provide additional information relating to solute transport in ground-water systems and not to replace the original report.

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Section A

SOLUTE TRANSPORT IN GROUND WATER SYSTEMS

Solute may be transported through a porous medium by the mechanisms of convection and diffusion/dispersion. In addition, solute may be distributed between the solid and fluid phases as a result of adsorption and/or absorption phenomena. Two models can be used to describe the interchange of solute between the fluid and solid phases. In the first approach, the concentrations in the fluid and solid phases are to be considered as distinct variables. Mass transfer between the two phases occurs at the fluid-solid interface and is approximated using an appropriate relationship for the rate of mass transfer.

A second approach assumes instantaneous equilibrium between the fluid and solid phases at any location and time. The concentration in the solid phase is expressed in terms of the fluid phase concentration through an appropriate "sorption isotherm."

The second approach has been adopted for this project. In addition the sorption isotherm is assumed to be linear. In other words

$$\frac{d\dot{C}_s}{dt} = \dot{K}_d \frac{d\dot{C}}{dt} \tag{A.1}$$

where

$\dot{C}_s$ = concentration in solid phase, lb solute/lb solid;

$\dot{C}$ = concentration in liquid phase, lb solute/lb liquid; and

$\dot{K}_d$ = distribution coefficient.

The diffusion/dispersion mechanism is used to account for all solute transport mechanisms other than convection and linear absorption. An effective dispersion coefficient will be defined before proceeding to the development of the solute transport equation. Let q_x, q_y, and q_z be the effective flux of solute in the x, y, and z coordinate directions, respectively. These fluxes are related to the concentration gradients through relationships analogous to Fick's Law given by

$$q_x = - D_x \frac{\partial C}{\partial x} \tag{A.2}$$

$$q_y = - D_y \frac{\partial C}{\partial y} \tag{A.3}$$

$$q_z = - D_z \frac{\partial C}{\partial z} \tag{A.4}$$

In these equations D_i is the effective solute dispersion coefficient in the porous media and C is the concentration of the fluid phase.

A.1 - Development of the Mathematical Model

A differential volume of porous media through which fluid and solute are flowing is shown in Figure A.1. Although only the x-direction components of the flows are illustrated, solute enters and leaves the volume element by convection and dispersion in the x, y, and z directions.

The solute transport equation is derived by writing a component mass balance around the differential volume element. Writing the mass balance over the time increment Δt,

solute in - solute out = solute accumulated

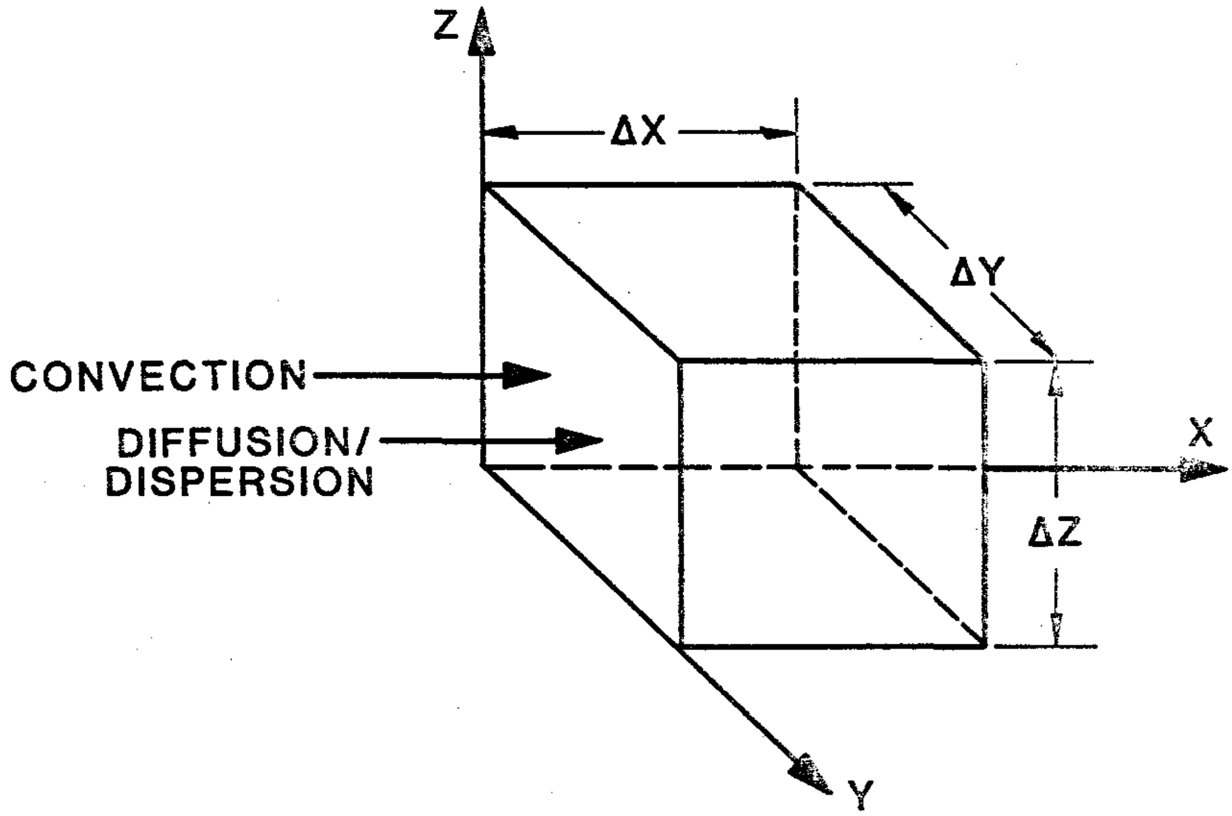


FIGURE A.1 - Differential volume of porous media.

$$\rho V_x \dot{C}\Big|_x \Delta y \Delta z \Delta t - \rho V_x \dot{C}\Big|_{x+\Delta x} \Delta y \Delta z \Delta t$$

$$+ \rho V_y \dot{C}\Big|_y \Delta x \Delta z \Delta t - \rho V_y \dot{C}\Big|_{y+\Delta y} \Delta x \Delta z \Delta t$$

$$+ \rho V_z \dot{C}\Big|_z \Delta x \Delta y \Delta t - \rho V_z \dot{C}\Big|_{z+\Delta z} \Delta x \Delta y \Delta t$$

NET SOLUTE TRANSPORT BY CONVECTION

$$+ q_x\Big|_x \Delta y \Delta z \Delta t - q_x\Big|_{x+\Delta x} \Delta y \Delta z \Delta t$$

$$+ q_y\Big|_y \Delta x \Delta z \Delta t - q_y\Big|_{y+\Delta y} \Delta x \Delta z \Delta t$$

$$+ q_z\Big|_z \Delta x \Delta y \Delta t - q_z\Big|_{z+\Delta y} \Delta x \Delta y \Delta t$$

NET SOLUTE TRANSPORT BY DISPERSION

$$+ \dot{Q}_{in} \dot{C}_{in} \Delta x \Delta y \Delta z \Delta t - \dot{Q}_{out} \dot{C} \Delta x \Delta y \Delta z \Delta t$$

NET SOLUTE ADDED FROM SOURCES/SINKS

$$= \left(\rho_s \dot{C}_s (1 - \phi) + \rho \dot{C} \phi\right)\Big|_{t+\Delta t}$$

$$- \left(\rho_s \dot{C}_x (1 - \phi) + \rho \dot{C} \phi\right)\Big|_t$$

NET ACCUMULATION OF SOLUTE DURING Δt

(A.5)

where

C = concentration in fluid phase, lb solute/lb fluid

C_s = concentration in solid phase lb solute/lb solid

V_x = fluid velocity in x direction, ft/sec

V_y = fluid velocity in y direction, ft/sec

V_z = fluid velocity in z direction, ft/sec

$\dot{Q}_{in}$ = mass rate of fluid added per unit volume, $lb/ft^3/sec$

$\dot{Q}_{out}$ = mass rate of fluid withdrawn per unit volume, $lb/ft^3/sec$

ρ = fluid density, lb/ft^3

ρ_s = bulk density of solid matrix, lb/ft^3

ϕ = porosity or volume void fraction of porous media, ft^3/ft^3

Dividing by $\Delta x \Delta y \Delta z \Delta t$ and taking the limit as Δx, Δy, Δz, and Δt approach zero leads to

$$- \frac{\partial}{\partial x} (\rho V_x \dot{C}) - \frac{\partial}{\partial y} (\rho V_y \dot{C}) - \frac{\partial}{\partial z} (\rho V_z \dot{C})$$

$$- \frac{\partial}{\partial x} q_x - \frac{\partial}{\partial y} q_y - \frac{\partial}{\partial z} q_z + \dot{Q}_{in} \dot{C}_{in} - \dot{Q}_{out} \dot{C}$$

$$= \frac{\partial}{\partial t} \left\{ \rho_x \dot{C}_s (1 - \phi) + \rho \dot{C} \phi \right\} \tag{A.6}$$

Equation A.6 can be written in vector notation as

$$- \nabla \cdot (\rho V \dot{C}) - \nabla \cdot \dot{q} + \dot{Q}_{in} \dot{C}_{in} - \dot{Q}_{out} \dot{C}$$

$$= \frac{\partial}{\partial t} \left\{ \rho_s \dot{C}_s (1 - \phi) + \rho \dot{C} \phi \right\} \tag{A.7}$$

Expanding the convection term results in

$$- (\rho V) \nabla C - C \nabla \cdot (\rho V) - \nabla \cdot q + \dot{Q}_{in} \dot{C}_{in} - \dot{Q}_{out} \dot{C}$$

$$= \frac{\partial}{\partial t} \left\{ \rho_s \dot{C}_s (1 - \phi) + \rho \dot{C} \phi \right\} \tag{A.8}$$

From the continuity equation (Equation 3.15)

$$- \nabla \cdot (\rho V) + \dot{Q}_{in} - \dot{Q}_{out} = \frac{\partial}{\partial t} (\rho \phi) \tag{A.9}$$

Substituting Equation A.9 into Equation A.8 yields

$$- (\rho V) \nabla \dot{C} + C \left\{ \frac{\partial}{\partial t} (\rho \phi) - \dot{Q}_{in} + \dot{Q}_{out} \right\} - \nabla \cdot q$$

$$+ \dot{Q}_{in} \dot{C}_{in} - \dot{Q}_{out} \dot{C} = \frac{\partial}{\partial t} \left\{ \rho_s \dot{C}_s (1 - \phi) + \rho \dot{C} \phi \right\} \tag{A.10}$$

Expanding terms gives

$$- (\rho V) \nabla\dot{C} + \dot{C} \frac{\partial}{\partial t} (\rho\phi) - \dot{Q}_{in} \dot{C} + \dot{Q}_{out} \dot{C})$$

$$- \nabla\cdot q + \dot{Q}_{in} \dot{C}_{in} - \dot{Q}_{out} \dot{C}$$

$$= \dot{C} \frac{\partial}{\partial t} (\rho\phi) + (\rho\phi) \frac{\partial \dot{C}}{\partial t}$$

$$+ \dot{C}_s \frac{\partial}{\partial t} \left[\rho_s (1 - \phi)\right] + \left[\rho_s (1 - \phi)\right] \frac{\partial \dot{C}_s}{\partial t} \tag{A.11}$$

which simplifies to

$$- (\rho V) \nabla\cdot\dot{C} - \nabla\cdot q + \dot{Q}_{in} (\dot{C}_{in} - \dot{C})$$

$$= \rho\phi \frac{\partial \dot{C}}{\partial t} + \rho_s (1 - \phi) \frac{\partial \dot{C}_s}{\partial t} + \dot{C}_s \frac{\partial}{\partial t} \left[\rho_s (1 - \phi)\right] \tag{A.12}$$

Now, in general $C_s = f(C)$ and

$$\frac{\partial \dot{C}_s}{\partial t} = \frac{d\dot{C}_s}{dC} \frac{\partial \dot{C}}{\partial t} \tag{A.13}$$

For a linear sorption isotherm

$$\frac{d\dot{C}_s}{d\dot{C}} = \dot{K}_d = \frac{\text{Mass of solute per mass of solid}}{\text{Mass of solute per mass of fluid}} \tag{A.14}$$

where $\dot{K}_d$ is a distribution coefficient.

Thus,

$$\frac{\partial \dot{C}_s}{\partial t} = \dot{K}_d \frac{\partial \dot{C}}{\partial t} \tag{A.15}$$

and

$$\dot{C}_s = \dot{K}_d \dot{C} \tag{A.16}$$

Also, recall that the change in porosity with time is given by

$$\frac{\partial \phi}{\partial t} = \rho g \alpha (1 - \phi) \frac{\partial h}{\partial t} \tag{A.17}$$

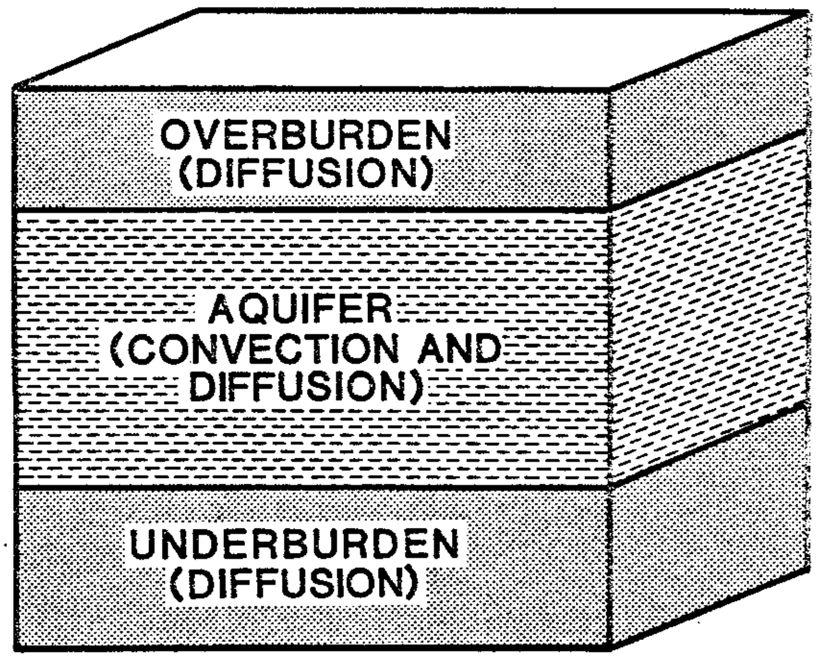


FIGURE A.2 - Region for solute transport model.

where α is the one-dimensional vertical compressibility and h is the hydraulic head.

Substituting Equations A.15, A.16, and A.17 into the accumulation terms of Equation A.12 yields

$$\rho\phi \frac{\partial \dot{C}}{\partial t} + \rho_s (1 - \phi) \frac{\partial \dot{C}_s}{\partial t} + \dot{C}_s (1 - \phi) \frac{\partial \rho_s}{\partial t} - \dot{C}_s \rho_s \frac{\partial \phi}{\partial t}$$

$$= \rho\phi \frac{\partial \dot{C}}{\partial t} + \rho_s (1 - \phi) \dot{K}_d \frac{\partial \dot{C}}{\partial t} - \dot{K}_d \dot{C} \rho_s \frac{\partial \phi}{\partial t}$$

$$= \left\{\rho_s \dot{K}_d (1 - \phi) + \rho\phi\right\} \frac{\partial \dot{C}}{\partial t}$$

$$- \left\{\rho_s \dot{K}_d \dot{C} \rho g \alpha (1 - \phi)\right\} \frac{\partial h}{\partial t} \qquad \text{(A.18)}$$

Substituting Equation A.18 into Equation A.12 gives

$$- \rho V \nabla \dot{C} - \nabla \cdot \dot{q} + \dot{Q}_{in} (\dot{C}_{in} - \dot{C})$$

$$= \left\{\rho_s \dot{K}_d (1 - \phi) + \rho\phi\right\} \frac{\partial \dot{C}}{\partial t}$$

$$- \left\{\rho_s \dot{K}_d \dot{C} \rho g \alpha (1 - \phi)\right\} \frac{\partial h}{\partial t} \qquad \text{(A.19)}$$

which is the solute transport equation for a compressible porous medium when ρ and $\dot{K}_d$ are constant.

A.2 - Boundary Conditions

The region included in the mathematical model of solute transport processes is shown in Figure A.2. The region is thicker than the comparable fluid-flow region shown in Figure 3.2 because solute transport to the overlying and underlying formations is included. Several boundary conditions can be used in the model. These are

a) Impervious boundary,

b) Specified concentration, and

c) Specified solute injection rates.

These boundary conditions are similar to those discussed in Section 3.2.2 for the fluid flow model with one major difference. In the solute transport model, solute is transported through the boundaries by two mechanisms, convection and diffusion/dispersion.

Solute flux by convection and diffusion in a direction normal to the boundary can be written as

$$q_{bn} = \rho V_{nb} \dot{C}_b - D_{bn} \left. \frac{\partial \dot{C}}{\partial n} \right|_b \tag{A.20}$$

This relationship assumes that the coordinate direction is normal to the boundary and serves as the basis for developing the following boundary conditions.

Impervious Boundary

The term impervious boundary implies that there is no solute flux by diffusion, or

$$- D_{bn} \left. \frac{\partial \dot{C}}{\partial n} \right|_b = 0 \tag{A.21}$$

An impervious boundary is not necessarily a zero solute-flux boundary as solute may enter or leave the region if V_{nb} is not equal to zero.

An impervious boundary can be simulated mathematically by setting either D_{bn} or $(\partial \dot{C}/\partial n)|_b$ equal to zero. The numerical model described in Supplement B handles an impervious boundary by setting $D_{bn} = 0$.

Specified Boundary Concentration

A boundary may exist where the concentration is specified or remains constant. When the velocity of the fluid normal to the boundary is zero, solute transport across the boundary is due to diffusion. The expression used to approximate this boundary condition is given by

$$\dot{Q}_{bn} = - D_{bn} \frac{\dot{C}_b - \dot{C}_{b-\Delta n}}{\Delta n} \tag{A.22}$$

where $\dot{C}_b$ is the boundary concentration, $\dot{C}_{b-\Delta n}$ is the concentration in the porous media at a distance b-Δn from the boundary, and D_{bn} is an equivalent mass dispersion coefficient for the region between b-Δn and b. Implementation of this boundary condition is similar to the method illustrated by Equations B.41 through B.47 in Section B.

At boundaries where solute enters or leaves by convection, the convection term in Equation A.20 is known. The diffusion term may be evaluated using either Equation A.21 or Equation A.22, and all parameters in Equation A.20 are known or approximated.

Specified Solute Injection Rates

Injection wells are simulated as point sources in the mathematical formulation of both the fluid-flow and solute-transport models. At the point of injection, the concentration will be a maximum or minimum, and the correct boundary conditions which apply in Equation A.19 at the point of injection are

$$\frac{\partial \dot{C}}{\partial x} = 0; \ \frac{\partial \dot{C}}{\partial y} = 0; \ \text{and} \ \frac{\partial \dot{C}}{\partial z} = 0 \tag{A.23}$$

However, since the numerical model discussed in Section B applies to a finite volume of the porous medium rather than a point, the boundary conditions described by Equation A.23 are relaxed. Further discussion of boundary conditions is presented in Section B.

A.3 - Numerical Solution Techniques

The mathematical solute-transport model represented by Equation A.19 and the approximate initial and boundary conditions is identical in form to the energy transport model represented by Equation 4.16 in Volume I. Thus, the same numerical solution techniques are used. The finite difference equations for the solute-transport model are formulated in Section B.

Section B

FORMULATION OF THE FINITE DIFFERENCE EQUATIONS FOR SOLUTE TRANSPORT

The partial differential equation for solute transport is given by Equation A.19, or

$$- \rho V \nabla \cdot \dot{C} - \nabla \cdot q + \dot{Q}_{in} (\dot{C}_{in} - \dot{C})$$
$$= [\rho_s \dot{K}_d (1 - \phi) + \rho \phi] \frac{\partial \dot{C}}{\partial t}$$
$$- [\rho_s \dot{K}_d \dot{C} \rho g \alpha (1 - \phi)] \frac{\partial h}{\partial t} \qquad \text{(A.19)}$$

Expanding the diffusion/dispersion terms using the Fickian model described by Equations A.2, A.3, and A.4 gives

$$- \rho V \nabla \cdot \dot{C}$$
$$+ \frac{\partial}{\partial x} (D_x \frac{\partial \dot{C}}{\partial x}) + \frac{\partial}{\partial y} (D_y \frac{\partial \dot{C}}{\partial y}) + \frac{\partial}{\partial z} (D_z \frac{\partial \dot{C}}{\partial z})$$
$$+ \rho Q_{in} (\dot{C}_{in} - \dot{C})$$
$$= [\rho_s \dot{K}_d (1 - \phi) + \rho \phi] \frac{\partial \dot{C}}{\partial t}$$
$$- [\rho_s \dot{K}_d \dot{C} \rho g \alpha (1 - \phi)] \frac{\partial h}{\partial t} \qquad \text{(B.1)}$$

Equation B.1 is identical in form to Equation 1.1-2, Volume II, for energy transport. With the exception of the convective terms Equation B.1 is also similar in form to Equation 1.1-1, Volume II, for fluid flow. Therefore, space and time derivatives are approximated by Taylor series expansions similar to those for the fluid-flow and energy-transport equations. The finite difference approximations are summarized below.

Diffusion term. Expanding the dispersion term of Equation A.19 gives

$$\nabla \cdot q = \frac{\partial q}{\partial x} + \frac{\partial q}{\partial y} + \frac{\partial q}{\partial z} \tag{B.2}$$

or

$$\nabla \cdot q = \frac{\partial}{\partial x} \left[- D_x \frac{\partial \dot{C}}{\partial x}\right] + \frac{\partial}{\partial y} \left[- D_y \frac{\partial \dot{C}}{\partial y}\right] + \frac{\partial}{\partial z} \left[- D_z \frac{\partial \dot{C}}{\partial z}\right] \tag{B.3}$$

Approximating the x-component as

$$\left(\frac{\partial q}{\partial x}\right)_{i,j,k} = \frac{q_{i+1/2,j,k} - q_{i-1/2,j,k}}{\Delta x} \tag{B.4}$$

and substituting the appropriate term from Equation 1.3-59 leads to

$$\left(\frac{\partial q}{\partial x}\right)_{i,j,k} = \frac{\left[- D_x \frac{\partial \dot{C}}{\partial x}\right]_{i+1/2,j,k} - \left[- D_x \frac{\partial \dot{C}}{\partial x}\right]_{i-1/2,j,k}}{\Delta x} \tag{B.5}$$

which is identical in form to Equation 1.3-6. Following derivations analogous to Equations 1.3-7 through 1.3-15

$$\left[D_x \frac{\partial \dot{C}}{\partial x}\right]_{i+1/2,j,k} = D_{x_{i+1/2,j,k}} \frac{\dot{C}_{i+1,j,k} - \dot{C}_{i,j,k}}{\Delta x} \tag{B.6}$$

$$\left[D_x \frac{\partial T}{\partial x}\right]_{i-1/2,j,k} = D_{x_{i-1/2,j,k}} \frac{\dot{C}_{i,j,k} - \dot{C}_{i-1,j,k}}{\Delta x} \tag{B.7}$$

$$D_{x_{i+1/2,j,k}} = \frac{2D_{x_{i+1,j,k}} D_{x_{i,j,k}}}{D_{x_{i+1,j,k}} + D_{x_{i,j,k}}} \tag{B.8}$$

$$D_{x_{i-1/2,j,k}} = \frac{2D_{x_{i,j,k}} D_{x_{i-1,j,k}}}{D_{x_{i,j,k}} + D_{x_{i-1,j,k}}} \tag{B.9}$$

and

$$-\left(\frac{\partial q}{\partial x}\right)_{i,j,k} = \frac{1}{\Delta x}\left[\frac{2K_{x_{i+1,j,k}} K_{x_{i,j,k}}}{K_{x_{i+1,j,k}} + K_{x_{i,j,k}}}\right]\left(\frac{T_{i+1,j,k} - T_{i,j,k}}{\Delta x}\right)$$

$$-\frac{1}{\Delta x}\left[\frac{2K_{x_{i,j,k}} K_{x_{i-1,j,k}}}{K_{x_{i,j,k}} + K_{x_{i-1,j,k}}}\right]\left(\frac{T_{i,j,k} - T_{i-1,j,k}}{\Delta x}\right) \quad (B.10)$$

Similar expressions are obtained for the y- and z-components of dispersion.

<u>Accumulation terms</u>. The second term of the right hand side of Equation B.1 contains the time derivative of the hydraulic head, or

$$\left.\frac{\partial h}{\partial t}\right|_{i,j,k} = \frac{h\Big|_{i,j,k}^{n+1} - h\Big|_{i,j,k}^{n}}{\Delta t} \quad 1.3\text{-}17$$

Now from Equation 1.3-57

$$\left.\frac{\partial h}{\partial t}\right|_{i,j,k} = \frac{1}{\Delta t}\sum_{l=1}^{M} \gamma\Big|_{i,j,k}^{l} \quad (B.11)$$

Using a forward difference approximation similar to Equations 1.3-16 and 1.3-17 for the time derivative of concentration results in

$$\left.\frac{\partial C}{\partial t}\right|_{i,j,k}^{n} \simeq \frac{\dot{C}\Big|_{i,j,k}^{n+1} - \dot{C}\Big|_{i,j,k}^{n}}{\Delta t} \quad (B.12)$$

Finally, substituting Equations B.11 and B.12 into the right hand side of Equation B.1 gives the finite difference approximation for the accumulation terms, or

$$(\rho_s \dot{K}_d (1-\phi) + \rho\phi)\,\frac{\dot{C}\Big|_{i,j,k}^{n+1} - \dot{C}\Big|_{i,j,k}^{n}}{\Delta t}$$

$$- C\Big|_{i,j,k}^{n+1} \rho_s \dot{K}_d \rho g \alpha\,(1-\phi)\,\frac{\sum_{l=1}^{M} \gamma\Big|_{i,j,k}^{l}}{\Delta t} \quad (B.13)$$

Convection terms. The convection terms are perhaps the most difficult expressions to handle in the numerical solution of Equation B.1. The finite difference formulations are relatively straight forward, but consideration must be given to the sign of the velocity components as well as their direction. In addition boundary conditions and wells requrie special handling. The derivation will be illustrated for the x-component; y- and z-components are formulated in an analogous fashion.

Expanding the x-component of convection in Equation B.1 results in

$$\rho V \frac{\partial C}{\partial x} \tag{B.14}$$

The velocity at node i,j,k is taken as the arithmetic average of the values at i+1/2,j,k and i-1/2,j,k, or

$$V_{x_{i,j,k}} = \frac{V_{x_{i+1/2,j,k}} + V_{x_{i-1/2,j,k}}}{2} \tag{B.15}$$

From Equation 3.8 of Volume I

$$V_{x_{i+1/2,j,k}} = -\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i+1/2,j,k} \left(\frac{\partial h}{\partial x}\right)\Big|_{i+1/2,j,k} \tag{B.16}$$

and

$$V_{x_{i-1/2,j,k}} = -\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i-1/2,j,k} \left(\frac{\partial h}{\partial x}\right)\Big|_{i-1/2,j,k}$$

Substituting Equations 1.3-13 and 1.3-17 into Equation B.16 and Equations 1.3-14 and 1.3-17 into Equation B.17 results in the following finite difference approximations:

$$V_{x_{i+1/2,j,k}} = -\frac{2\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i+1,j,k} \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k}}{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i+1,j,k} + \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k}}$$

$$\left(\frac{h\big|_{i+1,j,k} - h\big|_{i,j,k}}{\Delta x}\right) \tag{B.18}$$

and

$$V_{x_{i-1/2,j,k}} = - \frac{2\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k} \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i-1,j,k}}{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k} + \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i-1,j,k}} \left(\frac{h\big|_{i,j,k} - h\big|_{i-1,j,k}}{\Delta x}\right) \qquad (B.19)$$

Substituting Equations B.18 and B.19 into Equation B.15 gives

$$V_{x_{i,j,k}} = - \frac{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i+1,j,k} \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k}}{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i+1,j,k} + \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k}} \left(\frac{h\big|_{i+1,j,k} - h\big|_{i,j,k}}{\Delta x}\right) - \frac{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k} \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i-1,j,k}}{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k} + \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i-1,j,k}} \left(\frac{h_{i,j,k} - h_{i-1,j,k}}{\Delta x}\right) \qquad (B.20)$$

Equation B.20 is the finite difference formulation of the x-component of the superficial fluid velocity in the aquifer _except_ at the constant external head boundaries.

Although all boundaries are no-flow boundaries, there is a velocity-component arising from the constant external head boundary condition. The volumetric flow rate per unit volume at a boundary is given by

$$Q_{b_x}\Big|_{i,j,k} = - \mathrm{COEFX}\Big|_{i,j,k} \left[H_b\Big|_{i,j,k} - h\Big|_{i,j,k}^{n+1}\right] \qquad (1.3\text{-}28)$$

From Equations 1.3-26 and 1.3-29 the equivalent velocity component can be expressed as

$$V_{x_b} = \pm \text{COEFX}\Big|_{i,j,k} \Delta x^2 \left[\frac{H_b\Big|_{i,j,k} - h\Big|_{i,j,k}^{n+1}}{\Delta x}\right] \tag{B.21}$$

or

$$V_{x_b} = \pm \text{COEFX}\Big|_{i,j,k} \Delta x \left[H_b\Big|_{i,j,k} - h\Big|_{i,j,k}^{n+1}\right] \tag{B.22}$$

Whether the velocity component due to the constant head boundary condition is positive or negative depends upon which boundary is being considered. For example, consider the case where the external head $H_{b_{i,j,k}}$ is greater than the internal head, $h_{i,j,k}^{n+1}$. Thus the term in brackets in Equation B.22 is positive. Now at i=2 (See Figure 3.3) under these conditions flow is into the system and the velocity is positive in the x-direction. However, at i = NX - 1 under these same conditions, flow is again into the system but the velocity is in the negative x-direction. Thus the sign of this additional velocity component must be adjusted for the appropriate system boundary being evaluated.

Combining Equations B.20 and B.22 results in the finite difference formulation for the velocity component in the x-direction, or

$$V_x\Big|_{i,j,k} = - \frac{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i+1,j,k} \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k}}{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i+1,j,k} + \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k}} \left(\frac{h\Big|_{i+1,j,k} - h\Big|_{i,j,k}}{\Delta x}\right)$$

$$- \frac{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k} \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i-1,j,k}}{\left(\frac{k_x \rho g}{\mu}\right)\Big|_{i,j,k} + \left(\frac{k_x \rho g}{\mu}\right)\Big|_{i-1,j,k}} \left(\frac{h|_{i,j,k} - h|_{i-1,j,k}}{\Delta x}\right)$$

$$\pm \; COEFX|_{i,j,k} \, \Delta x \, [H_b|_{i,j,k} - h|^{n+1}_{i,j,k}] \qquad (B.23)$$

Equation B.23 is used as the finite difference expression for the x-component of velocity in Equation B.1. Similar formulations are used for the y- and z-components.

$$V_y|_{i,j,k} = - \frac{\left(\frac{k_y \rho g}{\mu}\right)\Big|_{i,j+1,k} \left(\frac{k_y \rho g}{\mu}\right)\Big|_{i,j,k}}{\left(\frac{k_y \rho g}{\mu}\right)\Big|_{i,j+1,k} + \left(\frac{k_y \rho g}{\mu}\right)\Big|_{i,j,k}} \left(\frac{h|_{i,j+1,k} - h|_{i,j,k}}{\Delta y}\right)$$

$$- \frac{\left(\frac{k_y \rho g}{\mu}\right)\Big|_{i,j,k} \left(\frac{k_y \rho g}{\mu}\right)\Big|_{i,j-1,k}}{\left(\frac{k_y \rho g}{\mu}\right)\Big|_{i,j,k} + \left(\frac{k_y \rho g}{\mu}\right)\Big|_{i,j-1,k}} \left(\frac{h|_{i,j,k} - h|_{i,j-1,k}}{\Delta y}\right)$$

$$\pm \; COEFY|_{i,j,k} \, \Delta y \, [H_b|_{i,j,k} - h|^{n+1}_{i,j,k}] \qquad (B.24)$$

$$V_z|_{i,j,k} = - \frac{\left(\frac{k_z \rho g}{\mu}\right)\Big|_{i,j,k+1} \left(\frac{k_z \rho g}{\mu}\right)\Big|_{i,j,k}}{\left(\frac{k_z \rho g}{\mu}\right)\Big|_{i,j,k+1} + \left(\frac{k_z \rho g}{\mu}\right)\Big|_{i,j,k}}$$

$$\left(\frac{h|_{i,j,k+1} - h|_{i,j,k}}{\Delta z}\right)$$

$$- \frac{\left(\frac{k_z \rho g}{\mu}\right)\Big|_{i,j,k} \left(\frac{k_z \rho g}{\mu}\right)\Big|_{i,j,k-1}}{\left(\frac{k_z \rho g}{\mu}\right)\Big|_{i,j,k} + \left(\frac{k_z \rho g}{\mu}\right)\Big|_{i,j,k-1}}$$

$$\left(\frac{h|_{i,j,k} - h|_{i,j,k-1}}{\Delta z}\right)$$

$$\pm \text{COEFZ}|_{i,j,k}\ \Delta z\ [H_b|_{i,j,k} - h\Big|_{i,j,k}^{h+1}] \qquad \text{(B.25)}$$

The spatial derivatives of concentration used in the convection terms are approximated by either a forward difference or a backward difference depending on the direction of the velocity component. The finite difference expressions are given by

$$\left(\frac{\partial \dot{C}}{\partial x}\right)\Big|_{i,j,k} = \frac{\dot{C}|_{i+1,j,k} - \dot{C}|_{i,j,k}}{\Delta x} \text{ for } V_x|_{i,j,k} < 0, \qquad \text{(B.26a)}$$

$$\left(\frac{\partial \dot{C}}{\partial x}\right)\Big|_{i,j,k} = \frac{\dot{C}|_{i,j,k} - \dot{C}|_{i-1,j,k}}{\Delta x} \text{ for } V_x|_{i,j,k} \geq 0, \qquad \text{(B.26b)}$$

$$\left(\frac{\partial \dot{C}}{\partial y}\right)\Big|_{i,j,k} = \frac{\dot{C}|_{i,j+1,k} - \dot{C}|_{i,j,k}}{\Delta y} \text{ for } V_y|_{i,j,k} < 0, \qquad \text{(B.27a)}$$

$$\left(\frac{\partial \dot{C}}{\partial y}\right)\Big|_{i,j,k} = \frac{\dot{C}|_{i,j,k} - \dot{C}|_{i,j-1,k}}{\Delta y} \text{ for } V_y|_{i,j,k} \geq 0, \qquad \text{(B.27b)}$$

$$\left(\frac{\partial \dot{C}}{\partial z}\right)\Big|_{i,j,k} = \frac{\dot{C}|_{i,j,k+1} - \dot{C}|_{i,j,k}}{\Delta z} \text{ for } V_z|_{i,j,k} < 0, \qquad \text{(B.28a)}$$

and

$$\left(\frac{\partial \dot{C}}{\partial z}\right)\Big|_{i,j,k} = \frac{\dot{C}|_{i,j,k} - \dot{C}|_{i,j,k-1}}{\Delta z} \text{ for } V_z|_{i,j,k} \geq 0. \qquad \text{(B.28b)}$$

The two formulations prevent oscillations in the numerical solution of the conduction-convection equation (Price, 1965). However, numerical dispersion may occur.

Rewriting Equation B.1 in finite difference form

$$- \rho \, [- \frac{(\frac{k_x \rho g}{\mu})|_{i+1,j,k} \; (\frac{k_x \rho g}{\mu})|_{i,j,k}}{(\frac{k_x \rho g}{\mu})|_{i+1,j,k} + (\frac{k_x \rho g}{\mu})|_{i,j,k}} \; (\frac{h|_{i+1,j,k} - h|_{i,j,k}}{\Delta x})$$

$$- \frac{(\frac{k_x \rho g}{\mu})|_{i,j,k} \; (\frac{k_x \rho g}{\mu})|_{i-1,j,k}}{(\frac{k_x \rho g}{\mu})|_{i,j,k} + (\frac{k_x \rho g}{\mu})|_{i-1,j,k}} \; (\frac{h|_{i,j,k} - h|_{i-1,j,k}}{\Delta x})$$

$$\pm \, COEFX|_{i,j,k} \, \Delta x \, (H_b|_{i,j,k} - h|_{i,j,k}^{n+1})] \; (\frac{\dot{C}|_{i,j,k} - \dot{C}|_{i-1,j,k}}{\Delta x})$$

$$- \rho \, [- \frac{(\frac{k_y \rho g}{\mu})|_{i,j+1,k} \; (\frac{k_y \rho g}{\mu})|_{i,j,k}}{(\frac{k_y \rho g}{\mu})|_{i,j+1,k} + (\frac{k_y \rho g}{\mu})|_{i,j,k}} \; (\frac{h|_{i,j+1,k} - h|_{i,j,k}}{\Delta y})$$

$$- \frac{(\frac{k_y \rho g}{\mu})|_{i,j,k} \; (\frac{k_y \rho g}{\mu})|_{i,j-1,k}}{(\frac{k_y \rho g}{\mu})|_{i,j,k} + (\frac{k_y \rho g}{\mu})|_{i,j-1,k}} \; (\frac{h|_{i,j,k} - h|_{i,j-1,k}}{\Delta y})$$

$$\pm \, COEFY|_{i,j,k} \, \Delta y \, (H_b|_{i,j,k} - h|_{i,j,k}^{n+1})]$$

$$(\frac{\dot{C}|_{i,j,k} - \dot{C}|_{i,j-1,k}}{\Delta x})$$

$$- \rho \, [- \frac{(\frac{k_z \rho g}{\mu})|_{i,j,k+1} \; (\frac{k_z \rho g}{\mu})|_{i,j,k}}{(\frac{k_z \rho g}{\mu})|_{i,j,k+1} + (\frac{k_z \rho g}{\mu})|_{i,j,k}} \; (\frac{h|_{i,j,k+1} - h|_{i,j,k}}{\Delta z})$$

$$- \frac{(\frac{k_z \rho g}{\mu})\Big|_{i,j,k} (\frac{k_z \rho g}{\mu})\Big|_{i,j,k-1}}{(\frac{k_z \rho g}{\mu})\Big|_{i,j,k} + (\frac{k_z \rho g}{\mu})\Big|_{i,j,k-1}} \left(\frac{h|_{i,j,k} - h|_{i,j,k-1}}{\Delta z}\right)$$

$$\pm \text{COEFZ}\Big|_{i,j,k} \Delta z \left(H_b\Big|_{i,j,k} - h\Big|_{i,j,k}^{n+1}\right)\Big]$$

$$\left(\frac{\dot{C}|_{i,j,k} - \dot{C}|_{i,j,k-1}}{\Delta z}\right)$$

$$+ \frac{\rho \dot{Q}|_{i,j,k}}{\Delta x \Delta y \Delta z} \left(\dot{C}|_{in} - \dot{C}|_{i,j,k}\right)$$

$$+ \frac{1}{\Delta x} \left(\frac{2D_x|_{i,j,k} D_x|_{i+1,j,k}}{D_x|_{i+1,j,k} + D_x|_{i,j,k}}\right) \left(\frac{\dot{C}|_{i+1,j,k} - \dot{C}|_{i,j,k}}{\Delta x}\right)$$

$$- \frac{1}{\Delta x} \left(\frac{2D_x|_{i,j,k} D_x|_{i-1,j,k}}{D_x|_{i,j,k} + D_x|_{i-1,j,k}}\right) \left(\frac{\dot{C}|_{i,j,k} - \dot{C}|_{i-1,j,k}}{\Delta x}\right)$$

$$+ \frac{1}{\Delta y} \left(\frac{2D_y|_{i,j,k} D_y|_{i,j+1,k}}{D_y|_{i,j,k} + D_y|_{i,j+1,k}}\right) \left(\frac{\dot{C}|_{i,j+1,k} - \dot{C}|_{i,j,k}}{\Delta y}\right)$$

$$- \frac{1}{\Delta y} \left(\frac{2D_y|_{i,j,k} D_y|_{i,j-1,k}}{D_y|_{i,j,k} + D_y|_{i,j-1,k}}\right) \left(\frac{\dot{C}|_{i,j,k} - \dot{C}|_{i,j-1,k}}{\Delta y}\right)$$

$$+ \frac{1}{\Delta z} \left(\frac{2D_z|_{i,j,k} D_z|_{i,j,k+1}}{D_z|_{i,j,k} + D_z|_{i,j,k+1}}\right) \left(\frac{\dot{C}|_{i,j,k+1} - \dot{C}|_{i,j,k}}{\Delta z}\right)$$

$$- \frac{1}{\Delta z} \left(\frac{2D_z|_{i,j,k} D_z|_{i,j,k-1}}{D_z|_{i,j,k} + D_z|_{i,j,k-1}}\right) \left(\frac{\dot{C}|_{i,j,k} - \dot{C}|_{i,j,k-1}}{\Delta z}\right)$$

$$= (\rho_s \dot{K}_d (1-\phi) + \rho_w \phi) \frac{\dot{C}\Big|_{i,j,k}^{n+1} - \dot{C}\Big|_{i,j,k}^{n}}{\Delta t}$$

$$- \dot{C}\Big|_{i,j,k}^{n+1} \rho_s \dot{K}_d \rho g\alpha (1-\phi) \frac{\sum_{l=1}^{M} \gamma\Big|_{i,j,k}^{l}}{\Delta t} \tag{B.29}$$

where the spatial derivatives for concentration have been written in backward difference form in the convection terms.

Since this finite difference equation is quite unwieldy it will be convenient to introduce the following shorthand notation.

$$VCX\Big|_{i,j,k} = \frac{\rho V_x\Big|_{i,j,k}}{\Delta x} \tag{B.30}$$

$$VCY\Big|_{i,j,k} = \frac{\rho V_y\Big|_{i,j,k}}{\Delta y} \tag{B.31}$$

$$VCZ\Big|_{i,j,k} = \frac{\rho V_z\Big|_{i,j,k}}{\Delta z} \tag{B.32}$$

$$RHOPOR = \rho_s \dot{K}_d (1-\phi) + \rho \phi \tag{B.33}$$

$$EXPAN = \rho_s \dot{K}_d \rho g\alpha (1-\phi) \tag{B.34}$$

In addition operators are defined as

$$\Delta_x^{,2} \dot{C}\Big|_{ijk} = \frac{2D_x\Big|_{i+1,j,k} D_x\Big|_{i,j,k}}{\Delta x^2 \left(D_x\Big|_{i+1,j,k} + D_x\Big|_{i,j,k}\right)} \left(\dot{C}\Big|_{i+1,j,k} - \dot{C}\Big|_{i,j,k}\right)$$
$$+ \frac{2D_x\Big|_{i,j,k} D_x\Big|_{i-1,j,k}}{\Delta x^2 \left(D_x\Big|_{i,j,k} + D_x\Big|_{i-1,j,k}\right)} \left(\dot{C}\Big|_{i-1,j,k} - \dot{C}\Big|_{i,j,k}\right) \tag{B.35}$$

$$\Delta_y'^2 \dot{C}|_{ijk} = \frac{2D_y|_{i,j+1,k} D_y|_{i,j,k}}{\Delta y^2 (D_y|_{i,j+1,k} + D_y|_{i,j,k})} (\dot{C}|_{i,j+1,k} - \dot{C}|_{i,j,k})$$

$$+ \frac{2D_y|_{i,j,k} D_y|_{i,j-1,k}}{\Delta y^2 (D_y|_{i,j,k} + D_y|_{i,j-1,k})} (\dot{C}|_{i,j-1,k} - \dot{C}|_{i,j,k}) \tag{B.36}$$

$$\Delta_z'^2 \dot{C}|_{ijk} = \frac{2D_z|_{i,j,k+1} D_z|_{i,j,k}}{\Delta z^2 (D_z|_{i,j,k+1} + D_z|_{i,j,k})} (\dot{C}_{i,j,k+1} - \dot{C}_{i,j,k})$$

$$+ \frac{2D_z|_{i,j,k} D_z|_{i,j,k-1}}{\Delta z^2 (D_z|_{i,j,k} + D_z|_{i,j,k-1})} (\dot{C}|_{i,j,k-1} - \dot{C}|_{i,j,k}) \tag{B.37}$$

Substituting Equations B.30 through B.37 into Equation B.29 results in

$$- VCX|_{i,j,k} (\dot{C}|_{i,j,k} - \dot{C}|_{i-1,j,k}) - VCY|_{i,j,k} (\dot{C}|_{i,j,k} - \dot{C}|_{i,j-1,k})$$

$$- VCZ|_{i,j,k} (\dot{C}|_{i,j,k} - \dot{C}|_{i,j,k-1}) + \frac{\rho Q|_{i,j,k}}{\Delta x \Delta y \Delta z} (\dot{C}_{in} - \dot{C}|_{i,j,k})$$

$$- \Delta_x'^2 (\dot{C}|_{i,j,k}) - \Delta_y'^2 (\dot{C}|_{i,j,k}) - \Delta_z'^2 (\dot{C}|_{i,j,k})$$

$$= RHOPOR \frac{\dot{C}|_{i,j,k}^{n+1} - \dot{C}|_{i,j,k}^{n}}{\Delta t}$$

$$- EXPAN \sum_{l=1}^{M} \gamma|_{i,j,k}^{l} \frac{C|_{i,j,k}^{n+1}}{\Delta t} \tag{B.38}$$

Boundary Conditions

As with the fluid-flow equations, two types of boundary conditions are considered.

No Diffusion. This boundary condition is completely analogous to the no fluid flow boundary condition for the fluid flow equation, or (see Figure 1.3-1)

$$D_x\Big|_{i+1/2,j,k} = 0 \tag{B.39}$$

Following the same procedure leading to Equation 1.3-25, this is accomplished by setting

$$D_x\Big|_{i+1,j,k} = 0 \tag{B.40}$$

Constant External Concentration. Concentration at the aquifer boundaries are assumed constant, as are the hydraulic heads. The rate of solute flux across an aquifer boundary in the x-direction (or y- and z-directions) is computed from

$$q_b = - D_b\Big|_{i,j,k} \left[\frac{\dot{C}_b\Big|_{i,j,k} - \dfrac{\dot{C}\Big|_{i,j,k}^{n+1} + \dot{C}\Big|_{i,j,k}^{n}}{2}}{\Delta L} \right] \tag{B.41}$$

where $\dot{C}_b\Big|_{i,j,k}$ is the concentration in a hypothetical grid block a distance ΔL away from the center of grid block i,j,k, and D_b is the effective mass dispersion coefficient for the material in the interval. In terms of a volumetric solute flow rate in the x-direction across a boundary, Equation 1.3-99 becomes

$$q_{b_x}\Big|_{i,j,k} = - \frac{\Delta y \Delta z \; D_{b_x}\Big|_{i,j,k}}{\Delta x \Delta y \Delta z}$$

$$\left[\frac{\dot{C}_b\Big|_{i,j,k} - \dfrac{(\dot{C}\Big|_{i,j,k}^{n+1} + \dot{C}\Big|_{i,j,k}^{n})}{2}}{\Delta L_x}\right] \qquad (B.42)$$

or

$$q_{bx}\Big|_{i,j,k} = - QX\Big|_{i,j,k} \left[\dot{C}_b\Big|_{i,j,k} - \frac{(\dot{C}\Big|_{i,j,k}^{n+1} + \dot{C}\Big|_{i,j,k}^{n})}{2}\right] \qquad (B.43)$$

where

$$QX\Big|_{i,j,k} = \frac{1}{\Delta x^2} K'_{b_x}\Big|_{i,j,k} \qquad (B.44)$$

and

$$D'_{b_x} = \frac{\Delta x}{\Delta L_x} K_{b_x} \qquad (B.45)$$

Similarily, for solute transfer in the y- and z-directions

$$QY\Big|_{i,j,k} = \frac{1}{\Delta y^2} D'_{b_y}\Big|_{i,j,k} \qquad (B.46)$$

and

$$QZ\Big|_{i,j,k} = \frac{1}{\Delta z^2} D'_{b_z}\Big|_{i,j,k} \qquad (B.47)$$

These boundary condition terms are introduced into the numerical model as additional source terms.

One further simplification can be made. Unlike the constant external head boundary conditions (Equations 1.3-29, 31 and 32) the individual components of the constant external concentration boundary terms are not required in the evaluation of other terms in either Equation 1.3-34 or Equation 1.3-96. Thus, the three components can be lumped into one overall solute dispersion coefficient as

$$QEXCHG|_{i,j,k} = QX|_{i,j,k} + QY|_{i,j,k} + QZ|_{i,j,k} \tag{B.48}$$

and

$$q_b|_{i,j,k} = - QEXCHG|_{i,j,k} \left[\dot{C}_b|_{i,j,k} - \frac{\dot{C}|^{n+1}_{i,j,k} + \dot{C}|^{n}_{i,j,k}}{2}\right] \tag{B.49}$$

In summary, the implicit finite difference equation describing solute transport in the mathematical model depicted in Figure 3.2 is

$$\begin{aligned}
&- VCX|_{i,j,k} \left(\dot{C}|^{n+1}_{i,j,k} - \dot{C}|^{n+1}_{i-1,j,k}\right) - VCY|_{i,j,k} \left(\dot{C}|^{n+1}_{i,j,k} - \dot{C}|^{n+1}_{i,j-1,k}\right) \\
&- VCZ|_{i,j,k} \left(\dot{C}|^{n+1}_{i,j,k} - \dot{C}|^{n+1}_{i,j,k-1}\right) + \frac{\rho\, Q|_{i,j,k}}{\Delta x \Delta y \Delta z} \left(\dot{C}_{in} - \dot{C}|^{n+1}_{i,j,k}\right) \\
&- \Delta'^2_x \left(\dot{C}|^{n+1}_{i,j,k}\right) - \Delta'^2_y \left(\dot{C}|^{n+1}_{i,j,k}\right) - \Delta'^2_z \left(\dot{C}|^{n+1}_{i,j,k}\right) \\
&= RHOPOR \frac{\dot{C}|^{n+1}_{i,j,k} - \dot{C}|^{n}_{i,j,k}}{\Delta t} - EXPAN \sum_{l=1}^{M} \gamma|^{l}_{i,j,k} \frac{\dot{C}|^{n+1}_{i,j,k}}{\Delta t} \\
&- QEXCHG|_{i,j,k} \left(\dot{C}_b|_{i,j,k} - \frac{\dot{C}|^{n+1}_{i,j,k} + \dot{C}|^{n}_{i,j,k}}{2}\right)
\end{aligned} \tag{B.50}$$

where the dispersion coefficients are equal to zero at all aquifer boundaries.

Numerical Solution of the Finite Difference Solute Transport Equations

The finite difference equation for solute transport in the aquifer is solved in the same manner as the fluid flow equations using the Douglas and Rachford method (1956). Equation B.50 is solved using the same basic computational algorithims used to solve Equation 1.3-108, Volume II, the finite difference equation for energy flow.

Section C

USER INFORMATION

C.1 - Equipment and Operating System

The program is written in Fortran IV and has been run on the IBM 370/168 computer system at Oklahoma State University. Memory requirements are determined by a dynamic storage allocation system so as not to exceed the maximum words of memory specified (MAXSZ in main program). The RESTART and/or RECORD options use logical unit 01, a magnetic tape or disk file.

Two IBM system subroutines are used. The first, ERRSET, is called from the main program and is used to suppress underflow warnings and tracebacks during execution. The second, ELAPSE, is called from Subroutine TMNOW and is used to calculate the processor time utilized during execution.

C.2 - Input data Requirements

Much of the required input data is in the form of arrays representing porous media properties, initial values of hydraulic heads, and concentrations. These data are read from punched cards when a simulation begins. The RECORD feature in the program allows all variable arrays to be written on magnetic tape or a disk file at prescribed time intervals in the simulation. The restart option permits resumption of computations using data saved by Subroutine RECORD at a specified time.

C.3 - Input Data Description

C.3.1 - Card Input Formats and Data

Cards 1,2 FORMAT 20A4/20A4 TITLE

Card 3, FORMAT 7I5

NX = Number of grid points in X direction

NY = Number of grid points in Y direction

NZ = Number of grid points in Z direction, solute transfer model

NZA = Number of grid points in Z direction, fluid flow model

NMAX = Largest of NX, NY, NZ, NZA

ISO = 1 if porous media is isotropic

= 2 if porous media is anisotropic

SOLUTE = 0 if solute transport equations are not solved

> 0 if solute transport equations are solved

Card 4, FORMAT 6F10.0

DELX = Space increment size in X direction, feet

DELY = Space increment size in Y direction, feet

DELZ = Space increment size in Z direction, feet

DELT = Initial time step size, sec.

TMAX = Maximum time simulated, days

TINC = Multiplier for time step increases,

$DELT_{n+1}$ = TINC * $DELT_n$. DELT = constant if TINC = 1.0

DELTMX = Maximum time step

If $DELT_{n+1}$ > DELTMX, $DELT_{n+1}$ = DELTMX

Card 5, FORMAT 2F10.0, 3I10

RHOW = Density of water, lb_m/ft^3

TREF = Temperature for fluid viscosity, ^oF

NAQ = Number of layers in alluvium

KFAQ = K index of first active layer in the alluvium relative to solute transport model grid

KLAQ = K index of last active layer in the alluvium relative to solute transport model grid

Card 6, FORMAT 4F10.0, I5

RHOR = Density of rock, lb/ft^3

CPR = Distribution coefficient (lb solute/lb solid)/(lb solute/lb fluid)

PORO = Porosity, volume fraction

COMP = Compressibility of porous media, psi

Card 7, FORMAT 3I10, 3F10.0

CFILE = First file read from magnetic tape or disk

NFILE = File where first write occurs

NTAPE = Identification number of magnetic tape or disk

RSTRT = 0 if arrays are read from punched cards

= > 0 when data are read from magnetic tape or disk

TPRO = Maximum processor time for this computation, hundredths of an hour

SAVE = 0 if data are not saved on magnetic tape or disk

= > 0 if data are saved on magnetic tapeor disk. This SAVE value causes initial values of arrays to be written on tape or disk before calculations begin if RSTRT = 0.

Card 8, FORMAT 10A6

AFMT(I) = Variable format

PROGRAM CONTROL TO CARD 9 IF RSTRT > 0

Deck 1 FORMAT AFMT(I), I = 1,10

(((COVERX (I,J,K), I=1, NX), J=1, NY), K=1, NZA) **(See Note 1)**

= Permeability, ft^2

Deck 2 FORMAT AFMT(I), I=1,10 **(Omit if SOLUTE $\leq$ 0)**

(((DX (I,J,K), I=1, NX), J=1, NY), K=1, NZ) **(See Note 2)**

= Effective mass dispersion coefficient $lb_m/hr/ft$

Deck 3 FORMAT AFMT(I), I=1,10

(((SS(I,J,K), I=1, NX), J=1, NY), K=1, NZA)

= Specific storage coefficient, ft^{-1}

Card 9 FORMAT 10A6

BFMT(I) = Variable format

Next card read is CARD 10 if RSTRT > 0

Deck 4 FORMAT BFMT(I), I=1,10

(((COEFX (I,J,K), I=1, NX), J=1, NY), K=1, NZA)

= Coefficient of exchange at boundaries in X direction, $lb_m/sec^2/ft^2$

(((COEFY (I,J,K), I=1, NX), J=1, NY), K=1, NZA)

= Coefficient of exchange at boundaries in Y direction, $lb_m/sec^2/ft^2$

(((COEFZ (I,J,K), I=1, NX), J=1, NY), K=1, NZA)

= Coefficient of exchange at boundaries in Z direction, $lb_m/sec^2/ft^2$

Card 10 FORMAT 10A6

CFMT(I) = Variable format

Next card read is CARD 11 if RSTRT > 0.

Deck 5 FORMAT CFMT(I), I=1,10

(((HEAD (I,J,K), I=1, NX), J=1, NY), K=1, NZA)

= Constant head distribution at boundaries, feet

Deck 6 FORMAT CFMT(I), I=1,10

(((PRES (I,J,K), K=1, NX), J=1, NY), K=1, NZA)

= Initial head distribution, feet

Deck 7 FORMAT CFMT(I), I=1,10 **(Omit if SOLUTE ≤ 0)**

(((QEXCHG (I,J,K), K=1, NX), J=1, NY), K=1, NZ)

= Mass transfer coefficients on the boundaries, $lb_m/sec/ft^3$

Deck 8 FORMAT CFMT(C), I=1,10 **(Omit if SOLUTE ≤ 0)**

(((BCONC (I,J,K), I=1, NX), J=1, NY), K=1, NZ)

= Constant concentration distribution at boundaries, lb solute/lb water

Deck 9 FORMAT CFMT (I), I=1,10 **(Omit if SOLUTE ≤ 0)**

(((F(I,J,K), I=1, NX), J=1, NY), K=1, NZ)

= Initial concentration distribution, lb solute/lb water

Card 11 FORMAT I5,F10.0

NWELLS = Number of injection wells

TLONGD = Total time that injection rates and/or concentrations remain at current values, days

Card 12 FORMAT 10A6 **(Omit if NWELLS = 0)**

DFMT(I) = Variable format

Deck 10 **(Omit if NWELLS = 0)**

Card A FORMAT 2I5, F10.0

LOCX = I coordinate of injection NODE

LOCY = J coordinate of injection NODE

CINJXY = Concentration of injected water, at node LOCX, LOCY, lb solute/lb water (May be left blank for withdrawal)

Card B FORMAT DFMT(I), I=1,10

(Q(LOCX, LOCY, K), K=1, NZA)

= Injection rate at each node, ft^3/sec (Enter negative rates for withdrawal)

Card 13 FORMAT 2I5,4F10.0

MXITTS = Maximum iterations per time step

MXITCY = Maximum iterations per iteration cycle

ELIM = Convergence limit on fluid flow iterations, feet

CLIM = Limit for shrinking fluid flow matrix, feet

ETIM = Convergence limit on solute transport iterations, lb_m

CTIM = Limit for shrinking solute transport matrix, lb_m

Card 14 FORMAT F10.0,I10,F10.0

SAVE = 0 when data are not written on magnetic tape

> 0 causes data to be written on magnetic tape

NOUT = Number of times output is required at a specified time

POUT = Number of time steps between printed output commands

This output occurs independently of output via TOUT(I). Data are not saved on magnetic tape.

Card 15 FORMAT 8F10.0

(TOUT(I), I=1, NOUT) = Times where output is printed and saved on magnetic tape or disk if SAVE > 0, days

Note: Output is automatically saved on magnetic tape or disk, at simulation time TMAX if SAVE > 0

Card 16 FORMAT I5,F10.0

NWELLS = Number of injection wells

TLONGD = Total time injection rates and/or concentrations remain at new values, days

Deck 11

Card A FORMAT 2I5,F10.0

LOCX = I coordinate of injection NODE

LOCY = J coordinate of injection NODE

CINJXY = Concentration of injected water at node LOCX,LOCY, lb solute/lb water (May be left blank for withdrawal)

Card B FORMAT DFMT(I), I=1,10

(Q(LOCX,LOCY, K), K=1,NZA)

= Injection rate at each node, ft^3/sec
(Enter negative rates for withdrawal)

Card 16 and Deck 11 are read in pairs during the computations when the total time simulated exceeds the current value of TLONGD. This option allows step changes of the injection concentration at specified times.

Note 1:

IF ISO = 2 Deck 1 Contains the following data

(((COVERX (I,J,K), I=1, NX), J=1, NY), K=1, NZA)

= Permeability in X direction, sec^{-1}

(((COVERY (I,J,K), I=1, NX), J=1, NY), K=1, NZA)

= Permeability in y direction, sec^{-1}

(((COVERZ (I,J,K), K=1, NX), J=1, NY), K=1, NZA)

= Permeability in z direction, sec^{-1}

Note 2:

IF ISO = 2 Deck 2 Contains the following data

(((DX(I,J,K), I=1, NX), J=1, NY), K=1, NZ)

= Effective mass dispersion coefficient in x direction, lb_m/hr/ft

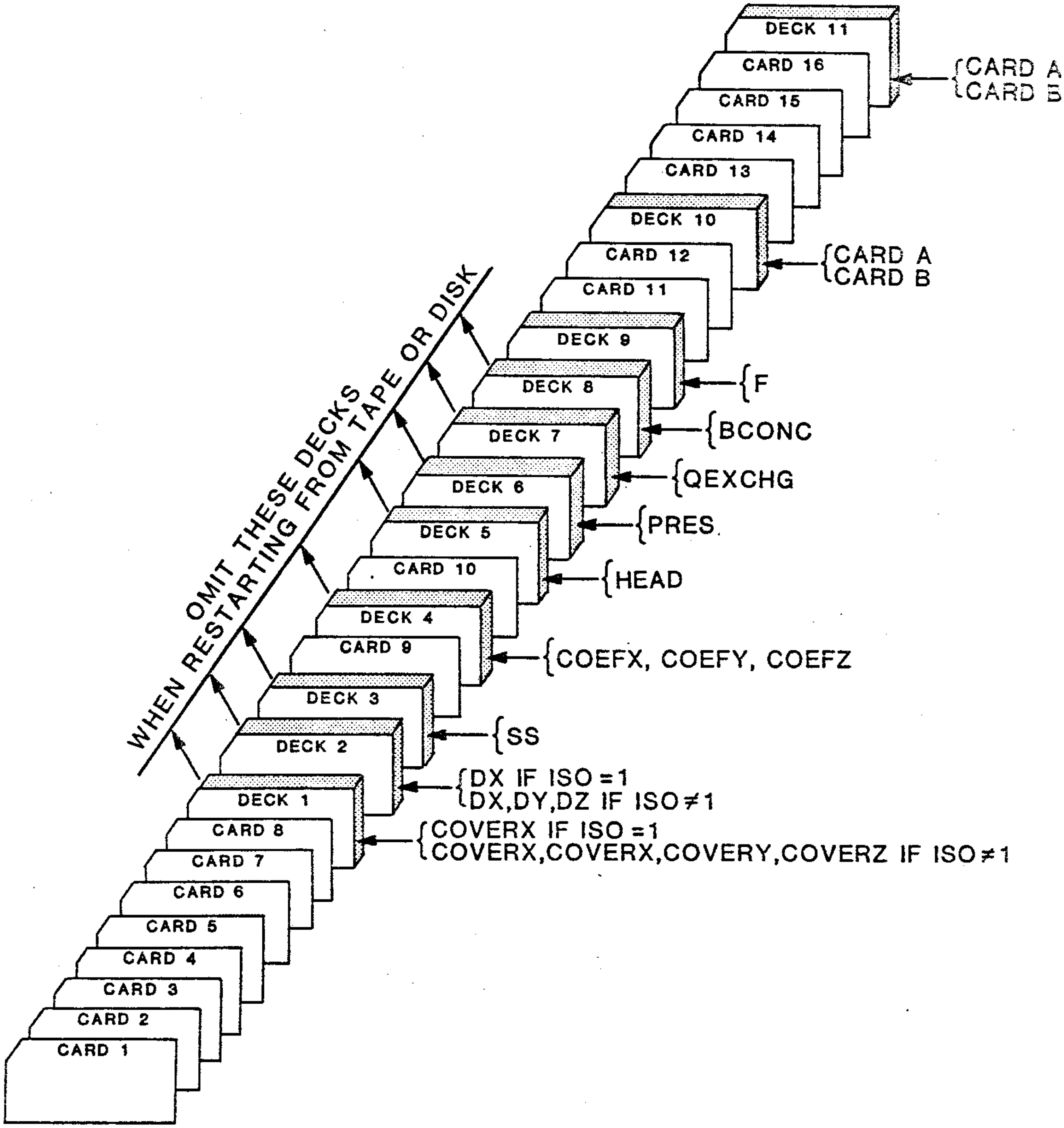
(((DY(I,J,K), I=1, NX), J=1, NY), K=1, NZ)

= Effective mass dispersion coefficient in y direction, lb_m/hr/ft

(((DZ(I,J,K), I=1, NX), J=1, NY), K=1, NZ)

= Effective mass dispersion coefficient in z direction, lb_m/hr/ft

Figure C.3.1 Summary of Required Cards in Data Deck.



C.3.2 - Secondary Storage Input Format

Data read from or written on magnetic tape are unformated. Each RSTRT or SAVE execution processes 17 files of data if SOLUTE > 0, i.e., the solute transport equations are solved. Only 11 files are processed if the solute transport equations are not solved. As written, the data are for anisotropic porous media. These files are ordered as follows and are read or written in sequential order.

Data file	File Number, NTAPE, NX, NY, NZA
1	COVERX = $(sec)^{-1}$
Data file	File Number, NTAPE, NX, NY, NZA
2	COVERY = $(sec)^{-1}$
Data file	File Number, NTAPE, NX, NY, NZA
3	COVERZ = $(sec)^{-1}$
Data file	File Number, FTAPE, NX, NY, NZA
4	SS = ft^{-1}
Data file	File Number, NTAPE, NX, NY, NZA
5	COEFX = $sec^{-1}\ ft^{-1}$
Data file	File Number, NTAPE, NX, NY, NZA
6	COEFY = $sec^{-1}\ ft^{-1}$
Data file	File Number, NTAPE, NX, NY, NZA
7	COEFZ = $sec^{-1}\ ft^{-1}$
Data file	File Number, NTAPE, NX, NY, NZA
8	HEAD = ft
Data file	File Number, NTAPE, NX, NY, NZA
9	PRES = ft
Data file	File Number, NTAPE, NX, NY, NZA
10	DRAWDN = ft

Data file	File Number, NTAPE, NX, NY, NZ
11	DX = lb_m/sec/ft
Data file	File Number, NTAPE, NX, NY, NZ
12	DY = lb_m/sec/ft
Data file	File Number, NTAPE, NX, NY, NZ
13	DZ = lb_m/sec/ft
Data file	File Number, NTAPE, NX, NY, NZ
14	QEXCHG = $lb_m/sec/ft^3$
Data file	File Number, NTAPE, NX, NY, NZ
15	BCONC = lb solute/lb water
Data file	File Number, NTAPE, NX, NY, NZ
16	F = lb solute/lb water
Data file	TOQINJ. = Total mass injected, lb_m
17	TOQACC = Total mass accumulated in system, lb_m
	TOQEX = Total mass lost to surroundings, lb_m
	TOTAL = Total simulation time, seconds
	TOINJ = Total fluid injected, cubic feet
	TOOUT = Total fluid lost to surroundings, cubic feet

C.4 - Program Output

Output from the computer program was designed to provide a printed record of input data, selected computed results, and to verify data transfer to and from the magnetic tape unit.

C.4.1 - Input Data

All data read from punched cards are printed prior to initiation of computations. Arrays read from tape or disk files are also listed before computations begin. Section E contains line printer output of input data and arrays for a test problem. When data are read from tape or disk, certain information is printed as each array is read to verify that the desired files were accessed. A sample of this output is shown in Table C.4.1.

Table C.4.1

Printer Output Verifying Files Read From Magnetic Tape

```
PROGRAM STARTS WITH DATA IN FILES   52 -   68 READ FROM TAPE NUMBER  11224 ON LOGICAL UNIT 01
FILE     52 ON TAPE 11224 HAS COVERX(22,13,10)
FILE     53 ON TAPE 11224 HAS COVERY(22,13,10)
FILE     54 ON TAPE 11224 HAS COVERZ(22,13,10)
FILE     55 ON TAPE 11224 HAS SS     (22,13,10)
FILE     56 ON TAPE 11224 HAS COEFX (22,13,10)
FILE     57 ON TAPE 11224 HAS COEFY (22,13,10)
FILE     58 ON TAPE 11224 HAS COEFZ (22,13,10)
FILE     59 ON TAPE 11224 HAS HEAD  (22,13,10)
FILE     60 ON TAPE 11224 HAS PRES  (22,13,10)
FILE     61 ON TAPE 11224 HAS DRAWDN(22,13,10)
FILE     62 ON TAPE 11224 HAS DX     (22,13,10)
FILE     63 ON TAPE 11224 HAS DY     (22,13,10)
FILE     64 ON TAPE 11224 HAS DZ     (22,13,10)
FILE     65 ON TAPE 11224 HAS QEXCHG(22,13,10)
FILE     66 ON TAPE 11224 HAS BCONC (22,13,10)
FILE     67 ON TAPE 11224 HAS F      (22,13,10)
FILE     68 ON TAPE 11224 HAS MISC. DATA NEEDED TO CONTINUE CALCULATIONS AT A LATER TIME
TOQINJ =  0.17467968E+08TOQACC =      0.10641238E+08   TOQEX = -0.60270898E+05   TOTAL = 0.31104000E+08
    TOINJ =   0.19709473E+01     TOOUT = 0.88023469E+06
```

Changes in the injection concentrations and/or rates can be made at specified times during the simulation. At the time the concentration/rates are changed, the printed output includes the new rates and concentrations, the time at which the change starts, and the time at which the next changes are to occur.

C.4.2 - Computed Results

Total and component mass and balance results are printed out at the end of every time step. All other output occurs at intervals specified by the user on the input data cards. Output of computed results is limited to the arrays listed in Table C.4.2. Other results can be obtained by appropriate modifications of Subroutines MASBAL and BALANC.

Table C.4.2

Computed Results Printed at Specified Time Intervals

Fluid Flow Model

SUMGAM = Drawdown during the previous time step, feet

DRAWDN = Cumulative drawdown in the active allowing layers, feet

PRES = Head distribution in active alluvium layers, feet

EXCHG = Water exchanged with the surroundings during last time step, cubic feet

Solute Transport Model

F = Concentration distribution in overburden, alluvium and underburden, lb solute/lb fluid

EXCHG = Distribution of solute exchanged with the surroundings through the boundaries of the prototype, lb_m, in Subroutine BALANC only.

There are two options available which enable the user to specify when computed results are printed. The variable POUT is the number of time steps between output commands on the line printer. The array TOUT( ) contains specified simulation times at which output is desired. Either or both options may be selected.

C.4.3 - Intermediate Output on Logical Unit 01

The user may save computed results and all arrays necessary to resume calculations at some point in time. When the variable SAVE is greater than zero, the printed output in Table C.4.3 is generated as the arrays are written on logical unit 01 (assumed to be a tape or disk) using Subroutine RECORD. Computed results are written when the time simulated equals values specified in TOUT( ). The variable POUT does not cause output to be saved on logical unit 01. The program has an internal processor time check which terminates the program before the processor time is exhausted. Computed results are written on tape or disk when the program is terminated in this manner.

A second output option is available. The value of SAVE is read in twice, once on Card 7 and again on Card 14. The read statements for these cards occur before and after the initialization of the arrays. It is possible to store these initial arrays if RSTRT and the first value of SAVE are both equal to zero. The value of SAVE read from Card 12 controls whether or not intermediate output occurs on Logical unit 01 after computations begin.

Table C.4.3

Printer Output After Data are Written on Magnetic Tape

```
FILE     86 ON TAPE 11224 HAS COVERX(22,13,10)
FILE     87 ON TAPE 11224 HAS COVERY(22,13,10)
FILE     88 ON TAPE 11224 HAS COVERZ(22,13,10)
FILE     89 ON TAPE 11224 HAS SS    (22,13,10)
FILE     90 ON TAPE 11224 HAS COEFX (22,13,10)
FILE     91 ON TAPE 11224 HAS COEFY (22,13,10)
FILE     92 ON TAPE 11224 HAS COEFZ (22,13,10)
FILE     93 ON TAPE 11224 HAS HEAD  (22,13,10)
FILE     94 ON TAPE 11224 HAS PRES  (22,13,10)
FILE     95 ON TAPE 11224 HAS DRAWDN(22,13,10)
FILE     96 ON TAPE 11224 HAS DX    (22,13,10)
FILE     97 ON TAPE 11224 HAS DY    (22,13,10)
FILE     98 ON TAPE 11224 HAS DZ    (22,13,10)
FILE     99 ON TAPE 11224 HAS QEXCHG(22,13,10)
FILE    100 ON TAPE 11224 HAS BCONC (22,13,10)
FILE    101 ON TAPE 11224 HAS F     (22,13,10)
FILE    102 ON TAPE 11224 HAS MISC. DATA NEEDED TO CONTINUE CALCULATIONS AT A LATER TIME
TOQINJ =  0.52403248E+08TOQACC =      0.34933360E+08   TOQEX = -0.71011137E+06   TOTAL = 0.93312000E+08
    TOINJ =  0.12845947E+02     TOOUT = 0.38838610E+07
FILE    103 ON TAPE 11224 IS EMPTY
```

C.5 - Offline Error Messages

Five messages are generated in the program when execution is terminated by the program. Each message and its origin are presented in this section.

Message:

PROGRAM TERMINATED IN MAIN **NZA IS GREATER THAN NZ

Origin: MAIN Program - MAIN0520

Message:

***PROGRAM TERMINATED--COMMON REQUIREMENT EXCEEDS SPACE ALLOCATED IN COMMON X (MAXSZ) AND MAXSZ = XXXXXX STATEMENTS

Origin: MAIN Program - MAINd1530

Message:

TAPE NOT CORRECTLY POSITIONED FOR RESTART

** FIPERM = XXXXX, CFILE = XXXXX

Origin: Subroutine RSTART - RSTR0360

Message:

FILE XXXXX ON TAPE XXXXX IS EMPTY

Origin: Subroutine RECORD - RCRD0400

Comment: A blank file is created when the program terminates in RECORD. This is necessary in order to position the tape at the first available free file space for subsequent write commands.

Message:

PROGRAM FAILED TO CONVERGE IN MOTION AFTER XXXXX ITERATIONS

EOLD = XXXXXXXXXXXXXXX PROGRAM TERMINATED.

Origin: Subroutine MOTION - MOTN2910

Message:

******ITERATION IN LAST TIME STEP EXCEEDS SPECIFIED MAXIMUM OF XXX PROGRAM TERMINATED ******

Origin: Subroutine Subroutine PREP - PREP4100

Comment: Program terminated if number of iterations (NIT) at that point exceed the maximum number of iterations in a time step (MXITTS). NIT is computed in Subroutine MASS and is the number of iterations required to solve the solute transport.

C.6 - Program Termination

Execution of the program is terminated at one other location which is not identified by printed output. This termination occurs in Subroutine PREP at location PREP 2900. Program terminated if estimated processor time at the end of the next time step will exceed the processor time specified in the input data (TPRO).

Section D

D.1 - Program Functions

Functions of the program and subprograms are subdivided into four categories in Table D.1. Program names are listed in alphabetical order following Table D.1 with a brief statement summarizing the function each program.

TABLE D.1

Program Function	Program Control	Data Input And Initialization	Fluid Flow and Solute Transport Calculations	Auxiliary Input/Output
Program Name	MAIN	ADISP	BALANC	RECORD
	PREP	APERM	MOTION	RSTART
	TMNOW	COEXCHG	MASBAL	
		CONC	MASS	
		CONCON	THOMAS	
		IDISP		
		IPERM		
		QTRANS		
		STORE		
		STRT		

PROGRAM NAME	FUNCTION
ADISP	Reads and/or writes anisotropic effective mass diffusion coefficient matrices
APERM	Reads and/or writes anisotropic permeability matrices
BALANC	Computes solute material balances, writes concentration and solute exchange distributions
COEXCH	Reads and/or writes fluid exchange coefficient matrices
CONC	Initializes the concentration distribution when RSTRT = 0 and/or writes the concentration distribution at the beginning of the computation
CONCON	Sets constant concentration boundary conditions and writes values
CONHD	Reads and/or writes constant head boundary conditions
IDISP	Reads and/or writes the isotropic effective mass diffusion coefficient matrix
IPERM	Reads and/or writes the isotropic permeability matrix
MAIN	Entry point to program, sets up size of variable arrays through dynamic storage allocation
MASBAL	Computes mass balance after each fluid flow calculation and outputs drawdown, head, and fluid exchange at the model boundaries
MASS	Solves the solute-transport equation for one time step using finite difference equations
MOTION	Solves the fluid-flow equation for one time step using finite difference equations
PREP	Controls the overall flow of data input, computations and output for the numerical solution
QTRANS	Reads and/or writes the solute transfer coefficients at the boundaries of the model
RECORD	Writes selected arrays and other data on logical unit 01 for resumption of computations with another computer run
RSTART	Reads arrays written by Subroutine RECORD on logical unit 01 at a specified point in time in order to resume calculations

PROGRAM	FUNCTION
STORE	Reads and/or writes the specific storage coefficient
STRT	Reads and/or writes the initial head distribution
THOMAS	Solves the tridiagonal system of linear equations by Gassian elimination
TMNOW	Calls system subroutine to calculate the elapsed processor time

D.2 PROGRAM LISTINGS

D.2.1 Variable Definitions

A	= Coefficient of tridiagonal matrix equation
ABS(a)	= Built-in function which determines the absolute value the real argument enclosed in the parenthesis
ACCUM	= Fluid accumulated in system in a time step, ft^3
DISP	= Subroutine which reads and writes anisotropic mass dispersion coefficient matrix
AFMT	= Variable format specification for reading data
ALPHA	= Head change in x-direction sweep
APERM	= Subroutine which reads and writes anisotropic permeability matrix
AQLIM	= Labeled COMMON
AX	= Temporary variable used in setting up the coefficients of the tridiagonal matrix equation, x-direction
AY	= Temporary variable used in setting up the coefficients of the tridiagonal matrix equation, y direction
AZ	= Temporary variable used in setting up the coefficients of the tridiagonal matrix equation, z direction
B	= Coefficient of tridiagonal matrix equation
BALANC	= Subroutine which calculates solute mass balance at every time step
BETA	= Head change in y direction sweep
BFMT	= Variable format specification for reading data
CONC	= Constant concentration boundary condition
BX	= Temporary variable used in setting up the coefficients of the tridiagonal matrix equation, x direction
BY	= Temporary variable used in setting up the coefficient of the tridiagonal matrix equation, y direction
BZ	= Temporary variable used in setting up the coefficient of the tridiagonal matrix equation, z direction

C = Coefficient of tridiagonal matrix equation

CFILE = Current file on magnetic tape or disk

CFMT = Variable format specification for reading data

CINJ = Concentration of injected or withdrawn fluid

CLIM = Minimum head change per iteration which is retained in the iterative solution. See Shrink feature

COEFX = Coefficient of fluid exchange with surroundings at a node in x direction

COEFY = Coefficient of fluid exchange with surroundings at a node in y direction

COEFZ = Coefficient of fluid exchange with surroundings at a node in z direction

COEXCH = Subroutine which reads and writes the values of the exchange coefficient for each cell

COMP = Compressibility of porous media

CONHD = Subroutine which reads and writes values of the constant heads at the boundaries

CONC = Subroutine which sets the initial concentration distribution and writes the array

CONCON = Subroutine which reads and writes values of the constant concentration boundaries

CONV = Dummy variable

COVERX = Permeability at a node in x direction, ft^2 or fluid conductivity at a node in x direction, ft/sec - (ft of fluid/ft)

COVERY = Permeability at a node in y direction, ft^2 or fluid conductivity at a node in y direction, ft/sec - (ft of fluid/ft)

COVERZ = Permeability at a node in z direction, ft^2 or fluid conductivity at a node in z direction, ft/sec - (ft of fluid/ft)

CPR = Solute distribution coefficient between solid and liquid phases

CTIM = Minimum temperature change in an iteration which is retained in the iterative solution. See Shrink feature.

CX = Temporary variable used in setting up the coefficients of the tridiagonal matrix equation, x direction

CY = Temporary variable used in setting up the coefficients of the tridiagonal matrix equation, y direction

CZ = Temporary variable used in setting up the coefficients of the tridiagonal matrix equation, z direction

D = Coefficient of tridiagonal matrix equation

DELT = Time step, seconds

DELT1 = Temporary variable used to store the time step size

DELT2 = Temporary variable used to store time step size

DELTA = Concentration change at every node in x sweep, iterative solution of solute transport equation

DELTDA = Time step, days

DELX = Node spacing in x direction

DELY = Node spacing in y direction

DELZ = Node spacing in z direction

DIF1 = Difference between TOQEX and TOQINJ

DIF3 = Difference between QINJ and QEX

DIFF1 = Difference between TOINJ and TOUT, ft^3

DIFF2 = Error in total accumulation, ft^3

DIFF3 = Difference between MASSIN and MASOUT, ft^3

DIFF4 = Error in accumulation in a time step

DRAWDN = Cummulative drawdown per cell, feet

DX = Mass dispersion coefficient at a node in x direction, $lb_m/sec/ft$

DY = Mass dispersion coefficient at a node in y direction, $lb_m/sec/ft$

DZ = Mass dispersion coefficient at a node in z direction, $lb_m/sec/ft$

EFCOEF = Arithmetic statement function which computes the value of a parameter at the mid-point between two grid nodes when the grid spacing is uniform

EITER = Solute loss due to inclusion of iteration parameter in final solution

ELIM = Convergence criterion for iterative solution of fluid flow equations

ENEW = Maximum change in PRES in an iteration

EOLD = Maximum change in PRES in an iteration

EPSILN = Concentration change at every node, y sweep

ETIM = Convergence criterion for iterative solution of the solute transport equation, lb_m

EXCHG = Fluid exchanged with surroundings, ft^3

EXPAN = Contribution of porous media compresibility to accumulation of solute at a grid node

F = Concentration at a node

FIBAL = Temporary variable which holds the file number of the last miscellaneous data read or written on tape

FIBTEM = Temporary variable which holds the file number of the last BCONC array read or written

FICOND = Temporary variable which holds the file number of the last DX array read or written

FICOX = Temporary variable which holds the file number of the last COEFX array read or written

FICOY = Temporary variable which holds the file number of the last COEFY array read or written

FICOZ = Temporary variable which holds the file number of the last COEFZ array read or written

FIDRAW = Temporary variable which holds the file number of the last DRAWDN array read or written

FIHCOF = Temporary variable which holds the file number of the last QEXCHG array read or written

FIHEAD = Temporary variable which holds the file number of the last HEAD array read or written

FIPERM = Temporary variable is the file number of the last COVERX array read or written

FIPRES = Temporary variable which holds the file number of the last PRES array read or written

FISS = Temporary variable which holds the file number of the last SS array read or written

FITEMP = Temporary variable which holds the file number of the last F array read or written

FLGEOF(I,V) = Subroutine provides a signal requesting a return to the calling subprogram if an end-of-file condition occurs. I is the logical file descriptor. V is non zero when an end of file is encountered.

FLOAT( ) = Built-in function which converts the value of a fixed point variable to a floating point value.

G = Temporary array used in solution of the tridiagonal matrix.

GAMMA = Head change in z direction sweep

GDUMMY = Temporary variable

H = Iteration parameter, current iteration.

H1 = Iteration parameter, last iteration

H2 = Iteration parameter at convergence of iterative solution of fluid flow or solute transport equations

HA = Temporary variable representing the base value of the iteration parameter for first iteration

HB = Iteration parameter representing the base values for second through last iteration

HDUMMY = Temporary variable

HEAD = Constant head boundary condition at a node, ft

HMAX = Maximum value of iteration parameter computed from the equations in Subroutine PREP

HMIN = Minimum value of iteration parameter computed from the formulas in Subroutine PREP

I = Counter in x direction

II = Counter for solution of tridiagonal matrix equation

IA = Starting location of A(NMAX) in blank COMMON

IALPHA = Starting location of ALPHA(NX,NY,NZ) in blank COMMON

IB = Starting location of B(NMAX) in blank COMMON

IBETA = Starting location of BETA(NX,NY,NZ) in blank COMMON

IBCONC = Starting location of BCONC(NX,NY,NZ) in blank COMMON

IC = Starting location of C(NMAX) in blank COMMON

ICFILE = Index indicating the last file read from magnetic tape

ICINJ = Starting location of CINJ(NX,NY) in blank COMMON

ICOEFX = Starting location of COEFX(NX,NY,NZA) in blank COMMON

ICOEFY = Starting location of COEFY(NX,NY,NZA) in blank COMMON

ICOEFZ = Starting location of COEFZ(NX,NY,NZA) in blank COMMON

ICOX = Starting location of COVERX(NX,NY,NZA) in blank COMMON

ID = Starting location of D(NMAX) in blank COMMON

IDELTA = Starting location of DELTA(NX,NY,NZ) in blank COMMON

IDISP = Subroutine which reads and writes the isotropic mass dispersion coefficient matrix

IDRAWN = Starting location of DRAWDN(NX,NY,NZA) in blank COMMON

IEOF = Temporary variable used to determine when an end of file condition has been encountered while reading a magnetic tape

IEPSIL = Starting location of EPSILN(NX,NY,NZ) in blank COMMON

IEXCHG = Starting location of EXCHG(NX,NY,NZ) in blank COMMON

IFIRST = First node in x direction sweep

IG = Starting location of G(NMAX) in blank COMMON

IGAMMA = Starting location of GAMMA(NX,NY,NZ) in blank COMMON

IHEAD = Starting location of HEAD(NX,NY,NZA) in blank COMMON

II = Temporary index in Shrink section

IDX = Starting location of DX(NX,NY,NZ) in blank COMMON

IDY = Starting location of DY(NX,NY,NZ) in blank COMMON

IDZ = Starting location of DX(NX,NY,NZ) in blank COMMON

ILAST = Last node in x direction sweep

IMAX = Number of storage locations in blank COMMON required for variable dimensioned arrays

IOUT = Index used to determine the value of TOUT where intermediate output on the line printer and magnetic tape is desired

IPERM = Subroutine which reads and writes the isotropic permeability matrix

IPRES = Starting location of PRES(NX,NY,NZA) in blank COMMON

IQ = Starting location of Q(NX,NY,NZA) in blank COMMON

IQEXCH = Starting location of QEXCHG(NX,NY,NZ) in blank COMMON

IR = Starting location of R(NMAX) in blank COMMON

ISO = Dictomous variable for specification of porous media permeability and thermal conductivity

01 = isotropic permeability
02 = anisotropic permeability

ISS = Starting location of SS(NX,NY,NZA) in blank COMMON

ISUMGM = Starting location of SUMGAM(NX,NY,NZA) in blank COMMON

ISUMZT = Starting location of SUMZET(NX,NY,NZ) in blank COMMON

IT = Number of time steps simulated

IT = Starting location of F(NX,NY,NZ) in blank COMMON in MAIN

= Time step number in all other subprograms

ITCY = Number of completed iterations in a cycle

ITER = Labeled COMMON

IW = Starting location of W(NMAX) in blank COMMON

IZ = Starting location of Z(NMAX) in blank COMMON

IZETA = Starting location of ZETA(NX,NY,NZ) in blank COMMON

J = Counter in y direction

JFIRST = First node in y direction sweep

JJ = Temporary index in Shrink feature

JLAST = Last node in y direction sweep

K = Counter in z dirction

KCK = Temporary variable used to check size of fluid flow arrays in Z dirction

KCOUNT = Variable representing the number of time steps between full printed output of fluid flow and solute transport results

KEND = Variable used to control whether or not an empty file is written on magnetic tape if the program is terminated

KEY = Variable used to control when arrays are printed in MASBAL and BALANC

KFAQ = Index of first aquifer layer relative to the grid layout of the solute transport model

KFIRST = First node in z direction sweep

KLAST = Last node in z direction sweep

KLAQ = Index of the last aquifer layer relative to the grid layout of the solute transport model

KOUT = Temporary counter of the number of printed outputs in MASBAL and BALANC

KT = Number of time steps

KTAPE = Variable used to cause printed output in MASBAL and BALANC when intermediate results are saved on magnetic tape

KTINJ = Variable which controls when the injection rates and/or concentrations are changed
When KTINJ = 0, injection rates and/or concentrations remain at previous value
KTINJ > 0, cards are read with the new injection rates and concentrations and time when next change in rate and/or concentration is to occur

L = Counter for solution of tridiagonal matrix equation

LIM1 = Temporary variable

LIM2 = Temporary variable

LIMIT = Labeled COMMON

LOCX = Coordinate of x node at a well

LOCY = Coordinate of y node at a well

MASBAL = Subroutine which calculates the material balance at each time step

MASOUT = Fluid leaving system in a time step, ft^3

MASS = Subroutine which solves the solute transport equation

MASSIN = Fluid entering system in a time step, ft^3

MAXSZ = Maximum storage available in blank COMMON

MOTION = Subroutine which solves the fluid flow equations

MXITCY = Maximum number of iterations per cycle

MXITTS = Maximum number of iterations per time step

N = Temporary index

NAQ = Number of active layers in the fluid flow model

NFILE = File number where next write occurs on magnetic tape or disk

NFIT = Number of iterations to convergence in the fluid flow model

NIT = Number of iterations completed in a time step or number of iterations for solution of solute transport equation

NITCY = Temporary variable used in calculating iteration parameters

NMAX = Maximum value of NX,NY,NZ

NOFILE = Temporary variable

NOUT = Number of times at which tape and printed output are requested

NTAPE = Identification number of magnetic tape which is used for input and output of intermediate arrays at specified times

NWELLS = Number of wells where injection/withdrawal occurs

NX = Number of grid nodes in the x direction

NXL1 = Number of grid nodes in x direction minus 1

NY = Number of grid nodes in y direction

NYL1 = Number of grid nodes in y direction minus 1

NZ = Number of grid nodes in the z direction, solute transport model

NZA = Number of grid nodes in the Z direction, fluid flow model

NZL1 = Number of grid nodes in z direction (solute transport model) minus 1

OUT = Labeled COMMON

PARAM = Labeled COMMON

PORO = Porosity of porous media

PREP = Subroutine which controls overall computations

PRES = Hydraulic head at a node, ft of fluid

PXX = Temporary variable

PZZ = Temporary variable

Q = Rate of fluid injected/withdrawn per cell at each grid node

QACCUM = Solute accumulated in system in a time step, lb_m

QBOUN = Solute exchanged with surroundings in the last time by dispersion, lb_m

QDUMMY = Temporary variable

QEX = Solute exchanged with surroundings in a time step by dispersion and convection, lb_m

QEXCHG = Coefficient of solute exchange with surroundings at a node

QINJ = Solute injected in a time step, lb_m

QTRANS = Subroutine which reads and writes mass transfer coefficients at the boundaries

R = Temporary variable used in solution of tridiagonal matrix equation

RECORD = Subroutine which writes arrays on tape for resumption of computations at a later time

RHOPOR = Density of skeletal component of the porous media

RHOR = Bulk density of porous media

RHOW = Density of fluid

RSTART = Subroutine which reads magnetic tape or disk to begin calculations from data stored on magnetic tape or disk

RSTRT = Variable which controls calls to Subroutine RSTART
When RSTRT > 0, program starts from data read from magnetic tape or disk
When RSTRT = 0, all data is read in on punched cards

SAVE = A variable which controls writing on magnetic tape or disk
When SAVE = 0, no results are written
When SAVE = >0, intermediate output occurs on magnetic tape or disk at specified times and when execution is terminated by the program

SDUMMY = Temporary variable

SIGN = Coefficient indicating direction of velocity components

SOLUTE = Dictomous variable for selecting solution of the solute transport equation
$\leq$ 0 solute transport equation not solved
$\geq$ 0 solute transport equations solved

STRT = Subroutine which reads and writes the initial head distribution

SUMGAM = Total change in head for a time step

SUMR = Sum of residuals from iterative solution of fluid flow or solute transport equations

SUMZET = Concentration change per time step at each grid node

THOMAS = Subroutine which solves the system of linear equations when the coefficients are in tridiagonal form

TINC = Proportionate increase in time step per iteration

TLAST = Processor time at the beginning of last time step

TLIM = Maximum processor time milliseconds

TLONG = Maximum time that well injection/withdrawal rates and concentrations remains at current value in seconds

TLONGD = TLONG in days

TLONGO	= Previous value of TLONGD
TMAX	= Maximum time of simulation
TMNOW	= Subroutine which returns the elapsed processor time since beginning of execution
TNEXT	= Estimated processor time at end of next time step, milliseconds
TNOW	= Elapsed processor time in milliseconds
TOACC	= Total accumulation of fluid since the beginning of injection, ft^3
TODAYS	= Cumulative period of simulation, days
TOINJ	= Cumulative fluid injected, ft^3
TOLD	= Concentration change at a node per time step
TOOUT	= Cumulative fluid leaving system, ft^3
TOQEX	= Cumulative solute exchanged with surroundings
TOQINJ	= Cumulative solute injected in system
TOSEC	= Time in seconds which corresponds to the current value of TOUT( ) which is in days
TOTAL	= Cumulative period of simulation, sec
TOUT	= Times where printed and magnetic tape output (If SAVE > 0) are specified in the input data
TPRO	= Maximum processor time in hundredths of an hour
TREF	= Reference temperature for viscosity calculations
TS	= Labeled COMMON
TTIME	= Estimated simulation time at end of next time step
VCX	= Coefficient of x direction convection term
VCY	= Coefficient of y direction convection term
VCZ	= Coefficient of z direction convection term
VISCOS	= Viscosity of fluid
VISW( )	= Arithmetic statement function which computes the viscosity of water at the temperature specified in the argument, lb_m/ft sec

W	=	Temporary variable used in the solution of the tridiagonal system of linear equations
X	=	Dummy variable used to set up variable arrays in blank COMMON
SCONV	=	Temporary variable used to set up coefficients of tridiagonal matrix equation
YCONV	=	Temporary variable used to set up coefficients of tridiagonal matrix equation
Z	=	Solution variables of tridiagonal matrix equation
ZCONV	=	Temporary variable used to set up coefficients of tridiagonal matrix equation
ZETA	=	Concentration change from z sweep of solute transport equation

D.2.2 Listings of Source Codes

The Fortran source codes for the programs and subprograms are listed on the following pages. The programs and subprograms are listed in alphabetical order.

```
C     SUBROUTINE ADISP                                                  ADIS0010
C     THIS SUBROUTINE READS AND WRITES THE ANISOTROPIC EFFECTIVE        ADIS0020
C     DISPERSION COEFFICIENT MATRIX                                     ADIS0030
      SUBROUTINE ADISP(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,  ADIS0040
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXADIS0050
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)ADIS0060
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME        ADIS0070
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,ADIS0080
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYADIS0090
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),  ADIS0100
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),ADIS0110
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZAADIS0120
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZAADIS0130
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                         ADIS0140
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME                ADIS0150
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),ADIS0160
     1Z(NMAX)                                                           ADIS0170
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,      ADIS0180
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,ADIS0190
     2RHOW,TOTAL,VISCOS                                                 ADIS0200
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND                    ADIS0210
      REAL MASSIN,MASOUT,DX,DY,DZ                                       ADIS0220
      IF(RSTRT.GT.0.) GO TO 810                                         ADIS0230
      READ(5,AFMT) (((DX(I,J,K),I=1,NX),J=1,NY),K=1,NZ)                 ADIS0240
      READ(5,AFMT) (((DY(I,J,K),I=1,NX),J=1,NY),K=1,NZ)                 ADIS0250
      READ(5,AFMT) (((DZ(I,J,K),I=1,NX),J=1,NY),K=1,NZ)                 ADIS0260
      DO 812  K=1,NZ                                                    ADIS0270
      DO 812  J=1,NY                                                    ADIS0280
      DO 812  I=1,NX                                                    ADIS0290
      DX(I,J,K)=DX(I,J,K)/3600.0                                        ADIS0300
      DY(I,J,K)=DY(I,J,K)/3600.0                                        ADIS0310
      DZ(I,J,K)=DZ(I,J,K)/3600.0                                        ADIS0320
  812 CONTINUE                                                          ADIS0330
C     OUTPUT OF DISPERSION COEFFICIENT MATRIX                           ADIS0340
  810 WRITE(6,8065)                                                     ADIS0350
 8065 FORMAT('1ANISOTROPIC DISPERSION COEFFICIENTS, LB/SEC/FT')         ADIS0360
      DO 821 K=1,NZ                                                     ADIS0370
      LIM1=1                                                            ADIS0380
      LIM2=9                                                            ADIS0390
  817 IF(NX.LE.LIM2)LIM2=NX                                             ADIS0400
      WRITE(6,808) K,(I,I=LIM1,LIM2)                                    ADIS0410
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)                        ADIS0420
      DO 820 J=1,NY                                                     ADIS0430
      WRITE(6,809) J, (DX(I,J,K),I=LIM1,LIM2)                           ADIS0440
  809 FORMAT(2X,I2,9(2X,E11.4))                                         ADIS0450
  820 CONTINUE                                                          ADIS0460
      IF(LIM2.EQ.NX)GO TO 821                                           ADIS0470
      LIM1=LIM1+9                                                       ADIS0480
      LIM2=LIM2+9                                                       ADIS0490
      GO TO 817                                                         ADIS0500
  821 CONTINUE                                                          ADIS0510
      WRITE(6,826)                                                      ADIS0520
  826 FORMAT(1H1,3X,11HY-DIRECTION)                                     ADIS0530
      DO 831 K=1,NZ                                                     ADIS0540
```

```
      LIM1=1                                                            ADIS0550
      LIM2=9                                                            ADIS0560
  827 IF(NX.LE.LIM2)LIM2=NX                                             ADIS0570
      WRITE(6,808) K,(I,I=LIM1,LIM2)                                    ADIS0580
      DO 830 J=1,NY                                                     ADIS0590
      WRITE(6,809) J, (DY(I,J,K),I=LIM1,LIM2)                           ADIS0600
  830 CONTINUE                                                          ADIS0610
      IF(LIM2.EQ.NX)GO TO 831                                           ADIS0620
      LIM1=LIM1+9                                                       ADIS0630
      LIM2=LIM2+9                                                       ADIS0640
      GO TO 827                                                         ADIS0650
  831 CONTINUE                                                          ADIS0660
      WRITE(6,836)                                                      ADIS0670
  836 FORMAT(1H1,3X,11HZ-DIRECTION)                                     ADIS0680
      DO 841 K=1,NZ                                                     ADIS0690
      LIM1=1                                                            ADIS0700
      LIM2=9                                                            ADIS0710
  837 IF(NX.LE.LIM2) LIM2=NX                                            ADIS0720
      WRITE(6,808) K,(I,I=LIM1,LIM2)                                    ADIS0730
      DO 840 J=1,NY                                                     ADIS0740
      WRITE(6,809) J, (DZ(I,J,K),I=LIM1,LIM2)                           ADIS0750
  840 CONTINUE                                                          ADIS0760
      IF(LIM2.EQ.NX)GO TO 841                                           ADIS0770
      LIM1=LIM1+9                                                       ADIS0780
      LIM2=LIM2+9                                                       ADIS0790
      GO TO 837                                                         ADIS0800
  841 CONTINUE                                                          ADIS0810
      RETURN                                                            ADIS0820
      END                                                               ADIS0830
```

```
C     SUBROUTINE APERM
C     THIS SUBROUTINE READS AND WRITES THE ANISOTROPIC PERMEABILITY
C     TENSOR
      SUBROUTINE APERM(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      COMMON/AQLIM/KFAQ,KLAQ,NAQ
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND
      REAL MASSIN,MASOUT,DX,DY,DZ
      IF(RSTRT.GT.0.) GO TO 810
      READ(5,AFMT) (((COVERX(I,J,K),I=1,NX),J=1,NY),K=1,NZA)
      READ(5,AFMT) (((COVERY(I,J,K),I=1,NX),J=1,NY),K=1,NZA)
      READ(5,AFMT) (((COVERZ(I,J,K),I=1,NX),J=1,NY),K=1,NZA)
      DO 842 K=1,NZA
      DO 842 J=1,NY
      DO 842 I=1,NX
      COVERX(I,J,K)=COVERX(I,J,K)*RHOW*32.17/VISCOS
      COVERY(I,J,K)=COVERY(I,J,K)*RHOW*32.17/VISCOS
      COVERZ(I,J,K)=COVERZ(I,J,K)*RHOW*32.17/VISCOS
  842 CONTINUE
C     OUTPUT OF ANISOTROPIC PERMEABILITY TENSOR
  810 WRITE(6,816)
  816 FORMAT('1 ANISOTROPIC PERMEABILITY TENSOR, (SEC)-1 ** ADJUSTED FOR
     1VISCOSITY AND DENSITY')
      DO 821 K=1,NZA
      M=K+KFAQ-2
      LIM1=1
      LIM2=9
  817 IF(NX.LE.LIM2)LIM2=NX
      WRITE(6,808) M,(I,I=LIM1,LIM2)
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)
      DO 820 J=1,NY
      WRITE(6,809) J,(COVERX(I,J,K),I=LIM1,LIM2)
  809 FORMAT(2X,I2,9(2X,E11.4))
  820 CONTINUE
      IF(LIM2.EQ.NX)GO TO 821
      LIM1=LIM1+9
      LIM2=LIM2+9
      GO TO 817
  821 CONTINUE
```

```
      WRITE(6,826)                                                      APER0550
  826 FORMAT(1H1,3X,11HY-DIRECTION)                                     APER0560
      DO 831 K=1,NZA                                                    APER0570
      M=K+KFAQ-2                                                        APER0580
      LIM1=1                                                            APER0590
      LIM2=9                                                            APER0600
  827 IF(NX.LE.LIM2)LIM2=NX                                             APER0610
      WRITE(6,808) M,(I,I=LIM1,LIM2)                                    APER0620
      DO 830 J=1,NY                                                     APER0630
      WRITE(6,809) J,(COVERY(I,J,K),I=LIM1,LIM2)                        APER0640
  830 CONTINUE                                                          APER0650
      IF(LIM2.EQ.NX)GO TO 831                                           APER0660
      LIM1=LIM1+9                                                       APER0670
      LIM2=LIM2+9                                                       APER0680
      GO TO 827                                                         APER0690
  831 CONTINUE                                                          APER0700
      WRITE(6,836)                                                      APER0710
  836 FORMAT(1H1,3X,11HZ-DIRECTION)                                     APER0720
      DO 841 K=1,NZA                                                    APER0730
      M=K+KFAQ-2                                                        APER0740
      LIM1=1                                                            APER0750
      LIM2=9                                                            APER0760
  837 IF(NX.LE.LIM2) LIM2=NX                                            APER0770
      WRITE(6,808) M,(I,I=LIM1,LIM2)                                    APER0780
      DO 840 J=1,NY                                                     APER0790
      WRITE(6,809) J,(COVERZ(I,J,K),I=LIM1,LIM2)                        APER0800
  840 CONTINUE                                                          APER0810
      IF(LIM2.EQ.NX)GO TO 841                                           APER0820
      LIM1=LIM1+9                                                       APER0830
      LIM2=LIM2+9                                                       APER0840
      GO TO 837                                                         APER0850
  841 CONTINUE                                                          APER0860
      RETURN                                                            APER0870
      END                                                               APER0880
```

```
C     SUBROUTINE BALANC
C     THIS SUBROUTINE CALCULATES THE COMPONENT MASS BALANCE FOR THE
C     AQUIFER AND PRINTS THE SOLUTION OF EQUATION OF CONSERVATION OF
C     MASS
      SUBROUTINE BALANC (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      COMMON/OUT/KEY,TOINJ,TOOUT,TOQINJ,TOQEX,TOQACC
      COMMON/AQLIM/KFAQ,KLAQ,NAQ
      COMMON/ITER/H
      COMMON/WELLS/LOCX(50),LOCY(50),NWELLS
      REAL MASSIN,MASOUT,DX,DY,DZ
      QINJ=0.0
      QACCUM=0.0
      QEX=0.0
      QBOUN = 0.
      CONV = 0.
      QTERM = 0.
      EITER = 0.
      H2 = H
      IF(NIT.GT.1) H2= H1
C     CALCULATE LOCAL ENTHALPY EXCHANGE WITH SURROUNDINGS
      DO 10 K=2,NZL1
      DO 10 J=2,NYL1
      B(J) = FLOAT(J-1)*DELY -DELY/2.
      DO 10 I=2,NXL1
      A(I) = FLOAT(I-1)*DELX-DELX/2.
      EXCHG(I,J,K) =EXCHG(I,J,K)*RHOW*(F(I,J,K))
      CONV=CONV+EXCHG(I,J,K)
      QBOUN = QBOUN + QEXCHG(I,J,K)*(BCONC(I,J,K)-(2.*F(I,J,K)-SUMZET(I,
     1J,K))/2.)*DELX*DELY*DELZ*DELT
C     CALCULATE TOTAL MASS INJECTED IN CONTROL VOLUME
      QDUMMY = 0.
      SDUMMY=0.
      N=K-KFAQ+2
      IF(K.LT.KFAQ.OR.K.GT.KLAQ) GO TO 5
      FAVE=(2.0*F(I,J,K)-SUMZET(I,J,K))/2.0
      QDUMMY=Q(I,J,K)*FAVE
      IF(Q(I,J,K).GT.0.0) QDUMMY=Q(I,J,K)*CINJ(I,J)
      SDUMMY=SUMGAM(I,J,N)
```

```
    5 QINJ=QINJ+QDUMMY*RHOW*DELT
      QACCUM=(RHOPOR*SUMZET(I,J,K) - EXPAN*SDUMMY*(F(I,J,K)))
     1*DELX*DELY*DELZ +QACCUM
C     SUM OF RESIDUALS
      EITER =EITER+H2*(ZETA(I,J,K)-EPSILN(I,J,K))
     1*DELX*DELY*DELZ*DELT
   10 CONTINUE
      QEX=CONV+QBOUN
      TOQEX=TOQEX+QEX
      TOQINJ=TOQINJ+QINJ
      TOQACC=TOQACC+QACCUM
      DIF1=TOQINJ+TOQEX
      DIF2 =DIF1-TOQACC
      DIF3=QINJ+QEX
      DIF4 =DIF3-QACCUM
      IF(KEY.GT.0) WRITE(6,980)
  980 FORMAT(1H1)
      WRITE(6,20) TOQINJ,TOQEX,DIF1,TOQACC,DIF2
      WRITE(6,30)QINJ,CONV,QBOUN,QEX,DIF3,QACCUM,DIF4,NIT,EITER
      IF(KEY.EQ.0) RETURN
C
C     OUTPUT OF WELL INJECTION/WITHDRAWL RATES/CONCENTRATIONS
      IF(NWELLS.LE.0) GO TO 70
      WRITE(6,40)
   40 FORMAT(1H1,5X,4HWELL,9X,11HCOORDINATES,9X,14HINJECTION RATE,
     1 3X,13HCONCENTRATION,/,19X,1HX,11X,1HY,10X,10HCU. FT/SEC,7X,
     2 5HLB/LB,//)
      NZA1 = NZA - 1
      DO 60 L = 1,NWELLS
      I=LOCX(L)
      J=LOCY(L)
      QOUT=0.0
      COUT=0.0
      DO 50 K = 2,NZA1
      N = K + KFAQ - 2
      COUT = COUT + Q(I,J,K)*((2.0*F(I,J,N)-SUMZET(I,J,N))/2.0)
      QOUT = QOUT + Q(I,J,K)
   50 CONTINUE
      IF(QOUT.LT.0.0) CINJ(I,J) = COUT/QOUT
      XLOC = FLOAT(I-1)*DELX - DELX/2.0
      YLOC = FLOAT(J-1)*DELY - DELY/2.0
      WRITE(6,55) L,XLOC,YLOC,QOUT,CINJ(I,J)
   55 FORMAT(6X,I4,3X,2F12.0,3X,F12.4,3X,E12.4)
   60 CONTINUE
   70 CONTINUE
      TODAYS = TOTAL/(24.*3600.)
C     OUTPUT OF TEMPERATURE
      DO 871  K=2,NZL1
      LIM1=2
      LIM2=10
  867 IF(NXL1.LE.LIM2) LIM2=NXL1
      WRITE(6,1060) TODAYS
      WRITE(6,1030) K
      WRITE(6,1000) ( A(I),I=LIM1,LIM2)
```

```
      DO 868 J=2,NYL1
  868 WRITE(6,1020) B(J),(F(I,J,K),I=LIM1,LIM2)
      IF(LIM2.EQ.NXL1) GO TO 871
      LIM1=LIM1+9
      LIM2=LIM2+ 9
      GO TO 867
  871 CONTINUE
C     OUTPUT OF EXCHANGE WITH BOUNDARIES
      WRITE(6,876)
  876 FORMAT('1   MASS EXCHANGE AT EACH LOCATION - THIS TIME STEP, LB'
     1//)
      DO 881  K=2,NZL1
      LIM1=2
      LIM2=10
  877 IF(NXL1.LE.LIM2) LIM2=NXL1
      WRITE(6,808) K,(I,I=LIM1,LIM2)
      DO 880  J=2,NYL1
      WRITE(6,809) J,(EXCHG(I,J,K),I=LIM1,LIM2)
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)
  809 FORMAT(2X,I2,9(2X,E11.4))
  880 CONTINUE
      IF(LIM2.EQ.NXL1) GO TO 881
      LIM1=LIM1+9
      LIM2=LIM2+9
      GO TO 877
  881 CONTINUE
      RETURN
   20 FORMAT('0      COMPONENT MASS INJECTED TO DATE',15X,E12.4,/,
     17X,'TOTAL MASS EXCHANGED WITH SURROUNDINGS         ',E12.4,
     2//,40X,
     3'DIFFERENCE    ',E12.4,//,7X,'CALCULATED ACCUMULATION TO DATE',
     415X,E12.4,//,40X,'ERROR',23X,E15.6)
   30 FORMAT(////,7X,'MASS INJECTED IN LAST TIME PERIOD',13X,
     1E12.4,/,7X,'MASS EXCHANGED WITH SURROUNDINGS',
     2/,16X,'CONVECTION',12X,E12.4,/,16X,'DIFFUSION ',12X,E12.4,/,
     316X,'TOTAL',32X,E12.4,//,40X,'DIFFERENCE    ',E12.4,//,7X,
     4'CALCULATED ACCUMULATION IN LAST TIME PERIOD  ',E13.4,//,
     5 40X,'ERROR',23X,E15.6,////,3X,'NUMBER OF ITERATIONS',I5,/,
     63X,'SUM OF RESIDUALS',8X,E12.6)
 1000 FORMAT('0'///'  Y',41X,'DISTANCE FROM X AXIS ORIGIN'/' FEET',49X,
     1'FEET'/' ',6X, 9F12.0//)
 1020 FORMAT('0',F6.0, 9E12.4)
 1030 FORMAT('0',//' CONCENTRATION DISTRIBUTION FOR LAYER NUMBER',I3, '
     1LB/LB WATER')
 1060 FORMAT('1TOTAL TIME SIMULATED  ',F10.2,' DAYS')
      END
```

```
C     SUBROUTINE COEXCH                                                 COEX0010
C      THE MASS TRANSFER COEFFICIENTS WHICH DEFINE THE BOUNDARY         COEX0020
C     CONDITIONS ARE READ IN AND PRINTED OUT                            COEX0030
      SUBROUTINE COEXCH (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,COEX0040
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXCOEX0050
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)COEX0060
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME        COEX0070
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,COEX0080
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYCOEX0090
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),  COEX0100
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),COEX0110
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZACOEX0120
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZACOEX0130
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                          COEX0140
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME                COEX0150
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),COEX0160
     1Z(NMAX)                                                           COEX0170
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,      COEX0180
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,COEX0190
     2RHOW,TOTAL,VISCOS                                                 COEX0200
      REAL MASSIN,MASOUT,DX,DY,DZ                                       COEX0210
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND                    COEX0220
      COMMON/AQLIM/KFAQ,KLAQ,NAQ                                        COEX0230
      INTEGER CFILE                                                     COEX0240
      IF(RSTRT.GT.0.) GO TO 790                                         COEX0250
      READ(5,BFMT) (((COEFX(I,J,K),I=1,NX),J=1,NY),K=1,NZA)             COEX0260
      READ(5,BFMT) (((COEFY(I,J,K),I=1,NX),J=1,NY),K=1,NZA)             COEX0270
      READ(5,BFMT) (((COEFZ(I,J,K),I=1,NX),J=1,NY),K=1,NZA)             COEX0280
      DO 812 K=KFAQ,KLAQ                                                COEX0290
      DO 812  J=1,NY                                                    COEX0300
      DO 812  I=1,NX                                                    COEX0310
      N = K - KFAQ + 2                                                  COEX0320
      COEFX(I,J,N) = COEFX(I,J,N)/VISCOS                                COEX0330
      COEFY(I,J,N) = COEFY(I,J,N)/VISCOS                                COEX0340
      COEFZ(I,J,N) = COEFZ(I,J,N)/ VISCOS                               COEX0350
  812 CONTINUE                                                          COEX0360
  790 DO 800  K=1,NZA                                                   COEX0370
      DO 800  J=1,NY                                                    COEX0380
      DO 800  I=1,NX                                                    COEX0390
      SUMGAM(I,J,K)=COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K)              COEX0400
  800 CONTINUE                                                          COEX0410
      WRITE(6,806)                                                      COEX0420
  806 FORMAT('1SUM OF COEFFICIENTS OF EXCHANGE WITH BOUNDARIES, 1/SEC', COEX0430
     1'/FT HEAD',//)                                                    COEX0440
      DO 811  K=1,NZA                                                   COEX0450
      M=K+KFAQ-2                                                        COEX0460
      LIM1=1                                                            COEX0470
      LIM2=9                                                            COEX0480
  807 IF(NX.LE.LIM2)LIM2=NX                                             COEX0490
      WRITE(6,808) M,(I,I=LIM1,LIM2)                                    COEX0500
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)                        COEX0510
      DO 810 J=1,NY                                                     COEX0520
      WRITE(6,809) J,(SUMGAM(I,J,K),I=LIM1,LIM2)                        COEX0530
  809 FORMAT(2X,I2,9(2X,E11.4))                                         COEX0540
```

```
810 CONTINUE
    IF(LIM2.EQ.NX)GO TO 811
    LIM1=LIM1+9
    LIM2=LIM2+9
    GO TO 807
811 CONTINUE
    RETURN
    END
```

```
C     SUBROUTINE CONC                                                   CONC0010
C     THE INITIAL CONCENTRATION DISTRIBUTION IS SPECIFIED               CONC0020
      SUBROUTINE CONC(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,   CONC0030
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXCONC0040
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)CONC0050
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME        CONC0060
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,CONC0070
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYCONC0080
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),  CONC0090
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),CONC0100
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZACONC0110
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZACONC0120
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                          CONC0130
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME                CONC0140
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),CONC0150
     1Z(NMAX)                                                           CONC0160
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,      CONC0170
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,CONC0180
     2RHOW,TOTAL,VISCOS                                                 CONC0190
      COMMON/AQLIM/KFAQ,KLAQ,NAQ                                        CONC0200
      REAL MASSIN,MASOUT,DX,DY,DZ                                       CONC0210
      INTEGER CFILE                                                     CONC0220
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND                    CONC0230
C     THE INITIAL TEMPERATURE IS ASSIGNED TO EACH CELL                  CONC0240
      IF(RSTRT.GT.0.) GO TO 800                                         CONC0250
      READ(5,CFMT) (((F(I,J,K),I=1,NX),J=1,NY),K=1,NZ)                  CONC0260
  800 WRITE(6,806)                                                      CONC0270
  806 FORMAT(1H1,'INITIAL CONCENTRATION DISTRIBUTION, LB/LB',//)        CONC0280
      DO 811  K=1,NZ                                                    CONC0290
      LIM1=1                                                            CONC0300
      LIM2=9                                                            CONC0310
  807 IF(NX.LE.LIM2)LIM2=NX                                             CONC0320
      WRITE(6,808) K,(I,I=LIM1,LIM2)                                    CONC0330
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)                        CONC0340
      DO 810 J=1,NY                                                     CONC0350
      WRITE(6,809) J,(F(I,J,K),I=LIM1,LIM2)                             CONC0360
  809 FORMAT(2X,I2,9(2X,E11.4))                                         CONC0370
  810 CONTINUE                                                          CONC0380
      IF(LIM2.EQ.NX)GO TO 811                                           CONC0390
      LIM1=LIM1+9                                                       CONC0400
      LIM2=LIM2+9                                                       CONC0410
      GO TO 807                                                         CONC0420
  811 CONTINUE                                                          CONC0430
      RETURN                                                            CONC0440
      END                                                               CONC0450
```

```
C       SUBROUTINE CONHD                                                CNHD0010
C       CONSTANT HEAD BOUNDARIES                                        CNHD0020
        SUBROUTINE CONHD(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY, CNHD0030
       1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXCNHD0040
       2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)CNHD0050
C       THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME      CNHD0060
        DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,CNHD0070
       1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYCNHD0080
       2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),  CNHD0090
       3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),CNHD0100
       4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZACNHD0110
       5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZACNHD0120
       6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                         CNHD0130
C       ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME              CNHD0140
        DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),CNHD0150
       1Z(NMAX)                                                         CNHD0160
        COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,     CNHD0170
       1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,CNHD0180
       2RHOW,TOTAL,VISCOS                                               CNHD0190
        REAL MASSIN,MASOUT,DX,DY,DZ                                     CNHD0200
        COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND                  CNHD0210
        COMMON/AQLIM/KFAQ,KLAQ,NAQ                                      CNHD0220
        INTEGER CFILE                                                   CNHD0230
        IF(RSTRT.GT.0.) GO TO 800                                       CNHD0240
        READ(5,CFMT) (((HEAD(I,J,K),I=1,NX),J=1,NY),K=1,NZA)            CNHD0250
  800 WRITE(6,806)                                                      CNHD0260
  806 FORMAT(1H1,'CONSTANT HEAD BOUNDARIES, FEET '//)                   CNHD0270
        DO 811 K=1,NZA                                                  CNHD0280
        M=K+KFAQ-2                                                      CNHD0290
        LIM1=1                                                          CNHD0300
        LIM2=9                                                          CNHD0310
  807 IF(NX.LE.LIM2)LIM2=NX                                             CNHD0320
        WRITE(6,808) M,(I,I=LIM1,LIM2)                                  CNHD0330
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)                        CNHD0340
        DO 810 J=1,NY                                                   CNHD0350
        WRITE(6,809) J,(HEAD(I,J,K),I=LIM1,LIM2)                        CNHD0360
  809 FORMAT(2X,I2,9(2X,E11.4))                                         CNHD0370
  810 CONTINUE                                                          CNHD0380
        IF(LIM2.EQ.NX)GO TO 811                                         CNHD0390
        LIM1=LIM1+9                                                     CNHD0400
        LIM2=LIM2+9                                                     CNHD0410
        GO TO 807                                                       CNHD0420
  811 CONTINUE                                                          CNHD0430
        RETURN                                                          CNHD0440
        END                                                             CNHD0450
```

```
C      SUBROUTINE CONCON
C      CONSTANT CONCENTRATION BOUNDARY CONDITIONS
       SUBROUTINE CONCON (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C      THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
       DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C      ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
       DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
       COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
       REAL MASSIN,MASOUT,DX,DY,DZ
       COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND
       INTEGER CFILE
       IF(RSTRT.GT.0.) GO TO 800
       READ(5,CFMT) (((BCONC(I,J,K),I=1,NX),J=1,NY),K=1,NZ)
   800 WRITE(6,806)
   806 FORMAT(1H1,'CONSTANT CONCENTRATION BOUNDARY CONDITIONS, LB/LB',//)
       DO 811  K=1,NZ
       LIM1=1
       LIM2=9
   807 IF(NX.LE.LIM2)LIM2=NX
       WRITE(6,808) K,(I,I=LIM1,LIM2)
   808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)
       DO 810 J=1,NY
       WRITE(6,809) J,(BCONC(I,J,K),I=LIM1,LIM2)
   809 FORMAT(2X,I2,9(2X,E11.4))
   810 CONTINUE
       IF(LIM2.EQ.NX)GO TO 811
       LIM1=LIM1+9
       LIM2=LIM2+9
       GO TO 807
   811 CONTINUE
       RETURN
       END
```

```
      FUNCTION EFCOEF(COEF1,COEF2)
      IF(COEF1.EQ.0.0.AND.COEF2.EQ.0.) GO TO 10
      EFCOEF=COEF1*COEF2/(COEF1+COEF2)
      RETURN
   10 EFCOEF=0.
      RETURN
      END
```

```
      SUBROUTINE FLGEOF(I,IEOF)
      DATA EOF/4H EOF/
    1 READ(I,END=99) FIND
      IF(FIND-EOF) 1,2,1
    2 IEOF=1
      RETURN
   99 WRITE(6,909)
  909 FORMAT(1H0,'--EOF ON DISK--SUB FLGEOF')
      RETURN
      END
```

```
C     SUBROUTINE IDISP
C     THIS SUBROUTINE READS AND WRITES THE ISOTROPIC DISPERSION
C     COEFFICIENT MATRIX
      SUBROUTINE IDISP(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      REAL MASSIN,MASOUT,DX,DY,DZ
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND
      INTEGER CFILE
      IF(RSTRT.GT.0.) GO TO 8065
C     ISOTROPIC DISPERSION COEFFICIENT MATRIX
      READ(5,AFMT) (((DX(I,J,K),I=1,NX),J=1,NY),K=1,NZ)
      DO 812  K=1,NZ
      DO 812  J=1,NY
      DO 812  I=1,NX
      DX(I,J,K)=DX(I,J,K)/3600.0
  812 CONTINUE
C     OUTPUT OF DISPERSION COEFFICIENT MATRIX
 8065 WRITE(6,8068)
 8068 FORMAT(1H1,'ISOTROPIC DISPERSION COEFFICIENT MATRIX,',
     1 ' LB/SEC/FT')
 8069 DO 811  K=1,NZ
      LIM1=1
      LIM2=9
  807 IF(NX.LE.LIM2) LIM2=NX
      WRITE(6,808) K,(I,I=LIM1,LIM2)
  808 FORMAT(//,3X,2HK=,I2,//4X,9(5X,I2,6X),//)
      DO 810  J=1,NY
      WRITE(6,809) J,(DX(I,J,K),I=LIM1,LIM2)
  809 FORMAT(2X,I2,9(2X,E11.4))
  810 CONTINUE
      IF(LIM2.EQ.NX) GO TO 811
      LIM1=LIM1+9
      LIM2=LIM2+9
      GO TO 807
  811 CONTINUE
      RETURN
      END
```

```
C       SUBROUTINE IPERM
C      THIS SUBROUTINE READS AND WRITES THE ISOTROPIC PERMEABILITY
       SUBROUTINE IPERM(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C      THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
       DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C      ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
       DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
       COMMON/PARAM/AFMT(10),BFMT(10),CFMT(10),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
       COMMON/AQLIM/KFAQ,KLAQ,NAQ
       COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND
       REAL MASSIN,MASOUT,DX,DY,DZ
       INTEGER CFILE
       IF(RSTRT.GT.0.)GO TO 8065
       READ(5,AFMT)(((COVERX(I,J,K),I=1,NX),J=1,NY),K=1,NZA)
       DO 812 K= KFAQ,KLAQ
       DO 812 J=1,NY
       DO 812 I=1,NX
       N = K - KFAQ + 2
       COVERX(I,J,N) =COVERX(I,J,N) * RHOW*32.17/VISCOS
       COVERY(I,J,N) = COVERX(I,J,N)
       COVERZ(I,J,N) = COVERX(I,J,N)
  812  CONTINUE
C      OUTPUT OF ISOTROPIC PERMEABILITY MATRIX
 8065  WRITE(6,8068)
 8068  FORMAT('1ISOTROPIC PERMEABILITY MATRIX, (SEC)-1 ** ADJUSTED FOR ',
     1'VISCOSITY AND DENSITY ',//)
 8069  DO 811  K=1,NZA
       M=K+KFAQ-2
       LIM1=1
       LIM2=9
  807  IF(NX.LE.LIM2)LIM2=NX
       WRITE(6,808) M,(I,I=LIM1,LIM2)
  808  FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)
       DO 810 J=1,NY
       WRITE(6,809) J,(COVERX(I,J,K),I=LIM1,LIM2)
  809  FORMAT(2X,I2,9(2X,E11.4))
  810  CONTINUE
       IF(LIM2.EQ.NX)GO TO 811
       LIM1=LIM1+9
       LIM2=LIM2+9
       GO TO 807
  811  CONTINUE
       RETURN
```

```
END                                                                 IPER0550
```

```
C     MAIN PROGRAM
C     THIS PROGRAM DETERMINES THE STARTING LOCATION OF DIMENSIONED
C     VARIABLE ARRAYS AT EXECUTION TIME USING DYNAMIC STORAGE ALLOCATION
C     ON THE GE 635
C     DISPOSAL OF HEATED WATER THROUGH GROUNDWATER SYSTEMS
C     GROUNDWATER AQUIFER MODEL  DEVELOPED UNDER OWRR-KWRRI MATCHING
C     GRANT CONTRACT B-023-KAN AT THE UNIVERSITY OF KANSAS
C     LAWRENCE,KANSAS  1974
C     PRINCIPAL INVESTIGATOR       G.PAUL WILLHITE
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C     DEPARTMENT OF CHEMICAL AND PETROLEUM ENGINEERING
C
C     MODIFIED BY JAN WAGNER, SCHOOL OF CHEMICAL ENGINEERING,
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C     MARCH 1982
C
      DIMENSION TITL(40)
      COMMON X(175000)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      COMMON/CLOCK/ILAPSE,TNEXT,TNOW
      COMMON/AQUIFR/ISO,SOLUTE
      INTEGER SOLUTE
      REAL MASSIN,MASOUT,DX,DY,DZ
      MAXSZ=175000
C     ERROR HANDLING ROUTINE
      CALL ERRSET(207,260,-1,1,0,208)
C     ISO=1 IF AQUIFER IS ISOTROPIC
C     CALL TMNOW1 STARTS THE PROCESSOR TIME CLOCK RUNNING
      CALL TMNOW1
C     AT EXECUTION TIME = LIMITS-(PROGRAM+BUFFERS+FCB+MISC) IN MAXSZ
C     READ TITLE
      READ(5,8)(TITL(I),I=1,40)
    8 FORMAT(20A4,/,20A4)
      WRITE(6,9)(TITL(I),I=1,40)
    9 FORMAT(1H1,2X,20A4,/,3X,20A4,////)
C     READ DIMENSIONS OF ARRAYS
      READ(5,10) NX,NY,NZ,NZA,NMAX,ISO,SOLUTE
   10 FORMAT(7I5)
      WRITE(6,20) NX,NY,NZ,NZA,NMAX,ISO,SOLUTE
C     NX = NUMBER OF GRIS NODES IN X-DIRECTION
C     NY = NUMBER OF GRID NODES IN Y-DIRECTION
C     NZ = NUMBER OF GRID NODES IN Z-DIRECTION
C     NZA = NUMBER OF GRID NODES IN Z-DIRECTION TO STORE AQUIFER ARRAYS
C     NZA MUST BE LESS THAN OR EQUAL TO NZ
C     NMAX = MAXIMUM OF NX, NY, NZ
C     STORAGE REQUIREMENT FOR EACH ARRAY APPEARS IN (   )
      IF(NZA.LE.NZ) GO TO 15
C     PROGRAM TERMINATED IF ERROR IS FOUND IN INPUT DATA
      WRITE(6,12)
   12 FORMAT(' PROGRAM TERMINATED IN MAIN**NZA IS GREATER THAN NZ')
      STOP
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   15 NXYZ=NX*NY*NZ
      NXYZA = NX*NY*NZA
      NXY = NX*NY
C     IALPHA = STARTING LOCATION OF ALPHA(NXYZ)
C     IBETA  = STARTING LOCATION OF BETA(NXYZ)
C     IBCONC = STARTING LOCATION OF BCONC(NXYZ)
C     ICOEFX = STARTING LOCATION OF COEFX(NXYZA)
C     ICOEFY = STARTING LOCATION OF COEFY(NXYZA)
C     ICOEFZ = STARTING LOCATION OF COEFZ(NXYZA)
C     ICOX   = STARTING LOCATION OF COVERX(NXYZA)
C     ICOY   = STARTING LOCATION OF COVERY(NXYZA)
C     ICOZ   = STARTING LOCATION OF COVERZ(NXYZA)
C     IDELTA = STARTING LOCATION OF DELTA(NXYZ)
C     IDRAWN = STARTING LOCATION OF DRAWDN(NXYZA)
C     IEPSIL = STARTING LOCATION OF EPSILN(NXYZ)
C     IEXCHG = STARTING LOCATION OF EXCHG(NXYZA)
C     IGAMMA = STARTING LOCATION OF GAMMA(NXYZ)
C     IHEAD  = STARTING LOCATION OF HEAD(NXYZA)
C     IDX    = STARTING LOCATION OF DX(NXYZ)
C     IDY    = STARTING LOCATION OF DY(NXYZ)
C     IDZ    = STARTING LOCATION OF DZ(NXYZ)
C     IPRES  = STARTING LOCATION OF PRES(NXYZA)
C     IQ     = STARTING LOCATION OF Q(NXYZA)
C     IQEXCH = STARTING LOCATION OF QEXCHG(NXYZ)
C     ISUMGM = STARTING LOCATION OF SUMGAM(NXYZA)
C     ISUMZT = STARTING LOCATION OF SUMZET(NXYZ)
C     ISS    = STARTING LOCATION OF SS(NXYZA)
C     IT     = STARTING LOCATION OF F(NXYZ)
C     IZETA  = STARTING LOCATION OF ZETA(NXYZ)
C     ICINJ  = STARTING LOCATION OF CINJ(NXY)
C     IA     = STARTING LOCATION OF A(NMAX)
C     IB     = STARTING LOCATION OF B(NMAX)
C     IC     = STARTING LOCATION OF C(NMAX)
C     ID     = STARTING LOCATION OF D(NMAX)
C     IG     = STARTING LOCATION OF G(NMAX)
C     IR     = STARTING LOCATION OF R(NMAX)
C     IW     = STARTING LOCATION OF W(NMAX)
C     IZ     = STARTING LOCATION OF Z(NMAX)
      IALPHA = 1
      IBETA  = IALPHA + NXYZ
      ICOEFX = IBETA  + NXYZ
      ICOEFY = ICOEFX + NXYZA
      ICOEFZ = ICOEFY + NXYZA
      ICOX   = ICOEFZ + NXYZA
      ICOY   = ICOX   + NXYZA
      IF(ISO.EQ.1) ICOY=ICOX
      ICOZ   = ICOY   + NXYZA
      IF(ISO.EQ.1) ICOZ=ICOX
      IEXCHG = ICOZ   + NXYZA
      IGAMMA = IEXCHG + NXYZ
      IHEAD  = IGAMMA + NXYZ
      IPRES  = IHEAD  + NXYZA
      IQ     = IPRES  + NXYZA
      ISUMGM = IQ     + NXYZA
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```
      IDRAWN = ISUMGM + NXYZA
      ISS    = IDRAWN + NXYZA
C
C     ARRAYS REQUIRED TO SOLVE SOLUTE TRANSPORT EQUATION
      IBCONC = ISS    + NXYZA
      IF(SOLUTE.LE.0) IBCONC = 1
      IDELTA = IALPHA
      IEPSIL = IBETA
      IDX    = IBCONC + NXYZ
      IF(SOLUTE.LE.0) IDX = 1
      IDY    = IDX    + NXYZ
      IF(ISO.EQ.1.OR.SOLUTE.LE.0) IDY=IDX
      IDZ    = IDY    + NXYZ
      IF(ISO.EQ.1.OR.SOLUTE.LE.0) IDZ=IDX
      IQEXCH = IDZ    + NXYZ
      IF(SOLUTE.LE.0) IQEXCH = 1
      ISUMZT = IQEXCH + NXYZ
      IF(SOLUTE.LE.0) ISUMZT = 1
      IT     = ISUMZT + NXYZ
      IF(SOLUTE.LE.0) IT = 1
      IZETA  = IGAMMA
C
C     TWO - DIMENSIONAL ARRAYS FOR WELL NODES
      ICINJ  = IT + NXYZ
      IF(SOLUTE.LE.0) ICINJ = ISS + NXYZA
C
C     ONE - DIMENSIONAL ARRAYS IN TRIDIAGONAL MATRIX EQUATIONS
      IA     = ICINJ + NXY
      IB     = IA + NMAX
      IC     = IB + NMAX
      ID     = IC + NMAX
      IG     = ID + NMAX
      IR     = IG + NMAX
      IW     = IR + NMAX
      IZ     = IW + NMAX
      IMAX   = IZ + NMAX
   20 FORMAT(3X,43HLIMITS USED TO SET SIZES OF VARIABLE ARRAYS,/,3X,
     15HNX = ,I5,5X,5HNY = ,I5,5X,5HNZ = ,I5,5X,6HNZA = ,I5,5X,7HNMAX =
     2,I5,//,3X,5HISO =,I5,5X,8HSOLUTE =,I5)
      WRITE(6,30) IMAX,MAXSZ
   30 FORMAT(3X,35HCOMMON REQUIRED FOR VARIABLE ARRAYS,4X,I10,/,3X,
     1'COMMON STORAGE AVAILABLE',15X,I10,////)
      IF(IMAX.LT.MAXSZ) GO TO 50
C     PROGRAM IS TERMINATED IF AVAILABLE COMMON STORAGE IS TOO SMALL
      WRITE(6,40) MAXSZ
   40 FORMAT(3X,'***PROGRAM TERMINATED--COMMON REQUIREMENT EXCEEDS SP',
     1 'ACE ALLOCATED IN COMMON X(MAXSZ) AND MAXSZ = ',I6,' STATEMENTS')
      STOP
   50 CONTINUE
      CALL PREP (NX,NY,NZ,NZA,NMAX,X(IALPHA),X(IBETA),X(IBCONC),
     1X(ICOEFX),X(ICOEFY),X(ICOEFZ),X(ICOX),X(ICOY),X(ICOZ),X(IDELTA),X(
     2IDRAWN),X(IEPSIL),X(IEXCHG),X(IGAMMA),X(IHEAD),X(IDX),X(IDY),X(IDZ
     3),X(IPRES),X(IQ),X(IQEXCH),X(ISUMGM),X(ISUMZT),X(ISS),X(IT),X(IZET
     4A),X(ICINJ),X(IA),X(IB),X(IC),X(ID),X(IG),X(IR),X(IW),X(IZ))
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100 CONTINUE
    STOP
    END
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C      SUBROUTINE MASBAL
C     THIS SUBROUTINE CALCULATES THE MASS BALANCES FOR THE AQUIFER
C     AND PRINTS OUT THE SOLUTION OF THE EQUATION OF MOTION
      SUBROUTINE MASBAL (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      COMMON/AQLIM/KFAQ,KLAQ,NAQ
      COMMON/OUT/KEY,TOINJ,TOOUT,TOQINJ,TOQEX,TOQACC
      REAL MASSIN,MASOUT,DX,DY,DZ
      SUMR = 0.
      MASOUT=0.0
      MASSIN=0.0
      ACCUM=0.0
      TOACC=0.0
      NZA1 = NZA - 1
      DO 515  K=2,NZA1
      DO 515 J=2,NYL1
      B(J) = FLOAT(J-1)*DELY -DELY/2.
      DO 515 I=2,NXL1
      A(I) = FLOAT(I-1)*DELX-DELX/2.
      HDUMMY = GAMMA(I,J,K) - BETA(I,J,K)
      IF(KFAQ.EQ.KLAQ) HDUMMY = GAMMA(I,J,K) - ALPHA(I,J,K)
  515 SUMR = SUMR + H1*DELX*DELY*DELZ*HDUMMY*DELT
C     CALCULATE NEW HEAD DISTRIBUTIONS AND DRAWDOWN
      DO 510 K=2,NZL1
      DO 510 J=2,NYL1
      DO 510 I=2,NXL1
      EXCHG(I,J,K) = 0.
      IF(K.LT.KFAQ.OR.K.GT.KLAQ)  GO TO 510
      N= K-KFAQ+2
      DRAWDN(I,J,N) = DRAWDN(I,J,N) - SUMGAM(I,J,N)
      PRES(I,J,N)=PRES(I,J,N)+SUMGAM(I,J,N)
      EXCHG(I,J,K)=(COEFX(I,J,N)+COEFY(I,J,N)+COEFZ(I,J,N))*(HEAD(I,J,N)
     1-     PRES(I,J,N)    )*DELT*DELX*DELY*DELZ
      MASOUT=MASOUT+EXCHG(I,J,K)
      MASSIN=MASSIN+Q(I,J,N)*DELT
      ACCUM=ACCUM+SS(I,J,N)*SUMGAM(I,J,N)*DELX*DELY*DELZ
      TOACC=TOACC+SS(I,J,N)*(PRES(I,J,N)-HEAD(I,J,N))*DELX*DELY*DELZ
  510 CONTINUE
C     UPDATE TIME AND PRINTOUT RESULTS
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      TOTAL = TOTAL + DELT
      TODAYS=TOTAL/3600.0/24.0
      DELTDA=DELT/3600.0/24.0
      TOINJ=TOINJ+MASSIN
      TOOUT=TOOUT+MASOUT
      DIFF1=TOINJ+TOOUT
      DIFF2=DIFF1-TOACC
C     OUTPUT OF TIME, QUANTITY INJECTED, MASS ACCUMULATION IN AQUIFER
      DIFF3=MASSIN+MASOUT
      DIFF4=DIFF3-ACCUM
C     OUTPUT OF TIME, QUANTITY INJECTED, MASS ACCUMULATION IN AQUIFER
      WRITE(6,860) TODAYS,TOTAL,TOINJ,TOOUT,DIFF1,TOACC,DIFF2,DELTDA,
     1DELT,MASSIN,MASOUT,DIFF3,ACCUM,DIFF4,NIT
      WRITE(6,516) SUMR
      IF(KEY.EQ.0) RETURN
C     OUTPUT OF DRAWDOWN
      WRITE(6,866)
  866 FORMAT(1H1,3X,'DRAWDOWN DURING LAST TIME STEP IN FEET',//)
      NZA1 = NZA - 1
      DO 871 K=2,NZA1
      M=K+KFAQ-2
      LIM1=2
      LIM2=10
  867 IF(NXL1.LE.LIM2) LIM2=NXL1
      WRITE(6,808) M,(I,I=LIM1,LIM2)
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)
      DO 870 J=2,NYL1
      WRITE(6,809) J,(SUMGAM(I,J,K),I=LIM1,LIM2)
  809 FORMAT(2X,I2,9(2X,E11.4))
  870 CONTINUE
      IF(LIM2.EQ.NXL1) GO TO 871
      LIM1=LIM1+9
      LIM2=LIM2+9
      GO TO 867
  871 CONTINUE
C     OUTPUT OF CUMULATIVE DRAWDOWN
      DO 891 K=2,NZA1
      KT = K + KFAQ - 2
      LIM1=2
      LIM2= 10
  887 IF(NXL1.LE.LIM2) LIM2=NXL1
      WRITE(6,1060) TODAYS
      WRITE(6,1040) KT
      WRITE(6,1000) ( A(I),I=LIM1,LIM2)
      DO  888  J = 2,NYL1
  888 WRITE(6,1020) B(J),(DRAWDN(I,J,K),I=LIM1,LIM2)
      IF(LIM2.EQ.NXL1) GO TO 891
      LIM1=LIM1+ 9
      LIM2=LIM2+ 9
      GO TO 887
  891 CONTINUE
C     OUTPUT OF PRESSURE
      DO 881 K=2,NZA1
      KT = K + KFAQ - 2
```

```
      LIM1=2                                                            MASB1090
      LIM2= 10                                                          MASB1100
  877 IF(NXL1.LE.LIM2) LIM2=NXL1                                        MASB1110
      WRITE(6,1060) TODAYS                                              MASB1120
      WRITE(6,1030) KT                                                  MASB1130
      WRITE(6,1000) ( A(I),I=LIM1,LIM2)                                 MASB1140
      DO  868  J = 2,NYL1                                               MASB1150
  868 WRITE(6,1020) B(J),(PRES(I,J,K),I=LIM1,LIM2)                      MASB1160
      IF(LIM2.EQ.NXL1) GO TO 881                                        MASB1170
      LIM1=LIM1+ 9                                                      MASB1180
      LIM2=LIM2+ 9                                                      MASB1190
      GO TO 877                                                         MASB1200
  881 CONTINUE                                                          MASB1210
C     OUTPUT OF EXCHANGE WITH BOUNDRIES                                 MASB1220
      WRITE(6,966)                                                      MASB1230
  966 FORMAT(1H1,3X,'FLUID EXCHANGE AT EACH LOCATION -  THIS TIME STEP, MASB1240
     1 CU.FT.'//)                                                       MASB1250
      DO 971 K=KFAQ,KLAQ                                                MASB1260
      LIM1=2                                                            MASB1270
      LIM2=10                                                           MASB1280
  967 IF(NXL1.LE.LIM2) LIM2=NXL1                                        MASB1290
      WRITE(6,808) K,(I,I=LIM1,LIM2)                                    MASB1300
      DO 970 J=2,NYL1                                                   MASB1310
      WRITE(6,809) J,(EXCHG(I,J,K),I=LIM1,LIM2)                         MASB1320
  970 CONTINUE                                                          MASB1330
      IF(LIM2.EQ.NXL1) GO TO 971                                        MASB1340
      LIM1=LIM1+9                                                       MASB1350
      LIM2=LIM2+9                                                       MASB1360
      GO TO 967                                                         MASB1370
  971 CONTINUE                                                          MASB1380
      RETURN                                                            MASB1390
  516 FORMAT(3X,16HSUM OF RESIDUALS,8X,E12.6)                           MASB1400
  860 FORMAT(1H1,25HTOTAL PERIOD OF INJECTION,16X,F9.4,7H DAYS (,       MASB1410
     1E10.3,9H SECONDS),//,7X,22HFLUID INJECTED TO DATE,24X,E12.4,/,    MASB1420
     27X,39HTOTAL FLUID EXCHANGED WITH SURROUNDINGS,7X,E12.4,//,40X,    MASB1430
     310HDIFFERENCE,3X,E12.4,//7X,31HCALCULATED ACCUMULATION TO DATE15X,MASB1440
     4E12.4,//,40X,5HERROR,23X,E15.6,////3X,26HLENGTH OF LAST TIME PERIOMASB1450
     5D,15X,F9.4,7H DAYS (,E10.3,9H SECONDS),//,7X,                     MASB1460
     634HFLUID INJECTED IN LAST TIME PERIOD,12X,E12.4,/,7X,33HFLUID EXCHMASB1470
     7ANGED WITH SURROUNDINGS,13X,E12.4,//,40X,10HDIFFERENCE,3X,E12.4,//MASB1480
     87X,43HCALCULATED ACCUMULATION IN LAST TIME PERIOD,3X,E12.4,//,40X,MASB1490
     95HERROR,23X,E15.6,////,3X,20HNUMBER OF ITERATIONS,I5)             MASB1500
 1000 FORMAT('0'///'  Y',41X,'DISTANCE FROM X AXIS ORIGIN'/' FEET',49X, MASB1510
     1'FEET'/' ',6X,9F12.0//)                                           MASB1520
 1020 FORMAT('0',F6.0,9F12.4)                                           MASB1530
 1030 FORMAT('0',//' HEAD DISTRIBUTION FOR LAYER NUMBER ',I3)           MASB1540
 1040 FORMAT('0',//,' CUMULATIVE DRAWDOWN FOR LAYER NUMBER ',I3)        MASB1550
 1060 FORMAT('1TOTAL TIME SIMULATED  ',F10.2,' DAYS')                   MASB1560
      END                                                               MASB1570
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C     SUBROUTINE MASS                                                   MASS0010
C     THIS SUBROUTINE SOLVES THE EQUATION OF CONSERVATION OF MASS       MASS0020
C     UTILIZING THE VELOCITY AND HEAD DISTRIBUTIONS OBTAINED FROM       MASS0030
C     THE SOLUTION OF THE EQUATION OF MOTION                            MASS0040
      SUBROUTINE MASS (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,  MASS0050
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXMASS0060
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)MASS0070
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME        MASS0080
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,MASS0090
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYMASS0100
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),  MASS0110
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),MASS0120
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZAMASS0130
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZAMASS0140
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                          MASS0150
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME                MASS0160
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),MASS0170
     1Z(NMAX)                                                           MASS0180
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,      MASS0190
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,MASS0200
     2RHOW,TOTAL,VISCOS                                                 MASS0210
      COMMON/AQLIM/KFAQ,KLAQ,NAQ                                        MASS0220
      COMMON/START/I1                                                   MASS0230
      COMMON/LIMIT/CLIM,CTIM,ETIM                                       MASS0240
      COMMON/ITER/H                                                     MASS0250
      REAL MASSIN,MASOUT,DX,DY,DZ                                       MASS0260
      ITCY=0                                                            MASS0270
      I1=2                                                              MASS0280
C     FLUID FLOW CONFINED TO THE AQUIFER  KFAQ.LE.K.LE.KLAQ             MASS0290
C     WHERE KFAQ = INDEX OF FIRST Z LAYER IN AQUIFER                    MASS0300
C    KLAQ = INDEX OF LAST Z LAYER IN AQUIFER                            MASS0310
C    2.LE.KFAQKLAQ.LE.NZA -1 KFAQ.LE.KLAQ                               MASS0320
C                                                                       MASS0330
C     FIRST ITERATION BEGINS                                            MASS0340
      EOLD=0.0                                                          MASS0350
C     CALCULATE ITERATION PARAMERER FOR FIRST CYCLE                     MASS0360
      NIT=0                                                             MASS0370
      NITCY=NIT+1-ITCY*MXITCY                                           MASS0380
      H=HMAX*((HMIN/HMAX)**((FLOAT(NITCY-1))/(FLOAT(MXITCY-2))))        MASS0390
      H=H/(DELX*DELY*DELZ)*1.E-05                                       MASS0400
   30 CONTINUE                                                          MASS0410
C     X-DIRECTION SWEEPS                                                MASS0420
      DO 60  K=2,NZL1                                                   MASS0430
      DO 60  J=2,NYL1                                                   MASS0440
      DO 40  I=2,NXL1                                                   MASS0450
C     SET UP COEFFICIENT MATRIX                                         MASS0460
      B(I)=(2.0/(DELX*DELX))*EFCOEF(DX(I,J,K),DX(I+1,J,K))              MASS0470
      C(I)=(2.0/(DELX*DELX))*EFCOEF(DX(I,J,K),DX(I-1,J,K))              MASS0480
      XCONV = 0.                                                        MASS0490
      YCONV = 0.                                                        MASS0500
      ZCONV = 0.                                                        MASS0510
      QDUMMY = 0.                                                       MASS0520
      SDUMMY = 0.                                                       MASS0530
      IF(K.LT.KFAQ.OR.K.GT.KLAQ) GO TO 44                               MASS0540
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      N=K-KFAQ+2                                                        MASS0550
      IF(Q(I,J,N).GT.0.0) QDUMMY=Q(I,J,N)                               MASS0560
      SDUMMY = SUMGAM(I,J,N)                                            MASS0570
C     CALCULATE COEFFICIENTS OF THE CONVECTION TERMS--VCX,VCY,VCZ       MASS0580
C     X-DIRECTION COMPONENTS                                            MASS0590
      SIGN=0.5                                                          MASS0600
      IF(COVERX(I+1,J,N).EQ.0.0) SIGN=-0.5                              MASS0610
      VCX=(-1.0*EFCOEF(COVERX(I+1,J,N),COVERX(I,J,N))*(PRES(I+1,J,N)-PREMASS0620
     1S(I,J,N))/DELX-EFCOEF(COVERX(I,J,N),COVERX(I-1,J,N))*(PRES(I,J,N)-MASS0630
     2PRES(I-1,J,N))/DELX+SIGN*COEFX(I,J,N)*DELX*(HEAD(I,J,N)-   PRES(  MASS0640
     3I,J,N)        ))*RHOW/DELX                                        MASS0650
C     Y-DIRECTION COMPONENTS                                            MASS0660
      SIGN = 0.5                                                        MASS0670
      IF(COVERY(I,J+1,N).EQ.0.0) SIGN=-0.5                              MASS0680
      VCY=(-1.0*EFCOEF(COVERY(I,J+1,N),COVERY(I,J,N))*(PRES(I,J+1,N)-PREMASS0690
     1S(I,J,N))/DELY-EFCOEF(COVERY(I,J,N),COVERY(I,J-1,N))*(PRES(I,J,N)-MASS0700
     2PRES(I,J-1,N))/DELY+SIGN*COEFY(I,J,N)*DELY*(HEAD(I,J,N)-   PRES(  MASS0710
     3I,J,N)        ))*RHOW/DELY                                        MASS0720
C     Z-DIRECTION COMPONENTS                                            MASS0730
      SIGN=0.5                                                          MASS0740
      IF(COVERZ(I,J,N+1).EQ.0.0) SIGN=-0.5                              MASS0750
      VCZ=(-1.0*EFCOEF(COVERZ(I,J,N+1),COVERZ(I,J,N))*(PRES(I,J,N+1)-PREMASS0760
     1S(I,J,N))/DELZ-EFCOEF(COVERZ(I,J,N),COVERZ(I,J,N-1))*(PRES(I,J,N)-MASS0770
     2PRES(I,J,N-1))/DELZ+SIGN*COEFZ(I,J,N)*DELZ*(HEAD(I,J,N)-   PRES(  MASS0780
     3I,J,N)        ))*RHOW/DELZ                                        MASS0790
   32 IF(VCX.GE.0.) GO TO 34                                            MASS0800
C     FORWARD DIFFERENCE WHEN VCX IS NEGATIVE                           MASS0810
      B(I)=B(I)- VCX                                                    MASS0820
      XCONV = VCX*(F(I+1,J,K)-F(I,J,K))                                 MASS0830
      GO TO 36                                                          MASS0840
   34 XCONV = VCX*(F(I,J,K)- F(I-1,J,K))                                MASS0850
      C(I) = C(I) + VCX                                                 MASS0860
   36 IF(VCY.GE.0.) GO TO 38                                            MASS0870
      YCONV = VCY*(F(I,J+1,K)-F(I,J,K))                                 MASS0880
      GO TO 42                                                          MASS0890
   38 YCONV = VCY*(F(I,J,K) - F(I,J-1,K))                               MASS0900
   42 ZCONV = VCZ*(F(I,J,K)-F(I,J,K-1))                                 MASS0910
      IF(VCZ.GE.0.) GO TO 44                                            MASS0920
      ZCONV = VCZ*(F(I,J,K+1) - F(I,J,K))                               MASS0930
   44 A(I)=-B(I)-C(I)-(QDUMMY  *RHOW)/(DELX*DELY*DELZ)-QEXCHG(I,J,K)    MASS0940
     1/2.0-RHOPOR/DELT+EXPAN*SDUMMY  /DELT-H                            MASS0950
C     RIGHT HAND SIDES                                                  MASS0960
      RHSA=XCONV+ YCONV+ZCONV                                           MASS0970
     1      -(2.0/(DELX*DELX))*EFCOEF(DX(I,J,K),DX(I+1,J,K))*(          MASS0980
     2F(I+1,J,K)-F(I,J,K))+(2.0/(DELX*DELX))*EFCOEF(DX(I,J,K),DX(I-1,J,KMASS0990
     3))*(F(I,J,K)-F(I-1,J,K))-(2.0/(DELY*DELY))*EFCOEF(DY(I,J,K),DY(I,JMASS1000
     4+1,K))*(F(I,J+1,K)-F(I,J,K))+(2.0/(DELY*DELY))*EFCOEF(DY(I,J,K),DYMASS1010
     5(I,J-1,K))*(F(I,J,K)-F(I,J-1,K))                                  MASS1020
      CDUM = 0.0                                                        MASS1030
      IF(CINJ(I,J).GT.0.0) CDUM = CINJ(I,J)                             MASS1040
      RHSB=-(2.0/(DELZ*DELZ))*EFCOEF(DX(I,J,K),DZ(I,J,K+1))             MASS1050
     1    *(F(I,J,K+1)-F(I,J,K))+(2.0/(DELZ*DELZ))*EFCOEF(DZ(I          MASS1060
     2,J,K),DZ(I,J,K-1))*(F(I,J,K)-F(I,J,K-1))-QDUMMY  *RHOW*(CDUM-F    MASS1070
     3(I,J,K))/(DELX*DELY*DELZ)-QEXCHG(I,J,K)*(BCONC(I,J,K)-F(I,J,K))   MASS1080
```

```
     4-EXPAN*SDUMMY  *(F(I,J,K))/DELT
      D(I)=RHSA+RHSB
      SUMZET(I,J,K) = 0.
   40 CONTINUE
C     THE BOUNDARY CONDITIONS AT I=2 ARE HANDLED AS FOLLOWS--
C   1) SINCE DELTA(1)=0 FOR ALL J, K, AND TIME, NO CORRECTION
C      OF D(2) IS REQUIRED
C   2) THE BOUNDARY CONDITION IS ELIMINATED FROM THE LEFT-HAND
C      SIDE OF THE EQUATION BY SETTING C(2)=0
      C(2)=0.0
      L=NXL1
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      Z(1)=0.0
      Z(NX)=0.0
      DO 50 I=1,NX
   50 DELTA(I,J,K)=Z(I)
   60 CONTINUE
C     Y-DIRECTION SWEEPS
      DO 90 I=2,NXL1
      DO 90 K=2,NZL1
C     SET UP COEFFICIENT MATRIX
      DO 70 J=2,NYL1
      B(J)=(2.0/(DELY*DELY))*EFCOEF(DY(I,J,K),DY(I,J+1,K))
      C(J)=(2.0/(DELY*DELY))*EFCOEF(DY(I,J,K),DY(I,J-1,K))
      QDUMMY = 0.
      SDUMMY = 0.
      IF(K.LT.KFAQ.OR.K.GT.KLAQ) GO TO 66
      N=K-KFAQ+2
      IF(Q(I,J,N).GT.0.0) QDUMMY = Q(I,J,N)
      SDUMMY = SUMGAM(I,J,N)
      SIGN=0.5
      IF(COVERY(I,J+1,N).EQ.0.0) SIGN=-0.5
      VCY=(-1.0*EFCOEF(COVERY(I,J+1,N),COVERY(I,J,N))*(PRES(I,J+1,N)-PRE
     1S(I,J,N))/DELY-EFCOEF(COVERY(I,J,N),COVERY(I,J-1,N))*(PRES(I,J,N)-
     2PRES(I,J-1,N))/DELY+SIGN*COEFY(I,J,N)*DELY*(HEAD(I,J,N)-   PRES(
     3I,J,N)       ))*RHOW/DELY
      IF(VCY.GE.0.) GO TO 64
C     FIRST DERIVATIVE IS ZERO AT MAXIMUM OR MINIMUM
C     FORWARD DIFFERENCE WHEN VCY IS NEGATIVE
      B(J) = B(J) - VCY
      GO TO 66
   64 C(J) = C(J) + VCY
   66 A(J)=-B(J)-C(J)-(QDUMMY  *RHOW)/(DELX*DELY*DELZ)-QEXCHG(I,J,K)
     1/2.0-RHOPOR/DELT+EXPAN*SDUMMY  /DELT-H
C     RIGHT HAND SIDES
      D(J)=(-QEXCHG(I,J,K)/2.0-RHOPOR/DELT-(QDUMMY  *RHOW)/(DELX*
     1DELY*DELZ)+EXPAN*SDUMMY    /DELT-2.*H)*DELTA(I,J,K)
   70 CONTINUE
      C(2)=0.0
      L=NYL1
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
```

```
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      Z(1)=0.0
      Z(NY)=0.0
      DO 80 J=1,NY
   80 EPSILN(I,J,K)=Z(J)
   90 CONTINUE
C     Z-DIRECTION SWEEPS
      DO 120 J=2,NYL1
      DO 120 I=2,NXL1
C     SET UP COEFFICIENT MATRIX
      DO 100 K=2,NZL1
      B(K)=(2.0/(DELZ*DELZ))*EFCOEF(DZ(I,J,K),DZ(I,J,K+1))
      C(K)=(2.0/(DELZ*DELZ))*EFCOEF(DZ(I,J,K),DZ(I,J,K-1))
      QDUMMY = 0.
      SDUMMY = 0.
      IF(K.LT.KFAQ.OR.K.GT.KLAQ) GO TO 96
      N=K-KFAQ+2
      IF(Q(I,J,N).GT.0.0) QDUMMY = Q(I,J,N)
      SDUMMY = SUMGAM(I,J,N)
      SIGN=0.5
      IF(COVERZ(I,J,N+1).EQ.0.0) SIGN=-0.5
      VCZ=(-1.0*EFCOEF(COVERZ(I,J,N+1),COVERZ(I,J,N))*(PRES(I,J,N+1)-PRE
     1S(I,J,N))/DELZ-EFCOEF(COVERZ(I,J,N),COVERZ(I,J,N-1))*(PRES(I,J,N)-
     2PRES(I,J,N-1))/DELZ+SIGN*COEFZ(I,J,N)*DELZ*(HEAD(I,J,N)-    PRES(
     3I,J,N)        ))*RHOW/DELZ
      IF(VCZ.GE.0.) GO TO 94
      B(K) = B(K) - VCZ
      GO TO 96
   94 C(K) = C(K) + VCZ
   96 A(K)=-B(K)-C(K)-(QDUMMY  *RHOW)/(DELX*DELY*DELZ)-QEXCHG(I,J,K)
     1/2.0-RHOPOR/DELT+EXPAN*SDUMMY  /DELT-H
C     RIGHT HAND SIDES
      D(K)=(-QEXCHG(I,J,K)/2.0-RHOPOR/DELT-(QDUMMY  *RHOW)/(DELX*
     1DELY*DELZ)+EXPAN*SDUMMY    /DELT  )*EPSILN(I,J,K)
     2-H*(2.*EPSILN(I,J,K)-DELTA(I,J,K))
  100 CONTINUE
      C(2)=0.0
      L=NZL1
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      Z(1)=0.0
      Z(NZ)=0.0
      DO 110 K=1,NZ
      ZETA(I,J,K)=Z(K)
      ENEW=ABS(Z(K))
      IF(ENEW.GT.EOLD)EOLD=ENEW
      SUMZET(I,J,K)=SUMZET(I,J,K)+Z(K)
  110 CONTINUE
  120 CONTINUE
      NIT=NIT+1
      IF(EOLD.LT.ETIM)GO TO 300
C     ITERATIONS 2 TO M BEGIN HERE
      IFIRST = 2
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      ILAST = NXL1
      JFIRST = 2
      JLAST = NYL1
      KFIRST =2
      KLAST = NZL1
  130 CONTINUE
C       SHRINK APPLIED TO I,J INDICES ONLY
C     FIND MAXIMUM VALUE OF I
      DO 500 I=IFIRST , ILAST
      II = ILAST + IFIRST-I
      DO 500 J=JFIRST,JLAST
      DO 500 K=KFIRST,KLAST
  500 CONTINUE
      IF(ABS(ZETA(II,J,K)).GT.CTIM) GO TO 510
  510 ILAST = II
C     FIND MINIMUM VALUE OF I
      DO 520 I=IFIRST,ILAST
      DO 520 J=JFIRST,JLAST
      DO 520 K=KFIRST,KLAST
      IF(ABS(ZETA(I,J,K)).GT.CTIM) GO TO 530
  520 CONTINUE
  530 IFIRST = I
C       FIND MAXIMUM VALUE OF J
      DO 540 J=JFIRST,JLAST
      JJ=JLAST+JFIRST-J
      DO 540 I=IFIRST,ILAST
      DO 540 K=KFIRST,KLAST
      IF(ABS(ZETA(I,JJ,K)).GT.CTIM) GO TO 550
  540 CONTINUE
  550 JLAST = JJ
C     FIND MINIMUM VALUE OF J
      DO 560 J=JFIRST,JLAST
      DO 560 I=IFIRST,ILAST
      DO 560 K=KFIRST,KLAST
      IF(ABS(ZETA(I,J,K)).GT.CTIM) GO TO 570
  560 CONTINUE
  570 JFIRST = J
C     WRITE(6,700) NIT,ITCY,IFIRST,ILAST,JFIRST,JLAST,KFIRST,KLAST
C 700 FORMAT(' CONC**NIT = ',I4,' ITCY = ',I4,' IFIRST = ',I4,' ILAST =
C    1',I4,' JFIRST = ',I4,' JLAST = ',I4,' KFIRST = ',I4,' KLAST = ',
C    2I4)
C     CALCULATE ITERATION PARAMETER
      NITCY=NIT+1-ITCY*MXITCY
      H1=HMAX*((HMIN/HMAX)**((FLOAT(NITCY-1))/(FLOAT(MXITCY-2))))
      H1=H1/(DELX*DELY*DELZ)*1.E-05
      IF(NITCY.NE.MXITCY)GO TO 140
      ITCY=ITCY+1
      H1=0.0
  140 CONTINUE
      EOLD=0.0
C     X-DIRECTION SWEEPS
      DO 170 K=KFIRST,KLAST
      DO 170 J=JFIRST,JLAST
C     SET UP COEFFICIENT MATRIX
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      DO 150 I=IFIRST,ILAST
      XCONV = 0.
      B(I)=(2.0/(DELX*DELX))*EFCOEF(DX(I,J,K),DX(I+1,J,K))
      C(I)=(2.0/(DELX*DELX))*EFCOEF(DX(I,J,K),DX(I-1,J,K))
      QDUMMY = 0.
      SDUMMY = 0.
      IF(K.LT.KFAQ.OR.K.GT.KLAQ) GO TO 146
      N=K-KFAQ+2
      IF(Q(I,J,N).GT.0.0) QDUMMY = Q(I,J,N)
      SDUMMY = SUMGAM(I,J,N)
      SIGN=0.5
      IF(COVERX(I+1,J,N).EQ.0.0) SIGN=-0.5
      VCX=(-1.0*EFCOEF(COVERX(I+1,J,N),COVERX(I,J,N))*(PRES(I+1,J,N)-PRE
     1S(I,J,N))/DELX-EFCOEF(COVERX(I,J,N),COVERX(I-1,J,N))*(PRES(I,J,N)-
     2PRES(I-1,J,N))/DELX+SIGN*COEFX(I,J,N)*DELX*(HEAD(I,J,N)-   PRES(
     3I,J,N)       ))*RHOW/DELX
      IF(VCX.GE.0.) GO TO 144
      B(I) = B(I) - VCX
      XCONV= VCX*((ZETA(I+1,J,K)-ZETA(I   ,J,K))-(DELTA(I+1,J,K)-DELTA(I,
     1J,K)))
      GO TO 146
  144 C(I) = C(I) + VCX
      XCONV =VCX*((ZETA(I,J,K)-ZETA(I-1,J,K))-(DELTA(I,J,K)-DELTA(I-1,J
     1,K)))
  146 A(I)=-B(I)-C(I)-(QDUMMY  *RHOW)/(DELX*DELY*DELZ)-QEXCHG(I,J,K)
     1/2.0-RHOPOR/DELT+EXPAN*SDUMMY  /DELT-H1
C     RIGHT HAND SIDES
      D(I) = XCONV
     1  -(2.0/(DELX*DELX))*EFCOEF(DX(I,J,K),DX(I+1,J,K))*(ZETA(I+1,J,K
     2)-ZETA(I,J,K))+(2.0/(DELX*DELX))*EFCOEF(DX(I+1,J,K),DX(I,J,K))*(DE
     3LTA(I+1,J,K)-DELTA(I,J,K))+(2.0/(DELX*DELX))*EFCOEF(DX(I,J,K),DX(I
     4-1,J,K))*(ZETA(I,J,K)-ZETA(I-1,J,K))-(2.0/(DELX*DELX))*EFCOEF(DX(I
     5,J,K),DX(I-1,J,K))*(DELTA(I,J,K)-DELTA(I-1,J,K))
     6-H*(ZETA(I,J,K)-EPSILN(I,J,K))
  150 CONTINUE
      C(2)=0.0
      I1=IFIRST
      L=ILAST
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      Z(1)=0.0
      Z(NX)=0.0
      DO 160 I=1,NX
      IF(I.LT.IFIRST.OR.I.GT.ILAST) Z(I)=0.
  160 DELTA(I,J,K)=Z(I)
  170 CONTINUE
C     Y-DIRECTION SWEEPS
      DO 200 I=IFIRST,ILAST
      DO 200 K=KFIRST,KLAST
C     SET UP COEFFICIENT MATRIX
      DO 180 J=JFIRST,JLAST
      B(J)=(2.0/(DELY*DELY))*EFCOEF(DY(I,J,K),DY(I,J+1,K))
      C(J)=(2.0/(DELY*DELY))*EFCOEF(DY(I,J,K),DY(I,J-1,K))
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      QDUMMY = 0.
      SDUMMY = 0.
      IF(K.LT.KFAQ.OR.K.GT.KLAQ) GO TO 176
      N=K-KFAQ+2
      IF(Q(I,J,N).GT.0.0) QDUMMY = Q(I,J,N)
      IF ( QDUMMY.LT.0.) QDUMMY=0.
      SDUMMY = SUMGAM(I,J,N)
      SIGN=0.5
      IF(COVERY(I,J+1,N).EQ.0.0) SIGN=-0.5
      VCY=(-1.0*EFCOEF(COVERY(I,J+1,N),COVERY(I,J,N))*(PRES(I,J+1,N)-PRE
     1S(I,J,N))/DELY-EFCOEF(COVERY(I,J,N),COVERY(I,J-1,N))*(PRES(I,J,N)-
     2PRES(I,J-1,N))/DELY+SIGN*COEFY(I,J,N)*DELY*(HEAD(I,J,N)-   PRES(
     3I,J,N)       ))*RHOW/DELY
      IF(VCY.GE.0.) GO TO 174
      B(J) = B(J) - VCY
      GO TO 176
  174 C(J) = C(J) + VCY
  176 A(J)=-B(J)-C(J)-(QDUMMY  *RHOW)/(DELX*DELY*DELZ)-QEXCHG(I,J,K)
     1/2.0-RHOPOR/DELT+EXPAN*SDUMMY  /DELT-H1
C     RIGHT HAND SIDES
      D(J)=-C(J)*(ZETA(I,J-1,K)-EPSILN(I,J-1,K))+(B(J)+C(J))*(ZETA(I,J,K
     1)-EPSILN(I,J,K))-B(J)*(ZETA(I,J+1,K)-EPSILN(I,J+1,K))
     2-(QEXCHG(I,J,K)/2.0+RHOPOR/DELT+(QDUMMY  *RHOW)/(DELX*DELY*
     3DELZ)-EXPAN*SDUMMY       /DELT+2.*H1)*DELTA(I,J,K)
  180 CONTINUE
      C(2)=0.0
      I1=JFIRST
      L=JLAST
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      Z(1)=0.0
      Z(NY)=0.0
      DO 190 J=1,NY
      IF(J.LT.JFIRST.OR.J.GT.JLAST) Z(J) =0.
  190 EPSILN(I,J,K)=Z(J)
  200 CONTINUE
C     Z-DIRECTION SWEEPS
      DO 230 J=JFIRST,JLAST
      DO 230 I=IFIRST,ILAST
C     SET UP COEFFICIENT MATRIX
      DO 210 K=KFIRST,KLAST
      B(K)=(2.0/(DELZ*DELZ))*EFCOEF(DZ(I,J,K),DZ(I,J,K+1))
      C(K)=(2.0/(DELZ*DELZ))*EFCOEF(DZ(I,J,K),DZ(I,J,K-1))
      QDUMMY = 0.
      SDUMMY = 0.
      IF(K.LT.KFAQ.OR.K.GT.KLAQ) GO TO 206
      N=K-KFAQ+2
      IF(Q(I,J,N).GT.0.0) QDUMMY = Q(I,J,N)
      SDUMMY = SUMGAM(I,J,N)
      SIGN=0.5
      IF(COVERZ(I,J,N+1).EQ.0.0) SIGN=-0.5
      VCZ=(-1.0*EFCOEF(COVERZ(I,J,N+1),COVERZ(I,J,N))*(PRES(I,J,N+1)-PRE
     1S(I,J,N))/DELZ-EFCOEF(COVERZ(I,J,N),COVERZ(I,J,N-1))*(PRES(I,J,N)-
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     2PRES(I,J,N-1))/DELZ+SIGN*COEFZ(I,J,N)*DELZ*(HEAD(I,J,N)-   PRES(
     3I,J,N)        ))*RHOW/DELZ
      IF(VCZ.GE.0.) GO TO 204
      B(K) = B(K) -VCZ
      GO TO 206
  204 C(K) = C(K) + VCZ
  206 A(K)=-B(K)-C(K)-(QDUMMY   *RHOW)/(DELX*DELY*DELZ)-QEXCHG(I,J,K)
     1/2.0-RHOPOR/DELT+EXPAN*SDUMMY  /DELT-H1
C     RIGHT HAND SIDES
      D(K)=(-QEXCHG(I,J,K)/2.0-RHOPOR/DELT-(QDUMMY  *RHOW)/(DELX*
     1DELY*DELZ)+EXPAN*SDUMMY     /DELT    )*EPSILN(I,J,K)
     2-H1*(2.*EPSILN(I,J,K)-DELTA(I,J,K))
  210 CONTINUE
      C(2)=0.0
      I1=KFIRST
      L=KLAST
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      Z(1)=0.0
      Z(NZ)=0.0
      DO 220 K=1,NZ
      IF(K.LT.KFIRST.OR.K.GT.KLAST)Z(K)=0.
      ZETA(I,J,K)=Z(K)
      ENEW=ABS(Z(K))
      IF(ENEW.GT.EOLD)EOLD=ENEW
      SUMZET(I,J,K)=SUMZET(I,J,K)+Z(K)
  220 CONTINUE
  230 CONTINUE
      H=H1
      NIT=NIT+1
      IF(EOLD.GT.ETIM.AND.NIT.LT.MXITTS)GO TO 130
C     ITERATION STOPS WHEN CONVERGENCE CRITERION IS SATISFIED OR THE
C     MAXIMUM ALLOWABLE NUMBER OF ITERATIONS PER TIME STEP IS REACHED
  300 CONTINUE
C     CALCULATE NEW CONCENTRATION DISTRIBUTION
      DO 310 K=2,NZL1
      DO 310 J=2,NYL1
      DO 310 I=2,NXL1
      F(I,J,K)=F(I,J,K)+SUMZET(I,J,K)
  310 CONTINUE
      RETURN
      END
```

```
C     SUBROUTINE MOTION
C     THIS SUBROUTINE SOLVES THE EQUATION OF MOTION
      SUBROUTINE MOTION (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      COMMON/START/I1
      COMMON/TS/IT
      COMMON/LIMIT/CLIM,CTIM,ETIM
      REAL MASSIN,MASOUT,DX,DY,DZ
C     CALCULATIONS FOR TIME STEP M+1 BEGIN HERE
      SUMR=0.0
      ITCY=0.0
C     FIRST ITERATION BEGINS
C     FLUID FLOW CALCULATIONS ARE RESTRICTED TO THE REGION 2 TO NZA - 1
      KFIRST=2
      KLAST=NZA-1
      EOLD=0.0
C     CALCULATE ITERATION PARAMETER FOR FIRST CYCLE
      NIT=0
      NITCY=NIT+1-ITCY*MXITCY
      HA = 0.
      H= HA * 1.E-10
  140 CONTINUE
C     X-DIRECTION SWEEPS
      I1=2
      DO 200 K=KFIRST,KLAST
      DO 200 J=2,NYL1
C     SET UP COEFFICIENT MATRIX
      DO 180 I=2,NXL1
      BX=(1.0/(DELX*DELX))*EFCOEF(COVERX(I,J,K),COVERX(I+1,J,K))
      CX=(1.0/(DELX*DELX))*EFCOEF(COVERX(I,J,K),COVERX(I-1,J,K))
      AX=-BX-CX
      CY=(1.0/(DELY*DELY))*EFCOEF(COVERY(I,J,K),COVERY(I,J-1,K))
      BY=(1.0/(DELY*DELY))*EFCOEF(COVERY(I,J,K),COVERY(I,J+1,K))
      AY=-BY-CY
      BZ=(1.0/(DELZ*DELZ))*EFCOEF(COVERZ(I,J,K),COVERZ(I,J,K+1))
      CZ=(1.0/(DELZ*DELZ))*EFCOEF(COVERZ(I,J,K),COVERZ(I,J,K-1))
      AZ=-BZ-CZ
      A(I)=AX-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))
     1  +H)
```

```
      B(I)=BX                                                           MOTN0550
      C(I)=CX                                                           MOTN0560
C     RIGHT HAND SIDES                                                  MOTN0570
      D(I)=-2.0*(CX*(PRES(I-1,J,K)- PRES(I,J,K))+BX*(PRES(I+1,J,K) -    MOTN0580
     1PRES(I,J,K))+CY*(PRES(I,J-1,K)- PRES(I,J,K))+BY*(PRES(I,J+1,K)-   MOTN0590
     2PRES(I,J,K)) +CZ*(PRES(I,J,K-1)- PRES(I,J,K))+BZ*(PRES(I,J,K+1)-  MOTN0600
     3PRES(I,J,K)))-Q(I,J,K)/(DELX*DELY*DELZ)-(COEFX(I,J,K)+ COEFY(I,J,KMOTN0610
     4)+ COEFZ(I,J,K))*(HEAD(I,J,K)- PRES(I,J,K))                       MOTN0620
      SUMGAM(I,J,K)=0.0                                                 MOTN0630
  180 CONTINUE                                                          MOTN0640
      L=NXL1                                                            MOTN0650
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       MOTN0660
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXMOTN0670
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)MOTN0680
      DO 185 I=2,NXL1                                                   MOTN0690
  185 ALPHA(I,J,K)=Z(I)                                                 MOTN0700
  200 CONTINUE                                                          MOTN0710
C     Y-DIRECTION SWEEPS                                                MOTN0720
      DO 250 I=2,NXL1                                                   MOTN0730
      DO 250 K=KFIRST,KLAST                                             MOTN0740
C     SET UP COEFFICIENT MATRIX                                         MOTN0750
      DO 210 J=2,NYL1                                                   MOTN0760
      BY=(1.0/(DELY*DELY))*EFCOEF(COVERY(I,J,K),COVERY(I,J+1,K))        MOTN0770
      CY=(1.0/(DELY*DELY))*EFCOEF(COVERY(I,J,K),COVERY(I,J-1,K))        MOTN0780
      AY=-BY-CY                                                         MOTN0790
      A(J)=AY-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))  MOTN0800
     1  +H)                                                             MOTN0810
      B(J)=BY                                                           MOTN0820
      C(J)=CY                                                           MOTN0830
C     RIGHT HAND SIDES                                                  MOTN0840
      D(J)=-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))    MOTN0850
     1+2.*H)*ALPHA(I,J,K)                                               MOTN0860
  210 CONTINUE                                                          MOTN0870
      L=NYL1                                                            MOTN0880
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       MOTN0890
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXMOTN0900
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)MOTN0910
      DO 220 J=2,NYL1                                                   MOTN0920
  220 BETA(I,J,K)=Z(J)                                                  MOTN0930
  250 CONTINUE                                                          MOTN0940
C     BY PASS Z SWEEP IF GROUND WATER FLOW IS TWO DIMENSIONAL           MOTN0950
C     IN THE HORIZONTAL PLANE                                           MOTN0960
      IF(KLAST.GT.2)  GO TO 259                                         MOTN0970
      DO 252  K=KFIRST,KLAST                                            MOTN0980
      DO 252  J=2,NYL1                                                  MOTN0990
      DO 252  I=2,NXL1                                                  MOTN1000
  252 GAMMA(I,J,K)  = BETA(I,J,K)                                       MOTN1010
      GO TO 301                                                         MOTN1020
C     Z-DIRECTION SWEEP                                                 MOTN1030
  259 DO 300 J=2,NYL1                                                   MOTN1040
      DO 300 I=2,NXL1                                                   MOTN1050
C     SET UP COEFFICIENT MATRIX                                         MOTN1060
      DO 260 K=KFIRST,KLAST                                             MOTN1070
      BX=(1.0/(DELX*DELX))*EFCOEF(COVERX(I,J,K),COVERX(I+1,J,K))        MOTN1080
```

```
      CX=(1.0/(DELX*DELX))*EFCOEF(COVERX(I,J,K),COVERX(I-1,J,K))
      BY=(1.0/(DELY*DELY))*EFCOEF(COVERY(I,J,K),COVERY(I,J+1,K))
      CY=(1.0/(DELY*DELY))*EFCOEF(COVERY(I,J,K),COVERY(I,J-1,K))
      BZ=(1.0/(DELZ*DELZ))*EFCOEF(COVERZ(I,J,K),COVERZ(I,J,K+1))
      CZ=(1.0/(DELZ*DELZ))*EFCOEF(COVERZ(I,J,K),COVERZ(I,J,K-1))
      AZ=-BZ-CZ
      A(K)=AZ-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))
     1  +H)
      B(K)=BZ
      C(K)=CZ
C     RIGHT HAND SIDES
      D(K)=-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))
     1)*BETA(I,J,K)-H*(2.*BETA(I,J,K)-ALPHA(I,J,K))
  260 CONTINUE
      I1 = KFIRST
      L = KLAST
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      DO 270 K=KFIRST,KLAST
  270 GAMMA(I,J,K)=Z(K)
  300 CONTINUE
  301 DO  302  K=KFIRST,KLAST
      DO  302  J=2,NYL1
      DO  302  I=2,NXL1
  302 SUMGAM(I,J,K)=SUMGAM(I,J,K)+GAMMA(I,J,K)
C     ITERATIONS 2 TO M BEGIN HERE
      IFIRST = 2
      ILAST = NXL1
      JFIRST = 2
      JLAST = NYL1
  310 CONTINUE
C      SHRINK APPLIED TO I,J INDICES ONLY
C     FIND MAXIMUM VALUE OF I
      DO 600 I=IFIRST , ILAST
      II = ILAST + IFIRST-I
      DO 600 J=JFIRST,JLAST
      DO 600 K=KFIRST,KLAST
      IF(ABS(GAMMA(II,J,K)).GT.CLIM) GO TO 610
  600 CONTINUE
  610 ILAST = II
C     FIND MINIMUM VALUE OF I
      DO 620 I=IFIRST,ILAST
      DO 620 J=JFIRST,JLAST
      DO 620 K=KFIRST,KLAST
      IF(ABS(GAMMA(I,J,K)).GT.CLIM) GO TO 630
  620 CONTINUE
  630 IFIRST = I
C      FIND MAXIMUM VALUE OF J
      DO 640 J=JFIRST,JLAST
      JJ=JLAST+JFIRST-J
      DO 640 I=IFIRST,ILAST
      DO 640 K=KFIRST,KLAST
      IF(ABS(GAMMA(I,JJ,K)).GT.CLIM) GO TO 650
```

```
  640 CONTINUE
  650 JLAST = JJ
C     FIND MINIMUM VALUE OF J
      DO 660 J=JFIRST,JLAST
      DO 660 I=IFIRST,ILAST
      DO 660  K=KFIRST,KLAST
      IF(ABS(GAMMA(I,J,K)).GT.CLIM) GO TO 670
  660 CONTINUE
  670 JFIRST = J
      NIT=NIT+1
      WRITE(6,700) NIT,ITCY,IFIRST,ILAST,JFIRST,JLAST,KFIRST,KLAST
  700 FORMAT(' FLOW**NIT = ',I4,' ITCY = ',I4,' IFIRST = ',I4,' ILAST =
     1',I4,' JFIRST = ',I4,' JLAST = ',I4,' KFIRST = ',I4,' KLAST = ',
     2I4)
C     CALCULATE ITERATION PARAMETER
      NITCY = MXITCY - (NIT + 1 - ITCY * MXITCY)
      HB=HMAX*((HMIN/HMAX)**((FLOAT(NITCY-1))/(FLOAT(MXITCY-2))))
      IF(NITCY.EQ.MXITCY)  HB=0.
      IF(NITCY.EQ.1)  ITCY = ITCY + 1
  311 CONTINUE
      H1 = HB * 1.E-10
      EOLD=0.0
C     X-DIRECTION SWEEPS
      DO 350 K=KFIRST,KLAST
      DO 350 J=JFIRST,JLAST
C     SET UP COEFFICIENT MATRIX
      DO 325 I=IFIRST,ILAST
      GDUMMY = GAMMA(I,J,K) - BETA(I,J,K)
      IF(KLAST.EQ.2)  GDUMMY = BETA(I,J,K) - ALPHA(I,J,K)
      BX=(1.0/(DELX*DELX))*EFCOEF(COVERX(I,J,K),COVERX(I+1,J,K))
      CX=(1.0/(DELX*DELX))*EFCOEF(COVERX(I,J,K),COVERX(I-1,J,K))
      AX=-BX-CX
      A(I)=AX-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))
     1  +H1)
      B(I)=BX
      C(I)=CX
C     RIGHT HAND SIDES
      D(I)=-(CX*(GAMMA(I-1,J,K)-ALPHA(I-1,J,K))+AX*(GAMMA(I,J,K)
     1-ALPHA(I,J,K))+BX*(GAMMA(I+1,J,K)-ALPHA(I+1,J,K)))
     2-H*(GDUMMY)
  325 CONTINUE
      I1=IFIRST
      L=ILAST
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      DO 330  I=IFIRST,ILAST
  330 ALPHA(I,J,K)=Z(I)
  350 CONTINUE
C     Y-DIRECTION SWEEPS
  370 EOLD = 0.
      DO  400  I=IFIRST,ILAST
      DO 400 K=KFIRST,KLAST
C     SET UP COEFFICIENT MATRIX
```

```
      DO 380 J=JFIRST,JLAST
      BY=(1.0/(DELY*DELY))*EFCOEF(COVERY(I,J,K),COVERY(I,J+1,K))
      CY=(1.0/(DELY*DELY))*EFCOEF(COVERY(I,J,K),COVERY(I,J-1,K))
      AY=-BY-CY
      A(J)=AY-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))
     1  +H1)
      B(J)=BY
      C(J)=CY
C     RIGHT HAND SIDES
      D(J)=-(CY*(GAMMA(I,J-1,K)-BETA(I,J-1,K))+AY*(GAMMA(I,J,K)
     1-BETA(I,J,K))+BY*(GAMMA(I,J+1,K)-BETA(I,J+1,K)))
     2-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))        )
     3*ALPHA(I,J,K)+H1*(    -2.*ALPHA(I,J,K))
  380 CONTINUE
      I1=JFIRST
      L=JLAST
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      DO 390  J=JFIRST,JLAST
C     CHECK FOR CONVERGENCE OF ITERATIVE PROCESS
      ENEW = ABS(Z(J))
      IF(ENEW.GT.EOLD)EOLD = ENEW
      IF(KLAST.EQ.2) GAMMA(I,J,K) = Z(J)
  390 BETA(I,J,K)=Z(J)
  400 CONTINUE
      IF(KLAST.GT.2)  GO TO 410
      IF(EOLD.GT.ELIM) GO TO 410
  402 DO  405  K=KFIRST,KLAST
      DO  405  I=IFIRST,ILAST
      DO  405  J=JFIRST,JLAST
  405 SUMGAM(I,J,K) = SUMGAM(I,J,K) + BETA(I,J,K)
      IF(EOLD.LE.ELIM)GO TO 500
      GO TO 460
  410 IF(KLAST.EQ.2)  GO TO 402
      EOLD = 0.
C     ZSWEEP BY PASSED IF PROBLEM IS TWO DIMENSIONAL
C     IN THE X-Y PLANE
C     Z-DIRECTION SWEEPS
      DO 450 J=JFIRST,JLAST
      DO 450 I=IFIRST,ILAST
C     SET UP COEFFICIENT MATRIX
      DO 420 K=KFIRST,KLAST
      BZ=(1.0/(DELZ*DELZ))*(EFCOEF(COVERZ(I,J,K),COVERZ(I,J,K+1)))
      CZ=(1.0/(DELZ*DELZ))*(EFCOEF(COVERZ(I,J,K),COVERZ(I,J,K-1)))
      AZ=-BZ-CZ
      A(K)=AZ-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))
     1  +H1)
      B(K)=BZ
      C(K)=CZ
C     RIGHT HAND SIDES
      D(K)=-(SS(I,J,K)/DELT+(COEFX(I,J,K)+COEFY(I,J,K)+COEFZ(I,J,K))
     1 )*BETA(I,J,K) -H1*(2.*BETA(I,J,K)-ALPHA(I,J,K))
  420 CONTINUE
```

```
      I1=KFIRST                                                         MOTN2710
      L=KLAST                                                           MOTN2720
      CALL THOMAS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       MOTN2730
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXMOTN2740
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)MOTN2750
      DO 430 K=KFIRST,KLAST                                             MOTN2760
      GAMMA(I,J,K)=Z(K)                                                 MOTN2770
      ENEW=ABS(Z(K))                                                    MOTN2780
      IF(ENEW.GT.EOLD) EOLD = ENEW                                      MOTN2790
      SUMGAM(I,J,K)=SUMGAM(I,J,K)+Z(K)                                  MOTN2800
  430 CONTINUE                                                          MOTN2810
  450 CONTINUE                                                          MOTN2820
  460 CONTINUE                                                          MOTN2830
      WRITE(6,550) NIT,H,H1                                             MOTN2840
  550 FORMAT('  NIT = ',I3,' H= ',E15.7,'H1 = ',E15.7)                  MOTN2850
      H = H1                                                            MOTN2860
      IF(EOLD.GT.ELIM.AND.NIT.LT.MXITTS)GO TO 310                       MOTN2870
C     ITERATION STOPS WHEN CONVERGENCE CRITERION IS SATISFIED OR THE    MOTN2880
C     MAXIMUM ALLOWABLE NUMBER OF ITERATIONS PER TIME STEP IS REACHED   MOTN2890
      IF(EOLD.LE.ELIM) GO TO 500                                        MOTN2900
      WRITE(6,509)  MXITTS,EOLD                                         MOTN2910
  509 FORMAT(' PROGRAM FAILED TO CONVERGE IN MOTION AFTER ',I5,' ITREATIMOTN2920
     1NS      EOLD  =  ',E15.8,' PROGRAM TERMINATED')                   MOTN2930
      STOP                                                              MOTN2940
  500 CONTINUE                                                          MOTN2950
      RETURN                                                            MOTN2960
      END                                                               MOTN2970
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C      SUBROUTINE PREP                                                  PREP0010
C      DATA REQUIRED BY THE MODEL ARE READ IN AND PRINTED OUT           PREP0020
C      COEFFICIENT MATRICES ARE ALSO SET UP IN THESE SUBROUTINE WHICH AREPREP0030
C      LATER USED IN THE TOTAL AND COMPONENT MASS BALANCE SOLUTIONS     PREP0040
       SUBROUTINE PREP(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,  PREP0050
      1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP0060
      2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP0070
C      THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME       PREP0080
       DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,PREP0090
      1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYPREP0100
      2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA), PREP0110
      3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),PREP0120
      4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZAPREP0130
      5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZAPREP0140
      6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                         PREP0150
C      ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME               PREP0160
       DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),PREP0170
      1Z(NMAX)                                                          PREP0180
       DIMENSION DFMT(20)                                               PREP0190
       DIMENSION TOUT(20)                                               PREP0200
       COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,     PREP0210
      1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,PREP0220
      2RHOW,TOTAL,VISCOS                                                PREP0230
       COMMON/AQLIM/KFAQ,KLAQ,NAQ                                       PREP0240
       COMMON/OUT/KEY,TOINJ,TOOUT,TOQINJ,TOQEX,TOQACC                   PREP0250
       COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND                   PREP0260
       COMMON/TS/IT                                                     PREP0270
       COMMON/CLOCK/ILAPSE,TNEXT,TNOW                                   PREP0280
       COMMON/LIMIT/CLIM,CTIM,ETIM                                      PREP0290
       COMMON/VARZ/ZK(30)                                               PREP0300
       COMMON/AQUIFR/ISO,SOLUTE                                         PREP0310
       COMMON/WELLS/LOCX(50),LOCY(50),NWELLS                            PREP0320
       INTEGER SOLUTE                                                   PREP0330
       REAL MASSIN,MASOUT,DX,DY,DZ                                      PREP0340
       INTEGER CFILE                                                    PREP0350
       VISW(TP)=0.0672/(1.19344*(TP-47.183+SQRT(26174.02+(TP-47.183)**2))PREP0360
      1 - 120.)                                                         PREP0370
       REWIND 01                                                        PREP0380
       KOUT = 1                                                         PREP0390
       KT = 0                                                           PREP0400
       NFIT = 0                                                         PREP0410
C      SPECIFY THE SPATIAL AND TIME INCREMENTS                          PREP0420
       READ(5,1)DELX,DELY,DELZ,DELT,TMAX,TINC,DELTMX                    PREP0430
     1 FORMAT(7F10.0)                                                   PREP0440
C      SPECIFY THE FLUID PROPERTIES OF THE SYSTEM AND THE INITIAL       PREP0450
C      TEMPERATURE                                                      PREP0460
       READ(5,3) RHOW, TREF,NAQ,KFAQ,KLAQ                               PREP0470
     3 FORMAT(2F10.0,3I10)                                              PREP0480
       WRITE(6,770)  NAQ,KFAQ,KLAQ                                      PREP0490
       KCK = KLAQ + 1                                                   PREP0500
       KCK = KLAQ + 1                                                   PREP0510
       IF(KCK.GT.NZ) STOP                                               PREP0520
       IF(KFAQ.GT.KLAQ) STOP                                            PREP0530
       VISCOS = VISW(TREF)                                              PREP0540
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C     THE PHYSICAL PROPERTIES OF THE POROUS MEDIA ARE SPECIFIED.          PREP0550
      READ(5,4)RHOR,CPR,PORO,COMP                                         PREP0560
    4 FORMAT(4F10.0)                                                      PREP0570
      WRITE(6,7)DELX,DELY,DELZ,DELT,TINC,DELTMX,TMAX,RHOW,                PREP0580
     1VISCOS,TREF                                                         PREP0590
    7 FORMAT(3X,23HSPATIAL INCREMENTS, FT.,/8X,7HDELX = ,F10.2,/8X,7HDELPREP0600
     1Y = ,F10.2,/8X,7HDELZ = ,F10.2,/3X,28HINITIAL TIME INCREMENT, SEC.PREP0610
     2,/,8X,7HDELT = ,F10.2,5X,7HTINC = ,F10.4,5X,                        PREP0620
     39HDELTMX =  ,G12.2,5X,                                              PREP0630
     47HTMAX = ,F10.6,4H DY.,                                             PREP0640
     5//3X,16HFLUID PROPERTIES,/,8X,'DENSITY, LB/CU.FT.        = ',       PREP0650
     6G12.4,                                          /,8X,'INITIAL VISPREP0660
     7COSITY,LB/FTSEC= ',G12.4,//,3X,'REFERENCE TEMPERATURE, F',          PREP0670
     87X,'= ',G12.4)                                                      PREP0680
      WRITE(6,8) RHOR,CPR,PORO,COMP                                       PREP0690
    8 FORMAT(//,3X,23HPOROUS MEDIA PROPERTIES,/,8X,'DENSITY, LB/CU.FT.  PREP0700
     1      = ',G12.4,/,8X,28HDISTRIBUTION COEF. LB/LB  = ,G12.4,/,8X,8 PREP0710
     2HPOROSITY,17X,3H = ,G12.4,/,8X,'COMPRESSIBILITY, 1/PSI',3X,3H = , PREP0720
     3G12.4)                                                              PREP0730
      TMAX=TMAX*24.*3600.0                                                PREP0740
      EXPAN=       RHOR*CPR *RHOW*   COMP*(1.0-PORO)/144.                 PREP0750
      RHOPOR=RHOR*CPR*(1.0-PORO)+RHOW*PORO                                PREP0760
      READ(5,6)  CFILE,NFILE,NTAPE,RSTRT,TPRO,SAVE                        PREP0770
    6 FORMAT(3I10,3F10.0)                                                 PREP0780
C     DATA FOR RESUMPTION OF COMPUTATIONS ARE READ FROM MAGNETIC TAPE     PREP0790
      ICFILE=CFILE+16                                                     PREP0800
      IF(SOLUTE.LE.0) ICFILE = CFILE + 10                                 PREP0810
      WRITE(6,730) NFILE,RSTRT                                            PREP0820
      WRITE(6,732) TPRO                                                   PREP0830
      IF(RSTRT.GT.0.) WRITE(6,734)  CFILE,ICFILE,NTAPE                    PREP0840
      CINIT = 60.                                                         PREP0850
      NZL1 = NZ - 1                                                       PREP0860
      NXL1 = NX - 1                                                       PREP0870
      NYL1 = NY - 1                                                       PREP0880
      IF(RSTRT.GT.0.)                                                     PREP0890
     1CALL RSTART(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,         PREP0900
     2COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP0910
     3,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP0920
C     COMPUTATION ARE DONE IN SINGLE PRECISION                            PREP0930
      DELT1 = DELT                                                        PREP0940
  119 CONTINUE                                                            PREP0950
C     NOTE--ALL NO FLOW BOUNDARIES ARE ASSIGNED ZERO PERMEABILITY         PREP0960
C     IF THE AQUIFER IS ANISOTROPIC THE PERMEABILITIES AND MASS           PREP0970
C     DIFFUSION COEFFICIENTS FOR EACH COORDINATE DIRECTION MUST           PREP0980
C     BE ENTERED.                                                         PREP0990
C     AFMT IS THE INPUT FORMAT FOR THE MASS DISPERSION AND                PREP1000
C     PERMEABILITY DATA                                                   PREP1010
      READ(5,5) (AFMT(I),I=1,20)                                          PREP1020
    5 FORMAT(20A3)                                                        PREP1030
      IF(ISO.NE.01)GO TO 15                                               PREP1040
C     ISOTROPIC AQUIFER                                                   PREP1050
C     SUBROUTINE IPERM READS AND WRITES THE ISOTROPIC PERMEABILITY        PREP1060
C     MATRIX                                                              PREP1070
      CALL IPERM(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,          PREP1080
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     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP1090
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP1100
C       SUBROUTINE IDISP READS AND WRITES THE ISOTROPIC MASS            PREP1110
C      DISPERSION COEFFICIENT MATRIX                                    PREP1120
      IF(SOLUTE.GT.0)                                                   PREP1130
     1CALL IDISP(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,        PREP1140
     2COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP1150
     3,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP1160
   10 CONTINUE                                                          PREP1170
      GO TO 20                                                          PREP1180
C     ANISOTROPIC AQUIFER                                               PREP1190
   15 CONTINUE                                                          PREP1200
C     SUBROUTINE APERM READS AND WRITES THE ANISOTROPIC PERMEABILITY    PREP1210
C     TENSOR                                                            PREP1220
      CALL APERM(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,        PREP1230
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP1240
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP1250
C     SUBROUTINE ADISP READS AND WRITES THE ANISOTROPIC MASS            PREP1260
C     DISPERSION TENSOR                                                 PREP1270
      IF(SOLUTE.GT.0)                                                   PREP1280
     1CALL ADISP(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,        PREP1290
     2COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP1300
     3,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP1310
   20 CONTINUE                                                          PREP1320
C     SUBROUTINE STORE READS AND WRITES THE SPECIFIC STORAGE COEFFICIENTPREP1330
C     MATRIX                                                            PREP1340
      CALL STORE(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,        PREP1350
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP1360
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP1370
C     THE BOUNDARY AND INITIAL CONDITIONS ARE SPECIFIED                 PREP1380
C     SINCE ALL BOUNDARIES ARE NO FLOW BOUNDARIES MATRICES OF MASS AND  PREP1390
C     HEAT TRANSFER COEFFICIENTS SPECIFY THE FLUX ACROSS THESE          PREP1400
C     BOUNDARIES                                                        PREP1410
C     THE IMPUT FORMAT FOR THE TRANSFER COEFFICIENTS IS SPECIFIED       PREP1420
      READ(5,25) (BFMT(I),I=1,20)                                       PREP1430
   25 FORMAT(20A3)                                                      PREP1440
C     MASS TRANSFER COEFFICIENTS                                        PREP1450
      CALL COEXCH(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       PREP1460
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP1470
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP1480
C     CFMT IS THE IMPUT FORMAT FOR THE CONSTANT HEAD BOUNDARY CONDITIONSPREP1490
C     AND THE INITIAL HEAD DISTRIBUTION MATRICES                        PREP1500
      READ(5,30) (CFMT(I),I=1,20)                                       PREP1510
   30 FORMAT(20A3)                                                      PREP1520
C       THE CONSTANT HEAD BOUNDARIES USED IN CONJUNCTION WITH THE       PREP1530
C     MASS TRANSFER COEFFICIENTS ARE SPECIFIED                          PREP1540
      CALL CONHD(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,        PREP1550
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP1560
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP1570
C     THE INITIAL HEAD DISTRIBUTION IS ENTERED                          PREP1580
      CALL STRT (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,        PREP1590
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP1600
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP1610
C     COMPONENT MASS TRANSFER COEFFICIENTS                              PREP1620
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      IF(SOLUTE.GT.0)
     1CALL QTRANS(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     2COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     3,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THE CONSTANT CONCENTRATION BOUNDARY CONDITIONS ARE SPECIFIED
      IF(SOLUTE.GT.0)
     1CALL CONCON(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     2COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     3,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THE INITIAL CONCENTRATION DISTRIBUTION IS ENTERED
      IF(SOLUTE.GT.0)
     1CALL CONC (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     2COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     3,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      IF(RSTRT.EQ.0..AND.SAVE.GT.0.)
     1CALL RECORD(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
      DO 35 K=1,NZ
      DO 35 J=1,NY
      DO 35 I=1,NX
C     THE VARIABLE USED TO ACCUMULATE THE CONCENTRATION CHANGE OVER
C     ONE TIME STEP IS SET EQUAL TO ZERO
      SUMZET(I,J,K) = 0.
      IF(K.GT.NZA)  GO TO 35
C     THE INJECTION RATE IN EACH CELL IS SET EQUAL TO ZERO
      Q(I,J,K)=0.0
      IF(RSTRT.GT.0.) GO TO 35
C     DRAWDOWN IN EACH CELL IS SET EQUAL TO ZERO
      DRAWDN(I,J,K)=0.0
   35 CONTINUE
      WRITE(6,736) (AFMT(I),I=1,20)
      WRITE(6,738) (BFMT(I),I=1,20)
      WRITE(6,740) (CFMT(I),I=1,20)
C     THE INJECTION WELLS ARE LOCATED AND THE RATE PER CELL IS SPECIFIED
      READ(5,50)NWELLS,TLONGD
   50 FORMAT(I5,F10.0)
      TLONG = 24.*3600.*TLONGD
      TLONGO = TOTAL/(24.*3600.)
      WRITE(6,754) TLONGO,TLONGD
      IF(NWELLS.LE.0) GO TO 56
      READ(5,51)(DFMT(I),I=1,20)
   51 FORMAT(20A3)
      WRITE(6,742) (DFMT(I),I=1,20)
      WRITE(6,744) NWELLS
      DO 55 L=1,NWELLS
      READ(5,52) LOCX(L),LOCY(L),CINJXY
   52 FORMAT(2I5,F10.0)
      IW = LOCX(L)
      JW = LOCY(L)
      CINJ(IW,JW) = CINJXY
      READ(5,DFMT)(Q(IW,JW,K),K=1,NZA)
      COUT = 0.0
      QOUT = 0.0
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      DO 54 K = 1,NZA
      N = K + KFAQ - 2
      COUT = COUT + Q(IW,JW,K)*F(IW,JW,N)
      QOUT = QOUT + Q(IW,JW,K)
   54 CONTINUE
      IF(QOUT.LT.0.0) CINJ(IW,JW) = COUT/QOUT
      WRITE(6,746) L,CINJ(IW,JW),IW,JW,(K,Q(IW,JW,K),K=1,1)
      WRITE(6,747) (K,Q(IW,JW,K),K=2,NZA)
   55 CONTINUE
   56 CONTINUE
C     BEFORE THE SOLUTION PROCEDURE BEGINS THE VALUES WHICH SPECIFY THE
C     ITERATION PARAMETERS AND CONVERGENCE CRITERION ARE ENTERED
      READ(5,60) MXITTS,MXITCY,ELIM,CLIM,ETIM,CTIM
   60 FORMAT(2I5,4F10.0)
      WRITE(6,748) MXITTS,MXITCY,ELIM,CLIM,ETIM,CTIM
C     NOUT = NUMBER OF TIMES AT WHICH TAPE AND PRINTED OUTPUT ARE
C     REQUESTED
      READ(5,65) SAVE,NOUT,POUT
   65 FORMAT(F10.0,I10,F10.0)
      READ(5,68) (TOUT(I),I=1,NOUT)
   68 FORMAT(8F10.0)
      WRITE(6,760) NOUT,(TOUT(I),I=1,NOUT)
      WRITE(6,750) SAVE,POUT
C     ACCORDING TO THE FORMULAS IN THE SPILLETTE AND NIELSEN (1967)
C     PAPER  THE VALUES OF HMAX AND HMIN ARE DETERMINED
      PXX=(2.0*(1.0-3.1416*3.1416 /(4.0*FLOAT(NX*NX))))/((DELX*DELX)/
     1(DELZ*DELZ)+1.0)
      PZZ=(2.0*(1.0-3.1416*3.1416/(4.0*FLOAT(NZ*NZ))))/((DELZ*DELZ)/
     1(DELX*DELX)+1.0)
      IF(PXX.GE.PZZ)GO TO 61
      HMAX=PZZ
      GO TO 62
   61 HMAX=PXX
   62 CONTINUE
      PXX=(1.0-3.1416*3.1416/(2.0*FLOAT(NX*NX)))/((DELX*DELX)/
     1(DELZ*DELZ)+1.0)
      PZZ=(1.0-3.1416*3.1416/(2.0*FLOAT(NZ*NZ)))/((DELZ*DELZ)/
     1(DELX*DELX)+1.0)
      IF(PXX.LE.PZZ)GO TO 63
      HMIN=PZZ
      GO TO 64
   63 HMIN=PXX
   64 HMIN = HMIN/10.
      HMAX = HMAX*1.E04
      HMIN = HMIN * 1.E05
C     PARAMETERS ARE INITIALIZED AND COUNTERS ARE SET UP
      IF(RSTRT.GT.0.) GO TO 105
      TOINJ=0.0
      TOOUT=0.0
      TOTAL=0.0
      TOQINJ=0.0
      TOQEX=0.0
      TOQACC=0.0
  105 NXL1=NX-1
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      NYL1=NY-1                                                         PREP2710
      NZL1=NZ-1                                                         PREP2720
      IT=1                                                              PREP2730
      KEND=0                                                            PREP2740
      IOUT = 1                                                          PREP2750
C      TPRO = PROCESSOR TIME ON $ LIMITS CARD IN HUNDREDTHS OF AN HOUR  PREP2760
C      TLIM = PROCESSOR TIME IN MILLISECONDS                            PREP2770
      TLIM = 0.1*TPRO*360000.                                           PREP2780
C     REDUCE TLIM BY 10000 MILLISECONDS TO ASSURE INTERNAL TERMINATION  PREP2790
C     OF PROGRAM BEFORE PROCESSOR LIMIT IS REACHED                      PREP2800
      TLIM = TLIM - 10000.                                              PREP2810
C     TNOW = ELAPSED PROCESSOR TIME IN MILLISECONDS                     PREP2820
C     TNEXT = ESTIMATED PROCESSOR TIME AT END OF NEXT TIME STEP         PREP2830
      CALL TMNOW2                                                       PREP2840
  100 CONTINUE                                                          PREP2850
      IF(IT.EQ.1) GO TO 110                                             PREP2860
      IF(TNEXT.GT.TLIM) GO TO 1100                                      PREP2870
      GO TO 110                                                         PREP2880
 1100 IF(SAVE.GT.0.) GO TO 1200                                         PREP2890
      STOP                                                              PREP2900
 1200 KEND = 10                                                         PREP2910
      CALL RECORD(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       PREP2920
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP2930
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP2940
      STOP                                                              PREP2950
  110 CONTINUE                                                          PREP2960
C     ARRAYS SAVED ON MAGNETIC TAPE WHEN KTAPE GT 0                     PREP2970
      KTAPE = 0                                                         PREP2980
C     TLONG = MAXIMUM TIME THAT CINJ REMAINS AT THE CURRENT VALUE,SEC   PREP2990
C     TLONGD=TLONG IN DAYS                                              PREP3000
      TTIME = TOTAL + DELT                                              PREP3010
      DELT1 = DELT                                                      PREP3020
      IF(TTIME.LT.TLONG)  GO TO 114                                     PREP3030
      IF(TTIME.EQ.TLONG)  GO TO 112                                     PREP3040
      DELT = TLONG - TOTAL                                              PREP3050
  112 KCINJ = 10                                                        PREP3060
      KTAPE = 10                                                        PREP3070
      GO TO 116                                                         PREP3080
  114 KCINJ = 0                                                         PREP3090
      GO TO 116                                                         PREP3100
  116 DELT2 = DELT                                                      PREP3110
      TTIME = TOTAL + DELT                                              PREP3120
      TOSEC = 3600.*24.*TOUT(IOUT)                                      PREP3130
      IF(TOSEC.GT.TTIME) GO TO 118                                      PREP3140
      IF(TOSEC.LT.TTIME) KCINJ = 0                                      PREP3150
      DELT = TOSEC - TOTAL                                              PREP3160
      DELT1 = DELT2                                                     PREP3170
      IOUT = IOUT + 1                                                   PREP3180
      KTAPE = 10                                                        PREP3190
  118 KT = KT + 1                                                       PREP3200
      KCOUNT = FLOAT(KT)/POUT +0.01                                     PREP3210
      IF(KCOUNT.EQ.KOUT) GO TO 120                                      PREP3220
      IF(KCINJ.GT.0) GO TO 122                                          PREP3230
      KEY = 0                                                           PREP3240
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      GO TO 140                                                         PREP3250
  120 KOUT = KOUT + 1                                                   PREP3260
  122 KEY = 10                                                          PREP3270
  140 CONTINUE                                                          PREP3280
      IF(KTAPE.GT.0)  KEY = 10                                          PREP3290
C     THE EQUATION OF MOTION IS SOLVED                                  PREP3300
      CALL MOTION(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       PREP3310
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP3320
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP3330
      NFIT = NIT                                                        PREP3340
C     TOTAL MASS BALANCES ARE CALCULATED AND THE RESULTS ARE PRINTED OUTPREP3350
      CALL MASBAL(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       PREP3360
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP3370
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP3380
C     NEXT THE EQUATION FOR COMPONENT MASS CONSERVATION IS SOLVED       PREP3390
C     MASS IS BYPASSED IF CINJ EQUALS F(1,1,1) = INITIAL CONCENTRATION  PREP3400
C     OF THE AQUIFER                                                    PREP3410
      IF(SOLUTE.LE.0) GO TO 590                                         PREP3420
      CALL MASS       (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,  PREP3430
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP3440
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP3450
C     MASS BALANCES ARE CALCULATED AND THE RESULTS ARE PRINTED OUT      PREP3460
      CALL BALANC(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       PREP3470
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP3480
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP3490
  590 CONTINUE                                                          PREP3500
      CALL TMNOW2                                                       PREP3510
      WRITE(6,1105)IT,ILAPSE,TNOW                                       PREP3520
 1105 FORMAT('0      TIME STEP NUMBER ',I5,' COMPLETED',/,              PREP3530
     16X, 'PROCESSOR TIME UTILIZED, MILLISECONDS',/,                    PREP3540
     26X,'   THIS TIME STEP -- ',I6,/,                                  PREP3550
     36X, '   TOTAL          -- ',E15.4,/,1H1)                          PREP3560
      IF(KTAPE.GT.0 .AND.SAVE.GT.0.)                                    PREP3570
     1CALL RECORD(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,       PREP3580
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXPREP3590
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)PREP3600
C     A CHECK IS MADE TO DETERMINE WHETHER THE MAXIMUM SIMULATION TIME  PREP3610
C     HAS BEEN REACHED.  IF NECESSARY, THE LAST TIME STEP IS ADJUSTED   PREP3620
C     SO THAT THE SIMULATION STOPS AT TMAX.                             PREP3630
      IF(TOTAL.EQ.TMAX)GO TO 1100                                       PREP3640
      IF(NFIT.GT.10) GO TO 710                                          PREP3650
      DELT=TINC*DELT                                                    PREP3660
      IF(DELT.GT.DELTMX) DELT=DELTMX                                    PREP3670
  710 IF(TMAX-TOTAL-DELT) 720,725,725                                   PREP3680
  720 DELT=TMAX-TOTAL                                                   PREP3690
      DELT1 = DELT                                                      PREP3700
  725 CONTINUE                                                          PREP3710
C     NEW VALUES FOR CINJ AND TLONG ARE READ IN IF KCINJ .GT. 0         PREP3720
      IF(KCINJ.EQ.0) GO TO 727                                          PREP3730
      TLONGO = TLONGD                                                   PREP3740
      READ(5,50)NWELLS,TLONGD                                           PREP3750
      TLONG = 24.*3600.*TLONGD                                          PREP3760
      TLONGO = TOTAL/(24.*3600.)                                        PREP3770
      WRITE(6,754) TLONGO,TLONGD                                        PREP3780
```

```
      IF(NWELLS.LE.0) GO TO 636
      READ(5,51)(DFMT(I),I=1,20)
      WRITE(6,742) (DFMT(I),I=1,20)
      WRITE(6,744) NWELLS
      DO 635 L=1,NWELLS
      READ(5,52) LOCX(L),LOCY(L),CINJXY
      IW = LOCX(L)
      JW = LOCY(L)
      CINJ(IW,JW) = CINJXY
      READ(5,DFMT)(Q(IW,JW,K),K=1,NZA)
      COUT = 0.0
      QOUT = 0.0
      DO 634 K = 1,NZA
      N = K + KFAQ - 2
      COUT = COUT + Q(IW,JW,K)*F(IW,JW,N)
      QOUT = QOUT + Q(IW,JW,K)
  634 CONTINUE
      IF(QOUT.LT.0.0) CINJ(IW,JW) = COUT/QOUT
      WRITE(6,746) L,CINJ(IW,JW),IW,JW,(K,Q(IW,JW,K),K=1,1)
      WRITE(6,747) L,CINJ(IW,JW),IW,JW,(K,Q(IW,JW,K),K=2,NZA)
  635 CONTINUE
  636 CONTINUE
      TLONG = 24.*3600.*TLONGD
      WRITE(6,754) TLONGO,TLONGD
  752 FORMAT(2F10.2)
  754 FORMAT('OTHE INJECTION RATE AND/OR CONCENTRATION CHANGED ',
     1'AFTER TIME = ',F8.2,
     2' DAYS AND WILL REMAIN THERE THROUGH TIME = ',F8.2,' DAYS')
  727 IF(DELT.LT.DELT1) DELT = DELT1
      IT=IT+ 1
      IF(NIT.LE.MXITTS) GO TO 100
  800 WRITE(6,780)NIT,MXITTS
  780 FORMAT('0******',I3,'ITERATION IN LAST TIME STEP EXECEEDS SPECIFIE
     1D MAXIMUM OF',I3,' -- PROGRAM TERMINATED ******')
      STOP
  730 FORMAT('OFIRST WRITE COMMAND BEGINS AT FILE NUMBER ',I4,' FOR THIS
     1 COMPUTATION    *** VALUE OF RSTRT = ',F10.0)
  732 FORMAT('OPROCESSOR TIME FOR INTERNAL PROGRAM TERMINATION ',F5.0,'
     1HUNDREDTHS OF AN HOUR ')
  734 FORMAT('OPROGRAM STARTS WITH DATA IN FILES ',I4,' - ',I4,' READ FR
     1OM TAPE NUMBER ',I6,' ON LOGICAL UNIT 01')
  736 FORMAT('1VARIABLE FORMAT AFMT(   ) =',20A3)
  738 FORMAT('OVARIABLE FORMAT BFMT(   ) =',20A3)
  740 FORMAT('OVARIABLE FORMAT CFMT(   ) =',20A3)
  742 FORMAT('OVARIABLE FORMAT DFMT(   ) =',20A3)
  744 FORMAT('ONUMBER OF WELLS =',I3,//,6X,'WELL   CONCENTRATION',
     18X,'COORDINATES',9X,'RATE/CELL',/,15X,'(LB/LB)',7X,'I(X)',
     24X,'J(Y)',4X,'K(Z)',4X,'(CU FT/SEC)')
  746 FORMAT('0',5X,I3,3X,G12.6,3X,I5,3X,I5,3X,I5,3X,F12.6)
  747 FORMAT(43X,I5,3X,F12.6)
  748 FORMAT('OMAXIMUM ITERATIONS PER TIME STEP ', I5,10X,'ITERATIONS PE
     1R CYCLE ',I5,/
     2'OCONVERGENCE LIMIT ON FLUID FLOW ITERATION    =',E15.8/
     3'OABSOLUTE VALUE OF SHRINK LIMIT-FLUID FLOW    =',E15.8/
```

```
   4'OCONVERGENCE LIMIT ON CONCENTRATION ITERATION =',E15.8/          PREP4330
   5'OABSOLUTE VALUE OF SHRINK LIMIT-CONCENTRATION =',E15.8)         PREP4340
750 FORMAT(' VALUE OF SAVE = ',F10.0,10X,'PRINTED OUTPUT REQUESTED EVEPREP4350
   1RY ',F5.0,' TIME STEPS',/,1H1)                                   PREP4360
760 FORMAT('0INTERMEDIATE RESULTS REQUESTED AT  ',I5, '  TIMES '/,    PREP4370
   18X,'TIMES IN DAYS    ',/(' ',F15.5))                             PREP4380
770 FORMAT('0AQUIFER SIMULATED USING ',I4,' LAYERS  FIRST LAYER IS AT PREP4390
   1K = ',I4,' LAST LAYER AT K = ',I4)                               PREP4400
    END                                                              PREP4410
```

```
C     SUBROUTINE QTRANS                                                 QTRN0010
C     COMPONENT MASS TRANSFER COEFFICIENT TERMS AT THE BOUNDARIES       QTRN0020
      SUBROUTINE QTRANS (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,QTRN0030
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXQTRN0040
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)QTRN0050
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME        QTRN0060
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,QTRN0070
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYQTRN0080
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),  QTRN0090
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),QTRN0100
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZAQTRN0110
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZAQTRN0120
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                          QTRN0130
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME                QTRN0140
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),QTRN0150
     1Z(NMAX)                                                           QTRN0160
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,      QTRN0170
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,QTRN0180
     2RHOW,TOTAL,VISCOS                                                 QTRN0190
      REAL MASSIN,MASOUT,DX,DY,DZ                                       QTRN0200
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND                    QTRN0210
      INTEGER CFILE                                                     QTRN0220
      IF(RSTRT.GT.0.) GO TO 800                                         QTRN0230
      READ(5,BFMT)(((QEXCHG(I,J,K),I=1,NX),J=1,NY),K=1,NZ)              QTRN0240
  800 WRITE(6,806)                                                      QTRN0250
  806 FORMAT(1H1,'COMPONENT MASS TRANSFER COEFFICIENTS ON THE',         QTRN0260
     1' BOUNDARIES, LB/SEC/CU FT',//)                                   QTRN0270
      DO 811  K=1,NZ                                                    QTRN0280
      LIM1=1                                                            QTRN0290
      LIM2=9                                                            QTRN0300
  807 IF(NX.LE.LIM2)LIM2=NX                                             QTRN0310
      WRITE(6,808) K,(I,I=LIM1,LIM2)                                    QTRN0320
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)                        QTRN0330
      DO 810 J=1,NY                                                     QTRN0340
      WRITE(6,809) J,(QEXCHG(I,J,K),I=LIM1,LIM2)                        QTRN0350
  809 FORMAT(2X,I2,9(2X,E11.4))                                         QTRN0360
  810 CONTINUE                                                          QTRN0370
      IF(LIM2.EQ.NX)GO TO 811                                           QTRN0380
      LIM1=LIM1+9                                                       QTRN0390
      LIM2=LIM2+9                                                       QTRN0400
      GO TO 807                                                         QTRN0410
  811 CONTINUE                                                          QTRN0420
      RETURN                                                            QTRN0430
      END                                                               QTRN0440
```

```
C     SUBROUTINE RECORD - CREATES FILES OF ALL INPUT MATRICES           RCRD0010
C     ON TAPE OR DISK                                                   RCRD0020
      SUBROUTINE RECORD (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,RCRD0030
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXRCRD0040
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)RCRD0050
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME        RCRD0060
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,RCRD0070
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYRCRD0080
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),  RCRD0090
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),RCRD0100
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZARCRD0110
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZARCRD0120
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                         RCRD0130
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME                RCRD0140
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),RCRD0150
     1Z(NMAX)                                                           RCRD0160
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,      RCRD0170
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,RCRD0180
     2RHOW,TOTAL,VISCOS                                                 RCRD0190
      COMMON/START/I1                                                   RCRD0200
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND                    RCRD0210
      COMMON/OUT/KEY,TOINJ,TOOUT,TOQINJ,TOQEX,TOQACC                    RCRD0220
      COMMON/AQUIFR/ISO,SOLUTE                                          RCRD0230
      INTEGER SOLUTE                                                    RCRD0240
      REAL MASSIN,MASOUT,DX,DY,DZ                                       RCRD0250
       INTEGER FIPERM,FICOND,FISS,FICOX,FICOY,FICOZ,FIHEAD,FIHCOF,FIBTEMRCRD0260
     1,FITEMP,CFILE,FIPRES,FIDRAW,FIBAL                                 RCRD0270
     2,FIPERY,FIPERZ,FICONY,FICONZ                                      RCRD0280
      DATA EOF/4H EOF/                                                  RCRD0290
C      NFILE = FILE WHERE NEXT WRITE IS TO OCCUR ON MAGNETIC TAPE       RCRD0300
C     TAPE IS ALWAYS POSITIONED AT CFILE WHEN SUBROUTINE RECORD         RCRD0310
C     IS CALLED**NEXT WRITE IS AT FILE NUMBER NFILE                     RCRD0320
      IF(CFILE.EQ.NFILE) GO TO 4                                        RCRD0330
      IF(CFILE.GT.NFILE) GO TO 2                                        RCRD0340
      NOFILE = NFILE - CFILE                                            RCRD0350
      DO 3 I=1,NOFILE                                                   RCRD0360
      CALL FLGEOF(01,IEOF)                                              RCRD0370
    3 CONTINUE                                                          RCRD0380
      GO TO 4                                                           RCRD0390
    2 WRITE(6,40)  CFILE,NFILE                                          RCRD0400
      STOP                                                              RCRD0410
   40 FORMAT(' TAPE NOT CORRECTLY POSITIONED FOR NEXT WRITE '/          RCRD0420
     1'  CFILE IS GREATER THAN NFILE**CFILE = ',I4,' NFILE =',I4)       RCRD0430
    4 CONTINUE                                                          RCRD0440
      CFILE = NFILE                                                     RCRD0450
C     TAPE IS POSITIONED AT FILE NUMBER NFILE IF NERROR EQ 0            RCRD0460
      FIPERM = NFILE                                                    RCRD0470
      WRITE (01) FIPERM,NTAPE,NX,NY,NZA                                 RCRD0480
      WRITE (01) COVERX                                                 RCRD0490
      WRITE(01) EOF                                                     RCRD0500
      WRITE(6,10) FIPERM,NTAPE,NX,NY,NZA                                RCRD0510
      FIPERY =FIPERM+1                                                  RCRD0520
      WRITE(01) FIPERY,NTAPE,NX,NY,NZA                                  RCRD0530
      WRITE(01) COVERY                                                  RCRD0540
```

```
      WRITE(01) EOF
      WRITE(6,41) FIPERY,NTAPE,NX,NY,NZA
   41 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COVERY(',I2,',',I2,',',
     1I2,')')
      FIPERZ=FIPERY+1
      WRITE(01) FIPERZ,NTAPE,NX,NY,NZA
      WRITE(01) COVERZ
      WRITE(01) EOF
      WRITE(6,42) FIPERZ,NTAPE,NX,NY,NZA
   42 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COVERZ(',I2,',',I2,',',
     1I2,')')
      FISS = FIPERZ + 1
      WRITE(01) FISS,NTAPE,NX,NY,NZA
      WRITE (01)  SS
      WRITE(01) EOF
      WRITE(6,14) FISS,NTAPE,NX,NY,NZA
      FICOX = FISS   +1
      WRITE (01)  FICOX,NTAPE,NX,NY,NZA
      WRITE (01) COEFX
      WRITE(01) EOF
      WRITE(6,16) FICOX,NTAPE,NX,NY,NZA
      FICOY =FICOX + 1
      WRITE(01) FICOY,NTAPE,NX,NY,NZA
      WRITE (01) COEFY
      WRITE(01) EOF
      WRITE(6,18) FICOY,NTAPE,NX,NY,NZA
      FICOZ =FICOY + 1
      WRITE (01) FICOZ,NTAPE,NX,NY,NZA
      WRITE (01) COEFZ
      WRITE(01) EOF
      WRITE(6,20) FICOZ,NTAPE,NX,NY,NZA
      FIHEAD = FICOZ + 1
      WRITE (01) FIHEAD,NTAPE,NX,NY,NZA
      WRITE (01) HEAD
      WRITE(01) EOF
      WRITE(6,22) FIHEAD,NTAPE,NX,NY,NZA
      FIPRES = FIHEAD + 1
      WRITE (01)  FIPRES,NTAPE,NX,NY,NZA
      WRITE (01)  PRES
      WRITE(01) EOF
      WRITE(6,24) FIPRES,NTAPE,NX,NY,NZA
      FIDRAW = FIPRES + 1
      WRITE(01) FIDRAW,NTAPE,NX,NY,NZA
      WRITE(01)  DRAWDN
      WRITE(01) EOF
      WRITE(6,32) FIDRAW,NTAPE,NX,NY,NZA
      IF(SOLUTE.LE.0) GO TO 100
      FICOND = FIDRAW + 1
      WRITE (01) FICOND,NTAPE,NX,NY,NZ
      WRITE (01) DX
      WRITE(01) EOF
      WRITE(6,12) FICOND,NTAPE,NX,NY,NZ
   12 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS DX    (',I2,',',I2,',',
     1I2,')')
```

```
      FICONY=FICOND+1
      WRITE(01) FICONY,NTAPE,NX,NY,NZ
      WRITE(01) DY
      WRITE(01) EOF
      WRITE(6,43) FICONY,NTAPE,NX,NY,NZ
   43 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS DY    (',I2,',',I2,',',
     1I2,')')
      FICONZ=FICONY+1
      WRITE(01) FICONZ,NTAPE,NX,NY,NZ
      WRITE(01)DZ
      WRITE(01)EOF
      WRITE(6,44) FICONZ,NTAPE,NX,NY,NZ
   44 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS DZ    (',I2,',',I2,',',
     1I2,')')
      FIHCOF = FICONZ + 1
      WRITE(01)  FIHCOF,NTAPE,NX,NY,NZ
      WRITE( 01)  QEXCHG
      WRITE(01) EOF
      WRITE(6,26)FIHCOF,NTAPE,NX,NY,NZ
      FIBTEM = FIHCOF + 1
      WRITE (01)  FIBTEM,NTAPE,NX,NY,NZ
      WRITE (01)  BCONC
      WRITE(01) EOF
      WRITE(6,28) FIBTEM,NTAPE,NX,NY,NZ
      FITEMP = FIBTEM + 1
      WRITE (01)  FITEMP,NTAPE,NX,NY,NZ
      WRITE(01) F
      WRITE(01) EOF
      WRITE(6,30) FITEMP,NTAPE,NX,NY,NZ
      FIBAL = FITEMP + 1
  100 IF(SOLUTE.LE.0) FIBAL = FIDRAW + 1
      WRITE(01)  TOQINJ,TOQACC,TOQEX,TOTAL,TOINJ,TOOUT
      WRITE(6,34) FIBAL,NTAPE,TOQINJ,TOQACC,TOQEX,TOTAL,TOINJ,TOOUT
      CFILE = FIBAL
      WRITE(01) EOF
      CFILE = CFILE + 1
      IF(KEND.NE.10) GO TO 8
C      PROGRAM TERMINATES WHEN KEND EQUALS 10
C     WRITE A BLANK FILE FOR FUTURE USE
      WRITE (01) CFILE
      WRITE(6,36) CFILE,NTAPE
      RETURN
    8 NFILE = CFILE
      IF(SOLUTE.LE.0) WRITE(6,37)
      RETURN
C     FORMAT STATEMENTS FOR FILE IDENTIFICATION
   10 FORMAT('OFILE ',I5,' ON TAPE ',I5,' HAS COVERX(',I2,',',I2,',',
     1I2,')')
   14 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS SS    (',I2,',',I2,',',
     1I2,')')
   16 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COEFX (',I2,',',I2,',',
     1I2,')')
   18 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COEFY (',I2,',',I2,',',
     1I2,')')
```

```
20 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COEFZ (',I2,',',I2,',',
  1I2,')')
22 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS HEAD  (',I2,',',I2,',',
  1I2,')')
24 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS PRES  (',I2,',',I2,',',
  1I2,')')
26 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS QEXCHG(',I2,',',I2,',',
  1I2,')')
28 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS BCONC (',I2,',',I2,',',
  1I2,')')
30 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS F     (',I2,',',I2,',',
  1I2,')')
32 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS DRAWDN(',I2,',',I2,',',
  1I2,')')
34 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS MISC. DATA NEEDED TO CONTI
  1NUE CALCULATIONS AT A LATER TIME '/' TOQINJ = ',E15.8,'TOQACC =
  2 ',E15.8,'    TOQEX = ',E15.8,'    TOTAL =',E15.8/'      TOINJ = ',
  3E15.8,'     TOOUT =',E15.8)
36 FORMAT(' FILE ',I5,' ON TAPE ',I5,' IS EMPTY')
37 FORMAT(' NOTE: FILES ARE FOR FLUID FLOW EQUATION ONLY')
   END
```

```
C     SUBROUTINE RSTART - READS IN INPUT ARRAYS FROM TAPE OR DISK FILES
C     FOR RESUMPTION OF CALCULATIONS
      SUBROUTINE RSTART (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      COMMON/START/I1
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND
      COMMON/OUT/KEY,TOINJ,TOOUT,TOQINJ,TOQEX,TOQACC
      COMMON/AQUIFR/ISO,SOLUTE
      REAL MASSIN,MASOUT,DX,DY,DZ
      INTEGER SOLUTE
       INTEGER FIPERM,FICOND,FISS,FICOX,FICOY,FICOZ,FIHEAD,FIHCOF,FIBTEM
     1,FITEMP,CFILE,FIPRES,FIDRAW,FIBAL
      NOFILE = CFILE - 1
      IF(NOFILE.EQ.0) GO TO 6
      DO  3  I=1,NOFILE
      CALL FLGEOF(01,IEOF)
    3 CONTINUE
C     TAPE IS NOW POSITIONED AT THE BEGINNING OF FILE NUMBER CFILE
    6 READ (01) FIPERM,ITAPE,IX,IY,IZ
      IF(FIPERM.EQ.CFILE) GO TO 8
      WRITE(6,40) FIPERM,CFILE
      STOP
    8 READ  (01) COVERX
      READ(01)
      WRITE(6,10) FIPERM,ITAPE,IX,IY,IZ
      READ (01) FIPERY,ITAPE,IX,IY,IZ
      READ (01) COVERY
      READ(01)
      WRITE(6,41) FIPERY,ITAPE,IX,IY,IZ
   41 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COVERY(',I2,',',I2,',',
     1I2,')')
      READ (01) FIPERZ,ITAPE,IX,IY,IZ
      READ(01) COVERZ
      READ(01)
      WRITE(6,42) FIPERZ,ITAPE,IX,IY,IZ
   42 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COVERZ(',I2,',',I2,',',
     1I2,')')
      CONTINUE
      READ (01) FISS,ITAPE,IX,IY,IZ
```

```
      READ  (01)  SS
      READ(01)
      CONTINUE
      WRITE(6,14) FISS,ITAPE,IX,IY,IZ
      READ  (01)  FICOX,ITAPE,IX,IY,IZ
      READ  (01) COEFX
      READ(01)
      CONTINUE
      WRITE(6,16) FICOX,ITAPE,IX,IY,IZ
      READ (01) FICOY,ITAPE,IX,IY,IZ
      READ  (01) COEFY
      READ(01)
      CONTINUE
      WRITE(6,18) FICOY,ITAPE,IX,IY,IZ
      READ  (01) FICOZ,ITAPE,IX,IY,IZ
      READ  (01) COEFZ
      READ(01)
      CONTINUE
      WRITE(6,20) FICOZ,ITAPE,IX,IY,IZ
      READ  (01) FIHEAD,ITAPE,IX,IY,IZ
      READ  (01) HEAD
      READ(01)
      CONTINUE
      WRITE(6,22) FIHEAD,ITAPE,IX,IY,IZ
      READ  (01)  FIPRES,ITAPE,IX,IY,IZ
      READ  (01)  PRES
      READ(01)
      CONTINUE
      WRITE(6,24) FIPRES,ITAPE,IX,IY,IZ
      READ (01) FIDRAW,ITAPE,IX,IY,IZ
      READ (01)  DRAWDN
      READ(01)
      CONTINUE
      WRITE(6,32) FIDRAW,ITAPE,IX,IY,IZ
      IF(SOLUTE.LE.0) GO TO 100
      READ  (01) FICOND,ITAPE,IX,IY,IZ
      READ  (01) DX
      READ(01)
      CONTINUE
      WRITE(6,12) FICOND,ITAPE,IX,IY,IZ
      READ(01) FICONY,ITAPE,IX,IY,IZ
      READ(01) DY
      READ(01)
      WRITE(6,43) FICONY,ITAPE,IX,IY,IZ
   43 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS DY    (',I2,',',I2,',',
     1I2,')')
      READ(01) FICONZ,ITAPE,IX,IY,IZ
      READ(01)DZ
      READ(01)
      CONTINUE
      WRITE(6,44) FICONZ,ITAPE,IX,IY,IZ
   44 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS DZ    (',I2,',',I2,',',
     1I2,')')
      READ (01)  FIHCOF,ITAPE,IX,IY,IZ
```

```
      READ ( 01)  QEXCHG
      READ(01)
      CONTINUE
      WRITE(6,26) FIHCOF,ITAPE,IX,IY,IZ
      READ  (01)  FIBTEM,ITAPE,IX,IY,IZ
      READ  (01)  BCONC
      READ(01)
      CONTINUE
      WRITE(6,28) FIBTEM,ITAPE,IX,IY,IZ
      READ  (01)  FITEMP,ITAPE,IX,IY,IZ
      READ  (01)  F
      READ(01)
      CONTINUE
      WRITE(6,30) FITEMP,ITAPE,IX,IY,IZ
      FIBAL = FITEMP + 1
  100 IF(SOLUTE.LE.0) FIBAL = FIDRAW + 1
      READ (01)  TOQINJ,TOQACC,TOQEX,TOTAL,TOINJ,TOOUT
      WRITE(6,34) FIBAL,ITAPE,TOQINJ,TOQACC,TOQEX,TOTAL,TOINJ,TOOUT
C     FIBAL IS THE LAST FILE READ --
C     TAPE IS POSITIONED AT THE BEGINNING OF THE FILE WHICH FOLLOWED
C     THE LAST FILE READ
      READ(01)
      CONTINUE
      CFILE = FIBAL + 1
      RETURN
C     FORMAT STATEMENTS FOR FILE IDENTIFICATION
   10 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COVERX(',I2,',',I2,',',
     1I2,')')
   12 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS DX    (',I2,',',I2,',',
     1I2,')')
   14 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS SS    (',I2,',',I2,',',
     1I2,')')
   16 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COEFX (',I2,',',I2,',',
     1I2,')')
   18 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COEFY (',I2,',',I2,',',
     1I2,')')
   20 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS COEFZ (',I2,',',I2,',',
     1I2,')')
   22 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS HEAD  (',I2,',',I2,',',
     1I2,')')
   24 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS PRES  (',I2,',',I2,',',
     1I2,')')
   26 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS QEXCHG(',I2,',',I2,',',
     1I2,')')
   28 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS BCONC (',I2,',',I2,',',
     1I2,')')
   30 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS F     (',I2,',',I2,',',
     1I2,')')
   32 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS DRAWDN(',I2,',',I2,',',
     1I2,')')
   34 FORMAT(' FILE ',I5,' ON TAPE ',I5,' HAS MISC. DATA NEEDED TO CONTI
     1NUE CALCULATIONS AT A LATER TIME '/' TOQINJ = ',E15.8,'TOQACC =
     2 ',E15.8,'   TOQEX = ',E15.8,'   TOTAL =',E15.8/'     TOINJ = ',
     3E15.8,'    TOOUT =',E15.8)
```

```
40 FORMAT(' TAPE NOT CORRECTLY POSITIONED FOR RESTART**FIPERM =',I5,'RSTR1630
  1CFILE =',I5)                                                         RSTR1640
   END                                                                  RSTR1650
```

```
C     SUBROUTINE STORE                                                  STOR0010
C     SPECIFIC STORAGE COEFFICIENT                                      STOR0020
      SUBROUTINE STORE(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,  STOR0030
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DXSTOR0040
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)STOR0050
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME        STOR0060
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,STOR0070
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERYSTOR0080
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),  STOR0090
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),STOR0100
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZASTOR0110
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZASTOR0120
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)                          STOR0130
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME                STOR0140
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),STOR0150
     1Z(NMAX)                                                           STOR0160
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,      STOR0170
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,STOR0180
     2RHOW,TOTAL,VISCOS                                                 STOR0190
      REAL MASSIN,MASOUT,DX,DY,DZ                                       STOR0200
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND                    STOR0210
      COMMON/AQLIM/KFAQ,KLAQ,NAQ                                        STOR0220
      INTEGER CFILE                                                     STOR0230
C     THE SPECIFIC STORAGE COEFFICIENT IS READ IN UNDER AFMT            STOR0240
      IF(RSTRT.GT.0.)GO TO 8055                                         STOR0250
      READ(5,AFMT) (((SS(I,J,K),I=1,NX),J=1,NY),K=1,NZA)                STOR0260
 8055 WRITE(6,806)                                                      STOR0270
  806 FORMAT(1H1,'SPECIFIC STORAGE COEFFICIENT, 1/FT',//)               STOR0280
      DO 811  K=1,NZA                                                   STOR0290
      M=K+KFAQ-2                                                        STOR0300
      LIM1=1                                                            STOR0310
      LIM2=9                                                            STOR0320
  807 IF(NX.LE.LIM2)LIM2=NX                                             STOR0330
      WRITE(6,808) M,(I,I=LIM1,LIM2)                                    STOR0340
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)                        STOR0350
      DO 810 J=1,NY                                                     STOR0360
      WRITE(6,809) J,(SS(I,J,K),I=LIM1,LIM2)                            STOR0370
  809 FORMAT(2X,I2,9(2X,E11.4))                                         STOR0380
  810 CONTINUE                                                          STOR0390
      IF(LIM2.EQ.NX)GO TO 811                                           STOR0400
      LIM1=LIM1+9                                                       STOR0410
      LIM2=LIM2+9                                                       STOR0420
      GO TO 807                                                         STOR0430
  811 CONTINUE                                                          STOR0440
      RETURN                                                            STOR0450
      END                                                               STOR0460
```

```
C     SUBROUTINE STRT
C     INITIAL HEAD DISTRIBUTION
      SUBROUTINE STRT(NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      REAL MASSIN,MASOUT,DX,DY,DZ
      COMMON/SAVED/SAVE,CFILE,NFILE,NTAPE,RSTRT,KEND
      COMMON/AQLIM/KFAQ,KLAQ,NAQ
      INTEGER CFILE
      IF(RSTRT.GT.0.) GO TO 800
      READ(5,CFMT) (((PRES(I,J,K),I=1,NX),J=1,NY),K=1,NZA)
  800 WRITE(6,806)
  806 FORMAT(1H1,'INITIAL HEAD DISTRIBUTION, FEET',//)
      DO 811  K=1,NZA
      M=K+KFAQ-2
      LIM1=1
      LIM2=9
  807 IF(NX.LE.LIM2)LIM2=NX
      WRITE(6,808) M,(I,I=LIM1,LIM2)
  808 FORMAT(//,3X,2HK=,I2,//,4X,9(5X,I2,6X),//)
      DO 810 J=1,NY
      WRITE(6,809) J,(PRES(I,J,K),I=LIM1,LIM2)
  809 FORMAT(2X,I2,9(2X,E11.4))
  810 CONTINUE
      IF(LIM2.EQ.NX)GO TO 811
      LIM1=LIM1+9
      LIM2=LIM2+9
      GO TO 807
  811 CONTINUE
      RETURN
      END
```

```
C     SUBROUTINE THOMAS
C      SOLUTION OF TRI-DIAGONAL MATRIX EQUATIONS
      SUBROUTINE THOMAS (NX,NY,NZ,NZA,NMAX,ALPHA,BETA,BCONC,COEFX,COEFY,
     1COEFZ,COVERX,COVERY,COVERZ,DELTA,DRAWDN,EPSILN,EXCHG,GAMMA,HEAD,DX
     2,DY,DZ,PRES,Q,QEXCHG,SUMGAM,SUMZET,SS,F,ZETA,CINJ,A,B,C,D,G,R,W,Z)
C     THREE DIMENSIONAL ARRAYS--SIZE SPECIFIED AT EXECUTION TIME
      DIMENSION ALPHA(NX,NY,NZ),BETA(NX,NY,NZ),BCONC(NX,NY,NZ),COEFX(NX,
     1NY,NZA),COEFY(NX,NY,NZA),COEFZ(NX,NY,NZA),COVERX(NX,NY,NZA),COVERY
     2(NX,NY,NZA),COVERZ(NX,NY,NZA),DELTA(NX,NY,NZ),DRAWDN(NX,NY,NZA),
     3EPSILN(NX,NY,NZ),EXCHG(NX,NY,NZ ),GAMMA(NX,NY,NZ),HEAD(NX,NY,NZA),
     4DX(NX,NY,NZ),DY(NX,NY,NZ),DZ(NX,NY,NZ),PRES(NX,NY,NZA),Q(NX,NY,NZA
     5),QEXCHG(NX,NY,NZ),SUMGAM(NX,NY,NZA),SUMZET(NX,NY,NZ),SS(NX,NY,NZA
     6),F(NX,NY,NZ),ZETA(NX,NY,NZ),CINJ(NX,NY)
C     ONE DIMENSIONAL ARRAYS--SIZE SET AT EXECUTION TIME
      DIMENSION A(NMAX),B(NMAX),C(NMAX),D(NMAX),G(NMAX),R(NMAX),W(NMAX),
     1Z(NMAX)
      COMMON/PARAM/AFMT(20),BFMT(20),CFMT(20),DELT,DELX,DELY,DELZ,
     1ELIM,EXPAN,H1,HMAX,HMIN,L,MXITCY,MXITTS,NIT,NXL1,NYL1,NZL1,RHOPOR,
     2RHOW,TOTAL,VISCOS
      COMMON/START/I1
      REAL MASSIN,MASOUT,DX,DY,DZ
C     SINCE C(I1)=0 OR X(I1-1)=0, LET C(I1)=0 AND SET R(I1-1)=0 AND
C     G(I1-1)=0
      I1M1 = I1 - 1
      R(I1M1) = 0.0
      G(I1M1) = 0.0
      LL1=L-1
      DO 10 I=I1,LL1
      W(I)=A(I)-C(I)*R(I-1)
      IF(W(I).EQ.0.) W(I) = 1.0
      R(I)=B(I)/W(I)
   10 G(I)=(D(I)-C(I)*G(I-1))/W(I)
      W(L)=A(L)-C(L)*R(L-1)
      IF(W(L).EQ.0.) W(L) = 1.0
      G(L)=(D(L)-C(L)*G(L-1))/W(L)
      Z(L)=G(L)
      DO 20 LBS=I1,LL1
      I = L - LBS - 1 + I1
      Z(I)=G(I)-R(I)*Z(I+1)
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TMNOW1                                                 TNOW0010
C     SUBROUTINE TNOW USES SYSTEM ASSEMBLY LANGUAGE SUBROUTINE 'ELAPSE' TNOW0020
C     TO CALCULATE THE PROCESSOR TIME UTILIZED IN MILLISECONDS.         TNOW0030
C     THE FIRSR CALL (FIRST EXECUTABLE STATEMENT IN MAIN PROGRAM) STARTSTNOW0040
C     THE CLOCK AND INITIALIXES TIME TOTAL ELAPSED TIME, TNOW           TNOW0050
      COMMON/CLOCK/ILAPSE,TNEXT,TNOW                                    TNOW0060
      CALL ELAPSE(ILAPSE)                                               TNOW0070
      TNOW=0.0                                                          TNOW0080
      RETURN                                                            TNOW0090
      ENTRY TMNOW2                                                      TNOW0100
      CALL ELAPSE(ILAPSE)                                               TNOW0110
      TNOW=TNOW+FLOAT(ILAPSE)                                           TNOW0120
      TNEXT=TNOW+FLOAT(ILAPSE)                                          TNOW0130
      RETURN                                                            TNOW0140
      END                                                               TNOW0150
```

Section E

Example Problems

Two example problems are included to enable the user to check the performance of the computer program. The first problem is also used to compare the drawdown distribution obtained from the finite difference model for fluid flow with the values of drawdown calculated using an analytical model (Cleary and Ungs, 1978). The second problem includes the solution of the solute-transport equations.

E.1- Drawdown in a Confined Aquifer of Finite Dimensions

The conceptualized grid system used to define parameters in the finite difference model for fluid flow in the aquifer is shown in Figure E.1.1. There are three no-flow boundaries and one constant head, or recharge, boundary. The physical properties for the system are summarized in Table E.1.1.

Computations were carried out for a total simulation time of 28 days. The input data deck and the complete computer printout are available on magnetic tape. The cumulative drawdown distribution after 28 days of pumping is shown in Table E.1.2 for the first active layer in the aquifer. The drawdown distribution predicted using the analytical model is presented in Table E.1.3.

The drawdown calculated using the finite-difference model represents the average drawdown over the volume of a grid cell while the analytical solution yields the drawdown at a point. Differences between the two sets of results are to be expected, and these differences can be minimized by using smaller grid increments in the finite difference model. The agreement between the drawdowns calculated using the finite-difference model and the values calculated using the analytical model are considered to be sufficiently close to verify the fluid-flow portion of the three-dimensional solute transport model.

Table E.1.1

Parameters used to Simulate Drawdown in a Confined Aquifer

Prototype

Width	7,040 ft
Length	12,800 ft
Thickness	208 ft

Numerical Model

Grid Axis	Number of Nodes	Grid Spacing
x	22	640 ft
y	13	640 ft
y	7	41.6 ft

Fluid Flow Parameters

Specific permeability	0.77051×10^{-11} ft^2
Porosity	0.35
Specific storage coefficient	0.28846×10^{-4} ft^{-1}
Formation compressibility	1.0×10^{-4} psi^{-1}
Fluid compressibility	3.3×10^{-6} psi^{-1}
Pumping rate	0.30 ft^3/sec
Initial head	958.0 ft

Solute Transport Parameters

Formation Density	167.0	lb_m/ft^3
Fluid Density	62.4	lb_m/ft^3
Distribution Coefficient	0.0	lb_m/lb_m
Reference Temperature	60.	^oF

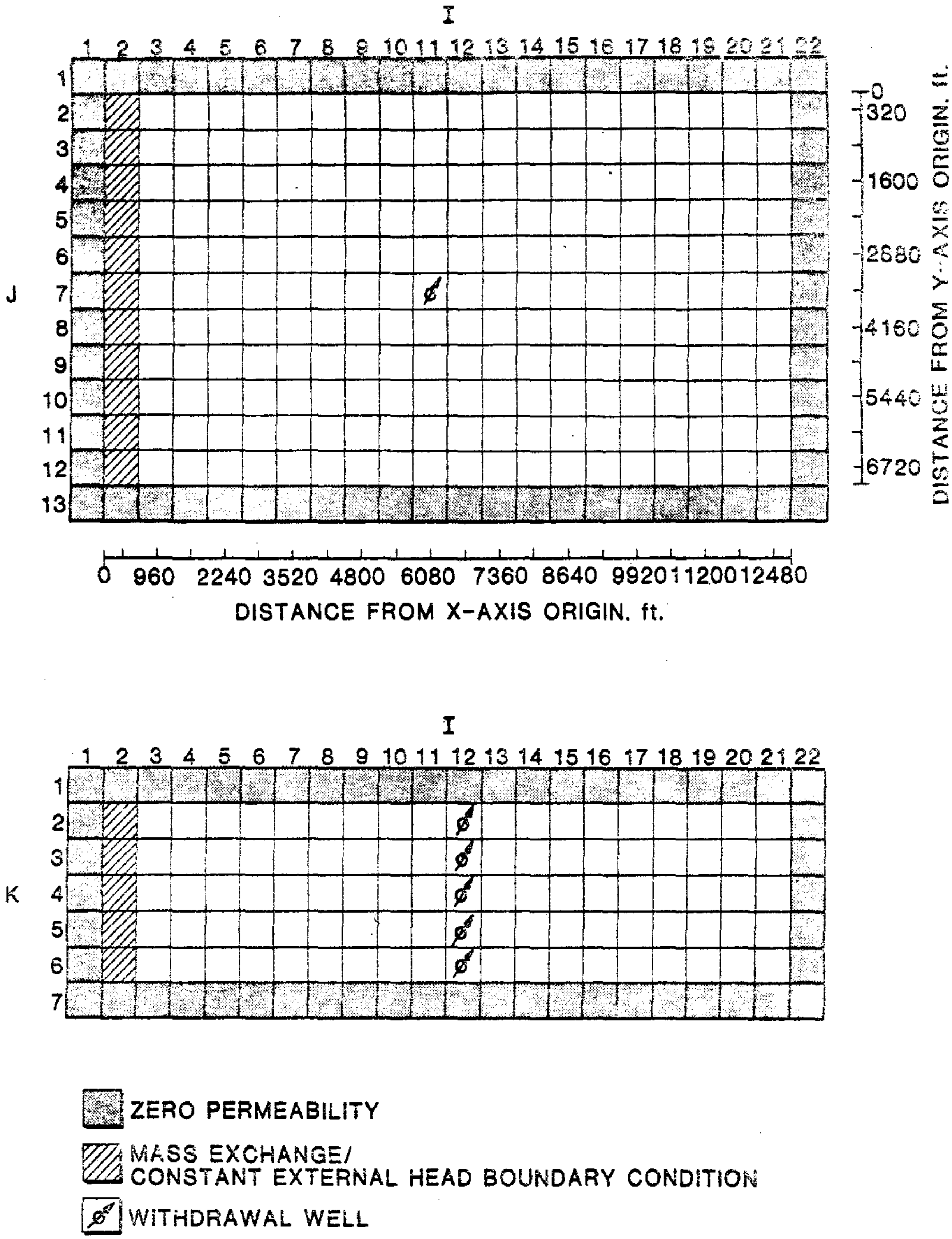

FIGURE E.1.1 - Grid system for drawdown in a confined aquifer with one recharge boundary.

Table E.1.2 - Results of Finite-Difference Model for Drawdown in a Confined Aquifer.

TOTAL TIME SIMULATED 28.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 2

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET 320.	960.	1600.	2240.	2880.	3520.	4160.	4800.	5440.
320.	0.0005	0.0027	0.0075	0.0195	0.0465	0.1017	0.2033	0.3614	0.5644
960.	0.0011	0.0039	0.0107	0.0281	0.0688	0.1539	0.3137	0.5752	0.9289
1600.	0.0015	0.0057	0.0171	0.0454	0.1120	0.2566	0.5409	1.0315	1.7479
2240.	0.0025	0.0088	0.0251	0.0667	0.1691	0.3976	0.8657	1.7290	3.1191
2880.	0.0028	0.0110	0.0321	0.0867	0.2219	0.5328	1.1989	2.5175	4.9177
3520.	0.0032	0.0119	0.0350	0.0949	0.2442	0.5934	1.3607	2.9645	6.2497
4160.	0.0028	0.0110	0.0321	0.0867	0.2219	0.5328	1.1989	2.5175	4.9177
4800.	0.0025	0.0088	0.0251	0.0667	0.1691	0.3976	0.8657	1.7290	3.1191
5440.	0.0015	0.0057	0.0171	0.0454	0.1120	0.2566	0.5409	1.0315	1.7479
6080.	0.0011	0.0039	0.0107	0.0281	0.0688	0.1539	0.3137	0.5752	0.9289
6720.	0.0005	0.0027	0.0075	0.0195	0.0465	0.1017	0.2033	0.3614	0.5644

TOTAL TIME SIMULATED 28.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 2

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET 6080.	6720.	7360.	8000.	8640.	9280.	9920.	10560.	11200.
320.	0.7539	0.8373	0.7539	0.5644	0.3614	0.2033	0.1017	0.0466	0.0196
960.	1.2846	1.4551	1.2846	0.9289	0.5752	0.3138	0.1540	0.0689	0.0284
1600.	2.5472	2.9979	2.5472	1.7479	1.0315	0.5409	0.2566	0.1122	0.0455
2240.	4.9258	6.2604	4.9258	3.1191	1.7290	0.8657	0.3977	0.1692	0.0673
2880.	8.7920	13.2712	8.7920	4.9177	2.5175	1.1989	0.5327	0.2221	0.0869
3520.	13.2692	30.5327	13.2692	6.2497	2.9646	1.3607	0.5935	0.2446	0.0954
4160.	8.7920	13.2712	8.7920	4.9177	2.5175	1.1989	0.5327	0.2221	0.0869
4800.	4.9258	6.2604	4.9258	3.1191	1.7290	0.8657	0.3977	0.1692	0.0673
5440.	2.5472	2.9979	2.5472	1.7479	1.0315	0.5409	0.2566	0.1122	0.0455
6080.	1.2846	1.4551	1.2846	0.9289	0.5752	0.3138	0.1540	0.0689	0.0284
6720.	0.7539	0.8373	0.7539	0.5644	0.3614	0.2033	0.1017	0.0466	0.0196

TOTAL TIME SIMULATED 28.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 2

DISTANCE FROM X AXIS ORIGIN FEET

Y FEET	11840.	12480.
320.	0.0079	0.0038
960.	0.0114	0.0054
1600.	0.0177	0.0084
2240.	0.0262	0.0122
2880.	0.0335	0.0150
3520.	0.0366	0.0161
4160.	0.0335	0.0150
4800.	0.0262	0.0122
5440.	0.0177	0.0084
6080.	0.0114	0.0054
6720.	0.0079	0.0038

Table E.1.3

EXAMPLE 1: ANALYTICAL SOLUTION

ANALYTIC SOLUTION TO THE UNSTEADY STATE
TWO-DIMENSIONAL FLOW EQUATION FOR A CONFINED AQUIFER
WITH FINITE DIMENSIONS, ONE RECHARGE BOUNDARY AND THREE
ZERO FLUX BOUNNDARIES

SYSTEM PARAMETERS
(UNITS OF FT AND DY)

```
NUMBER OF SUMMATIONS USED PER SERIES :NMAX = 195
                 STORAGE COEFFICIENT :  ST =  0.600000D-02
   TRANSMISSIVITY IN THE X DIRECTION : TXX =  0.368064D+03 (SQ FT/DY)
   TRANSMISSIVITY IN THE Y DIRECTION : TYY =  0.368064D+03 (SQ FT/DY)
           INITIAL PIEZOMETRIC HEAD :  H0 =  0.958000D+03 (FT)

          X-CORNER NODES OF AQUIFER :  X0 =  0.0          (FT)
                                       X1 =  0.128000D+05 (FT)
          Y-CORNER NODES OF AQUIFER :  Y0 =  0.0          (FT)
                                       Y1 =  0.704000D+04 (FT)

        HENCE, THE CONFINED AQUIFER IS RECTANGULAR IN SHAPE, DEFINED
 ALONG SIDE (X0,Y0) - (X0,Y1)   RECHARGE  BOUNDARY(I.E.,DRAWDOWN = 0)
 ALONG      (X0,Y1) - (X1,Y1)   ZERO FLUX
 ALONG      (X1,Y1) - (X1,Y0)   ZERO FLUX
 ALONG      (X1,Y0) - (X0,Y0)   ZERO FLUX

             TOTAL NUMBER OF WELLS: NW =   1

          WELL LOCATION AND ITS PUMPING(-) OR RECHARGE(+) RATE
          I     XW(I)  (FT)    YW(I)  (FT)    GL(I)  (FT**3/DY)

          1     0.6720D+04     0.3520D+04    -0.2592D+05
```

TIME = 28.000 DY
PLOTTING DRAWDOWN(FT)

DISTANCE (FT) →Y

DISTANCE DOWN (FT) X	320.0	960.0	1600.0	2240.0	2880.0	3520.0	4160.0	4800.0
320.0	0.000	0.001	0.001	0.001	0.001	0.006	0.001	0.001
960.0	0.002	0.003	0.004	0.006	0.007	0.020	0.007	0.006
1600.0	0.007	0.009	0.014	0.020	0.025	0.042	0.025	0.020
2240.0	0.019	0.027	0.042	0.060	0.075	0.094	0.075	0.060
2880.0	0.048	0.070	0.112	0.163	0.207	0.226	0.207	0.163
3520.0	0.108	0.163	0.269	0.403	0.521	0.553	0.521	0.403
4160.0	0.215	0.336	0.577	0.901	1.203	1.290	1.203	0.901
4800.0	0.374	0.610	1.103	1.826	2.567	2.836	2.567	1.826
5440.0	0.564	0.959	1.842	3.306	5.104	5.968	5.104	3.306
6080.0	0.727	1.277	2.591	5.110	9.334	12.776	9.334	5.110
6720.0	0.775	1.392	2.910	6.049	12.879	53.693	12.879	6.049
7360.0	0.728	1.277	2.591	5.110	9.334	12.761	9.334	5.110
8000.0	0.564	0.959	1.842	3.306	5.104	5.939	5.104	3.306
8640.0	0.374	0.610	1.103	1.826	2.568	2.801	2.568	1.826
9280.0	0.215	0.336	0.577	0.901	1.203	1.255	1.203	0.901
9920.0	0.108	0.163	0.269	0.403	0.521	0.527	0.521	0.403
10560.0	0.048	0.070	0.112	0.163	0.207	0.215	0.207	0.163
11200.0	0.019	0.027	0.042	0.060	0.075	0.101	0.075	0.060
11840.0	0.007	0.009	0.014	0.020	0.025	0.069	0.025	0.020
12480.0	0.003	0.004	0.005	0.007	0.009	0.064	0.009	0.007

V
DISTANCE
DOWN(FT)
X

TIME = 28.000 DY
PLOTTING DRAWDOWN(FT)

DISTANCE (FT)

DISTANCE DOWN (FT) X	5440.0	6080.0	6720.0
320.0	0.001	0.001	0.000
960.0	0.004	0.003	0.002
1600.0	0.014	0.009	0.007
2240.0	0.042	0.027	0.019
2880.0	0.112	0.070	0.048
3520.0	0.269	0.163	0.108
4160.0	0.577	0.336	0.215
4800.0	1.103	0.610	0.374
5440.0	1.842	0.959	0.564
6080.0	2.591	1.277	0.727
6720.0	2.910	1.392	0.775
7360.0	2.591	1.277	0.728
8000.0	1.842	0.959	0.564
8640.0	1.103	0.610	0.374
9280.0	0.577	0.336	0.215
9920.0	0.269	0.163	0.108
10560.0	0.112	0.070	0.048
11200.0	0.042	0.027	0.019
11840.0	0.014	0.009	0.007
12480.0	0.005	0.004	0.003

E.2 - Solute Transport in a Confined Aquifer with One Recharge Boundary

The example problem for solute transport is basically an extension of the first example problem. The conceptual grid system is shown in Figure E.2.1. A low permeability zone separates a "fresh-water" aquifer from an underlying "saline" aquifer. Fresh water is pumped from the upper aquifer at a total rate of 0.3 ft^3/sec and salt water is injected into the lower formation at the same rate. A "window" in the low permeability zone serves as a hydraulic connection between the fresh and saline aquifers. The physical properties of the system are summarized in Table E.2.1.

Fluid-flow and solute transport were simulated for a total period of 3 years. The simulation consisted of four computer runs utilizing the restart options. The intermediate results were saved on Logical Unit 01 at the end of each run. Parameters which changed from run to run are summarized in Table E.2.2. Portions of the printed results are included in Table E.2.3. The data deck and complete results for each of the four runs are available on mganetic tape.

Table E.2.1

Parameters Used to Simulate Solute Transport in a Confined Aquifer

<u>Prototype</u>

Width	7,040 ft.
Length	12,800 ft.
Thickness	332.8 ft.

<u>Numerical Model</u>

Grid Axis	Number of Nodes	Grid Spacing
x	22	640 ft.
y	13	640 ft.
y	10	41.6 ft.

<u>Fluid Flow Parameters</u>

Specific Permeability	0.77051×10^{-1} ft^2 K≠7
	0.12343×10^{-14} ft^2 K=7
Specific storage coefficient	0.28846×10^{-4} ft^{-1}
Formation compressibility	1.0×10^{-4} psi^{-1}
Fluid compressibility	3.3×10^{-6} psi^{-1}
Pumping/Injection ratio	0.30 ft^3/sec
Initial Head	958.0 ft.

<u>Solute Transport Parameters</u>

Formation Density	167.0 lb_m/ft^3
Fluid Density	62.4 lb_m/ft^3
Distribution Coefficient	0.0 lb_m/lb_m
Reference Temperature	60.0 °F
Initial Concentration	0.0 lb_m/lb_m K=2,7
	0.02 lb_m/lb_m K=8,9

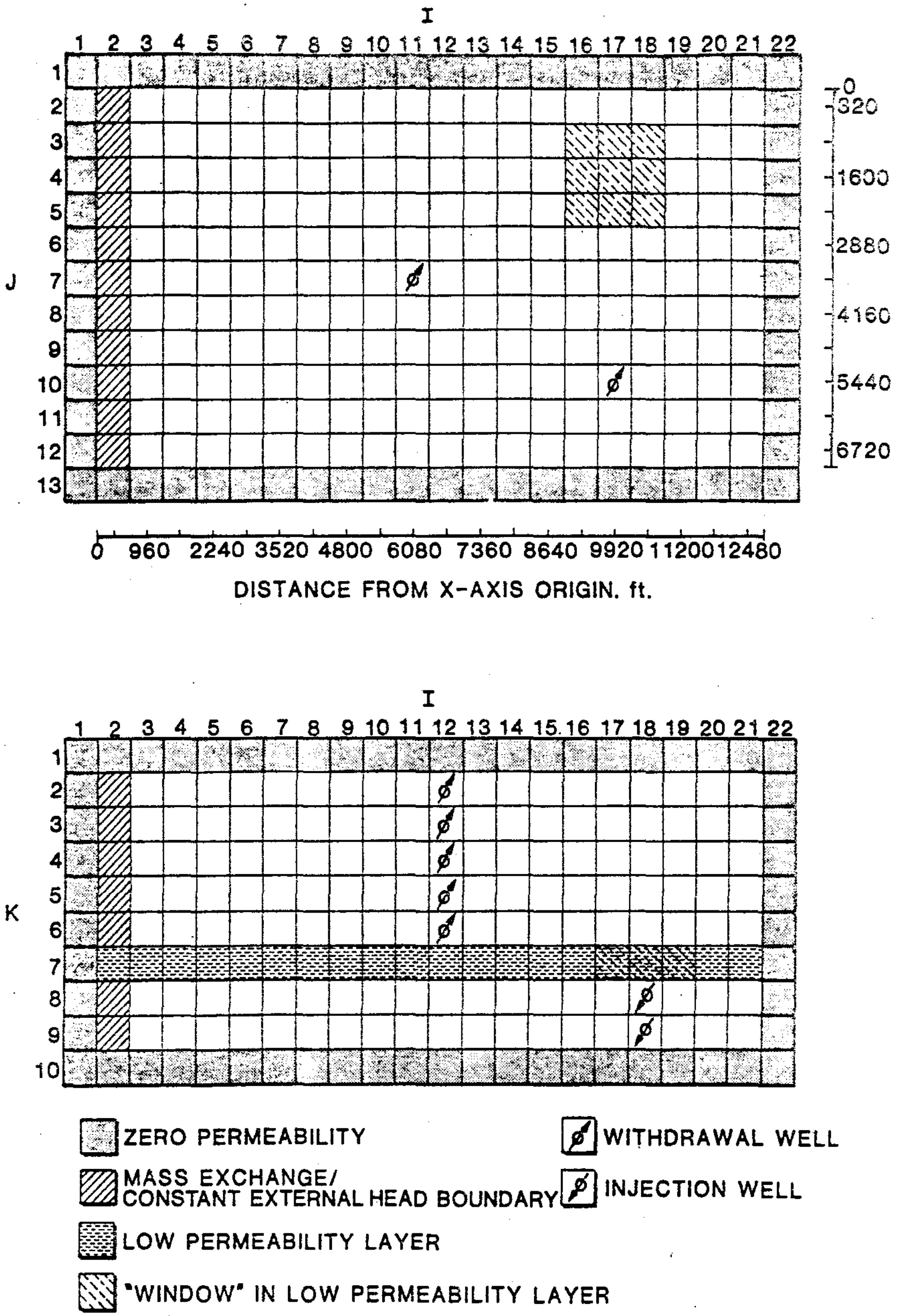

FIGURE E.2.1 - Grid system for solute transport in a confined aquifer

Table E.2.2

Time and Output Parameters for Example Problem 2

	Card 4			Card 7				Card 14		Card 15
RUN	DELT	TMAX	TINC	CFILE	NFILE	RSTRT	SAVE	NOUT	POUT	TOUT(I)
1	2700.	1.0	1.00	1	1	0.	10.	1	25.	3600.
2	2700.	30.0	1.25	18	35	10.	0.	1	25.	3600.
3	172800.	360.0	1.25	35	52	10.	0.	1	19.	3600.
4	2592000.	1080.0	1.25	52	69	10.	0.	1	25.	1080.

Table E.2.3

Partial Listing of Computer Printout for Solute Transport in a Confined Aquifer with One Recharge Boundary

```
GARBER-WELLINGTON AQUIFER SIMULATION
TEST FOR DR. WAGNER



LIMITS USED TO SET SIZES OF VARIABLE ARRAYS
NX =     22     NY =     13     NZ =     10     NZA =     10     NMAX =     22

ISO =     1     SOLUTE =     1
COMMON REQUIRED FOR VARIABLE ARRAYS           54803
COMMON STORAGE AVAILABLE                     175000



AQUIFER SIMULATED USING    8 LAYERS  FIRST LAYER IS AT K =    2 LAST LAYER AT K =    9
  SPATIAL INCREMENTS, FT.
       DELX =       640.00
       DELY =       640.00
       DELZ =        41.60
  INITIAL TIME INCREMENT, SEC.
       DELT = 2592000.00     TINC =     1.2500     DELTMX =      .10E+08     TMAX = ********** DY.

  FLUID PROPERTIES
       DENSITY, LB/CU.FT.          =    62.40
       INITIAL VISCOSITY,LB/FTSEC=    .7552E-03

  REFERENCE TEMPERATURE, F         =    60.00


  POROUS MEDIA PROPERTIES
       DENSITY, LB/CU.FT.          =    167.0
       DISTRIBUTION COEF. LB/LB    =    .0
       POROSITY                    =    .3500
       COMPRESSIBILITY, 1/PSI      =    .1000E-03

FIRST WRITE COMMAND BEGINS AT FILE NUMBER   69 FOR THIS COMPUTATION    *** VALUE OF RSTRT =        10.

PROCESSOR TIME FOR INTERNAL PROGRAM TERMINATION    9. HUNDREDTHS OF AN HOUR

PROGRAM STARTS WITH DATA IN FILES   52 -   68 READ FROM TAPE NUMBER  11224 ON LOGICAL UNIT 01
FILE    52 ON TAPE 11224 HAS COVERX(22,13,10)
FILE    53 ON TAPE 11224 HAS COVERY(22,13,10)
FILE    54 ON TAPE 11224 HAS COVERZ(22,13,10)
FILE    55 ON TAPE 11224 HAS SS    (22,13,10)
FILE    56 ON TAPE 11224 HAS COEFX (22,13,10)
FILE    57 ON TAPE 11224 HAS COEFY (22,13,10)
FILE    58 ON TAPE 11224 HAS COEFZ (22,13,10)
FILE    59 ON TAPE 11224 HAS HEAD  (22,13,10)
FILE    60 ON TAPE 11224 HAS PRES  (22,13,10)
FILE    61 ON TAPE 11224 HAS DRAWDN(22,13,10)
FILE    62 ON TAPE 11224 HAS DX    (22,13,10)
FILE    63 ON TAPE 11224 HAS DY    (22,13,10)
FILE    64 ON TAPE 11224 HAS DZ    (22,13,10)
FILE    65 ON TAPE 11224 HAS QEXCHG(22,13,10)
FILE    66 ON TAPE 11224 HAS BCONC (22,13,10)
FILE    67 ON TAPE 11224 HAS F     (22,13,10)
FILE    68 ON TAPE 11224 HAS MISC. DATA NEEDED TO CONTINUE CALCULATIONS AT A LATER TIME
TOQINJ =  0.17467968E+08TOQACC =     0.10641238E+08   TOQEX = -0.60270898E+05   TOTAL = 0.31104000E+08
    TOINJ =  0.19709473E+01     TOOUT = 0.88023469E+06
```

ISOTROPIC PERMEABILITY MATRIX, (SEC)-1 ** ADJUSTED FOR VISCOSITY AND DENSITY

K= 1

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 2

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
3	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
4	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
5	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
6	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
7	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
8	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
9	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
10	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
11	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
12	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
3	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
4	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
5	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
6	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
7	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
8	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
9	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
10	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
11	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
12	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.2048E-04	0.2048E-04	0.2048E-04	0.0
3	0.2048E-04	0.2048E-04	0.2048E-04	0.0
4	0.2048E-04	0.2048E-04	0.2048E-04	0.0
5	0.2048E-04	0.2048E-04	0.2048E-04	0.0
6	0.2048E-04	0.2048E-04	0.2048E-04	0.0
7	0.2048E-04	0.2048E-04	0.2048E-04	0.0
8	0.2048E-04	0.2048E-04	0.2048E-04	0.0
9	0.2048E-04	0.2048E-04	0.2048E-04	0.0
10	0.2048E-04	0.2048E-04	0.2048E-04	0.0
11	0.2048E-04	0.2048E-04	0.2048E-04	0.0
12	0.2048E-04	0.2048E-04	0.2048E-04	0.0
13	0.0	0.0	0.0	0.0

K= 3

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
3	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
4	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04

6	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
7	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
8	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
9	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
10	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
11	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
12	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 6

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.2048E-04	0.2048E-04	0.2048E-04	0.0
3	0.2048E-04	0.2048E-04	0.2048E-04	0.0
4	0.2048E-04	0.2048E-04	0.2048E-04	0.0
5	0.2048E-04	0.2048E-04	0.2048E-04	0.0
6	0.2048E-04	0.2048E-04	0.2048E-04	0.0
7	0.2048E-04	0.2048E-04	0.2048E-04	0.0
8	0.2048E-04	0.2048E-04	0.2048E-04	0.0
9	0.2048E-04	0.2048E-04	0.2048E-04	0.0
10	0.2048E-04	0.2048E-04	0.2048E-04	0.0
11	0.2048E-04	0.2048E-04	0.2048E-04	0.0
12	0.2048E-04	0.2048E-04	0.2048E-04	0.0
13	0.0	0.0	0.0	0.0

K= 7

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
3	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
4	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
5	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
6	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
7	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
8	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
9	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
10	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
11	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
12	0.0	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 7

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
3	0.3281E-08	0.3281E-06	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.2048E-04	0.2048E-04
4	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.2048E-04	0.2048E-04
5	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.2048E-04	0.2048E-04
6	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
7	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
8	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
9	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
10	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
11	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08
12	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08	0.3281E-08

13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 7

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.3281E-08	0.3281E-08	0.3281E-08	0.0
3	0.2048E-04	0.3281E-08	0.3281E-08	0.0
4	0.2048E-04	0.3281E-08	0.3281E-08	0.0
5	0.2048E-04	0.3281E-08	0.3281E-08	0.0
6	0.3281E-08	0.3281E-08	0.3281E-08	0.0
7	0.3281E-08	0.3281E-08	0.3281E-08	0.0
8	0.3281E-08	0.3281E-08	0.3281E-08	0.0
9	0.3281E-08	0.3281E-08	0.3281E-08	0.0
10	0.3281E-08	0.3281E-08	0.3281E-08	0.0
11	0.3281E-08	0.3281E-08	0.3281E-08	0.0
12	0.3281E-08	0.3281E-08	0.3281E-08	0.0
13	0.0	0.0	0.0	0.0

K= 8

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
3	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
4	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
5	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
6	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
7	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
8	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
9	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
10	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
11	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
12	0.0	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 8

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
3	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
4	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
5	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
6	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
7	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
8	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
9	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
10	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
11	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
12	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04	0.2048E-04
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 8

	19	20	21	22
1	0.0	0.0	0.0	0.0

ISOTROPIC DISPERSION COEFFICIENT MATRIX, LB/SEC/FT

K= 1

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 2

	1	2	3	4	5	6	7	8	9

SPECIFIC STORAGE COEFFICIENT, 1/FT

K= 1

	1	2	3	4	5	6	7	8	9
1	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
2	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
3	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
4	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
5	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
6	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
7	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
8	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
9	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
10	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
11	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
12	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
13	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04

K= 1

	10	11	12	13	14	15	16	17	18
1	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
2	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
3	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
4	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
5	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
6	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
7	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
8	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
9	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
10	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
11	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
12	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
13	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04

K= 1

	19	20	21	22
1	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
2	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
3	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
4	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
5	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
6	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
7	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
8	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
9	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
10	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
11	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
12	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04
13	0.2885E-04	0.2885E-04	0.2885E-04	0.2885E-04

K= 2

SUM OF COEFFICIENTS OF EXCHANGE WITH BOUNDARIES, 1/SEC/FT HEAD

K= 1

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 2

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 3

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0

6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 6

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 7

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 7

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 7

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 8

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.5000E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 8

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 8

	19	20	21	22
1	0.0	0.0	0.0	0.0

CONSTANT HEAD BOUNDARIES, FEET

K= 1

	1	2	3	4	5	6	7	8	9
1	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
2	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
3	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
4	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
5	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
6	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
7	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
8	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
9	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
10	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
11	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
12	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
13	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03

K= 1

	10	11	12	13	14	15	16	17	18
1	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
2	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
3	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
4	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
5	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
6	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
7	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
8	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
9	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
10	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
11	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
12	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
13	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03

K= 1

	19	20	21	22
1	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
2	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
3	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
4	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
5	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
6	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
7	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
8	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
9	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
10	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
11	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
12	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
13	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03

K= 2

INITIAL HEAD DISTRIBUTION, FEET

K= 1

	1	2	3	4	5	6	7	8	9
1	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
2	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
3	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
4	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
5	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
6	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
7	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
8	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
9	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
10	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
11	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
12	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
13	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03

K= 1

	10	11	12	13	14	15	16	17	18
1	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
2	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
3	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
4	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
5	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
6	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
7	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
8	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
9	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
10	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
11	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
12	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
13	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03

K= 1

	19	20	21	22
1	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
2	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
3	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
4	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
5	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
6	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
7	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
8	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
9	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
10	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
11	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
12	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03
13	0.9580E+03	0.9580E+03	0.9580E+03	0.9580E+03

K= 2

COMPONENT MASS TRANSFER COEFFICIENTS ON THE BOUNDARIES, LB/SEC/CU FT

K= 1

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 2

CONSTANT CONCENTRATION BOUNDARY CONDITIONS, LB/LB

K= 1

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 2

13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 7

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 8

	1	2	3	4	5	6	7	8	9
1	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
2	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
3	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
4	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
5	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
6	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
7	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
8	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
9	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
10	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
11	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
12	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
13	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01

K= 8

	10	11	12	13	14	15	16	17	18
1	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
2	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
3	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
4	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
5	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
6	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
7	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
8	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
9	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
10	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
11	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
12	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01
13	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01

K= 8

	19	20	21	22
1	0.2000E-01	0.2000E-01	0.2000E-01	0.2000E-01

INITIAL CONCENTRATION DISTRIBUTION, LB/LB

K= 1

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 1

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K- 1

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0

K= 2

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.3842E-28	0.2149E-26	0.7532E-26	0.2801E-25	0.8602E-25	0.2092E-23	0.1780E-23	0.4465E-23
3	0.0	0.2723E-28	0.9234E-28	0.3473E-25	0.1117E-24	0.4391E-24	0.1466E-23	0.2907E-23	0.1156E-22
4	0.0	0.2646E-28	0.1086E-26	0.2932E-25	0.2621E-24	0.3864E-24	0.4321E-23	0.3197E-23	0.1133E-22
5	0.0	0.1365E-28	0.1449E-26	0.5998E-26	0.9716E-25	0.8386E-24	0.5220E-23	0.5692E-23	0.2603E-22
6	0.0	0.5021E-28	0.1895E-26	0.6409E-26	0.9725E-25	0.9674E-24	0.2721E-23	0.3593E-22	0.5749E-22
7	0.0	0.2771E-29	0.3384E-26	0.4722E-26	0.8584E-25	0.8579E-24	0.2884E-23	0.1651E-22	0.1798E-21
8	0.0	0.6427E-29	0.1275E-26	0.1237E-25	0.1855E-24	0.1241E-23	0.7808E-23	0.4767E-22	0.1116E-21
9	0.0	0.1134E-27	0.5946E-27	0.9208E-26	0.7845E-25	0.1545E-23	0.1517E-22	0.2708E-22	0.7733E-22
10	0.0	0.1432E-32	0.4090E-27	0.1365E-25	0.5127E-24	0.6082E-24	0.1330E-22	0.2448E-22	0.4815E-22
11	0.0	0.3404E-28	0.3367E-26	0.8490E-26	0.4541E-25	0.1057E-23	0.2250E-23	0.4709E-22	0.3008E-22
12	0.0	0.1742E-28	0.6506E-26	0.2313E-25	0.4203E-24	0.2462E-24	0.4609E-23	0.1536E-22	0.3567E-22
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	10	11	12	13	14	15	16	17	18
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.1598E-22	0.1438E-22	0.5633E-22	0.3171E-22	0.4616E-23	0.2296E-23	0.8655E-21	0.5535E-18	0.1138E-21
3	0.5498E-22	0.3563E-22	0.1434E-21	0.4092E-22	0.2613E-22	0.7463E-20	0.3561E-17	0.2531E-14	0.5005E-18
4	0.1039E-21	0.5588E-22	0.3375E-21	0.1380E-21	0.8393E-22	0.2520E-19	0.8812E-17	0.4404E-14	0.8262E-16
5	0.2062E-21	0.7983E-21	0.5380E-21	0.1186E-20	0.7446E-19	0.2552E-16	0.6764E-14	0.3160E-11	0.1601E-12
6	0.8324E-21	0.2764E-20	0.8626E-20	0.2358E-20	0.1003E-20	0.5815E-19	0.1218E-16	0.3033E-14	0.1511E-15
7	0.8212E-21	0.1101E-19	0.1923E-18	0.1672E-19	0.3037E-20	0.6882E-20	0.9167E-20	0.2397E-17	0.1151E-18
8	0.6695E-21	0.2806E-20	0.2939E-19	0.1237E-19	0.5042E-20	0.2166E-19	0.1254E-19	0.4320E-19	0.3609E-19
9	0.5472E-21	0.2269E-20	0.6127E-20	0.1108E-19	0.6643E-20	0.5036E-19	0.3613E-19	0.3587E-18	0.8455E-18
10	0.2851E-21	0.1390E-20	0.2593E-20	0.7231E-20	0.7819E-20	0.6697E-19	0.9308E-19	0.1746E-17	0.2982E-16
11	0.2769E-21	0.7118E-21	0.1495E-20	0.6816E-20	0.8156E-20	0.3333E-19	0.1946E-18	0.8225E-18	0.2469E-17
12	0.3899E-21	0.3418E-21	0.3726E-20	0.2459E-20	0.1445E-19	0.4226E-19	0.1479E-18	0.2126E-18	0.1177E-17
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	19	20	21	22
1	0.0	0.0	0.0	0.0
2	0.6758E-20	0.1743E-24	0.7897E-27	0.0
3	0.4190E-16	0.1909E-20	0.8132E-25	0.0
4	0.9654E-15	0.3724E-18	0.3049E-22	0.0
5	0.1504E-11	0.6747E-15	0.1007E-18	0.0
6	0.1199E-14	0.3445E-18	0.3050E-21	0.0
7	0.8699E-18	0.1771E-20	0.2912E-20	0.0
8	0.6370E-19	0.1128E-19	0.2361E-19	0.0
9	0.3508E-18	0.9770E-19	0.8800E-19	0.0
10	0.1648E-17	0.3275E-18	0.1958E-18	0.0
11	0.5458E-18	0.5559E-18	0.2292E-18	0.0
12	0.3900E-18	0.3759E-18	0.1989E-18	0.0
13	0.0	0.0	0.0	0.0

K= 3

	1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.9485E-24	0.5577E-22	0.8753E-21	0.2596E-20	0.1423E-19	0.2032E-19	0.1196E-18	0.2499E-18
3	0.0	0.1423E-23	0.9342E-22	0.5998E-21	0.4776E-20	0.1632E-19	0.3630E-19	0.1327E-18	0.2461E-18
4	0.0	0.6879E-24	0.7234E-22	0.4949E-21	0.4476E-20	0.2378E-19	0.4396E-19	0.2042E-18	0.5696E-18

VARIABLE FORMAT AFMT( ) =(6E12.5,/,6E12.5,/,6E12.5,/,4E12.5)

VARIABLE FORMAT BFMT( ) =(6E12.5,/,6E12.5,/,6E12.5,/,4E12.5)

VARIABLE FORMAT CFMT( ) =(6E12.5,/,6E12.5,/,6E12.5,/,4E12.5)

THE INJECTION RATE AND/OR CONCENTRATION CHANGED AFTER TIME = 360.00 DAYS AND WILL REMAIN THERE THROUGH TIME = 3650.00 DAYS

VARIABLE FORMAT DFMT( ) =(10F8.0)

NUMBER OF WELLS = 2

WELL	CONCENTRATION (LB/LB)	COORDINATES I(X)	J(Y)	K(Z)	RATE/CELL (CU FT/SEC)
1	.111877E-06	12	7	1	0.0
				2	-0.060000
				3	-0.060000
				4	-0.060000
				5	-0.060000
				6	-0.060000
				7	0.0
				8	0.0
				9	0.0
				10	0.0
2	.300000E-01	18	10	1	0.0
				2	0.0
				3	0.0
				4	0.0
				5	0.0
				6	0.0
				7	0.0
				8	0.150000
				9	0.150000
				10	0.0

MAXIMUM ITERATIONS PER TIME STEP 20 ITERATIONS PER CYCLE 5

CONVERGENCE LIMIT ON FLUID FLOW ITERATION = 0.10000000E-03

ABSOLUTE VALUE OF SHRINK LIMIT-FLUID FLOW = 0.10000003E-05

CONVERGENCE LIMIT ON CONCENTRATION ITERATION = 0.10000000E-03

ABSOLUTE VALUE OF SHRINK LIMIT-CONCENTRATION = 0.10000003E-05

INTERMEDIATE RESULTS REQUESTED AT 1 TIMES
TIMES IN DAYS
1080.00000
VALUE OF SAVE = 10. PRINTED OUTPUT REQUESTED EVERY 25. TIME STEPS

```
FLOW**NIT =     1 ITCY =     0 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    1 H=   0.0            H1 =    0.3229580E-07
FLOW**NIT =     2 ITCY =     0 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    2 H=   0.3229580E-07H1 =    0.2504652E-06
FLOW**NIT =     3 ITCY =     0 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    3 H=   0.2504652E-06H1 =    0.1942443E-05
FLOW**NIT =     4 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    4 H=   0.1942443E-05H1 =    0.0
FLOW**NIT =     5 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    5 H=   0.0            H1 =    0.4164320E-08
FLOW**NIT =     6 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    6 H=   0.4164320E-08H1 =    0.3229580E-07
FLOW**NIT =     7 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    7 H=   0.3229580E-07H1 =    0.2504652E-06
FLOW**NIT =     8 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    8 H=   0.2504652E-06H1 =    0.1942443E-05
```

```
TOTAL PERIOD OF INJECTION                    390.0000 DAYS ( 0.337E+08 SECONDS)

     FLUID INJECTED TO DATE                                0.2158E+01
     TOTAL FLUID EXCHANGED WITH SURROUNDINGS               0.1017E+07

                                      DIFFERENCE           0.1017E+07

     CALCULATED ACCUMULATION TO DATE                       0.1014E+07

                                      ERROR                                  0.299081E+04


  LENGTH OF LAST TIME PERIOD                    30.0000 DAYS ( 0.259E+07 SECONDS)

     FLUID INJECTED IN LAST TIME PERIOD                    0.1875E+00
     FLUID EXCHANGED WITH SURROUNDINGS                     0.1369E+06

                                      DIFFERENCE           0.1369E+06

     CALCULATED ACCUMULATION IN LAST TIME PERIOD           0.1369E+06

                                      ERROR                                  0.128125E+02


  NUMBER OF ITERATIONS       8
  SUM OF RESIDUALS           0.161910E+01

     COMPONENT MASS INJECTED TO DATE                       0.1892E+08
     TOTAL MASS EXCHANGED WITH SURROUNDINGS               -0.7425E+05

                                      DIFFERENCE           0.1885E+08

     CALCULATED ACCUMULATION TO DATE                       0.1164E+08

                                      ERROR                                  0.721353E+07


     MASS INJECTED IN LAST TIME PERIOD                     0.1456E+07
     MASS EXCHANGED WITH SURROUNDINGS
             CONVECTION                  -0.1398E+05
             DIFFUSION                    0.0
             TOTAL                                        -0.1398E+05

                                      DIFFERENCE           0.1442E+07

     CALCULATED ACCUMULATION IN LAST TIME PERIOD           0.9946E+06

                                      ERROR                                  0.447089E+06

  NUMBER OF ITERATIONS       2
  SUM OF RESIDUALS           0.637613E-01

    TIME STEP NUMBER      1 COMPLETED
    PROCESSOR TIME UTILIZED, MILLISECONDS
       THIS TIME STEP --  11359
       TOTAL          --       0.1547E+05
```

```
FLOW**NIT =    1 ITCY =     0 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    1 H=   0.0            H1 =    0.3229580E-07
FLOW**NIT =    2 ITCY =     0 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    2 H=   0.3229580E-07H1 =    0.2504652E-06
FLOW**NIT =    3 ITCY =     0 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    3 H=   0.2504652E-06H1 =    0.1942443E-05
FLOW**NIT =    4 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    4 H=   0.1942443E-05H1 =    0.0
FLOW**NIT =    5 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    5 H=   0.0            H1 =    0.4164320E-08
FLOW**NIT =    6 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    6 H=   0.4164320E-08H1 =    0.3229580E-07
FLOW**NIT =    7 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    7 H=   0.3229580E-07H1 =    0.2504652E-06
FLOW**NIT =    8 ITCY =     1 IFIRST =     2 ILAST =    21 JFIRST =     2 JLAST =    12 KFIRST =     2 KLAST =     9
 NIT =    8 H=   0.2504652E-06H1 =    0.1942443E-05
```

```
TOTAL PERIOD OF INJECTION              1080.0000 DAYS ( 0.933E+08 SECONDS)

     FLUID INJECTED TO DATE                          0.1285E+02
     TOTAL FLUID EXCHANGED WITH SURROUNDINGS         0.3884E+07

                                   DIFFERENCE        0.3884E+07

     CALCULATED ACCUMULATION TO DATE                 0.3880E+07

                                   ERROR                            0.421400E+04


  LENGTH OF LAST TIME PERIOD               33.3320 DAYS ( 0.288E+07 SECONDS)

     FLUID INJECTED IN LAST TIME PERIOD              0.0
     FLUID EXCHANGED WITH SURROUNDINGS               0.1127E+06

                                   DIFFERENCE        0.1127E+06

     CALCULATED ACCUMULATION IN LAST TIME PERIOD     0.1127E+06

                                   ERROR                            0.268750E+02


  NUMBER OF ITERATIONS     8
  SUM OF RESIDUALS         -.245790E+01
```

DRAWDOWN DURING LAST TIME STEP IN FEET

K= 2

	2	3	4	5	6	7	8	9	10
2	0.5601E-01	0.3925E-01	0.4958E-01	0.6263E-01	0.7215E-01	0.7803E-01	0.8204E-01	0.8243E-01	0.7258E-01
3	0.2098E-02	0.4155E-01	0.5386E-01	0.7413E-01	0.9524E-01	0.1174E+00	0.1441E+00	0.1712E+00	0.1997E+00
4	0.3046E-01	0.4134E-01	0.5192E-01	0.6836E-01	0.8478E-01	0.1018E+00	0.1239E+00	0.1426E+00	0.1608E+00
5	0.2176E-01	0.4091E-01	0.5675E-01	0.7738E-01	0.9609E-01	0.1175E+00	0.1396E+00	0.1629E+00	0.1812E+00
6	0.6037E-01	0.3685E-01	0.4763E-01	0.5865E-01	0.6584E-01	0.7255E-01	0.7531E-01	0.7433E-01	0.6345E-01
7	0.2079E-01	0.3767E-01	0.5353E-01	0.6755E-01	0.8554E-01	0.1012E+00	0.1174E+00	0.1318E+00	0.1466E+00
8	0.2569E-01	0.4038E-01	0.5352E-01	0.6848E-01	0.8505E-01	0.1016E+00	0.1197E+00	0.1378E+00	0.1541E+00
9	0.2945E-01	0.3952E-01	0.5242E-01	0.6794E-01	0.8281E-01	0.9657E-01	0.1149E+00	0.1335E+00	0.1486E+00
10	0.3090E-01	0.3845E-01	0.5395E-01	0.6446E-01	0.8176E-01	0.9558E-01	0.1133E+00	0.1295E+00	0.1434E+00
11	0.3147E-01	0.3713E-01	0.5169E-01	0.6608E-01	0.8255E-01	0.9731E-01	0.1108E+00	0.1272E+00	0.1416E+00
12	0.3000E-01	0.3799E-01	0.5291E-01	0.6796E-01	0.8243E-01	0.9820E-01	0.1122E+00	0.1287E+00	0.1392E+00

K= 2

	11	12	13	14	15	16	17	18	19
2	0.5624E-01	0.2151E-01	-0.3958E-01	-0.1786E+00	-0.5382E+00	-0.1441E+01	-0.8951E+00	-0.1151E+01	-0.1174E+01
3	0.2311E+00	0.2472E+00	0.2457E+00	0.1689E+00	-0.1208E+00	-0.9188E+00	0.1483E+01	0.1422E+01	0.1670E+01
4	0.1786E+00	0.1848E+00	0.1702E+00	0.8224E-01	-0.2185E+00	-0.1014E+01	0.1158E+01	0.1102E+01	0.1373E+01
5	0.1989E+00	0.2098E+00	0.1906E+00	0.1048E+00	-0.1788E+00	-0.9285E+00	0.1084E+01	0.1090E+01	0.1391E+01
6	0.5010E-01	0.2280E-01	-0.2347E-01	-0.1248E+00	-0.3957E+00	-0.1078E+01	-0.6668E+00	-0.8462E+00	-0.9304E+00
7	0.1599E+00	0.1700E+00	0.1740E+00	0.1484E+00	0.9344E-02	-0.4330E+00	0.1702E-01	-0.1051E+00	-0.1523E+00
8	0.1741E+00	0.1907E+00	0.2109E+00	0.2182E+00	0.1367E+00	-0.1819E+00	0.2581E+00	0.1530E+00	0.1269E+00
9	0.1644E+00	0.1870E+00	0.2065E+00	0.2247E+00	0.1735E+00	-0.7254E-01	0.3307E+00	0.2350E+00	0.2184E+00
10	0.1598E+00	0.1789E+00	0.2012E+00	0.2226E+00	0.1897E+00	-0.1509E-01	0.3497E+00	0.2615E+00	0.2496E+00
11	0.1576E+00	0.1736E+00	0.1979E+00	0.2210E+00	0.1975E+00	0.1347E-01	0.3532E+00	0.2660E+00	0.2589E+00
12	0.1575E+00	0.1710E+00	0.1987E+00	0.2179E+00	0.1979E+00	0.2804E-01	0.3556E+00	0.2652E+00	0.2615E+00

K= 2

	20	21
2	-0.1470E+01	-0.7641E+00
3	-0.7951E+00	-0.1225E+00
4	-0.9647E+00	-0.2924E+00
5	-0.8976E+00	-0.2661E+00
6	-0.1118E+01	-0.5841E+00
7	-0.3365E+00	0.3081E-01
8	-0.4868E-01	0.2182E+00
9	0.5753E-01	0.2673E+00
10	0.1071E+00	0.2778E+00
11	0.1288E+00	0.2796E+00
12	0.1418E+00	0.2822E+00

K= 3

	2	3	4	5	6	7	8	9	10
2	0.5617E-01	0.3984E-01	0.4994E-01	0.6101E-01	0.6908E-01	0.8122E-01	0.8032E-01	0.7978E-01	0.7345E-01
3	0.1650E-02	0.3977E-01	0.5671E-01	0.7405E-01	0.9524E-01	0.1195E+00	0.1429E+00	0.1726E+00	0.2028E+00
4	0.3055E-01	0.3859E-01	0.5326E-01	0.6926E-01	0.8391E-01	0.1045E+00	0.1201E+00	0.1406E+00	0.1623E+00

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 2

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET								
	320.	960.	1600.	2240.	2880.	3520.	4160.	4800.	5440.
320.	1.0662	2.1473	3.2168	4.2802	5.3237	6.3170	7.1984	7.8731	8.1957
960.	1.0918	2.1604	3.2450	4.3306	5.4110	6.4659	7.4452	8.2653	8.7749
1600.	1.0911	2.1864	3.2970	4.4262	5.5824	6.7643	7.9530	9.0944	10.0520
2240.	1.1062	2.2136	3.3467	4.5229	5.7651	7.0979	8.5572	10.1657	11.8854
2880.	1.0988	2.2327	3.3886	4.6040	5.9217	7.3952	9.1273	11.2730	14.0796
3520.	1.1120	2.2314	3.3880	4.6140	5.9506	7.4770	9.3267	11.7760	15.4819
4160.	1.0999	2.2090	3.3538	4.5573	5.8597	7.3207	9.0383	11.1733	13.9744
4800.	1.0822	2.1733	3.2888	4.4456	5.6685	6.9861	8.4323	10.0353	11.7643
5440.	1.0638	2.1324	3.2105	4.3146	5.4406	6.5968	7.7635	8.8943	9.8633
6080.	1.0469	2.0955	3.1452	4.1978	5.2456	6.2699	7.2300	8.0392	8.5627
6720.	1.0380	2.0752	3.1057	4.1307	5.1338	6.0877	6.9367	7.5893	7.9137

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 2

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET								
	6080.	6720.	7360.	8000.	8640.	9280.	9920.	10560.	11200.
320.	7.9755	7.0233	5.2497	2.7956	-0.0179	-2.6847	-5.8467	-7.6940	-8.9895
960.	8.7347	7.8608	5.9534	3.2379	0.0867	-3.0673	-7.8251	-9.4952	-10.9010
1600.	10.5211	9.9471	7.7365	4.4868	0.7868	-2.9523	-8.2985	-10.1121	-11.6016
2240.	13.4206	13.7543	10.6466	6.3340	1.8312	-2.6145	-9.1269	-11.2601	-12.8554
2880.	17.7422	21.2594	15.0459	8.7076	3.3151	-1.1642	-5.5830	-8.1448	-9.6299
3520.	22.2971	38.5968	19.6365	10.2087	4.0304	-0.5355	-4.5090	-7.1343	-8.8064
4160.	17.6451	21.1951	15.0507	8.8440	3.6822	-0.4477	-4.0701	-6.6030	-8.3251
4800.	13.3380	13.7512	10.7961	6.7514	2.7277	-0.8173	-4.0901	-6.4834	-8.1438
5440.	10.3756	9.8998	7.8712	4.9256	1.7032	-1.3502	-4.3191	-6.5890	-8.1311
6080.	8.5767	7.8112	6.0954	3.6743	0.9227	-1.7813	-4.4882	-6.5792	-8.0984
6720.	7.7290	6.8681	5.2590	3.0521	0.5160	-2.0144	-4.5772	-6.5693	-8.0749

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 2

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET	
	11840.	12480.
320.	-9.4986	-10.1518
960.	-10.0894	-10.5616
1600.	-10.4017	-10.6805
2240.	-10.7083	-10.7518
2880.	-9.8873	-10.2835
3520.	-9.5983	-10.1321
4160.	-9.2802	-9.8586
4800.	-9.1071	-9.6757
5440.	-9.0488	-9.5890
6080.	-9.0164	-9.5470
6720.	-8.9984	-9.5296

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 6

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET 320.	960.	1600.	2240.	2880.	3520.	4160.	4800.	5440.
320.	1.0662	2.1466	3.2160	4.2787	5.3209	6.3142	7.1939	7.8694	8.1920
960.	1.0903	2.1603	3.2432	4.3286	5.4085	6.4615	7.4416	8.2600	8.7695
1600.	1.0893	2.1859	3.2945	4.4246	5.5802	6.7610	7.9481	9.0903	10.0469
2240.	1.1050	2.2134	3.3452	4.5211	5.7617	7.0942	8.5524	10.1608	11.8771
2880.	1.0989	2.2309	3.3851	4.6016	5.9179	7.3922	9.1233	11.2674	14.0710
3520.	1.1106	2.2304	3.3856	4.6121	5.9474	7.4729	9.3216	11.7679	15.4733
4160.	1.0991	2.2082	3.3518	4.5550	5.8565	7.3165	9.0342	11.1678	13.9661
4800.	1.0822	2.1723	3.2863	4.4437	5.6654	6.9811	8.4267	10.0291	11.7574
5440.	1.0628	2.1308	3.2097	4.3109	5.4369	6.5926	7.7582	8.8878	9.8559
6080.	1.0469	2.0936	3.1437	4.1952	5.2422	6.2664	7.2239	8.0333	8.5546
6720.	1.0382	2.0735	3.1041	4.1283	5.1300	6.0848	6.9323	7.5837	7.9066

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 6

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET								
	6080.	6720.	7360.	8000.	8640.	9280.	9920.	10560.	11200.
320.	7.9710	7.0183	5.2458	2.7930	-0.0195	-2.6846	-5.8396	-7.6890	-8.9846
960.	8.7299	7.8544	5.9485	3.2305	0.0781	-3.0790	-7.8811	-9.5136	-10.9069
1600.	10.5157	9.9406	7.7299	4.4805	0.7838	-2.9556	-8.3831	-10.1387	-11.6380
2240.	13.4128	13.7455	10.6389	6.3235	1.8174	-2.6380	-9.3721	-11.4538	-13.0558
2880.	17.7341	21.2485	15.0382	8.7003	3.3094	-1.1686	-5.5835	-8.1475	-9.6318
3520.	22.2856	38.5799	19.6249	10.1977	4.0197	-0.5454	-4.5158	-7.1421	-8.8131
4160.	17.6367	21.1834	15.0398	8.8334	3.6700	-0.4612	-4.0831	-6.6169	-8.3386
4800.	13.3282	13.7413	10.7856	6.7384	2.7134	-0.8342	-4.1095	-6.5083	-8.1638
5440.	10.3671	9.8892	7.8585	4.9137	1.6877	-1.3695	-4.3444	-6.6283	-8.1582
6080.	8.5681	7.7999	6.0845	3.6624	0.9061	-1.8024	-4.5116	-6.6066	-8.1246
6720.	7.7209	6.8581	5.2483	3.0369	0.4996	-2.0343	-4.5987	-6.5944	-8.0980

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 6

DISTANCE FROM X AXIS ORIGIN FEET

Y FEET	11840.	12480.
320.	-9.4952	-10.1496
960.	-10.0984	-10.5700
1600.	-10.4029	-10.6819
2240.	-10.7326	-10.7663
2880.	-9.8918	-10.2885
3520.	-9.6054	-10.1407
4160.	-9.2946	-9.8714
4800.	-9.1252	-9.6936
5440.	-9.0702	-9.6086
6080.	-9.0375	-9.5676
6720.	-9.0217	-9.5505

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 8

Y FEET	320.	960.	1600.	2240.	2880.	3520.	4160.	4800.	5440.
	DISTANCE FROM X AXIS ORIGIN FEET								
320.	-0.4576	-0.9408	-1.4579	-2.0331	-2.6815	-3.4116	-4.2291	-5.1270	-6.0860
960.	-0.4874	-0.9862	-1.5383	-2.1528	-2.8475	-3.6363	-4.5252	-5.5127	-6.5881
1600.	-0.4920	-1.0260	-1.5983	-2.2415	-2.9744	-3.8117	-4.7664	-5.8474	-7.0490
2240.	-0.5405	-1.1099	-1.7351	-2.4414	-3.2536	-4.1935	-5.2821	-6.5356	-7.9695
2880.	-0.5573	-1.1766	-1.8368	-2.5908	-3.4652	-4.4900	-5.6985	-7.1166	-8.7765
3520.	-0.6313	-1.2839	-2.0149	-2.8533	-3.8369	-5.0056	-6.4029	-8.0755	-10.0754
4160.	-0.6771	-1.3872	-2.1872	-3.1121	-4.2080	-5.5245	-7.1237	-9.0739	-11.4620
4800.	-0.7191	-1.4850	-2.3473	-3.3504	-4.5499	-6.0088	-7.8028	-10.0221	-12.7834
5440.	-0.7564	-1.5680	-2.4809	-3.5512	-4.8407	-6.4208	-8.3806	-10.8253	-13.8946
6080.	-0.7859	-1.6284	-2.5798	-3.6970	-5.0514	-6.7182	-8.7981	-11.4057	-14.6894
6720.	-0.8003	-1.6596	-2.6297	-3.7749	-5.1627	-6.8762	-9.0173	-11.7096	-15.1022

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 8

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET								
	6080.	6720.	7360.	8000.	8640.	9280.	9920.	10560.	11200.
320.	-7.0606	-7.9756	-8.7150	-9.1422	-9.1684	-8.9552	-10.1495	-10.1485	-11.9846
960.	-7.7132	-8.8202	-9.7940	-10.4671	-10.6673	-10.3239	-8.0209	-9.5347	-10.9913
1600.	-8.3494	-9.6924	-10.9629	-11.9368	-12.3085	-11.7475	-8.4971	-10.1358	-11.7155
2240.	-9.5824	-11.3560	-13.2112	-14.8906	-15.9718	-15.6721	-9.7563	-11.6417	-13.4047
2880.	-10.7075	-12.9411	-15.5041	-18.1442	-20.5551	-22.4357	-24.5583	-25.9113	-28.2967
3520.	-12.4655	-15.3280	-18.8865	-22.8789	-27.1433	-31.5079	-36.6689	-39.6533	-41.3788
4160.	-14.3959	-18.0302	-22.5590	-27.9902	-34.3658	-41.7047	-50.5060	-56.5460	-56.2813
4800.	-16.2325	-20.5625	-26.0099	-32.8101	-41.3410	-52.2512	-67.0257	-81.5863	-73.7892
5440.	-17.7574	-22.6305	-28.7873	-36.5947	-46.7249	-60.7661	-84.1088	-131.1178	-91.6523
6080.	-18.8308	-24.0459	-30.5993	-38.8006	-49.0498	-61.8617	-78.2877	-94.0485	-86.3309
6720.	-19.3793	-24.7529	-31.4592	-39.7256	-49.6927	-61.1926	-73.8342	-82.6721	-82.1101

TOTAL TIME SIMULATED 1080.00 DAYS

CUMULATIVE DRAWDOWN FOR LAYER NUMBER 8

DISTANCE FROM X AXIS ORIGIN FEET

Y FEET	11840.	12480.
320.	-12.1644	-13.0572
960.	-14.2568	-15.4585
1600.	-16.4010	-18.1894
2240.	-21.5744	-23.9355
2880.	-29.8622	-31.0977
3520.	-41.0499	-41.2287
4160.	-53.5115	-52.2727
4800.	-66.1560	-62.8206
5440.	-76.3064	-70.9268
6080.	-78.3949	-74.6868
6720.	-78.1578	-75.8540

TOTAL TIME SIMULATED 1080.00 DAYS

HEAD DISTRIBUTION FOR LAYER NUMBER 2

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET 6080.	6720.	7360.	8000.	8640.	9280.	9920.	10560.	11200.
320.	950.0188	950.9709	952.7444	955.1990	958.0132	960.6802	963.8425	965.6899	966.9856
960.	949.2588	950.1326	952.0400	954.7561	957.9084	961.0618	965.8208	967.4900	968.8965
1600.	947.4717	948.0430	950.2563	953.5068	957.2068	960.9478	966.2942	968.1077	969.5969
2240.	944.5693	944.2363	947.3425	951.6582	956.1619	960.6089	967.1226	969.2554	970.8511
2880.	940.2478	936.7312	942.9436	949.2827	954.6765	959.1575	963.5767	966.1392	967.6250
3520.	935.6934	919.3948	938.3528	947.7817	953.9604	958.5305	962.5032	965.1292	966.8018
4160.	940.3440	936.7957	942.9387	949.1460	954.3108	958.4409	962.0645	964.5979	966.3201
4800.	944.6521	944.2388	947.1936	951.2407	955.2651	958.8118	962.0850	964.4795	966.1394
5440.	947.6165	948.0906	950.1206	953.0664	956.2915	959.3452	962.3137	964.5837	966.1262
6080.	949.4172	950.1824	951.8979	954.3196	957.0718	959.7771	962.4832	964.5740	966.0942
6720.	950.2656	951.1257	952.7356	954.9431	957.4790	960.0095	962.5723	964.5647	966.0708

TOTAL TIME SIMULATED 1080.00 DAYS

HEAD DISTRIBUTION FOR LAYER NUMBER 2

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET								
	320.	960.	1600.	2240.	2880.	3520.	4160.	4800.	5440.
320.	956.9299	955.8489	954.7786	953.7151	952.6711	951.6785	950.7969	950.1223	949.7986
960.	956.9053	955.8352	954.7502	953.6650	952.5842	951.5295	950.5496	949.7290	949.2200
1600.	956.9058	955.8098	954.6992	953.5696	952.4124	951.2302	950.0425	948.8994	947.9409
2240.	956.8901	955.7825	954.6482	953.4727	952.2307	950.8967	949.4368	947.8276	946.1069
2880.	956.8972	955.7634	954.6082	953.3916	952.0740	950.5986	948.8667	946.7192	943.9109
3520.	956.8843	955.7644	954.6074	953.3811	952.0439	950.5176	948.6675	946.2156	942.5090
4160.	956.8965	955.7866	954.6423	953.4380	952.1353	950.6733	948.9556	946.8186	944.0156
4800.	956.9138	955.8223	954.7070	953.5500	952.3269	951.0083	949.5623	947.9580	946.2273
5440.	956.9329	955.8640	954.7849	953.6816	952.5542	951.3982	950.2312	949.0991	948.1301
6080.	956.9492	955.9001	954.8508	953.7979	952.7500	951.7249	950.7656	949.9551	949.4321
6720.	956.9578	955.9216	954.8901	953.8652	952.8606	951.9075	951.0581	950.4055	950.0806

TOTAL TIME SIMULATED 1080.00 DAYS

HEAD DISTRIBUTION FOR LAYER NUMBER 2

DISTANCE FROM X AXIS ORIGIN FEET

Y FEET	11840.	12480.
320.	967.4937	968.1475
960.	968.0845	968.5574
1600.	968.3975	968.6760
2240.	968.7043	968.7473
2880.	967.8831	968.2791
3520.	967.5925	968.1270
4160.	967.2759	967.8540
4800.	967.1025	967.6711
5440.	967.0449	967.5845
6080.	967.0112	967.5430
6720.	966.9941	967.5251

FLUID EXCHANGE AT EACH LOCATION - THIS TIME STEP, CU.FT.

K= 2

	2	3	4	5	6	7	8	9	10
2	0.2626E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.2686E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.2685E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.2723E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.2706E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.2738E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.2708E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.2665E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.2618E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.2578E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.2557E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	11	12	13	14	15	16	17	18	19
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	20	21
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
6	0.0	0.0
7	0.0	0.0
8	0.0	0.0
9	0.0	0.0
10	0.0	0.0
11	0.0	0.0
12	0.0	0.0

K= 3

	2	3	4	5	6	7	8	9	10
2	0.2625E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.2687E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.2684E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
     COMPONENT MASS INJECTED TO DATE                        0.5240E+08
     TOTAL MASS EXCHANGED WITH SURROUNDINGS                -0.7101E+06

                                      DIFFERENCE            0.5169E+08

     CALCULATED ACCUMULATION TO DATE                        0.3493E+08

                                      ERROR                                  0.167598E+08


     MASS INJECTED IN LAST TIME PERIOD                      0.1617E+07
     MASS EXCHANGED WITH SURROUNDINGS
              CONVECTION                 -0.4206E+05
              DIFFUSION                   0.0
              TOTAL                                        -0.4206E+05

                                      DIFFERENCE            0.1575E+07

     CALCULATED ACCUMULATION IN LAST TIME PERIOD            0.1149E+07

                                      ERROR                                  0.425875E+06


 NUMBER OF ITERATIONS      2
 SUM OF RESIDUALS          -.162206E+00
```

WELL	COORDINATES X	Y	INJECTION RATE CU. FT/SEC	CONCENTRATION LB/LB
1	6720.	3520.	-0.3000	0.1202E-05
2	10560.	5440.	0.3000	0.3000E-01

TOTAL TIME SIMULATED 1080.00 DAYS

CONCENTRATION DISTRIBUTION FOR LAYER NUMBER 2 LB/LB WATER

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET 320.	960.	1600.	2240.	2880.	3520.	4160.	4800.	5440.
320.	0.7160E-25	0.1420E-22	0.3326E-22	0.1064E-20	0.3810E-20	0.6835E-20	0.1347E-19	0.5741E-19	0.2504E-19
960.	0.1413E-23	0.8874E-23	0.2455E-21	0.2921E-21	0.1109E-20	0.7354E-20	0.1290E-19	0.2937E-19	0.9886E-19
1600.	0.1171E-24	0.3090E-22	0.1252E-21	0.3954E-21	0.1807E-20	0.9786E-20	0.6507E-19	0.8146E-19	0.1222E-18
2240.	0.8023E-24	0.1556E-22	0.1563E-21	0.1567E-20	0.2061E-20	0.1523E-19	0.3611E-19	0.1997E-18	0.2874E-18
2880.	0.1080E-24	0.2168E-22	0.2153E-21	0.1443E-20	0.2505E-20	0.1616E-19	0.5512E-19	0.3597E-18	0.1160E-17
3520.	0.2050E-23	0.6713E-22	0.2738E-21	0.9194E-21	0.9796E-20	0.1959E-19	0.9828E-19	0.2496E-18	0.1555E-17
4160.	0.8548E-24	0.1038E-22	0.2432E-21	0.8114E-21	0.4422E-20	0.1811E-19	0.7056E-19	0.4364E-18	0.1311E-17
4800.	0.1278E-23	0.2264E-22	0.2825E-21	0.3064E-20	0.4096E-20	0.4533E-19	0.6930E-19	0.8062E-18	0.1101E-17
5440.	0.2948E-23	0.1454E-22	0.1306E-20	0.2324E-20	0.8089E-20	0.4165E-19	0.7008E-19	0.4276E-18	0.8380E-18
6080.	0.9524E-23	0.7323E-22	0.1685E-21	0.8366E-21	0.9719E-20	0.2107E-19	0.1256E-18	0.2027E-18	0.6460E-18
6720.	0.1289E-23	0.3062E-22	0.6354E-21	0.1932E-20	0.1594E-19	0.2140E-19	0.6506E-19	0.4374E-18	0.1003E-17

TOTAL TIME SIMULATED 1080.00 DAYS

CONCENTRATION DISTRIBUTION FOR LAYER NUMBER 6 LB/LB WATER

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET 320.	960.	1600.	2240.	2880.	3520.	4160.	4800.	5440.
320.	0.3562E-08	0.1452E-07	0.3528E-07	0.6407E-07	0.9797E-07	0.1636E-06	0.2166E-06	0.2934E-06	0.3681E-06
960.	0.4956E-08	0.1474E-07	0.3763E-07	0.6717E-07	0.1093E-06	0.1700E-06	0.2397E-06	0.3305E-06	0.4216E-06
1600.	0.3421E-08	0.1670E-07	0.3891E-07	0.7183E-07	0.1197E-06	0.1894E-06	0.2720E-06	0.3879E-06	0.5315E-06
2240.	0.4278E-08	0.2283E-07	0.4099E-07	0.7541E-07	0.1344E-06	0.2172E-06	0.3263E-06	0.4795E-06	0.7132E-06
2880.	0.4306E-08	0.1763E-07	0.4232E-07	0.8330E-07	0.1499E-06	0.2412E-06	0.3972E-06	0.6061E-06	0.9934E-06
3520.	0.4724E-08	0.2227E-07	0.4669E-07	0.9378E-07	0.1564E-06	0.2674E-06	0.4341E-06	0.7199E-06	0.1240E-05
4160.	0.6667E-08	0.2049E-07	0.4949E-07	0.9736E-07	0.1660E-06	0.2827E-06	0.4651E-06	0.7353E-06	0.1200E-05
4800.	0.5055E-08	0.2098E-07	0.5041E-07	0.9589E-07	0.1737E-06	0.2875E-06	0.4525E-06	0.6999E-06	0.1091E-05
5440.	0.5004E-08	0.2115E-07	0.5079E-07	0.9996E-07	0.1690E-06	0.2949E-06	0.4382E-06	0.6640E-06	0.1010E-05
6080.	0.5608E-08	0.2123E-07	0.5269E-07	0.9970E-07	0.1714E-06	0.2847E-06	0.4490E-06	0.6526E-06	0.9571E-06
6720.	0.5385E-08	0.2242E-07	0.4998E-07	0.1027E-06	0.1627E-06	0.2840E-06	0.4327E-06	0.6365E-06	0.9307E-06

TOTAL TIME SIMULATED 1080.00 DAYS

CONCENTRATION DISTRIBUTION FOR LAYER NUMBER 6 LB/LB WATER

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET								
	6080.	6720.	7360.	8000.	8640.	9280.	9920.	10560.	11200.
320.	0.3989E-06	0.4254E-06	0.3766E-06	0.2712E-06	0.1565E-06	0.6972E-07	0.4284E-06	0.3002E-07	0.8950E-07
960.	0.4734E-06	0.5108E-06	0.4513E-06	0.3329E-06	0.2230E-06	0.2931E-05	0.1726E-03	0.6464E-05	0.4029E-04
1600.	0.6574E-06	0.7375E-06	0.6549E-06	0.4772E-06	0.3637E-06	0.3481E-05	0.1745E-03	0.5013E-05	0.6837E-04
2240.	0.1013E-05	0.1170E-05	0.1071E-05	0.8221E-06	0.1232E-05	0.3722E-04	0.1452E-02	0.5863E-03	0.1175E-02
2880.	0.1576E-05	0.2311E-05	0.1826E-05	0.1392E-05	0.1137E-05	0.1245E-05	0.1661E-04	0.6024E-05	0.1121E-04
3520.	0.2358E-05	0.6147E-05	0.2923E-05	0.2133E-05	0.1947E-05	0.1829E-05	0.2053E-05	0.2041E-05	0.2075E-05
4160.	0.1959E-05	0.3061E-05	0.2775E-05	0.2599E-05	0.2926E-05	0.3370E-05	0.4254E-05	0.5041E-05	0.4555E-05
4800.	0.1644E-05	0.2221E-05	0.2616E-05	0.2962E-05	0.3904E-05	0.5280E-05	0.8083E-05	0.1206E-04	0.8717E-05
5440.	0.1455E-05	0.1953E-05	0.2528E-05	0.3266E-05	0.4658E-05	0.7076E-05	0.1382E-04	0.4113E-04	0.1457E-04
6080.	0.1342E-05	0.1844E-05	0.2510E-05	0.3398E-05	0.4821E-05	0.7167E-05	0.1097E-04	0.1611E-04	0.1210E-04
6720.	0.1298E-05	0.1850E-05	0.2452E-05	0.3444E-05	0.4866E-05	0.6896E-05	0.9390E-05	0.1168E-04	0.1075E-04

TOTAL TIME SIMULATED 1080.00 DAYS

CONCENTRATION DISTRIBUTION FOR LAYER NUMBER 6 LB/LB WATER

Y FEET	DISTANCE FROM X AXIS ORIGIN FEET	
	11840.	12480.
320.	0.1040E-07	0.2148E-07
960.	0.3927E-07	0.3248E-07
1600.	0.1654E-06	0.9234E-07
2240.	0.5420E-05	0.2834E-06
2880.	0.7501E-06	0.8439E-06
3520.	0.1936E-05	0.1920E-05
4160.	0.3833E-05	0.3593E-05
4800.	0.6465E-05	0.5582E-05
5440.	0.9057E-05	0.7421E-05
6080.	0.9639E-05	0.8289E-05
6720.	0.9432E-05	0.8521E-05

MASS EXCHANGE AT EACH LOCATION - THIS TIME STEP, LB

K= 2

	2	3	4	5	6	7	8	9	10
2	0.1173E-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.2369E-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.1961E-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.1363E-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.1823E-19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.3501E-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.1444E-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.2125E-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.4817E-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.1532E-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.2057E-18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	11	12	13	14	15	16	17	18	19
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 2

	20	21
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
6	0.0	0.0
7	0.0	0.0
8	0.0	0.0
9	0.0	0.0
10	0.0	0.0
11	0.0	0.0
12	0.0	0.0

K= 3

	2	3	4	5	6	7	8	9	10
2	0.4965E-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.5540E-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.9541E-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

K= 9

	20	21
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
6	0.0	0.0
7	0.0	0.0
8	0.0	0.0
9	0.0	0.0
10	0.0	0.0
11	0.0	0.0
12	0.0	0.0

```
TIME STEP NUMBER     10 COMPLETED
PROCESSOR TIME UTILIZED, MILLISECONDS
   THIS TIME STEP --  13044
   TOTAL          --       0.1243E+06
```

```
FILE    69 ON TAPE 11224 HAS COVERX(22,13,10)
FILE    70 ON TAPE 11224 HAS COVERY(22,13,10)
FILE    71 ON TAPE 11224 HAS COVERZ(22,13,10)
FILE    72 ON TAPE 11224 HAS SS    (22,13,10)
FILE    73 ON TAPE 11224 HAS COEFX (22,13,10)
FILE    74 ON TAPE 11224 HAS COEFY (22,13,10)
FILE    75 ON TAPE 11224 HAS COEFZ (22,13,10)
FILE    76 ON TAPE 11224 HAS HEAD  (22,13,10)
FILE    77 ON TAPE 11224 HAS PRES  (22,13,10)
FILE    78 ON TAPE 11224 HAS DRAWDN(22,13,10)
FILE    79 ON TAPE 11224 HAS DX    (22,13,10)
FILE    80 ON TAPE 11224 HAS DY    (22,13,10)
FILE    81 ON TAPE 11224 HAS DZ    (22,13,10)
FILE    82 ON TAPE 11224 HAS QEXCHG(22,13,10)
FILE    83 ON TAPE 11224 HAS BCONC (22,13,10)
FILE    84 ON TAPE 11224 HAS F     (22,13,10)
FILE    85 ON TAPE 11224 HAS MISC. DATA NEEDED TO CONTINUE CALCULATIONS AT A LATER TIME
TOQINJ =  0.52403248E+08TOQACC =     0.34933360E+08   TOQEX = -0.71011137E+06   TOTAL = 0.93312000E+08
    TOINJ =  0.12845947E+02    TOOUT = 0.38838610E+07

FILE    86 ON TAPE 11224 HAS COVERX(22,13,10)
FILE    87 ON TAPE 11224 HAS COVERY(22,13,10)
FILE    88 ON TAPE 11224 HAS COVERZ(22,13,10)
FILE    89 ON TAPE 11224 HAS SS    (22,13,10)
FILE    90 ON TAPE 11224 HAS COEFX (22,13,10)
FILE    91 ON TAPE 11224 HAS COEFY (22,13,10)
FILE    92 ON TAPE 11224 HAS COEFZ (22,13,10)
FILE    93 ON TAPE 11224 HAS HEAD  (22,13,10)
FILE    94 ON TAPE 11224 HAS PRES  (22,13,10)
FILE    95 ON TAPE 11224 HAS DRAWDN(22,13,10)
FILE    96 ON TAPE 11224 HAS DX    (22,13,10)
FILE    97 ON TAPE 11224 HAS DY    (22,13,10)
FILE    98 ON TAPE 11224 HAS DZ    (22,13,10)
FILE    99 ON TAPE 11224 HAS QEXCHG(22,13,10)
FILE   100 ON TAPE 11224 HAS BCONC (22,13,10)
FILE   101 ON TAPE 11224 HAS F     (22,13,10)
FILE   102 ON TAPE 11224 HAS MISC. DATA NEEDED TO CONTINUE CALCULATIONS AT A LATER TIME
TOQINJ =  0.52403248E+08TOQACC =     0.34933360E+08   TOQEX = -0.71011137E+06   TOTAL = 0.93312000E+08
    TOINJ =  0.12845947E+02    TOOUT = 0.38838610E+07
FILE   103 ON TAPE 11224 IS EMPTY
```

Section F

REFERENCES

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GROUND-WATER AND CONTAMINANT TRANSPORT MODELING: GARBER-WELLINGTON AQUIFER IN OKLAHOMA

PART III

POTENTIAL SALT-WATER UPCONING IN THE YUKON WELL FIELD

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POTENTIAL SALT-WATER UPCONING

IN THE YUKON WELL FIELD

Introduction

The potential for salinization of the Yukon Well Field can be evaluated using a relatively simple analytical model for the rise of a salt-water/fresh-water interface below a pumping well. This approach is justified since data are not available for concentrations of salt water underlying the fresh water. In addition, there does not appear to be a documented case of salt-water upconing on the Garber-Wellington Aquifer.

The mathematical development of the analytical model is presented in the next section. The model is then used to estimate the potential for salt water upconing below Well No. 5 of the Yukon Well Field.

Mathematical Development

McWhorter (1972) presented the equations which describe the flow in saturated aquifers which are underlain by a zone of saline water and pointed out the difficulties in obtaining solutions to these problems. The complexity of the flow phenomenon has led many investigators to idealize the system as a fresh-water zone separated from an underlying salt-water zone by a sharp interface. In other words, the two fluids are assumed to be immiscible.

Upconing of an Abrupt Interface

The following discussion is based on the studies of Bear and Dagan as reported by Schmorak and Mercado (1969). The basic assumptions underlying the theoretical development are: (1) the porous medium is homogeneous and nondeformable, (2) the two fluids are incompressible, immiscible, and separated by an abrupt interface (a geometric surface), and (3) the flow obeys Darcy's law. The non-linear boundary condition along the interface between the two fluids constitutes the major difficulty with the immiscible formulation of the problem. Bear and Dagan used the method of small pertubations to obtain an approximate solution for the position of the interface which served as a tool for obtaining analytical solutions for cases involving small deviations from an initially steady interface.

For the case of upconing beneath a pumping well partially penetrating a relatively thick confined aquifer as shown in Figure 1, Schmorak and Mercado (1969) presented Bear and Dagan's solution for the position of the interface as a function of time and radial distance from the pumping well as

$$X(r,t) = \frac{Q}{2\pi(\Delta\rho/\rho)K_x d}\left\{\frac{1}{(1+R^2)^{\frac{1}{2}}} - \frac{1}{\left[(1+\tau)^2+R^2\right]^{\frac{1}{2}}}\right\} \qquad (1)$$

where R and τ are dimensionless distance and time parameters defined by

$$R = \frac{r}{d}\left(\frac{K_z}{K_x}\right)^{\frac{1}{2}} \qquad (2)$$

and

$$\tau = \frac{(\Delta\rho/\rho)K_z}{2\theta d}\, t \qquad (3)$$

Other notations are defined as follows (also refer to Figure 1):

d	distance from the bottom of the well to the initial interface elevation (L)
K_x, K_z	horizontal and vertical permeabilities, respectively (L/t)
Q	well pumping rate (L^3/t)
r	radial distance from well axis (L)
t	time elapsed since start of pumping (t)

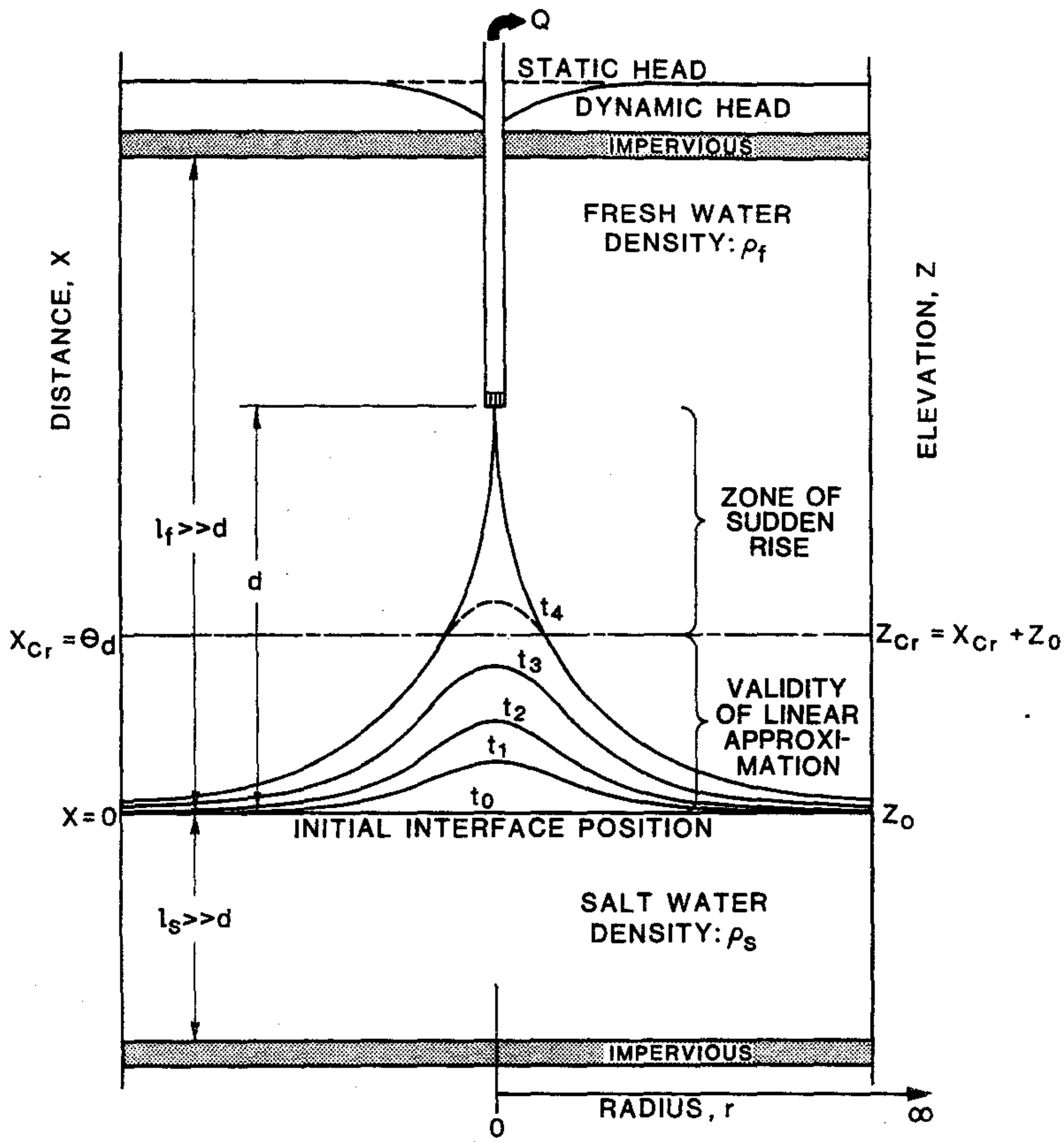

Figure 1. Upconing of an abrupt interface below a pumping well.

X rise of the interface above its initial position (L)

$\Delta\rho/\rho$ dimensionless density difference between the two fluids, $(\rho_s - \rho_f)/\rho_f$

θ porosity of the aquifer

Application of the method of small pertubations restricts changes in the interface elevation to relatively small values. In terms of the physical problem, this restriction implies $d<<l_f$ and $d<<l_s$. Although the governing differential equations have been formulated for a confined aquifer, the results can be applied to unconfined systems if the drawdown is negligible compared to the saturated thickness of the fresh-water zone.

The linear relationship, Equation 1, between the rise of the interface and the pumping rate is limited to a certain "critical rise," X_{cr}. This limitation arises from linear approximation of the boundary conditions. As the interface approaches this critical rise, the rate of rise increases. Above the critical rise the interface reaches the pumping well with a sudden jump. Muskat (1946) defines the zone of accelerated rise for $X/d > 0.48$ and the critical rise within the limits of $X/d \sim 0.60$ to 0.75. Schmorak and Mercado (1966) recommend application of the linear approximation for $X/d < \sim 0.5$. Sahni (1972) investigated the zone of instability of the interface using both numerical and physical models and recommended design criteria for skimming wells.

An abrupt interface such that (1) salinization of the pumping well occurs only for $X > X_{cr}=fd$ where f is the fractional critical rise, and (2) Equation 1 is valid for $0 \leq X \leq X_{cr}$ will be assumed in this report. Thus, the maximum permissible pumping rate which will ensure salt-free water can be obtained from Equation 1.

For $r = 0$ and $t \to \infty$

$$X(0,\infty) = \frac{Q}{2\pi d(\Delta\rho/\rho)K_x} \tag{4}$$

and

$$Q_{max} = 2\pi d(\Delta\rho/\rho)K_x X_{cr} \tag{5}$$

The time required for the interface to reach the critical rise at a specified pumping rate, Q, estimated by rewriting Equation 1 as

$$\tau(x = x_{cr}) = \frac{2\theta d}{(\Delta\rho/\rho)K_z} \left\{ \frac{1}{1 - \left[2\pi(\Delta\rho/\rho)K_x dX_{cr}\right] /Q} - 1 \right\} \tag{6}$$

Substituting Equation 5 into Equation 6 yields

$$\tau(x = x_{cr}) = \frac{2\theta d}{(\Delta\rho/\rho)K_z} \left\{ \frac{1}{1-Q_{max}/Q} - 1 \right\} \tag{7}$$

Equation 7 can be used to estimate the time required to reach a predetermined salinity in the pumped water for pumping rates, Q, greater than the maximum steady-state pumping rate, Q_{max}.

Well No. 5

Data for Well No. 5 of the Yukon Well Field are summarized in Table 1. The fresh-water and salt-water specific gravities have been assumed to be 1.000 and 1.025, respectively. The average pumping rate for this well has been estimated at 112.2 gpm, or 21,600 ft^3/day, with the bottom of the well located 125 ft. above the salt-water/fresh-water interface.

Geologic cross sections developed from well logs indicated that the salt water was confined by a low permeability shale zone. In an effort to determine the effect of the "layered" geologic structure below Well No. 5, upconing curves were computed using Equation 4 and the data from Table 1 for several values of vertical permeability. The maximum steady-state pumping rate and times required for an abrupt interface to reach the critical

TABLE 1

Yukon Well Field
Well No. 5

Depth of well	825. ft
Depth to salt-water interface	950. ft
Distance from bottom of well to initial interface	125. ft
Porosity	0.3
Permeability	3.34 ft/dy
Average pumping rate	21,600. ft^3/dy
Specific gravity of fresh water	1.000
Specific gravity of salt water	1.025 (Assumed)
Fractional critical rise	0.5 (Assumed)

use were also calculated using Equations 5 and 7. The results of these calculations are summarized in Figure 2 and Table 2.

As the vertical permeability decreases the rate of upconing decreases. Thus, as the formation becomes more stratified in the horizontal plane, the potential for salinization of the well during the life of the well field decreases.

These upconing simulations can only be interpreted qualitatively as a result of inadequate field data. However, the results do tend to support the hypothesis that salt water is confined by the shale zones of the Garber-Wellington formation in the area of the Yukon Well Field.

TABLE 2

Results of Simulated Upconing

Yukon Well Field
Well No. 5

Pumping Rate	112.2 GPM
Horizontal Permeability K_x	3.34 ft/day
Maximum permissible steady state pumping rate to prevent salinization of well	21.29 GPM

K_z/K_x	Time to Reach Critical Rise (Yr.)
1.0	0.58
0.75	0.77
0.50	1.15
0.25	2.30
0.10	5.76
0.05	11.53
0.01	57.63

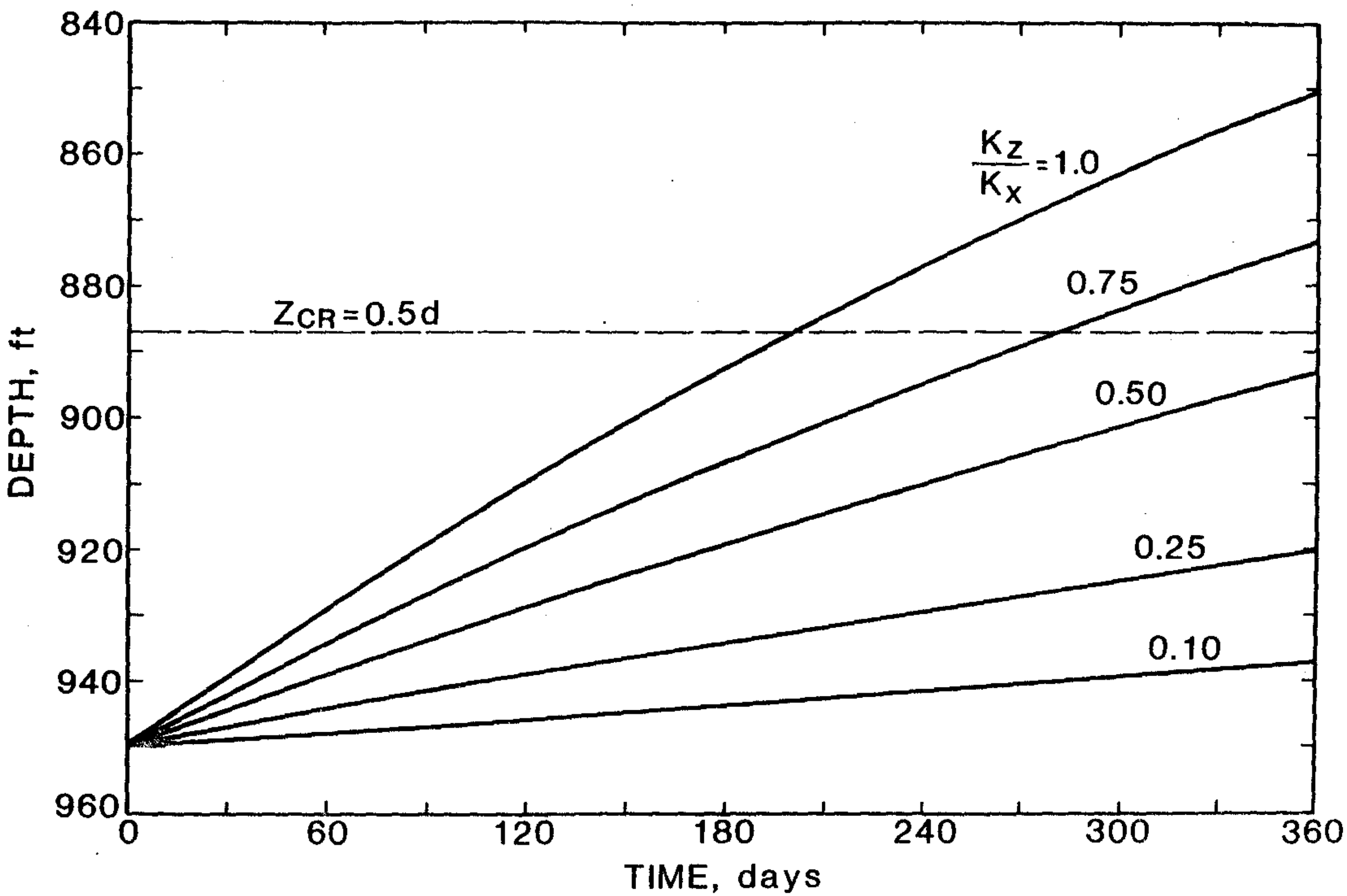

Figure 2 - Simulated upconing for Well No. 5 Yukon Well Field

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