A ONE-DIMENSIONAL, FINITE ELEMENT SALT WATER INTRUSION MODEL

By

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Groundwater resources near the coastline and on islands should be managed in such a way that salt water intrusion into the aquifer does not jeopardize the quality of the water resource. Management of the salt water intrusion means knowing the location of the wedge and predicting its response to changes in aquifer recharge and pumpage so that its future location can be controlled. Observation wells strategically located in the aquifer could be used to determine the present location of the salt water wedge. However, to predict the response of the wedge to altered conditions of recharge and pumping, one must have a model to simulate the dynamics of the salt water wedge. These models may be analytical in nature for simple geometries or numerical for more complicated aquifers.

For many aquifers, one may assume that the fresh water and the salt water are two immiscible liquids of different densities that are separated by a sharp interface. A variety of numerical, computer models have been reported in the technical literature simulating the dynamics of the interface (1,2,3). Continuity of pressure across the interface is maintained and the velocity of the two fluids parallel to the interface can and will be different. If the velocity of the salt water is assumed to be zero everywhere, then the Ghyben-Herzberg condition is satisfied. Interface models have been applied to confined and unconfined aquifers, can be steady or unsteady and have been applied in one or more dimensions.

A sharp interface model is only a convenient approximation to actual field conditions. The shear stress along the interface and the hydrodynamic dispersion that occurs when the interface moves (due to sea-level fluctuations or variations in recharge) causes the interface to lose its sharpness and the density to vary gradually across a transition zone. If it can be shown that the density does not vary over a significant portion of the aquifer; i.e. the transition zone is narrow, one may still use a sharp interface model. However, there do exist some aquifers where the sharp interface model will not provide meaningful results and a dispersion model would have to be used. Compared with sharp-interface models, dispersion models are more complex as they have to take into account the mass balance of salt and the relationship between salt concentration and density of the salt water. Most of the dispersion models have been developed for a vertical cross section only (4,5). In addition to knowing the usual aquifer properties such as porosity and permeability, dispersion models also require knowledge of dispersion coefficients of the aquifer. Because of these difficulties, dispersion models have been applied to relatively few natural aquifers.

This report describes a one-dimensional, finite element salt water intrusion model. Such a model can be very useful in understanding local features of an extensive aquifer system. Certainly, two-dimensional models are available and should be used whenever the necessary data, computer facilities and cost are available. However, when first-cut results are necessary in a limited time frame, a one-dimensional model may be the appropriate tool. Two dimensional models can of course be used to provide one dimensional results; but, only by the use of twice the number of nodes as used in a one-dimensional model.

FINITE ELEMENT METHOD

The depth-averaged equations of motion and continuity have been derived in references 1,2,3 and 6. The one-dimensional equations for fresh water and salt water are given below.

$$\frac{\partial}{\partial x}\left(K^f b^f \frac{\partial \phi^f}{\partial x}\right) + q^f + N = \frac{n\gamma^f}{\Delta\gamma}\frac{\partial \phi^f}{\partial t} - \frac{n\gamma^s}{\Delta\gamma}\frac{\partial \phi^s}{\partial t} \quad \ldots\ldots(1)$$

$$\frac{\partial}{\partial x}\left(K^s b^s \frac{\partial \phi^s}{\partial x}\right) = \frac{n\gamma^s}{\Delta\gamma}\frac{\partial \phi^s}{\partial t} - \frac{n\gamma^f}{\Delta\gamma}\frac{\partial \phi^f}{\partial t} \quad \ldots\ldots(2)$$

To maintain continuity of pressure at the interface, the following equation must be satisfied, resulting in the depth of the interface below mean sea level.

$$\zeta = \frac{\gamma^s}{\Delta\gamma}\phi^s - \frac{\gamma^f}{\Delta\gamma}\phi^f \quad \ldots\ldots\ldots\ldots(3)$$

The partial differential equations (1) and (2) are solved numerically using the finite element method. Linear variation of variables within an element is assumed.

Thus,
$$\phi^f = N_1\phi_1^f + N_2\phi_2^f \quad \ldots\ldots\ldots\ldots(4)$$

where
$$N_1 = 1 - \frac{x}{l} \quad \ldots\ldots\ldots\ldots(5)$$

and
$$N_2 = \frac{x}{l} \quad \ldots\ldots\ldots\ldots(6)$$

Similar equations can be written for ϕ^s, b^f and b^s. The variables N, K and n are assumed to be constant within an element. Substituting these approximations into equations (1) and (2) will yield residuals R^f and R^s from each equation. Using Galerkin's method, we have

$$\int N_i R^f dx = 0 \qquad i = 1,2 \quad \cdots\cdots (7)$$

$$\int N_i R^s dx = 0 \qquad i = 1,2 \quad \cdots\cdots (8)$$

Upon integration, the final element equations are given below.

$$-\frac{K^f b^f}{l}\Big|_1 [-1 \ \ +1]\{\phi^f\}^e - K^f\left(\frac{b_1^f + b_2^f}{2l}\right)[+1 \ \ -1]\{\phi^f\}^e + \frac{Nl}{2}$$
$$+ q_v^f + \frac{n\gamma^s}{\Delta\gamma}\left[\frac{l}{3} \ \ \frac{l}{6}\right]\left\{\frac{\partial\phi^s}{\partial t}\right\}^e - \frac{n\gamma^f}{\Delta\gamma}\left[\frac{l}{3} \ \ \frac{l}{6}\right]\left\{\frac{\partial\phi^f}{\partial t}\right\}^e = 0. \quad (9)$$

$$\frac{K^f b^f}{l}\Big|_2 [-1 \ \ +1]\{\phi^f\}^e - K^f\left(\frac{b_1^f + b_2^f}{2l}\right)[-1 \ \ +1]\{\phi^f\}^e + \frac{Nl}{2}$$
$$+ \frac{n\gamma^s}{\Delta\gamma}\left[\frac{l}{6} \ \ \frac{l}{3}\right]\left\{\frac{\partial\phi^s}{\partial t}\right\}^e - \frac{n\gamma^f}{\Delta\gamma}\left[\frac{l}{6} \ \ \frac{l}{3}\right]\left\{\frac{\partial\phi^f}{\partial t}\right\}^e = 0 \quad ..(10)$$

$$-\frac{K^s b^s}{l}\Big|_1 [-1 \ \ +1]\{\phi^s\}^e - K^s\left(\frac{b_1^s + b_2^s}{2l}\right)[+1 \ \ -1]\{\phi^s\}^e$$
$$- \frac{n\gamma^s}{\Delta\gamma}\left[\frac{l}{3} \ \ \frac{l}{6}\right]\left\{\frac{\partial\phi^s}{\partial t}\right\}^e + \frac{n\gamma^f}{\Delta\gamma}\left[\frac{l}{3} \ \ \frac{l}{6}\right]\left\{\frac{\partial\phi^f}{\partial t}\right\}^e = 0 \quad \ldots(11)$$

$$\frac{K^s b^s}{l}\Big|_2 [-1 \ \ +1]\{\phi^s\}^e - K^s\left(\frac{b_1^s + b_2^s}{2l}\right)[-1 \ \ +1]\{\phi^s\}^e$$
$$- \frac{n\gamma^s}{\Delta\gamma}\left[\frac{l}{6} \ \ \frac{l}{3}\right]\left\{\frac{\partial\phi^s}{\partial t}\right\}^e + \frac{n\gamma^f}{\Delta\gamma}\left[\frac{l}{6} \ \ \frac{l}{3}\right]\left\{\frac{\partial\phi^f}{\partial t}\right\}^e = 0 \quad \ldots(12)$$

ϕ^f and ϕ^s can be evaluated at any time between t and t + Δt, using the following equations

$$\phi^f = (1-\theta)\,\phi^f_t + \theta\,\phi^f_{t+\Delta t} \quad \ldots\ldots (13a)$$

$$\phi^s = (1-\theta)\,\phi^s_t + \theta\,\phi^s_{t+\Delta t} \quad \ldots\ldots (13b)$$

Also, the time derivatives can be approximated as

$$\frac{\partial \phi^f}{\partial t} = (\phi^f_{t+\Delta t} - \phi^f_t)/\Delta t \quad \ldots\ldots (14a)$$

$$\frac{\partial \phi^s}{\partial t} = (\phi^s_{t+\Delta t} - \phi^s_t)/\Delta t \quad \ldots\ldots (14b)$$

Substituting equations (13) and (14) into equations (9) thru (12) one can develop the final element equations in the following form.

$$\begin{bmatrix} A_1 & A_2 & A_3 & A_4 \\ A_5 & A_6 & A_7 & A_8 \\ A_6 & A_{10} & A_{11} & A_{12} \\ A_{13} & A_{14} & A_{15} & A_{16} \end{bmatrix} \begin{Bmatrix} \phi^f_1 \\ \phi^s_1 \\ \phi^f_2 \\ \phi^s_2 \end{Bmatrix} = \begin{Bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \end{Bmatrix} \quad \ldots (15)$$

These element equations can be assembled for all the elements in the system to build up the global matrix. The global matrix thus developed has an unsymmetrical banded structure consisting of 3 upper co-diagonals, the main diagonal and 3 lower co-diagonals. The first terms of equations (9) thru (12) form the boundary conditions and have to be applied only for the first and last elements.

DESCRIPTION OF COMPUTER PROGRAM

The computer program has been written in Fortran and uses the concepts and methodology described in ref. 2. The nodes are numbered consecutively from left to right and the elements are numbered so that they are the same as the node number at the left hand end of the element. A pump can be located at any node in the system. The lower boundary can be of any general shape and its elevation is specified at each node. The aquifer properties are read in as a function of the element number. Three types of boundary conditions can be specified at either end. Boundary condition type I specifies the variation of the head at the boundary as a function of time. The second type of boundary condition specifies the discharge at the boundary as a function of time. Finally, the third type of boundary condition is a mixed boundary condition, where $q = K(\phi^f - \phi^s)$. Both confined and unconfined flows can be handled in the program.

The program code uses a constant time interval Δt. The matrix of equations can be solved in a fully implicit condition (THETA=1.0) or using the Crank-Nicolson approximation (THETA=0.5) or for any value of THETA in between. A subroutine that solves a banded matrix using the Gauss Elimination technique is also provided in the code. Two variables (the fresh water head and the salt water head) are solved for at each node. If the aquifer is such that a salt water toe develops along the lower boundary, then in the region where only fresh water is supposed to exist, a very thin (0.25 ft.) layer of salt water is also assumed to exist. Similarly, where a fresh water toe is expected, a thin (0.25 ft.) layer of fresh water is assumed to exist beyond the toe. The location of the salt water toe is obtained by extrapolating the interface from the adjacent element and determining where it intersects the impervious boundary. Similarly, the location of the fresh water toe is obtained from the intersection of the phreatic surface in the adjacent element and the impervious boundary.

APPLICATIONS OF THE COMPUTER PROGRAM

The results of the program were compared with two analytic results. The first was the steady interface flow in an aquifer having a phreatic surface with precipitation. The analytic solution is derived in ref. 7. Fig. 1 shows the results of the computer program for this situation. The computed phreatic surface is within 1% of the analytic results because the tolerance used for convergence was 1%. The phreatic surface responds to changes in input variables quite rapidly (in days or weeks). However, the interface responds to the same changes very slowly (in years). Final steady state results are obtained when the salt water head becomes zero or close to zero everywhere. This aquifer configuration is also representative of the situation beneath an island because the first mode can be taken to be the centerline of the island if symmetrical conditions exist about the island center.

Fig. 2 shows the location of the interface in a confined aquifer that has a constant fresh water discharge. The analytic solution is presented in refs. 8 and 9. The computed results vary from the analytic results by less than 1%. Thus, it can be assumed that the numerical, computer model behaves well for steady state flows. Fig. 3 shows the location of the interface in an unconfined aquifer but which has a lower impermeable boundary at 300 ft. below MSL. It can be seen that the salt water toe is further inland in this case than in figure 2. This is so because the piezometric heads in this case are lower and hence the salt water wedge intrudes further inland into the aquifer.

Figure 4 shows the behavior of the interface in an aquifer with a lower impervious boundary with a constant slope. The break in the slope shown in the figure is only due to the change in the scale of the y axis

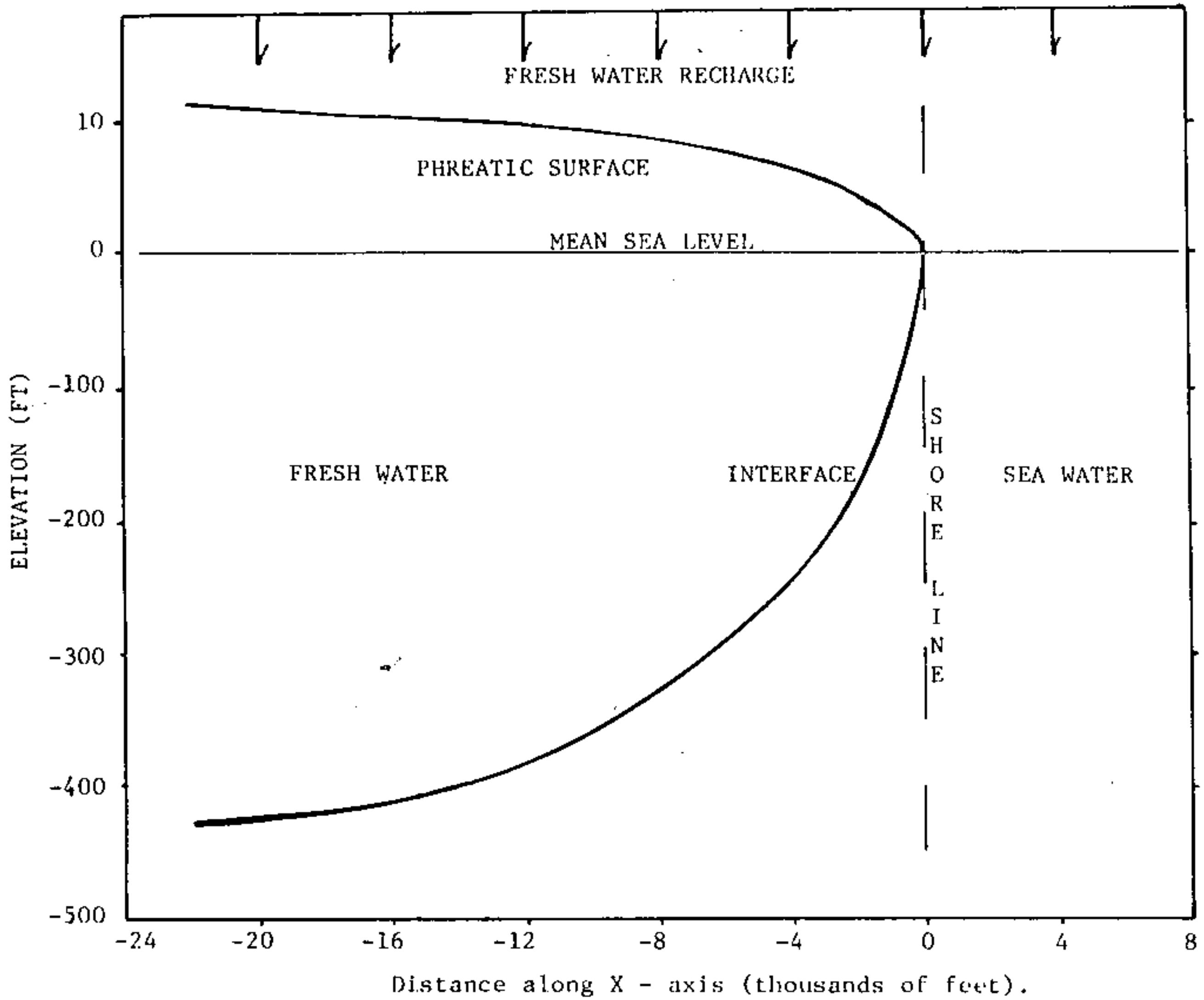

FIGURE 1. Results of 1-D salt water intrusion model; aquifer with a fresh water lens.

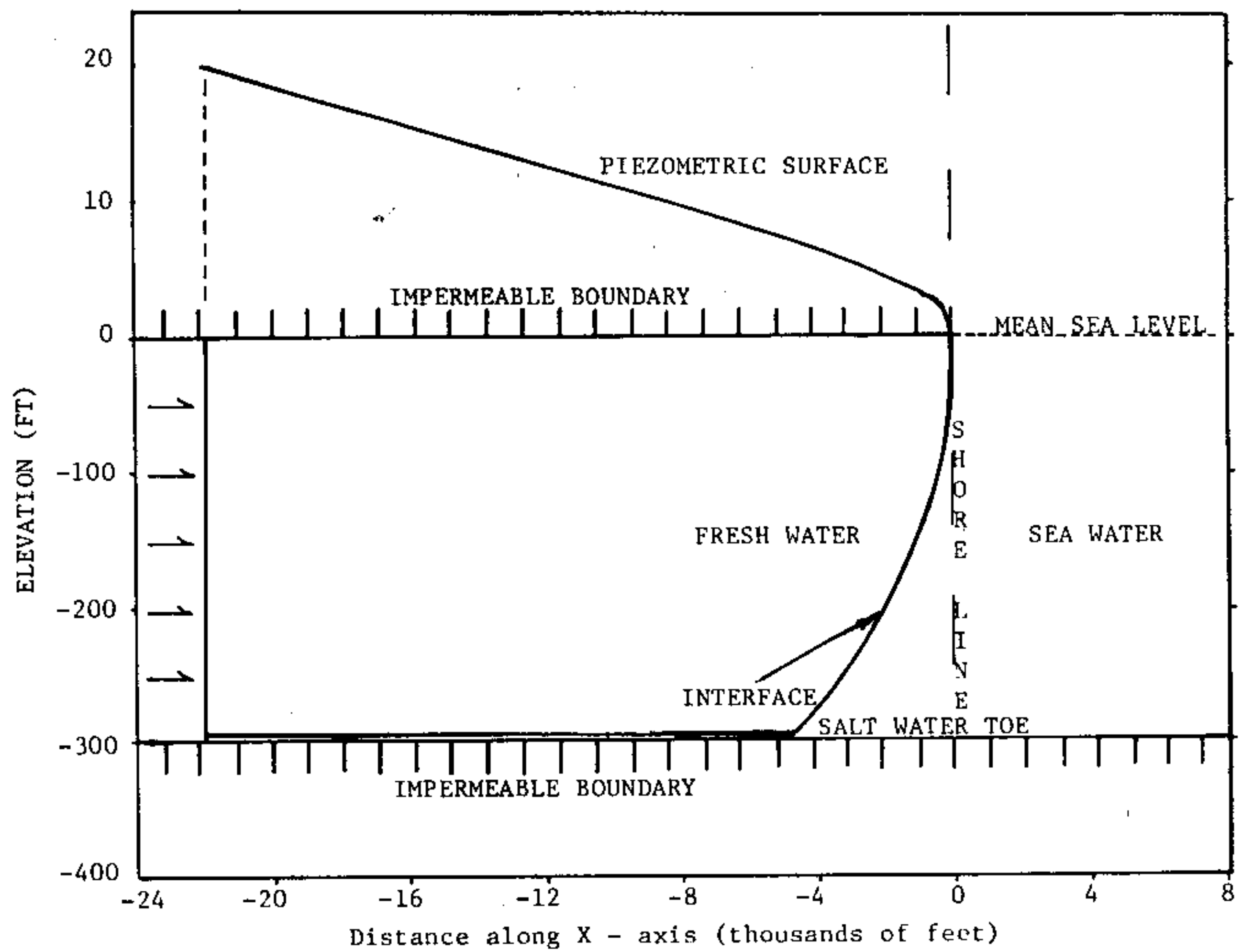

FIGURE 2. Results of 1-D salt water intrusion model; confined aquifer with constant fresh water discharge.

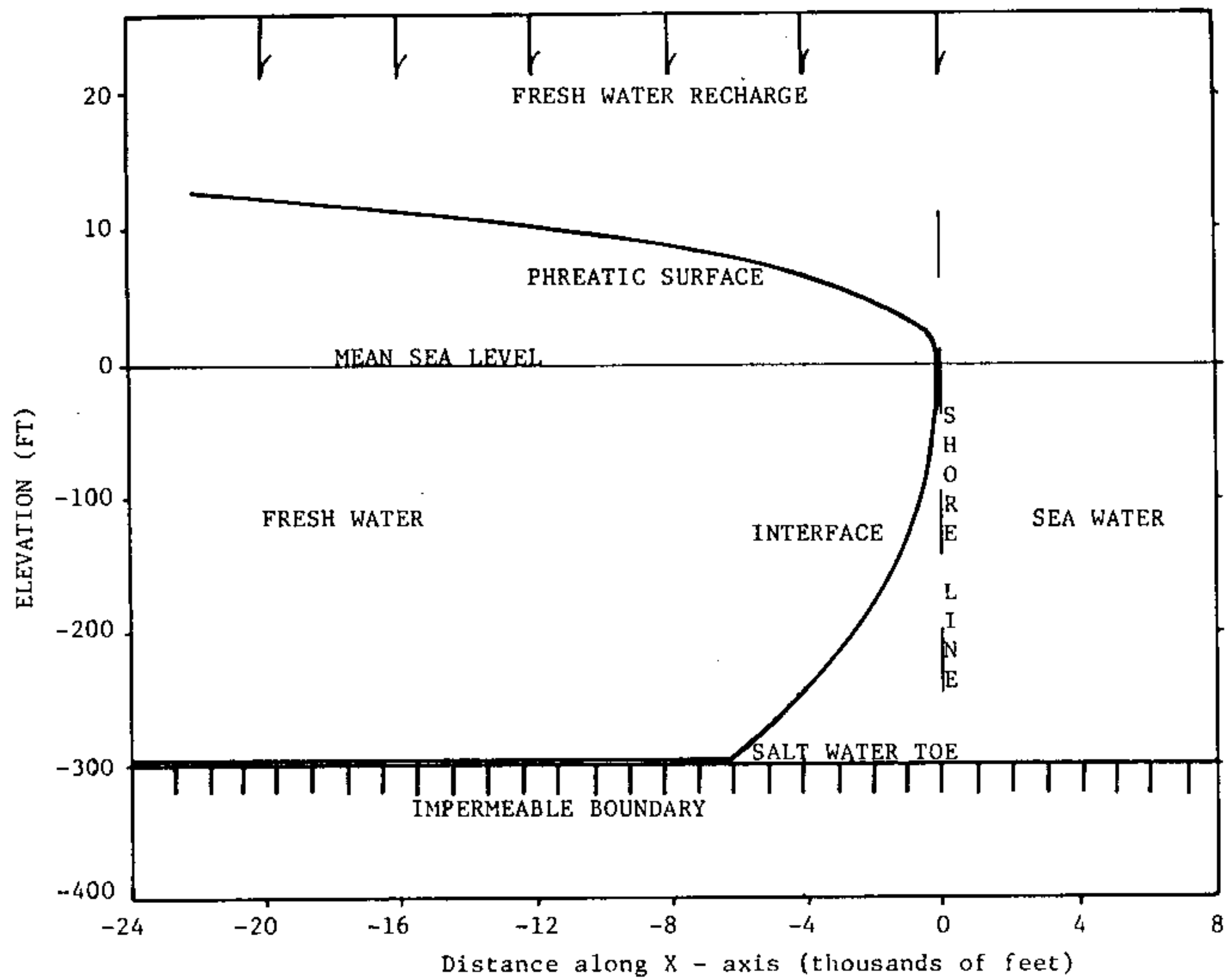

FIGURE 3. Results of 1-D salt water intrusion model; coastal aquifer with a salt water toe.

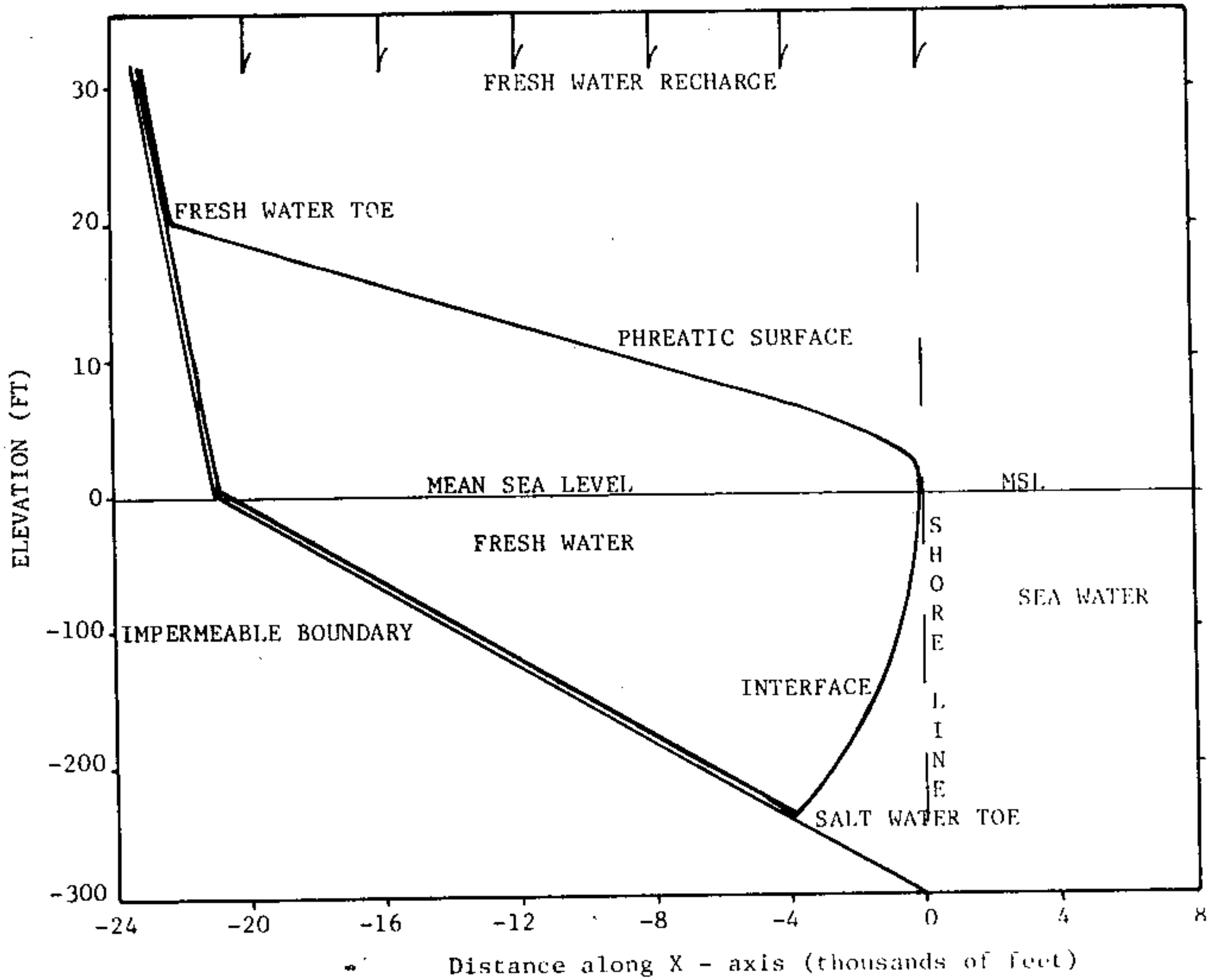

FIGURE 4. Results of 1-D salt water intrusion model; aquifer with a salt water toe and a fresh water toe.

above and below mean sea level. In this situation, both a salt water toe and a fresh water toe exist in the system and the program keeps track of both the toes.

Figure 5 shows the effect of a non-homogenous aquifer on the phreatic surface. The aquifer from the shoreline to x=-5000 ft. has a permeability one-tenth that of the permeability in the rest of the aquifer. It can be seen that the phreatic surface rises considerably to force the flow through the region with low permeability. Figure 6 shows the effect of a pump located approximately in the middle of the aquifer. The amount of pumpage is equal to half the total recharge. It can be seen that the phreatic surface is drawn down and the salt water toe moves inland by approximately 1000 ft. Figure 7 shows the effect of the same amount of pumpage located at x=-2000 ft. The change in the phreatic surface is only slight and the salt water toe is drawn inland by approximately 300 ft.

Figure 8 shows the effect of tides on the locations of the interface and the piezometric surface. The sea level is varied sinusoidally with an amplitude of one foot and a period of 12 hours. The tidal fluctuations do not effect the interface except within the first 100 feet from the shoreline. The piezometric surface however does respond and the range of its variation is shown. Finally, figure 9 shows the variation of the interface location due to an annual cycle of recharge. A typical cycle of annual recharge is taken from table 2 of reference 10. The first six months of the year are the dry months when evapotranspiration exceeds rainfall and hence groundwater recharge is zero. In the last 6 months, rainfall exceeds evapotranspiration and the excess rainfall becomes groundwater recharge. The following table gives the magnitude of the recharge for the last 6 months.

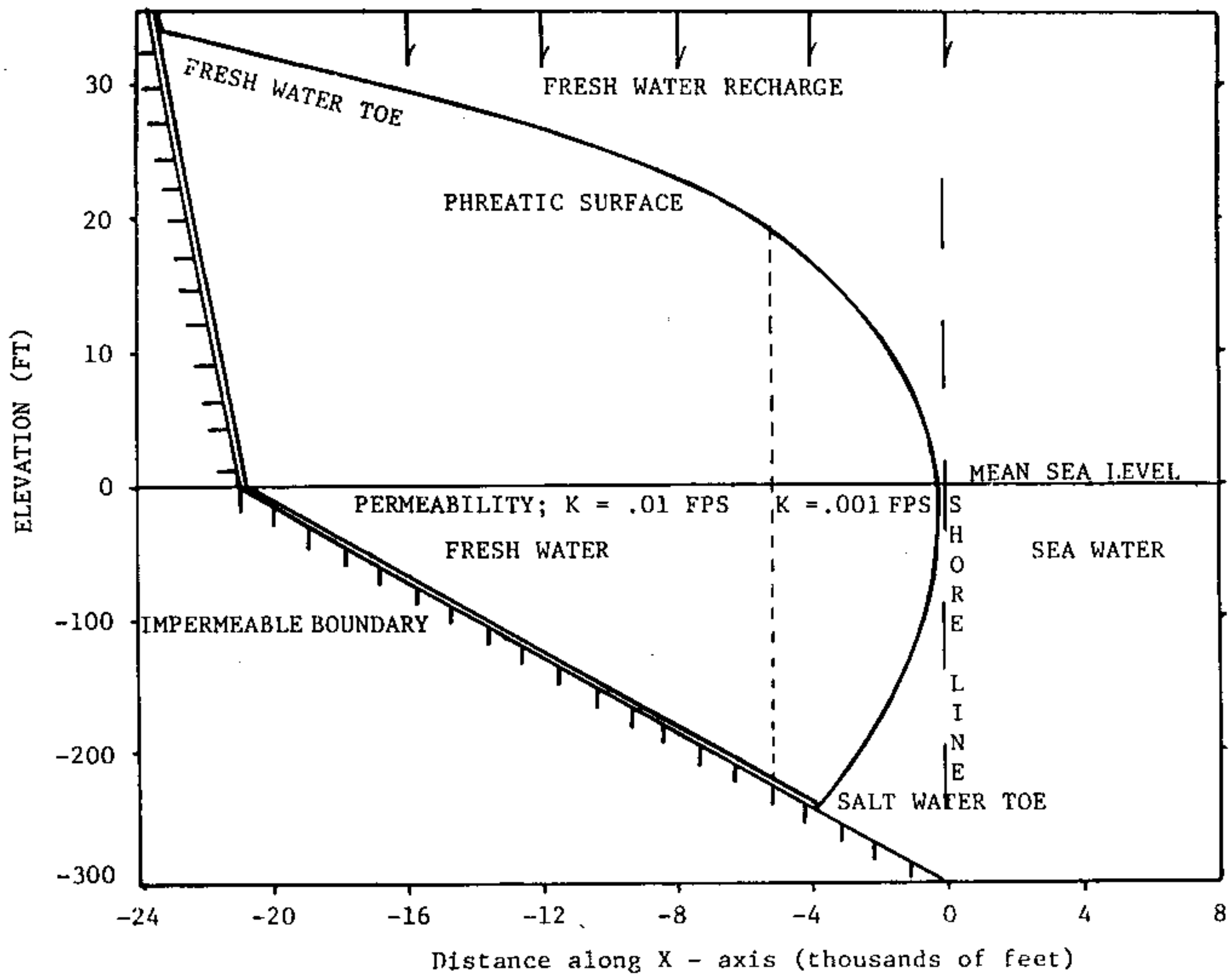

FIGURE 5. Results of 1-D salt water intrusion model; a non-homogeneous coastal aquifer.

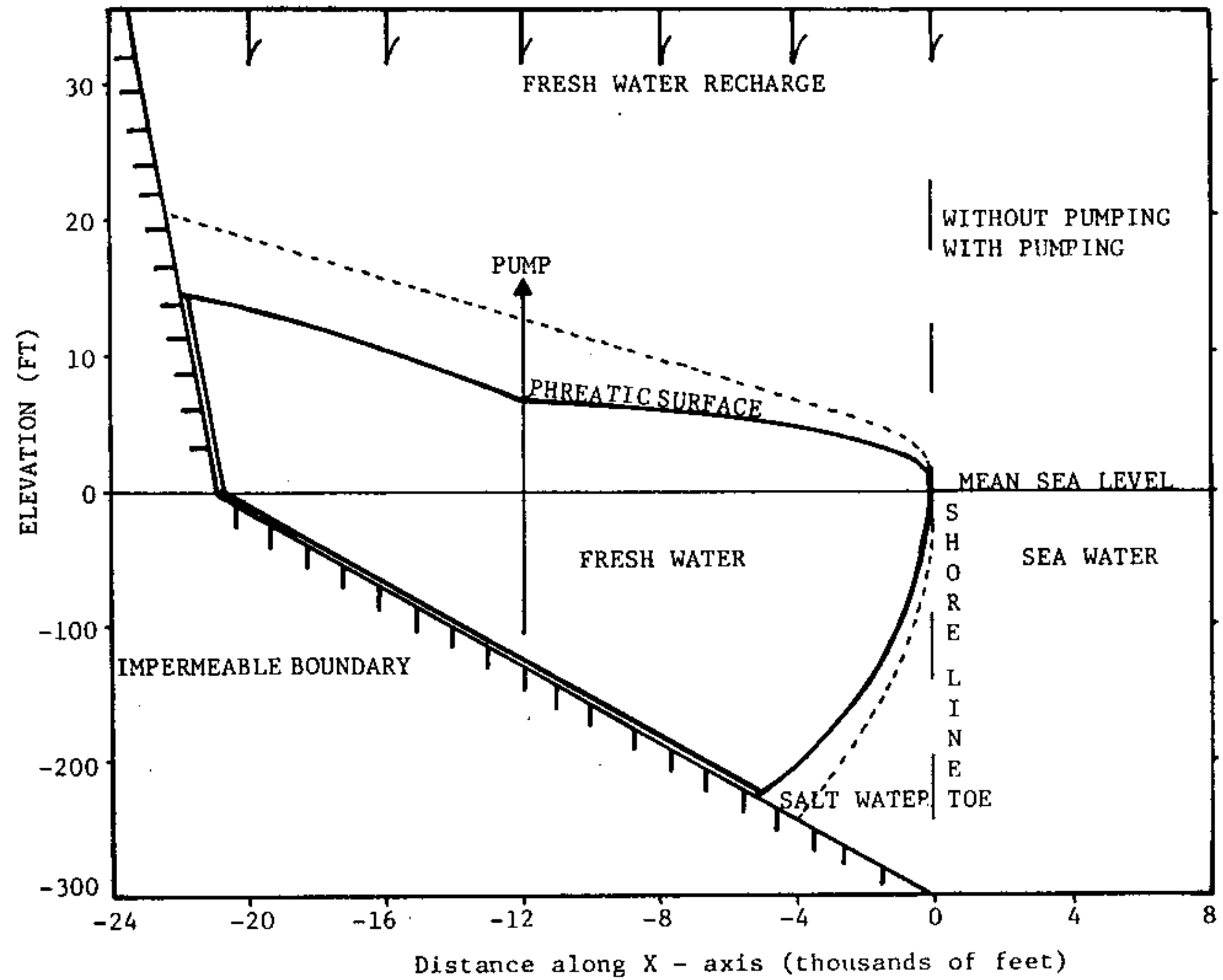

FIGURE 6. Results of 1-D salt water intrusion model; effect of a pump located at X = -12000 ft.

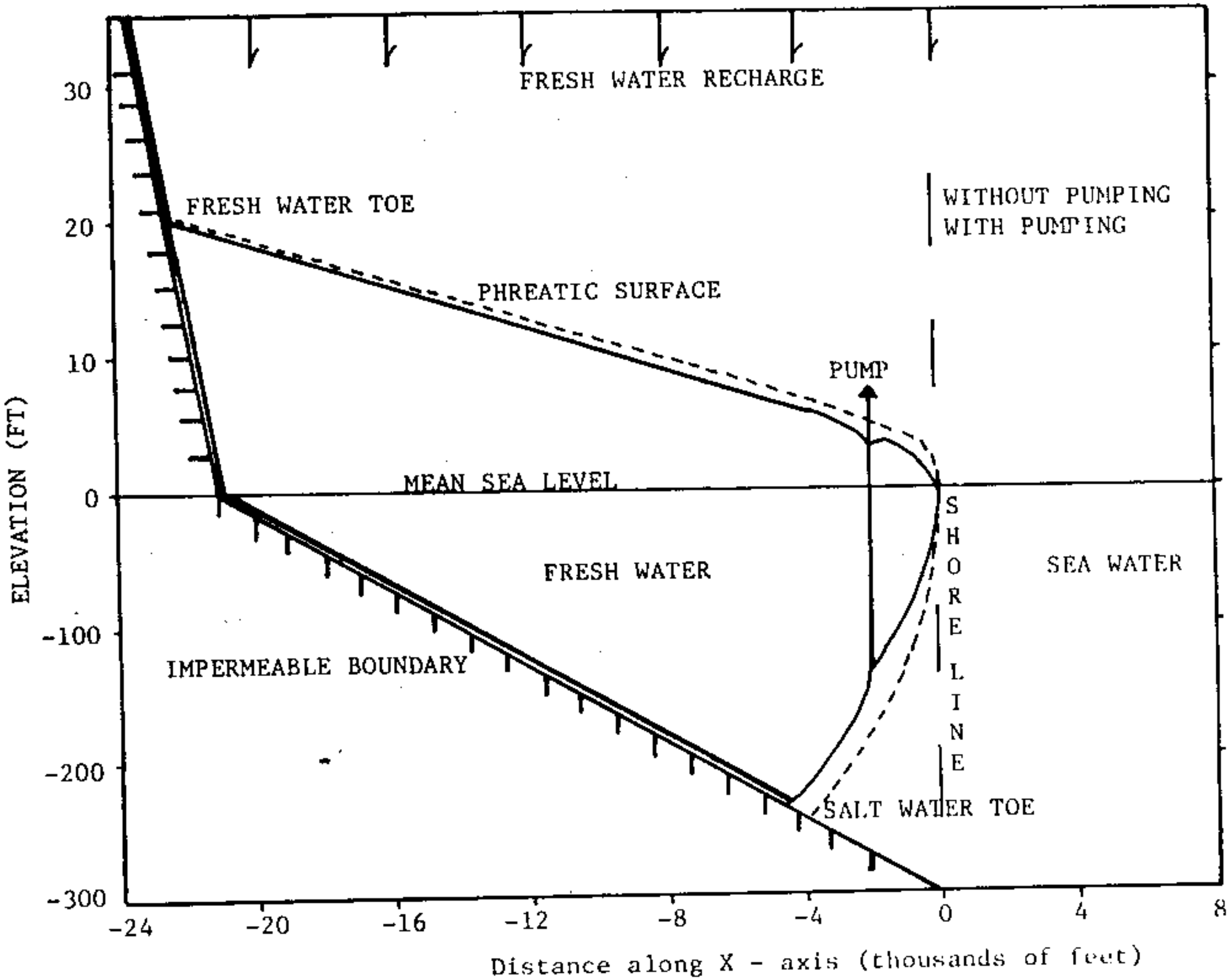

FIGURE 7. Results of 1-D salt water intrusion model; effect of a pump located at X = -2100.0 ft.

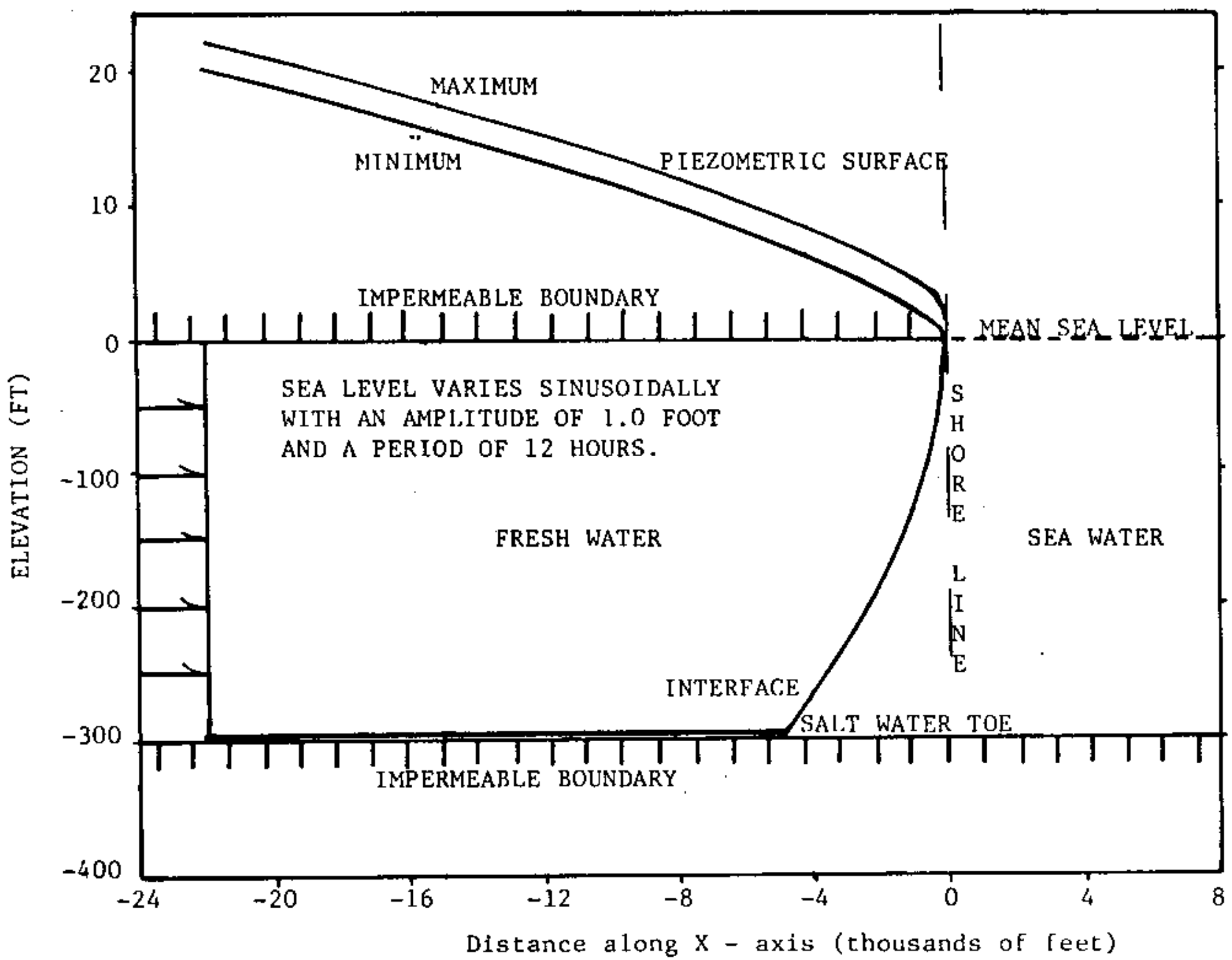

FIGURE 8. Results of 1-D salt water intrusion model; effect of tidal fluctuations.

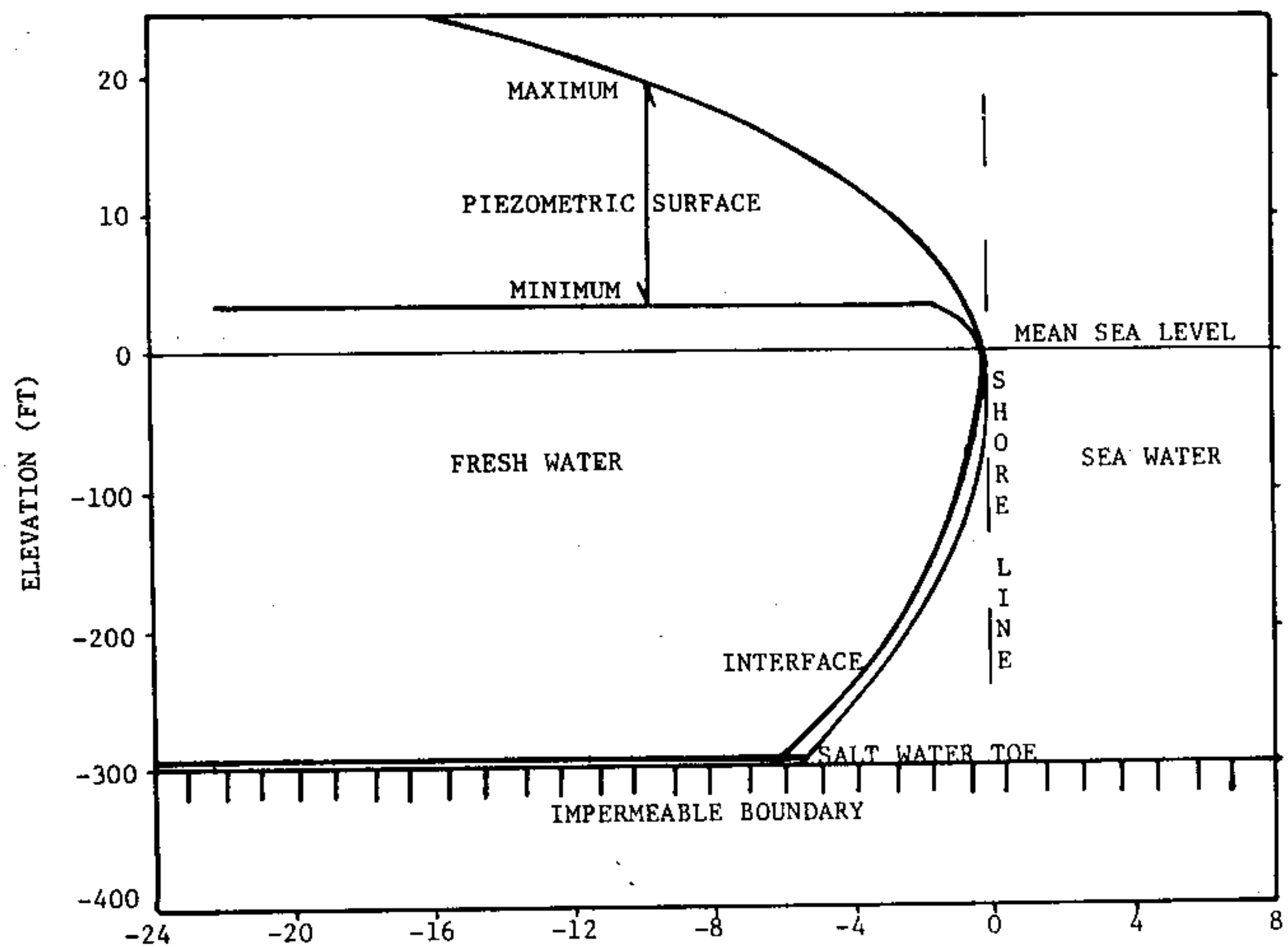

FIGURE 9. Results of 1-D salt water intrusion model; effect of annual recharge cycle in the aquifer.

July	3.92	inches
August	6.63	inches
September	9.34	inches
October	7.35	inches
November	2.83	inches
December	0.247	inches

The range of variation (max. and min.) of the phreatic surface and the interface for these recharge conditions is shown in figure 9. It can be seen that the interface does move inland by about 1000 ft. at the end of the dry season. The phreatic surface also falls to low levels at the same time. At the height of the recharge, the phreatic surface rises and the interface moves out toward the shore line.

CONCLUSIONS

A one-dimensional model of salt water intrusion into coastal or insular aquifers can be very helpful to managers of aquifers. The advantages of such a model arise out of its simplicity, low cost of data aquisition, low computer time and low total cost. The versatility of such a model has been demonstrated in this report. Confined and unconfined aquifers can be handled. Time dependent situations can also be taken into account. Non-homogeneities can be specified in the longitudinal direction.

Thus, the model can be used to get preliminary insights into a problem when there is a time deadline and when data or finances for a two-dimensional model are not available.

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APPENDIX A

List of Symbols

Symbol	Description	Units
A_1–A_{16}	Matrix constants for an element	L/T
b	Thickness of saturated aquifer	L
K	Coefficient of Permeability	L/T
ℓ	Length of an element	L
n	Porosity of aquifer	
N	Recharge or Accretion	L/T
N_i	Shape or Interpolation function	
q^f	Pump flow rate	L^2/T
R	Residue	L^2/T
R_1–R_4	Right hand side of element matrix	L^2/T
t	Time	T
x	Distance	L
γ	Specific weight of fluid	$\frac{M}{L^2T^2}$
ϕ	Piezometric head	L
ζ	Location of interface from MSL	L
Δt	Computational time interval	T
Θ	Weighting factor	
Supercripts		
f	Fresh water	
s	Salt water	
e	Element	
Subscripts		
1, 2	Nodes of an element	

APPENDIX B

Input Data and Format

ist of Input Variables

NN -	Number of Nodes.
IE -	Number of Elements.
NCONF -	= 0, for unconfined flow
	= 1, for confined flow
C -	X coordinate of node.
B -	Elevation of the lower impervious boundary.
KFF -	Freshwater coefficient of permeability
SS -	Saltwater coefficient of permeability
ORSTY -	Porosity of aquifer
JMAX -	Number of time intervals Δt, that program must execute.
ITERMX -	Max. number of iterations for convergence at each time interval.
ISWTOE -	= 0, when no salt water toe exists
	= I, element number in which salt water toe exists
NFWTOE -	= 0, when no fresh water toe exists in the system
	= I, element number in which fresh water toe exists
T -	Computational time interval, Δt
THETA -	= 0.5, for Crank-Nicolson approximation
	= 1.0, for fully implicit calculations
OL -	Tolerance (as a fraction) used in convergence of solution.
FWBCI -	Type of fresh water bodary condition at I=1
SWBCI -	Type of salt water boundary condition at I=1
WBCN -	Type of fresh water boundary condition at I=NN
SWBCN -	Type of Salt water boundary condition at I=NN

(FWBCI, SWBCI, WBCN, SWBCN: =1, for specified head; =2, for " discharge; =3, for mixed boundary conditions.)

FWH1 -	Fresh water head at I=1 as a function of time
SWH1 -	Salt Water Head at I=1 as a function of time
FWQ1 -	Fresh water discharge at I=1 as a function of time
SWQ1 -	Salt water discharge at I=1 as a function of time
FWHNN -	Fresh water head at I=NN as a function of time
SWHNN -	Salt water head at I=NN as a function of time
FWQN -	Fresh water discharge at I=NN as a function of time
SWQN -	Salt water discharge at I=NN as a function of time
RECHG -	Fresh water recharge as a function of x and time
NPUMPS -	Number of pumps in the system
NODEP -	Node numbers at which pumps are located.
PUMPQ -	Pump discharge as a function of time.
HF (I,1) -	Fresh water head as a function of x
HS (I,1) -	Salt water head as a function of x
BF (I,1) -	Thickness of fresh water zone as a function of x
BS (I,1) -	Thickness of salt water zone as a function of x

(HF, HS, BF, BS: Initial Conditions)

IO (I) -	=0, when no output at node (I) is required
	=1, when output at node (I) is required

List and Format of Input

No. of Cards.	List of Variables	Format
1	NN,NE, NCONF	16I5
NN	(XC(I),ZB(I),I=1,NN)	5X,2F10.0
NE	(KFF(I),KSS(I),PORSTY(I),I=1,NE)	5X,3F10.0
1	JMAX,ITERMX,NSWTOE,NFWTOE	16I5
1	DT,THETA,TOL	E15.7,6F10.0
1	FWBC1,SWBC1,FWBCN,SWBCN	16I5
JMAX/8	(FWH1(J),J=1,JMAX),IF FWBC1=1	8F10.2
JMAX/8	(FWO1(J),J=1,JMAX),IF FWBC1=2	8F10.2
JMAX/8	(SWH1(J),J=1,JMAX),IF SWBC1=1	8F10.2
JMAX/8	(SWQ1(J),J=1,JMAX),IF SWBC1=2	8F10.2
JMAX/8	(FWHNN(J),J=1,JMAX),IF FWBCN=1	8F10.2
JMAX/8	(FWQN(J),J=1,JMAX),IF FWBCN=2	8F10.2
JMAX/8	(SWHNN(J),J=1,JMAX),IF SWBCN=1	8F10.2
JMAX/8	(SWON(J),J=1,JMAX),IF SWBCN=2	8F10.2
NE*(JMAX/8)	((RECHG(I,J),J=1,JMAX),I=1,NE)	8F10.2
1	NPUMPS	16I5
NPUMPS/16	(NODEP(I),I=1,NPUMPS)	16I5
NPUMPS*(JMAX/8)	((PUMPQ(NODEP(I),J),J=1,JMAX),I=1,NPUMPS)	8F10.2
NN	((HF(I,1),HS(I,1),BF(I,1),BS(I,1)),I=1,NN)	5X,4F10.0
NN/80	IO(I),I=1,NN	80I1

Dimension Statements

Some of the dimension statements have to be adjusted according to the number of nodes (NN) in the system and the maximum number of computational time steps (JMAX) that the program is to execute. Some variables will have dimensions that are fixed, since only linear elements are used. The dimension statements are presented below in terms of NN and JMAX.

```
DIMENSION  XC(NN),NODEP (NN),KF(NN),KS(NN),RECHG(NN,JMAX), PUMPQ(NN,JMAX)

DIMENSION  A1(7x(NNx2-1)-6),HF(NN,JMAX),HS(NN,JMAX),BF(NN,JMAX),BS(NN,JMAX),
           R1(2xNN-1)

DIMENSION  A(14xNN-6),R(2xNN),B(16),RHJ(4),ZB(NN),ZETA(NN,JMAX),SWQN(JMAX)

DIMENSION  ERROR1(NN),ERROR2(NN),IO(NN),FWQ1(JMAX),SWQ1(JMAX),FWQN(JMAX)

DIMENSION  FWH1(JMAX),SWH1(JMAX),FWHNN(JMAX),SWHNN(JMAX),KFF(NN),KSS(NN)

DIMENSION  PORSTY (NN)
```

APPENDIX C

Listing of Source Program

```
C
C     ****************************************
C     *  ONE-DIMENSIONAL SALT WATER INTRUSION MODEL  *
C     ****************************************
C
C       DEPTH AVERAGED EQUATIONS USED FOR FRESH AND SALT WATER.
C       FINITE ELEMENT METHOD USED WITH IMPLICIT TIME INTEGRATION.
C       LINEAR ELEMENTS USED. IBM-SSP SUBROUTINE GELB USED TO SOLVE ECUATIONS.
        DIMENSION XC(21),NODEP(21),KF(21),KS(21),RECHG(21,96),PUMPQ(21,96)
        DIMENSION A1(281),HF(21,95),HS(21,96),BF(21,96),BS(21,96),R1(41)
        DIMENSION A(288),R(42),G(16),RHS(4),ZB(21),ZETA(21,96),SWQN(96)
        DIMENSION ERROR1(21),ERROR2(21),IO(21),FWQ1(96),SWQ1(96),FWQN(96)
        DOUBLE PRECISION A,R,A1,R1
        F(A,B)=A*THETA1+B*THETA
        DIMENSION FWH1(96),SWH1(96),FWHNN(96),SWHNN(96),KFF(21),KSS(21)
        INTEGER RD,WR,FWBC1,SWBC1,FWBCN,SWBCN
        REAL KF,KS,KFT,KST,KFF,KSS
        DATA GF,GS,DG/62.4,64.0,1.6/
        DIMENSION PORSTY(21)
        RD=1
        WR=3
        WRITE(WR,1010)
1010    FORMAT('1 ONE-DIMENSIONAL SALT WATER INTRUSION MODEL')
C
C       READ IN DATA
C       NCONF=1 FOR CONFINED FLOW, =0 FOR UNCONFINED FLOW
        READ(RD,1020)NN,NE,NCONF
1020    FORMAT(16I5)
C       READ IN NODE NUMBERS, NODAL COORDINATES AND BED ELEVATIONS
        READ(RD,1030)(  XC(I),ZB(I),I=1,NN)
1030    FORMAT(5X,2F10.0)
C       READ IN PERMEABILITIES AND POROSITIES
C       ELEMENT NUMBER, FRESH WATER PERM.,SALT WATER PERM, AND POROSITY
        READ(RD,1032)(  KFF(I),KSS(I),PORSTY(I),I=1,NE)
1031    FORMAT(5X,4F10.0)
C
C       PRINT OUT ALL DATA
C
        WRITE(WR,1050)NN,NE,NCONF
1050    FORMAT('0NO. OF NODES=',I5,5X,'NO. OF ELEM.=',I5,5X,'NCONF=',I5)
        WRITE(WR,1060)
        WRITE(WR,1070)(I,XC(I),ZB(I),I=1,NN)
1060    FORMAT('0NODE',5X,'X-COORDINATE',5X,'BED ELEVATION')
1070    FORMAT(1X,I4,5X,F10.2,5X,F10.2)
        WRITE(WR,1080)
        WRITE(WR,1090)(I,KFF(I),KSS(I),PORSTY(I),I=1,NE)
1080    FORMAT('0ELEMENT',5X,'F. W. PERM.',5X,'S. W. PERM.',5X,'POROSITY')
1032    FORMAT(5X,3F10.0)
1090    FORMAT(1X,I5,05X,F10.5,5X,F10.8,5X,F10.8)
        READ(RD,1020)JMAX,ITERMX,NSWTOE,NFWTOE
        READ(RD,1110)DT,THETA,TOL
        READ(RD,1020)FWBC1,SWBC1,FWBCN,SWBCN
        WRITE(WR,2050)FWBC1,SWBC1,FWBCN,SWBCN
C       FWBC1,SWBC1,FWBCN,SWBCN =1 FOR SPECIFIED HEAD,  = 2 FOR SPECIFIED DISCH.
```

```
C      = 3 FOR MIXED BOUNDARY CONDITION.
2050   FORMAT('OFWBC1 =',I3,5X,'SWBC1=',I3,5X,'FWBCN=',I3,5X,'SWBCN=',I3)
       GO TO (1,2,3),FWBC1
1      READ(RD,4)(FWH1(J),J=1,JMAX)
       WRITE(WR,2000)(J,FWH1(J),J=1,JMAX)
2000   FORMAT('OFW HEAD SPEC. AT LEFT HAND END',/,10(2X,I2,1X,F7.1))
       GO TO 3
2      READ(RD,4)(FWQ1(J),J=1,JMAX)
       WRITE(WR,2010)(J,FWQ1(J),J=1,JMAX)
2010   FORMAT('OFW DISCH. SPEC. AT LEFT HAND END',/,10(2X,I2,1X,F7.4))
4      FORMAT(8F10.0)
3      GO TO (5,6),SWBC1
5      READ(RD,4)(SWH1(J),J=1,JMAX)
       WRITE(WR,2020)(J,SWH1(J),J=1,JMAX)
2020   FORMAT('OSW HEAD SPEC. AT LEFT HAND END',/,10(2X,I2,1X,F7.1))
       GO TO 7
6      READ(RD,4)(SWQ1(J),J=1,JMAX)
       WRITE(WR,2030)(J,SWQ1(J),J=1,JMAX)
7      GO TO (8,9,11),FWBCN
8      READ(RD,4)(FWHNN(J),J=1,JMAX)
       WRITE(WR,2040)(J,FWHNN(J),J=1,JMAX)
2040   FORMAT('OFW HEAD SPEC. AT RIGHT HAND END',/,10(2X,I2,1X,F7.1))
       GO TO 11
9      READ(RD,4)(FWQN(J),J=1,JMAX)
       WRITE(WR,2060)(J,FWQN(J),J=1,JMAX)
2060   FORMAT('OFW DISCH. SPEC. AT RIGHT HAND END',/,10(2X,I2,1X,F7.4))
11     GO TO (12,13),SWBCN
12     READ(RD,4)(SWHNN(J),J=1,JMAX)
       WRITE(WR,2070)(J,SWHNN(J),J=1,JMAX)
2070   FORMAT('OSW HEAD SPEC. AT RIGHT HAND END',/,10(2X,I2,1X,F7.4))
       GO TO 14
13     READ(RD,4)(SWQN(J),J=1,JMAX)
       WRITE(WR,2080)(J,SWQN(J),J=1,JMAX)
2080   FORMAT('OSW DISCH. SPEC. AT RIGHT HAND END',/,10(2X,I2,1X,F7.1))
14     CONTINUE
2030   FORMAT('OSW DISCH. SPEC. AT LEFT  HAND END',/,10(2X,I2,1X,F7.4))
       DO 21 I=1,NE
       KF(I)=KFF(I)
21     KS(I)=KSS(I)
       GF1=PORSTY(I)*GF/(DG*DT)
       GS1=PORSTY(I)*GS/(DG*DT)
       GS3=PORSTY(I)*GS/(3.*DG*DT)
       GS6=GS3/2.
       GF3=PORSTY(I)*GF/(3.*DG*DT)
       GF6=GF3/2.

1095   FORMAT(4(E15.7,5X))
1110   FORMAT(E15.7,6F10.0)


1100   FORMAT(8F10.2)
C      READ IN RECHARGE AND PUMPING CONDITIONS
       DO 10 I=1,NE
       READ(RD,1100)(RECHG(I,J),J=1,JMAX)
```

```
10    CONTINUE
      READ(RD,1020)NPUMPS
      READ(RD,1020)(NODEP(I),I=1,NPUMPS)
      DO 20 I=1,NPUMPS
      READ(RD,1100)(PUMPQ(NODEP(I),J),J=1,JMAX)
20    CONTINUE
C
C     READ IN INITIAL CONDITIONS
C
      READ(RD,1031)(  HF(I,1),HS(I,1),BF(I,1),BS(I,1),I=1,NN)
      WRITE(WR,1150)DT,THETA,JMAX,TOL
1150  FORMAT          ('0TIME INTERVAL DT = ',E15.7,10X,'WEIGHTING FACTOR
     1 THETA = ',F5.2,/,' MAX. NO. OF TIME ITERATIONS, JMAX = ',I4,10X,
     2' TOLERANCE ON CONVERGENCE AS A FRACTION = ',F10.5)
      DO 28 I=1,NN
28    ZETA(I,1)=(GS*HS(I,1)-GF*HF(I,1))/DG
      WRITE(WR,1160)
1160  FORMAT('0RECHARGE AS A FUNCTION OF TIME')
      DO 15 I=1,NE
      WRITE(WR,1170)I
1170  FORMAT(' ELEMENT I = ',I3)
      WRITE(WR,1180)(J,RECHG(I,J),J=1,JMAX)
1180  FORMAT(8(2X,I2,1X,F11.9))
15    CONTINUE
      DO 16 I=1,NPUMPS
      WRITE(WR,1200)NODEP(I)
1200  FORMAT('0PUMP AT NODE ',I3,/,' FLOW RATE AS A FUNCTION OF TIME')
16    WRITE(WR,1180)(J,PUMPQ(NODEP(I),J),J=1,JMAX)
      THETA1=1.0-THETA
      WRITE(WR,1210)
1210  FORMAT('0INITIAL CONDITIONS',/,' NODE NUMBER F.W. READ S.W. HEAD
     1F.W. THICKNESS S.W. THICKNESS')
      DO 17 I=1,NN
17    WRITE(WR,1033)I,HF(I,1),HS(I,1),BF(I,1),BS(I,1)
      J=1
25    J=J+1
      IF(J.GT.JMAX)GO TO 1000
      DO 26 I=1,NN
      BF(I,J)=BF(I,J-1)
26    BS(I,J)=BS(I,J-1)
1033  FORMAT(' ',I4,4(2X,F10.2))
      ITER=0
50    MA=NN*14-6
      ME=MA-6
      DO 30 I=1,MA
30    A(I)=0.
      DO 40 I=1,NN
      R(2*I-1)=0.
40    R(2*I)=0.
      ITER=ITER+1
C     CYCLE FOR EACH ELEMENT AND FORM SYSTEM MATRICES
      DO 500 K=1,NE
      EL=XC(K+1)-XC(K)
      KFT=KF(K)*(F(BF(K,J-1),BF(K,J))+F(BF(K+1,J-1),BF(K+1,J)))*THETA/(2
```

```
     1.*EL)
      KST=KS(K)*(F(BS(K,J-1),BS(K,J))+F(BS(K+1,J-1),BS(K+1,J)))*THETA/(2
     1.*EL)
      B(1)=-KFT-GF3*EL
      B(2)=GS3*EL
      B(3)=KFT-GF6*EL
      B(4)=GS6*EL
      B(5)=GF3*EL
      B(6)=-KST-GS3*EL
      B(7)=GF6*EL
      B(8)=KST-GS6*EL
      B(9)=KFT-GF6*EL
      B(10)=GS6*EL
      B(11)=-KFT-GF3*EL
      B(12)=GS3*EL
      B(13)=GF6*EL
      B(14)=KST-GS6*EL
      B(15)=GF3*EL
      B(16)=-KST-GS3*EL
      RHS(1)=KF(K)*(F(BF(K,J-1),BF(K,J))+F(BF(K+1,J-1),BF(K+1,J)))*
     1THETA1/(2.*EL)*(HF(K,J-1)-HF(K+1,J-1))-(F(RECHG(K,J-1),RECHG(K,J))
     2)*EL/2.+GS1*(HS(K,J-1)/3.+HS(K+1,J-1)/6.)*EL-GF1*(HF(K,J-1)/3.
     3+HF(K+1,J-1)/6.)*EL
      RHS(2)=KS(K)*(F(BS(K,J-1),BS(K,J))+F(BS(K+1,J-1),BS(K+1,J)))*THETA
     11/2./EL *(HS(K,J-1)-HS(K+1,J-1))-GS1*(HS(K,J-1)/3.+HS(K+1,J-1)/6.)
     2*EL+GF1*(HF(K,J-1)/3.+HF(K+1,J-1)/6.)*EL
      RHS(3)=KF(K)*(F(BF(K,J-1),BF(K,J))+F(BF(K+1,J-1),BF(K+1,J)))*THETA
     11/2./EL*(-HF(K,J-1)+HF(K+1,J-1))-(F(RECHG(K,J-1),RECHG(K,J)))
     2*EL/2.+GS1*(HS(K,J-1)/6.+HS(K+1,J-1)/3.)*EL-GF1*(HF(K,J-1)/6.+
     3HF(K+1,J-1)/3.)*EL
      RHS(4)=KS(K)*(F(BS(K,J-1),BS(K,J))+F(BS(K+1,J-1),BS(K+1,J)))*THETA
     11/2./EL *(-HS(K,J-1)+HS(K+1,J-1))-GS1*(HS(K,J-1)/6.+HS(K+1,J-1)/3.
     2)*EL+GF1*(HF(K,J-1)/6.+HF(K+1,J-1)/3.)*EL
C     DO 55 I=1,16,4
C55   WRITE(WR,1220)B(I),B(I+1),B(I+2),B(I+3)

C     WRITE(WR,1220)(RHS(I),I=1,4)
      DO 60 KK=1,NPUMPS
      IF(K.NE.NODEP(KK))GO TO 60
      RHS(1)=RHS(1)-    (PUMPQ(K,J-1)*THETA1   +PUMPQ(K,J)*THETA     )
C     RHS(3)=RHS(3)-EL*(PUMPQ(K,J-1)*THETA1   +PUMPQ(K,J)*THETA     )
 60   CONTINUE
      IF(K.NE.1)GO TO 200
      DO 100 KK=1,8
100   A(KK)=B(KK)
      DO 105 KK=1,4
      A(9+KK)=B(8+KK)

      A(15+KK)=B(12+KK)
105   R(KK)=RHS(KK)
1220  FORMAT(' ',4(E15.7,5X))
C     BOUNDARY CONDITIONS AT LEFT-HAND END
C
      GO TO (110,115,116),FWBC1
```

```
110   R(1)=R(1)-A(1)*FWH1(J)-KF(1)*F(BF(1,J-1),BF(1,J))*THETA/EL*FWH1(J)
     1+KF(1)*F(BF(1,J-1),BF(1,J))*THETA1/EL*(-HF(1,J-1)+HF(2,J-1))
      R(2)=R(2)-A(5)*FWH1(J)
      R(3)=R(3)-A(10)*FWH1(J)
      R(4)=R(4)-A(16)*FWH1(J)
      A(1)=0.
      A(3)=A(3)-KF(1)*F(BF(1,J-1),BF(1,J))*THETA/EL
      A(5)=0.
      A(10)=0.
      A(16)=0.
      GO TO 120
115   R(1)=R(1)-F(FWQ1(J-1),FWQ1(J))
      GO TO 120
116   A(1)=A(1)-KF(1)*THETA
      A(2)=A(2)+KF(1)*THETA
      R(1)=R(1)-KF(1)*THETA1*(HS(1,J-1)-HF(1,J-1))
120   GO TO (125,130),SWBC1
125   R(1)=R(1)-A(2)*SWH1(J)
      R(2)=R(2)-A(6)*SWH1(J)-KS(1)*F(BS(1,J-1),BS(1,J))*THETA/EL*SWH1(J)
     1+KS(1)*F(BS(1,J-1),BS(1,J))*THETA1/EL*(-HS(1,J-1)+HS(2,J-1))
      R(3)=R(3)-A(11)*SWH1(J)
      R(4)=R(4)-A(17)*SWH1(J)
      A(2)=0.
      A(6)=0.
      A(11)=0.
      A(17)=0.
      A(8)=A(8)-KS(1)*F(BS(1,J-1),BS(1,J))*THETA/EL
      GO TO 135
130   R(2)=R(2)-SWQ1(J)
135   CONTINUE

      GO TO 500
200   IF(K.EQ.NE)GO TO 400
      DO 205 KK=1,4
      A(14*K-17+KK)=B(0+KK)+A(14*K-17+KK)
      A(14*K-11+KK)=B(4+KK)+A(14*K-11+KK)
      A(14*K-5+KK)=B(8+KK)+A(14*K-5+KK)

      R(2*K-2+KK)=RHS(KK)+R(2*K-2+KK)
205   A(14*K+1+KK)=B(12+KK)+A(14*K+1+KK)
      GO TO 500
400   DO 405 KK=1,4
      A(ME-19+KK)=B(KK)+A(ME-19+KK)
      R(2*NE-2+KK)=RHS(KK)+R(2*NE-2+KK)
      A(ME-13+KK)=B(4+KK)+A(ME-13+KK)
      A(ME-8+KK)=B(8+KK)+A(ME-8+KK)

405   A(ME-4+KK)=B(12+KK)+A(ME-4+KK)
C
C     BOUNDARY CONDITIONS AT RIGHT-HAND END
      GO TO (410,415,416),FWBCN
410   R(2*NE-1)=R(2*NE-1)-A(ME-16)*FWHNN(J)
      R(2*NE)=R(2*NE)-A(ME-10)*FWHNN(J)
      R(2*NE+1)=R(2*NE+1)-A(ME-5)*FWHNN(J)-KF(NE)*F(BF(NN,J-1),BF(NN,J))
```

```
     1*THETA/EL*FWHNN(J)-KF(NE)*F(BF(NN,J-1),BF(NN,J))*THETA1/EL*(-HF(NN
     2-1,J-1)+HF(NN,J-1))
      R(2*NE+2)=R(2*NE+2)-A(ME-1)*FWHNN(J)
      A(ME-16)=0.
      A(ME-10)=0.
      A(ME-7)=A(ME-7)-KF(NE)*F(BF(NN,J-1),BF(NN,J))*THETA/EL
      A(ME-5)=0.
      A(ME-1)=0.
      GO TO 420
415   R(2*NE+1)=R(2*NE+1)+F(FWQN(J-1),FWQN(J))
      GO TO 420
416   A(ME-05)=A(ME-05)-KF(NE)*THETA
      A(ME-4)=A(ME-4)+KF(NE)*THETA
      R(2*NE+1)=R(2*NE+1)+KF(NE)*THETA1*(HF(NN,J-1)-HS(NN,J-1))

420   GO TO (425,430),SWBCN
425   R(2*NE-1)=R(2*NE-1)-A(ME-15)*SWHNN(J)
      R(NE*2)=R(2*NE)-A(ME-9)*SWHNN(J)
      R(2*NE+1)=R(2*NE+1)-A(ME-4)*SWHNN(J)
      R(2*NE+2)=R(2*NE+2)-A(ME)*SWHNN(J)-KS(NE)*F(BS(NN,J-1),BS(NN,J))*
     1THETA/EL*SWHNN(J)-KS(NE)*F(BS(NN,J-1),BS(NN,J))*THETA1/EL*(-HS(NN-
     21,J-1)+HS(NN,J-1))
      A(ME-15)=0.
      A(ME-9)=0.
      A(ME-2)=A(ME-2)-KS(NE)*F(BS(   NN,J-1),BS(   NN,J))*THETA/EL
      A(ME-4)=0.
      A(ME)=0.
      GO TO 435
430   R(2*NE+2)=R(2*NE+2)+SWQN(J)
435   CONTINUE
500   CONTINUE
C     DO 510 I=1,280,10
C510  WRITE(WR,1230)A(I),(A(I+JJ),JJ=1,9)
C     WRITE(WR,1230)A(281),A(282)
1230  FORMAT(' ',10(E12.5,1X))
C     DO 520 I=1,40,10
C520  WRITE(WR,1230)R(I),(R(I+JJ),JJ=1,9)
C     WRITE(WR,1230)R(41),R(42)
      NN1=2*NN-1
      MA1=7*NN1-6
      DO 550 I=1,NN1
550   R1(I)=0.
      DO 540 I=1,MA1
540   A1(I)=0.


      IF(FWBC1.NE.1)GO TO 840
      DO 800 I=1,4
800   A1(I)=A(I+5)
      DO810 I=5,9
810   A1(I)=A(I+6)
      N=2*NN-1
      MA=7*N-6
      ME=MA-6
```

```
      DO 820 I=10,ME
820   A1(I)=A(I+7)
      DO 830 I=1,N
830   R1(I)=R(I+1)
      GO TO 999
840   IF(SWBC1.NE.1)GO TO 1500
      A1(1)=A(1)
      A1(2)=A(3)
      A1(3)=A(4)
      A1(4)=A(9)
      A1(5)=A(10)
      DO 1510 I=6,10
1510  A1(I)=A(I+6)
      N=2*NN-1
      MA=7*N-6
      ME=MA-6
      DO 1520 I=11,ME
1520  A1(I)=A(I+7)
      R1(1)=R(1)
      DO 1530 I=2,N
1530  R1(I)=R(I+1)
      GO TO 979
1500  IF(FWBCN.NE.1)GO TO 1600
      ME16=ME-16
      ME12=ME-12
      DO 1610 I=ME16,ME12
1610  A1(I)=A(I+1)
      A1(ME-11)=A(ME-9)
      DO 1620 I=1,4
1620  A1(ME-11+I)=A(ME-4+I)
      N=2*NN-1
      MA=7*N-6
      ME=MA-6
      DO 1630 I=1,N
      IF(I.EQ.N)GO TO 1640
      R1(I)=R(I)
      GO TO 1630
1640  R1(I)=R(I+1)
1630  CONTINUE
      GO TO 999
1600  IF(SWBCN.NE.1)GO TO 1700
      ME16=ME-16
      DO 700 I=1,ME16
700   A1(I)=A(I)
      ME15=ME-15
      ME11=ME-11
      DO 710 I=ME15,ME11
710   A1(I)=A(I+1)
      ME10=ME-10
      ME7=ME-7
      DO 720 I=ME10,ME7
720   A1(I)=A(I+2)
      N=2*NN-1
      MA=7*N-6
```

```
      ME=MA-6
      DO 730 I=1,N
730   R1(I)=R(I)
      GO TO 999
1700  DO 1710 I=1,ME
1710  A1(I)=A(I)
      DO 1720 I=1,NN
1720  R1(I)=R(I)
      N=2*NN
999   CONTINUE
      CALL GELB(R1,A1,N,1,3,3,MA,1.0E-15,IER)
      IF(FWBC1.NE.1)GO TO 1800
      R(1)=FWH1(J)
      DO 1810 I=1,N
1810  R(I+1)=R1(I)
      GO TO 1900

1800  IF(SWBC1.NE.1)GO TO 1820
      R(1)=R1(1)
      R(2)=SWH1(J)
      DO 1830 I=2,N
1830  R(I+1)=R1(I)
      GO TO 1900
1820  IF(FWBCN.NE.1)GO TO 1840
      DO 1850 I=1,N
      IF(I.EQ.N)GO TO 1855
      R(I)=R1(I)
      GO TO 1850
1855  R(N)=FWHNN(J)
      R(N+1)=R1(N)
1850  CONTINUE
      GO TO 1900
1840  IF(SWBCN.NE.1)GO TO 1860
      DO 1870 I=1,N
1870  R(I)=R1(I)
      R(2*NN)=SWHNN(J)
      GO TO 1900
1860  DO 1890 I=1,NN
      R(2*I-1)=R1(2*I-1)
1890  R(2*I)=R1(2*I)
1900  CONTINUE
      IF (IER.NE.0)WRITE(WR,530)IER
C     IF(J.EQ.3)WRITE(WR,126)J,ITER
      DO 600 I=1,NN
      ZETA(I,J)=(GS*R(2*I)-GF*R(2*I-1))/DG
      IF(ZETA(I,J).LE.(ZB(I)+0.25))GO TO 605
      IF(NCONF.EQ.1.AND.ZETA(I,J).GE.0.)ZETA(I,J)=-0.25
      KS(I)=KSS(I)
      BSNEW=ZETA(I,J)-ZB(I)
      BFNEW=R(2*I-1)-ZETA(I,J)
      IF(NCONF.EQ.1)BFNEW=-ZETA(I,J)
      IF(BFNEW.LE.0.25)BFNEW=0.25
      GO TO 606
```

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605   ZETA(I,J)=ZB(I)+0.25
      BFNEW=R(2*I-1)-ZB(I)-0.25
      IF(NCONF.EQ.1)BFNEW=-ZB(I)-0.25
      BSNEW=0.25
      IF(BFNEW.LE.0.25)BFNEW=0.25
      IF(I.GT.NSWTOE)KS(NSWTOE)=KSS(NSWTOE)*1.0E-5
606   ERROR1(I)=(BF(I,J)-BFNEW)/BF(I,J)
      ERROR2(I)=(BS(I,J)-BSNEW)/BS(I,J)
      BF(I,J)=BFNEW
      BS(I,J)=BSNEW
      HF(I,J)=R(I*2-1)
      HS(I,J)=R(I*2)
      IF(BFNEW.LE.0.25.AND.ZETA(I,J).GT.0.)HF(I,J)=ZB(I)+0.5
126   FORMAT(' TIME STEP = ',I3,10X,'ITERATION NO. = ',I3)
C     IF(J.EQ.3)WRITE(WR,124)I,HF(I,J),HS(I,J),BF(I,J),BS(I,J),ZETA(I,J)
124   FORMAT(' ',I4,8(E13.5,2X))
600   CONTINUE
      IF(NSWTOE.EQ.0)GO TO 615
      DO 625 I=1,NE
      IF((ZETA(I,J)-ZB(I)).LE.0.25.AND.(ZETA(I+1,J)-ZB(I+1)).GT.0.25)GO
     1TO 620
625   CONTINUE
620   NSWTOE=I
      ZB2=ZB(I+1)-(ZB(I)-ZB(I+1))*(XC(I+1)-XC(I+2))/(XC(I)-XC(I+1))
      EL2=(XC(I+2)-XC(I+1))*(ZETA(I+1,J)-ZB(I+1))/(ZETA(I+2,J)-ZB2-ZETA
     1(I+1,J)+ZB(I+1))
      XSWTOE=XC(I+1)-EL2
C     WRITE(WR,630)XSWTOE
630   FORMAT(' S.W. TOE LOCATED AT X = ',E15.7)
      IF(EL2.LT.(XC(NSWTOE+1)-XC(NSWTOE)))GO TO 631
      BS(NSWTOE,J)=BS(NSWTOE+1,J)*(1.-(XC(NSWTOE+1)-XC(NSWTOE))/EL2)
      BF(NSWTOE,J)=BF(NSWTOE,J)-BS(NSWTOE,J)
      NSWTOE=I-1
      KS(NSWTOE)=KSS(NSWTOE)*1.0E5
631   CONTINUE
615   IF(NFWTOE.EQ.0)GO TO 635
      DO 640 I=1,NE
      IF((HF(I,J)-ZETA(I,J)).LE.0.25.AND.(HF(I+1,J)-ZETA(I+1,J)).GT..25)
     1GO TO 645
640   CONTINUE
645   NFWTOE=I
C     KF(NFWTOE)=1.0E-8
      ZB2=ZETA(I+1,J)-(ZETA(I,J)-ZETA(I+1,J))*(XC(I+1)-XC(I+2))/(XC(I)-
     1XC(I+1))
      EL2=(XC(I+2)-XC(I+1))*(HF(I+1,J)-ZETA(I+1,J))/(HF(I+2,J)-ZB2-HF(I+
     11,J)+ZETA(I+1,J))
      XFWTOE=XC(NFWTOE+1)-EL2
C     WRITE(WR,650)XFWTOE
650   FORMAT(' F.W. TOE LOCATED AT X =',E15.7)
635   DO 610 I=1,NN
      IF(ITER.GE.ITERMX)GO TO 610
      IF(ABS(ERROR1(I)).GT.TOL.OR.ABS(ERROR2(I)).GT.TOL)GO TO 50
610   CONTINUE
      WRITE(WR,1175)J,ITER
```

```
      IF(ITER.GE.ITERMX)WRITE(WR,1185)
      IF(NSWTOE.GT.0)WRITE(WR,630)XSWTOE
1175  FORMAT(' SOLUTION OBTAINED AT J =',I3,3X,'IN',I3,' ITERATIONS.')
      IF(NFWTOE.GT.0)WRITE(WR,650)XFWTOE
1185  FORMAT(' ITERATIONS, ITER = MAX. SPECIFIED, ITERMX')
      GO TO 25
530   FORMAT(' ERROR IN GELB, IER = ',I5)
C     OUTPUT OF RESULTS
C
1000  READ(RD,1120)(IO(I),I=1,NN)
1120  FORMAT(80I1)
      DO 900 I=1,NN
      IF(IO(I).EQ.0)GO TO 900
      WRITE(WR,1125)I
1125  FORMAT(/,'OOUTPUT AT NODE',I5,/)
      WRITE(WR,1130)(J,HF(I,J),J=1,JMAX)
      WRITE(WR,1135)(J,HS(I,J),J=1,JMAX)
      WRITE(WR,1140)(J,BF(I,J),J=1,JMAX)
      WRITE(WR,1155)(J,BS(I,J),J=1,JMAX)
      WRITE(WR,1178)(J,ZETA(I,J),J=1,JMAX)
1130  FORMAT('OPIEZOMETRIC HEAD OF FRESH WATER, HF        ',/,
     110(2X,I2,1X,F7.3))
1135  FORMAT('OPIEZOMETRIC HEAD OF SALT WATER, HS ',/,
     110(2X,I2,1X,F8.4))
1140  FORMAT('OTHICKNESS OF FRESH WATER LENS',/,10(2X,I2,1X,F7.2))
1155  FORMAT('0THICKNESS OF SALT WATER LENS',/,10(2X,I2,1X,F7.3))
1178  FORMAT('ODEPTH OF INTERFACE ABOVE MSL',/, 10(2X,I2,1X,F7.2))
900   CONTINUE
      WRITE(WR,2200)
      DO 910 I=1,NN
910   WRITE(WR,124)I,HF(I,JMAX),HS(I,JMAX),BF(I,JMAX),BS(I,JMAX)
2200  FORMAT('O AQUIFER CONDITIONS AT TIME J = JMAX')
      STOP
      END

C
      SUBROUTINE GELB(R,A,M,N,MUD,MLD,MA,EPS,IER)
C
C
      DIMENSION R(M),A(MA)
      DOUBLE PRECISION A,R,TB,PIV
C     TEST ON WRONG INPUT PARAMETERS
      IF(MLD)47,1,1
 1    IF(MUD)47,2,2
 2    MC=1+MLD+MUD
      IF(MC+1-M-M)3,3,47
C
C     PREPARE INTEGER PARAMETERS
C        MC=NUMBER OF COLUMNS IN MATRIX A
C        MU=NUMBER OF ZEROS TO BE INSERTED IN FIRST ROW OF MATRIX A
C        ML=NUMBER OF MISSING ELEMENTS IN LAST ROW OF MATRIX A
C        MR=INDEX OF LAST ROW IN MATRIX A WITH MC ELEMENTS
C        MZ=TOTAL NUMBER OF ZEROS TO BE INSERTED IN MATRIX A
C        MA=TOTAL NUMBER OF STORAGE LOCATIONS NECESSARY FOR MATRIX A
```

```
C        NM=NUMBER OF ELEMENTS IN MATRIX A                              GEL00860
   3    IF(MC-M)5,5,4                                                   GEL00870
   4    MC=M                                                            GEL00880
   5    MU=MC-MUD-1                                                     GEL00890
        ML=MC-MLD-1                                                     GEL00900
        MR=M-ML                                                         GEL00910
        MZ=(MU*(MU+1))/2                                                GEL00920
        MA=M*MC-(ML*(ML+1))/2                                           GEL00930
        NM=N*M                                                          GEL00940
C       DIMENSION R(M),A(MA)                                            GEL00950
C       MOVE ELEMENTS BACKWARD AND SEARCH FOR ABSOLUTELY GREATEST ELEMENT GEL00960
C       (NOT NECESSARY IN CASE OF A MATRIX WITHOUT LOWER CODIAGONALS)   GEL00970
        IER=0                                                           GEL00980
        PIV=0.                                                          GEL00990
        IF(MLD)14,14,6                                                  GEL01000
   6    JJ=MA                                                           GEL01010
        J=MA-MZ                                                         GEL01020
        KST=J                                                           GEL01030
        DO 9 K=1,KST                                                    GEL01040
        TB=A(J)                                                         GEL01050
        A(JJ)=TB                                                        GEL01060
        TB=DABS(TB)                                                     GEL01070
        IF(TB-PIV)8,8,7                                                 GEL01080
   7    PIV=TB                                                          GEL01090
   8    J=J-1                                                           GEL01100
   9    JJ=JJ-1                                                         GEL01110
C                                                                       GEL01120
C       INSERT ZEROS IN FIRST MU ROWS (NOT NECESSARY IN CASE MZ=0)      GEL01130
        IF(MZ)14,14,10                                                  GEL01140
  10    JJ=1                                                            GEL01150
        J=MZ+1                                                          GEL01160
        IC=1+MUD                                                        GEL01170
        DO 13 I=1,MU                                                    GEL01180
        DO 12 K=1,MC                                                    GEL01190
        A(JJ)=0.                                                        GEL01200
        IF(K-IC)11,11,12                                                GEL01210
  11    A(JJ)=A(J)                                                      GEL01220
        J=J+1                                                           GEL01230
  12    JJ=JJ+1                                                         GEL01240
  13    IC=IC+1                                                         GEL01250
C                                                                       GEL01260
C       GENERATE TEST VALUE FOR SINGULARITY                             GEL01270
  14    TOL=EPS*PIV                                                     GEL01280
C                                                                       GEL01290
C       START DECOMPOSITION LOOP                                        GEL01310
        KST=1                                                           GEL01320
        IDST=MC                                                         GEL01330
        IC=MC-1                                                         GEL01340
        DO 38 K=1,M                                                     GEL01350
        IF(K-MR-1)16,16,15                                              GEL01360
  15    UDST=IDST-1                                                     GEL01370
  16    ID=IDST                                                         GEL01380
        ILR=K+MLD                                                       GEL01390
        IF(ILR-M)18,18,17                                               GEL01400
```

```
 17   ILR=M
 18   II=KST
C
C     PIVOT  SEARCH IN FIRST COLUMN(ROW INDEXES FROM I=K TO I=ILR)
      PIV=0.
      DO 22 I=K,ILR
      TB=DABS(A(II))
      IF(TB-PIV)20,20,19
 19   PIV=TB
      J=I
      JJ=II
 20   IF(I-MR)22,22,21
 21   ID=ID-1
 22   II=II+ID
C
C     TEST ON SINGULARITY
      IF(PIV)47,47,23
 23   IF(IER)26,24,26
 24   IF(PIV-TOL)25,25,26
 25   IER=K-1
 26   PIV=1./A(JJ)
C
C     PIVOT ROW REDUCTION AND ROW INTERCHANGE IN RIGHT HAND SIDE R
      ID=J-K
      DO 27 I=K,NM,M
      II=I+ID
      TB=PIV=R(II)
      R(II)=R(I)
 27   R(I)=TB
C
C     PIVOT TOW REDUCTION AND ROW INTERCHANGE IN COEFFICIENT MATRIX A
      II=KST
      J=JJ+IC
      DO 28 I=JJ,J
      TB=PIV=A(I)
      A(I)=A(II)
      A(II)=TB
 28   II=II+1
C
C     ELEMENT REDUCTION
      IF(K-ILR)29,34,34
 29   ID=KST
      II=K+1
      MU=KST+1
      MZ=KST+IC
      DO 33 I=II,ILR
C
C     IN MATRIX A
      ID=ID+MC
      JJ=I-MR-1
      IF(JJ)31,31,30
 30   ID=ID-JJ
 31   PIV=-A(ID)
      J=ID+1
```

```
      DO 32 JJ=MU,MZ
      A(J-1)=A(J)+PIV*A(JJ)
   32 J=J+1
      A(J-1)=0.
C
C     IN MATRIX R
      J=K
      DO 33 JJ=I,NM,M
      R(JJ)=R(JJ)+PIV*R(J)
   33 J=J+M
   34 KST=KST+MC
      IF(ILR-MR)36,35,35
   35 IC=IC-1
   36 ID=K-MR
      IF(ID)38,38,37
   37 KST=KST-ID
   38 CONTINUE
C     END OF DECOMPOSITION LOOP
C
C
C     BACK SUBSTITUTION
      IF(MC-1)46,46,39
   39 IC=2
      KST=MA+ML-MC+2
      II=M
      DO 45 I=2,M
      KST=KST-MC
      II=II-1
      J=II-MR
      IF(J)41,41,40
   40 KST=KST+J
   41 DO 43 J=II,NM,M
      TB=R(J)
      MZ=KST+IC-2
      ID=J
      DO 42 JJ=KST,MZ
      ID=ID+1
   42 TB=TB-A(JJ)*R(ID)
   43 R(J)=TB
      IF(IC-MC)44,45,45
   44 IC=IC+1
   45 CONTINUE
   46 RETURN
C
C
C     ERROR RETURN
   47 IER=-1
      RETURN
      END
```

APPENDIX D

Sample Problems

The input and output for two different problems are given. The first problem is that of an aquifer with a uniform recharge and a fresh water lens over the salt water. The results of this example are plotted in figure 1. The second example is that of a confined aquifer with a fresh water discharge flowing into the aquifer at the left-hand end and the ocean on the right-hand end. This situation is identical to that shown in figure 2.

```
      DATA FOR SAMPLE PROGRAM # 1.
      AQUIFEP WITH UNIFORM RECHARGE AND A FRESH WATER LENS OVER SALT WATER
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

   21   20    0
1     -22000.     -600.
2     -20000.     -600.
3     -17100.     -600.
4     -15300.     -600.
5     -13600.     -600.
6     -12000.     -600.
7     -10500.     -600.
8     -9100.      -600.
9     -7800.      -600.
10    -6600.      -600.
11    -5500.      -600.
12    -4500.      -600.
13    -3600.      -600.
14    -2800.      -600.
15    -2100.      -600.
16    -1500.      -600.
17    -1000.      -600.
18    -600.       -600.
19    -300.       -600.
20    -100.       -600.
21    0.          -600.
1        .01      .01025      0.3
2        .01      .01025      0.3
3        .01      .01025      0.3
4        .01      .01025      0.3
5        .01      .01025      0.3
6        .01      .01025      0.3
7        .01      .01025      0.3
8        .01      .01025      0.3
9        .01      .01025      0.3
10       .01      .01025      0.3
11       .01      .01025      0.3
12       .01      .01025      0.3
13       .01      .01025      0.3
14       .01      .01025      0.3
15       .01      .01025      0.3
16       .01      .01025      0.3
17       .01      .01025      0.3
18       .01      .01025      0.3
19       .01      .01025      0.3
20       .01      .01025      0.3
   16   10    0    0
 +C.8640000E+051.0           .005
    2    2    3    1
0.        0.        0.        0.        0.        0.        0.        0.
0.        0.        0.        0.        0.        0.        0.        0.
0.        0.        C.        0.        0.        0.        0.        0.
0.        0.        0.        0.        0.        0.        0.        0.
```

0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001

1	10.87	0.000	446.00	154.0
2	10.82	0.000	444.00	156.0
3	10.59	0.000	434.00	166.0
4	10.35	0.000	424.00	176.0
5	10.04	0.000	412.00	188.0
6	9.68	0.000	397.00	203.00
7	9.26	0.000	380.00	220.00
8	8.80	0.000	361.00	239.00
9	8.300	0.000	340.00	260.0
10	7.760	0.000	318.00	282.00
11	7.19	0.000	295.00	305.0
12	6.590	0.000	270.00	330.00
13	5.960	.000	244.00	356.0
14	5.31	.000	218.0	382.0
15	4.63	.000	190.0	410.0
16	4.040	.000	162.0	438.0
17	3.240	.000	133.0	467.0
18	2.550	.000	92.0	508.0
19	1.800	.000	73.0	527.0
20	1.040	.000	42.00	558.0
21	0.203	0.00	8.570	591.40

1 1 1 1 11

Output of Sample Problem 1.

ONE-DIMENSIONAL SALT WATER INTRUSION MODEL

NO. OF NODES= 21   NO. OF ELEM.= 20   NCONF= 0

NODE	X-COORDINATE	BED ELEVATION
1	-22000.00	-600.00
2	-20000.00	-600.00
3	-17100.00	-600.00
4	-15300.00	-600.00
5	-13600.00	-600.00
6	-12000.00	-600.00
7	-10500.00	-600.00
8	-9100.00	-600.00
9	-7800.00	-600.00
10	-6600.00	-600.00
11	-5500.00	-600.00
12	-4500.00	-600.00
13	-3600.00	-600.00
14	-2800.00	-600.00
15	-2100.00	-600.00
16	-1500.00	-600.00
17	-1000.00	-600.00
18	-600.00	-600.00
19	-300.00	-600.00
20	-100.00	-600.00
21	0.0	-600.00

ELEMENT	F. W. PERM.	S. W. PERM.	POROSITY
1	0.01000	0.01025000	0.29999995
2	0.01000	0.01025000	0.29999995
3	0.01000	0.01025000	0.29999995
4	0.01000	0.01025000	0.29999995
5	0.01000	0.01025000	0.29999995
6	0.01000	0.01025000	0.29999995
7	0.01000	0.01025000	0.29999995
8	0.01000	0.01025000	0.29999995
9	0.01000	0.01025000	0.29999995
10	0.01000	0.01025000	0.29999995
11	0.01000	0.01025000	0.29999995
12	0.01000	0.01025000	0.29999995
13	0.01000	0.01025000	0.29999995
14	0.01000	0.01025000	0.29999995
15	0.01000	0.01025000	0.29999995
16	0.01000	0.01025000	0.29999995
17	0.01000	0.01025000	0.29999995
18	0.01000	0.01025000	0.29999995
19	0.01000	0.01025000	0.29999995
20	0.01000	0.01025000	0.29999995

```
FWBCI =  2       SWBCI=  2       FWBCN=  3       SWBCN=  1

FW DISCH. SPEC. AT LEFT HAND END
  1      0.0   2      0.0   3      0.0   4      0.0   5      0.0   6      0.0   7
0.0   8      0.0   9      0.0  10      0.0
 11      0.0  12      0.0  13      0.0  14      0.0  15      0.0  16      0.0

SW DISCH. SPEC. AT RIGHT HAND END
  1      0.0   2      0.0   3      0.0   4      0.0   5      0.0   6      0.0   7
0.0   8      0.0   9      0.0  10      0.0
 11      0.0  12      0.0  13      0.0  14      0.0  15      0.0  16      0.0

SW HEAD SPEC. AT RIGHT HAND END
  1      0.0   2      0.0   3      0.0   4      0.0   5      0.0   6      0.0   7



0.0   8      0.0   9      0.0  10      0.0
 11      0.0  12      0.0  13      0.0  14      0.0  15      0.0  16      0.0

TIME INTERVAL DT =    0.8640000E 05          WEIGHTING FACTOR  THETA =  1.00
MAX. NO. OF TIME ITERATIONS, JMAX =    16             TOLERANCE ON CONVERGENCE AS A
 FRACTION =     0.00500

RECHARGE AS A FUNCTION OF TIME
ELEMENT I =    1
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
ELEMENT I =    2
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
ELEMENT I =    3
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
ELEMENT I =    4
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
ELEMENT I =    5
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
ELEMENT I =    6
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
ELEMENT I =    7
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
ELEMENT I =    8
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
ELEMENT I =    9
  1  0.0000001   2  0.0000001   3  0.0000001   4  0.0000001   5  0.0000001   6
0.0000001   7  0.0000001   8  0.0000001
  9  0.0000001  10  0.0000001  11  0.0000001  12  0.0000001  13  0.0000001  14
0.0000001  15  0.0000001  16  0.0000001
```

```
ELEMENT I =  10
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  11
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  12
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  13
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  14
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  15
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  16
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  17
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  18
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  19
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001
ELEMENT I =  20
  1  0.0000001    2  0.0000001    3  0.0000001    4  0.0000001    5  0.0000001    6
0.0000001    7  0.0000001    8  0.0000001
  9  0.0000001   10  0.0000001   11  0.0000001   12  0.0000001   13  0.0000001   14
0.0000001   15  0.0000001   16  0.0000001

PUMP AT NODE    6
FLOW RATE AS A FUNCTION OF TIME
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0

PUMP AT NODE   10
FLOW RATE AS A FUNCTION OF TIME
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0
```

```
PUMP AT NODE  15
FLOW RATE AS A FUNCTION OF TIME
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6

0.0        7  0.0        8  0.0                     12  0.0        13  0.0        14
  9  0.0       10  0.0       11  0.0
0.0       15  0.0       16  0.0
   INITIAL CONDITIONS
   NODE NUMBER F.W. HEAD S.W. HEAD  F.W. THICKNESS S.W. THICKNESS
       1          10.87       0.0        446.00       154.00
       2          10.82       0.0        444.00       156.00
       3          10.59       0.0        434.00       166.00
       4          10.35       0.0        424.00       176.00
       5          10.04       0.0        412.00       188.00
       6           9.68       0.0        397.00       203.00
       7           9.26       0.0        380.00       220.00
       8           8.80       0.0        361.00       239.00
       9           8.30       0.0        340.00       260.00
      10           7.76       0.0        318.00       282.00
      11           7.19       0.0        295.00       305.00
      12           6.59       0.0        270.00       330.00
      13           5.96       0.0        244.00       356.00
      14           5.31       0.0        218.00       382.00
      15           4.63       0.0        190.00       410.00
      16           4.04       0.0        162.00       438.00
      17           3.24       0.0        133.00       467.00
      18           2.55       0.0         92.00       508.00
      19           1.80       0.0         73.00       527.00
      20           1.04       0.0         42.00       558.00
      21           0.20       0.0          8.57       591.40
   TIME STEP =   2            ITERATION NO. =    1
   TIME STEP =   2            ITERATION NO. =    2
   TIME STEP =   2            ITERATION NO. =    3
   SOLUTION OBTAINED AT J =  2   IN  3 ITERATIONS.
   TIME STEP =   3            ITERATION NO. =    1
   TIME STEP =   3            ITERATION NO. =    2
   SOLUTION OBTAINED AT J =  3   IN  2 ITERATIONS.
   TIME STEP =   4            ITERATION NO. =    1
   TIME STEP =   4            ITERATION NO. =    2
   SOLUTION OBTAINED AT J =  4   IN  2 ITERATIONS.
   TIME STEP =   5            ITERATION NO. =    1
   SOLUTION OBTAINED AT J =  5   IN  1 ITERATIONS.
   TIME STEP =   6            ITERATION NO. =    1
   SOLUTION OBTAINED AT J =  6   IN  1 ITERATIONS.
   TIME STEP =   7            ITERATION NO. =    1
   SOLUTION OBTAINED AT J =  7   IN  1 ITERATIONS.
   TIME STEP =   8            ITERATION NO. =    1
   SOLUTION OBTAINED AT J =  8   IN  1 ITERATIONS.
   TIME STEP =   9            ITERATION NO. =    1
   SOLUTION OBTAINED AT J =  9   IN  1 ITERATIONS.
   TIME STEP =  10            ITERATION NO. =    1
   SOLUTION OBTAINED AT J = 10   IN  1 ITERATIONS.
   TIME STEP =  11            ITERATION NO. =    1
   SOLUTION OBTAINED AT J = 11   IN  1 ITERATIONS.
   TIME STEP =  12            ITERATION NO. =    1
   SOLUTION OBTAINED AT J = 12   IN  1 ITERATIONS.
   TIME STEP =  13            ITERATION NO. =    1
   SOLUTION OBTAINED AT J = 13   IN  1 ITERATIONS.
   TIME STEP =  14            ITERATION NO. =    1
   SOLUTION OBTAINED AT J = 14   IN  1 ITERATIONS.
   TIME STEP =  15            ITERATION NO. =    1
   SOLUTION OBTAINED AT J = 15   IN  1 ITERATIONS.
   TIME STEP =  16            ITERATION NO. =    1
   SOLUTION OBTAINED AT J = 16   IN  1 ITERATIONS.
```

```
OUTPUT AT NODE     1


PIEZOMETRIC HEAD OF FRESH WATER, HF
  1  10.870    2  10.961    3  10.974    4   10.975    5   10.976    6   10.980    7  10.
974   8  10.977    9  10.971   10  10.980
 11  10.985  12  10.976  13  10.973  14   10.976  15   10.978  16   10.981

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0       2  0.0888    3  0.1017    4   0.1025    5   0.1040    6   0.1073    7  0.1
017    8  0.1048    9  0.0991   10  0.1077
 11  0.1128  12  0.1036  13  0.1004  14   0.1035  15   0.1054  16   0.1084

THICKNESS OF FRESH WATER LENS
  1  446.00    2  434.89    3  434.90    4   434.90    5   434.90    6   434.90    7  434
.90    8  434.90    9  434.89   10  434.90
 11  434.90  12  434.89  13  434.89  14   434.89  15   434.89  16   434.89

THICKNESS OF SALT WATER LENS
  1 154.000   2 176.071   3 176.073   4 176.074   5 176.075   6 176.077   7 176.
078    8 176.080   9 176.081  10 176.083
 11 176.084  12 176.085  13 176.086  14 176.088  15 176.090  16 176.091

DEPTH OF INTERFACE ABOVE MSL
  1 -423.93   2 -423.93   3 -423.93   4 -423.93   5 -423.92   6 -423.92   7 -423
.92    8 -423.92   9 -423.92  10 -423.92
 11 -423.92  12 -423.91  13 -423.91  14 -423.91  15 -423.91  16 -423.91


OUTPUT AT NODE     5


PIEZOMETRIC HEAD OF FRESH WATER, HF
  1  10.040    2  10.123    3  10.134    4   10.133    5   10.135    6   10.138    7  10.
133    8  10.136    9  10.131   10  10.139
 11  10.143  12  10.135  13  10.132  14   10.135  15   10.137  16   10.140

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0       2  0.0806    3  0.0915    4   0.0907    5   0.0924    6   0.0949    7  0.0
905    8  0.0931    9  0.0883   10  0.0957
 11  0.1002  12  0.0922  13  0.0889  14   0.0921  15   0.0936  16   0.0962

THICKNESS OF FRESH WATER LENS
  1  412.00    2  401.69    3  401.70    4   401.70    5   401.71    6   401.71    7  401
.71    8  401.71    9  401.71   10  401.72
 11  401.73  12  401.72  13  401.72  14   401.73  15   401.73  16   401.73

THICKNESS OF SALT WATER LENS
  1 188.000   2 208.437   3 208.435   4 208.432   5 208.429   6 208.427   7 208.
425    8 208.422   9 208.419  10 208.418
 11 208.416  12 208.414  13 208.412  14 208.410  15 208.408  16 208.407

DEPTH OF INTERFACE ABOVE MSL
  1 -391.56   2 -391.56   3 -391.57   4 -391.57   5 -391.57   6 -391.57   7 -391
.58    8 -391.58   9 -391.58  10 -391.58
 11 -391.58  12 -391.59  13 -391.59  14 -391.59  15 -391.59  16 -391.59
```

```
OUTPUT AT NODE   10


PIEZOMETRIC HEAD OF FRESH WATER, HF
  1   7.760   2    7.809   3    7.815   4    7.815   5    7.816   6    7.817   7   7.
815   8   7.816   9    7.814  10    7.818
 11   7.820  12    7.816  13    7.815  14    7.816  15    7.817  16    7.818

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0       2  0.0482   3  0.0539   4  0.0534   5  0.0543   6  0.0554   7  0.0

534   8  0.0546   9  0.0521  10  0.0559
 11  0.0582  12  0.0541  13  0.0525  14  0.0541  15  0.0545  16  0.0561

THICKNESS OF FRESH WATER LENS
  1  318.00   2  310.45   3  310.46   4  310.46   5  310.47   6  310.47   7  310
.47   8  310.47   9  310.47  10  310.48
 11  310.48  12  310.48  13  310.48  14  310.48  15  310.49  16  310.49

THICKNESS OF SALT WATER LENS
  1 282.000   2 297.358   3 297.355   4 297.353   5 297.350   6 297.348   7 297.
346   8 297.343   9 297.341  10 297.339
 11 297.337  12 297.335  13 297.333  14 297.332  15 297.330  16 297.328

DEPTH OF INTERFACE ABOVE MSL
  1 -302.64   2 -302.64   3 -302.64   4 -302.65   5 -302.65   6 -302.65   7 -302
.65   8 -302.66   9 -302.66  10 -302.66
 11 -302.66  12 -302.67  13 -302.67  14 -302.67  15 -302.67  16 -302.67
OUTPUT AT NODE   15


PIEZOMETRIC HEAD OF FRESH WATER, HF
  1   4.630   2    4.653   3    4.658   4    4.661   5    4.663   6    4.665   7   4.
665   8   4.667   9    4.666  10    4.668
 11   4.669  12    4.668  13    4.668  14    4.669  15    4.669  16    4.670

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0       2  0.0175   3  0.0181   4  0.0169   5  0.0165   6  0.0162   7  0.0
150   8  0.0151   9  0.0139  10  0.0149
 11  0.0155  12  0.0140  13  0.0134  14  0.0139  15  0.0139  16  0.0144

THICKNESS OF FRESH WATER LENS
  1  190.00   2  185.44   3  185.62   4  185.75   5  185.86   6  195.94   7  186
.01   8  186.06   9  186.10  10  186.13
 11  186.16  12  186.18  13  186.19  14  186.20  15  186.21  16  186.22

THICKNESS OF SALT WATER LENS
  1 410.000   2 419.212   3 419.042   4 418.908   5 418.804   6 418.722   7 418.
658   8 418.607   9 418.567  10 418.536
 11 418.511  12 418.492  13 418.478  14 418.467  15 418.458  16 418.452

DEPTH OF INTERFACE ABOVE MSL
  1 -180.57   2 -180.79   3 -180.96   4 -181.09   5 -181.20   6 -181.28   7 -181
.34   8 -181.39   9 -181.43  10 -181.46
 11 -181.49  12 -181.51  13 -181.52  14 -181.53  15 -181.54  16 -181.55
```

```
OUTPUT AT NODE   20


PIEZOMETRIC HEAD OF FRESH WATER, HF
  1   1.040   2   1.046   3   1.049   4   1.052   5   1.054   6   1.056   7   1.
057   8   1.058   9   1.058  10   1.059
 11   1.060  12   1.060  13   1.060  14   1.061  15   1.061  16   1.061

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0      2  0.0016   3  0.0015   4  0.0013   5  0.0013   6  0.0012   7  0.0
010   8  0.0010   9  0.0009  10  0.0009
 11  0.0009  12  0.0008  13  0.0008  14  0.0008  15  0.0008  16  0.0008

THICKNESS OF FRESH WATER LENS
  1   42.00   2   41.77   3   41.91   4   42.03   5   42.12   6   42.19   7   42



.24   8   42.28   9   42.30  10   42.33
 11   42.35  12   42.36  13   42.38  14   42.39  15   42.40  16   42.42

THICKNESS OF SALT WATER LENS
  1 558.000   2 559.277   3 559.135   4 559.025   5 558.935   6 558.868   7 558.
819   8 558.783   9 558.755  10 558.732
 11 558.713  12 558.697  13 558.683  14 558.670  15 558.657  16 558.645

DEPTH OF INTERFACE ABOVE MSL
  1  -40.56   2  -40.72   3  -40.86   4  -40.98   5  -41.07   6  -41.13   7  -41
.18   8  -41.22   9  -41.25  10  -41.27
 11  -41.29  12  -41.30  13  -41.32  14  -41.33  15  -41.34  16  -41.35

 OUTPUT AT NODE   21


 PIEZOMETRIC HEAD OF FRESH WATER, HF
   1   0.203   2   0.207   3   0.210   4   0.211   5  -0.212   6   0.213   7   0.
 214   8   0.214   9   0.215  10   0.215
  11   0.215  12   0.215  13   0.216  14   0.216  15   0.216  16   0.216

 PIEZOMETRIC HEAD OF SALT WATER, HS
   1  0.0      2  0.0      3  0.0      4  0.0      5  0.0      6  0.0      7  0.0
       8  0.0      9  0.0     10  0.0
  11  0.0     12  0.0     13  0.0     14  0.0     15  0.0     16  0.0

 THICKNESS OF FRESH WATER LENS
   1    8.57   2    8.30   3    8.39   4    8.45   5    8.49   6    8.52   7    8
 .55   8    8.57   9    8.59  10    8.60
  11    8.61  12    8.62  13    8.63  14    8.63  15    8.64  16    8.64

 THICKNESS OF SALT WATER LENS
   1 591.400   2 591.910   3 591.819   4 591.759   5 591.726   6 591.693   7 591.
 666   8 591.644   9 591.628  10 591.615
  11 591.604  12 591.597  13 591.590  14 591.584  15 591.579  16 591.574

 DEPTH OF INTERFACE ABOVE MSL
   1   -7.92   2   -8.09   3   -8.18   4   -8.24   5   -8.27   6   -8.31   7   -8
 .33   8   -8.36   9   -8.37  10   -8.39
  11   -8.40  12   -8.40  13   -8.41  14   -8.42  15   -8.42  16   -8.43
```

```
      DATA FOR SAMPLE PROBLEM # 2.
      CONFINED AQUIFER WITH A CONSTANT FRESH WATER DISCHARGE.
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890
   21   20     1
1     -22000.   -300.
2     -20000.    -300.
3     -17100.    -300.
4     -15300.    -300.
5     -13600.    -300.
6     -12000.    -300.
7     -10500.    -300.
8     -9100.     -300.
9     -7800.     -300.
10    -6600.     -300.
11    -5500.     -300.
12    -4500.     -300.
13    -3600.     -300.
14    -2800.     -300.
15    -2100.     -300.
16    -1500.     -300.
17    -1000.     -300.
18    -600.      -300.
19    -300.      -300.
20    -100.      -300.
21    0.         -300.
1       .01     .0000001   0.3
2       .01     .0000001   0.3
3       .01     .0000001   0.3
4       .01     .0000001   0.3
5       .01     .0000001   0.3
6       .01     .0000001   0.3
7       .01     .0000001   0.3
8       .01     .0000001   0.3
9       .01     .0000001   0.3
10      .01     .0000001   0.3
11      .01     .0000001   0.3
12      .01     .01025     0.3
13      .01     .01025     0.3
14      .01     .01025     0.3
15      .01     .01025     0.3
16      .01     .01025     0.3
17      .01     .01025     0.3
18      .01     .01025     0.3
19      .01     .01025     0.3
20      .01     .01025     0.3
   16   10   11    0
+0.1036800E+081.0          .005
    2    2    3    1
0.0022    0.0022    0.0022    0.0022    0.0022    0.0022    0.0022    0.0022
0.0022    0.0022    0.0022    0.0022    0.0022    0.0022    0.0022    0.0022
0.        0.        0.        0.        0.        0.        0.        0.
0.        0.        0.        0.        0.        0.        0.        0.
```

0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
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

6 10 15

0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
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	20.04	0.000	299.75	0.250
2	18.54	0.000	299.75	0.250
3	16.44	0.000	299.75	0.250
4	15.12	0.000	299.75	0.250
5	13.87	0.000	299.75	0.250
6	12.69	0.000	299.75	0.250
7	11.59	0.000	299.75	0.250
8	10.56	0.000	299.75	0.250
9	9.60	0.000	299.75	0.250
10	8.72	0.000	299.75	0.250
11	7.88	0.000	299.75	0.250
12	7.080	0.000	277.90	22.100
13	6.300	.000	248.60	51.40
14	5.54	.000	219.3	80.70
15	4.79	.000	190.0	110.0
16	4.040	.000	160.6	139.4
17	3.240	.000	133.0	167.0
18	2.550	.000	92.0	208.0
19	1.800	.000	73.0	227.0
20	1.040	.000	42.00	258.0
21	0.303	0.00	8.570	291.40

1 1 1 1 11

Output of Sample Problem #2.

ONE-DIMENSIONAL SALT WATER INTRUSION MODEL

NO. OF NODES= 21 NO. OF ELEM.= 20 NCONF= 1

NODE	X-COORDINATE	BED ELEVATION
1	-22000.00	-300.00
2	-20000.00	-300.00
3	-17100.00	-300.00
4	-15300.00	-300.00
5	-13600.00	-300.00
6	-12000.00	-300.00
7	-10500.00	-300.00
8	-9100.00	-300.00
9	-7800.00	-300.00
10	-6600.00	-300.00
11	-5500.00	-300.00
12	-4500.00	-300.00
13	-3600.00	-300.00
14	-2800.00	-300.00
15	-2100.00	-300.00
16	-1500.00	-300.00
17	-1000.00	-300.00
18	-600.00	-300.00
19	-300.00	-300.00
20	-100.00	-300.00
21	0.0	-300.00

ELEMENT	F. W. PERM.	S. W. PERM.	POROSITY
1	0.01000	0.00000010	0.29999995
2	0.01000	0.00000010	0.29999995
3	0.01000	0.00000010	0.29999995
4	0.01000	0.00000010	0.29999995
5	0.01000	0.00000010	0.29999995
6	0.01000	0.00000010	0.29999995
7	0.01000	0.00000010	0.29999995
8	0.01000	0.00000010	0.29999995
9	0.01000	0.00000010	0.29999995
10	0.01000	0.00000010	0.29999995
11	0.01000	0.00000010	0.29999995
12	0.01000	0.01025000	0.29999995
13	0.01000	0.01025000	0.29999995
14	0.01000	0.01025000	0.29999995
15	0.01000	0.01025000	0.29999995
16	0.01000	0.01025000	0.29999995
17	0.01000	0.01025000	0.29999995
18	0.01000	0.01025000	0.29999995
19	0.01000	0.01025000	0.29999995
20	0.01000	0.01025000	0.29999995

```
FWBCI =  2     SWBCI=  2     FWBCN=  3     SWBCN=  1

FW DISCH. SPEC. AT LEFT HAND END
  1  0.0022   2  0.0022   3  0.0022   4  0.0022   5  0.0022   6  0.0022   7  0.0
022   8  0.0022   9  0.0022  10  0.0022
 11  0.0022  12  0.0022  13  0.0022  14  0.0022  15  0.0022  16  0.0022

SW DISCH. SPEC. AT RIGHT HAND END
  1      0.0   2      0.0   3      0.0   4      0.0   5      0.0   6      0.0   7
0.0   8      0.0   9      0.0  10      0.0
 11      0.0  12      0.0  13      0.0  14      0.0  15      0.0  16      0.0

SW HEAD SPEC. AT RIGHT HAND END
  1      0.0   2      0.0   3      0.0   4      0.0   5      0.0   6      0.0   7



0.0   8      0.0   9      0.0  10      0.0
 11      0.0  12      0.0  13      0.0  14      0.0  15      0.0  16      0.0

TIME INTERVAL DT =   0.1036800E 08           WEIGHTING FACTOR  THETA =  1.00
MAX. NO. OF TIME ITERATIONS, JMAX =   16           TOLERANCE ON CONVERGENCE AS A
 FRACTION =     0.00500

RECHARGE AS A FUNCTION OF TIME
ELEMENT I =    1
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
ELEMENT I =    2
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
ELEMENT I =    3
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
ELEMENT I =    4
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
ELEMENT I =    5
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
ELEMENT I =    6
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
ELEMENT I =    7
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
ELEMENT I =    8
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
ELEMENT I =    9
  1  0.0        2  0.0        3  0.0        4  0.0        5  0.0        6
0.0        7  0.0        8  0.0
  9  0.0       10  0.0       11  0.0       12  0.0       13  0.0       14
0.0       15  0.0       16  0.0
```

```
ELEMENT I =  10
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0
ELEMENT I =  11
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14

0.0         15  0.0         16  0.0
ELEMENT I =  12
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0
ELEMENT I =  13
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0
ELEMENT I =  14
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0
ELEMENT I =  15
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0
ELEMENT I =  16
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0

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

PUMP AT NODE    6
FLOW RATE AS A FUNCTION OF TIME
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0

PUMP AT NODE   10
FLOW RATE AS A FUNCTION OF TIME
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0          7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0         15  0.0         16  0.0
```

```
PUMP AT NODE  15
FLOW RATE AS A FUNCTION OF TIME
  1  0.0          2  0.0          3  0.0          4  0.0          5  0.0          6
0.0         7  0.0          8  0.0
  9  0.0         10  0.0         11  0.0         12  0.0         13  0.0         14
0.0        15  0.0         16  0.0
```

INITIAL CONDITIONS

NODE NUMBER	F.W. HEAD	S.W. HEAD	F.W. THICKNESS	S.W. THICKNESS
1	20.04	0.0	299.75	0.25
2	18.54	0.0	299.75	0.25
3	16.44	0.0	299.75	0.25
4	15.12	0.0	299.75	0.25
5	13.87	0.0	299.75	0.25
6	12.69	0.0	299.75	0.25
7	11.59	0.0	299.75	0.25
8	10.56	0.0	299.75	0.25
9	9.60	0.0	299.75	0.25
10	8.72	0.0	299.75	0.25
11	7.88	0.0	299.75	0.25
12	7.08	0.0	277.90	22.10
13	6.30	0.0	248.60	51.40
14	5.54	0.0	219.30	80.70
15	4.79	0.0	190.00	110.00
16	4.04	0.0	160.60	139.40
17	3.24	0.0	133.00	167.00
18	2.55	0.0	92.00	208.00
19	1.80	0.0	73.00	227.00
20	1.04	0.0	42.00	258.00
21	0.20	0.0	8.57	291.40

```
TIME STEP =    2            ITERATION NO. =    1
S.W. TOE LOCATED AT X =   -0.5229191E 04
TIME STEP =    2            ITERATION NO. =    2
S.W. TOE LOCATED AT X =   -0.5226313E 04
TIME STEP =    2            ITERATION NO. =    3
S.W. TOE LOCATED AT X =   -0.5226457E 04
SOLUTION OBTAINED AT J =  2   IN   3 ITERATIONS.
TIME STEP =    3            ITERATION NO. =    1
S.W. TOE LOCATED AT X =   -0.5235496E 04
TIME STEP =    3            ITERATION NO. =    2
S.W. TOE LOCATED AT X =   -0.5235250E 04
SOLUTION OBTAINED AT J =  3   IN   2 ITERATIONS.
TIME STEP =    4            ITERATION NO. =    1
S.W. TOE LOCATED AT X =   -0.5238676E 04
SOLUTION OBTAINED AT J =  4   IN   1 ITERATIONS.
TIME STEP =    5            ITERATION NO. =    1
S.W. TOE LOCATED AT X =   -0.5238664E 04
SOLUTION OBTAINED AT J =  5   IN   1 ITERATIONS.
TIME STEP =    6            ITERATION NO. =    1
S.W. TOE LOCATED AT X =   -0.5236582E 04
TIME STEP =    6            ITERATION NO. =    2
S.W. TOE LOCATED AT X =   -0.5236781E 04
SOLUTION OBTAINED AT J =  6   IN   2 ITERATIONS.
TIME STEP =    7            ITERATION NO. =    1
S.W. TOE LOCATED AT X =   -0.5233578E 04
TIME STEP =    7            ITERATION NO. =    2
S.W. TOE LOCATED AT X =   -0.5233816E 04
SOLUTION OBTAINED AT J =  7   IN   2 ITERATIONS.
TIME STEP =    8            ITERATION NO. =    1
S.W. TOE LOCATED AT X =   -0.5230023E 04
TIME STEP =    8            ITERATION NO. =    2
S.W. TOE LOCATED AT X =   -0.5230266E 04
SOLUTION OBTAINED AT J =  8   IN   2 ITERATIONS.
TIME STEP =    9            ITERATION NO. =    1
S.W. TOE LOCATED AT X =   -0.5226230E 04
TIME STEP =    9            ITERATION NO. =    2
```

```
S.W. TOE LOCATED AT X =  -0.5226469E 04
SOLUTION OBTAINED AT J =  9   IN  2 ITERATIONS.
TIME STEP =  10           ITERATION NO. =    1
S.W. TOE LOCATED AT X =  -0.5222414E 04
TIME STEP =  10           ITERATION NO. =    2
S.W. TOE LOCATED AT X =  -0.5222641E 04
SOLUTION OBTAINED AT J = 10   IN  2 ITERATIONS.
TIME STEP =  11           ITERATION NO. =    1
S.W. TOE LOCATED AT X =  -0.5218680E 04
TIME STEP =  11           ITERATION NO. =    2
S.W. TOE LOCATED AT X =  -0.5218895E 04
SOLUTION OBTAINED AT J = 11   IN  2 ITERATIONS.
TIME STEP =  12           ITERATION NO. =    1
S.W. TOE LOCATED AT X =  -0.5215137E 04
TIME STEP =  12           ITERATION NO. =    2
S.W. TOE LOCATED AT X =  -0.5215324E 04
SOLUTION OBTAINED AT J = 12   IN  2 ITERATIONS.
TIME STEP =  13           ITERATION NO. =    1
S.W. TOE LOCATED AT X =  -0.5211785E 04
SOLUTION OBTAINED AT J = 13   IN  1 ITERATIONS.
TIME STEP =  14           ITERATION NO. =    1
S.W. TOE LOCATED AT X =  -0.5208512E 04
SOLUTION OBTAINED AT J = 14   IN  1 ITERATIONS.
TIME STEP =  15           ITERATION NO. =    1
S.W. TOE LOCATED AT X =  -0.5205492E 04
SOLUTION OBTAINED AT J = 15   IN  1 ITERATIONS.
TIME STEP =  16           ITERATION NO. =    1
S.W. TOE LOCATED AT X =  -0.5202738E 04
SOLUTION OBTAINED AT J = 16   IN  1 ITERATIONS.


OUTPUT AT NODE     1


PIEZOMETRIC HEAD OF FRESH WATER, HF
  1  20.040   2  19.996   3  19.997   4  20.006   5  20.004   6  19.999   7  19.
999   8  19.999   9  19.999  10  19.999
 11  19.999  12  19.999  13  20.001  14  20.001  15  20.001  16  20.001

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0      2 -0.0424   3 -0.0414   4 -0.0336   5 -0.0352   6 -0.0402   7 -0.0
399   8 -0.0398   9 -0.0396  10 -0.0395
 11 -0.0394  12 -0.0393  13 -0.0378  14 -0.0378  15 -0.0379  16 -0.0379

THICKNESS OF FRESH WATER LENS
  1  299.75   2  299.75   3  299.75   4  299.75   5  299.75   6  299.75   7  299
.75   8  299.75   9  299.75  10  299.75
 11  299.75  12  299.75  13  299.75  14  299.75  15  299.75  16  299.75

THICKNESS OF SALT WATER LENS
  1   0.250   2   0.250   3   0.250   4   0.250   5   0.250   6   0.250   7   0.
250   8   0.250   9   0.250  10   0.250
 11   0.250  12   0.250  13   0.250  14   0.250  15   0.250  16   0.250

DEPTH OF INTERFACE ABOVE MSL
  1 -781.56   2 -299.75   3 -299.75   4 -299.75   5 -299.75   6 -299.75   7 -299
.75   8 -299.75   9 -299.75  10 -299.75
 11 -299.75  12 -299.75  13 -299.75  14 -299.75  15 -299.75  16 -299.75
```

```
OUTPUT AT NODE    5

PIEZOMETRIC HEAD OF FRESH WATER, HF
  1  13.870   2  13.831   3  13.832   4  13.840   5  13.839   6  13.834   7  13.
834   8  13.834   9  13.834  10  13.834
 11  13.834  12  13.834  13  13.836  14  13.836  15  13.836  16  13.836

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0      2 -0.0377   3 -0.0367   4 -0.0288   5 -0.0305   6 -0.0355   7 -0.0
353   8 -0.0351   9 -0.0350  10 -0.0349
 11 -0.0348  12 -0.0347  13 -0.0332  14 -0.0332  15 -0.0333  16 -0.0333

THICKNESS OF FRESH WATER LENS
  1  299.75   2  299.75   3  299.75   4  299.75   5  299.75   6  299.75   7  299
.75   8  299.75   9  299.75  10  299.75
 11  299.75  12  299.75  13  299.75  14  299.75  15  299.75  16  299.75

THICKNESS OF SALT WATER LENS
  1   0.250   2   0.250   3   0.250   4   0.250   5   0.250   6   0.250   7   0.
250   8   0.250   9   0.250  10   0.250
 11   0.250  12   0.250  13   0.250  14   0.250  15   0.250  16   0.250

DEPTH OF INTERFACE ABOVE MSL
  1 -540.93   2 -299.75   3 -299.75   4 -299.75   5 -299.75   6 -299.75   7 -299
.75   8 -299.75   9 -299.75  10 -299.75
 11 -299.75  12 -299.75  13 -299.75  14 -299.75  15 -299.75  16 -299.75


OUTPUT AT NODE   10

PIEZOMETRIC HEAD OF FRESH WATER, HF
  1   8.720   2   8.694   3   8.695   4   8.703   5   8.701   6   8.696   7   8.
696   8   8.696   9   8.696  10   8.697
 11   8.697  12   8.697  13   8.698  14   8.698  15   8.698  16   8.698

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0      2 -0.0252   3 -0.0241   4 -0.0163   5 -0.0181   6 -0.0233   7 -0.0
233   8 -0.0233   9 -0.0234  10 -0.0235
 11 -0.0236  12 -0.0237  13 -0.0224  14 -0.0226  15 -0.0228  16 -0.0230

THICKNESS OF FRESH WATER LENS
  1  299.75   2  299.75   3  299.75   4  299.75   5  299.75   6  299.75   7  299
.75   8  299.75   9  299.75  10  299.75
 11  299.75  12  299.75  13  299.75  14  299.75  15  299.75  16  299.75

THICKNESS OF SALT WATER LENS
  1   0.250   2   0.250   3   0.250   4   0.250   5   0.250   6   0.250   7   0.
250   8   0.250   9   0.250  10   0.250
 11   0.250  12   0.250  13   0.250  14   0.250  15   0.250  16   0.250

DEPTH OF INTERFACE ABOVE MSL
  1 -340.09   2 -299.75   3 -299.75   4 -299.75   5 -299.75   6 -299.75   7 -299
.75   8 -299.75   9 -299.75  10 -299.75
 11 -299.75  12 -299.75  13 -299.75  14 -299.75  15 -299.75  16 -299.75
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OUTPUT AT NODE    15

PIEZOMETRIC HEAD OF FRESH WATER, HF
  1   4.790   2   4.843   3   4.848   4   4.858   5   4.859   6   4.858   7   4.
860   8   4.861   9   4.863  10   4.864
 11   4.864  12   4.865  13   4.867  14   4.867  15   4.868  16   4.868

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0      2  0.0427   3  0.0373   4  0.0362   5  0.0297   6  0.0230   7  0.0


204   8  0.0181   9  0.0162  10  0.0146
 11  0.0131  12  0.0119  13  0.0113  14  0.0102  15  0.0092  16  0.0083

THICKNESS OF FRESH WATER LENS
  1  190.00   2  187.16   3  187.59   4  188.01   5  188.33   6  188.55   7  188
.73   8  188.87   9  188.99  10  189.10
 11  189.19  12  189.27  13  189.34  14  189.41  15  189.47  16  189.52

THICKNESS OF SALT WATER LENS
  1 110.000   2 112.838   3 112.412   4 111.986   5 111.670   6 111.450   7 111.
274   8 111.128   9 111.006  10 110.901
 11 110.811  12 110.731  13 110.657  14 110.591  15 110.532  16 110.480

DEPTH OF INTERFACE ABOVE MSL
  1 -186.81   2 -187.16   3 -187.59   4 -188.01   5 -188.33   6 -188.55   7 -188
.73   8 -188.87   9 -188.99  10 -189.10
 11 -189.19  12 -189.27  13 -189.34  14 -189.41  15 -189.47  16 -189.52

OUTPUT AT NODE    20

PIEZOMETRIC HEAD OF FRESH WATER, HF
  1   1.040   2   1.069   3   1.073   4   1.076   5   1.078   6   1.079   7   1.
080   8   1.081   9   1.081  10   1.081
 11   1.082  12   1.082  13   1.082  14   1.083  15   1.083  16   1.083

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0      2  0.0024   3  0.0017   4  0.0014   5  0.0011   6  0.0008   7  0.0
007   8  0.0006   9  0.0005  10  0.0005
 11  0.0004  12  0.0004  13  0.0004  14  0.0003  15  0.0003  16  0.0003

THICKNESS OF FRESH WATER LENS
  1   42.00   2   41.58   3   41.79   4   41.92   5   42.02   6   42.06   7   42
.09   8   42.12   9   42.14  10   42.16
 11   42.17  12   42.19  13   42.20  14   42.21  15   42.22  16   42.23

THICKNESS OF SALT WATER LENS
  1 258.000   2 258.421   3 258.206   4 258.080   5 257.983   6 257.944   7 257.
908   8 257.881   9 257.860  10 257.842
 11 257.826  12 257.813  13 257.802  14 257.791  15 257.781  16 257.773

DEPTH OF INTERFACE ABOVE MSL
  1  -40.56   2  -41.58   3  -41.79   4  -41.92   5  -42.02   6  -42.06   7  -42
.09   8  -42.12   9  -42.14  10  -42.16
 11  -42.17  12  -42.19  13  -42.20  14  -42.21  15  -42.22  16  -42.23
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OUTPUT AT NODE   21

PIEZOMETRIC HEAD OF FRESH WATER, HF
  1   0.203   2   0.213   3   0.215   4   0.216   5   0.217   6   0.218   7   0.
218   8   0.218   9   0.218  10   0.219
 11   0.219  12   0.219  13   0.219  14   0.219  15   0.219  16   0.219

PIEZOMETRIC HEAD OF SALT WATER, HS
  1  0.0       2  0.0       3  0.0       4  0.0       5  0.0       6  0.0       7  0.0
     8  0.0       9  0.0      10  0.0
 11  0.0      12  0.0      13  0.0      14  0.0      15  0.0      16  0.0

THICKNESS OF FRESH WATER LENS
  1    8.57   2    8.31   3    8.39   4    8.42   5    8.46   6    8.49   7    8


.50   8    8.51   9    8.52  10    8.53
 11    8.53  12    8.54  13    8.54  14    8.54  15    8.55  16    8.55

THICKNESS OF SALT WATER LENS
  1 291.400   2 291.685   3 291.607   4 291.580   5 291.542   6 291.509   7 291.
497   8 291.487   9 291.479  10 291.473
 11 291.467  12 291.462  13 291.460  14 291.456  15 291.452  16 291.449

DEPTH OF INTERFACE ABOVE MSL
  1   -7.92   2   -8.31   3   -8.39   4   -8.42   5   -8.46   6   -8.49   7   -8
.50   8   -8.51   9   -8.52  10   -8.53
 11   -8.53  12   -8.54  13   -8.54  14   -8.54  15   -8.55  16   -8.55
```