THE COMPUTER MODEL SHARP, A QUASI-THREE-DIMENSIONAL FINITE-DIFFERENCE MODEL TO SIMULATE FRESHWATER AND SALTWATER FLOW IN LAYERED COASTAL AQUIFER SYSTEMS

By Hedeff I. Essaid

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MANUEL LUJAN, Jr., Secretary

U. S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

Project Chief
U.S. Geological Survey
345 Middlefield Rd., MS 421
Menlo Park, CA 94025

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CONVERSION FACTORS

The International System of Units (SI) can be converted to inch-pound units by the following conversion factors:

Multiply metric unit	By	To obtain inch-pound-unit
centimeter (cm)	0.03281	foot
centimeter (cm)	0.3937	inch
gram (gm)	0.002205	pound
meter (m)	3.281	foot
millimeter (mm)	0.0397	inch

LIST OF SYMBOLS

A	finite difference grid block area, L^2
$\mathbf{A}$	septadiagonal block coefficient matrix multiplying unknown heads
$\mathbf{B}$	coefficient submatrix multiplying i-1,j,k heads
B'	thickness of the confining layer, L
B_f	thickness of the freshwater zone, L
B_s	thickness of the saltwater zone, L
$\mathbf{D}$	coefficient submatrix multiplying i,j-1,k heads
D	aquifer thickness, L
$\mathbf{D}_h$	hydrodynamic dispersion coefficient tensor, L^2T^{-1}
$\mathbf{E}$	coefficient submatrix multiplying i,j,k heads
$\mathbf{F}$	coefficient submatrix multiplying i,j+1,k heads
g	gravitational acceleration, LT^{-2}
$\mathbf{H}$	coefficient submatrix multiplying i+1,j,k heads
h_s	depth to interface below sea level, L
i	y-direction discretization index
j	x-direction discretization index
k	layer discretization index
$\underline{\underline{\mathbf{k}}}$	permeability tensor, L^2
k'	vertical permeability of confining layer, L^2
K'	vertical hydraulic conductivity of confining layer, LT^{-1}
K_f	freshwater hydraulic conductivity, LT^{-1}
$\underline{\underline{\mathbf{K}}}_f'$	$= \underline{\underline{\mathbf{k}}}(x,y)\gamma_f/\mu_f$ vertically averaged freshwater hydraulic conductivity, LT^{-1}
$\underline{\underline{\mathbf{K}}}_s'$	$= \underline{\underline{\mathbf{k}}}(x,y)\gamma_s/\mu_s$ vertically averaged saltwater hydraulic conductivity, LT^{-1}
K_{fx}	freshwater hydraulic conductivity in the x-direction, LT^{-1}
K_{sx}	saltwater hydraulic conductivity in the x-direction, LT^{-1}
K_{fy}	freshwater hydraulic conductivity in the y-direction, LT^{-1}
K_{sy}	saltwater hydraulic conductivity in the y-direction, LT^{-1}
L	distance to interface toe from its initial position, L
m	superscript for iteration level index
M	number of finite-difference blocks in system
n	effective porosity
n	superscript for time level index
N	recharge rate, LT^{-1}
p	fluid pressure, $ML^{-1}T^{-2}$

p_f freshwater fluid pressure, $ML^{-1}T^{-2}$

p_s saltwater fluid pressure, $ML^{-1}T^{-2}$

P_f freshwater pumpage from grid block ijk, L^3T^{-1}

P_s saltwater pumpage from grid block ijk, L^3T^{-1}

P_t total fluid pumpage from a well, L^3T^{-1}

$\mathbf{q_f'}$ vertically averaged freshwater flux, LT^{-1}

q_{fz} vertical freshwater specific discharge, LT^{-1}

q_{fl_b} freshwater leakage across bottom of aquifer, LT^{-1}

q_{fl_t} freshwater leakage across top of aquifer, LT^{-1}

q_l vertical leakage, positive upwards, LT^{-1}

q_s saltwater specific discharge, LT^{-1}

$\mathbf{q_s'}$ vertically averaged saltwater flux, LT^{-1}

q_{sz} vertical saltwater specific discharge, LT^{-1}

q_{sl_b} saltwater leakage across bottom of aquifer, LT^{-1}

q_{sl_t} saltwater leakage across top of aquifer, LT^{-1}

Q vector of known right-hand-side values

Q' vector of known right-hand-side values at a node

Q_f freshwater source/sink term, LT^{-1}

Q_s saltwater source/sink term, LT^{-1}

Q_{lf} freshwater leakage term, LT^{-1}

Q_{ls} saltwater leakage term, LT^{-1}

R vector of residuals

S coefficient submatrix multiplying i,j,k+1 heads

S_f freshwater specific storage, L^{-1}

S_s saltwater specific storage, L^{-1}

t elapsed time, T

T transmissivity term, LT^{-1}

Th_f length of open interval of a well penetrating freshwater, L

Th_t total open interval of a well, L

x	spatial coordinate, L
y	spatial coordinate, L
$\mathbf{Z}$	coefficient submatrix multiplying i,j,k-1 heads
z_a	elevation of top of confining layer, L
z_b	elevation of bottom of confining layer, L
z	elevation, L
α	parameter = 1 for an unconfined aquifer, = 0 for a confined aquifer
$\bar{\gamma}$	average specific weight, $ML^{-2}T^{-2}$
γ_a	specific weight of fluid above confining layer, $ML^{-2}T^{-2}$
γ_b	specific weight of fluid below confining layer, $ML^{-2}T^{-2}$
γ_f	freshwater specific weight, $ML^{-2}T^{-2}$
γ_s	saltwater specific weight, $ML^{-2}T^{-2}$
δ	$= \gamma_f/(\gamma_s-\gamma_f)$
λ	subscript = f for freshwater, = s for saltwater
μ	dynamic viscosity, $ML^{-1}T^{-1}$
μ_f	freshwater dynamic viscosity, $ML^{-1}T^{-1}$
μ_s	saltwater dynamic viscosity, $ML^{-1}T^{-1}$
$\mathbf{\Phi}$	vector of heads
$\mathbf{\Phi}'$	vector of heads at a node
Φ_a	hydraulic head above a confining layer, L
Φ_b	hydraulic head below a confining layer, L
Φ_f	freshwater head, L
$\tilde{\Phi}_f$	vertically averaged freshwater head, L
Φ_s	saltwater head, L
$\tilde{\Phi}_s$	vertically averaged saltwater head, L
ρ	fluid density, ML^{-3}
$\Delta\rho$	density difference = $\rho_s - \rho_f$, ML^{-3}
ζ_o	elevation of base of aquifer, L
ζ_1	elevation of interface, L
ζ_2	elevation of top of aquifer, L
$\boldsymbol{\xi}$	vector of head changes
ω	weighting factor

THE COMPUTER MODEL SHARP, A QUASI-THREE-DIMENSIONAL FINITE-DIFFERENCE

MODEL TO SIMULATE FRESHWATER AND SALTWATER FLOW IN

LAYERED COASTAL AQUIFER SYSTEMS

by H. I. Essaid

ABSTRACT

This report documents the quasi-three-dimensional, finite-difference model, SHARP, which simulates freshwater and saltwater flow separated by a sharp interface in layered coastal aquifer systems. The model accommodates multiple aquifers separated by confining layers, with spatially variable porous media properties. The uppermost aquifer can be confined, unconfined or semi-confined with areally distributed recharge. Temporal variations in recharge and pumping are accounted for by multiple pumping periods. The boundary conditions which can be simulated in the model are: prescribed flux boundaries, constant freshwater head and/or constant saltwater head boundaries, and leaky head-dependent boundaries.

For each aquifer, the vertically integrated freshwater and saltwater flow equations are solved. These two equations are coupled by the boundary condition at the interface. Leakage between aquifers is calculated by applying Darcy's law. The resulting system of coupled, non-linear partial differential equations is discretized using an implicit finite-difference scheme. The discretized system of equations is solved using the strongly implicit procedure (SIP). The positions of the interface tip and toe, within the discretized finite-difference grid blocks, are tracked using linear extrapolation of the interface elevations calculated at grid points.

This documentation includes an overview of saltwater intrusion modeling approaches and the mathematical formulation of SHARP. The model is verified against experimental and analytical solutions, and sample areal and cross-sectional applications are presented.

INTRODUCTION

Purpose and Scope

Coastal aquifers are an important ground-water resource for urban and agricultural areas bordering seas. In some areas, coastal hydrogeological conditions can simply be represented by an individual unconfined, island, or confined aquifer (fig. 1). More commonly, the hydrogeologic setting in coastal environments is that of a sequence of layers with varying hydraulic properties combining confined and unconfined conditions. A few previously studied examples of such systems are found in the north Atlantic and Israeli coastal plains, and the Llobregat delta in Barcelona, Spain (Collins and Gelhar, 1971; Schmorak, 1967; Custodio, 1981). Protection of water quality in these aquifers during development requires an understanding of the dynamic relation between freshwater and adjacent saltwater.

In this report, the model SHARP, a quasi-three-dimensional, numerical finite-difference model which simulates freshwater and saltwater flow separated by a sharp interface in layered coastal aquifer - confining unit systems is documented. SHARP facilitates regional simulation of coastal ground-water conditions in layered systems, and includes the effects of saltwater dynamics on the freshwater flow system.

The model accommodates multiple aquifers, separated by confining units, with spatially variable porous media properties. The uppermost aquifer of the system may be confined, unconfined, or semi-confined with an areally distributed recharge. Temporal variations in recharge and pumping are accounted for by multiple pumping periods. The boundary conditions which may be simulated in the model are: prescribed flux boundaries, constant freshwater head and/or constant saltwater head boundaries, and leaky head-dependent boundaries in the uppermost aquifer. The program is written in FORTRAN 77.

An overview of coastal hydrogeologic conditions and saltwater intrusion modeling approaches is given in the first part of this report. The development of the equations solved in SHARP is presented in the model development section and is followed by an explanation of the solution technique used. Model verification for single-layer and multilayer cases is presented. The last part of the report describes the computer program, its application, and sample problems. Appendixes A and B give the details of the coefficients of the discretized flow equations and the strongly implicit solution procedure. The data input formats, program variables, and program listing are given in Attachments A through C.

Coastal Hydrogeologic Conditions

To illustrate coastal conditions, an idealized hydrogeologic section through a layered coastal aquifer system extending offshore to a submarine canyon outcrop is shown in figure 2. Under natural, undisturbed conditions, an equilibrium seaward hydraulic gradient exists within each aquifer with freshwater discharging to the sea (fig.2a). In the uppermost, unconfined aquifer the freshwater flows out to sea across the ocean floor. In the lower, confined aquifers the freshwater discharges to the sea by leaking upward through the overlying layers, and (or) by flowing out the canyon outcrop. Within each layer, saltwater flows in from the sea and a wedge-shaped body of denser saltwater develops beneath the lighter freshwater. Under steady-state conditions a stationary interface is maintained, its shape and position being determined by the freshwater potential and gradient. In the case of one-layer systems, the sea water will essentially be static under steady-state conditions. In a layered system, if there is vertical leakage of freshwater into an overlying saltwater zone, this zone of mixed water will not be static.

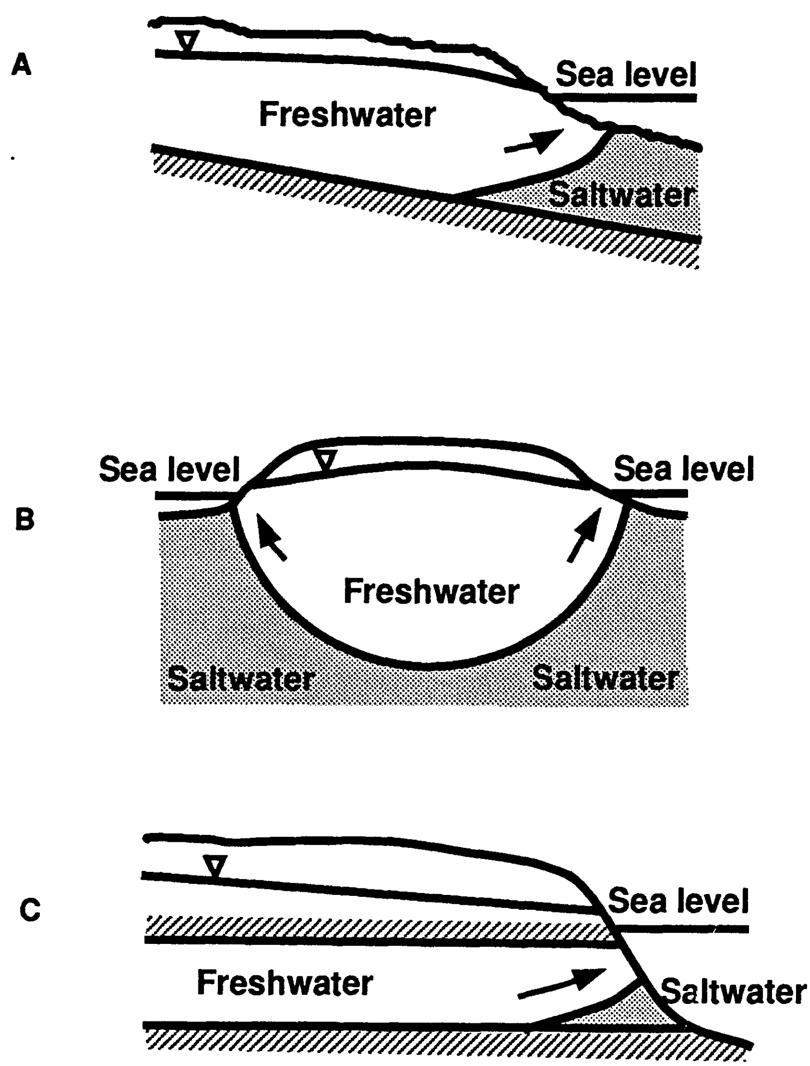

Figure 1.--Examples of hydrogeologic conditions in coastal aquifers:
A. unconfined aquifer with an impermeable bottom,
B. unconfined island aquifer with a free bottom, and
C. confined aquifer.

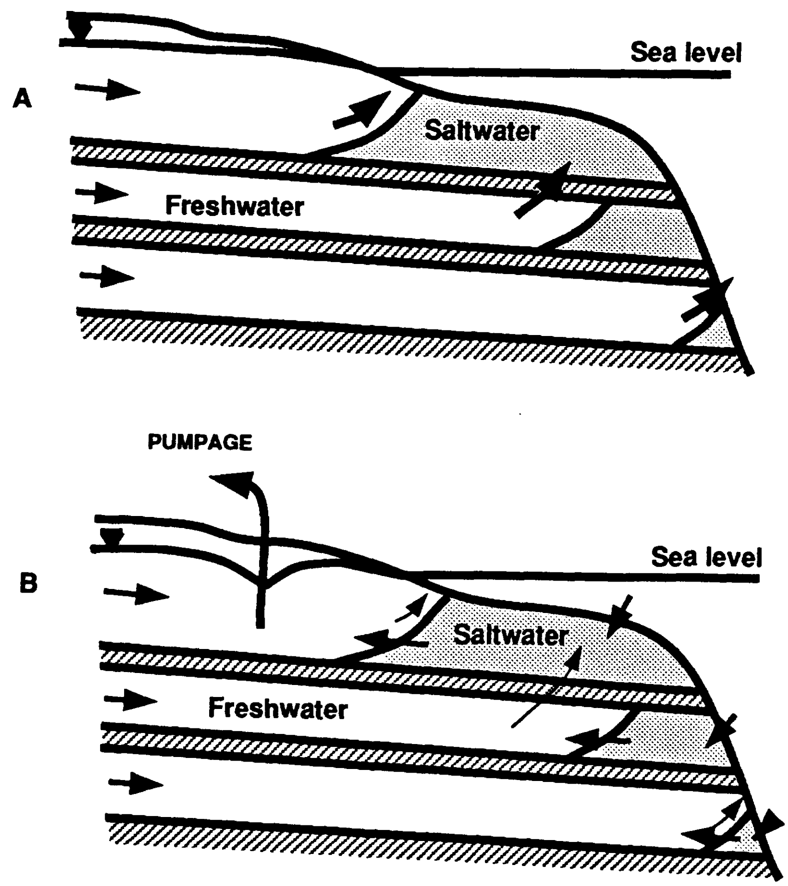

Figure 2.--Idealized cross-section of a layered coastal aquifer system showing paths of freshwater discharge and potential paths for saltwater intrusion:

A. steady-state system with constant freshwater discharge offshore,
B. transient system with intruding saltwater and inland interface movement.

In reality, the interface separating fresh and saltwater is a transition zone created by the mixing of waters due to the effects of diffusion and mechanical dispersion. Cooper (1959) and Kohout (1964) have shown that in the zone of mixing, the diluted saltwater is less dense than the original sea water, causing it to rise and move seaward along the interface (fig. 3). This induces a cyclic flow of saltwater from the sea, through the ocean floor, to the zone of mixing, and back to the sea. This cyclic flow occurs even under steady-state conditions.

Inland changes in recharge or discharge modify the flow within the freshwater region, inducing movement of the interface. Reduction in freshwater flow towards the sea causes the interface to move inland and results in the intrusion of saltwater into the aquifer. Conversely, an increase in freshwater flow pushes the interface seaward. The rate of interface movement and the transient aquifer head response will depend on the boundary conditions and aquifer properties on both sides of the interface. The ease with which saltwater can move into, or out of, an aquifer system affects the rate of interface movement in response to changes in offshore freshwater discharge. In a layered system, saltwater can enter an aquifer by flowing through the aquifer outcrop, and/or leaking across the confining layers and ocean floor (fig. 2b). Therefore, in order to understand coastal systems, it is necessary to examine the dynamics of both the freshwater and saltwater flow domains.

Management of coastal ground-water resources requires an understanding of the physical dynamics of the phenomenon of saltwater intrusion. For this reason, considerable effort has been put into developing numerical models for saltwater intrusion that can represent the physical complexities, as well as the spatial and temporal variations inherent in coastal systems.

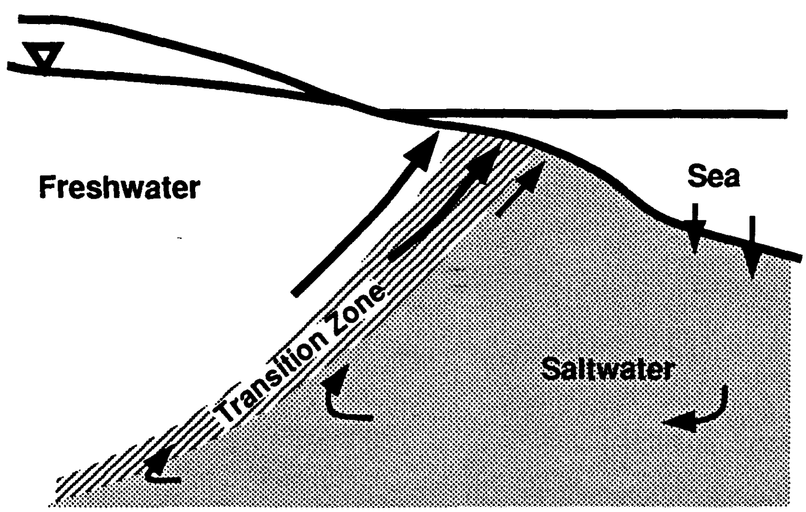

Figure 3.--Circulation of saltwater from the sea to the transition zone and back to the sea induced by mixing at the interface.

Saltwater Intrusion Modeling Approaches

Disperse and sharp interface approaches have been used to analyze saltwater intrusion in coastal aquifers (Reilly and Goodman, 1985). The disperse interface approach explicitly represents the transition zone, where there is mixing of freshwater and saltwater due to the effects of hydrodynamic dispersion (molecular diffusion and mechanical dispersion). The sharp interface approach simplifies the analysis by assuming that freshwater and saltwater do not mix and are separated by an abrupt interface. Both approaches have been used to develop numerical models to study and predict the flow of ground water in coastal aquifers. A summary of the numerical models that have been developed for simulation of saltwater intrusion problems is given in table 1.

Table 1.--Summary of numerical salt water intrusion models (DI-disperse interface, DD-density dependent, NDD-non-density-dependent, SI-sharp interface, F-fresh water only, FS-fresh and salt water, FD-finite difference, FE-finite element, BIM-boundary integral method, A2-D-areal two-dimensional, VCS-vertical cross-section, Q3-D-quasi-three-dimensional, 3-D-three-dimensional, TIME DEP.-time dependence, TR-transient, SS-steady state, DUP. APP.-Dupuit approximation, G-H APP.-Ghyben-Herzberg approximation)

GROUP	AUTHOR	APPROACH	METHOD	GEOMETRY	TIME DEP.	DUP. APP.	G-H APP.	FIELD APPLICATION
	Reddell & Sunada, 1970	DI-NDD	FD	A2-D	TR	YES	NO	
I-1	Bredehoeft & Pinder, 1973	DI-NDD	FD	A2-D	TR	YES	NO	Brunswick, Georgia
	Andrews, 1981	DI-NDD	FE	A2-D	TR	YES	NO	Costa de Hermosillo, Mexico
	Pinder & Cooper, 1970	DI-DD	FD	VCS	TR	NO	NO	
	Volker & Rushton, 1982	DI-DD	FD	VCS	SS	NO	NO	
	Sanford & Konikow, 1985	DI-DD	FD	VCS	TR	NO	NO	
	Segol and others, 1975	DI-DD	FE	VCS	TR	NO	NO	Biscayne aquifer, Florida (Segol & Pinder, 1976)
	Lee & Cheng, 1974	DI-DD	FE	VCS	SS	NO	NO	Biscayne aquifer, Florida
I-2	Frind, 1982a,b	DI-DD	FE	VCS	TR	NO	NO	
	Voss, 1984b	DI-DD	FE	VCS	TR	NO	NO	Southern Oahu, Hawaii (Souza & Voss, 1986)
	INTERA, 1979	DI-DD	FD	3-D	TR	NO	NO	
	Kipp, 1987	DI-DD	FD	3-D	TR	NO	NO	
	Huyakorn and others, 1987	DI-DD	FE	3-D	TR	NO	NO	
	Fetter, 1972	SI-F	FD	A2-D	SS	YES	YES	South Fork, Long Island
	Anderson, 1976	SI-F	FD	VCS	TR	YES	YES	South Fork, Long Island
II-1	Ayers & Vacher, 1983	SI-F	FD	A2-D	TR	YES	YES	Somerset Island, Bermuda
	Guswa & LeBlanc, 1985	SI-F	FD	3-D	SS	NO	YES	Cape Cod, Massachusetts
	Sapik, 1988	SI-F	FD	Q3-D	SS	YES	YES	
	Voss, 1984a	SI-F	FE	A2-D	TR	YES	YES	Southeast Oahu, Hawaii (Eyre, 1985)
	Taigbenu and others, 1984	SI-F	BIM	A2-D	TR	YES	YES	
	Volker & Rushton, 1982	SI-F	BIM	VCS	SS	NO	YES	
	Shamir & Dagan, 1971	SI-FS	FD	VCS	TR	YES	NO	
	Bonnet & Sauty, 1975	SI-FS	FD	A2-D	TR	YES	NO	Morrocan Atlantic Coast
	Mercer and others, 1980a,b	SI-FS	FD	A2-D	TR	YES	NO	Maui, Hawaii
II-2	Polo & Ramis, 1983	SI-FS	FD	A2-D	TR	YES	NO	Spain
	Pinder & Page, 1977	SI-FS	FE	A2-D	TR	YES	NO	North Haven, New York
	Wilson & Sa da Costa, 1982	SI-FS	FE	A2-D	TR	YES	NO	Algarve, Portugal (Sa da Costa, 1986)
	Contractor, 1983	SI-FS	FE	A2-D	TR	YES	NO	North Guam
	Liu and others, 1981	SI-FS	BIM	VCS	TR	NO	NO	

Disperse Interface Approach

To represent the physics of a disperse interface separating freshwater and saltwater, the equations governing fluid flow must be solved in conjunction with the solute transport equation for a conservative chemical species (Bear, 1979):

$$\frac{\partial(n\rho)}{\partial t} = -\mathbf{\nabla}.\rho\mathbf{q} \qquad \text{fluid mass balance,} \qquad (1)$$

$$q = -\frac{\underline{\underline{\mathbf{k}}}}{\mu}(\mathbf{\nabla}p + \rho g\mathbf{\nabla}z) \qquad \text{Darcy's law,} \qquad (2)$$

$$\frac{\partial(nc)}{\partial t} = \mathbf{\nabla}.n\underline{\underline{\mathbf{D_h}}}.\mathbf{\nabla}c - \mathbf{\nabla}.\mathbf{q}c \qquad \text{transport equation,} \qquad (3)$$

where:
$\underline{\underline{\mathbf{k}}}$ = permeability tensor (L^2);
μ = $\mu(c)$ is dynamic viscosity ($ML^{-1}T^{-1}$);
ρ = $\rho(c)$ is fluid density (ML^{-3});
p = pressure ($ML^{-1}T^{-2}$);
z = the vertical dimension (L);
g = gravitational acceleration (LT^{-2});
n = porosity;
c = concentration (ML^{-3});
$\underline{\underline{\mathbf{D_h}}}$ = the hydrodynamic dispersion coefficient tensor (L^2T^{-1});
q = the specific discharge or Darcy velocity (LT^{-1});
t = time (T); and
$\mathbf{\nabla}(\ ) = \frac{\partial(\ )}{\partial x}\mathbf{x} + \frac{\partial(\ )}{\partial y}\mathbf{y} + \frac{\partial(\ )}{\partial z}\mathbf{z}$, where **x**, **y** and **z** are unit vectors in the x-, y- and z- directions.

Because density is a function of concentration, these equations must be solved simultaneously to simulate coupled density-dependent fluid flow and solute transport. If the transition zone is very disperse and chloride concentrations gradients are low, the effects of variable density may be neglected. This simplification makes it possible to decouple the equations, solving first for the flow field and subsequently for the concentration field. Use of this approach, in conjunction with the Dupuit assumption of horizontal flow, is suitable for areal modeling of aquifer systems with low chloride concentration gradients, or when vertical resolution is not needed (Group I-1, table 1).

In many cases, however, the density gradient is significant and must be accounted for (Group I-2, table 1). Generally, the flow and transport equations are solved simultaneously by iterating between the two equations, increasing computational effort considerably. This has limited most solutions to two-dimensional vertical cross-sections. Three-dimensional, density-dependent solute transport codes have been developed (INTERA, 1979; Huyakorn and others, 1987; Kipp, 1987; Andersen and others, 1988) but have restricted applicability for regional studies due to computational constraints.

Sharp Interface Approach

When the width of the transition zone is small relative to the thickness of the aquifer it can be assumed, for the purpose of analysis, that the saltwater and freshwater are immiscible fluids separated by a sharp interface. This approach reproduces the general position, shape, and behavior of the interface. These models couple the freshwater and saltwater flow domains through the interfacial boundary condition of continuity of flux and pressure. In three dimensions this boundary condition is highly non-linear (Bear, 1979), making the solution difficult. The problem can be simplified, however, by integrating the flow equations over the vertical and assuming horizontal flow within the aquifer. Sharp interface models generally fall into two categories: those that model coupled freshwater and saltwater flow (two-fluid approach), and those that model freshwater flow only (one-dynamic-fluid approach).

Badon-Ghyben (1889) and Herzberg (1901) related the freshwater head above sea level (Φ_f) to the depth to the interface below sea level (h_s) for a system in static equilibrium; that is, steady horizontal freshwater flow and stationary saltwater (fig. 4). At the interface, the pressure due to the overlying column of freshwater must be equivalent to that due to the column of saltwater; therefore, the following relation must hold:

$$h_s \gamma_s = (h_s + \Phi_f)\gamma_f , \quad (4)$$

or

$$h_s = \delta \Phi_f , \quad (5)$$

where $\delta = \gamma_f/(\gamma_s - \gamma_f)$ and γ_f, γ_s are the fresh and saltwater specific weights, respectively. For the common values of freshwater and saltwater densities (1.0 gm/cm^3 and 1.025 gm/cm^3, respectively) the value of δ is 40, that is, the depth to the interface below sea level, is forty times the freshwater head. The sharp interface models that simulate flow in the freshwater region only, (Group II-1, table 1) incorporate the Ghyben-Herzberg relation (5) assuming that at each time step saltwater adjusts instantaneously to changes in the freshwater zone, and an equilibrium interface position is achieved.

In the two-fluid approach the freshwater and the saltwater flow equations, which are coupled by the interface boundary condition, are solved simultaneously (Group II-2, table 1). On the basis of the principle of continuity of pressure, the interface elevation can be expressed as a function of the freshwater head and the saltwater head. The movement of the interface is dictated by the freshwater and saltwater flow dynamics.

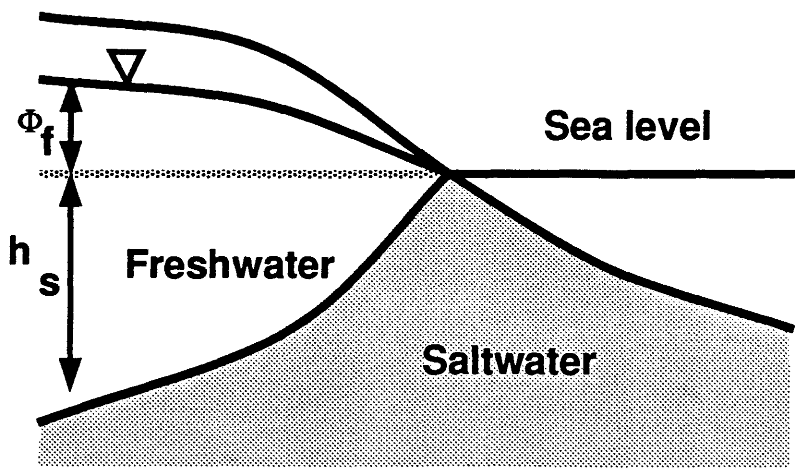

Figure 4.--The Ghyben-Herzberg interface model.

Discussion of Approaches

Each of the above approaches has advantages and limitations, and can be employed successfully only under the appropriate conditions. The disperse interface is necessary in areas where the transition zone is wide. Density effects can be neglected when chloride concentration gradients are low and the governing equations can be solved areally on a basin-wide scale. However, when the flow is density-dependent, the vertical dimension must be included. Studies using this approach generally have been limited to two-dimensional vertical cross-sections due to computational constraints. There are also numerical instabilities and errors which are encountered when simulating the movement of a narrow concentration front, especially in zones where the transition zone approaches a sharp interface. Frind (1982a) showed that when a velocity-dependent dispersion coefficient is used, instabilities are encountered in areas of stagnant saltwater. Voss and Souza (1986, 1987) indicate that when flow is predominantly horizontal, the vertical discretization must be of the same order of magnitude as the transverse dispersivity in order to avoid introducing numerical dispersion.

The sharp interface approach, in conjunction with the application of the hydraulic approach (integration of the flow equations over the vertical), allows the problem to be reduced by one dimension. Thus, it can be applied areally to large physical systems. This approach does not give information concerning the nature of the transition zone; however, it does represent the overall flow dynamics of the system and will reproduce the general response of the interface to applied stresses. Volker and Rushton (1982) compared steady-state solutions for both the disperse interface and the sharp interface approaches and showed that as the coefficient of hydrodymic dispersion decreases, the two solutions approach each other.

Sharp interface models that simulate flow in the freshwater region only by incorporating the Ghyben-Herzberg approximation assume that the saltwater zone adjusts rapidly to the applied stresses. This may be a reasonable assumption in long-term studies if the interface can respond quickly to applied stresses. However, to reproduce the short-term response of a coastal aquifer, it is necessary to include the influence of saltwater flow (Essaid, 1986).

Individually, none of the above approaches can fully characterize the behavior and complexities of coastal aquifer systems. The choice of the approach used to model a particular system will depend on the nature of the system as well as the goals of the modeling effort. The sharp interface approach can represent the overall flow characteristics of the system, but cannot give details concerning the nature of the transition zone. When studying an aquifer system, it is important to first understand its overall behavior before examining smaller scale effects. Therefore, the ideal characterization of such systems may involve a two-step process integrating the sharp interface and disperse interface modeling approaches.

The Multilayer Freshwater - Saltwater Flow Model SHARP

Saltwater intrusion models have generally been limited to single aquifer problems, although a few have been developed for more complicated geometries (table 1). The two-dimensional, areal, sharp interface, numerical models of Mercer and others (1980a,b) and Voss (1984a) allow for an overlying leaky confining unit. Fetter (1972) and Anderson (1976) represented layers with different hydraulic conductivities by a single layer with an averaged conductivity value. Density-dependent solute transport models that can handle an overlying leaky confining unit have been developed (Frind, 1982a,b; Voss, 1984b; Huyakorn and others, 1987). Mercer and others (1986) used the INTERA (1979) code to build a quasi-three-dimensional solute transport model of Volusia County, Florida by neglecting the density dependence of the problem. Some analytical solutions have dealt with the problem of the position of a steady-state, sharp interface in a layered or stratified aquifer (Collins and others, 1972; Rumer and Shiau, 1968; Mualem, 1973; Collins and Gelhar, 1971 and 1977; Mualem and Bear, 1974). The only sharp interface model of coupled freshwater and saltwater flow presented for a multilayered case is that of Bear and Kapuler (1981), a cross-sectional model for two aquifers separated by a thin impervious layer. Sapik (1988) has developed a multilayered model for freshwater flow only by incorporating the Ghyben-Herzberg approximation into a three-dimensional ground-water flow model.

SHARP is a quasi-three-dimensional, finite-difference model that simulates coupled freshwater and saltwater flow separated by a sharp interface in multilayered coastal systems. It can be used for both areal (regional) and cross-sectional studies.

MODEL DEVELOPMENT

Vertical Integration of the Coupled Freshwater - Saltwater Flow Equations

For each aquifer within a layered coastal system two flow domains must be considered: freshwater and saltwater (fig. 5). The two domains are coupled because they share a common boundary at the interface (Bear, 1979). Within each flow domain the equation of continuity must hold:

$$S_f \frac{\partial \Phi_f}{\partial t} = -\nabla . \mathbf{q}_f \quad \text{freshwater flow domain,} \tag{6a}$$

$$S_s \frac{\partial \Phi_s}{\partial t} = -\nabla . \mathbf{q}_s \quad \text{saltwater flow domain,} \tag{6b}$$

where:
Φ_f = $z + p_f/\gamma_f$, the freshwater head (L);
Φ_s = $z + p_s/\gamma_s$, the saltwater head (L);
z = elevation (L);
p_f, p_s = the fresh and saltwater fluid pressures ($ML^{-1}T^{-2}$), respectively;
γ_f, γ_s = the fresh and saltwater specific weights ($ML^{-2}T^{-2}$);
S_f, S_s = the fresh and saltwater specific storages (L^{-1}); and
q_f, q_s = the fresh and saltwater specific discharges (LT^{-1}).

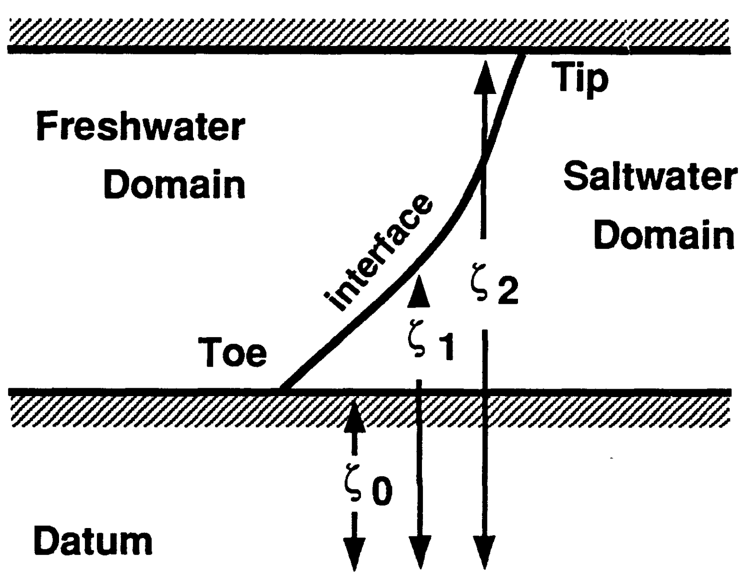

Figure 5.--Freshwater and saltwater flow domains in a confined aquifer

Equations (6a) and (6b) can be integrated over the vertical dimension, within their respective domains. In the vicinity of the interface, the lower boundary of the saltwater domain is the bottom of the aquifer which has an elevation of ζ_0. The interface is the upper boundary of the saltwater domain and its elevation is given by ζ_1. The freshwater domain is bounded on the bottom by the interface (ζ_1). In the case of a confined aquifer, the elevation of the top of the aquifer (ζ_2) is the upper boundary. For an unconfined aquifer, the top of the freshwater domain (ζ_2) is given by the water table elevation.

Vertical integration of the freshwater and saltwater flow equations implies the Dupuit approximation of vertical equipotential lines and horizontal flow within the aquifer. This approximation reduces the problem to two spatial dimensions (x and y). For a confined aquifer, integrating the freshwater flow equation from the interface (ζ_1) to the top of the aquifer (ζ_2) and substituting Darcy's Law yields:

$$\int_{\zeta_1}^{\zeta_2} (\nabla . \mathbf{q_f} + S_f \frac{\partial \Phi_f}{\partial t}) dz \simeq \nabla' . (-B_f \underline{\underline{\mathbf{K_f}}}' . \nabla' \tilde{\Phi}_f) + S_f B_f \frac{\partial \tilde{\Phi}_f}{\partial t}$$

$$- \mathbf{q_f}'|_{\zeta_2} . \nabla' \zeta_2 + q_{fz}|_{\zeta_2} + \mathbf{q_f}'|_{\zeta_1} . \nabla' \zeta_1 - q_{fz}|_{\zeta_1} = 0 \,, \qquad (7a)$$

where: $\tilde{\Phi}_f = \frac{1}{B_f} \int_{\zeta_1}^{\zeta_2} \Phi_f dz \simeq \Phi_f$, the vertically averaged freshwater head (L);

$\mathbf{q_f}' \simeq \frac{1}{B_f} \int_{\zeta_1}^{\zeta_2} \mathbf{q_f} dz \simeq -\underline{\underline{\mathbf{K_f}}}' . \nabla' \Phi_f$, the vertically averaged freshwater flux (LT^{-1});

$\mathbf{q}' = q_x \mathbf{1x} + q_y \mathbf{1y}$;

$\nabla'() = \frac{\partial()}{\partial x} \mathbf{x} + \frac{\partial()}{\partial y} \mathbf{y}$;

$B_f = \zeta_2 - \zeta_1$, thickness of the freshwater zone (L);

q_{fz} = the vertical component of freshwater flux (LT^{-1}); and

$\underline{\underline{\mathbf{K_f}}}' = \underline{\underline{\mathbf{K_f}}}'(x,y)$ = the vertically averaged freshwater hydraulic conductivity (LT^{-1}).

Similarly, the vertically integrated saltwater equation becomes:

$$\int_{\zeta_0}^{\zeta_1}(\nabla.\mathbf{q_s} + S_s\frac{\partial\Phi_s}{\partial t})dz \simeq \nabla'.(-B_s\underline{\underline{\mathbf{K_s}}}'.\nabla'\tilde{\Phi}_s) + S_sB_s\frac{\partial\tilde{\Phi}_s}{\partial t}$$

$$- \mathbf{q_s}'|_{\zeta_1}.\nabla'\zeta_1 + q_{sz}|_{\zeta_1} + \mathbf{q_s}'|_{\zeta_0}.\nabla'\zeta_0 - q_{sz}|_{\zeta_0} = 0 \ , \qquad (7b)$$

where: $\tilde{\Phi}_s = \frac{1}{B_s}\int_{\zeta_0}^{\zeta_1}\Phi_s dz \simeq \Phi_s$, the vertically averaged saltwater head (L);

$\mathbf{q_s}' \simeq \frac{1}{B_s}\int_{\zeta_0}^{\zeta_1}\mathbf{q_s}dz \simeq -\underline{\underline{\mathbf{K_s}}}'.\nabla'\Phi_s$, the vertically averaged saltwater flux (LT^{-1});

$B_s = \zeta_1 - \zeta_0$, the thickness of the saltwater zone (L);

q_{sz} = the vertical component of saltwater flux (LT^{-1}); and

$\underline{\underline{\mathbf{K_s}}}' = \underline{\underline{\mathbf{K_s}}}'(x,y)$ = the vertically averaged saltwater hydraulic conductivity (LT^{-1}).

Boundary Terms

The last four terms appearing in equations (7a) and (7b) represent the boundary conditions at the top and bottom of each domain. These terms are given by the boundary conditions at the interface, and at the top and bottom of the aquifer. To satisfy continuity of pressure at the interface, the fluid pressure in the freshwater domain must equal the fluid pressure in the saltwater domain:

$$p_f = (\Phi_f - \zeta_1)\gamma_f = p_s = (\Phi_s - \zeta_1)\gamma_s \ , \qquad (8)$$

where ζ_1 is the interface elevation. Solving for the interface elevation:

$$\zeta_1 = (1+\delta)\Phi_s - \delta\Phi_f \ , \qquad (9)$$

where $\delta = \gamma_f/(\gamma_s-\gamma_f)$.

The geometry of the interface can be described in terms of the elevation (z) and the freshwater and saltwater heads:

$$F \equiv z - \zeta_1 = z - (1+\delta)\Phi_s + \delta\Phi_f = 0. \qquad (10)$$

The interface is a moving surface, its velocity depending on the velocities of the water on both sides of the interface. Because the interface is a material surface, and no change in F takes place as the interface moves, the substantial derivative of F is equal to zero (Bear, 1979, p. 99):

$$n\frac{DF}{DT} = n\frac{\partial F}{\partial t} + \mathbf{q_f}.\nabla F = n\frac{\partial F}{\partial t} + \mathbf{q_s}.\nabla F = 0 \ , \qquad (11)$$

where F has been multiplied by n, the effective porosity. Expanding equation (11) and using the relations in equations (9) and (10), it can be shown that:

$$\underbrace{- \mathbf{q_f}'|_{\zeta_1}.\nabla'\zeta_1 + q_{fz}|_{\zeta_1}}_{\text{(from 7a)}} = \underbrace{- \mathbf{q_s}'|_{\zeta_1}.\nabla'\zeta_1 + q_{sz}|_{\zeta_1}}_{\text{(from 7b)}} = n(1+\delta)\frac{\partial \Phi_s}{\partial t} - n\delta\frac{\partial \Phi_f}{\partial t} \ . \qquad (12)$$

The remaining terms:

$$- \mathbf{q_f}'|_{\zeta_2}.\nabla'\zeta_2 + q_{fz}|_{\zeta_2} \qquad \text{(from 7a)},$$

and

$$\mathbf{q_s}'|_{\zeta_0}.\nabla'\zeta_0 - q_{sz}|_{\zeta_0} \qquad \text{(from 7b)},$$

represent the boundary conditions at the top and bottom of the aquifer, respectively. If the boundaries are impermeable, these terms equal zero. For the case of an unconfined aquifer, the upper boundary is a free surface and the drainage from the water table is given by $n\partial\Phi_f/\partial t$. If the boundaries are permeable, these terms will equal the leakage through the overlying and underlying confining layers.

Leakage Terms

Leakage through a confining layer can be calculated by applying Darcy's law in one dimension (fig. 6) if the following assumptions are made (Bredehoeft and Pinder, 1970): (1) the effects of storage within the confining layer are negligible, and (2) flow through the confining layer is essentially vertical. When the conductivity of the aquifer is two or more orders of magnitude greater than the conductivity of the confining layer, the flow lines are nearly horizontal in the aquifers and vertical through the confining layers (Freeze and Cherry, 1979).

If the water on both sides of the confining layer has the same density, Darcy's law can be formulated in terms of hydraulic head differences across the layer. However, when the density is different, vertical density gradients become important and Darcy's law must be formulated in terms of pressure:

$$q_1 = - \frac{k'}{\mu}\left(\frac{P_a - P_b}{\Delta z} + \rho g\right) \ , \qquad (13)$$

where: q_l = vertical leakage, positive upwards (LT^{-1});

k' = vertical permeability of the confining layer (L^2);

μ = dynamic viscosity ($ML^{-1}T^{-1}$);

p_a, p_b = fluid pressures above and below the confining layer, respectively ($ML^{-1}T^{-2}$);

ρ = fluid density (ML^{-3});

Δz = thickness of the confining layer (L); and

g = gravitational acceleration (LT^{-2}).

Using definitions for hydraulic head ($\Phi = z + p/\gamma$), specific weight ($\gamma = \rho g$), and freshwater hydraulic conductivity of the confining layer ($K' = k'\rho_f g/\mu$), equation (13) can be rewritten as:

$$q_l = -\frac{K'}{B'\gamma_f}\left[\gamma_a(\Phi_a - z_a) - \gamma_b(\Phi_b - z_b) + \gamma B'\right], \qquad (14)$$

where: B' = $z_a - z_b$, thickness of the confining layer (L);

Φ_a, Φ_b = hydraulic heads above and below the confining layer (L), respectively; and

z_a, z_b = elevations of the top and bottom of the confining layer (L).

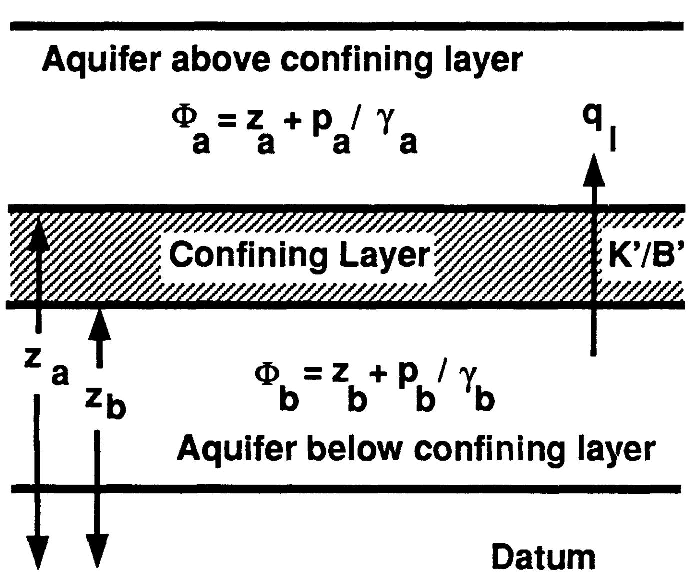

Figure 6.--Leakage through a confining layer.

When freshwater occurs on one side of the confining layer and saltwater occurs on the other, the density distribution within the confining layer depends on the direction of flow. This is unknown until the equation is solved, so, for simplicity, the final term in (14) has been approximated by an average of the specific weights above the confining layer (γ_a) and below (γ_b):

$$\gamma \simeq \bar{\gamma} = (\gamma_a + \gamma_b)/2 \ . \tag{15}$$

Rearranging, the general form of the leakage term becomes:

$$q_l = - \frac{K'}{B'} \left[\frac{\gamma_a}{\gamma_f} \Phi_a - \frac{\gamma_b}{\gamma_f} \Phi_b + \frac{(\gamma_b - \gamma_a)}{\gamma_f} \frac{(z_b + z_a)}{2} \right] , \tag{16}$$

and K'/B' is the leakance of the confining layer (T^{-1}). The first two terms in (16) represent the equivalent freshwater heads above and below the confining layer. The third term incorporates the effect of gravity on the water in the confining layer. For the case of waters with equal density above and below the confining layer, this equation reduces to:

$$q_l = - \left(\frac{K'}{B'}\right) (\Phi_a - \Phi_b) \ . \tag{17}$$

The Integrated Equations

Introducing these boundary conditions and accounting for source/sink terms, the vertically integrated equations for freshwater and saltwater flow, respectively, become:

$$\underset{(1)}{S_f B_f \frac{\partial \Phi_f}{\partial t}} + \underset{(2)}{n\alpha \frac{\partial \Phi_f}{\partial t}} + \underset{(3)}{\left[n\delta \frac{\partial \Phi_f}{\partial t} - n(1+\delta) \frac{\partial \Phi_s}{\partial t} \right]}$$

$$= \underset{(4)}{\frac{\partial}{\partial x}\left(B_f K_{fx} \frac{\partial \Phi_f}{\partial x}\right)} + \underset{(4)}{\frac{\partial}{\partial y}\left(B_f K_{fy} \frac{\partial \Phi_f}{\partial y}\right)} + \underset{(5)}{Q_f} + \underset{(6)}{Q_{lf}} \ , \tag{18a}$$

$$\underset{(1)}{S_s B_s \frac{\partial \Phi_s}{\partial t}} + \underset{(3)}{\left[n(1+\delta) \frac{\partial \Phi_s}{\partial t} - n\delta \frac{\partial \Phi_f}{\partial t} \right]}$$

$$= \underset{(4)}{\frac{\partial}{\partial x}\left(B_s K_{sx} \frac{\partial \Phi_s}{\partial x}\right)} + \underset{(4)}{\frac{\partial}{\partial y}\left(B_s K_{sy} \frac{\partial \Phi_s}{\partial y}\right)} + \underset{(5)}{Q_s} + \underset{(6)}{Q_{ls}} \ , \tag{18b}$$

where: K_{fx}, K_{sx} = fresh and saltwater hydraulic conductivities in the x-direction (LT^{-1});

K_{fy}, K_{sy} = fresh and saltwater hydraulic conductivities in the y-direction (LT^{-1});

Q_f, Q_s = fresh and saltwater source/sink terms (LT^{-1});

Q_{1f}, Q_{1s} = fresh and saltwater leakage terms (LT^{-1}) given by equation (14);

α = 1 for an unconfined aquifer, = 0 for a confined aquifer;

and all other variables are as defined earlier.

In equations (18a, b) the type (1) terms represent the change in elastic storage within each domain. The type (2) term represents the change in freshwater storage due to drainage at the water table, the type (3) terms represent the change in storage within each domain due to movement of the interface, the type (4) terms represent the divergence of the fluxes in the x and y directions, the type (5) terms (recharge, pumpage) and type (6) terms (leakage) represent the sources and sinks to the aquifer.

Equations (18a) and (18b) represent two coupled, parabolic partial differential equations that must be solved simultaneously for the freshwater head (Φ_f) and the saltwater head (Φ_s). Once these values are obtained the interface elevation (ζ_1) can be calculated from (eq. 9):

$$\zeta_1 = (1+\delta)\Phi_s - \delta\Phi_f .$$

In regions away from the interface, only one type of fluid (freshwater or saltwater) is present in the aquifer and the flow is described by the appropriate single equation without the interface (type (3)) storage terms.

Numerical Form of the Freshwater and Saltwater Flow Equations

The continuous spatial and temporal derivatives of the freshwater and saltwater flow equations are discretized using finite-difference methods. Spatial discretization is achieved by using a block-centered finite-difference grid that allows for variable grid spacing (fig. 7). An implicit scheme that is backward in time has been adopted to ensure stability.

In the development of the finite-difference approximations that follows, the terms in the flow equations have been multiplied by the grid block area. Spatial subscripts are indicated only when differing from i, j, or k, for example freshwater head at block (i,j-1,k) is referred to as $\Phi_{f_{j-1}}$.

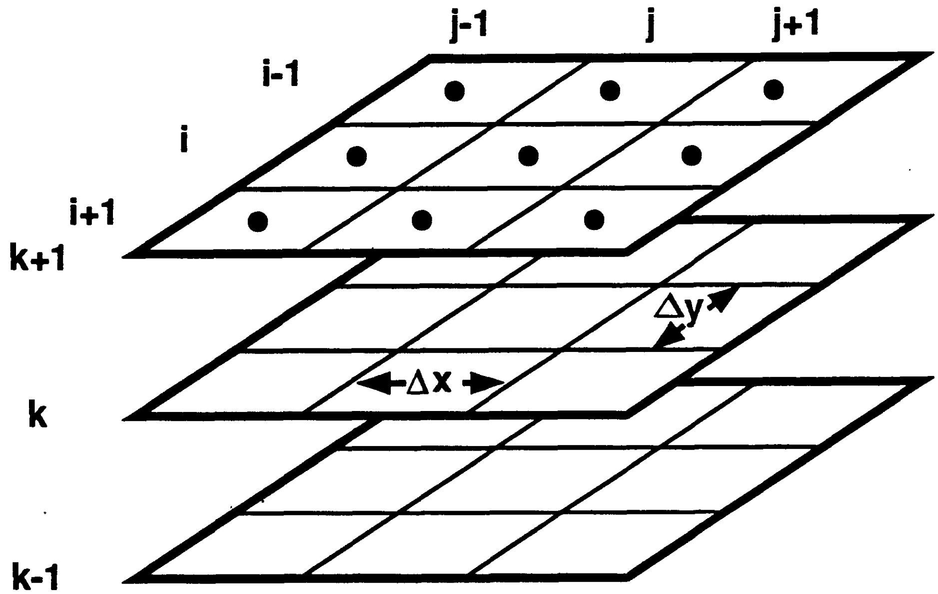

Figure 7.--Block-centered finite-difference grid.

Finite-Difference Approximations of Spatial and Temporal Derivatives

The second-order approximation for the space derivative in the x-direction at grid node (i,j,k) and time level n is given by:

$$A\left[\frac{\partial}{\partial x}\left(B_\lambda K_{\lambda x}\frac{\partial \Phi_\lambda}{\partial x}\right)\right]^n \simeq T^n_{\lambda x_{j+1/2}} \Delta y(\Phi_{\lambda_{j+1}} - \Phi_\lambda)^n - T^n_{\lambda x_{j-1/2}} \Delta y(\Phi_\lambda - \Phi_{\lambda_{j-1}})^n, \quad (19)$$

where λ = 'f' for freshwater flow and 's' for saltwater flow, and A is the grid block area ($A=\Delta x \Delta y$). The transmissivity terms at the block boundaries are given by:

$$T^n_{\lambda x_{j+1/2}} = B^n_{\lambda_{j+1/2}} \left(\frac{K_{\lambda x}}{\Delta x}\right)_{j+1/2}, \quad (20a)$$

and

$$T^n_{\lambda x_{j-1/2}} = B^n_{\lambda_{j-1/2}} \left(\frac{K_{\lambda x}}{\Delta x}\right)_{j-1/2}. \quad (20b)$$

The thicknesses at the block boundaries are linearly interpolated on the basis of adjacent nodal values, and the conductivity terms are estimated using the harmonic mean of the nodal values. The central difference approximations for the space derivative in the y-direction are made in the same manner and the result is:

$$A\left[\frac{\partial}{\partial y}\left(B_\lambda K_{\lambda y}\frac{\partial \Phi_\lambda}{\partial y}\right)\right]^n \simeq T^n_{\lambda y_{i+1/2}} \Delta x(\Phi_{\lambda_{i+1}} - \Phi_\lambda)^n - T^n_{\lambda y_{i-1/2}} \Delta x(\Phi_\lambda - \Phi_{\lambda_{i-1}})^n . \quad (21)$$

The time derivatives of the freshwater and saltwater potentials in equations (18a) and (18b) are approximated by using a backward difference:

$$\frac{\partial \Phi_\lambda}{\partial t} \simeq \frac{\Phi^n_\lambda - \Phi^{n-1}_\lambda}{\Delta t} . \quad (22)$$

Sources and Sinks

The potential sources (or sinks) of freshwater and saltwater in a block are pumpage (or injection), recharge, and leakage from the overlying or underlying confining layers. The proportion of freshwater and saltwater extracted from a well depends on the position of the interface relative to the elevation of the screened interval of the well (fig. 8). The rate of freshwater extraction at a node is determined by a linear apportionment of the total extraction from the well based on the proportion of the open interval of the well penetrating the freshwater zone:

$$P^n_f \simeq \frac{Th^n_f}{Th_t} P_t , \quad (23)$$

where: P^n_f = freshwater pumpage from grid block ijk at time level n (L^3/T);

Th^n_f = length of the open interval penetrating the freshwater zone at time level n (L);

Th_t = total open interval of the well (L); and

P_t = total pumpage from the well (L^3/T).

The saltwater pumpage from the well at time level n (P^n_s) is given by:

$$P^n_s \simeq P_t - P^n_f . \quad (24)$$

Positive values of P_t represent extraction of water from a well, negative values represent injection of water into a well. Using equations (23) and (24), the source/sink terms in (18a) and (18b) become:

$$A\ Q_f \approx \alpha N\Delta x\Delta y - \{\frac{Th_f P_t}{Th_t}\}^n , \qquad (25a)$$

and

$$A\ Q_s \approx \{P_t - \frac{Th_f P_t}{Th_t}\}^n , \qquad (25b)$$

where N is the recharge rate (LT^{-1}). Recharge is not allowed at confined grid blocks where $\alpha = 0$.

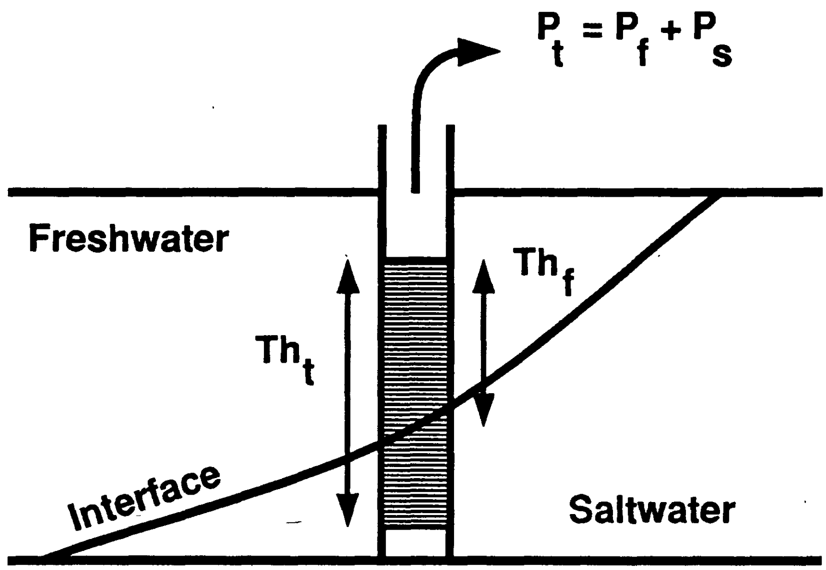

Figure 8.--A well penetrating freshwater and saltwater in an aquifer (Th_t is the total open interval of the well, Th_f is the length of the open interval penetrating freshwater).

Interface Tip and Toe Tracking

To develop a sharp interface model for freshwater and saltwater flow in layered coastal aquifers, representation of the moving interface within a discretized system is necessary. The position of the interface tip (the intersection of the interface with the top of the aquifer) and the interface toe (the intersection of the interface with the bottom of the aquifer) will not always coincide with the block or element boundaries. Shamir and Dagan (1971) overcame this for a vertical cross-section by using a moving grid. At each time step the new position of the toe of the interface was calculated using a linear extrapolation, and rezoning of the grid was performed in order to align the block boundary with the toe. This same approach was used by Bear and Kapuler (1981) for the case of two aquifers separated by an impermeable layer. Wilson and Sa da Costa (1982) incorporated an indirect toe tracking algorithm into a fixed grid finite-element model. Other sharp interface models have made no attempt to track the interface tip and toe positions. SHARP incorporates a tip and toe tracking algorithm based on a weighted extrapolation of the interface slope at finite-difference blocks containing the tip and toe.

To determine the net freshwater and saltwater leakage into a block, the extent of freshwater and saltwater in contact with the top and bottom of the block must be known. This is achieved by determining the positions of the interface tip and toe within the finite-difference grid for each aquifer (fig. 9). The tip is located by linearly projecting the interface in the x- and y- directions, based on the interface slope, until it intersects the top of the aquifer. Similarly, at the toe the interface is projected until it intersects the bottom of the aquifer. Tip projection is carried out at locations where there is transition from a block containing some freshwater to a block containing no freshwater. Similarly, toe projection is carried out where there is a transition from a block containing some saltwater to a block containing no saltwater.

In the vicinity of the tip and toe, the finite-difference approximation of the interface slope in the x- and y- directions can be obtained by differentiating equation (9) with respect to x and y. The slope is then approximated based on weighted freshwater and saltwater head derivatives as follows:

$$\frac{\partial \zeta_1}{\partial x} = (1+\delta)\frac{\partial \Phi_s}{\partial x} - \delta\frac{\partial \Phi_f}{\partial x}$$

$$\simeq (1+\delta)\left[(1-\omega)\frac{\partial \Phi_s}{\partial x}_{j+1/2} + \omega\frac{\partial \Phi_s}{\partial x}_{j-1/2}\right] - \delta\left[(1-\omega)\frac{\partial \Phi_f}{\partial x}_{j+1/2} + \omega\frac{\partial \Phi_f}{\partial x}_{j-1/2}\right], \qquad (26a)$$

$$\frac{\partial \zeta_1}{\partial y} = (1+\delta)\frac{\partial \Phi_s}{\partial y} - \delta\frac{\partial \Phi_f}{\partial y}$$

$$\simeq (1+\delta)\left[(1-\omega)\frac{\partial \Phi_s}{\partial y}_{i+1/2} + \omega\frac{\partial \Phi_s}{\partial y}_{i-1/2}\right] - \delta\left[(1-\omega)\frac{\partial \Phi_f}{\partial y}_{i+1/2} + \omega\frac{\partial \Phi_f}{\partial y}_{i-1/2}\right], \qquad (26b)$$

where: $$\frac{\partial \Phi_\lambda}{\partial x}_{j+1/2} = \frac{\Phi_{\lambda_{j+1}} - \Phi_\lambda}{0.5(\Delta x_{j+1} + \Delta x)},$$

and

$$\frac{\partial \Phi_\lambda}{\partial x}\,j\text{-}1/2 = \frac{\Phi_\lambda - \Phi_{\lambda_{j-1}}}{0.5(\Delta x + \Delta x_{j-1})} ,$$

are the derivatives of freshwater and saltwater heads in front of, and behind the interface tip or toe in the x-direction. Derivatives in the y-direction are calculated in a similar manner.

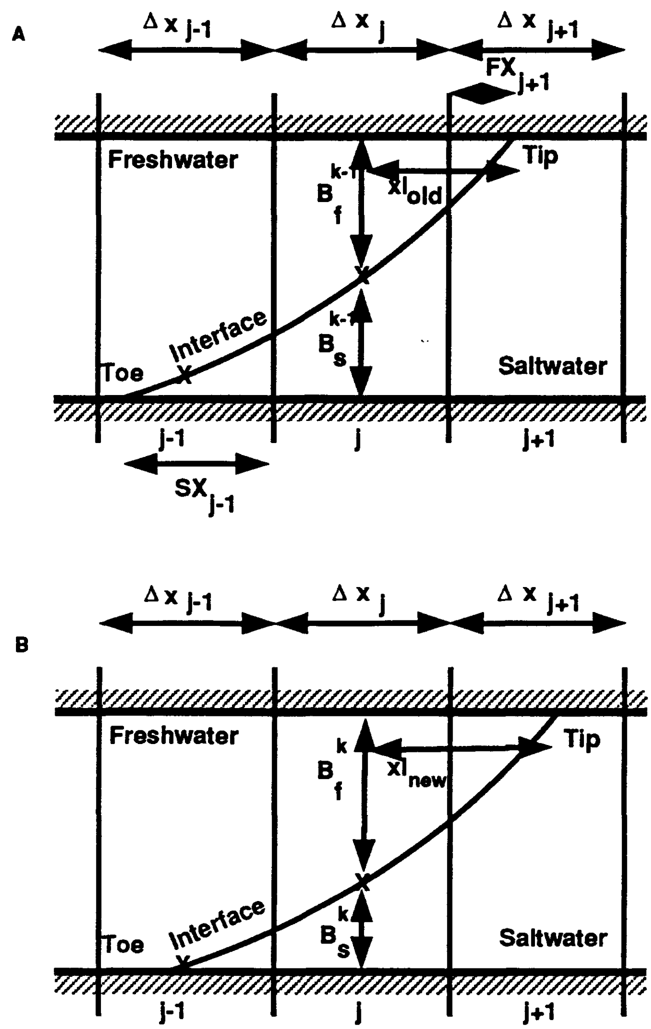

Figure 9.--Interface tip projection in the positive x-direction and toe projection in the negative x-direction (X's represent the calculated interface elevations at center of finite-difference blocks).

A. The projected interface at iteration k-1, and the FX and SX values used in interface projection calculations for iteration k.

B. The new projected interface position at iteration level k.

The weighting of factor ω is necessary to prevent abrupt changes in slope as the interface tip or toe crosses from one block to another, because the slope may change rapidly from j-1/2 to j+1/2. To obtain smooth movement of the interface, ω varies from 0 to 1 as the interface moves. The weight of a derivative increases as the interface tip or toe moves farther into the interval over which it is calculated. For example, for interface tip projection in the positive x-direction (indicated by a + subscript and illustrated in figure 9), the weighting factor is given by:

$$\omega_+ = 1-2(FX_{j+1}) \quad \text{for } FX_{j+1} \leq 0.5 \, , \tag{27}$$
$$\omega_+ = 0 \quad \text{for } FX_{j+1} > 0.5 \, ,$$

where FX_{j+1} is the distance to the interface tip in block i,j+1,k expressed as a ratio of Δx_{j+1}, and the interface slope is obtained from (26a).

The new position of the interface tip is obtained by projecting the interface, based on its slope, until it intersects the top of the aquifer. The slope of the top of the aquifer in the positive x-direction is given by:

$$\left[\frac{\partial Z_{top}}{\partial x}\right]_+ = \frac{Z_{top_{j+1}} - Z_{top_j}}{0.5(\Delta x_j + \Delta x_{j+1})} \, . \tag{28}$$

The new projected distance in the positive x-direction, measured from the center of block ijk to the interface tip, for the current iteration is then calculated using equations (26) and (28) as follows:

$$x1_{new} = B_f / \left[\left(\frac{\partial \zeta_1}{\partial x}\right)_+ - \left(\frac{\partial Z_{top}}{\partial x}\right)_+\right] \, , \tag{29}$$

where B_f is the freshwater thickness in block ijk. The final projected distance is a weighted average of the old and new values:

$$x1 = WFAC*x1_{new} + (1-WFAC)*x1_{old} \, , \tag{30}$$

where $x1_{old}$ is the projected interface position from the previous iteration and WFAC is a user specified weighting factor. A WFAC value of 0.5 will give equal weighting to both values, a value greater than 0.5 will give the new interface position a greater weight. Averaging the old and new values smooths out interface tip and toe movement over time. Generally, it is recommended to use a value of 0.5, as values greater than this may lead to oscillations in tip and toe positions, resulting in an unstable solution.

Following interface projection, the block boundary transmissive coefficients are readjusted based on the new interpolated freshwater and saltwater thicknesses at the block boundaries. The new projected interface tip position is then expressed as a ratio of the block dimension Δx (FXN).

For $xl \leq 0.5\Delta x_j$:

$$FXN_j = (xl + 0.5\Delta x_j)/\Delta x_j \ ,$$

$$FXN_{j+1} = 0.0 \ ,$$

and for $xl > 0.5\Delta x_j$,

$$FXN_j = 1.0 \ ,$$

$$FXN_{j+1} = (xl-0.5\Delta x_j)/\Delta x_{j+1} \ .$$

This procedure is repeated in the negative x-direction with:

$$\omega_- = 2(FX_{j-1}) \quad \text{for } FX_{j-1} \leq 0.5,$$

$$\omega_- = 1 \quad \text{for } FX_{j-1} > 0.5,$$

to obtain projections of the interface where it extends past a block center in the negative x-direction. The interface projection is then repeated in the positive and negative y-directions to obtain FYN.

The interface toe is projected in a similar manner, but with a different weighting scheme which results in a more stable movement of the interface toe. The equations in the positive x-direction are:

$$\omega = \frac{xl_{old}}{0.5(\Delta x_j+\Delta x_{j+1})} \ , \qquad (31)$$

where xl_{old} is taken from the projected interface position from the previous iteration, and the interface slope is calculated using (26b). The slope of the bottom of the aquifer in the positive x-direction is given by:

$$[\frac{\partial Z_{bot}}{\partial x}]_+ = \frac{Z_{bot_{j+1}} - Z_{bot_j}}{0.5(\Delta x_j+\Delta x_{j+1})} \ . \qquad (32)$$

The new positive x-direction projected distance for this iteration is given by:

$$xl_{new} = B_s/[(\frac{\partial Z_{bot}}{\partial x})_+ - (\frac{\partial \zeta_1}{\partial x})_+] \ , \qquad (33)$$

where B_s is the thickness of the saltwater zone. Equation (33) is used to calculate SXN, the interface toe projected distance expressed as a fraction of Δx. The entire procedure is repeated in the negative x-direction (as shown in figure 9), and the positive and negative y-directions to obtain SYN.

When the projections of the interface tip and toe in the x- and y-directions are completed, the fractions of the top and bottom of a block in contact with freshwater and saltwater are calculated. At each grid block the fraction of the top of the block in contact with freshwater is (FAREA) and the remaining fraction is in contact with saltwater (1-FAREA). The fraction of the bottom of the block in contact with saltwater is given by

(SAREA), and (1-SAREA) represents the area of freshwater (fig. 10). Hence, if FAREA=0 the block contains only saltwater; if SAREA=0 the block contains only freshwater; if FAREA=SAREA=1 the interface passes though the block and both freshwater and saltwater are present; and if 0<FAREA<1 the interface tip is within the block, or if 0<SAREA<1 the interface toe is within the block.

The block freshwater and saltwater area factors (FAREA and SAREA) are computed by combining the x- and y-direction projections (FXN, FYN, SXN and SYN) in a manner to ensure smooth variation in FAREA and SAREA (between 0 and 1) as the interface moves. This is accomplished as follows. If FXN and FYN are less than or equal to 0.5, then:

$$FAREA = [1-(FXN*FYN)^{1/2}](FXN+FYN) , \qquad (34)$$

which gives a value of FAREA which varies between 0 and 0.5, otherwise if FXN and FYN are greater than 0.5:

$$FAREA = (FXN*FYN)[1+\frac{1}{(FXN*FYN+0.75)^7}] , \qquad (35)$$

and FAREA varies between 0.5 and 1. For the special case of only one projection factor being less than 0.5, equation (34) is used and the resulting FAREA can be greater than 0.5. The exponent seven in the denominator of equation (35) has been chosen to provide a smooth transition from the case of one projection factor being less than 0.5 to both factors being greater than 0.5. Similarly, if SXN or SYN is less than or equal to 0.5, then:

$$SAREA = [1-(SXN*SYN)^{1/2}](SXN+SYN) , \qquad (36)$$

otherwise:

$$SAREA = (SXN*SYN)[1+\frac{1}{(SXN*SYN+0.75)^7}] . \qquad (37)$$

Using these fractional areas, FAREA and SAREA, the leakage across the overlying and underlying aquitards can be calculated.

Leakage Calculations

Once tip and toe positions have been determined, the leakage terms at each block may be calculated. Two methods are available for allocating leakage between model layers. The two methods are identical in the case of single-layer problems. They differ for multilayered problems in the manner which leakage is allocated when freshwater in one aquifer overlies saltwater in another aquifer, or vice versa. Comparisons of simulations using the two different methods are presented in the model verification section.

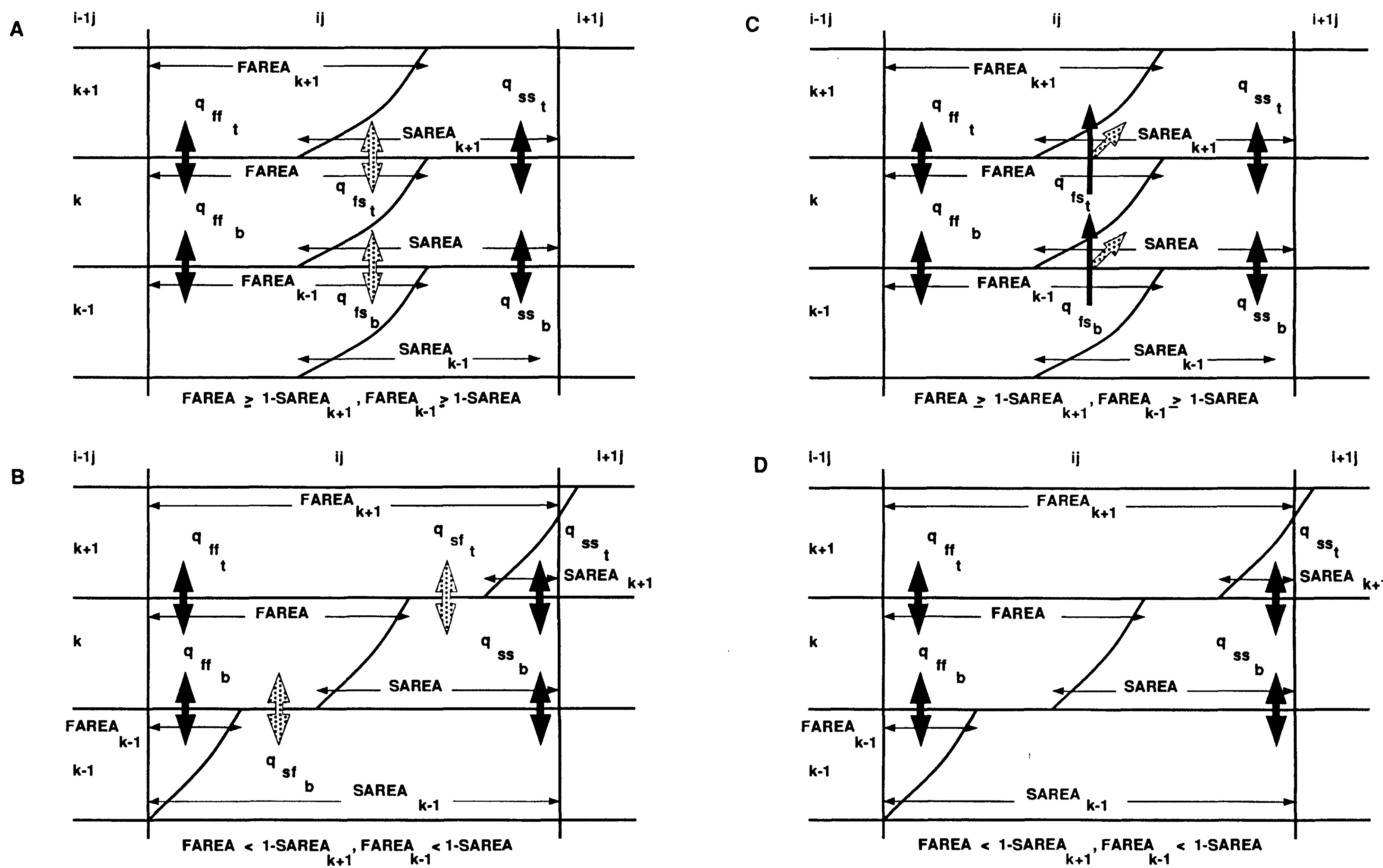

Figure 10.-- Leakage elements (solid arrows represent leakage across confining layers without water type change, shaded arrows represent leakage with water type change - fresh to salt or salt to fresh, arrow heads point in allowed leakage directions):
A. method 1-complete mixing, $FAREA \geq 1-SAREA_{k-1}$, $FAREA_{k-1} \geq 1-SAREA$, B. method 1-complete mixing, $FAREA < 1-SAREA_{k-1}$, $FAREA_{k-1} < 1-SAREA$,
C. method 2-restricted mixing, $FAREA \geq 1-SAREA_{k-1}$, $FAREA_{k-1} \geq 1-SAREA$, D. method 2-restricted mixing, $FAREA < 1-SAREA_{k-1}$, $FAREA_{k-1} < 1-SAREA$.

In method 1 leakage (complete mixing) it is assumed that when freshwater leaks into saltwater or saltwater leaks into freshwater, the amount of leakage is small relative to the water in place, and the water mixes instantaneously and is incorporated into the flow zone that it leaks into. This means that when freshwater leaks into saltwater it becomes part of the saltwater domain, and vice versa for saltwater leaking into freshwater. This assumption is reasonable for low rates of leakage; however, if there is significant vertical flow in the system from one kind of water into the other it does not always yield good results. For example, if there is considerable flow of freshwater in one layer to saltwater in the layer above, this method does not account for the fact that the saltwater in the overlying layer would eventually be flushed completely by freshwater. Also, if inland pumpage reduces freshwater heads significantly in areas having saltwater in the overlying aquifer, downward saltwater leakage into freshwater can be induced, acting as a source of water.

Method 2 (restricted mixing) limits the mixing of freshwater and saltwater. In this method, saltwater is not allowed to leak into the freshwater zone, and downward leakage of freshwater into saltwater is not allowed. Upward leakage of freshwater is distributed between the overlying freshwater and saltwater zones based on the amount of freshwater in the overlying block as represented by the value of FAREA. If FAREA equals 1 in the overlying block, all freshwater leakage goes into the overlying freshwater zone. If FAREA = 0.5, half goes into the freshwater zone and the other half is incorporated into the saltwater zone. When FAREA = 0.0, all freshwater leakage is incorporated into the overlying saltwater zone. The components of freshwater and saltwater leakage across the top and bottom of a finite-difference block for each method are shown in figure 10. Table 2 summarizes the freshwater and saltwater leakage terms for a block.

Finally, the total net freshwater and saltwater leakage into a block is given by the sum of the leakages across the top and bottom:

$$A\ Q_{fl} \simeq (q_{fl_t} + q_{fl_b})\Delta x \Delta y\ , \tag{38a}$$

and

$$A\ Q_{sl} \simeq (q_{sl_t} + q_{sl_b})\Delta x \Delta y\ , \tag{38b}$$

Positive leakage represents flow of water into a layer and negative leakage represents flow out of the layer.

Table 2A.--Leakage terms for Method 1 - Complete Mixing

Across Top	$FAREA \geq 1\text{-}SAREA_{k+1}$	$FAREA < 1\text{-}SAREA_{k+1}$
Freshwater Leakage q_{fl_t} =	$(1\text{-}SAREA_{k+1})q_{ff_t} + (FAREA\text{-}(1\text{-}SAREA_{k+1}))q_{fs_t}$	$(FAREA)q_{ff_t}$
Saltwater Leakage q_{sl_t} =	$(1\text{-}FAREA)q_{ss_t}$	$(1\text{-}FAREA\text{-}SAREA_{k+1})q_{sf_t} + (SAREA_{k+1})q_{ss_t}$
Across Bottom	$FAREA_{k-1} \geq 1\text{-}SAREA$	$FAREA_{k-1} < 1\text{-}SAREA$
Freshwater Leakage q_{fl_b} =	$(1\text{-}SAREA)q_{ff_b}$	$(FAREA_{k-1})q_{ff_b} + (1\text{-}FAREA_{k+1}\text{-}SAREA)q_{sf_b}$
Saltwater Leakage q_{sl_b} =	$(FAREA_{k-1}\text{-}(1\text{-}SAREA))q_{fs_b} + (1\text{-}FAREA_{k-1})q_{ss_b}$	$(SAREA)q_{ss_b}$

Table 2B.--Leakage terms for Method 2 - Restricted Mixing

Across Top	$FAREA \geq 1\text{-}SAREA_{k+1}$	$FAREA < 1\text{-}SAREA_{k+1}$
Freshwater Leakage q_{fl_t} =	$(1\text{-}SAREA_{k+1})q_{ff_t} + \Psi(FAREA\text{-}(1\text{-}SAREA_{k+1}))q_{fs_t}$	$(FAREA)q_{ff_t}$
Saltwater Leakage q_{sl_t} =	$(1\text{-}FAREA)q_{ss_t}$	$(SAREA_{k+1})q_{ss_t}$
Across Bottom	$FAREA_{k-1} \geq 1\text{-}SAREA$	$FAREA_{k-1} < 1\text{-}SAREA$
Freshwater Leakage q_{fl_b} =	$(1\text{-}SAREA)q_{ff_b} + \Psi[FAREA(FAREA_{k-1}\text{-}(1\text{-}SAREA))]q_{fs_b}$	$(FAREA_{k-1})q_{ff_b}$
Saltwater Leakage q_{sl_b} =	$\Psi(1\text{-}FAREA)(FAREA_{k-1}\text{-}(1\text{-}SAREA))q_{fs_b} + (1\text{-}FAREA_{k-1})q_{ss_b}$	$(SAREA)q_{ss_b}$

Explanation:

$$q_{ff_t} = \left(\frac{K'}{B'}\right)(\Phi_{f_{k+1}} - \Phi_f) \qquad q_{ff_b} = \left(\frac{K'}{B'}\right)_{k-1}(\Phi_{f_{k-1}} - \Phi_f)$$

$$q_{fs_t} = \left(\frac{K'}{B'}\right)\left\{\left(\frac{\gamma_s}{\gamma_f}\Phi_{s_{k+1}} - \Phi_f\right) - \frac{z_a + z_b}{2\delta}\right\} \qquad q_{fs_b} = \left(\frac{K'}{B'}\right)_{k-1}\left\{\left(\Phi_{f_{k-1}} - \frac{\gamma_s}{\gamma_f}\Phi_s\right) + \left(\frac{z_a + z_b}{2\delta}\right)_{k-1}\right\}$$

$$q_{ss_t} = \left(\frac{K'}{B'}\right)(\Phi_{s_{k+1}} - \Phi_s) \qquad q_{ss_b} = \left(\frac{K'}{B'}\right)_{k-1}(\Phi_{s_{k-1}} - \Phi_s)$$

$$q_{sf_t} = \left(\frac{K'}{B'}\right)\left\{\left(\Phi_{f_{k+1}} - \frac{\gamma_s}{\gamma_f}\Phi_s\right) + \frac{z_a + z_b}{2\delta}\right\} \qquad q_{sf_t} = \left(\frac{K'}{B'}\right)_{k-1}\left\{\left(\frac{\gamma_s}{\gamma_f}\Phi_{s_{k-1}} - \Phi_f\right) - \left(\frac{z_a + z_b}{2\delta}\right)_{k-1}\right\}$$

$\delta = \frac{\gamma_f}{\gamma_s - \gamma_f}$, $\Psi = 1$ when direction of leakage is from freshwater to overlying saltwater, $\Psi = 0$ when direction of leakage is from overlying saltwater to freshwater. For all flux terms, a positive value indicates flow into the aquifer layer k, and a negative value indicates flow out of the aquifer layer k.

Discretized Flow Equations

Substituting the finite-difference approximations given by equations (19), (21), (22), (25a, b), (38a, b) into equations (18a) and (18b) and rearranging, the freshwater and saltwater finite-difference equations at each node for time level n are expressed as:

$$T^n_{fx_{j+1/2}} \Delta y(\Phi_{f_{j+1}} - \Phi_f)^n - T^n_{fx_{j-1/2}} \Delta y(\Phi_f - \Phi_{f_{j-1}})^n + T^n_{fy_{i+1/2}} \Delta x(\Phi_{f_{i+1}} - \Phi_f)^n -$$

$$T^n_{fy_{i-1/2}} \Delta x(\Phi_f - \Phi_{f_{i-1}})^n + \{ \frac{[S_f B^n_f + n(\alpha + (SAREA)\delta)]}{\Delta t} (\Phi^n_f - \Phi^{n-1}_f) +$$

$$\frac{(SAREA)n(1+\delta)}{\Delta t} (\Phi^n_s - \Phi^{n-1}_s) + (1-\alpha)Q^n_{f1} + \alpha N\} \Delta x \Delta y - \{\frac{Th_f P_t}{Th_t}\}^n = 0, \quad (39a)$$

$$T^n_{sx_{j+1/2}} \Delta y(\Phi_{s_{j+1}} - \Phi_s)^n - T^n_{sx_{j-1/2}} \Delta y(\Phi_s - \Phi_{s_{j-1}})^n + T^n_{sy_{i+1/2}} \Delta x(\Phi_{s_{i+1}} - \Phi_s)^n -$$

$$T^n_{sy_{i-1/2}} \Delta x(\Phi_s - \Phi_{s_{i-1}})^n + \{ \frac{[S_s B^n_s + (FAREA)n(1+\delta)]}{\Delta t} (\Phi^n_s - \Phi^{n-1}_s) +$$

$$\frac{(FAREA)n\delta}{\Delta t} (\Phi^n_f - \Phi^{n-1}_f) + Q^n_{1s} + \alpha N\} \Delta x \Delta y - \{P_t - \frac{Th_f P_t}{Th_t}\}^n = 0 \ . \quad (39b)$$

By introducing FAREA and SAREA into the equations the interface storage terms go to zero when no interface is present in the block.

Rearranging and collecting terms, these two equations can be consolidated into a more compact form with all unknowns on the left hand side and the known values on the right hand side:

$$\mathbf{Z\Phi'}^n_{k-1} + \mathbf{B\Phi'}^n_{i-1} + \mathbf{D\Phi'}^n_{j-1} + \mathbf{E\Phi'}^n + \mathbf{F\Phi'}^n_{j+1} + \mathbf{H\Phi'}^n_{i+1} + \mathbf{S\Phi'}^n_{k+1} = \mathbf{Q'}, (40)$$

where **Z**, **B**, **D**, **E**, **F**, **H** and **S** are 2 x 2 coeficient submatrices with the form $\begin{bmatrix} Z^1 & Z^2 \\ Z^3 & Z^4 \end{bmatrix}$; $\mathbf{\Phi'} = \begin{bmatrix} \Phi_f \\ \Phi_s \end{bmatrix}$ the unknown head values; and $\mathbf{Q'} = \begin{bmatrix} Q^1 \\ Q^2 \end{bmatrix}$ the known right-hand side values. These matrix coefficients are defined in Appendix A. Equation (40) is non-linear as the values of the coefficients **Z**, **B**, **D**, **E**, **F**, **H** and **S** depend on the position of the interface. Their values change with time and are unknown until the solution is obtained.

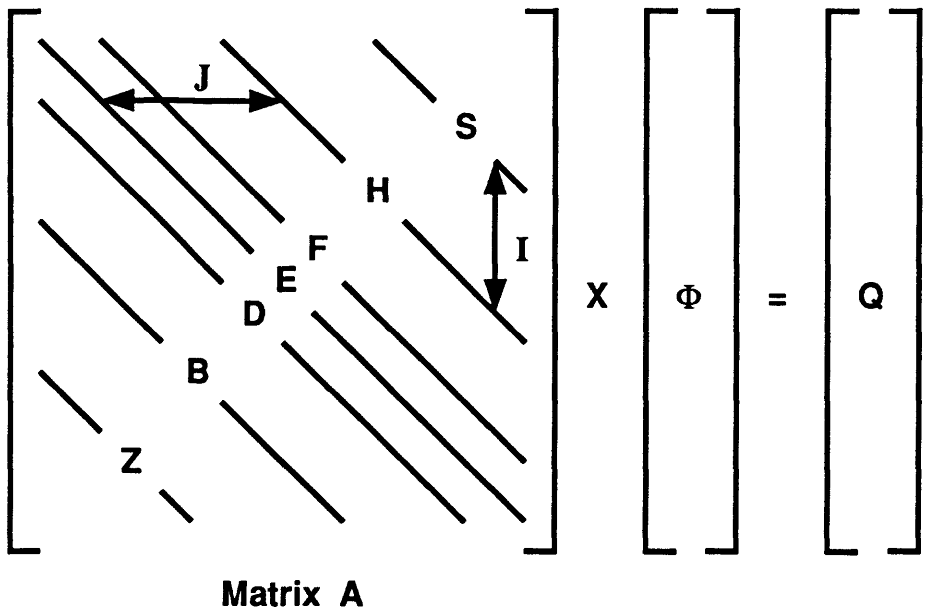

Figure 11.--The system of coupled freshwater and saltwater flow equations in matrix form (I = number of rows, J = number of columns).

The system of M coupled equations representing freshwater and saltwater flow at each node may be expressed in matrix notation as:

$$\mathbf{A}\mathbf{\Phi}^{n} = \mathbf{Q} , \qquad (41)$$

where:
M = the number of nodes in the system;
A = an M by M septadiagonal block matrix of the coefficient submatrices **Z**, **B**, **D**, **E**, **F**, **H** and **S**;
$\mathbf{\Phi}^{n}$ = a block column vector of the unknown freshwater and saltwater heads at time level n; and
Q = a block column vector containing the known values.

The structure of these matrices is shown in figure 11.

SOLUTION OF THE COUPLED FLOW EQUATIONS

To reduce roundoff error and increase solution accuracy during computations, the matrix equation is expressed in residual form by subtracting $\mathbf{A}\mathbf{\Phi}^{n-1}$ from both sides:

$$\mathbf{A}[\mathbf{\Phi}^{n}-\mathbf{\Phi}^{n-1}] = \mathbf{Q}-\mathbf{A}\mathbf{\Phi}^{n-1} ,$$

or

$$\mathbf{A}\xi^{n} = \mathbf{R}^{n-1} , \qquad (42)$$

where:

$\xi^{n} = \Phi^{n} - \Phi^{n-1}$ the head change from n-1 to n;

$R^{n-1} = Q - A\Phi^{n-1}$ the residual right-hand-side.

The M by M square coefficient matrix **A** has a block septadiagonal structure. Each of its rows (with the exception of those representing boundary nodes) contains seven non-zero 2 by 2 coefficient submatrices making up the seven coefficient blocks. Both arrays ξ^{n} and R^{n-1} are column vectors of length M that also exhibit a block structure. Each entry of ξ^{n} corresponds to a given grid location and is a 2 by 1 submatrix containing the change in the freshwater head and saltwater head; similarly each entry of R^{n-1} is a 2 by 1 submatrix of freshwater and saltwater residuals.

The Strongly Implicit Procedure (SIP)

Direct solution of equation (42) by Gaussian elimination requires excessive computational effort and storage requirements for large systems. For this reason, an iterative solution method has been implemented. The strongly implicit procedure (SIP) is an iterative solution technique that solves a modified problem obtained by adding an M by M matrix **B** to coefficient matrix **A** (Stone, 1968; Weinstein and others, 1969, 1970). The matrix **B** is chosen so that the resulting matrix **(A+B)** may be factored into a sparse lower triangular matrix **L** and a sparse upper triangular matrix **U**, each of which has four non-zero block elements per row, corresponding to the positions of the non-zero elements of matrix **A**. After this modification the equation to be solved becomes:

$$(A+B)\xi^{m} = R^{m-1} , \qquad (43)$$

where ξ^{m} represents the change in heads from iteration level m-1 to m and R^{m-1} represents the residuals for iteration level m-1. In the SIP solution algorithm, only the coefficients of **A**, and the factored, sparse **L** and **U** matrices are stored resulting in considerable savings in storage requirements over direct solution methods.

At each time step equation (43) is solved iteratively with R^{o} (the residual for the first iteration) set equal to R^{n-1}, the residual from the previous time step. As iteration proceeds and the solution converges, ξ^{m} and R^{m-1} go to zero. The expanded version of the SIP algorithm for three-dimensional, two-phase flow is given in Appendix B.

The nonlinearity of equation (40) is incorporated directly within the solution procedure using Picard iteration. The equations are linearized within the iterative solution technique by evaluating the coefficients at the previous iteration level. As mentioned above, the coefficients of matrix **A** are time-dependent and change with the position of the interface.

The values of these coefficients are updated at the end of each iteration based on the new interface position and then used in the next iteration level calculations.

Convergence of SIP

The rate of convergence of the SIP scheme may be improved by the appropriate choice of values for the iteration parameters and by the introduction of a relaxation factor. Stone (1968), Weinstein and others (1970) and Trescott and others (1976) have shown that SIP converges more rapidly than other iterative techniques when there is considerable anisotropy, heterogeneity, and irregularity of geometry. More recent literature (Meijerink and Van der Vorst, 1977) has indicated that the preconditioned conjugate gradient method may converge more rapidly than SIP; however, this method has not been adapted to this problem.

Iteration Parameters

To study the convergence of the SIP algorithm, Stone (1968) applied Von Neumann error analysis to a simple two-dimensional, homogeneous, isotropic problem of rectangular geometry assuming that the dimensions of the problem were large enough that the influence of the boundary conditions would be negligible. From this analysis he concluded that it was best to use a cycle of iteration parameters within the range of zero to one, because values near one tend to decay the low frequency errors most rapidly, while the values near zero decay the high frequency errors most rapidly. The minimum parameter is always set to zero, but the maximum value is problem dependent. Too large a value will cause divergence, and too small a value will lead to slow convergence. Weinstein and others (1969, 1970) found it best to calculate the maximum SIP iteration parameter (ω_{max}) using the equation for the minimum ADIP (alternating direction implicit procedure) parameter for a homogeneous one-phase problem with rectangular grid blocks:

$$1-\omega_{max} = \min_{\text{over grid}} \left[\frac{\pi^2}{2J^2(1+\rho)}, \frac{\pi^2}{2I^2(1+1/\rho)}\right], \quad (44)$$

where: $\rho = \frac{K_{fy}\Delta x^2}{K_{fx}\Delta y^2}$;

J = the number of columns; and
I = the number of rows.

The intermediate parameters are spaced geometrically, based on the value of ω_{max}:

$$1-\omega_m = (1-\omega_{max})^{m/(M-1)}, \quad (45)$$

where:

$m = 1,2,3,\ldots\ldots,M-1$

M = number of iteration parameters in a cycle.

Stone (1968) recommended using the same parameter on successive normal and reverse iterations; however, Weinstein and others (1970) found this to be of no advantage in solving multiphase two-dimensional problems. Weinstein and others also used the same parameters for all phases and layers and recommended that if a sequence of parameters caused divergence, $(1-\omega_{max})$ should be multiplied by a factor (WITER) of two to ten, and if convergence was slow, it should be divided by a factor of two to ten. The guidelines presented by Weinstein and others (1970) have been implemented in SHARP. The number of iteration parameters (NITP) is user specified. Generally between four and ten parameters are sufficient. The factor WITER is also user specified. For problems that are highly anisotropic or that have highly variable grid spacing, WITER may need to be considerably larger than ten to achieve convergence (see practical considerations section).

Relaxation Factor

A relaxation factor (RFAC), multiplying the residual terms on the right hand side of equation (43) may be introduced to accelerate the rate of convergence:

$$(\mathbf{A}+\mathbf{B})\xi^{m} = \mathrm{RFAC} * \mathbf{R}^{m-1} \ .$$

A factor between one and two leads to over-relaxation of the solution, increasing the increments of head change for each iteration. For highly non-linear problems, under-relaxation or decreasing the increment of head change per iteration by a factor between zero and one, will generally improve convergence. Under-relaxation may be necessary to prevent overshooting or oscillation in the solution (see practical considerations section).

MODEL VERIFICATION

To verify the numerical solution obtained from the finite-difference model, numerical simulations have been compared with analytical solutions, experimental Hele-Shaw analogs, and other model results.

Single Layer Problems

Model results for one layer problems without leakage have been verified for the motion of a linear interface and a retreating and intruding interface (Essaid, 1984). SHARP results are compared with an analytical solution and model simulations of Mercer and others (1980a) and Shamir and Dagan (1971). These results are summarized below.

Keulegan (1954) presented an analytical solution for the location of the toe of an initially vertical interface rotating towards an equilibrium position in a confined aquifer of uniform thickness:

$$L(t) = \left(\frac{t\Delta\rho K_f D}{n\rho_f}\right)^{1/2} , \qquad (46)$$

where L(t) is the distance to the interface toe from its initial position, $\Delta\rho = \rho_s - \rho_f$, and D is the aquifer thickness. To compare SHARP model results with another numerical model and the analytical solution, the parameters of table 3 and the initial conditions of Mercer and others (1980a) were used. The initial position of the interface was set at L = 20 m, a position corresponding to a time of 12.28 days of rotation from the vertical position. The results obtained for a simulation period of 20 days and the results of Mercer and others (1980a) are shown in figure 12. Both numerical solutions fit the analytical solution quite well.

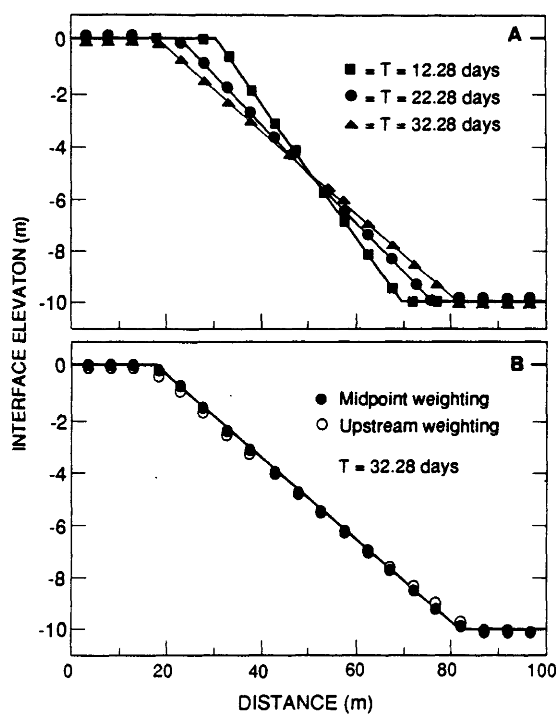

Figure 12.--Simulation of a rotating linear interface (points represent numerical results, lines represent analytical solutions):
A. results of SHARP,
B. results of Mercer and others, (1980a).

Table 3.--Paramaters used in model verification simulations

Parameter	Rotating Interface	Retreating and Intruding Interface	Layered Aquifer
D (m)	10.	27.	
ρ_f (gm/cm^3)	1.0	1.0	1.0
ρ_s (gm/cm^3)	1.025	1.030	1.025
K_f (m/s)	4.52×10^{-4}	.69	.10
K' (m/s)			8.0×10^{-4}
S_f (m^{-1})	1.0×10^{-4}	1.0×10^{-4}	
S_s (m^{-1})	1.025×10^{-4}	1.03×10^{-4}	
n	0.3	1.0	0.1
Δx (m)	5.0	0.1	0.05
Δt (s)	86400.0	5.0	

Simulations for a retreating and intruding interface were compared to observed interface behavior in a Hele-Shaw experiment carried out by Bear and Dagan (1964), and the numerical model results of Shamir and Dagan (1971). In both cases the same parameters were used (table 3) and the outflow, or seepage face, was approximated by assigning the boundary node a high leakance value (3.3 s^{-1}) and a zero head in the overlying aquifer. For the retreating interface the seaward freshwater discharge was suddenly increased from a steady-state value of 3.9 cm^3/s to 18.8 cm^3/s (fig. 13). In the case of the intruding interface, the initial steady-state freshwater flux of 19.1 cm^3/s was stopped abruptly and the transient interface allowed to intrude (fig. 14). The numerical results of Shamir and Dagan (1971) and the present model both do not reproduce the experimentally observed interface curvature, and show some lag in interface translation. This can be attributed to the error introduced by the Dupuit assumption of horizontal flow. This approximation deteriorates as vertical flow becomes more pronounced at the outflow face. There is also the difficulty of realistically representing the seepage boundary condition at the outflow face. Shamir and Dagan (1971) introduced the actual experimental values for freshwater head and interface elevation at the outflow face into their solution to improve their results.

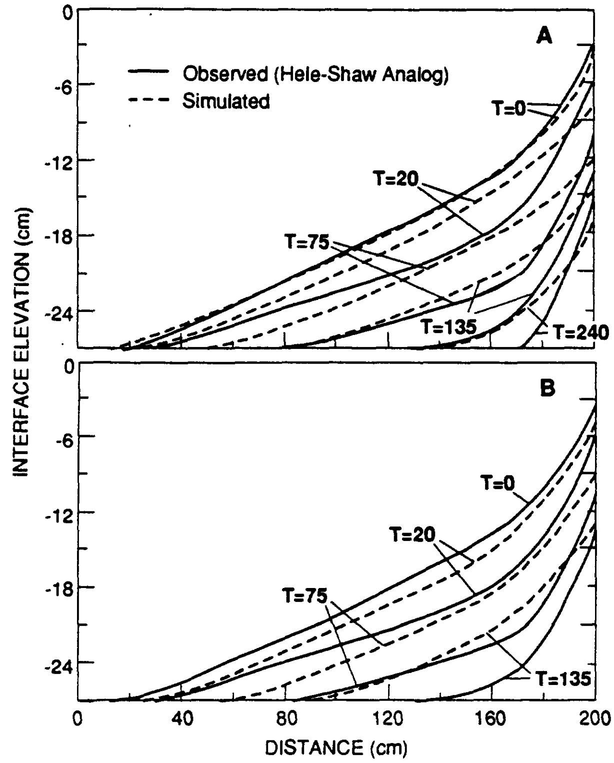

Figure 13.--Simulation of a retreating interface (lines represent experimental results, dashed lines respresent numerical results):
A. results of SHARP,
B. results of Shamir and Dagan (1971).

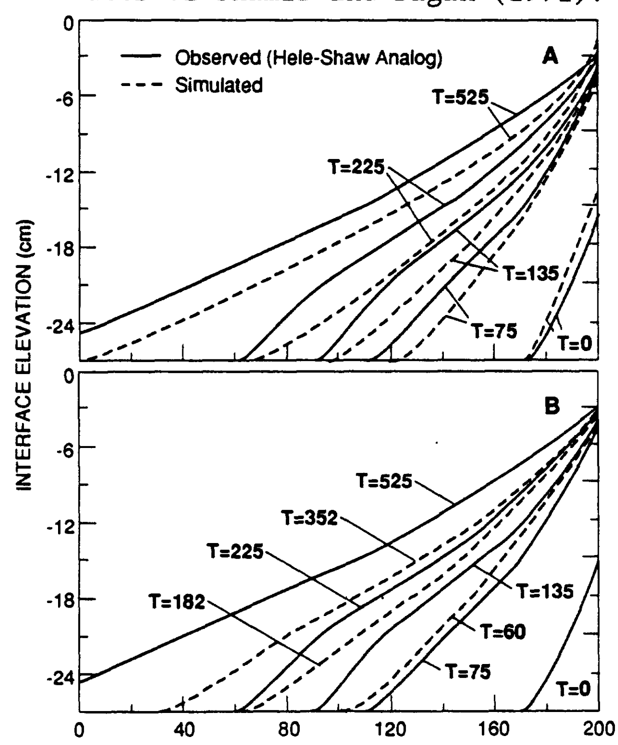

Figure 14.--Simulation of an intruding interface (lines represent experimental results, dashed lines respresent numerical results):
A. results of SHARP,
B. results of Shamir and Dagan (1971).

Steady-State Interface in a Layered Coastal Aquifer

Incorporation of interface tip and toe tracking and accurate leakage calculations makes comparison of the numerical model with an analytical solution for a layered problem possible. Mualem and Bear (1974) have presented an approximate analytical solution for the steady-state shape of an interface in a coastal aquifer when a thin horizontal semiconfining layer is present (fig. 15). Their solution, which showed good agreement with Hele-Shaw analog experiments they conducted, is based on the Dupuit assumption and a linearization of the flow equations. In addition, Mualem and Bear (1974) made two simplifying assumptions regarding the leakage conditions in the region where saltwater is present above the semiconfining layer: (1) Φ_a was constant above the semiconfining layer in this region, and (2) the freshwater leaking through the semiconfining layer from below was incorporated into the freshwater flow zone above. This is approxitely equivalent to the restricted mixing leakage option of SHARP (method 2).

The geometry of the test problem is shown in figure 16, and the parameters used in the simulation are given in table 3. To compare the numerical solution with the analytical solution, method 2 leakage calculations (restricted mixing) were used to approximate Mualem and Bear's assumptions. Figure 17a shows good agreement between the two solutions. The same problem was then simulated using the method 1 leakage conditions (complete mixing), and the results are shown in figure 17b. In this second solution, the freshwater flowing through the semiconfining layer leaks into the overlying saltwater zone. The saltwater zone is no longer static, as was assumed in the analytical solution. The interface below the semipervious layer is slightly deeper while the interface extends further inland above the layer. This result is caused by: (1) the leakage of freshwater into the overlying saltwater, and (2) flow in the saltwater zone, which is actually a mixing zone. In the Hele-Shaw experiments, Mualem and Bear (1974) observed that there was a clear boundary between the freshwater and mixing zone but no clear boundary could be distinguished between the mixing zone and the saltwater zone. In the complete mixing simulation, the position of the interface separates the zone containing freshwater from the zone containing any mixed water.

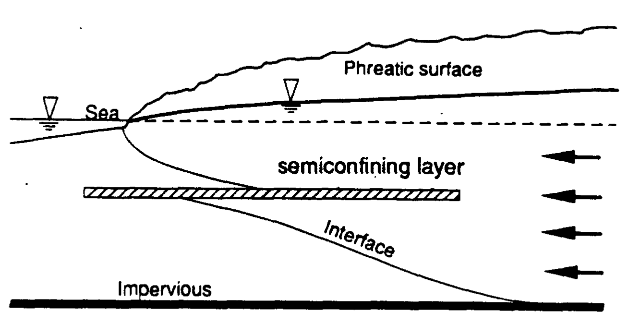

Figure 15.--The interface in a coastal aquifer with a thin horizontal semiconfining layer (modified from Mualem and Bear, 1974).

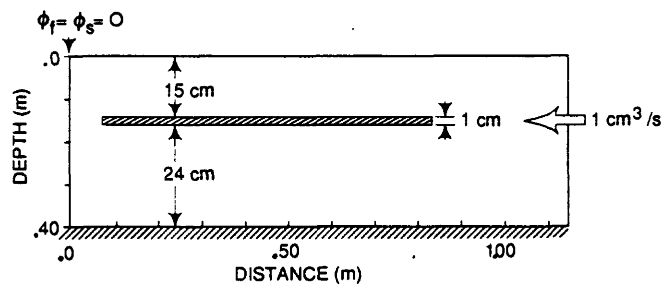

Figure 16.--Geometry of the layered test problem.

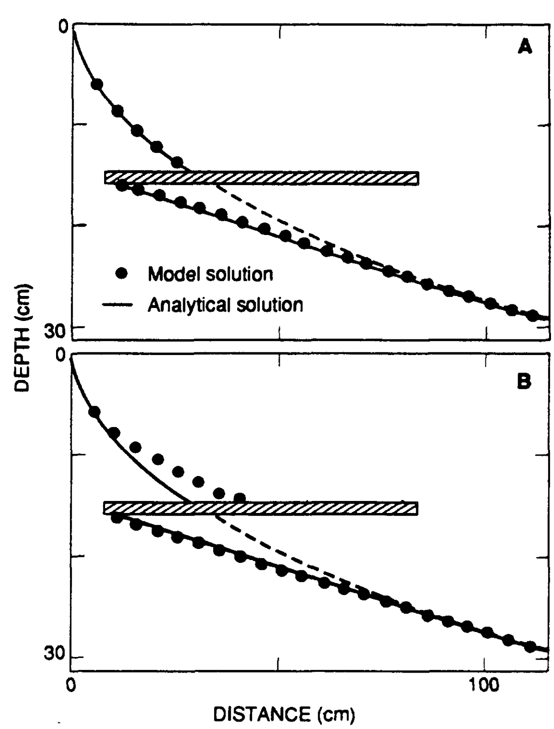

Figure 17.--Comparison of numerical and analytical solutions for the layered case (dashed line represents the position of the interface in the absence of a semiconfining layer):

A. restricted mixing leakage (method 2),

B. complete mixing leakage (method 1).

Comparison of Sharp Interface and Disperse Interface Solutions

Hill (1988) presented a comparison of the sharp interface and disperse interface solutions for a generalized cross-section through the ground-water system in the coastal area of Cape May County, New Jersey. The comparison was made using the complete mixing leakage (method 1) calculations in the sharp interface model. The disperse interface simulation was carried out using the density-dependent, convective-dispersive transport model SUTRA, described by Voss (1984b).

The geometry of the simulated cross-section is shown in figure 18. The system consists of an unconfined aquifer overlying two confined aquifers. The boundary conditions imposed on the system were no-flow across the bottom and the landward-vertical boundaries, a constant head of sealevel at the seaward-vertical boundary, and a parabolic distribution of head specified in an overlying layer varying from sea level at the shore to 12 feet above sea level onshore. Offshore, equivalent freshwater heads for the column of seawater were specified in the overlying layer. The upper boundary was a head-dependent boundary condition in SHARP simulations and a constant-head boundary condition in SUTRA simulations. Other parameters used in the simulation are given in table 4, and the details of the convective-dispersive simulation are given by Hill (1988).

The results of Hill's SHARP simulations with complete mixing are shown in figure 19. The sharp interface results of an additional simulation using the restricted mixing leakage method are also shown in figure 19. In general, the sharp interface is closer to land than the lines of equal chloride concentration, expressed as a fraction of seawater, from the SUTRA simulations. This is because the effects of mixing lead to circulation of saltwater at the interface. This can be seen in the plot of velocity vectors from the SUTRA simulations in figure 19b. Cooper (1959), Kohout (1964) and Volker and Rushton (1982) have shown that because the effects of dispersion are neglected, the position of the toe predicted by the sharp interface tends to be farther inland than the actual transition zone. Thus, the sharp interface solution gives a more conservative estimate of saltwater

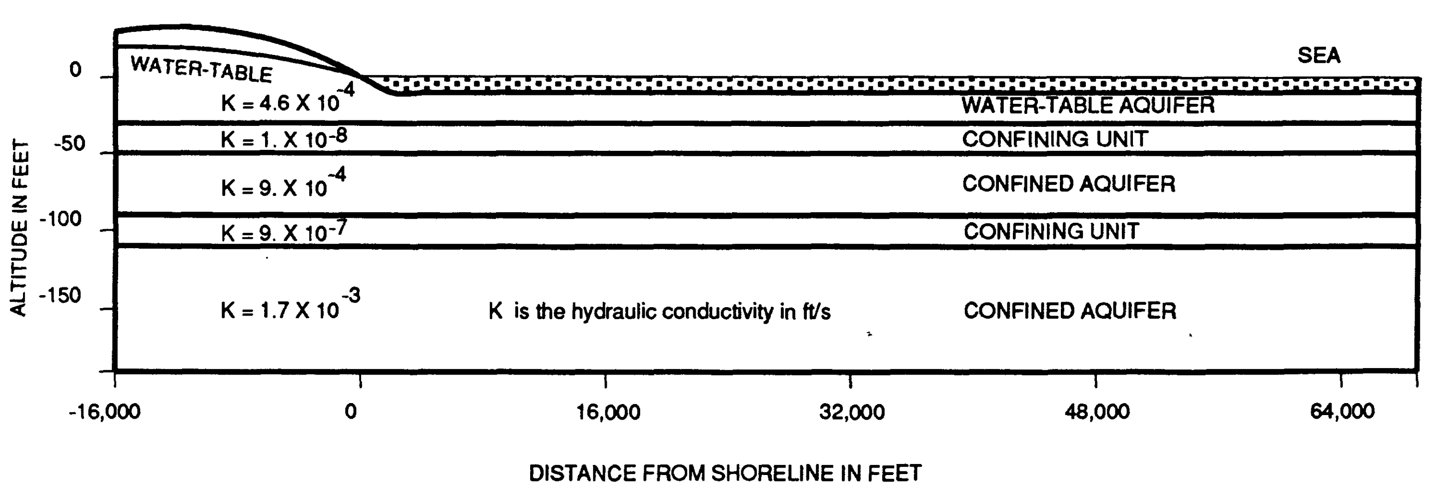

Figure 18.--Modeled cross-section for Cape May simulation (modified from Hill, 1988).

Table 4.--Parameters used in Cape May cross-section simulation

Parameter	Value
Aquifer horizontal to vertical anisotropy	100.
Confining bed horizontal to vertical anisotropy	10.
Aquifer Porosity	0.1
δ	40.
Maximum longitudinal dispersivity (feet)	25.
Minimum longitudinal dispersivity (feet)	2.5
Transverse dispersivity (feet)	2.5

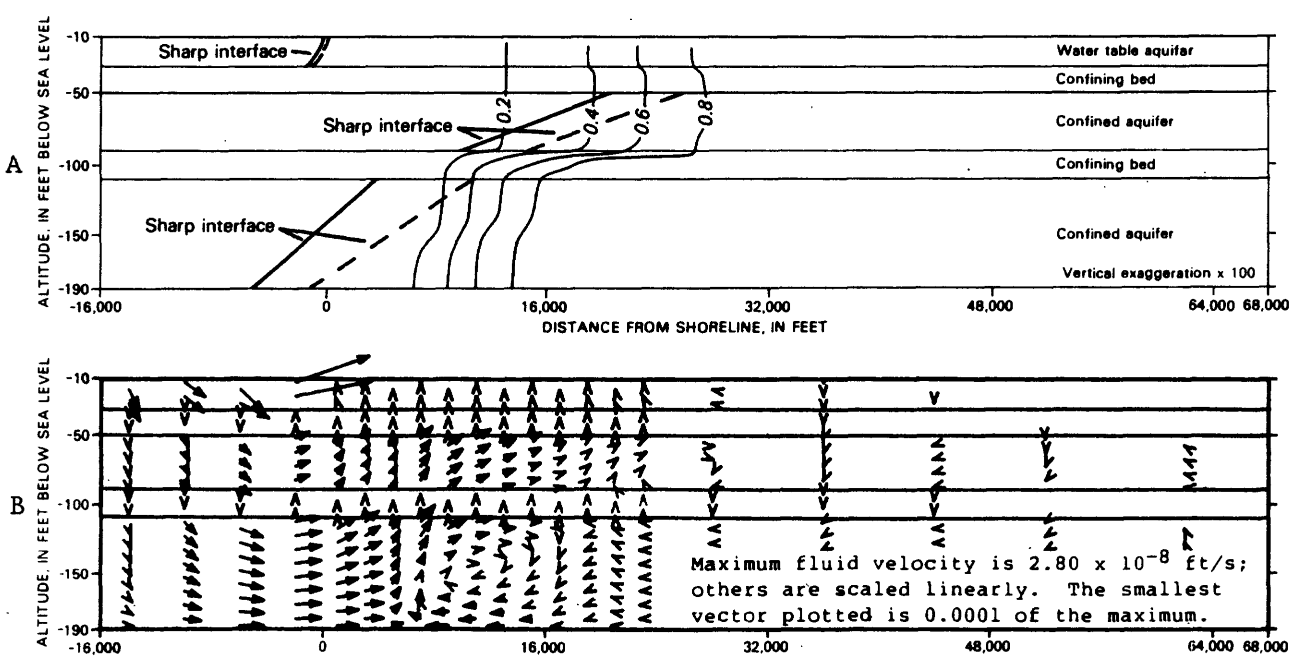

Figure 19.--Results of steady-state simulations:

A. lines of equal chloride concentration from the SUTRA simulation and the sharp interface positions from the SHARP simulations (solid lines are interface with method 1 leakage, dashed lines are interface with method 2 leakage),

B. fluid velocity vectors from SUTRA (modified from Hill, 1988).

intrusion and interface toe position. Hill (1988) indicated that as the coefficient of hydrodynamic dispersion was reduced, the orientation of the lines of equal concentration approached that of the sharp interface. In the following discussion, the position of the sharp interface is compared to the zone between the 0.4 and 0.6 concentrations lines obtained from the SUTRA simulations. This corresponds to the zone containing approximately half freshwater and half saltwater, and will be referred to as the 0.5 zone.

The sharp interface is considerably landward of the 0.5 zone in the upper unconfined aquifer for both complete and restricted mixing simulations. In this unconfined aquifer, the sharp interface position approximates the boundary of the active freshwater flow zone and the offshore zone of sluggish fluid flow. That is, the interface is the location where most of the freshwater is being discharged from the unconfined layer to the sea. The zone of relatively stagnant freshwater present offshore in the SUTRA simulation is not included in the freshwater domain of either sharp interface simulation. In the SUTRA steady-state simulation, this zone has been flushed of saltwater by upward leakage of freshwater from below. During transient conditions induced by inland pumpage, this zone would not be a useful source of freshwater, because flow directions would quickly be reversed, resulting in saltwater leakage into this zone from the sea.

In the middle aquifer, for both leakage simulations, the sharp interface very roughly passes through the 0.5 zone, but has a different slope (because dispersion is not accounted for). The interface is closer to the shore in the complete mixing simulation because there is some loss of freshwater by downward leakage into the underlying saltwater domain.

The interface in the lowermost aquifer is considerably landward of the 0.5 zone when using the complete mixing leakage conditions. When using the restricted mixing conditions, the tip of the interface is close to the 0.5 zone; however, the toe is still considerably landward. In the complete mixing case, some freshwater from confined aquifer 2 leaks down into the saltwater zone of the bottom aquifer, and is mixed into the saltwater domain. This results in shrinkage of the freshwater zone in the lowermost aquifer. In the restricted mixing calculations, freshwater leakage from above is not allowed into saltwater below, and loss of freshwater to the underlying saltwater domain does not occur. The toe of the interface in this case, however, is still landward of the 0.5 zone as the sharp interface approach does not reproduce the circulation of saltwater in the transition zone. The sharp interface position approximately corresponds to the boundary between the freshwater flow vectors and the zone of saltwater recirculation.

The system illustrated in this example is strongly influenced by vertical flow components, and therefore, the restricted mixing leakage option yields better results.

DESCRIPTION OF THE COMPUTER PROGRAM

The computer program is segmented into a main program and fifteen subroutines which are described below. The flow charts in figures 20 and 21 present the overall structure of the major calculations and operations in the program. The data input formats are given in attachment A, and the main program variables are defined in attachment B. The complete program listing is given in attachment C. In the following description of the program, line numbers referenced are the line numbers in attachment C.

MAIN Routine

The MAIN routine controls the general flow and execution structure of the model. As shown in figure 20, subroutine INPUT is called to read the model input parameters, and other arrays are initialized accordingly. For new model runs (NCONT=0), the interface elevations are used to determine the node type: freshwater only (F), saltwater only (S), or freshwater overlying saltwater (M); and, the interface projection factors (FX, FY, SX and SY) are initialized. For continuation runs (NCONT>0), the interface projections factors are read in by subroutine INPUT. Subroutine IPARAM is then called to calculate the iteration parameters used in the SIP algorithm, and subroutine KMEAN is called to calculate the hydraulic conductivities at grid block boundaries ($i\pm1/2$, $j\pm1/2$).

Each pumping period is initiated by calling PUMPER (a secondary entry point in INPUT) to read the time-step and pumping specifications, and recharge for that pumping period. Time-step calculations then commence. Heads from the previous time step are saved and subroutine SIP is called to solve the freshwater and saltwater flow equations.

If the maximum number of time steps allowed has been reached upon completion of a time step, subroutine OUTPUT is called to calculate the mass balance and print time-step results, terminating program execution. If steady-state has been achieved, OUTPUT is called to print results and a new pumping period is initiated. If the last pumping period has been reached, program execution is terminated. If neither of these conditions is met, but the number of time steps between printouts has been reached, OUTPUT is called to print results and a new time step is initiated. Otherwise, subroutine OUTPUT is called to print time-step iteration information and to perform cumulative mass balance calculations, and a new time step is initiated. If the end of a pumping period has been reached, a new pumping period is initiated. If the last pumping period has been completed, OUTPUT is called and calculations are terminated.

The final step of the program, when the simulation has been completed, is to write the simulated heads and interface elevations at observation nodes, for each time step, to a file.

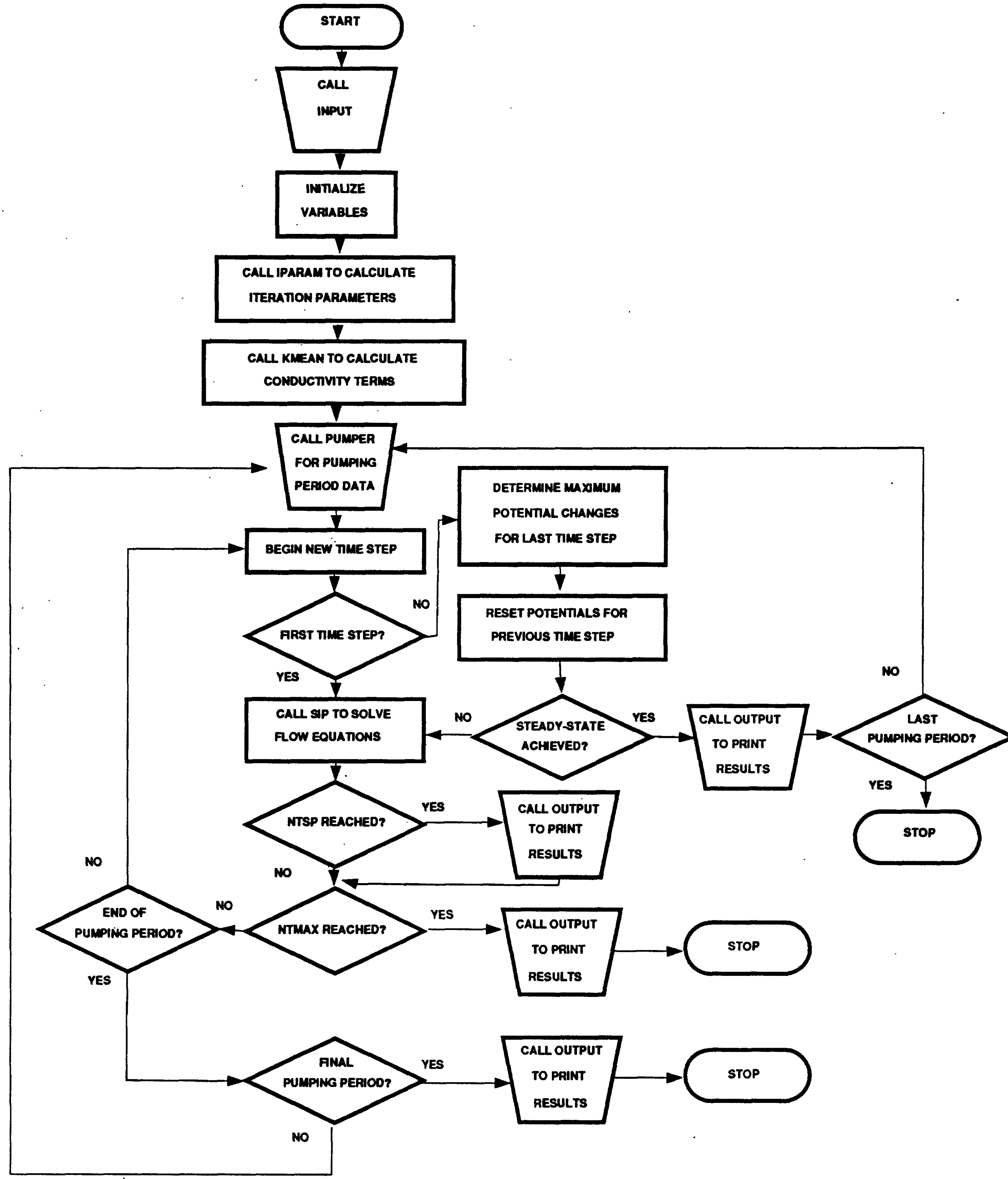

Figure 20.--Flow chart for the MAIN program.

Subroutine INPUT

The input data required for a model run is read in and printed out by subroutine INPUT, which is called from the MAIN routine. Data may be input in any consistent set of units having time units of seconds. The first data group read (lines IN 330 to IN 400) includes the simulation title, grid dimensions, iteration and time-step information, closure criterion, and fluid properties. Following this, locations of observations nodes are read in, and the initialization for the current run is specified (NCONT, TSEC and NINT). At this point, if NOPT=1, user specified input/output options (stored in the array IOP) are read. The data group that is read next (lines IN 900 to IN1370) contains aquifer properties and initial freshwater head and interface elevation values. The secondary entry point PUMPER is accessed at the beginning of each pumping period to read in time-step parameters, well information, and recharge values for that period. A detailed description of data input format is given in Attachment A.

Subroutine READ

Subroutine READ is called from INPUT to read and write two- and three-dimensional arrays. Elements of the array are assigned a fixed value if M=1; if M≠1 the individual element values are read one row at a time, and scaled using a multiplication factor. The first section of the routine is for three-dimensional arrays (RD 40 to RD 380), and the second section, which is accessed through the secondary entry point READ1 is for two-dimensional arrays (RD 410 to RD 690).

Subroutine IPARAM

Subroutine IPARAM is called from the main program to calculate the iteration parameters used in the SIP solution algorithm. The number of iteration parameters is specified in the data input and the calculated sequence is cycled through during SIP iterations. The same set of iteration parameters is used for all layers.

Subroutine KMEAN

Freshwater hydraulic conductivity terms in the x- and y-directions at grid block boundaries are calculated in subroutine KMEAN based on the harmonic means of values at adjacent nodes. Zero values for the x-direction hydraulic conductivity (FKX) must be specified along the exterior of the grid, and also at inactive nodes, to ensure no flow out of the solution domain. At these locations, the y-direction conductivities (FKY) are set to zero during model calculations. The saltwater hydraulic conductivities (SKX and SKY) are calculated from the freshwawter conductivities and fluid densities and viscosities.

Subroutine SIP

Subroutine SIP is called from the main routine at each time step to solve the freshwater and saltwater flow equations using the SIP solution algorithm (see Appendix B and fig. 21). Coefficients and variables are initialized in lines SI 450 to SI 590. If the maximum number of iterations has not been reached, calculations for a new iteration commence on line SI 610. If the maximum number of iterations per time step is exceeded, OUTPUT is called to print the results of the last iteration and program execution is terminated. Otherwise, an iteration parameter is selected from the calculated sequence of parameters. Subroutine TCOEF is then called to evaluate the new interface elevations and node types. These are used to calculate the transmissive coefficients, and freshwater and saltwater block area factors from the interface tip and toe projections.

For odd iterations the normal SIP algorithm is applied and for even iterations the reverse algorithm is applied. In both cases subroutine FACTOR is called to evaluate SIP coefficients and to factor the matrix. These results are used to solve for the changes in freshwater and saltwater heads. The maximum changes in freshwater and saltwater head for the iteration are stored, and head values are updated. If convergence has been achieved, values at observation nodes are stored and control is transferred to the MAIN program. Otherwise the iteration procedure is repeated.

Subroutine TCOEF

Subroutine TCEOF is called from SIP at the beginning of each iteration to update transmissive coefficients and projected interface positions (fig. 21). First, new interface elevations are calculated, node types (F, M, S) are determined, and the freshwater and saltwater thicknesses at each grid point are calculated (TC 510 to TC 930). Following this, new transmissive coefficients are calculated using the interpolated freshwater and saltwater thicknesses at block boundaries and mean hydraulic conductivities (TC 950 to TC 1200). The next group of calculations in TCOEF involves the evaluation of the freshwater and saltwater block area factors. The interface tip and toe are projected in the x- and y-directions and the new projected distance factors (FXN, FYN, SXN, and SYN) are used to determine the proportion of the area of the top and bottom of each block that is in contact with freshwater and in contact with saltwater (FAREA and SAREA).

Subroutine FACTOR

Subroutine FACTOR is called from SIP to calculate the residuals ($\mathbf{R}^{k-1}$) and factor the modified matrix (**A+B**). The matrix (**A+B**) is decomposed into its corresponding lower triangular (**L**) and upper triangular (**U**) matrices. In lines FA 430 to FA2320 the coefficients of matrix **A** are evaluated. In lines FA2340 to FA2580 the residual terms are calculated. At constant head nodes, all coefficients off the main diagonal and the residual on the right hand side are set to zero, which forces the change in head to be zero.

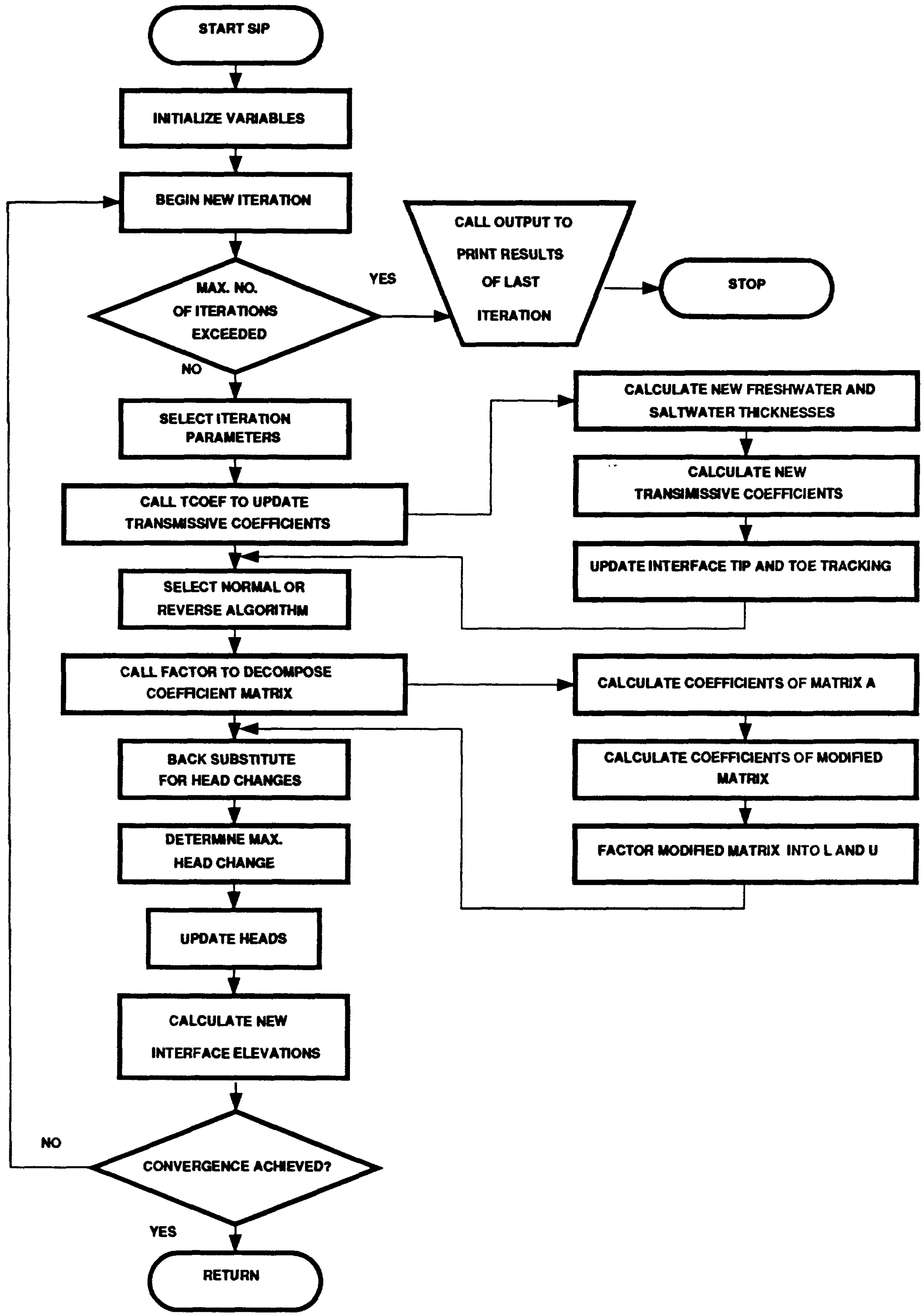

Figure 21.--Flow charts for subroutines SIP, TCOEF and FACTOR.

Modification of matrix **A** and factorization takes place in lines FA2770 to FA3570. Five subroutines are used to simplify the calculations in this process: ASSIGN, MULT, INV, MAT1, and MAT2. Subroutine ASSIGN assigns values to a 2x2 submatrix, subroutine MULT multiplies two submatrices, INV calculates the inverse of a submatrix, and MAT1 and MAT2 carry out submatrix calculations that are used repeatedly in the SIP algorithm.

Subroutine RESULTS

In subroutine RESULTS, the results of the latest time step are written to file in a format that can subsequently be read into the model for a continuation run. The matrices written to file are the freshwater heads, interface elevations and interface tip and toe projection factors (FX, FY, SX, and SY). If IOP(12)=0, the relevant file units are rewound and RESULTS is called from the MAIN program after each time step. In this manner, the results of the latest time-step computation are written to file. If IOP(12)=1, RESULTS is called every time the number of time steps between printouts is reached. In this manner the results for all output time steps are written to file.

Subroutine OUTPUT

The main routine calls OUTPUT at the end of each time step. It will print out the full time-step results to unit IUN(24) when the number of time steps between subsequent printouts is reached (NP), a steady-state solution is achieved, or the final time step is reached. It may also be called from SIP to print out results of the last iteration when a solution does not converge within the maximum number of iterations allowed. OUTPUT prints out time-step and pumping-period information, and the maximum head changes per iteration. Then, for each aquifer (beginning with the lowermost) subroutine MASBAL is called. Mass balance information, freshwater and saltwater heads, interface elevations and a map showing the extent of intrusion will then be printed as specified by the user. An output value of 11111. indicates a null value. For example, if the freshwater head at a block has a value of 11111., there is no freshwater present in that block. For other time steps, OUTPUT is called only to print time-step information and to evaluate the mass balance for the aquifers of the system. Control is then returned to MAIN.

Subroutine MASBAL

Subroutine MASBAL is called from OUTPUT to calculate time-step and cumulative freshwater and saltwater aquifer mass balances. Freshwater and saltwater flows into and out of each layer through constant freshwater head nodes, constant saltwater head nodes, recharge, pumpage and leakage are calculated. For an accurate solution, the difference between the influx and outflux should equal the change in storage. Any deviation represents an error in the solution and is reported as a percent error relative to the total influx and the change in storage. All time-step values are expressed as a volume rate and cumulative values are expressed as total volumes.

PRACTICAL CONSIDERATIONS FOR MODEL APPLICATION

Array Dimensions

The dimensions of the arrays in the program are specified in a PARAMETER statement at the beginning of each subroutine. the values of NR, NC, and NL specified in the PARAMETER statement must be equal to the values of NNR, NNC, and NNL specified in the input. For example, for a problem with 20 row, 25 columns, and 3 layers the PARAMETER statement in each subroutine must be modified to look like this:

```
PARAMETER(NR=20,NC=25,NL=3).
```

The arrays TIME, FWH, SWH, ZI, FAR, SAR, and IC store the values of time, freshwater head, saltwater head, interface elevation, FAREA, SAREA, and F, M, S code values for each time step at the user specified observation nodes. These arrays are dimensioned to allow for 10 observation nodes and 200 time steps. This may be changed by the user to accomodate problem requirements.

As the model is currently dimensioned, the maximum number of freshwater constant head nodes allowed is 200, as is the maximum number of constant saltwater heads allowed. To increase this, the dimensions of the arrays FFLOW, SFLOW, IFL, JFL, ISL, and JSL must be increased. The maximum number of iterations allowed in the model is 200. If more iterations are needed, the arrays DMAXF and DMAXS must be made larger.

As a measure of required storage, example problem one (see below), which has 28 rows, 8 columns, and 1 layer requires approximately 215 kilobytes of memory.

Input/Output File Units

The file unit numbers used for input and output are specified in the array IUN. The model has default settings for the elements of IUN which are listed in table 5. They are specified in the data statement on line MA 410 of the MAIN program. By default, all input parameters are read from unit 5 and aquifer parameters are specified layer by layer starting from the bottom up. The basic model input parameters and general output are written to the output file on unit 6. The values of the PHIF, ZINT, FX, FY, SX, and SY matrices for each layer are written to file unit 7 in a format that is ready to be used for input. These arrays can then be inserted into the input file to initialize a continuation run. The heads at the user-specified observation blocks are written to file unit 8 and the leakages at each block are written to file unit 9. If the option to open files internally within the program is used, these default file units take the names INPUT, OUTPUT, RESULTS, HEADS, and LEAK, respectively. If the default unit numbers are not used, the data statement on line MA 410 must be modified to reflect the user's input/output file unit number. If the option to open files internally is used, the program must be modified to open the appropriate files (line MA440 to MA500 and MA2550 to MA2610). This allows user flexibility in terms of how input and output is structured. It is possible to set up input so that input files are grouped according to the input

Table 5.--Default input/output file unit numbers.

IUN(i)	Default Input File Unit Number & Name		Data Set
1	5	INPUT	General Information
2	5	INPUT	FKX
3	5	INPUT	FKY
4	5	INPUT	STORF
5	5	INPUT	STORS
6	5	INPUT	POR
7	5	INPUT	THCK
8	5	INPUT	ZBOT
9	5	INPUT	PHIF (initial values)
10	5	INPUT	ZINT (initial values)
11	5	INPUT	FX (initial values)
12	5	INPUT	FY (initial values)
13	5	INPUT	SX (initial values)
14	5	INPUT	SY (initial values)
15	5	INPUT	AQL
16	5	INPUT	HEAD
17	5	INPUT	BATH
18	5	INPUT	IWT
19	5	INPUT	DX
20	5	INPUT	DY
21	5	INPUT	Time Step and Well Information
22	5	INPUT	RECH
IUN(i)	**Default Output Unit**		**Data Set**
23	6	OUTPUT	Input Data
24	6	OUTPUT	Time Step Results
25	7	RESULTS	PHIF (last values)
26	7	RESULTS	ZINT (last values)
27	7	RESULTS	FX (last values)
28	7	RESULTS	FY (last values)
29	7	RESULTS	SX (last values)
30	7	RESULTS	SY (last values)
31	8	HEADS	Observation Node Heads
32	9	LEAK	Block Leakages

parameters. For example, conductivities for all layers could be in one input file, heads for all layers could be in another input file, and so on.

User Specified Input/Output Options

Model input can be in any consistent set of units with time in seconds. All elevations must be relative to sea level. The input/output control options for the model are specified in the array IOP. The model has default settings for the elements of IOP, which are set in the data statement on line MA 420 of the MAIN program. The default values, and an explanation of the options are listed in table 6. If NOPT=0, these default values are used. If NOPT=1, the user must specify the values for IOP(2) through IOP(12). IOP(1) controls whether the input/output file units are opened internally within the program using OPEN statements, or if they are opened prior to execution of the program. By default the model opens file units internally (IOP(1)=0). If the user wishes to open files externally (IOP(1)=1), line MA 420 must be replaced with line MA 424.

Initial Conditions

The amount of input information needed to specify initial conditions depends on the type of simulation. Model runs may be initialized in two manners, as a new run (NCONT=0) or as a continuation run (NCONT=1). In all cases, initial saltwater heads are calculated by the model based on initial freshwater head and interface elevation. A continuation run could be a transient simulation initialized using a previously obtained steady-state solution, or a run which is a continuation of a previous transient simulation. In a new run, no information regarding the interface projection factors is needed. In a continuation run, the projection factors obtained from the previous simulation, as well as freshwater heads and interface elevations, must be included in the input.

New runs may be initialized in two different manners. If NINT=0, initial freshwater heads and initial interface elevations must be specified and are used to calculate initial saltwater heads. If NINT=1, only initial freshwater heads are needed and initial interface elevations are calculated as $\zeta_1 = -\delta \Phi_f$ (the Ghyben-Herzberg equilibrium interface). The resulting initial saltwater heads will be zero. It is important that initial saltwater heads be zero, even in blocks not containing saltwater.

For continuation runs, the model output from the previous simulation, which is contained in file units IUN(25) to IUN(30), must be used as the initial values of freshwater head, interface elevation, and interface projection factors (FX, FY, SX, and SY). The new starting time of the simulation in seconds (TSEC) must be specified in the input file.

Problems may arise later with interface projection and movement if initial values are not properly specified. When initializing new runs, it is advisable to use values of head and interface elevation that result in saltwater heads close to zero (even in blocks where saltwater is not present). It is important to keep in mind that the initial values of

Table 6.--Input/output options specified in array IOP (default values are used when NOPT=0, non-default options must be input by the user if NOPT=1)

IOP(i)	Option	Default Value
1	0 = Open files internally	0
	1 = Open file externally	
2	0 = Do not print input aquifer parameters	1
	1 = Print input aquifer parameters	
3	0 = Do not print input pumping and recharge values	1
	1 = Print input pumping and recharge values	
4	0 = Do not print time-step freshwater heads	1
	1 = Print time-step freshwater heads	
5	0 = Do not print time-step saltwater heads	1
	1 = Print time-step saltwater heads	
6	0 = Do not print time-step interface elevations	1
	1 = Print time-step saltwater heads	
7	0 = Do not print time-step FAREA values	0
	1 = Print time-step FAREA values	
8	0 = Do not print time-step SAREA values	0
	1 = Print time-step SAREA values	
9	0 = Do not print time-step F-M-S map	1
	1 = Print time-step F-M-S map	
10	0 = Do not print time-step block leakage values	1
	1 = Print time-step block leakage values	
11	0 = Do not write iteration information to screen	0
	1 = Write iteration information to screen	
12	0 = Write latest time-step results to file	0
	1 = Write time-step results to file every NP time-steps	

freshwater head and interface elevation will determine the initial distribution of freshwater and saltwater in the aquifers. If a problem is initialized with isolated pockets of saltwater in the freshwater zone, or conversely, these pockets will remain as there will be no outlet for that water. To avoid problems, check the initial freshwater and saltwater distribution by running the model for one very small time step (such as one second). Pockets of freshwater or saltwater can be removed by adjusting the initial heads and interface elevations.

Another consideration when specifying initial conditions is the initial position of the interface. If the interface is initialized to a very unstable position (for example a vertical interface), computational instabilities could arise.

Boundary Conditions

The model can simulate freshwater and saltwater constant flux (no-flow or prescribed flux), constant head, and head-dependent leaky boundaries. No-flow boundaries are specified using inactive nodes. Inactive nodes within the grid must be assigned an x-direction freshwater hydraulic conductivity (FKX) of zero. During model calculations, FKY will be set to zero at these blocks. In this manner, the harmonic mean of the conductivities at these boundaries is zero. The outer boundaries of each layer must have a row (or column) of nodes with FKX=0, preventing inflow or outflow from the system. Constant fluxes into or out of a block can be prescribed in two manners. At unconfined blocks in the uppermost aquifer, constant flux can be specified by the recharge matrix (RECH, L/T). At confined blocks in the upper aquifer, recharge is zeroed out. Otherwise, for all layers, the pumpage matrix (PUMP, L^3/T) can be used to specify a constant flux. A positive pumpage value represents extraction of water from a block and a negative value represents addition of water to the block.

A constant freshwater head block is specified by assigning a negative specific storage to that location in the matrix STORF. This is a flag indicating that the block should be handled as a constant head block with the head fixed to the initial value specified in PHIF. Likewise, a constant saltwater head block is specified by assigning a negative saltwater specific storage in STORS. In the model, initial saltwater heads are calculated from initial freshwater heads and interface elevations. Therefore, at constant saltwater head nodes, the initial freshwater head and interface elevations must be specified so as to give the desired saltwater head, where:

$$\Phi_s = \frac{\zeta_1 + \delta\Phi_f}{(1+\delta)} \qquad \text{(from equation (9)).}$$

The saltwater head will then remain fixed at its initial value for the duration of the simulation, although freshwater head and interface location at this node may change. Fixing both freshwater and saltwater head at a node also fixes the interface position in that node.

The leaky, head-dependent boundary condition can be used to represent boundaries such as streams, springs, or offshore outcrop areas. The flux at head-dependent boundaries is calculated as follows:

flux = leakance (fixed head value - head in aquifer block).

The leakance and fixed head value are specified by the user. The head in the aquifer is calculated in the model solution. Thus, as the head in the aquifer changes, the flux across the boundary changes. The leakance value at the node can be adjusted to obtain the desired interaction between the aquifer and the fixed head node. In the uppermost aquifer, a head-dependent boundary is specified by assigning the fixed value of head to the HEAD matrix, and assigning a vertical leakance to the block in the AQL matrix. At unconfined nodes the flux will be zeroed out, and therefore, to use this type of boundary condition in a block it must be specified as a confined block. If this type of boundary is used offshore, the fixed head value must be the freshwater head equivalent to the overlying column of saltwater:

$$\Phi_f = -Z/\delta ,$$

where:

Z = the bathymetry or elevation of the ocean floor relative to sea level.

In the underlying layers, this same type of boundary condition can be achieved if a leakance is specified and the head in the overlying aquifer block is fixed. This can be done by giving the overlying block a constant head. Another way to handle this, if the overlying block is not part of the active region of the overlying aquifer, is to initialize the freshwater head at the overlying inactive block to be the required fixed value. In this case, the head in the overlying inactive block remains constant throught the simulation and is used only for leakage calculations at this boundary. At offshore blocks where the bathymetry is less than zero, the water in the overlying inactive block is assumed to be saltwater. If the leakance at a head-dependent boundary block is sufficiently large, the block will act as a constant head block with a head equal to the overlying fixed head value.

Steady-State Simulations

Steady-state simulations can only be obtained by running a transient simulation until it achieves steady state. This is because the interface position must be allowed to move gradually as steady state is approached. Generally, the interface responds quite slowly; however, the approach to steady state can be accelerated in several ways. First, the initial conditions should be set close to the expected steady-state solution. The specific storage of the aquifers should be very small or zero to eliminate elastic storage terms from equations (18a and b). In addition, the movement of the interface can be accelerated by using a very small porosity (as small as .0001). In this manner, the interface storage terms in equations (18a and b) become small, and less water must be moved as the interface changes position. Care must be taken when choosing the porosity, because choosing too small a value will cause the the interface to move too rapidly leading to instability in the solution. In such cases a larger porosity value can be used to get a solution close to steady state, and then a much smaller porosity can be used to continue the simulation. The steady-state solution is not a function of specific storage or porosity; however, transient solutions are. After obtaining the steady-state solution, the values of specific storage and porosity must be set to their true values for subsequent transient simulations.

Notes on Discretization

Caution should be exercised in choosing both the spatial and temporal discretization. The model is quite sensitive to time-step size. If time steps are too large compared with the rate of interface movement, the solution will become unstable due to too much adjustment of the interface per time step. Also, to obtain accurate interface projections, it is advisable to use smaller blocks in the zone of the interface. Where the interface is present in only one block, the projection of the tip and toe becomes less accurate. If the interface tip or toe oscillates at a block boundary, smaller block sizes or smaller time steps may be needed to stabilize the solution.

Notes on Parameters RFAC, WITER, WFAC, and NUP

The model contains several parameters that are problem dependent and must be adjusted by the user to obtain the most stable solution. For a given case, successive simulations varying these parameters will indicate the best values for the most rapid convergence. The use of these parameters, RFAC, WITER, WFAC, and NUP, is explained below.

An iterative solution technique (SIP) is used in the model. The parameters WITER and RFAC can be adjusted to optimize the convergence of the solution algorithm. WITER is a factor used in the calculation of the iteration parameters (see section on convergence of SIP):

$$1-\omega_m = [\mathrm{WITER} * (1-\omega_{max})]^{m/(M-1)} . \qquad (45)$$

In problems with considerable anisotropy in hydraulic conductivity or block dimensions (for example $\Delta x >> \Delta y$), the parameters calculated using the above algorithnm will tend to be clustered near the upper limit of 1. Generally it is best to use a sequence of iteration parameters with a spread between 0 and 1. If WITER=1 yields clustered iteration parameters, WITER should be increased to a value greater than 1 (for some extreme cases it may be necessary to use a value of one hundred or larger).

RFAC is a relaxation factor used in the iterative solution of the equations (see section on convergence of SIP). As the equations are highly nonlinear (especially for multilayered systems with considerable leakage), problems of overshoot and oscillation may arise. To dampen out these effects, a relaxation factor less than one can be implemented.

Another cause of solution instability is oscillation in the interface tip and toe projections. The parameters WFAC and NUP are used to control this. WFAC is a weighting factor used to calculate the interface projections based on the projections from the previous and current iterations as given in equation 30:

$$xl = WFAC*xl_{new} + (1-WFAC)*xl_{old}. \qquad (30)$$

Generally, a WFAC of 0.5 gives the smoothest solution.

The above parameters can be adjusted through a trial and error process to achieve the best solution and convergence. However, for some systems the solution will still show small oscillations. The solution will almost converge and then continue to oscillate or hover about the correct solution. This is generally caused by small oscillations in the interface tip and toe positions. The parameter NUP is used to control these oscillations. The interface position is fixed after NUP iterations, and the interface elevations are not updated in following iterations. Care must be taken not to fix the interface too early during the iterative solution. If head changes are still large when the interface is fixed, the solution will not be correct. Generally, this parameter should be made large enough so that it is reached only for time steps in which there is oscillation. For example, a value of NUP equal to 20 is appropriate if most time steps converge in less than 20 iterations. For time steps which take more than 20 iterations, the maximum change in head at iteration 20 should be small (less than .001). If these criteria are not met, NUP should be increased.

Mass Balance Calculations

A mass balance is calculated for each layer in the system. Values are reported as cumulative volumes for the total duration of the simulation and rates for the time step under consideration. The mass balance error is the difference between the change in storage and the net sources minus sinks. To evaluate the significance of the error, it must be compared with the amount of flow through the system, and/or the change in storage in the system. The mass balance error is reported as a percent error relative to the amount of influx into the layer and also the change in storage in the layer. If the change in storage is small (as is the case at steady state) the relative error will tend to be large and is not a good criterion for the mass balance. Similarly, if the influx into the system is small, the error relative to the influx will not be a good criterion. At steady state, both influx and change in storage will be small in the saltwater zone, resulting in apparently large errors even when a good solution is obtained. These considerations must be kept in mind when interpreting the mass balance errors.

Influx of water into a layer by leakage is broken up into components from overlying and underlying freshwater and saltwater. When the restricted mixing option is used, the only source of water to the freshwater zone is from overlying or underlying freshwater. No saltwater can leak into the freshwater. The sources of influx by leakage to the saltwater zone are overlying and underlying saltwater, as well as underlying freshwater. When complete mixing is used, potentially all leakage components could occur (see figure 10).

The global mass balance for all layers can be obtained by summing the inflows and outflows across the boundaries of each layer. Fluxes across constant head boundaries can be taken directly from the mass balance reported for each layer. Since head-dependent boundaries are handled as leakages, fluxes across these boundaries are lumped with the fluxes reported as leakage across the top of each aquifer. The actual values at each head-dependent block can be obtained from the values reported in file unit IUN(32) (LEAK file).

Leakage Conditions

As described earlier, two methods can be used for leakage calculations. The choice of method is important for multilayered problems. In method 1 or complete mixing (NLK=1), it is assumed that the amount of freshwater leaking into saltwater (or conversely) is small and that it mixes instantaneously and becomes part of the saltwater domain. However, in systems with considerable vertical flow and leakage, this assumption may not be valid. For these cases, a second method of handling leakage calculations, restricted mixing, is available (NLK=0). In this method, the mixing of freshwater and saltwater is restricted. Saltwater is not allowed to leak into freshwater, and leakage of freshwater is distributed between the overlying freshwater and saltwater zones based on the amount of freshwater in the overlying block. The decision of which method to use is problem dependent. Method 1 gives the most conservative position of the interface, because the freshwater leaking into saltwater is fully incorporated into the saltwater domain. The interface position predicted by this method is farther inland than that predicted by method 2 (restricted mixing). If the position of the interface seems to be too far inland, and if it displays erratic movement during transient runs, method 2 leakage conditions should be used.

For both leakage methods, the water overlying offshore outcrops is assumed to be saltwater. These outcrops are identified by a bathymetry less than zero for the uppermost layer, and in addiiton, an overlying inactive block for the deeper layers. When using complete mixing (method 1), leakage across the upper confining layer in the offshore area must be examined closely to see if there is downward leakage of saltwater into a freshwater zone. This would be a potential source of water quality degradation that would not appear as inland movement of the interface. Similarly, when using method 1, leakage between layers must be monitored to see if there is leakage of saltwater into a freshwater zone.

EXAMPLE PROBLEMS

Two example problems are presented below. The first is an areal single layer model of part of the southeastern coast of Oahu, Hawaii. The second is the cross-section layered problem for Cape May, New Jersey, described in the model verification section.

Example 1: Single Layer Model of Southeastern Oahu

The Hawaiian island of Oahu, which is underlain by an extensive freshwater lens, was built by the growth of two volcanoes which eventually joined and overlapped to form one island (Stearns, 1946). The thick sequence of thin bedded basaltic lava flows forms the principal aquifer in which freshwater floats on top of saltwater (Visher and Mink, 1964; Takasaki and Mink, 1982). In its inland area the ground water is unconfined, but toward the coast the ground water is confined by a caprock of reef and marine sedimentary deposits. The seaward flow of freshwater is impeded by the caprock, allowing inland freshwater heads to build up and a thicker freshwater lens to develop. Discharge from the freshwater lens takes place either by springs which occur at the landward edge of the caprock or by upward leakage through the caprock.

In this example a part of the Oahu coast has been simulated as a semiconfined aquifer with a free bottom (see fig 1B). The lava flows are treated as a single model layer which is unconfined inland, but confined near the shore and offshore by the caprock (fig. 22). The modeled area extends about 20 miles offshore to capture the offshore boundary condition. Variable grid spacing is used to extend the model to this distance, as well as to allow for finer discretization near the coast. The area is bounded laterally by relatively impermeable dikes. Variable x-direction grid spacing is used to accurately locate the right-hand-boundary dike. The simulated grid is 28 rows by 8 columns. There is one pumping well at 13,4,1, and recharge is specified at the inland unconfined blocks. The lateral and bottom boundaries are no-flow, and in the areas covered by the caprock, a head-dependent boundary is used with equivalent freshwater heads specified for the offshore areas. This specifies the boundary conditions for both the freshwater and saltwater flow domains and allows leakage of freshwater through the caprock to the sea.

The simulation is initiated as a new run with the model calculating the initial interface elevations from the Ghyben-Herzberg relation. A small storage coefficient and a small porosity (0.0001) are used to accelerate the approach to the steady-state solution. The default input/output options are used, and method 1 leakage is specified. The simulation input and output files are given in tables 7 and 8, respectively. A relaxation factor of 0.8, an interface weighting factor of 0.5, and an iteration parameter weighting factor of 1.0 are used for this simulation. The maximum number of iterations allowed per time step is 60, and the interface position is fixed after 50 (NUP) iterations. During the first two time steps, the solution does not converge within 50 iterations, causing the interface position to be fixed. However, in subsequent time steps the solution converges in less that 50 iterations and no interface fixing takes place.

The change in freshwater and saltwater head from time step 4 to time step 5 is less than the steady-state criterion (0.000001), and the output for the steady-state solution is given. It is important to confirm that a true steady-state solution has been obtained by checking the mass balance and the saltwater heads. At steady state the change in storage, which includes elastic storage and interface storage, should be close to zero. Also, the saltwater heads should be close to zero unless there are zones where there is freshwater leakage into saltwater. Both of these conditions are satisfied in this simulation.

As discussed in the practical considerations section, the mass balance error is expressed as a percentage relative to total influx and change in storage. The freshwater mass balance indicates that 8.979 ft^3/s of freshwater water enters the system as recharge. One ft^3/s of freshwater is pumped out of the aquifer, and 7.979 ft^3/s leaves the aquifer by leakage across the top of the aquifer (leakage through the caprock to the sea). The freshwater mass balance error relative to total influx is very small (3.4×10^{-6} percent), indicating an accurate solution. The error relative to change in storage appears to be large because at steady-state the change in storage is very small. There is no saltwater influx to the system, and therefore no saltwater mass balance error relative to influx is reported. As in the case of freshwater, the error relative to change in storage is large. This example illustrates that the user must interpret the mass balance carefully.

Default output options are used in this example resulting in the output of freshwater and saltwater heads, interface elevations, and a map of block codes (F, M, S). Values reported as 11111. indicate absence of the attribute at that block. For example, a freshwater head of 11111. indicates that there is no freshwater in the block.

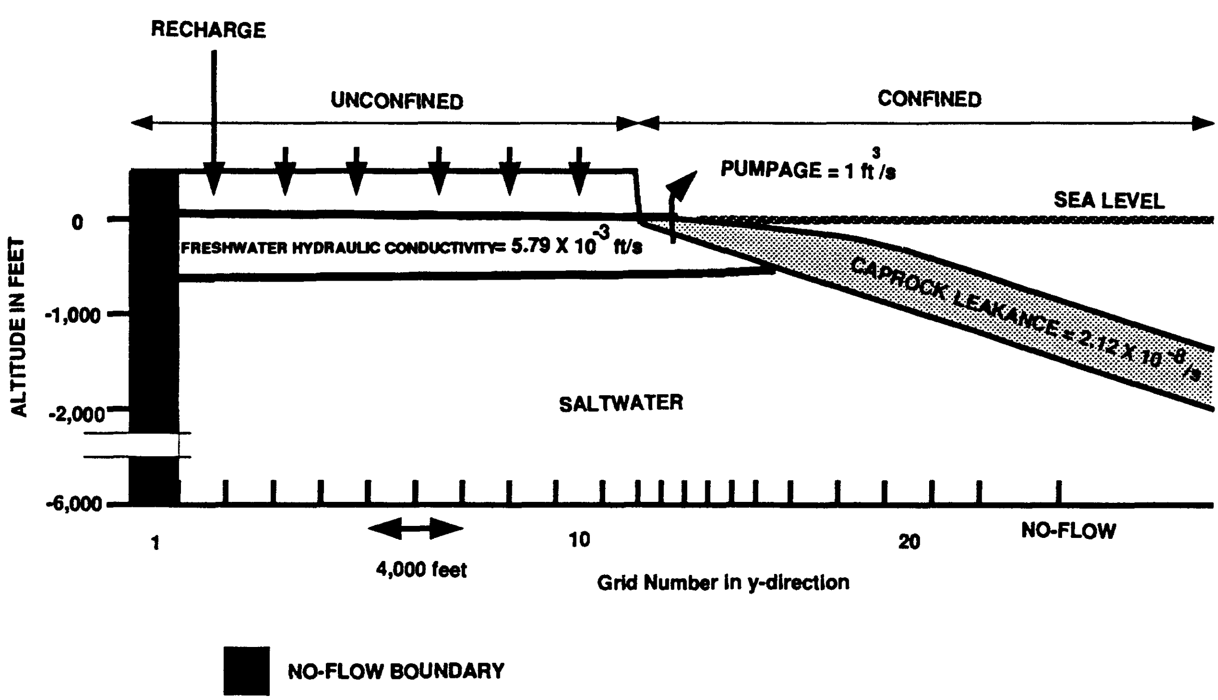

Figure 22.--Southeast Oahu simulation:
A. cross-section showing model geometry.

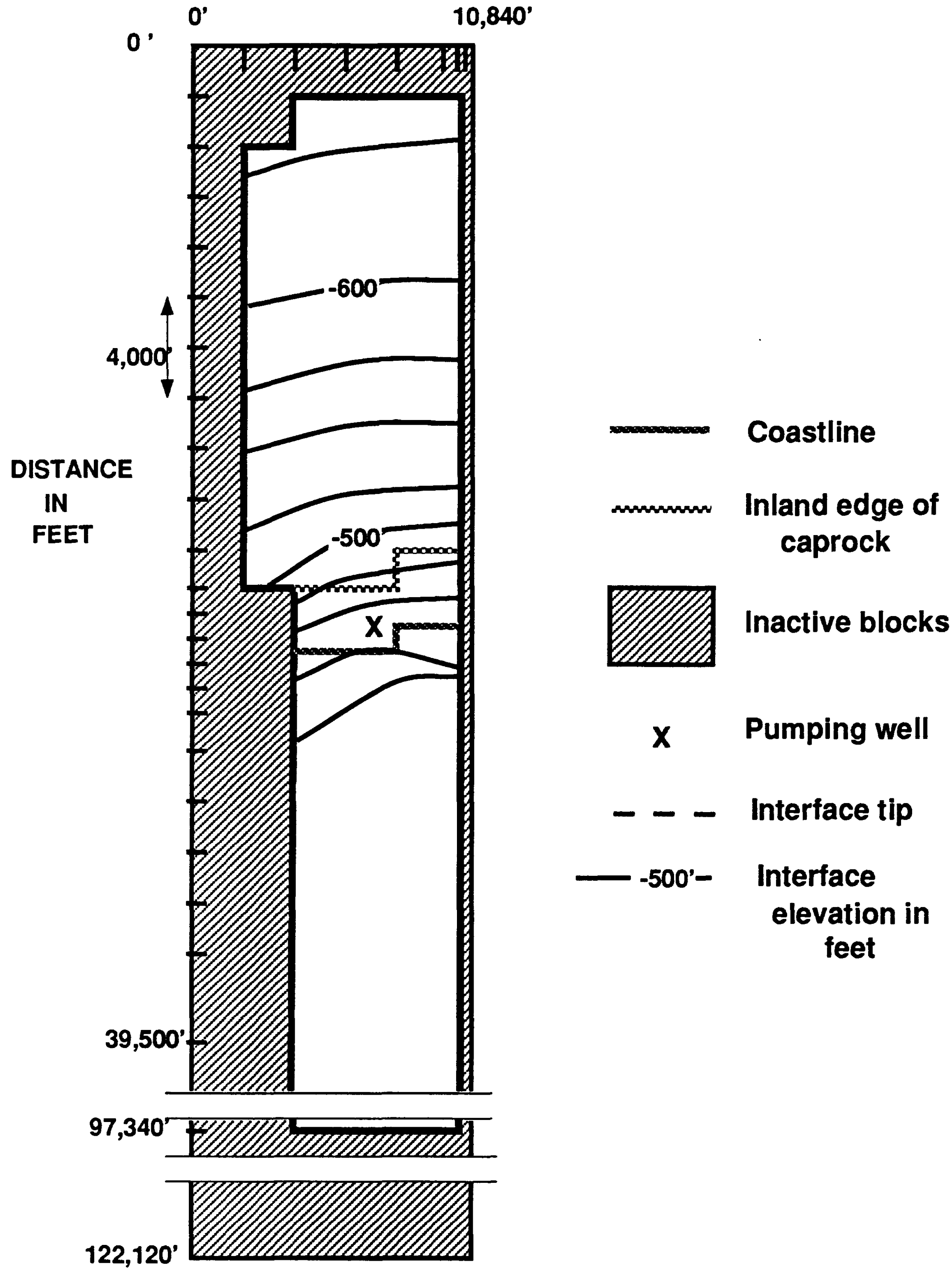

Figure 22.--Southeast Oahu simulation--continued:
B. map view showing steady-state interface elevation.

Table 7.--Input file for example 1

```
AREAL MODEL OF SE OAHU
   28    8    1   10   60    6    1    1   50    0    0
 0.100E-05 0.100E-05       0.80       0.5       1.0   62.4100  63.97025  2.09E-05  2.09E-05
    0       0.0                1  NEW RUN SIMULATION
   10    4    1                   LOCATION OF OBSERVATION BLOCK
    0 0.100E-02                   FKX
  0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
    1 5.790E-03                   FKY
    1 1.E-09                      STORF
    1 1.E-09                      STORS
    1 0.0001                      POR
    0  1.00                       THCK
 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
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 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.600E+04 0.600E+04 0.600E+04 0.590E+04
```

Table 7.--Input file for example 1--continued

```
 0.650E+04 0.650E+04 0.600E+04 0.600E+04 0.600E+04 0.600E+04 0.600E+04 0.590E+04
 0.650E+04 0.650E+04 0.600E+04 0.600E+04 0.590E+04 0.590E+04 0.590E+04 0.573E+04
 0.650E+04 0.650E+04 0.591E+04 0.591E+04 0.581E+04 0.581E+04 0.581E+04 0.590E+04
 0.650E+04 0.650E+04 0.582E+04 0.582E+04 0.572E+04 0.572E+04 0.572E+04 0.550E+04
 0.650E+04 0.650E+04 0.573E+04 0.573E+04 0.563E+04 0.563E+04 0.563E+04 0.590E+04
 0.650E+04 0.650E+04 0.562E+04 0.562E+04 0.552E+04 0.552E+04 0.552E+04 0.540E+04
 0.650E+04 0.650E+04 0.546E+04 0.546E+04 0.536E+04 0.536E+04 0.536E+04 0.510E+04
 0.650E+04 0.650E+04 0.528E+04 0.528E+04 0.518E+04 0.518E+04 0.518E+04 0.480E+04
 0.650E+04 0.650E+04 0.510E+04 0.510E+04 0.500E+04 0.500E+04 0.500E+04 0.465E+04
 0.650E+04 0.650E+04 0.492E+04 0.492E+04 0.482E+04 0.482E+04 0.482E+04 0.450E+04
 0.650E+04 0.650E+04 0.471E+04 0.471E+04 0.460E+04 0.460E+04 0.460E+04 0.420E+04
 0.650E+04 0.650E+04 0.423E+04 0.423E+04 0.412E+04 0.412E+04 0.412E+04 0.350E+04
 0.650E+04 0.650E+04 0.350E+04 0.350E+04 0.350E+04 0.350E+04 0.350E+04 0.350E+04
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 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
    1-0.600E+04                     ZBOT
    0  1.00                         PHIF
   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
   0.00000   0.00000  14.73666  14.72435  14.69776  14.69058  14.68993   0.00000
   0.00000  14.62849  14.64578  14.62728  14.59585  14.58804  14.58745   0.00000
   0.00000  14.47214  14.45803  14.42619  14.39189  14.38526  14.38487   0.00000
   0.00000  14.18175  14.15061  14.11768  14.08651  14.08082  14.08042   0.00000
   0.00000  13.78930  13.75558  13.72692  13.71053  13.70655  13.70611   0.00000
   0.00000  13.31096  13.29549  13.26575  13.25028  13.24609  13.24553   0.00000
   0.00000  12.79268  12.76784  12.72685  12.69833  12.69146  12.69086   0.00000
   0.00000  12.24402  12.17205  12.09534  12.03961  12.02980  12.02910   0.00000
   0.00000  11.67991  11.51296  11.36790  11.25449  11.22933  11.22824   0.00000
   0.00000  11.23644  10.76127  10.49894  10.13175  10.07038  10.06757   0.00000
   0.00000   0.00000  10.13260   9.96250   9.80279   9.76959   9.76798   0.00000
   0.00000   0.00000   9.50360   9.42700   9.47479   9.46919   9.46888   0.00000
   0.00000   0.00000   9.31360   9.30150   9.47479   9.46919   9.46888   0.00000
   0.00000   0.00000   9.12149   9.17606   9.50000   9.50000   9.50000   0.00000
   0.00000   0.00000   9.12149   9.17606   9.25000   9.25000   9.25000   0.00000
   0.00000   0.00000   9.53750   9.52750   9.00000   9.00000   9.00000   0.00000
   0.00000   0.00000   9.00000   9.00000   9.00000   9.00000   9.00000   0.00000
   0.00000   0.00000   8.50000   8.50000   8.50000   8.50000   8.50000   0.00000
   0.00000   0.00000   8.00000   8.00000   8.00000   8.00000   8.00000   0.00000
   0.00000   0.00000   7.50000   7.50000   7.50000   7.50000   7.50000   0.00000
   0.00000   0.00000   7.00000   7.00000   7.00000   7.00000   7.00000   0.00000
   0.00000   0.00000   6.50000   6.50000   6.50000   6.50000   6.50000   0.00000
   0.00000   0.00000   6.00000   6.00000   6.00000   6.00000   6.00000   0.00000
   0.00000   0.00000   5.50000   5.50000   5.50000   5.50000   5.50000   0.00000
   0.00000   0.00000   5.00000   5.00000   5.00000   5.00000   5.00000   0.00000
   0.00000   0.00000   4.50000   4.50000   4.50000   4.50000   4.50000   0.00000
   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
    1 2.12E-08                         AQL
```

Table 7.--Input file for example 1--continued

```
  0    1.000                  HEAD
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     1.25     1.25     1.25     0.00
    0.00     0.00     1.25     1.25     3.75     3.75     3.75     0.00
    0.00     0.00     1.50     1.50     4.00     4.00     4.00     0.00
    0.00     0.00     1.75     1.75     4.25     4.25     4.25     0.00
    0.00     0.00     2.00     2.00     4.50     4.50     4.50     0.00
    0.00     0.00     3.50     3.50     6.00     6.00     6.00     0.00
    0.00     0.00     5.50     5.50     8.00     8.00     8.00     0.00
    0.00     0.00     7.50     7.50    10.00    10.00    10.00     0.00
    0.00     0.00    12.00    12.00    14.50    14.50    14.50     0.00
    0.00     0.00    17.25    17.25    20.00    20.00    20.00     0.00
    0.00     0.00    29.25    29.25    32.00    32.00    32.00     0.00
    0.00     0.00    47.50    47.50    47.50    47.50    47.50     0.00
    0.00     0.00    47.50    47.50    47.50    47.50    47.50     0.00
    0.00     0.00    47.50    47.50    47.50    47.50    47.50     0.00
    0.00     0.00    47.50    47.50    47.50    47.50    47.50     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
  0    1.000                  BATH
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    0.00     0.00     0.00     0.00     -50.     -50.     -50.     0.00
    0.00     0.00     -50.     -50.    -150.    -150.    -150.     0.00
    0.00     0.00     -60.     -60.    -160.    -160.    -160.     0.00
    0.00     0.00     -70.     -70.    -170.    -170.    -170.     0.00
    0.00     0.00     -80.     -80.    -180.    -180.    -180.     0.00
    0.00     0.00    -140.    -140.    -240.    -240.    -240.     0.00
    0.00     0.00    -220.    -220.    -320.    -320.    -320.     0.00
    0.00     0.00    -300.    -300.    -400.    -400.    -400.     0.00
    0.00     0.00    -480.    -480.    -580.    -580.    -580.     0.00
```

Table 7.--Input file for example 1--continued

```
     0.00       0.00      -690.      -690.      -800.      -800.      -800.       0.00
     0.00       0.00     -1170.     -1170.     -1280.     -1280.     -1280.       0.00
     0.00       0.00     -1900.     -1900.     -1900.     -1900.     -1900.       0.00
     0.00       0.00     -1900.     -1900.     -1900.     -1900.     -1900.       0.00
     0.00       0.00     -1900.     -1900.     -1900.     -1900.     -1900.       0.00
     0.00       0.00     -1900.     -1900.     -1900.     -1900.     -1900.       0.00
     0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
    1    1    1    1    1    1    1    1                   IWT
    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1
    1    1    1    1    1    1    1    1
    1    1    1    1    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0
 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.600E+03 0.120E+03 0.120E+03                      DX
 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04   DY
 0.150E+04 0.100E+04 0.100E+04 0.100E+04 0.100E+04 0.100E+04 0.150E+04 0.200E+04 0.200E+04 0.200E+04
 0.200E+04 0.350E+04 0.675E+041.0125E+041.6187E+042.4780E+042.4780E+042.4780E+04
 15778800.        1.     20454.   10    1                 PUMPING PERIOD INFO
   13    4    1     1.000      -280.      -290.            PUMPING WELL INFO
    0 0.100E-06               RECH
 0.100      0.100      0.100      0.100      0.100      0.100      0.100      0.100
 0.100      0.100      0.900      0.970      0.750      0.676      0.360      0.360
 0.100      1.200      1.140      1.000      0.700      0.600      0.380      0.330
 0.100      1.240      1.140      0.900      0.620      0.600      0.520      0.270
 0.100      1.050      0.676      0.600      0.333      0.333      0.203      0.203
 0.100      0.865      0.380      0.365      0.497      0.497      0.267      0.340
 0.100      0.290      0.500      0.350      0.497      0.497      0.184      0.184
 0.100      0.250      0.450      0.400      0.450      0.404      0.163      0.132
 0.100      0.450      0.254      0.260      0.300      0.404      0.212      0.059
```

Table 7.--Input file for example 1--continued

0.100	0.160	0.172	0.350	0.300	0.151	0.212	0.212
0.100	0.086	0.151	0.151	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100

Table 8.--Output file for example 1

```
----------------------------------------------------------------------------
    AREAL MODEL OF SE OAHU
----------------------------------------------------------------------------

NUMBER OF ROWS=  28
NUMBER OF COLUMNS=   8
NUMBER OF  AQUIFERS=   1
NUMBER OF TIME STEPS BETWEEN PRINTOUT=  10
MAXIMUM NUMBER OF ITERATIONS=  60
NUMBER OF ITERATION PARAMETERS=   6
NUMBER OF PUMPING PERIODS=   1
INTERFACE FIXED AFTER   50 ITERATIONS
INPUT/OUTPUT OPTIONS' PARAMETER=   0 (0=USE DEFAULTS, 1=READ IN OPTIONS ARRAY)
LEAKAGE OPTION PARAMETER=   0 (0=RESTRICTED MIXING, 1=COMPLETE MIXING)

CONVERGENCE CRITERION= 0.1000E-05
STEADY STATE CRITERION= 0.1000E-05
RELAXATION FACTOR= 0.8000
WEIGHTING FACTOR= 0.5000
ITERATION PARAMETER FACTOR=  1.000
SPECIFIC GRAVITY OF FRESHWATER=  62.41
SPECIFIC GRAVITY OF SALTWATER=  63.97
VISCOSITY OF FRESHWATER= 0.2090E-04
VISCOSITY OF SALTWATER= 0.2090E-04


NEW RUN
   INTERFACE ELEVATIONS INITIALIZED TO -DEL*PHIF

LOCATIONS OF    1 OBSERVATION NODES TRACKED:
  10    4    1

SPECIFIED INPUT/OUTPUT OPTIONS:

   1: 1=PRINT INPUT AQUIFER PARAMETERS, 0=DO NOT PRINT
   1: 1=PRINT INPUT PUMPING PERIOD WELL AND RECHARGE DATA, 0=DO NOT PRINT
   1: 1=PRINT CALCULATED FRESHWATER HEADS, 0=DO NOT PRINT
   1: 1=PRINT CALCULATED SALTWATER HEADS, 0=DO NOT PRINT
   1: 1=PRINT CALCULATED INTERFACE ELEVATIONS, 0=DO NOT PRINT
   0: 1=PRINT CALCULATED FAREA FACTORS, 0=DO NOT PRINT
   0: 1=PRINT CALCULATED SAREA FACTORS, 0=DO NOT PRINT
   1: 1=PRINT F-M-S MAP, 0=DO NOT PRINT
   1: 1=WRITE BLOCK LEAKAGE VALUES TO FILE, 0=DO NOT WRITE TO FILE
   0: 1=PRINT ITERATION INFORMATION TO SCREEN, 0=DO NOT PRINT
   0: 0=REWRITE LATEST RESULTS TO FILE AFTER EACH TIME STEP,
      1=WRITE RESULTS TO FILE EVERY NP TIME STEPS
```

Table 8.--Output file for example 1--continued

AQUIFER PARAMETERS FOR LAYER 1

HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
3	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
4	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
5	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
6	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
7	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
8	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
9	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
10	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
11	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
12	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
13	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
14	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
15	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
16	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
17	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
18	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
19	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
20	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
21	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
	.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
	000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
	00	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
26	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
27	0.0000	0.0000	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.5790E-02	0.0000
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION

0.5790E-02

FRESHWATER SPECIFIC STORAGE

0.1000E-08

SALTWATER SPECIFIC STORAGE

0.1000E-08

EFFECTIVE POROSITY

0.1000E-03

Table 8.--Output file for example 1--continued

AQUIFER THICKNESS

1	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
2	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
3	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
4	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
5	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
6	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
7	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
8	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
9	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
10	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.
11	6500.	6500.	6500.	6500.	6000.	6000.	6000.	5900.
12	6500.	6500.	6000.	6000.	6000.	6000.	6000.	5900.
13	6500.	6500.	6000.	6000.	5900.	5900.	5900.	5730.
14	6500.	6500.	5910.	5910.	5810.	5810.	5810.	5900.
15	6500.	6500.	5820.	5820.	5720.	5720.	5720.	5500.
16	6500.	6500.	5730.	5730.	5630.	5630.	5630.	5900.
17	6500.	6500.	5620.	5620.	5520.	5520.	5520.	5400.
18	6500.	6500.	5460.	5460.	5360.	5360.	5360.	5100.
19	6500.	6500.	5280.	5280.	5180.	5180.	5180.	4800.
20	6500.	6500.	5100.	5100.	5000.	5000.	5000.	4650.
21	6500.	6500.	4920.	4920.	4820.	4820.	4820.	4500.
22	6500.	6500.	4710.	4710.	4600.	4600.	4600.	4200.
23	6500.	6500.	4230.	4230.	4120.	4120.	4120.	3500.
24	6500.	6500.	3500.	3500.	3500.	3500.	3500.	3500.
25	6500.	6500.	3500.	3500.	3500.	3500.	3500.	3500.
26	6500.	6500.	3500.	3500.	3500.	3500.	3500.	3500.
27	6500.	6500.	3500.	3500.	3500.	3500.	3500.	3500.
28	6500.	6500.	6500.	6500.	6500.	6500.	6500.	6500.

ELEVATION OF BASE OF AQUIFER

-6000.

INITIAL FRESHWATER HEAD

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	14.74	14.72	14.70	14.69	14.69	0.0000
3	0.0000	14.63	14.65	14.63	14.60	14.59	14.59	0.0000
4	0.0000	14.47	14.46	14.43	14.39	14.39	14.38	0.0000
5	0.0000	14.18	14.15	14.12	14.09	14.08	14.08	0.0000
6	0.0000	13.79	13.76	13.73	13.71	13.71	13.71	0.0000
7	0.0000	13.31	13.30	13.27	13.25	13.25	13.25	0.0000
8	0.0000	12.79	12.77	12.73	12.70	12.69	12.69	0.0000
9	0.0000	12.24	12.17	12.10	12.04	12.03	12.03	0.0000
10	0.0000	11.68	11.51	11.37	11.25	11.23	11.23	0.0000
11	0.0000	11.24	10.76	10.50	10.13	10.07	10.07	0.0000
12	0.0000	0.0000	10.13	9.962	9.803	9.770	9.768	0.0000
13	0.0000	0.0000	9.504	9.427	9.475	9.469	9.469	0.0000
14	0.0000	0.0000	9.314	9.302	9.475	9.469	9.469	0.0000
15	0.0000	0.0000	9.121	9.176	9.500	9.500	9.500	0.0000
16	0.0000	0.0000	9.121	9.176	9.250	9.250	9.250	0.0000

Table 8.--Output file for example 1--continued

17	0.0000	0.0000	9.538	9.528	9.000	9.000	9.000	0.0000
18	0.0000	0.0000	9.000	9.000	9.000	9.000	9.000	0.0000
19	0.0000	0.0000	8.500	8.500	8.500	8.500	8.500	0.0000
20	0.0000	0.0000	8.000	8.000	8.000	8.000	8.000	0.0000
21	0.0000	0.0000	7.500	7.500	7.500	7.500	7.500	0.0000
22	0.0000	0.0000	7.000	7.000	7.000	7.000	7.000	0.0000
23	0.0000	0.0000	6.500	6.500	6.500	6.500	6.500	0.0000
24	0.0000	0.0000	6.000	6.000	6.000	6.000	6.000	0.0000
25	0.0000	0.0000	5.500	5.500	5.500	5.500	5.500	0.0000
26	0.0000	0.0000	5.000	5.000	5.000	5.000	5.000	0.0000
27	0.0000	0.0000	4.500	4.500	4.500	4.500	4.500	0.0000
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

INITIAL INTERFACE ELEVATION

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	-589.5	-589.0	-587.9	-587.6	-587.6	0.0000
3	0.0000	-585.1	-585.8	-585.1	-583.8	-583.5	-583.5	0.0000
4	0.0000	-578.9	-578.3	-577.0	-575.7	-575.4	-575.4	0.0000
5	0.0000	-567.3	-566.0	-564.7	-563.5	-563.2	-563.2	0.0000
6	0.0000	-551.6	-550.2	-549.1	-548.4	-548.3	-548.2	0.0000
7	0.0000	-532.4	-531.8	-530.6	-530.0	-529.8	-529.8	0.0000
8	0.0000	-511.7	-510.7	-509.1	-507.9	-507.7	-507.6	0.0000
9	0.0000	-489.8	-486.9	-483.8	-481.6	-481.2	-481.2	0.0000
10	0.0000	-467.2	-460.5	-454.7	-450.2	-449.2	-449.1	0.0000
11	0.0000	-449.5	-430.5	-420.0	-405.3	-402.8	-402.7	0.0000
12	0.0000	0.0000	-405.3	-398.5	-392.1	-390.8	-390.7	0.0000
13	0.0000	0.0000	-380.1	-377.1	-379.0	-378.8	-378.8	0.0000
14	0.0000	0.0000	-372.5	-372.1	-379.0	-378.8	-378.8	0.0000
15	0.0000	0.0000	-364.9	-367.0	-380.0	-380.0	-380.0	0.0000
16	0.0000	0.0000	-364.9	-367.0	-370.0	-370.0	-370.0	0.0000
17	0.0000	0.0000	-381.5	-381.1	-360.0	-360.0	-360.0	0.0000
18	0.0000	0.0000	-360.0	-360.0	-360.0	-360.0	-360.0	0.0000
19	0.0000	0.0000	-340.0	-340.0	-340.0	-340.0	-340.0	0.0000
20	0.0000	0.0000	-320.0	-320.0	-320.0	-320.0	-320.0	0.0000
21	0.0000	0.0000	-300.0	-300.0	-300.0	-300.0	-300.0	0.0000
22	0.0000	0.0000	-280.0	-280.0	-280.0	-280.0	-280.0	0.0000
23	0.0000	0.0000	-260.0	-260.0	-260.0	-260.0	-260.0	0.0000
24	0.0000	0.0000	-240.0	-240.0	-240.0	-240.0	-240.0	0.0000
25	0.0000	0.0000	-220.0	-220.0	-220.0	-220.0	-220.0	0.0000
26	0.0000	0.0000	-200.0	-200.0	-200.0	-200.0	-200.0	0.0000
27	0.0000	0.0000	-180.0	-180.0	-180.0	-180.0	-180.0	0.0000
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

INITIAL SALTWATER HEADS

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	-0.1137E-12	-0.1137E-12	0.0000	0.0000
3	0.0000	-0.1137E-12	-0.1137E-12	0.0000	0.1137E-12	0.0000	-0.1137E-12	0.0000
4	0.0000	0.0000	0.0000	-0.1137E-12	0.0000	-0.1137E-12	0.0000	0.0000
5	0.0000	-0.1137E-12	0.1137E-12	0.0000	0.0000	-0.1137E-12	0.0000	0.0000
6	0.0000	-0.1137E-12	-0.1137E-12	0.0000	-0.1137E-12	0.0000	0.0000	0.0000
7	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000	0.0000	-0.1137E-12	0.0000

Table 8.--Output file for example 1--continued

8	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000	-0.1137E-12	-0.1137E-12	0.0000
9	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000
10	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000	-0.1137E-12	0.0000
11	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000	-0.1137E-12	0.0000
12	0.0000	0.0000	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000
13	0.0000	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000	-0.1137E-12	0.0000
14	0.0000	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000	-0.1137E-12	0.0000
15	0.0000	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000
16	0.0000	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000
17	0.0000	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000
18	0.0000	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000
19	0.0000	0.0000	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	-0.1137E-12	0.0000
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	0.0000	0.0000	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	0.0000
22	0.0000	0.0000	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	0.0000
23	0.0000	0.0000	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	0.0000
24	0.0000	0.0000	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	0.0000
25	0.0000	0.0000	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	0.0000
26	0.0000	0.0000	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	0.0000
27	0.0000	0.0000	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	-0.5684E-13	0.0000
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AQUITARD LEAKANCES (K"/B")

0.2120E-07

HEAD IN OVERLYING AQUIFER

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000	1.250	1.250	1.250	0.0000
14	0.0000	0.0000	1.250	1.250	3.750	3.750	3.750	0.0000
15	0.0000	0.0000	1.500	1.500	4.000	4.000	4.000	0.0000
16	0.0000	0.0000	1.750	1.750	4.250	4.250	4.250	0.0000
17	0.0000	0.0000	2.000	2.000	4.500	4.500	4.500	0.0000
18	0.0000	0.0000	3.500	3.500	6.000	6.000	6.000	0.0000
19	0.0000	0.0000	5.500	5.500	8.000	8.000	8.000	0.0000
20	0.0000	0.0000	7.500	7.500	10.00	10.00	10.00	0.0000
21	0.0000	0.0000	12.00	12.00	14.50	14.50	14.50	0.0000
22	0.0000	0.0000	17.25	17.25	20.00	20.00	20.00	0.0000
23	0.0000	0.0000	29.25	29.25	32.00	32.00	32.00	0.0000
24	0.0000	0.0000	47.50	47.50	47.50	47.50	47.50	0.0000

Table 8.--Output file for example 1--continued

25	0.0000	0.0000	47.50	47.50	47.50	47.50	47.50	0.0000
26	0.0000	0.0000	47.50	47.50	47.50	47.50	47.50	0.0000
27	0.0000	0.0000	47.50	47.50	47.50	47.50	47.50	0.0000
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

BATHYMETRY

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000	-50.00	-50.00	-50.00	0.0000
14	0.0000	0.0000	-50.00	-50.00	-150.0	-150.0	-150.0	0.0000
15	0.0000	0.0000	-60.00	-60.00	-160.0	-160.0	-160.0	0.0000
16	0.0000	0.0000	-70.00	-70.00	-170.0	-170.0	-170.0	0.0000
17	0.0000	0.0000	-80.00	-80.00	-180.0	-180.0	-180.0	0.0000
18	0.0000	0.0000	-140.0	-140.0	-240.0	-240.0	-240.0	0.0000
19	0.0000	0.0000	-220.0	-220.0	-320.0	-320.0	-320.0	0.0000
20	0.0000	0.0000	-300.0	-300.0	-400.0	-400.0	-400.0	0.0000
21	0.0000	0.0000	-480.0	-480.0	-580.0	-580.0	-580.0	0.0000
22	0.0000	0.0000	-690.0	-690.0	-800.0	-800.0	-800.0	0.0000
23	0.0000	0.0000	-1170.	-1170.	-1280.	-1280.	-1280.	0.0000
24	0.0000	0.0000	-1900.	-1900.	-1900.	-1900.	-1900.	0.0000
25	0.0000	0.0000	-1900.	-1900.	-1900.	-1900.	-1900.	0.0000
26	0.0000	0.0000	-1900.	-1900.	-1900.	-1900.	-1900.	0.0000
27	0.0000	0.0000	-1900.	-1900.	-1900.	-1900.	-1900.	0.0000
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

CODE FOR UPPER LAYER (1-UNCONFINED NODE,0-CONFINED NODE)

1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1
11	1	1	1	1	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0

Table 8.--Output file for example 1--continued

15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0

DELTA X

2000.	2000.	2000.	2000.	2000.	600.0	120.0	120.0

DELTA Y

2000.	2000.	2000.	2000.	2000.	2000.	2000.	2000.	2000.	2000.
1500.	1000.	1000.	1000.	1000.	1000.	1500.	2000.	2000.	2000.
2000.	3500.	6750.	0.1012E+05	0.1619E+05	0.2478E+05	0.2478E+05	0.2478E+05		

ITERATION PARAMETERS:

FRESHWATER EQUATION:.0000 .9570 .9981 .9999 1.000 1.000

PUMPING PERIOD 1

INITIAL TIME STEP(SEC)= 0.1578E+08
MULTIPLICATION FACTOR FOR DELTA T= 1.000
LENGTH OF PUMPING PERIOD(DAYS)= 0.2045E+05
MAXIMUM NUMBER OF TIME STEPS= 10
NUMBER OF ACTIVE WELLS= 1

PUMPING NODES:

I	J	K	PUMPAGE	SCREEN TOP	SCREEN BOTTOM
13	4	1	1.000	-280.0	-290.0

RECHARGE

1	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
2	0.1000E-07	0.1000E-07	0.9000E-07	0.9700E-07	0.7500E-07	0.6760E-07	0.3600E-07	0.3600E-07
3	0.1000E-07	0.1200E-06	0.1140E-06	0.1000E-06	0.7000E-07	0.6000E-07	0.3800E-07	0.3300E-07
4	0.1000E-07	0.1240E-06	0.1140E-06	0.9000E-07	0.6200E-07	0.6000E-07	0.5200E-07	0.2700E-07

Table 8.--Output file for example 1--continued

5	0.1000E-07	0.1050E-06	0.6760E-07	0.6000E-07	0.3330E-07	0.3330E-07	0.2030E-07	0.2030E-07
6	0.1000E-07	0.8650E-07	0.3800E-07	0.3650E-07	0.4970E-07	0.4970E-07	0.2670E-07	0.3400E-07
7	0.1000E-07	0.2900E-07	0.5000E-07	0.3500E-07	0.4970E-07	0.4970E-07	0.1840E-07	0.1840E-07
8	0.1000E-07	0.2500E-07	0.4500E-07	0.4000E-07	0.4500E-07	0.4040E-07	0.1630E-07	0.1320E-07
9	0.1000E-07	0.4500E-07	0.2540E-07	0.2600E-07	0.3000E-07	0.4040E-07	0.2120E-07	0.5900E-08
10	0.1000E-07	0.1600E-07	0.1720E-07	0.3500E-07	0.3000E-07	0.1510E-07	0.2120E-07	0.2120E-07
11	0.1000E-07	0.8600E-08	0.1510E-07	0.1510E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
12	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
13	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
14	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
15	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
16	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
17	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
18	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
19	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
20	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
21	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
22	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
23	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
24	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
25	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
26	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
27	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07
28	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07	0.1000E-07

```
-------------
TIME STEP   1
-------------
                         SECONDS      HOURS      DAYS       YEARS
  TIME STEP SIZE:        0.1578E+08  4383.      182.6      0.5000
  PUMPING PERIOD TIME:   0.1578E+08  4383.      182.6      0.5000
  TOTAL SIMULATION TIME: 0.1578E+08  4383.      182.6      0.5000

MAXIMUM FRESHWATER HEAD CHANGE: 0.6508     0.2995     0.9971     1.357      0.6734     0.2476     0.6640E-01 0.1621
                                 0.1427     0.1115     0.2869E-01 0.2119E-01 0.6646E-02 0.3227E-01 0.9569E-02 0.5877E-01
                                 0.4315E-01 0.1452E-01 0.2436E-02 0.1173E-01 0.8951E-02 0.1973E-01 0.9869E-02 0.2029E-02
                                 0.4931E-03 0.4165E-02 0.1591E-02 0.7814E-02 0.4815E-02 0.1351E-02 0.2526E-03 0.1524E-02
                                 0.8791E-03 0.2821E-02 0.1591E-02 0.3990E-03 0.8196E-04 0.5699E-03 0.2746E-03 0.1062E-02
                                 0.6253E-03 0.1661E-03 0.3250E-04 0.2110E-03 0.1110E-03 0.3922E-03 0.2264E-03 0.5862E-04
                                 0.1172E-04 0.7849E-04 0.5869E-04 0.5953E-04 0.1510E-04 0.2790E-05 0.1007E-05 0.1095E-04
                                 0.7564E-05 0.6274E-05 0.8986E-06
MAXIMUM SALTWATER HEAD CHANGE:  0.3086E-05 0.2250E-04 0.2236E-02 0.1763E-01 0.4982E-02 0.7243E-04 0.9547E-04 0.3859E-03
                                 0.7973E-03 0.4679E-03 0.5008E-03 0.1623E-04 0.4996E-04 0.9853E-04 0.1150E-03 0.7365E-03
                                 0.5743E-03 0.7263E-05 0.6959E-05 0.4803E-04 0.8676E-04 0.1424E-03 0.1473E-03 0.2305E-05
                                 0.4541E-05 0.1582E-04 0.1266E-04 0.7526E-04 0.6680E-04 0.8891E-06 0.1307E-05 0.6268E-05
                                 0.8386E-05 0.2392E-04 0.2274E-04 0.3065E-06 0.5512E-06 0.2259E-05 0.2485E-05 0.9583E-05
                                 0.8806E-05 0.1180E-06 0.1934E-06 0.8511E-06 0.1032E-05 0.3440E-05 0.3210E-05 0.4312E-07
                                 0.7380E-07 0.3141E-06 0.5071E-06 0.1396E-05 0.2529E-06 0.8121E-08 0.7755E-08 0.7228E-07
                                 0.1193E-06 0.1950E-06 0.9872E-08
```

Table 8.--Output file for example 1--continued

```
 -------------
 TIME STEP   2
 -------------
                              SECONDS     HOURS      DAYS       YEARS
   TIME STEP SIZE:          0.1578E+08  4383.       182.6      0.5000
   PUMPING PERIOD TIME:     0.3156E+08  8766.       365.2       1.000
   TOTAL SIMULATION TIME:   0.3156E+08  8766.       365.2       1.000

 MAXIMUM FRESHWATER HEAD CHANGE: 0.7347E-03 0.3701E-02 0.2681E-01 0.6498E-01 0.3909E-01 0.9040E-02 0.3279E-02 0.1499E-01
                                  0.1152E-01 0.2180E-01 0.1084E-01 0.2252E-02 0.5394E-03 0.4873E-02 0.1736E-02 0.9094E-02
                                  0.5664E-02 0.1616E-02 0.2952E-03 0.1759E-02 0.1028E-02 0.3231E-02 0.1810E-02 0.4501E-03
                                  0.9230E-04 0.6538E-03 0.3075E-03 0.1213E-02 0.7154E-03 0.1911E-03 0.3700E-04 0.2406E-03
                                  0.1264E-03 0.4446E-03 0.2560E-03 0.6623E-04 0.1315E-04 0.8903E-04 0.4441E-04 0.1648E-03
                                  0.9602E-04 0.2524E-04 0.4950E-05 0.3286E-04 0.1681E-04 0.6078E-04 0.3521E-04 0.9185E-05
                                  0.1812E-05 0.1214E-04 0.9084E-05 0.9271E-05 0.2377E-05 0.4581E-06
 MAXIMUM SALTWATER HEAD CHANGE:  0.5681E-04 0.3210E-03 0.2241E-02 0.7197E-02 0.1777E-02 0.3998E-04 0.3979E-04 0.2041E-03
                                  0.7214E-03 0.3438E-03 0.1639E-03 0.5878E-05 0.9704E-05 0.1296E-04 0.1995E-04 0.8617E-04
                                  0.7541E-04 0.1125E-05 0.1517E-05 0.7464E-05 0.1174E-04 0.2616E-04 0.2599E-04 0.3560E-06
                                  0.6446E-06 0.2576E-05 0.2806E-05 0.1100E-04 0.1009E-04 0.1356E-06 0.2206E-06 0.9689E-06
                                  0.1176E-05 0.3906E-05 0.3641E-05 0.4902E-07 0.8437E-07 0.3551E-06 0.4065E-06 0.1473E-05
                                  0.1361E-05 0.1828E-07 0.3064E-07 0.1317E-06 0.1549E-06 0.5387E-06 0.4998E-06 0.6722E-08
                                  0.1141E-07 0.4855E-07 0.7935E-07 0.2177E-06 0.3987E-07 0.1262E-08

 -------------
 TIME STEP   3
 -------------
                              SECONDS     HOURS      DAYS       YEARS
   TIME STEP SIZE:          0.1578E+08  4383.       182.6      0.5000
   PUMPING PERIOD TIME:     0.4734E+08 0.1315E+05  547.9        1.500
   TOTAL SIMULATION TIME:   0.4734E+08 0.1315E+05  547.9        1.500

 MAXIMUM FRESHWATER HEAD CHANGE: 0.5195E-04 0.1719E-03 0.1276E-02 0.3205E-02 0.1984E-02 0.4638E-03 0.1622E-03 0.7518E-03
                                  0.5747E-03 0.1111E-02 0.5560E-03 0.1173E-03 0.2773E-04 0.2467E-03 0.8939E-04 0.4605E-03
                                  0.2861E-03 0.8140E-04 0.1490E-04 0.8910E-04 0.5182E-04 0.1638E-03 0.9185E-04 0.2289E-04
                                  0.4685E-05 0.3311E-04 0.1561E-04 0.6140E-04 0.3620E-04 0.9662E-05 0.1871E-05 0.1218E-04
                                  0.6389E-05 0.2251E-04 0.1296E-04 0.3355E-05 0.6660E-06
 MAXIMUM SALTWATER HEAD CHANGE:  0.3108E-05 0.1706E-04 0.1093E-03 0.3529E-03 0.8700E-04 0.1989E-05 0.1948E-05 0.9934E-05
                                  0.3473E-04 0.1612E-04 0.8281E-05 0.2904E-06 0.4821E-06 0.6670E-06 0.1032E-05 0.4341E-05
                                  0.3820E-05 0.5674E-07 0.7719E-07 0.3771E-06 0.5873E-06 0.1331E-05 0.1318E-05 0.1801E-07
                                  0.3260E-07 0.1305E-06 0.1424E-06 0.5567E-06 0.5109E-06 0.6863E-08 0.1118E-07 0.4905E-07
                                  0.5938E-07 0.1979E-06 0.1844E-06 0.2483E-08 0.4270E-08

 -------------
 TIME STEP   4
 -------------
                              SECONDS     HOURS      DAYS       YEARS
   TIME STEP SIZE:          0.1578E+08  4383.       182.6      0.5000
   PUMPING PERIOD TIME:     0.6312E+08 0.1753E+05  730.5        2.000
   TOTAL SIMULATION TIME:   0.6312E+08 0.1753E+05  730.5        2.000
```

Table 8.--Output file for example 1--continued

MAXIMUM FRESHWATER HEAD CHANGE: 0.2263E-05 0.7824E-05 0.5932E-04 0.1510E-03 0.9407E-04 0.2193E-04 0.7664E-05 0.3558E-04 0.2720E-04 0.5265E-04 0.2641E-04 0.5582E-05 0.1317E-05 0.1169E-04 0.4246E-05 0.2181E-04 0.1354E-04 0.3852E-05 0.7053E-06

MAXIMUM SALTWATER HEAD CHANGE: 0.1538E-06 0.8427E-06 0.5361E-05 0.1739E-04 0.4233E-05 0.9800E-07 0.9564E-07 0.4838E-06 0.1691E-05 0.8000E-06 0.3940E-06 0.1402E-07 0.2318E-07 0.3152E-07 0.4986E-07 0.2051E-06 0.1806E-06 0.2694E-08 0.3662E-08

****

STEADY STATE ACHIEVED AT:

****

TIME STEP 5

	SECONDS	HOURS	DAYS	YEARS
TIME STEP SIZE:	0.1578E+08	4383.	182.6	0.5000
PUMPING PERIOD TIME:	0.7889E+08	0.2191E+05	913.1	2.500
TOTAL SIMULATION TIME:	0.7889E+08	0.2191E+05	913.1	2.500

MAXIMUM FRESHWATER HEAD CHANGE: 0.4592E-06

MAXIMUM SALTWATER HEAD CHANGE: 0.7557E-08

AQUIFER 1

MASS BALANCE:

	FRESHWATER		SALTWATER	
	T.S. RATE	CUM. VOLUME	T.S. RATE	CUM. VOLUME
CHANGE IN STORAGE	0.6918E-10	0.9071E+06	-0.6142E-10	-0.8896E+06
SOURCES				
RECHARGE	8.979	0.7084E+09		
CONSTANT HEAD NODES	0.0000	0.0000	0.0000	0.0000
INJECTION	0.0000	0.0000	0.0000	0.0000
LEAKAGE ACROSS TOP	0.0000	0.0000	0.0000	0.0000
LEAKAGE ACROSS BOT	0.0000	0.0000	0.0000	0.0000
TOTAL	8.979	0.7084E+09	0.0000	0.0000
SINKS				
CONSTANT HEAD NODES	0.0000	0.0000	0.0000	0.0000
PUMPAGE	1.000	0.7889E+08	0.0000	0.0000
LEAKAGE ACROSS TOP	7.979	0.6286E+09	0.6164E-05	0.8897E+06
LEAKAGE ACROSS BOT	0.0000	0.0000	0.0000	0.0000
TOTAL	8.979	0.7075E+09	0.6164E-05	0.8897E+06
SOURCES-SINKS	0.3061E-06	0.9069E+06	-0.6164E-05	-0.8897E+06
RELATIVE ERROR (%)				
INFLUX	-0.3408E-05	0.2579E-04	0.0000	0.0000
STORAGE	-0.4424E+06	0.2014E-01	-0.1004E+08	-0.1064E-01

Table 8.--Output file for example 1--continued

FRESHWATER HEADS

1	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
2	11111.	11111.	15.703	15.691	15.666	15.659	15.659	11111.
3	11111.	15.601	15.617	15.600	15.570	15.563	15.563	11111.
4	11111.	15.455	15.441	15.411	15.379	15.373	15.373	11111.
5	11111.	15.183	15.154	15.123	15.094	15.089	15.088	11111.
6	11111.	14.817	14.786	14.759	14.744	14.740	14.740	11111.
7	11111.	14.373	14.358	14.331	14.317	14.313	14.313	11111.
8	11111.	13.895	13.870	13.833	13.808	13.802	13.802	11111.
9	11111.	13.395	13.321	13.251	13.206	13.199	13.198	11111.
10	11111.	12.893	12.711	12.582	12.500	12.484	12.483	11111.
11	11111.	12.580	12.077	11.875	11.742	11.725	11.724	11111.
12	11111.	11111.	11.428	11.288	11.289	11.289	11.289	11111.
13	11111.	11111.	11.011	10.851	10.974	10.988	10.989	11111.
14	11111.	11111.	10.677	10.600	10.699	10.719	10.720	11111.
15	11111.	11111.	10.366	10.333	10.441	10.468	10.469	11111.
16	11111.	11111.	10.069	10.057	10.200	10.246	10.247	11111.
17	11111.	11111.	9.7139	9.7022	11111.	11111.	11111.	11111.
18	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
19	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
20	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
21	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
22	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
23	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
24	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
25	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
26	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
27	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
28	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.

SALTWATER HEADS

1	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
2	11111.	11111.	0.15917E-05	0.15936E-05	0.15949E-05	0.15961E-05	0.15962E-05	11111.
3	11111.	0.15852E-05	0.15891E-05	0.15905E-05	0.15918E-05	0.15929E-05	0.15930E-05	11111.
4	11111.	0.15804E-05	0.15823E-05	0.15832E-05	0.15843E-05	0.15854E-05	0.15854E-05	11111.
5	11111.	0.15702E-05	0.15715E-05	0.15720E-05	0.15729E-05	0.15740E-05	0.15740E-05	11111.
6	11111.	0.15560E-05	0.15569E-05	0.15570E-05	0.15576E-05	0.15586E-05	0.15587E-05	11111.
7	11111.	0.15380E-05	0.15385E-05	0.15380E-05	0.15383E-05	0.15392E-05	0.15393E-05	11111.
8	11111.	0.15169E-05	0.15164E-05	0.15150E-05	0.15146E-05	0.15154E-05	0.15155E-05	11111.
9	11111.	0.14936E-05	0.14909E-05	0.14877E-05	0.14863E-05	0.14869E-05	0.14869E-05	11111.
10	11111.	0.14703E-05	0.14614E-05	0.14555E-05	0.14529E-05	0.14532E-05	0.14532E-05	11111.
11	11111.	0.14554E-05	0.14292E-05	0.14215E-05	0.14187E-05	0.14191E-05	0.14191E-05	11111.
12	11111.	11111.	0.13965E-05	0.13931E-05	0.13913E-05	0.13919E-05	0.13920E-05	11111.
13	11111.	11111.	0.13706E-05	0.13690E-05	0.13678E-05	0.13685E-05	0.13685E-05	11111.
14	11111.	11111.	0.13445E-05	0.13438E-05	0.13430E-05	0.13437E-05	0.13438E-05	11111.
15	11111.	11111.	0.13180E-05	0.13177E-05	0.13172E-05	0.13178E-05	0.13179E-05	11111.
16	11111.	11111.	0.12911E-05	0.12909E-05	0.12905E-05	0.12909E-05	0.12910E-05	11111.
17	11111.	11111.	0.12569E-05	0.12567E-05	0.12563E-05	0.12565E-05	0.12565E-05	11111.
18	11111.	11111.	0.12089E-05	0.12088E-05	0.12086E-05	0.12086E-05	0.12086E-05	11111.
19	11111.	11111.	0.11551E-05	0.11550E-05	0.11549E-05	0.11549E-05	0.11549E-05	11111.
20	11111.	11111.	0.11025E-05	0.11024E-05	0.11023E-05	0.11022E-05	0.11022E-05	11111.

Table 8.--Output file for example 1--continued

21	11111.	11111.	0.10511E-05	0.10510E-05	0.10509E-05	0.10509E-05	0.10509E-05	11111.
22	11111.	11111.	0.98244E-06	0.98237E-06	0.98230E-06	0.98226E-06	0.98225E-06	11111.
23	11111.	11111.	0.86045E-06	0.86036E-06	0.86020E-06	0.86015E-06	0.86015E-06	11111.
24	11111.	11111.	0.67495E-06	0.67486E-06	0.67471E-06	0.67467E-06	0.67466E-06	11111.
25	11111.	11111.	0.44518E-06	0.44517E-06	0.44515E-06	0.44514E-06	0.44514E-06	11111.
26	11111.	11111.	0.24076E-06	0.24076E-06	0.24075E-06	0.24075E-06	0.24075E-06	11111.
27	11111.	11111.	0.14716E-06	0.14716E-06	0.14716E-06	0.14716E-06	0.14716E-06	11111.
28	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.

INTERFACE ELEVATION

1	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
2	11111.	11111.	-628.10	-627.64	-626.64	-626.37	-626.35	11111.
3	11111.	-624.04	-624.69	-624.00	-622.82	-622.52	-622.50	11111.
4	11111.	-618.18	-617.65	-616.46	-615.18	-614.93	-614.91	11111.
5	11111.	-607.32	-606.15	-604.92	-603.76	-603.55	-603.53	11111.
6	11111.	-592.68	-591.42	-590.36	-589.75	-589.60	-589.59	11111.
7	11111.	-574.93	-574.33	-573.23	-572.68	-572.52	-572.50	11111.
8	11111.	-555.82	-554.82	-553.31	-552.32	-552.09	-552.06	11111.
9	11111.	-535.80	-532.85	-530.05	-528.25	-527.96	-527.93	11111.
10	11111.	-515.71	-508.43	-503.28	-499.99	-499.35	-499.32	11111.
11	11111.	-503.21	-483.10	-475.01	-469.67	-468.98	-468.95	11111.
12	11111.	11111.	-457.13	-451.53	-451.56	-451.54	-451.54	11111.
13	11111.	11111.	-440.42	-434.06	-438.94	-439.52	-439.55	11111.
14	11111.	11111.	-427.06	-424.00	-427.97	-428.75	-428.78	11111.
15	11111.	11111.	-414.63	-413.31	-417.65	-418.70	-418.75	11111.
16	11111.	11111.	-402.77	-402.28	11111.	11111.	11111.	11111.
17	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
18	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
19	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
20	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
21	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
22	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
23	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
24	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
25	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
26	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
27	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.
28	11111.	11111.	11111.	11111.	11111.	11111.	11111.	11111.

Table 8.--Output file for example 1--continued

```
 MAP OF EXTENT OF INTRUSION (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)

    1    . . . . . . . .
    2    . . M M M M M .
    3    . M M M M M M .
    4    . M M M M M M .
    5    . M M M M M M .
    6    . M M M M M M .
    7    . M M M M M M .
    8    . M M M M M M .
    9    . M M M M M M .
   10    . M M M M M M .
   11    . M M M M M M .
   12    . . M M M M M .
   13    . . M M M M M .
   14    . . M M M M M .
   15    . . M M M M M .
   16    . . M M S S S .
   17    . . S S S S S .
   18    . . S S S S S .
   19    . . S S S S S .
   20    . . S S S S S .
   21    . . S S S S S .
   22    . . S S S S S .
   23    . . S S S S S .
   24    . . S S S S S .
   25    . . S S S S S .
   26    . . S S S S S .
   27    . . S S S S S .
   28    . . . . . . . .
```

Example 2: Layered Cross-section of Cape May, New Jersey

The geometry of this problem is described in the model verification section and illustrated in figure 23. It is made up of three confined layers. The simulation shown here is for method 2 leakage conditions (restricted mixing). The input is for a continuation run and therefore includes initial interface elevations and projection factors (FX, FY, SX, and SY) for each layer. Default input/output options are used. Grid spacing in the x-direction is 4000 feet except near the coast where it is reduced to 2000 feet to improve interface projection accuracy. The simulation of a cross-section requires three rows. The middle row is the active region of the cross-section slice, and the rows on either side are inactive. These two rows provide the no-flow boundary condition which prevents flow out the sides of the simulated section. Thus, flow in the y-direction is zero, and the value assigned to FKY does not affect the solution. The value assigned to DY specifies the width of the simulated cross-section.

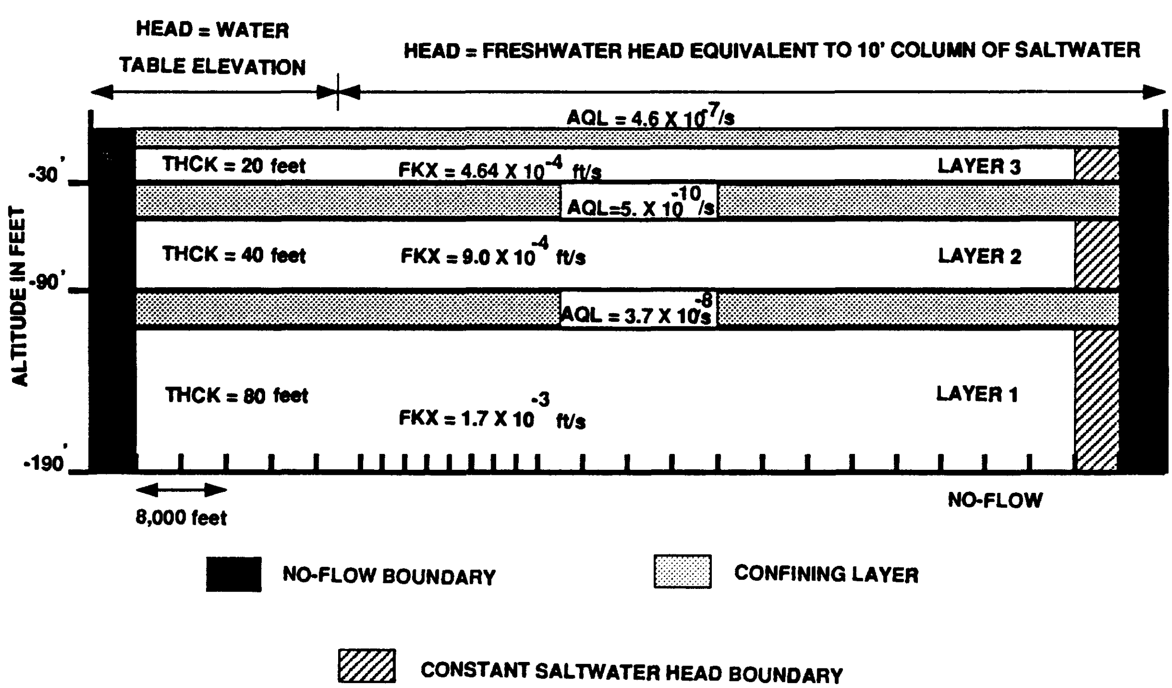

Figure 23.--Cross-section showing the geometry and boundary conditions for the layered example from Cape May, New Jersey. AQL is the confining layer leakance, THCK is the aquifer thickness, and FKX is the aquifer hydraulic conductivity in the x-direction.

A head-dependent boundary is imposed over the top of the upper aquifer. Onshore, the HEAD matrix is assigned the water table elevation, and offshore it is assigned the freshwater head equivalent to a 10 foot deep column of saltwater. A constant saltwater head of 0.0 (sea level) is imposed on the vertical-seaward boundary. The simulation input and output files are given in tables 9 and 10, respectively. In this simulation a relaxation factor (RFAC) of 0.8 was used and an interface projection weighting factor (WFAC) of 0.3 was used. The iteration parameter factor (WITER) is large in this problem (10,000.) because of the strong anisotropy introduced by the dummy FKY value (1.0).

As in example 1, this simulation is a steady-state run. A freshwater and saltwater specific storage of 0.0 is used. At the seaward boundary, the saltwater specific storage is negative to indicate a constant saltwater head boundary. The steady-state criterion (0.0001) is satisfied at time step 13. The simulated interface position is shown in figure 19. The discussion regarding mass balance interpretation given in example 1 is applicable to this problem also. Figure 24 shows the components of freshwater leakage as given in the mass balance. Freshwater enters the system by leaking down into the uppermost aquifer (layer 3). It leaves the system by flowing through the aquifer layers and then leaking out to the sea. Freshwater leaking upward from layer 2 is apportioned to the overlying freshwater and saltwater zones. In this example the global freshwater mass balance is given by the freshwater leakage into the system across the top of layer 3 (0.3×10^{-2} ft^3/s). This freshwater is discharged by leakage of freshwater from layer 2 to the overlying saltwater (0.2×10^{-2} ft^3/s) and by leakage to the sea across the top of layer 3 (0.1×10^{-2} ft^3/s).

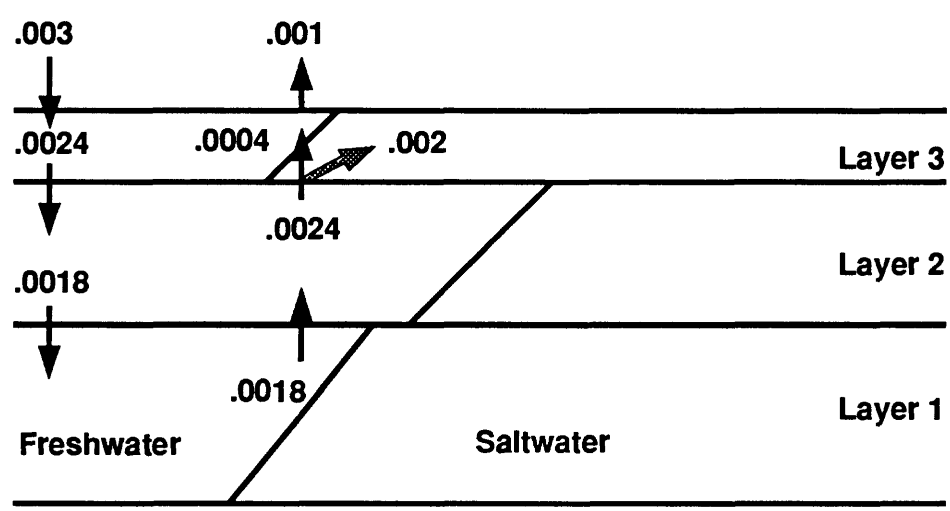

Figure 24.--Diagram showing the freshwater leakages from the mass balance for the Cape May example (leakage is in cubic feet per second, solid arrows represent freshwater leaking into freshwater, shaded arrow represents freshwater leaking into saltwater).

Table 9.--Input file for example 2

```
CAPE MAY - CROSS-SECTIONAL MODEL WITH 3 LAYERS
    3   28    3   50   50    6    1    3   20    0    0
    0.0001    0.0001      0.80      0.30    10000.   62.4100  63.97025  2.09E-05  2.09E-05
    1       0.0              0
    2    7    1
    2    7    2
    2    7    3
    0   29.0E-07                        FKX
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0    582.76    582.76    582.76    582.76    582.76    582.76    582.76    582.76    582.76
    582.76    582.76    582.76    582.76    582.76    582.76    582.76    582.76    582.76    582.76
    582.76    582.76    582.76    582.76    582.76    582.76    582.76       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
    1       1.0                         FKY
    1       0.0                         STORF
    0       1.0       1                 STORS
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0      -1.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
    1   1.0E-04                         POR
    1      80.0                         THCK
    1    -190.0                         ZBOT
    0       1.0    PHIF LAYER  1
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     5.775     5.634     5.274     4.769     4.197     3.781     3.508     3.234     2.949
     2.621     0.086     1.625     0.028     0.000     0.001     0.001     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0       1.0    ZINT LAYER  1
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
     0.000  -234.520  -228.960  -214.800  -190.799  -167.895  -151.284  -140.345  -129.373  -117.972
  -104.880    -3.480   -65.040    -1.160    -0.040    -0.040    -0.040     0.000     0.000     0.000
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table 9.--Input file for example 2--continued

```
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0       1.0   FX LAYER  1,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   0.167     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0       1.0   FY LAYER  1,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0       1.0   SX LAYER  1,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.482     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0       1.0   SY LAYER  1,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0  3.73E-08     1             AQL  (LEAKANCES)
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.500     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
```

Table 9.--Input file for example 2--continued

```
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0  29.0E-07                 FKX
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0          6
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0    310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34
  310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34
  310.34    310.34    310.34    310.34    310.34    310.34    310.34       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  1       1.0                 FKY
  1       0.0                 STORF
  0       1.0                 STORS
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0      -1.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  1   1.0E-04
  1      40.0
  1     -90.0
  0       1.0   PHIF LAYER  2,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     5.838     5.683     5.307     4.767     4.158     3.746     3.474     3.201     2.912
   2.577     2.299     2.078     1.878     1.606     1.334     0.325     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0       1.0   ZINT LAYER  2,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000  -237.040  -230.920  -216.080  -195.280  -170.040  -153.440  -142.560  -131.640  -120.320
-107.560   -91.987   -83.155   -75.137   -64.279   -53.382   -13.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table 9.--Input file for example 2--continued

```
 0       1.0   FX LAYER  2,
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     0.811     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0       1.0   FY LAYER  2,
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0       1.0   SX LAYER  2,
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.325     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0       1.0   SY LAYER  2,
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0  5.00E-10                      AQL
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.500     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table 9.--Input file for example 2--continued

```
0  29.0E-07                      FKX
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      160      160      160      160      160      160      160      160      160
    160      160      160      160      160      160      160      160      160      160
    160      160      160      160      160      160      160      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1       1.0                      FKY
1       0.0                      STORF
0       1.0                      STORS
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0     -1.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1   1.0E-04
1      20.0
1     -30.0
0       1.0   PHIF LAYER  3,
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000   11.989   10.387    8.481    5.999    0.011    0.258    0.006    0.005    0.004
  0.004    0.003    0.002    0.002    0.002    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
0       1.0   ZINT LAYER  3,
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000 -479.560 -415.480 -339.240 -239.831   -0.302  -10.196   -0.120   -0.120   -0.080
 -0.080   -0.080   -0.040   -0.040   -0.040    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
0       1.0   FX LAYER  3,
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
```

Table 9.--Input file for example 2--continued

```
  0.000     1.000     1.000     1.000     1.000     0.481     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0       1.0    FY LAYER  3,
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     1.000     1.000     1.000     1.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0       1.0    SX LAYER  3,
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.216     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0       1.0    SY LAYER  3,
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0  4.64E-07                   AQL
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.500     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
  1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table 9.--Input file for example 2--continued

```
   0       1.0                     HEAD (FIXED FRESHWATER HEAD IN OVERLYING LAYER)
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0      12.0   10.3923    8.4853    6.0000     0.000       .25       .25       .25       .25
      .25       .25       .25       .25       .25       .25       .25       .25       .25       .25
      .25       .25       .25       .25       .25       .25       .25       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
   0       1.0                     BATH
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0      00.0       0.0       0.0       0.0     0.000      -10.      -10.      -10.      -10.
     -10.      -10.      -10.      -10.      -10.      -10.      -10.      -10.      -10.      -10.
     -10.      -10.      -10.      -10.      -10.      -10.      -10.       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0        IWT
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0
    4000.     4000.     4000.     4000.     4000.     4000.     2000.     2000.     2000.     2000.
    2000.     2000.     2000.     2000.     4000.     4000.     4000.     4000.     4000.     4000.
    4000.     4000.     4000.     4000.     4000.     4000.     4000.     4000.
     100.      100.      100.
 3155760.      1.30  3652500.    29    0
   1       0.0
```

Table 10.--Output file for example 2

```
 ----------------------------------------------------------------------------
     CAPE MAY - CROSS-SECTIONAL MODEL WITH 3 LAYERS
 ----------------------------------------------------------------------------


 NUMBER OF ROWS=    3
 NUMBER OF COLUMNS=  28
 NUMBER OF  AQUIFERS=    3
 NUMBER OF TIME STEPS BETWEEN PRINTOUT=  50
 MAXIMUM NUMBER OF ITERATIONS=  50
 NUMBER OF ITERATION PARAMETERS=   6
 NUMBER OF PUMPING PERIODS=   1
 INTERFACE FIXED AFTER   20 ITERATIONS
 INPUT/OUTPUT OPTIONS' PARAMETER=   0 (0=USE DEFAULTS, 1=READ IN OPTIONS ARRAY)
 LEAKAGE OPTION PARAMETER=   0 (0=RESTRICTED MIXING, 1=COMPLETE MIXING)

 CONVERGENCE CRITERION= 0.1000E-03
 STEADY STATE CRITERION= 0.1000E-03
 RELAXATION FACTOR= 0.8000
 WEIGHTING FACTOR= 0.3000
 ITERATION PARAMETER FACTOR= 0.1000E+05
 SPECIFIC GRAVITY OF FRESHWATER=  62.41
 SPECIFIC GRAVITY OF SALTWATER=  63.97
 VISCOSITY OF FRESHWATER= 0.2090E-04
 VISCOSITY OF SALTWATER= 0.2090E-04


CONTINUATION RUN
   INITIAL TIME =    0.0000000000    SEC

 LOCATIONS OF    3 OBSERVATION NODES TRACKED:
    2    7    1
    2    7    2
    2    7    3

 SPECIFIED INPUT/OUTPUT OPTIONS:

    1: 1=PRINT INPUT AQUIFER PARAMETERS, 0=DO NOT PRINT
    1: 1=PRINT INPUT PUMPING PERIOD WELL AND RECHARGE DATA, 0=DO NOT PRINT
    1: 1=PRINT CALCULATED FRESHWATER HEADS, 0=DO NOT PRINT
    1: 1=PRINT CALCULATED SALTWATER HEADS, 0=DO NOT PRINT
    1: 1=PRINT CALCULATED INTERFACE ELEVATIONS, 0=DO NOT PRINT
    0: 1=PRINT CALCULATED FAREA FACTORS, 0=DO NOT PRINT
    0: 1=PRINT CALCULATED SAREA FACTORS, 0=DO NOT PRINT
    1: 1=PRINT F-M-S MAP, 0=DO NOT PRINT
    1: 1=WRITE BLOCK LEAKAGE VALUES TO FILE, 0=DO NOT WRITE TO FILE
    0: 1=PRINT ITERATION INFORMATION TO SCREEN, 0=DO NOT PRINT
    0: 0=REWRITE LATEST RESULTS TO FILE AFTER EACH TIME STEP,
       1=WRITE RESULTS TO FILE EVERY NP TIME STEPS
```

Table 10.--Output file for example 2--continued

```
 -------------------------------
 AQUIFER PARAMETERS FOR LAYER  1
 -------------------------------

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION
    1     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    2     0.0000     0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02
          0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02
          0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.1690E-02 0.0000
    3     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION

   1.000

 FRESHWATER SPECIFIC STORAGE

  0.0000

 SALTWATER SPECIFIC STORAGE
    1     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    2     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     -1.000     0.0000
    3     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 EFFECTIVE POROSITY

  0.1000E-03

 AQUIFER THICKNESS

   80.00

 ELEVATION OF BASE OF AQUIFER

  -190.0

 INITIAL FRESHWATER HEAD
    1     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
          0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
   2   0.0000     5.775      5.634      5.274      4.769      4.197      3.781      3.508      3.234      2.949
        2.621     0.8600E-01 1.625      0.2800E-01 0.0000     0.1000E-02 0.1000E-02 0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 INITIAL INTERFACE ELEVATION
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     -234.5     -229.0     -214.8     -190.8     -167.9     -151.3     -140.3     -129.4     -118.0
       -104.9     -3.480     -65.04     -1.160    -0.4000E-01-0.4000E-01-0.4000E-01 0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 INITIAL SALTWATER HEADS
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000    -0.8585E-01-0.8780E-01-0.9366E-01-0.9512E-03-0.3659E-03-0.1073E-02-0.6098E-03-0.3171E-03-0.2927E-03
     -0.9756E-03-0.9756E-03-0.9756E-03-0.9756E-03-0.9756E-03-0.6939E-17-0.6939E-17 0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 FX
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       0.1670     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 FY
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
 SX
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     0.0000     0.0000     0.0000     0.4820      1.000      1.000      1.000      1.000      1.000
        1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
        1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 SY
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     0.0000     0.0000     0.0000     0.0000      1.000      1.000      1.000      1.000      1.000
        1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
        1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 AQUITARD LEAKANCES (K"/B")
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     0.1865E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07
       0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07
       0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.3730E-07 0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 -------------------------------
 AQUIFER PARAMETERS FOR LAYER  2
 -------------------------------

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03
       0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03
       0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.9000E-03 0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION

1.000

FRESHWATER SPECIFIC STORAGE

0.0000

SALTWATER SPECIFIC STORAGE

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.000	0.0000		
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		

EFFECTIVE POROSITY

0.1000E-03

AQUIFER THICKNESS

40.00

ELEVATION OF BASE OF AQUIFER

-90.00

INITIAL FRESHWATER HEAD

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
2	0.0000	5.838	5.683	5.307	4.767	4.158	3.746	3.474	3.201	2.912
	2.577	2.299	2.078	1.878	1.606	1.334	0.3250	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		

INITIAL INTERFACE ELEVATION

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
2	0.0000	-237.0	-230.9	-216.1	-195.3	-170.0	-153.4	-142.6	-131.6	-120.3
	-107.6	-91.99	-83.15	-75.14	-64.28	-53.38	-13.00	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		

Table 10.--Output file for example 2--continued

```
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 INITIAL SALTWATER HEADS
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000    -0.8585E-01-0.8780E-01-0.9268E-01-0.1122    -0.9073E-01-0.8780E-01-0.8780E-01-0.8780E-01-0.9366E-01
      -0.1093    -0.6585E-03-0.8537E-03-0.4146E-03-0.9512E-03-0.5366E-03-0.3553E-14 0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 FX
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
        1.000      1.000      1.000      1.000      1.000     0.8110     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 FY
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
        1.000      1.000      1.000      1.000      1.000      1.000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 SX
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.3250      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
        1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
SY
  1    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
        1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
  3    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

AQUITARD LEAKANCES (K"/B")
  1    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2    0.0000     0.2500E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09
       0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09
       0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.0000
  3    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

------------------------------
AQUIFER PARAMETERS FOR LAYER  3
------------------------------

HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION
  1    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2    0.0000     0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03
       0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03
       0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.0000
  3    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION

  1.000

FRESHWATER SPECIFIC STORAGE

 0.0000

SALTWATER SPECIFIC STORAGE
  1    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
   2   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    -1.000    0.0000
   3   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

 EFFECTIVE POROSITY

  0.1000E-03

 AQUIFER THICKNESS

   20.00

 ELEVATION OF BASE OF AQUIFER

  -30.00

 INITIAL FRESHWATER HEAD
   1   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   2   0.0000     11.99     10.39     8.481     5.999    0.1100E-01 0.2580    0.6000E-02 0.5000E-02 0.4000E-02
       0.4000E-02 0.3000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   3   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

 INITIAL INTERFACE ELEVATION
   1   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   2   0.0000    -479.6    -415.5    -339.2    -239.8    -0.3020    -10.20    -0.1200   -0.1200   -0.8000E-01
      -0.8000E-01-0.8000E-01-0.4000E-01-0.4000E-01-0.4000E-01 0.0000   0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   3   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

 INITIAL SALTWATER HEADS
   1   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   2   0.0000   -0.1137E-12-0.2274E-12-0.1137E-12 0.3146E-02 0.3366E-02 0.3024E-02 0.2927E-02 0.1951E-02 0.1951E-02
       0.1951E-02 0.9756E-03 0.9756E-03 0.9756E-03 0.9756E-03 0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   3   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
```

Table 10.--Output file for example 2--continued

```
 FX
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000      1.000      1.000      1.000      1.000     0.4810     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 FY
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000      1.000      1.000      1.000      1.000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 SX
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000     0.0000     0.0000     0.0000     0.2160      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 SY
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000     0.0000     0.0000     0.0000     0.0000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 AQUITARD LEAKANCES (K"/B")
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000     0.2320E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06
      0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06
      0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.0000
```

Table 10.--Output file for example 2--continued

```
   3  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 HEAD IN OVERLYING AQUIFER
   1  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   2  0.0000    12.00    10.39    8.485    6.000   0.0000   0.2500   0.2500   0.2500   0.2500
      0.2500   0.2500   0.2500   0.2500   0.2500   0.2500   0.2500   0.2500   0.2500   0.2500
      0.2500   0.2500   0.2500   0.2500   0.2500   0.2500   0.2500   0.0000
   3  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 BATHYMETRY
   1  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   2  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   -10.00   -10.00   -10.00   -10.00
      -10.00   -10.00   -10.00   -10.00   -10.00   -10.00   -10.00   -10.00   -10.00   -10.00
      -10.00   -10.00   -10.00   -10.00   -10.00   -10.00   -10.00   0.0000
   3  0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

CODE FOR UPPER LAYER (1-UNCONFINED NODE,0-CONFINED NODE)
   1     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
         0    0    0
   2     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
         0    0    0
   3     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
         0    0    0

 DELTA X

  4000.     4000.     4000.     4000.     4000.     4000.     2000.     2000.     2000.     2000.
  2000.     2000.     2000.     2000.     4000.     4000.     4000.     4000.     4000.     4000.
  4000.     4000.     4000.     4000.     4000.     4000.     4000.     4000.

 DELTA Y

  100.0     100.0     100.0

 ITERATION PARAMETERS:
  FRESHWATER EQUATION:.0000    .8872    .9873    .9986    .9998    1.000
```

Table 10.--Output file for example 2--continued

```
 ------------------------------------------------------------------------------
                                PUMPING PERIOD  1
 ------------------------------------------------------------------------------

                    INITIAL TIME STEP(SEC)= 0.3156E+07
                    MULTIPLICATION FACTOR FOR DELTA T=  1.300
                    LENGTH OF PUMPING PERIOD(DAYS)= 0.3652E+07
                    MAXIMUM NUMBER OF TIME STEPS= 29
                    NUMBER OF ACTIVE WELLS=  0

 RECHARGE

  0.0000

 -------------
 TIME STEP    1
 -------------
                              SECONDS      HOURS       DAYS       YEARS
   TIME STEP SIZE:            0.3156E+07  876.6       36.53      0.1000
   PUMPING PERIOD TIME:       0.3156E+07  876.6       36.53      0.1000
   TOTAL SIMULATION TIME:     0.3156E+07  876.6       36.53      0.1000

 MAXIMUM FRESHWATER HEAD CHANGE: 0.2175E-01 0.3895E-01 0.3998E-01 0.4530E-01 0.3370E-02 0.1787E-02 0.2179E-02 0.2680E-02
                                 0.2287E-02 0.1434E-02 0.1756E-02 0.4387E-03 0.2180E-03 0.5058E-03 0.1524E-03 0.4178E-03
                                 0.2612E-03 0.8152E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.5923E-02 0.2567E-01 0.2210E-01 0.4110E-01 0.3155E-02 0.1172E-02 0.1057E-02 0.2896E-02
                                 0.1983E-02 0.1525E-02 0.1026E-02 0.4757E-03 0.1226E-03 0.3019E-03 0.1469E-03 0.1504E-03
                                 0.9171E-04 0.4893E-04

 -------------
 TIME STEP    2
 -------------
                              SECONDS      HOURS       DAYS       YEARS
   TIME STEP SIZE:            0.4102E+07  1140.       47.48      0.1300
   PUMPING PERIOD TIME:       0.7258E+07  2016.       84.01      0.2300
   TOTAL SIMULATION TIME:     0.7258E+07  2016.       84.01      0.2300

 MAXIMUM FRESHWATER HEAD CHANGE: 0.3241E-02 0.1937E-02 0.6434E-02 0.4095E-02 0.7411E-02 0.8529E-03 0.6667E-03 0.2246E-02
                                 0.1448E-02 0.3731E-02 0.3432E-02 0.2778E-03 0.2860E-03 0.1050E-02 0.5048E-03 0.1243E-02
                                 0.1155E-02 0.1168E-03 0.9512E-04 0.4140E-03 0.1944E-03 0.4521E-03 0.3867E-03 0.3804E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.1731E-01 0.3973E-02 0.4697E-02 0.4275E-02 0.7108E-02 0.2727E-02 0.9611E-03 0.2407E-02
                                 0.1369E-02 0.2987E-02 0.3031E-02 0.6075E-03 0.2829E-03 0.1132E-02 0.4801E-03 0.1253E-02
                                 0.1123E-02 0.1940E-03 0.1144E-03 0.4539E-03 0.1848E-03 0.4583E-03 0.3768E-03 0.6324E-04

 -------------
 TIME STEP    3
 -------------
                              SECONDS      HOURS       DAYS       YEARS
   TIME STEP SIZE:            0.5333E+07  1481.       61.73      0.1690
   PUMPING PERIOD TIME:       0.1259E+08  3498.       145.7      0.3990
   TOTAL SIMULATION TIME:     0.1259E+08  3498.       145.7      0.3990
```

Table 10.--Output file for example 2--continued

```
 MAXIMUM FRESHWATER HEAD CHANGE: 0.1639E-02 0.2436E-02 0.6955E-02 0.5804E-02 0.8797E-02 0.9678E-03 0.7604E-03 0.2898E-02
                                  0.1952E-02 0.4601E-02 0.4194E-02 0.4008E-03 0.3404E-03 0.1411E-02 0.7621E-03 0.1713E-02
                                  0.1606E-02 0.1628E-03 0.1204E-03 0.6062E-03 0.3277E-03 0.6894E-03 0.6027E-03 0.6513E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.1247E-01 0.4247E-02 0.4963E-02 0.5988E-02 0.8456E-02 0.3048E-02 0.1130E-02 0.3104E-02
                                  0.1851E-02 0.3827E-02 0.3771E-02 0.7025E-03 0.3678E-03 0.1527E-02 0.7267E-03 0.1726E-02
                                  0.1562E-02 0.2541E-03 0.1662E-03 0.6643E-03 0.3110E-03 0.6996E-03 0.5874E-03 0.9553E-04


 -------------
 TIME STEP   4
 -------------
                         SECONDS      HOURS      DAYS       YEARS
   TIME STEP SIZE:       0.6933E+07  1926.       80.25      0.2197
   PUMPING PERIOD TIME:  0.1952E+08  5424.       226.0      0.6187
   TOTAL SIMULATION TIME: 0.1952E+08  5424.      226.0      0.6187

 MAXIMUM FRESHWATER HEAD CHANGE: 0.3133E-02 0.2676E-02 0.6400E-02 0.6334E-02 0.8801E-02 0.1420E-02 0.8424E-03 0.3058E-02
                                  0.2218E-02 0.4813E-02 0.4380E-02 0.4520E-03 0.3473E-03 0.1585E-02 0.9339E-03 0.1960E-02
                                  0.1854E-02 0.1835E-03 0.1211E-03 0.7348E-03 0.4411E-03 0.8640E-03 0.7698E-03 0.8754E-04
                                  0.5866E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.9004E-02 0.4499E-02 0.4400E-02 0.6497E-02 0.8470E-02 0.2975E-02 0.1137E-02 0.3278E-02
                                  0.2107E-02 0.4095E-02 0.3974E-02 0.7045E-03 0.4002E-03 0.1714E-02 0.8917E-03 0.1974E-02
                                  0.1804E-02 0.2848E-03 0.1970E-03 0.8034E-03 0.4189E-03 0.8759E-03 0.7505E-03 0.1213E-03
                                  0.8687E-04


 -------------
 TIME STEP   5
 -------------
                         SECONDS      HOURS      DAYS       YEARS
   TIME STEP SIZE:       0.9013E+07  2504.       104.3      0.2856
   PUMPING PERIOD TIME:  0.2854E+08  7927.       330.3      0.9043
   TOTAL SIMULATION TIME: 0.2854E+08  7927.      330.3      0.9043

 MAXIMUM FRESHWATER HEAD CHANGE: 0.4111E-02 0.2547E-02 0.5406E-02 0.6011E-02 0.7985E-02 0.1648E-02 0.8939E-03 0.2869E-02
                                  0.2229E-02 0.4547E-02 0.4131E-02 0.4304E-03 0.3210E-03 0.1582E-02 0.9958E-03 0.1986E-02
                                  0.1892E-02 0.1816E-03 0.1175E-03 0.7837E-03 0.5099E-03 0.9482E-03 0.8593E-03 0.1007E-03
                                  0.5788E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.6534E-02 0.4200E-02 0.3526E-02 0.6149E-02 0.7689E-02 0.2672E-02 0.1042E-02 0.3082E-02
                                  0.2121E-02 0.3903E-02 0.3790E-02 0.6381E-03 0.3919E-03 0.1707E-02 0.9513E-03 0.2000E-02
                                  0.1841E-02 0.3092E-03 0.2038E-03 0.8545E-03 0.4851E-03 0.9594E-03 0.8377E-03 0.1462E-03
                                  0.9734E-04


 -------------
 TIME STEP   6
 -------------
                         SECONDS      HOURS      DAYS       YEARS
   TIME STEP SIZE:       0.1172E+08  3255.       135.6      0.3713
   PUMPING PERIOD TIME:  0.4025E+08 0.1118E+05  465.9       1.276
   TOTAL SIMULATION TIME: 0.4025E+08 0.1118E+05 465.9       1.276

 MAXIMUM FRESHWATER HEAD CHANGE: 0.4072E-02 0.2166E-02 0.4261E-02 0.5151E-02 0.6682E-02 0.1566E-02 0.7937E-03 0.2451E-02
                                  0.2017E-02 0.3924E-02 0.3559E-02 0.3646E-03 0.2716E-03 0.1431E-02 0.9493E-03 0.1821E-02
```

```
                              0.1746E-02 0.1636E-03 0.1038E-03 0.7526E-03 0.5202E-03 0.9319E-03 0.8573E-03 0.1025E-03
                              0.5047E-04
MAXIMUM SALTWATER HEAD CHANGE: 0.4672E-02 0.3545E-02 0.2589E-02 0.5266E-02 0.6436E-02 0.2212E-02 0.8785E-03 0.2637E-02
                              0.1920E-02 0.3385E-02 0.3289E-02 0.5730E-03 0.3535E-03 0.1537E-02 0.9065E-03 0.1833E-02
                              0.1698E-02 0.3020E-03 0.1885E-03 0.8161E-03 0.4958E-03 0.9405E-03 0.8357E-03 0.1542E-03
                              0.9659E-04

-------------
TIME STEP   7
-------------
                        SECONDS      HOURS      DAYS      YEARS
  TIME STEP SIZE:       0.1523E+08  4231.       176.3     0.4827
  PUMPING PERIOD TIME:  0.5549E+08 0.1541E+05  642.2      1.758
  TOTAL SIMULATION TIME: 0.5549E+08 0.1541E+05 642.2      1.758

MAXIMUM FRESHWATER HEAD CHANGE: 0.3333E-02 0.1652E-02 0.3120E-02 0.3989E-02 0.5125E-02 0.1264E-02 0.6068E-03 0.1903E-02
                              0.1634E-02 0.3076E-02 0.2782E-02 0.2795E-03 0.2085E-03 0.1166E-02 0.8077E-03 0.1504E-02
                              0.1449E-02 0.1388E-03 0.7548E-04 0.6464E-03 0.4707E-03 0.8198E-03 0.7607E-03 0.9173E-04
                              0.3731E-04
MAXIMUM SALTWATER HEAD CHANGE: 0.3210E-02 0.2705E-02 0.1724E-02 0.4079E-02 0.4937E-02 0.1668E-02 0.6751E-03 0.2051E-02
                              0.1554E-02 0.2663E-02 0.2586E-02 0.4723E-03 0.2861E-03 0.1248E-02 0.7706E-03 0.1513E-02
                              0.1410E-02 0.2636E-03 0.1611E-03 0.6984E-03 0.4523E-03 0.8218E-03 0.7414E-03 0.1428E-03
                              0.8701E-04

-------------
TIME STEP   8
-------------
                        SECONDS      HOURS      DAYS      YEARS
  TIME STEP SIZE:       0.1980E+08  5501.       229.2     0.6275
  PUMPING PERIOD TIME:  0.7529E+08 0.2091E+05  871.4      2.386
  TOTAL SIMULATION TIME: 0.7529E+08 0.2091E+05 871.4      2.386

MAXIMUM FRESHWATER HEAD CHANGE: 0.2280E-02 0.1109E-02 0.2508E-02 0.2905E-02 0.3561E-02 0.8879E-03 0.4470E-03 0.1279E-02
                              0.1261E-02 0.2329E-02 0.2140E-02 0.2226E-03 0.1204E-03 0.8290E-03 0.6340E-03 0.1126E-02
                              0.1094E-02 0.1034E-03 0.5552E-04 0.4846E-03 0.3589E-03 0.6238E-03 0.5810E-03 0.6836E-04
                              0.2481E-04
MAXIMUM SALTWATER HEAD CHANGE: 0.2054E-02 0.1670E-02 0.1275E-02 0.2968E-02 0.3405E-02 0.1283E-02 0.4881E-03 0.1359E-02
                              0.1186E-02 0.1920E-02 0.1895E-02 0.3947E-03 0.2050E-03 0.8846E-03 0.6016E-03 0.1127E-02
                              0.1064E-02 0.1995E-03 0.1193E-03 0.5189E-03 0.3440E-03 0.6227E-03 0.5661E-03 0.1119E-03
                              0.6733E-04

-------------
TIME STEP   9
-------------
                        SECONDS      HOURS      DAYS      YEARS
  TIME STEP SIZE:       0.2574E+08  7151.       297.9     0.8157
  PUMPING PERIOD TIME:  0.1010E+09 0.2806E+05  1169.      3.201
  TOTAL SIMULATION TIME: 0.1010E+09 0.2806E+05 1169.      3.201

MAXIMUM FRESHWATER HEAD CHANGE: 0.1314E-02 0.6800E-03 0.1545E-02 0.1797E-02 0.2212E-02 0.5297E-03 0.2645E-03 0.8020E-03
                              0.8040E-03 0.1456E-02 0.1336E-02 0.1450E-03 0.7177E-04 0.5323E-03 0.4215E-03 0.7294E-03
```

```
                                  0.7123E-03 0.6896E-04 0.3462E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.1199E-02 0.1017E-02 0.6773E-03 0.1836E-02 0.2112E-02 0.7717E-03 0.2980E-03 0.8523E-03
                                  0.7536E-03 0.1201E-02 0.1180E-02 0.2443E-03 0.1307E-03 0.5669E-03 0.3988E-03 0.7301E-03
                                  0.6922E-03 0.1315E-03 0.7849E-04

 -------------
 TIME STEP  10
 -------------
                         SECONDS       HOURS       DAYS        YEARS
   TIME STEP SIZE:       0.3347E+08  9296.       387.3       1.060
   PUMPING PERIOD TIME:  0.1345E+09 0.3736E+05  1557.        4.262
   TOTAL SIMULATION TIME: 0.1345E+09 0.3736E+05  1557.       4.262

 MAXIMUM FRESHWATER HEAD CHANGE: 0.5876E-03 0.4042E-03 0.8119E-03 0.1097E-02 0.1274E-02 0.2457E-03 0.1251E-03 0.4793E-03
                                  0.4940E-03 0.8331E-03 0.7788E-03 0.1021E-03 0.3884E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.5855E-03 0.5945E-03 0.2743E-03 0.1117E-02 0.1216E-02 0.4100E-03 0.1652E-03 0.5086E-03
                                  0.4607E-03 0.7195E-03 0.7090E-03 0.1514E-03 0.8184E-04

 -------------
 TIME STEP  11
 -------------
                         SECONDS       HOURS       DAYS        YEARS
   TIME STEP SIZE:       0.4350E+08 0.1208E+05  503.5        1.379
   PUMPING PERIOD TIME:  0.1780E+09 0.4944E+05  2060.        5.641
   TOTAL SIMULATION TIME: 0.1780E+09 0.4944E+05  2060.       5.641

 MAXIMUM FRESHWATER HEAD CHANGE: 0.2581E-03 0.2398E-03 0.4172E-03 0.6943E-03 0.7415E-03 0.1107E-03 0.6151E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.2642E-03 0.3520E-03 0.1677E-03 0.7053E-03 0.7068E-03 0.2149E-03 0.9177E-04

 -------------
 TIME STEP  12
 -------------
                         SECONDS       HOURS       DAYS        YEARS
   TIME STEP SIZE:       0.5656E+08 0.1571E+05  654.6        1.792
   PUMPING PERIOD TIME:  0.2346E+09 0.6516E+05  2715.        7.433
   TOTAL SIMULATION TIME: 0.2346E+09 0.6516E+05  2715.       7.433

 MAXIMUM FRESHWATER HEAD CHANGE: 0.9342E-04 0.1489E-03 0.2412E-03 0.4586E-03 0.4684E-03 0.5356E-04 0.3564E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.1118E-03 0.2230E-03 0.1221E-03 0.4657E-03 0.4457E-03 0.1227E-03 0.5523E-04

 *************************
 STEADY STATE ACHIEVED AT:
 *************************

 -------------
 TIME STEP  13
 -------------
                         SECONDS       HOURS       DAYS        YEARS
   TIME STEP SIZE:       0.7352E+08 0.2042E+05  851.0        2.330
   PUMPING PERIOD TIME:  0.3081E+09 0.8558E+05  3566.        9.763
   TOTAL SIMULATION TIME: 0.3081E+09 0.8558E+05  3566.       9.763
```

Table 10.--Output file for example 2--continued

```
 MAXIMUM FRESHWATER HEAD CHANGE: 0.4119E-04
 MAXIMUM SALTWATER HEAD CHANGE:  0.5008E-04

 AQUIFER   1
 -----------
      MASS BALANCE:
                                        FRESHWATER                      SALTWATER
                                T.S. RATE   CUM. VOLUME         T.S. RATE   CUM. VOLUME
          CHANGE IN STORAGE     0.2796E-08  543.1              -0.2796E-08 -543.1
           SOURCES
             RECHARGE            0.0000     0.0000
             CONSTANT HEAD NODES 0.0000     0.0000               0.0000     0.0000
             INJECTION           0.0000     0.0000               0.0000     0.0000
             FW LEAKAGE ACROSS TOP 0.1800E-02 0.5539E+06         0.0000     0.0000
             FW LEAKAGE ACROSS BOT 0.0000   0.0000               0.0000     0.0000
             SW LEAKAGE ACROSS TOP 0.0000   0.0000               0.7825E-07  146.8
             SW LEAKAGE ACROSS BOT 0.0000   0.0000               0.0000     0.0000
             TOTAL               0.1800E-02 0.5539E+06           0.7825E-07  146.8
           SINKS
             CONSTANT HEAD NODES 0.0000     0.0000               0.1553E-06  224.3
             PUMPAGE             0.0000     0.0000               0.0000     0.0000
             LEAKAGE ACROSS TOP  0.1800E-02 0.5534E+06           0.2986E-06  695.5
             LEAKAGE ACROSS BOT  0.0000     0.0000               0.0000     0.0000
             TOTAL               0.1800E-02 0.5534E+06           0.4540E-06  919.8
           SOURCES-SINKS        -0.4922E-07  520.1              -0.3757E-06 -772.9
         RELATIVE ERROR (%)
             INFLUX              0.2890E-02 0.4160E-02            476.6      156.5
             STORAGE              1860.      4.243              -0.1334E+05 -42.32

 FRESHWATER HEADS
    1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    2   11111.     5.8641     5.7254     5.3717     4.8757     4.2943     3.8756     3.6007     3.3266     3.0461
        2.7356     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 SALTWATER HEADS
    1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    2   11111.     11111.     11111.     11111.    0.60417E-030.60152E-030.59940E-030.59794E-030.59644E-030.59490E-03
       0.59332E-030.59169E-030.58943E-030.58224E-030.55821E-030.51332E-030.45684E-030.40546E-030.35839E-030.31360E-03
       0.26944E-030.22500E-030.18007E-030.13488E-030.89756E-040.44839E-040.00000     11111.
    3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
```

Table 10.--Output file for example 2--continued

```
 INTERFACE ELEVATION
   1    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   2    11111.     11111.     11111.     11111.     11111.    -171.75    -155.00    -144.00    -133.04    -121.82
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   3    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 MAP OF EXTENT OF INTRUSION (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)

   1    . . . . . . . . . . . . . . . . . . . . . . . . . . . .
   2    . F F F F M M M M M S S S S S S S S S S S S S S S S S S .
   3    . . . . . . . . . . . . . . . . . . . . . . . . . . . .

 AQUIFER   2
 -----------
      MASS BALANCE:
                                        FRESHWATER                     SALTWATER
                                  T.S. RATE   CUM. VOLUME        T.S. RATE   CUM. VOLUME
          CHANGE IN STORAGE       0.2861E-08  276.9             -0.2861E-08 -276.9
           SOURCES
             RECHARGE              0.0000      0.0000
             CONSTANT HEAD NODES   0.0000      0.0000             0.0000      0.0000
             INJECTION             0.0000      0.0000             0.0000      0.0000
             FW LEAKAGE ACROSS TOP 0.2367E-02 0.7289E+06          0.0000      0.0000
             FW LEAKAGE ACROSS BOT 0.1800E-02 0.5534E+06          0.0000      0.0000
             SW LEAKAGE ACROSS TOP 0.0000      0.0000             0.0000      0.0000
             SW LEAKAGE ACROSS BOT 0.0000      0.0000             0.2986E-06  695.5
             TOTAL                 0.4167E-02 0.1282E+07          0.2986E-06  695.5
           SINKS
             CONSTANT HEAD NODES   0.0000      0.0000             0.4086E-07  59.21
             PUMPAGE               0.0000      0.0000             0.0000      0.0000
             LEAKAGE ACROSS TOP    0.2367E-02 0.7281E+06          0.4927E-06  867.6
             LEAKAGE ACROSS BOT    0.1800E-02 0.5539E+06          0.7825E-07  146.8
             TOTAL                 0.4167E-02 0.1282E+07          0.6118E-06  1074.
           SOURCES-SINKS          -0.2414E-07  265.3             -0.3131E-06 -378.2
         RELATIVE ERROR (%)
             INFLUX                0.6478E-03 0.9085E-03           103.9       14.56
             STORAGE                943.7       4.207            -0.1085E+05 -36.58

 FRESHWATER HEADS
   1    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   2    11111.     5.9269     5.7741     5.4039     4.8840     4.2536     3.8386     3.5662     3.2935     3.0106
        2.6922     2.3853     2.1553     1.9482     1.6668     1.3773     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
```

Table 10.--Output file for example 2--continued

```
   3   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.

 SALTWATER HEADS
   1   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
   2   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.   0.59451E-030.58513E-030.55923E-030.51368E-030.45326E-030.40229E-030.35568E-030.31124E-03
      0.26735E-030.22316E-030.17850E-030.13362E-030.88852E-040.44294E-040.00000      11111.
   3   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.

 INTERFACE ELEVATION
   1   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
   2   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.   -86.188   -77.904   -66.647   -55.072    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
   3   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
       11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.

 MAP OF EXTENT OF INTRUSION (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)

   1   . . . . . . . . . . . . . . . . . . . . . . . . . . . .
   2   . F F F F F F F F F F F M M M M S S S S S S S S S S S .
   3   . . . . . . . . . . . . . . . . . . . . . . . . . . . .
```

Table 10.--Output file for example 2--continued

```
 AQUIFER   3
 -----------
      MASS BALANCE:
                                       FRESHWATER                      SALTWATER
                                 T.S. RATE   CUM. VOLUME        T.S. RATE   CUM. VOLUME
          CHANGE IN STORAGE      0.3316E-14 0.6953             -0.3316E-14-0.6953
           SOURCES
             RECHARGE             0.0000     0.0000
             CONSTANT HEAD NODES  0.0000     0.0000              0.3297E-15 0.1016E-06
             INJECTION            0.0000     0.0000              0.0000     0.0000
             FW LEAKAGE ACROSS TOP 0.3048E-02 0.9387E+06         0.0000     0.0000
             FW LEAKAGE ACROSS BOT 0.3827E-03 0.1179E+06         0.1985E-02 0.6101E+06
             SW LEAKAGE ACROSS TOP 0.0000     0.0000             0.0000     0.0000
             SW LEAKAGE ACROSS BOT 0.0000     0.0000             0.4927E-06  867.6
             TOTAL                0.3431E-02 0.1057E+07          0.1985E-02 0.6110E+06
           SINKS
             CONSTANT HEAD NODES  0.0000     0.0000              0.1132E-10 0.1467E-01
             PUMPAGE              0.0000     0.0000              0.0000     0.0000
             LEAKAGE ACROSS TOP   0.1064E-02 0.3278E+06          0.1985E-02 0.6110E+06
             LEAKAGE ACROSS BOT   0.2367E-02 0.7289E+06          0.0000     0.0000
             TOTAL                0.3431E-02 0.1057E+07          0.1985E-02 0.6110E+06
           SOURCES-SINKS         -0.5195E-09  1.243              0.2415E-07  6.010
         RELATIVE ERROR (%)
             INFLUX               0.1514E-04-0.5183E-04         -0.1216E-02-0.1097E-02
             STORAGE              0.1567E+08 -78.77              0.7282E+09  964.3

 FRESHWATER HEADS
    1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    2   11111.     11.989     10.387     8.4813     5.9982    0.11911E-01 11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 SALTWATER HEADS
    1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    2   11111.     11111.     11111.     11111.     11111.    0.30458E-020.30539E-020.27623E-020.24686E-020.21640E-02
       0.18216E-020.14916E-020.12437E-020.10207E-020.71777E-030.38088E-030.97665E-060.43643E-060.38486E-060.33615E-06
       0.28818E-060.24014E-060.19187E-060.14358E-060.95501E-070.47611E-070.00000     11111.
    3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
```

Table 10.--Output file for example 2--continued

```
 INTERFACE ELEVATION
    1   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
    2   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
    3   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.

 MAP OF EXTENT OF INTRUSION (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)

    1   . . . . . . . . . . . . . . . . . . . . . . . . . . . .
    2   . F F F F S S S S S S S S S S S S S S S S S S S S S S .
    3   . . . . . . . . . . . . . . . . . . . . . . . . . . . .
```

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APPENDIX A. MATRIX COEFFICIENTS

The compact finite-difference equation (40) can be expanded into the discretized freshwater and saltwater flow equations, respectively:

$$Z^1\Phi^n_{f_{k-1}} + Z^2\Phi^n_{s_{k-1}} + B^1\Phi^n_{f_{i-1}} + D^1\Phi^n_{f_{j-1}} + E^1\Phi^n_f + E^2\Phi^n_s +$$

$$F^1\Phi^n_{f_{j+1}} + H^1\Phi^n_{f_{i+1}} + S^1\Phi^n_{f_{k+1}} + S^2\Phi^n_{s_{k+1}} = Q^1 \qquad \text{(A.1)}$$

$$Z^3\Phi^n_{f_{k-1}} + Z^4\Phi^n_{s_{k-1}} + B^4\Phi^n_{s_{i-1}} + D^4\Phi^n_{s_{j-1}} + E^3\Phi^n_f + E^4\Phi^n_s +$$

$$F^4\Phi^n_{s_{j+1}} + H^4\Phi^n_{s_{i+1}} + S^3\Phi^n_{f_{k+1}} + S^4\Phi^n_{s_{k+1}} = Q^2 \qquad \text{(A.2)}$$

where:

$$B^1 = T^n_{fy_{i-1/2}}\Delta x \qquad B^4 = T^n_{sy_{i-1/2}}\Delta x$$

$$D^1 = T^n_{fx_{j-1/2}}\Delta y \qquad D^4 = T^n_{sx_{j-1/2}}\Delta y$$

$$F^1 = T^n_{fx_{j+1/2}}\Delta y \qquad F^4 = T^n_{sx_{j+1/2}}\Delta y$$

$$H^1 = T^n_{fy_{i+1/2}}\Delta x \qquad H^4 = T^n_{sy_{i+1/2}}\Delta x$$

$$B^2 = B^3 = D^2 = D^3 = F^2 = F^3 = H^2 = H^3 = 0$$

$$E^1 = -\{(Z^1 - z^1) + \frac{\gamma_f}{\gamma_s}Z^2 + B^1 + D^1 + F^1 + H^1 + S^1 + \frac{\gamma_f}{\gamma_s}S^2 + [\frac{S_f B^n_f + n(\alpha + \text{SAREA}\,\delta)}{\Delta t}]\ \Delta x\Delta y\}$$

$$E^2 = \frac{\text{SAREA}\ n(1+\delta)}{\Delta t}\ \Delta x\Delta y - e^5$$

$$E^3 = \frac{\text{FAREA}\ n\delta}{\Delta t}\ \Delta x\Delta y$$

$$E^4 = -\{\frac{\gamma_s}{\gamma_f}Z^3 + Z^4 + B^4 + D^4 + F^4 + H^4 + \frac{\gamma_s}{\gamma_f}S^3 + S^4 + [\frac{S_s B^n_s + \text{FAREA}\ n(1+\delta)}{\Delta t}]\ \Delta x\Delta y\}$$

$$Q^1 = (E^2 - e^5)\Phi_s^{n-1} - [\frac{S_f B_f^n + n(\alpha + SAREA\delta)}{\Delta t}]\ \Phi_f^{n-1}\Delta x\Delta y - \alpha N\Delta x\Delta y - \{\frac{Th_f P_t}{Th_t}\}^n - QFL^1 - QFL^2$$

$$Q^2 = E^3\Phi_f^{n-1} - [\frac{S_s B_s^n + FAREA\ n(1+\delta)}{\Delta t}]\ \Phi_s^{n-1}\Delta x\Delta y - \{P_t - \frac{Th_f P_t}{Th_t}\}^n - QSL^1 - QSL^2$$

and z^1, z^2, z^3, z^4, s^1, s^2, s^3, s^4, QFL and QSL are as given below.

$FAREA \geq 1-SAREA_{k+1}$: $\quad s^1 = (1-SAREA_{k+1})\ (\frac{K'}{B'})\ \Delta x\Delta y$

$$s^2 = \omega_1(FAREA-(1-SAREA_{k+1}))(\frac{K'}{B'})\ (\frac{\gamma_s}{\gamma_f})\ \Delta x\Delta y$$

$$s^4 = (1-FAREA)\ (\frac{K'}{B'})\ \Delta x\Delta y$$

$$QFL^1 = -\omega_1(FAREA-(1-SAREA_{k+1}))(\frac{K'}{B'})\ \frac{z_a + z_b}{2\delta}\ \Delta x\Delta y$$

$FAREA < 1-SAREA_{k+1}$: $\quad s^1 = FAREA\ (\frac{K'}{B'})\ \Delta x\Delta y$

$$s^3 = \omega_2(1-FAREA-SAREA_{k+1})\ (\frac{K'}{B'})\ \Delta x\Delta y$$

$$s^4 = SAREA_{k+1}\ (\frac{K'}{B'})\ \Delta x\Delta y$$

$$QSL^1 = \omega_1(1-FAREA-SAREA_{k+1})\ (\frac{K'}{B'})\ \frac{z_a + z_b}{2\delta}\ \Delta x\Delta y$$

$FAREA_{k-1} \geq 1-SAREA$: $\quad z^1 = (1-SAREA)\ (\frac{K'}{B'})_{k-1}\ \Delta x\Delta y + z^1$

$$z^3 = \psi(1-\omega_3)(FAREA_{k-1}-(1-SAREA))\ (\frac{K'}{B'})_{k-1}\ \Delta x\Delta y$$

$$z^4 = (1-FAREA_{k-1})\ (\frac{K'}{B'})_{k-1}\ \Delta x\Delta y$$

$$QFL^2 = z^1\ (\frac{z_a + z_b}{2\delta})_{k-1}$$

$$QSL^2 = \psi(1-\omega_3)(FAREA_{k-1}-(1-SAREA))$$

$$(\frac{K'}{B'})_{k-1}(\frac{z_a + z_b}{2\delta})_{k-1}\Delta x\Delta y$$

$FAREA_{k-1} < 1-SAREA$: $\quad z^1 = FAREA_{k-1}\ (\frac{K'}{B'})_{k-1}\ \Delta x\Delta y$

$$Z^2 = \omega_4(1\text{-FAREA}_{k-1}\text{-SAREA})\ (\frac{K'}{B'})_{k-1}\ \frac{\gamma_s}{\gamma_f}\ \Delta x \Delta y$$

$$Z^4 = \text{SAREA}\ (\frac{K'}{B'})_{k-1}\ \Delta x \Delta y$$

$$QFL^2 = \omega_4(1\text{-FAREA}_{k-1}\text{-SAREA})\ (\frac{K'}{B'})_{k-1}(\frac{z_a + z_b}{2\delta})_{k+1}\Delta x \Delta y$$

where:

$$z^1 = \psi\omega_3(\text{FAREA}_{k-1}\text{-}(1\text{-SAREA}))\ (\frac{K'}{B'})_{k-1}\ \Delta x \Delta y$$

$$e^5 = \frac{\gamma_s}{\gamma_f}\ z^1$$

and for method 1 leakage (complete mixing):

$\omega_1 = \omega_2 = \omega_4 = \psi = 1$

$\omega_3 = 0$

for method 2 leakage (restricted mixing):

$\omega_2 = \omega_4 = 0$

$\omega_3 = F_{ar}$

$\psi = \omega_1 = 1$ for freshwater leaking upwards into saltwater

$\psi = \omega_1 = 0$ for saltwater leaking downwards into freshwater

APPENDIX B. THE STRONGLY IMPLICIT PROCEDURE (SIP) FOR THREE-DIMENSIONAL TWO-PHASE FLOW

The strongly implicit procedure for three-dimensional two-phase flow is developed below. Figure B1 shows the structure of the modified coefficient matrix (**A+B**) and the sparse lower and upper triangular matrices (**LU**) into which this matrix can be factored.

A.1 The SIP algorithm

The system of equations which must be solved is expressed as:

$$\mathbf{A}\xi^{n} = \mathbf{R}^{n-1} \tag{B.1}$$

where the finite-difference equations at each node are:

$$\mathbf{B}\xi_{i-1jk}+\mathbf{D}\xi_{ij-1k}+\mathbf{E}\xi_{ijk}+\mathbf{F}\xi_{ij+1k}+\mathbf{H}\xi_{i+1jk}+\mathbf{Z}\xi_{ijk-1}+\mathbf{S}\xi_{ijk+1} = \mathbf{R}^{n-1}_{ijk} \tag{B.2}$$

The modified equation solved in the SIP algorithm is:

$$(\mathbf{A}+\mathbf{B})\xi^{n} = \mathbf{R}^{n-1} \tag{B.3}$$

and at each node (ω is a weighting factor):

$$\begin{aligned}
&\mathbf{B}\xi_{i-1jk}+\mathbf{D}\xi_{ij-1k}+\mathbf{E}\xi_{ijk}+\mathbf{F}\xi_{ij+1k}+\mathbf{H}\xi_{i+1jk}+\mathbf{Z}\xi_{ijk-1}+\mathbf{S}\xi_{ijk+1} + \\
&\quad \mathbf{C}[\xi_{i-1j+1k}-\omega(-\xi_{ijk}+\xi_{ij+1k}+\xi_{i-1jk})] + \mathbf{G}[\xi_{i+1j-1k}-\omega(-\xi_{ijk}+\xi_{ij-1k}+\xi_{i+1jk})] + \\
&\quad \mathbf{A}[\xi_{ij+1k-1}-\omega(-\xi_{ijk}+\xi_{ij+1k}+\xi_{ijk-1})] + \mathbf{W}[\xi_{ij-1k+1}-\omega(-\xi_{ijk}+\xi_{ij-1k}+\xi_{ijk+1})] + \\
&\quad \mathbf{T}[\xi_{i+1jk-1}-\omega(-\xi_{ijk}+\xi_{ijk-1}+\xi_{i+1jk})] + \mathbf{U}[\xi_{i-1jk+1}-\omega(-\xi_{ijk}+\xi_{ijk+1}+\xi_{i-1jk})] = \mathbf{R}^{n-1}
\end{aligned} \tag{B.4}$$

Rearranging and collecting terms:

$$\begin{aligned}
&\mathbf{A}\xi_{ij+1k-1}+\tilde{\mathbf{B}}\xi_{i-1jk}+\mathbf{C}\xi_{i-1j+1k}+\tilde{\mathbf{D}}\xi_{ij-1k}+\tilde{\mathbf{E}}\xi_{ijk}+\tilde{\mathbf{F}}\xi_{ij+1k}+\mathbf{G}\xi_{i+1j-1k}+\tilde{\mathbf{H}}\xi_{i+1jk}+\tilde{\mathbf{Z}}\xi_{ijk-1}+ \\
&\quad \tilde{\mathbf{S}}\xi_{ijk+1}+\mathbf{W}\xi_{ij-1k+1}+\mathbf{T}\xi_{i+1jk-1}+\mathbf{U}\xi_{i-1jk+1} = \mathbf{R}^{n-1}
\end{aligned} \tag{B.5}$$

where:

$$\tilde{\mathbf{B}} = \mathbf{B}-\omega(\mathbf{C}-\mathbf{U}) \tag{B.6a}$$

$$\tilde{\mathbf{D}} = \mathbf{D}-\omega(\mathbf{G}-\mathbf{W}) \tag{B.6b}$$

$$\tilde{\mathbf{E}} = \mathbf{E}+\omega(\mathbf{C}+\mathbf{G}+\mathbf{A}+\mathbf{W}+\mathbf{T}+\mathbf{U}) \tag{B.6c}$$

$$\tilde{\mathbf{F}} = \mathbf{F}-\omega(\mathbf{C}-\mathbf{A}) \tag{B.6d}$$

$$\tilde{\mathbf{H}} = \mathbf{H}-\omega(\mathbf{G}-\mathbf{T}) \tag{B.6e}$$

$$\tilde{\mathbf{Z}} = \mathbf{Z}-\omega(\mathbf{A}-\mathbf{T}) \tag{B.6f}$$

$$\tilde{\mathbf{S}} = \mathbf{S}-\omega(\mathbf{W}-\mathbf{U}) \tag{B.6g}$$

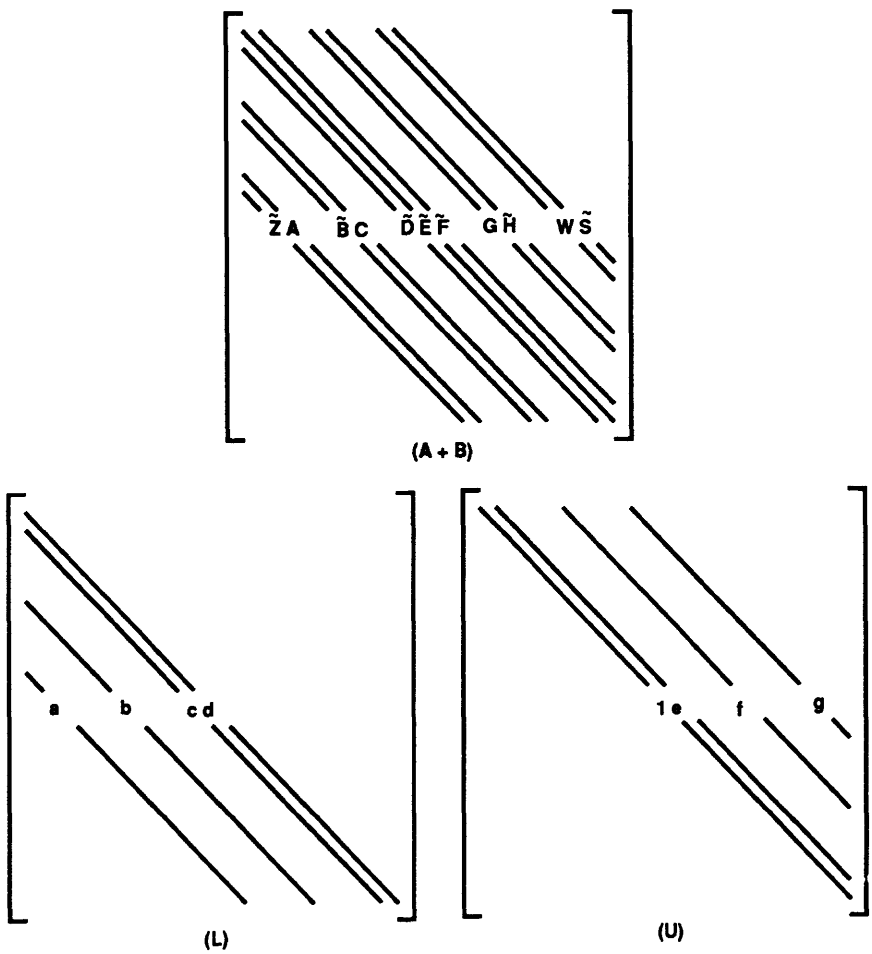

Figure B1.--The structure of the modified coefficient matrix (**A**+**B**) and the sparse lower triangular (**L**) and upper triangular (**U**) matrices used in the strongly implicit procedure.

By factorization of $(\mathbf{A}+\mathbf{B})$:

$$(\mathbf{A}+\mathbf{B}) = \mathbf{LU}$$

the coefficients become:

$$\tilde{\mathbf{Z}} = \mathbf{a}_{ijk} \tag{B.7a}$$

$$\mathbf{A} = \mathbf{a}_{ijk}\mathbf{e}_{ijk-1} \tag{B.7b}$$

$$\mathbf{T} = \mathbf{a}_{ijk}\mathbf{f}_{ijk-1} \tag{B.7c}$$

$$\tilde{\mathbf{B}} = \mathbf{b}_{ijk} \tag{B.7d}$$

$$\mathbf{C} = \mathbf{b}_{ijk}\mathbf{e}_{i-1jk} \tag{B.7e}$$

$$\tilde{\mathbf{D}} = \mathbf{c}_{ijk} \tag{B.7f}$$

$$\tilde{\mathbf{E}} = \mathbf{a}_{ijk}\mathbf{g}_{ijk-1}+\mathbf{b}_{ijk}\mathbf{f}_{i-1jk}+\mathbf{c}_{ijk}\mathbf{e}_{ij-1k}+\mathbf{d}_{ijk} \tag{B.7g}$$

$$\tilde{\mathbf{F}} = \mathbf{d}_{ijk}\mathbf{e}_{ijk} \tag{B.7h}$$

$$\mathbf{G} = \mathbf{c}_{ijk}\mathbf{f}_{ij-1k} \tag{B.7i}$$

$$\tilde{\mathbf{H}} = \mathbf{d}_{ijk}\mathbf{f}_{ijk} \tag{B.7j}$$

$$\mathbf{U} = \mathbf{b}_{ijk}\mathbf{g}_{i-1jk} \tag{B.7k}$$

$$\mathbf{W} = \mathbf{c}_{ijk}\mathbf{g}_{ij-1k} \tag{B.7l}$$

$$\tilde{\mathbf{S}} = \mathbf{d}_{ijk}\mathbf{g}_{ijk} \tag{B.7m}$$

From (B.6f) and (B.7a):

$$\tilde{\mathbf{Z}} = \mathbf{a}_{ijk} = \mathbf{Z}-\omega(\mathbf{A}-\mathbf{T}) \tag{B.8}$$

and substituting (B.7b) and (B.7c):

$$\tilde{\mathbf{Z}} = \mathbf{a}_{ijk} = \mathbf{Z} -\omega(\mathbf{a}_{ijk}\mathbf{e}_{ijk-1}-\mathbf{a}_{ijk}\mathbf{f}_{ijk-1}) \tag{B.9}$$

rearranging:

$$\mathbf{a}_{ijk} = \mathbf{Z}(1+\omega(\mathbf{e}_{ijk-1}+\mathbf{f}_{ijk-1})^{-1} \tag{B.10}$$

Similarly:

$$\mathbf{b}_{ijk} = \mathbf{B}(1+\omega(\mathbf{e}_{i-1jk}+\mathbf{f}_{i-1jk})^{-1} \tag{B.11}$$

$$\mathbf{c}_{ijk} = \mathbf{D}(1+\omega(\mathbf{f}_{ij-1k}+\mathbf{g}_{ij-1k})^{-1} \tag{B.12}$$

From (B.6c) and (B.7g):

$$\mathbf{d}_{ijk} = \mathbf{E}+\omega(\mathbf{C}+\mathbf{G}+\mathbf{A}+\mathbf{W}+\mathbf{T}+\mathbf{U})-\mathbf{a}_{ijk}\mathbf{g}_{ijk-1}-\mathbf{b}_{ijk}\mathbf{f}_{i-1jk}-\mathbf{c}_{ijk}\mathbf{e}_{ij-1k} \tag{B.13}$$

From (B.6d) and (B.7h):

$$\mathbf{e}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{F}-\omega(\mathbf{C}+\mathbf{A})) \tag{B.14}$$

Similarly:

$$\mathbf{f}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{H}-\omega(\mathbf{G}+\mathbf{T})) \tag{B.15}$$

$$\mathbf{g}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{S}-\omega(\mathbf{W}+\mathbf{U})) \tag{B.16}$$

Finally the three-dimensional SIP algorithm becomes:

$$\mathbf{a}_{ijk} = \mathbf{Z}(1+\omega(\mathbf{e}_{ijk-1}+\mathbf{f}_{ijk-1})^{-1} \tag{B.17}$$

$$a^1 = [Z^1(1+\omega(e^4_{ijk-1}+f^4_{ijk-1})-Z^2(\omega(e^3_{ijk-1}+f^3_{ijk-1}))]\div det1$$

$$a^2 = [Z^2(1+\omega(e^1_{ijk-1}+f^1_{ijk-1})-Z^1(\omega(e^2_{ijk-1}+f^2_{ijk-1}))]\div det1$$

$$a^3 = [Z^3(1+\omega(e^4_{ijk-1}+f^4_{ijk-1})-Z^4(\omega(e^3_{ijk-1}+f^3_{ijk-1}))]\div det1$$

$$a^4 = [Z^4(1+\omega(e^1_{ijk-1}+f^1_{ijk-1})-Z^3(\omega(e^2_{ijk-1}+f^2_{ijk-1}))]\div det1$$

$$det1 = (1+\omega(e^1_{ijk-1}+f^1_{ijk-1}))(1+\omega(e^4_{ijk-1}+f^4_{ijk-1}))-(\omega(e^2_{ijk-1}+f^2_{ijk-1}))(\omega(e^3_{ijk-1}+f^3_{ijk-1}))$$

$$\mathbf{b}_{ijk} = \mathbf{B}(1+\omega(\mathbf{e}_{i-1jk}+\mathbf{f}_{i-1jk})^{-1} \tag{B.18}$$

$$b^1 = [BF(1+\omega(e^4_{i-1jk}+g^4_{i-1jk}))]\div det2$$

$$b^2 = [-BF(\omega(e^2_{i-1jk}+g^2_{i-1jk}))]\div det2$$

$$b^3 = [-BS(\omega(e^3_{i-1jk}+g^3_{i-1jk}))]\div det2$$

$$b^4 = [BS(1+\omega(e^1_{i-1jk}+g^1_{i-1jk}))]\div det2$$

$$det2 = (1+\omega(e^1_{i-1jk}+g^1_{i-1jk}))(1+\omega(e^4_{i-1jk}+g^4_{i-1jk}))-(\omega(e^2_{i-1jk}+g^2_{i-1jk}))(\omega(e^3_{i-1jk}+g^3_{i-1jk}))$$

$$\mathbf{c}_{ijk} = \mathbf{D}(1+\omega(\mathbf{f}_{ij-1k}+\mathbf{g}_{ij-1k})^{-1} \tag{B.19}$$

$$c^1 = [DF(1+\omega(f^4_{ij-1k}+g^4_{ij-1k}))]\div det3$$

$$c^2 = [-DF(\omega(f^2_{ij-1k}+g^2_{ij-1k}))]\div det3$$

$$c^3 = [-DS(\omega(f^3_{ij-1k}+g^3_{ij-1k}))]\div det3$$

$$c^4 = [DS(1+\omega(f^1_{ij-1k}+g^1_{ij-1k}))]\div det3$$

$$det3 = (1+\omega(f^1_{ij-1k}+g^1_{ij-1k}))(1+\omega(f^4_{ij-1k}+g^4_{ij-1k}))-(\omega(f^2_{ij-1k}+g^2_{ij-1k}))(\omega(f^3_{ij-1k}+g^3_{ij-1k}))$$

$$\mathbf{A} = \mathbf{a}_{ijk}\mathbf{e}_{ijk-1} \qquad \text{(B.20)}$$

$$A^1 = a^1 e^1_{ijk-1} + a^2 e^3_{ijk-1}$$

$$A^2 = a^1 e^2_{ijk-1} + a^2 e^4_{ijk-1}$$

$$A^3 = a^3 e^1_{ijk-1} + a^4 e^3_{ijk-1}$$

$$A^4 = a^3 e^2_{ijk-1} + a^4 e^4_{ijk-1}$$

$$\mathbf{C} = \mathbf{b}_{ijk}\mathbf{e}_{i-1jk} \qquad \text{(B.21)}$$

$$C^1 = b^1 e^1_{i-1jk} + b^2 e^3_{i-1jk}$$

$$C^2 = b^1 e^2_{i-1jk} + b^2 e^4_{i-1jk}$$

$$C^3 = b^3 e^1_{i-1jk} + b^4 e^3_{i-1jk}$$

$$C^4 = b^3 e^2_{i-1jk} + b^4 e^4_{i-1jk}$$

$$\mathbf{G} = \mathbf{c}_{ijk}\mathbf{f}_{ij-1k} \qquad \text{(B.22)}$$

$$G^1 = c^1 f^1_{ij-1k} + c^2 f^3_{ij-1k}$$

$$G^2 = c^1 f^2_{ij-1k} + c^2 f^4_{ij-1k}$$

$$G^3 = c^3 f^1_{ij-1k} + c^4 f^3_{ij-1k}$$

$$G^4 = c^3 f^2_{ij-1k} + c^4 f^4_{ij-1k}$$

$$\mathbf{W} = \mathbf{c}_{ijk}\mathbf{g}_{ij-1k} \qquad \text{(B.23)}$$

$$W^1 = c^1 g^1_{ij-1k} + c^2 g^3_{ij-1k}$$

$$W^2 = c^1 g^2_{ij-1k} + c^2 g^4_{ij-1k}$$

$$W^3 = c^3 g^1_{ij-1k} + c^4 g^3_{ij-1k}$$

$$W^4 = c^3 g^2_{ij-1k} + c^4 g^4_{ij-1k}$$

$$\mathbf{T} = \mathbf{a}_{ijk}\mathbf{f}_{ijk-1} \qquad \text{(B.24)}$$

$$T^1 = a^1 f^1_{ijk-1} + a^2 f^3_{ijk-1}$$

$$T^2 = a^1 f^2_{ijk-1} + a^2 f^4_{ijk-1}$$

$$T^3 = a^3 f^1_{ijk-1} + a^4 f^3_{ijk-1}$$

$$T^4 = a^3 f^2_{ijk-1} + a^4 f^4_{ijk-1}$$

$$\mathbf{U} = \mathbf{b}_{ijk} \mathbf{g}_{i-1jk} \tag{B.25}$$

$$U^1 = b^1 g^1_{i-1jk} + b^2 g^3_{i-1jk}$$

$$U^2 = b^1 g^2_{i-1jk} + b^2 g^4_{i-1jk}$$

$$U^3 = b^3 g^1_{i-1jk} + b^4 g^3_{i-1jk}$$

$$U^4 = b^3 g^2_{i-1jk} + b^4 g^4_{i-1jk}$$

$$\mathbf{d}_{ijk} = \mathbf{E} + \omega(\mathbf{C}+\mathbf{G}+\mathbf{A}+\mathbf{W}+\mathbf{T}+\mathbf{U}) - \mathbf{a}_{ijk} \mathbf{g}_{ijk-1} - \mathbf{b}_{ijk} \mathbf{f}_{i-1jk} - \mathbf{c}_{ijk} \mathbf{e}_{ij-1k} \tag{B.26}$$

$$d^1 = EF + \omega(C^1+G^1+A^1+W^1+T^1+U^1) - (a^1 g^1_{ijk-1} + a^2 g^3_{ijk-1} + b^1 f^1_{i-1jk} + b^2 f^3_{i-1jk} + c^1 e^1_{ij-1k} + c^2 e^3_{ij-1k})$$

$$d^2 = EFS + \omega(C^2+G^2+A^2+W^2+T^2+U^2) - (a^1 g^2_{ijk-1} + a^2 g^4_{ijk-1} + b^1 f^2_{i-1jk} + b^2 f^4_{i-1jk} + c^1 e^2_{ij-1k} + c^2 e^4_{ij-1k})$$

$$d^3 = ESF + \omega(C^3+G^3+A^3+W^3+T^3+U^3) - (a^3 g^1_{ijk-1} + a^4 g^3_{ijk-1} + b^3 f^1_{i-1jk} + b^4 f^3_{i-1jk} + c^3 e^1_{ij-1k} + c^4 e^3_{ij-1k})$$

$$d^4 = ES + \omega(C^4+G^4+A^4+W^4+T^4+U^4) - (a^3 g^2_{ijk-1} + a^4 g^4_{ijk-1} + b^3 f^2_{i-1jk} + b^4 f^4_{i-1jk} + c^3 e^2_{ij-1k} + c^4 e^4_{ij-1k})$$

$$\mathbf{e}_{ijk} = \mathbf{d}^{-1}_{ijk}(\mathbf{F} - \omega(\mathbf{C}+\mathbf{A})) \tag{B.27}$$

$$e^1 = \{d^4(F^1-\omega(C^1+A^1)) - d^2(F^3-\omega(C^3+A^3))\} \div det4$$

$$e^2 = \{d^4(F^2-\omega(C^2+A^2)) - d^2(F^4-\omega(C^4+A^4))\} \div det4$$

$$e^3 = \{d^1(F^3-\omega(C^3+A^3)) - d^3(F^1-\omega(C^1+A^1))\} \div det4$$

$$e^4 = \{d^1(F^4-\omega(C^4+A^4)) - d^3(F^2-\omega(C^2+A^2))\} \div det4$$

$$det4 = d^1 d^4 - d^2 d^3$$

$$\mathbf{f}_{ijk} = \mathbf{d}^{-1}_{ijk}(\mathbf{H} - \omega(\mathbf{G}+\mathbf{T})) \tag{B.28}$$

$$f^1 = \{d^4(H^1-\omega(G^1+T^1)) - d^2(H^3-\omega(G^3+T^3))\} \div det4$$

$$f^2 = \{d^4(H^2-\omega(G^2+T^2)) - d^2(H^4-\omega(G^4+T^4))\} \div det4$$

$$f^3 = \{d^1(H^3-\omega(G^3+T^3)) - d^3(H^1-\omega(G^1+T^1))\} \div det4$$

$$f^4 = \{d^1(H^4-\omega(G^4+T^4)) - d^3(H^2-\omega(G^2+T^2))\} \div det4$$

$$\mathbf{g}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{S}-\omega(\mathbf{W}+\mathbf{U})) \quad \text{(B.29)}$$

$g^1 = \{d^4(S^1-\omega(W^1+U^1))-d^2(S^3-\omega(W^3+U^3))\}\div\text{det4}$

$g^2 = \{d^4(S^2-\omega(W^2+U^2))-d^2(S^4-\omega(W^4+U^4))\}\div\text{det4}$

$g^3 = \{d^1(S^3-\omega(W^3+U^3))-d^3(S^1-\omega(W^1+U^1))\}\div\text{det4}$

$g^4 = \{d^1(S^4-\omega(W^4+U^4))-d^3(S^2-\omega(W^2+U^2))\}\div\text{det4}$

By forward substitution:

$$\mathbf{V}_{ijk}^{n} = \mathbf{d}_{ijk}^{-1}(\mathbf{R}^{n-1}-\mathbf{a}_{ijk}\mathbf{V}_{ijk-1}^{n}-\mathbf{b}_{ijk}\mathbf{V}_{i-1jk}^{n}-\mathbf{c}_{ijk}\mathbf{V}_{ij-1k}^{n}) \quad \text{(B.30)}$$

$VF = (d^4XF-d^2XS)\div\text{det4}$

$VS = (d^1XS-d^3XF)\div\text{det4}$

$XF = RF-(a^1VF_{ijk-1}+a^2VS_{ijk-1}+b^1VF_{i-1jk}\ b^2VS_{i-1jk}+c^1VF_{ij-1k}+c^2VS_{ij-1k})$

$XS = RS-(a^3VF_{ijk-1}+a^4VS_{ijk-1}+b^3VF_{i-1jk}\ b^4VS_{i-1jk}+c^3VF_{ij-1k}+c^4VS_{ij-1k})$

By backward substitution:

$$\boldsymbol{\xi}_{ijk}^{n} = \mathbf{V}_{ijk}^{n}-(\mathbf{e}_{ijk}\boldsymbol{\xi}_{ij+1k}^{n}+\mathbf{f}_{ijk}\boldsymbol{\xi}_{i+1jk}^{n}+\mathbf{g}_{ijk}\boldsymbol{\xi}_{ijk+1}^{n}) \quad \text{(B.31)}$$

$\xi_f = VF-(e^1\xi_{f_{ij+1k}}+e^2\xi_{s_{ij+1k}}+f^1\xi_{f_{i+1jk}}+f^2\xi_{s_{i+1jk}}+g^1\xi_{f_{ijk+1}}+g^2\xi_{s_{ijk+1}})$

$\xi_s = VS-(e^3\xi_{f_{ij+1k}}+e^4\xi_{s_{ij+1k}}+f^3\xi_{f_{i+1jk}}+f^4\xi_{s_{i+1jk}}+g^3\xi_{f_{ijk+1}}+g^4\xi_{s_{ijk+1}})$

To enhance convergence of SIP, on alternate iterations the directions of forward substitution and backward substitution are reversed. The matrix is swept through in the reverse direction. In the reverse algorithm the S and Z coefficients are switched as well as the B and H coefficients. All k-1 values are switched with k+1 values, and i-1 values are switched with i+1 values. The matrix is swept through in the increasing j, decreasing i, and decreasing k directions.

ATTACHMENT A. DATA INPUT FORMATS

Data Group I: Simulation Parameters

Line	Columns	Format	Variable	Definition
A-1	1-70	A70	TITLE	Title describing simulation
A-2	1-5	I5	NNR	Number of rows
	6-10	I5	NNC	Number of columns
	11-15	I5	NNL	Number of aquifers (layers)
	16-20	I5	NP	Number of time steps between print-outs
	21-25	I5	ITMAX	Maximum number of iterations allowed
	26-30	I5	NITP	Number of iteration parameters
	31-35	I5	NPUMP	Number of pumping periods
	36-40	I5	LW	Number of observation points
	41-45	I5	NUP	Number of iterations in a time step after which interface position is fixed
	46-50	I5	NOPT	Input/output options parameter: NOPT=0 for default options, NOPT=1 for user specified options (must read in values of IOP array below)
	51-55	I5	NLK	Leakage method parameter, if NLK=1 use method 1 (complete mixing), if NLK=0 use method 2 (restricted mixing)
A-3	1-10	G10.0	ERR	Convergence closure criteria
	11-20	G10.0	STST	Steady-state closure criteria
	21-30	G10.0	RFAC	Relaxation factor
	31-40	G10.0	WFAC	Weighting factor used in calculating projected interface position which is given by: WFAC*new projection+(1-WFAC)* old projection
	41-50	G10.0	WITER	Factor used in calculating iteration parameters: usually =1, if divergence occurs a value >1 should be used, if convergence is slow a value <1 should be used
	51-60	G10.0	SGF	Fresh water specific gravity
	61-70	G10.0	SGS	Salt water specific gravity
	71-80	G10.0	VIF	Fresh water viscosity
	81-90	G10.0	VIS	Salt water viscosity
A-4	1-5	I5	NCONT	NCONT=0 for new simulations, NCONT=1 for continuation simulations
	6-25	G20.0	TSEC	TSEC=0. for new simulations, TSEC is the starting time in seconds for a continuation

				run
	26-30	I5	NINT	Interface initialization parameter, if NINT=0 read in interface elevations, if NINT=1 initialize ZINT to DEL*PHIF (Ghyben-Herzberg interface)

The following three parameters values are specified for LW observation nodes.

A-5 to LW+4	1-5	I5	IW(L)	Row index of observation point
	6-10	I5	JW(L)	Column index of observation point
	11-15	I5	KW(L)	Layer index of observation point (layer 1 is the bottom layer)

The following lines are needed only if NOPT=1, otherwise, the default values for IOP specified in the data statement on line MA 420 of MAIN are used.

A-LW+5	1-5	I5	IOP(2)	Input/output options parameters, see table 5 for explanation of each option. IOP(1) is not an input parameter, but is specified in the data statement on line MA 420.
	6-10	I5	IOP(3)	
	11-15	I5	IOP(4)	
	16-20	I5	IOP(5)	
	21-25	I5	IOP(6)	
	26-30	I5	IOP(7)	
	31-35	I5	IOP(8)	
	36-40	I5	IOP(9)	
	41-45	I5	IOP(10)	
	46-50	I5	IOP(11)	
	51-55	I5	IOP(12)	

Data Group II: Aquifer parameters

Data sets B-1 through B-15 in this input group are preceeded by a leading line having the following format and parameters:

1-5	I5	M	Set M=1 if every array element has the same value, set M=0 if the array elements differ in value
6-15	G10.0	DUMMY	If M=1, every element of the array is assigned the value DUMMY and no further input for the data set is necessary. If M=0, the complete array must be read in. In this case all the values are multiplied by the scaling factor, DUMMY.

In all data sets that follow, array elements are read in row order with a new line for each row. Data sets B-1 through B-14 are repeated NL times, beginning with the lowermost aquifer.

Data Set	Columns	Format	Variable	Definition
B-1	1-100	10G10.0	FKX(I,J,K)	Freshwater hydraulic conductivity in x-direction, must be set equal to zero at inactive nodes
B-2	1-100	10G10.0	FKY(I,J,K)	Freshwater hydraulic conductivity in y-direction
B-3	1-100	10G10.0	STORF(I,J,K)	Freshwater specific storage, must be negative at constant freshwater head nodes
B-4	1-100	10G10.0	STORS(I,J,K)	Saltwater specific storage, must be negative at constant saltwater head nodes
B-5	1-100	10G10.0	POR(I,J,K)	Porosity
B-6	1-100	10G10.0	THCK(I,J,K)	Thickness of aquifer, must be greater than maximum saturated thickness for an unconfined aquifer
B-7	1-100	10G10.0	ZBOT(I,J,K)	Elevation of base of aquifer
B-8	1-100	10G10.0	PHIF(I,J,K)	Initial fresh water heads

Data set B-9 is needed only if NINT=0. For NINT=1 ZINT is initialized to -DEL*PHIF (Ghyben-Herzberg interface).

B-9	1-100	10G10.0	ZINT(I,J,K)	Initial interface elevations

Data sets B-10 through B-13 are not needed for a new simulation (NCONT=0). For a continuation run, input the values obtained from the previous simulation (from file units IUNIT(27) to IUNIT(30)).

B-10	1-100	10G10.0	FX(I,J,K)	Interface tip projection factor in x-direction
B-11	1-100	10G10.0	FY(I,J,K)	Interface tip projection factor in y-direction
B-12	1-100	10G10.0	SX(I,J,K)	Interface toe projection factor in x-direction
B-13	1-100	10G10.0	SY(I,J,K)	Interface toe projection factor in y-direction

This data set must be specified for each layer.

B-14	1-100	10G10.0	AQL(I,J,K)	Leakance (K'/B') of overlying confining layer

The following data sets, B-15 through B-18 are specified only once.

B-15	1-100	10G10.0	HEAD(I,J)	Fixed fresh water head above top confining layer, used

				for leakage calculations at confined nodes in uppermost aquifer
B-16	1-100	10G10.0	BATH(I,J)	Bathymetry, ocean floor elevation
B-17	1-100	25I5	IWT(I,J)	Code for uppermost aquifer (α): =0 at confined nodes, =1 at unconfined nodes
B-18	1-100	10G10.0	DX(J)	Grid block size in x-direction
B-19	1-100	10G10.0	DY(I)	Grid block size in y-direction

Data Group III: Pumping period data

This group of values must be specified NPUMP times, that is, for each pumping period. Line 2 of the group is specified NWELL times, that is for the number of pumping wells within the pumping period.

Line	Columns	Format	Variable	Definition
C-1	1-10	G10.0	DT	Initial time step size in seconds
	11-20	G10.0	TFAC	Multiplication factor for time step size
	21-30	G10.0	TMAX	Maximum length of pumping period in days
	31-35	I5	NTSP	Maximum number of time steps allowed, simulation is terminated when either TMAX or NTSP is exceeded
	36-40	i5	NWELL	Number of pumping wells
C-2	1-5	I5	I	Row index of pumping well
	6-10	I5	J	Column index of pumping well
	11-15	I5	K	Layer index of pumping well
	16-25	G10.0	PUMP(I,J,K)	Well pumpage (L^3/T), positive for extraction, negative for injection
	26-35	G10.0	WTOP(I,J,K)	Elevation of top of open interval of well
	36-45	G10.0	WBOT(I,J,K)	Elevation of bottom of open interval of well
C-3	1-5	I5	M	See Group II for explanation
	6-15	G10.0	DUMMY	See Group II for explanation
C-4	1-100	10G10.0	RECH(I,J)	Recharge rate (L/T)

ATTACHMENT B. LIST OF SELECTED PROGRAM VARIABLES

A(4)	Submatrix element of lower triangular matrix **L**
AA(4)	Submatrix element of modified matrix **(A+B)**
AL	α, =1 for an unconfined node, =0 for a confined node
APROP	FAREA(I,J,K)+SAREA(I,J,K)-1.
AQL(NR,NC,NL)	Leakance of confining layer (K'/B')
AQLBOT	Leakance of underlying confining layer times block area
AQLTOP	Leakance of overlying confining layer times block area
ARDT	Block area divided by time step size
AREA	Block area
ARRAY(4)	Submatrix used in SIP factoriztion
AXL	Projected interface tip/toe distance in x-direction
AYL	Projected interface tip/toe distance in y-direction
B(4)	Submatrix element of lower triangular matrix **L**
BATH(NR,NC)	Bathymetry
BB(4)	Submatrix element of modified matrix **(A+B)**
C(4)	Submatrix element of lower triangular matrix **L**
CC(4)	Submatrix element of modified matrix **(A+B)**
CFDIF	Net cumulative freshwater influx to layer (volume)
CFIN(5)	Cumulative freshwater influxes to layer (volume)
CFOUT(5)	Cumulative freshwater outflows from layer (volume)
CFRERF	Cumulative freshwater mass balance error relative to influx
CFRERS	Cumulative freshwater mass balance error relative to change in storage
CFSTR	Cumulative freshwater change in storage (volume)
CSDIF	Net cumulative saltwater influx to layer (volume)
CSIN(5)	Cumulative saltwater influxes to layer (volume)
CSOUT(5)	Cumulative saltwater outflows from layer (volume)
CSRERF	Cumulative saltwater mass balance error relative to influx
CSRERS	Cumulative saltwater mass balance error relative to change in storage
CSSTR	Cumulative saltwater change in storage
D(4)	Submatrix element of lower triangular matrix **L**
DD(4)	Submatrix element of modified matrix **(A+B)**
DEL	$\gamma_f/(\gamma_s-\gamma_f)$
DFM	Freshwater head derivative at i or j-1/2
DFMAX	Maximum change in freshwater head over time step
DFP	Freshwater head derivative at i or j+1/2
DMAXF(ITMAX)	Maximum changes in freshwater head over iterations
DMAXS(ITMAX)	Maximum changes in saltwater head over iterations
DPHIF(NR,NC,NL)	Change in freshwater head over iteration
DPHIS(NR,NC,NL)	Change in saltwater head over iteration
DSM	Saltwater head derivative at i or j-1/2
DSMAX	Maximum change in saltwater head over time step
DSP	Saltwater head derivative at i or j+1/2
DT	Time step size in seconds
DTDAYS	Time step size in days
DTHRS	Time step size in hours
DTYRS	Time step size in years
DX(NC)	Grid block dimension in x-direction

DY(NR)	Grid block dimension in y-direction
DZBOT	Slope of bottom of aquifer
DZINT	Slope of interface
DZTOP	Slope of top of aquifer
E(NR,NC,NL,4)	Submatrix element of upper triangular matrix **U**
EE(4)	Submatrix element of modified matrix **(A+B)**
EI1(4)	Submatrix used in SIP factorization
EIJK(4)	Submatrix used in SIP factorization
EK1(4)	Submatrix used in SIP factorization
ERR	Convergence closure criteria
F(NR,NC,NL,4)	Submatrix element of upper triangular matrix **U**
FAREA(NR,NC,NL)	Freshwater area factor for top of block
FDIF	Net freshwater influx to layer (rate)
FF(4)	Submatrix element of modified matrix **(A+B)**
FFLOW(1000)	Freshwater flow in/out of constant head nodes
FIJK(4)	Submatrix used in SIP factorization
FIN(5)	Freshwater influxes to layer (rate)
FJ1(4)	Submatrix used in SIP factorization
FK1(4)	Submatrix used in SIP factorization
FKX(NR,NC,NL)	Freshwater hydraulic conductivity in x-direction
FKY(NR,NC,NL)	Freshwater hydraulic conductivity in y-direction
FLKB(NR,NC)	Freshwater leakage across bottom of aquifer
FLKT(NR,NC)	Freshwater leakage across top of aquifer
FM	Weighting factor for calculating interface slope
FOUT(5)	Freshwater outflows from layer
FP	Weighting factor for calculating interface slope
FR	Code for freshwater nodes
FRERF	Freshwater mass balance error relative to influx
FRERS	Freshwater mass balance error relative to change in storage
FSTOR	Freshwater change in storage (rate)
FWH(LW,NTSP)	Freshwater head at observation points
FX(NR,NC,NL)	Interface tip projection from previous iteration expressed as a ratio of DX
FXN(NR,NC,NL)	Interface tip projection for new iteration expressed as a ratio of DX
FY(NR,NC,NL)	Interface tip projection from previous iteration expressed as a ratio of DY
FYN(NR,NC,NL)	Interface tip projection for new iteration expressed as a ratio of DY
G(NR,NC,NL,4)	Submatrix element of upper triangular matrix **U**
GG(4)	Submatrix element of modified matrix **(A+B)**
GI1(4)	Submatrix used in SIP factorization
GIJK(4)	Submatrix used in SIP factorization
GJ1(4)	Submatrix used in SIP factorization
HEAD(NR,NC)	Freshwater head in topmost inactive layer
HH(4)	Submatrix element of modified matrix **(A+B)**
ICODE(NR,NC,NL)	Code identifying nature of node
IFL(1000)	Row index of constant freshwater head node
IOP(12)	Input/output options parameters (default or user-specified)
IPUMP	Pumping period index
ISL(1000)	Row index of constant saltwater head node
IUN(32)	Input/output unit numbers (default or user-specified)

IW(LW)	Row index of observation point
JFL(1000)	Column index of constant freshwater head node
JSL(1000)	Column index of constant saltwater head node
JW(LW)	Column index of observation point
KW(LW)	Layer index of observation point
LW	Number of observation points
M	Code for mixed nodes
NC	Number of columns
NCONT	=0 for new simulation, =1 for continuation run
NFH	Number of constant freshwater head nodes in layer
NINT	Interface initialization parameter, =0 to read in interface elevations, >0 to initialize interface elevations to -DEL*PHIF
NIT	Iteration index
NITP	Number of iteration parameters
NL	Number of layers
NLK	Leakage method parameter, =0 method 1 (complete mixing, >0 method 2 (restricted mixing)
NOPT	Input/output options parameter, =0 to use default options, >0 to use user specified options
NP	Number of time steps between print outs
NPUMP	Number of pumping periods
NR	Number of rows
NSH	Number of constant saltwater head nodes in layer
NTSP	Maximum number of time steps allowed
NUP	Number of iterations after which interface position is fixed
PDAYS	Elapsed pumping period time in days
PHIF(NR,NC,NL)	Freshwater heads
PHIFP(NR,NC,NL)	Freshwater heads from previous time step
PHIS(NR,NC,NL)	Saltwater heads
PHISP(NR,NC,NL)	Saltwater heads from previous time step
PHRS	Elapsed pumping period time in hours
POR(NR,NC,NL)	Porosity
PUMP(NR,NC,NL)	Total well pumpage (L^3/T)
PUMPF(NR,NC,NL)	Freshwater pumpage (L^3/T)
PUMPS	Saltwater pumpage (L^3/T)
PYRS	Elapsed pumping period time in years
QF	Right hand side of freshwater flow equation
QS	Right hand side of saltwater flow equation
RECH(NR,NC)	Recharge rate (L/T)
RESF	Freshwater equation residual
RESS	Saltwater equation residual
RFAC	Relaxation factor
S	Code for saltwater nodes
SAREA(NR,NC,NL)	Saltwater area factor for bottom of block
SDIF	Net saltwater influx to layer (rate)
SFLOW(1000)	Saltwater flow in/out of constant head nodes
SGF	Freshwater specific gravity
SGR	SGS/SGF
SGS	Saltwater specific gravity
SLKB(NR,NC)	Saltwater leakage across bottom of aquifer

SLKT(NR,NC)	Saltwater leakage across bottom of aquifer
SM	Weighting factor for calculating interface derivative
SOUT(5)	Saltwater outflows from layer (rate)
SP	Weighting factor for calculating interface derivative
SRERF	Saltwater mass balance error relative to influx
SRERS	Saltwater mass balance error relative to change in storage
SS(4)	Submatrix element of modified matrix **(A+B)**
SSIN(5)	Saltwater influxes to layer (rate)
SSTOR	Saltwater change in storage (rate)
STORF(NR,NC,NL)	Freshwater specific storage
STORS(NR,NC,NL)	Saltwater specific storage
STST	Steady state closure criteria
SWH(LW,NTSP)	Saltwater head at observation points
SX(NR,NC,NL)	Interface toe projection from previous iteration expressed as a ratio of DX
SXN(NR,NC,NL)	Interface toe projection for new iteration expressed as a ratio of DX
SY(NR,NC,NL)	Interface toe projection from previous iteration expressed as a ratio of DY
SYN(NR,NC,NL)	Interface toe projection for new iteration expressed as a ratio of DY
TCFIN	Total cumulative freshwater influx for layer (volume)
TCFOUT	Total cumulative freshwater outflow from layer
TCSIN	Total cumulative saltwater influx for layer (volume)
TCSOUT	Total cumulative saltwater outflow from layer (volume)
TDAYS	Elapsed simulation time in days
TFAC	Time step size multiplication factor
TFIN	Total freshwater influx for layer (rate)
TFOUT	Total freshwater outflow from layer (rate)
TFX(NR,NC-1,NL)	Mean hydraulic conductivity term in x-direction
TFY(NR-1,NC,NL)	Mean hydraulic conductivity term in y-direction
THCK(NR,NC,NL)	Aquifer thickness
THF(NR,NC,NL)	Freshwater thickness
THIC	Thickness of freshwater/saltwater at block boundary
THICK	Saturated thickness of aquifer
THRS	Elapsed simulation time in hours
THS(NR,NC,NL)	Saltwater thickness
TIME(NTSP+1)	Elapsed simulation time for each time step in years?
TITLE	Title describing simulation
TMAX	Length of pumping period in days
TPUMP	Elapsed pumping period time in seconds
TSEC	Elapsed simulation time in seconds
TSOUT	Total saltwater outflow from layer (rate)
TSSIN	Total saltwater influx to layer (rate)
TT(4)	Submatrix element of modified matrix **(A+B)**
TTFX(NR,NC-1,NL)	Freshwater transmissive coefficient in x-direction
TTFY(NR-1,NC,NL)	Freshwater transmissive coefficient in y-direction
TTSX(NR,NC-1,NL)	Saltwater transmissive coefficient in x-direction
TTSY(NR-1,NC,NL)	Saltwater transmissive coefficient in y-direction
TYRS	Elapsed simulation time in years
UU(4)	Submatrix element of modified matrix **(A+B)**
VF(NR,NC,NL)	Freshwater element of vector **V**

VIF	Freshwater viscosity
VIS	Saltwater viscosity
VS(NR,NC,NL)	Saltwater element of vector **V**
WBOT(NR,NC,NL)	Elevation of bottom of well screen
WFAC	Weighting factor for interface projection
WITER	Iteration paramater factor
WOPTF(NITP)	Iteration parameter sequence
WTOP(NR,NC,NL)	Elevation of top of well screen
WW(4)	Submatrix element of modified matrix **(A+B)**
XF	Freshwater element of vector **X**
XLNEW	New x-projected interface distance
XLOLD	X-projected interface distance from previous iteration
XS	Saltwater element of vector **X**
YLNEW	New y-projected interface distance
YLOLD	Y-projected interface distance from previous iteration
ZBOT(NR,NC,NL)	Elevation of bottom of aquifer
ZI(LW,NTSP)	Interface elevation at observation points
ZINT(NR,NC,NL)	Interface elevation
ZTOP(NR,NC,NL)	Elevation of top of aquifer
ZZ(4)	Submatrix element of modified matrix **(A+B)**

ATTACHMENT C: PROGRAM LISTING

```
C ---------------------------------------------------------------------------
C                              PROGRAM SHARP
C  SIMULATION OF FRESHWATER AND SALTWATER FLOW ASSUMING AN ABRUPT INTERFACE
C          A QUASI-THREE DIMENSIONAL FINITE DIFFERENCE MODEL
C                    VERSION AS OF SEPT. 12, 1990
C
C  SEE WRIR 90-4130, ATTACHMENT A FOR INPUT FORMATS, ATTACHMENT B FOR DEFINITION
C                         OF PROGRAM VARIABLES
C ---------------------------------------------------------------------------
C  SPECIFICATIONS
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /XNEW/FXN(NR,NC,NL),FYN(NR,NC,NL),SXN(NR,NC,NL),
     1SYN(NR,NC,NL)
C
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),
     6ZI(10,200),FAR(10,200),SAR(10,200)
C
      COMMON /WHEAD/WPHIF(NR,NC),WPHIS(NR,NC),WZINT(NR,NC)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
      DATA IUN/22*5,2*6,6*7,8,9/
      DATA IOP/0,1,1,1,1,1,0,0,1,1,0,0/
C
```

```
C  TO OPEN FILES INTERNALLY, REPLACE THE ABOVE DATA STATEMENT WITH THE
C  FOLLOWING DATA STATEMENT
C      DATA IOP/1,1,1,1,1,1,0,0,1,1,0,0/
C
      IF(IOP(1).EQ.1)THEN
        OPEN(UNIT=5,FILE='INPUT',STATUS='OLD')
        OPEN(UNIT=6,FILE='OUTPUT',STATUS='NEW')
        OPEN(UNIT=7,FILE='RESULTS',STATUS='NEW')
        OPEN(UNIT=8,FILE='HEADS',STATUS='NEW')
        OPEN(UNIT=9,FILE='LEAK',STATUS='NEW')
      END IF
C
C  READ AND WRITE MODEL INPUT
      CALL INPUT
C
C  SET VALUES EQUAL TO ZERO AT INACTIVE NODES
      DO 10 K=1,NNL
      DO 10 I=1,NNR
      DO 10 J=1,NNC
        TTFX(I,J,K)=0.0
        TTFY(I,J,K)=0.0
        TTSX(I,J,K)=0.0
        TTSY(I,J,K)=0.0
        THF(I,J,K)=0.0
        THS(I,J,K)=0.0
        IF(FKX(I,J,K).NE.0.) GO TO 10
        FKY(I,J,K)=0.0
        POR(I,J,K)=0.0
        THCK(I,J,K)=0.0
        ZINT(I,J,K)=0.0
        AQL(I,J,K)=0.0
        FX(I,J,K)=0.0
        FY(I,J,K)=0.0
        SX(I,J,K)=0.0
        SY(I,J,K)=0.0
   10 CONTINUE
C
      FR='F'
      M='M'
      S='S'
      NFLAG=1
      DEL=SGF/(SGS-SGF)
      C2=SGF/SGS
      C3=1./(1.+DEL)
C
C  CALCULATE INITIAL SALTWATER POTENTIAL AND TYPE OF NODE:
C    F-FRESHWATER ONLY, S-SALTWATER ONLY, M-FRESH AND SALTWATER
      DO 20 K=1,NNL
      DO 20 I=1,NNR
      DO 20 J=1,NNC
        FAREA(I,J,K)=0.
        SAREA(I,J,K)=0.
        ICODE(I,J,K)='.'
        FXN(I,J,K)=0.
```

```
        FYN(I,J,K)=0.
        SXN(I,J,K)=0.
        SYN(I,J,K)=0.
        ZTOP(I,J,K)=ZBOT(I,J,K)+THCK(I,J,K)
        IF(FKX(I,J,K).EQ.0.)GO TO 20
        IF(IWT(I,J).EQ.1.AND.K.EQ.NNL)THEN
          ZTOP(I,J,K)=PHIF(I,J,K)
          IF(ZTOP(I,J,K).GT.(ZBOT(I,J,K)+THCK(I,J,K)))WRITE(IUN(23),170)
     &      I,J,K
        END IF
        TOP=ZTOP(I,J,K)
        THICK=TOP-ZBOT(I,J,K)
        IF(ZINT(I,J,K).LT.ZBOT(I,J,K))ZINT(I,J,K)=ZBOT(I,J,K)
        IF(ZINT(I,J,K).GT.TOP)ZINT(I,J,K)=TOP
        THS(I,J,K)=ZINT(I,J,K)-ZBOT(I,J,K)
        THF(I,J,K)=ZTOP(I,J,K)-ZINT(I,J,K)
        IF(NCONT.GT.0)GO TO 20
        FX(I,J,K)=0.0
        FY(I,J,K)=0.0
        SX(I,J,K)=0.0
        SY(I,J,K)=0.0
        IF(DABS(ZINT(I,J,K)-ZBOT(I,J,K)).LE.(0.001*THICK))THEN
          ICODE(I,J,K)=FR
          FAREA(I,J,K)=1.
          FX(I,J,K)=1.
          FXN(I,J,K)=1.
          FY(I,J,K)=1.
          FYN(I,J,K)=1.
       ELSE IF(DABS(ZINT(I,J,K)-TOP).LE.(0.001*THICK))THEN
          ICODE(I,J,K)=S
          SAREA(I,J,K)=1.
          SX(I,J,K)=1.
          SXN(I,J,K)=1.
          SY(I,J,K)=1.
          SYN(I,J,K)=1.
        ELSE
          ICODE(I,J,K)=M
          FAREA(I,J,K)=1.
          SAREA(I,J,K)=1.
          FX(I,J,K)=1.
          FXN(I,J,K)=1.
          FY(I,J,K)=1.
          FYN(I,J,K)=1.
          SX(I,J,K)=1.
          SXN(I,J,K)=1.
          SY(I,J,K)=1.
          SYN(I,J,K)=1.
        END IF
   20 CONTINUE
C
C  CALCULATE ITERATION PARAMETERS
      CALL IPARAM
C
C  CALCULATE HYDRAULIC CONDUCTIVITIES AT GRID BLOCK BOUNDARIES
```

```
      CALL KMEAN
C
      NT=0
      TIME(1)=TSEC/31557600.
      DO 25 L=1,LW
        I=IW(L)
        J=JW(L)
        K=KW(L)
        FWH(L,1)=PHIF(I,J,K)
        SWH(L,1)=PHIS(I,J,K)
        ZI(L,1)=ZINT(I,J,K)
        IC(L,1)=ICODE(I,J,K)
        FAR(L,1)=FAREA(I,J,K)
        SAR(L,1)=SAREA(I,J,K)
   25 CONTINUE
C
C  BEGIN NEW PUMPING PERIOD CALCULATIONS
      DO 90 IPUMP=1,NPUMP
        CALL PUMPER(IPUMP)
        TSEC=TSEC+DT
        TPUMP=DT
C
C  BEGIN CALCULATIONS FOR NEW TIME STEP
   30 NT=NT+1
      DFMAX=0.0
      DSMAX=0.0
C
C  RESET POTENTIALS FOR PREVIOUS TIME STEP
      DO 40 K=1,NNL
      DO 40 I=1,NNR
      DO 40 J=1,NNC
        PHIFP(I,J,K)=PHIF(I,J,K)
        PHISP(I,J,K)=PHIS(I,J,K)
   40 CONTINUE
C
C  SOLVE FRESHWATER AND SALTWATER FLOW EQUATIONS
        CALL SIP(*100)
C
C  DETERMINE MAXIMUM FRESHWATER AND SALTWATER POTENTIAL CHANGE OVER
C    TIME STEP
        DO 60 K=1,NNL
        DO 60 I=1,NNR
        DO 60 J=1,NNC
          DELF=DABS(PHIFP(I,J,K)-PHIF(I,J,K))
          DELS=DABS(PHISP(I,J,K)-PHIS(I,J,K))
          IF(DELF.GT.DFMAX)DFMAX=DELF
          IF(DELS.GT.DSMAX)DSMAX=DELS
   60   CONTINUE
C
C  WRITE CURRENT RESULTS TO FILE
      IF(IOP(12).EQ.0)THEN
        CALL RESULTS
        REWIND(IUN(25))
        REWIND(IUN(26))
```

```
        REWIND(IUN(27))
        REWIND(IUN(28))
        REWIND(IUN(29))
        REWIND(IUN(30))
      END IF
C
C  STOP IF MAXIMUM NUMBER OF TIME STEPS IS REACHED
      IF(NT.GE.NTSP)THEN
        CALL OUTPUT(1)
        IF(IOP(12).GT.0)CALL RESULTS
C
C  PRINT RESULTS AND BEGIN NEW PUMPING PERIOD IF STEADY STATE HAS
C    BEEN REACHED
      ELSE IF(DFMAX.LT.STST.AND.DSMAX.LT.STST)THEN
          WRITE(IUN(24),70)
          CALL OUTPUT(1)
          IF(IOP(12).GT.0)CALL RESULTS
          DT=TMAX-TPUMP
          TPUMP=TMAX
          TSEC=TSEC+DT
          GO TO 90
C
      ELSE
C
C  PRINT RESULTS IF NUMBER OF TIME STEPS BETWEEN PRINTOUTS IS REACHED
        IF(MOD(NT,NP).EQ.0.)THEN
          CALL OUTPUT(1)
          IF(IOP(12).GT.0)CALL RESULTS
        ELSE IF(IPUMP.EQ.NPUMP.AND.TPUMP.GE.TMAX)THEN
          CALL OUTPUT(1)
          IF(IOP(12).GT.0)CALL RESULTS
          GO TO 90
        ELSE
          CALL OUTPUT(0)
        END IF
        DT=TFAC*DT
C
C  BEGIN NEW TIME STEP
        IF((TPUMP+DT).LT.TMAX) THEN
          TPUMP=TPUMP+DT
          TSEC=TSEC+DT
          GO TO 30
        ELSE IF(TPUMP.NE.TMAX) THEN
          DT=TMAX-TPUMP
          TPUMP=TMAX
          TSEC=TSEC+DT
          GO TO 30
        END IF
      END IF
   90 CONTINUE
  100 CONTINUE
C
C  WRITE OBSERVED HEADS AND INTERFACE ELEVATIONS TO FILE
      DO 140 L=1,LW
```

```
      I=IW(L)
      J=JW(L)
      K=KW(L)
      WRITE(IUN(31),150)I,J,K
      WRITE(IUN(31),160)(TIME(N),FWH(L,N),SWH(L,N),ZI(L,N),IC(L,N),
   &FAR(L,N),SAR(L,N),N=1,NT+1)
 140  CONTINUE
C
C  CLOSE OUTPUT FILES
      IF(IOP(1).EQ.1)THEN
        CLOSE(5,STATUS='KEEP')
        CLOSE(6,STATUS='KEEP')
        CLOSE(7,STATUS='KEEP')
        CLOSE(8,STATUS='KEEP')
        CLOSE(9,STATUS='KEEP')
      END IF
C
   70 FORMAT(/1X,25('*')/' STEADY STATE ACHIEVED AT:'/1X,25('*'))
   80 FORMAT(10F10.3)
  150 FORMAT(/' NODE(',I3,',',I3,',',I3,'):'//'    TIME(YR)    FW HEAD',
     1'     SW HEAD    INTERFACE     ICODE     FAREA     SAREA')
  160 FORMAT(4F12.5,7X,A1,2F12.5)
  170 FORMAT(/' ***WARNING: WATER TABLE ABOVE LAND SURFACE AT BLOCK:',
     &I3,2X,I3,2X,I3)
      END
C
C ----------------------------------------------------------------------
      SUBROUTINE INPUT
C ----------------------------------------------------------------------
C
C  A SUBROUTINE TO READ AND WRITE MODEL INPUT PARAMETERS
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
```

```
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
      READ(IUN(1),10)TITLE
      WRITE(IUN(23),20)TITLE
      WRITE(IUN(31),20)TITLE
      WRITE(IUN(32),20)TITLE
      READ(IUN(1),30)NNR,NNC,NNL,NP,ITMAX,NITP,NPUMP,LW,NUP,NOPT,NLK
      WRITE(IUN(23),40)NNR,NNC,NNL,NP,ITMAX,NITP,NPUMP,NUP,NOPT,NLK
      IF(NNR.GT.NR)WRITE(IUN(23),41)
      IF(NNC.GT.NC)WRITE(IUN(23),42)
      IF(NNL.GT.NL)WRITE(IUN(23),43)
      READ(IUN(1),50)ERR,STST,RFAC,WFAC,WITER,SGF,SGS,VIF,VIS
      WRITE(IUN(23),60)ERR,STST,RFAC,WFAC,WITER,SGF,SGS,VIF,VIS
C
C  CONTINUATION RUN INFORMATION
      READ(IUN(1),31)NCONT,TSEC,NINT
   31 FORMAT(I5,G20.0,I5)
      IF(NCONT.GT.0)THEN
        WRITE(IUN(23),32)TSEC
   32   FORMAT(/ 'CONTINUATION RUN'/'   INITIAL TIME =',G20.10,'SEC')
        NINT=0
      ELSE
        WRITE(IUN(23),33)
   33   FORMAT(/' NEW RUN')
        IF(NINT.GT.0)WRITE(IUN(23),34)
   34   FORMAT('    INTERFACE ELEVATIONS INITIALIZED TO -DEL*PHIF')
      END IF
C
      IF(LW.GT.0)THEN
        READ(IUN(1),29)(IW(L),JW(L),KW(L),L=1,LW)
   29 FORMAT(3I5)
        WRITE(IUN(23),65)LW
        WRITE(IUN(23),29)(IW(L),JW(L),KW(L),L=1,LW)
   65 FORMAT(/' LOCATIONS OF ',I4,' OBSERVATION NODES TRACKED:')
      END IF
C
C  USER SPECIFIED OPTIONS
      IF(NOPT.EQ.1)READ(IUN(1),30)(IOP(I),I=2,12)
        WRITE(IUN(23),35)(IOP(I),I=2,12)
   35 FORMAT(/' SPECIFIED INPUT/OUTPUT OPTIONS:'/
     &/I5,': 1=PRINT INPUT AQUIFER PARAMETERS, 0=DO NOT PRINT'/
     &I5,': 1=PRINT INPUT PUMPING PERIOD WELL AND RECHARGE DATA, ',
     &'0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED FRESHWATER HEADS,',
     &' 0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED SALTWATER HEADS,',
     &' 0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED INTERFACE ELEVATIONS,',
     &' 0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED FAREA FACTORS,',
     &' 0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED SAREA FACTORS,',
     &' 0=DO NOT PRINT'/I5,': 1=PRINT F-M-S MAP, 0=DO NOT PRINT'/I5,
     &': 1=WRITE BLOCK LEAKAGE VALUES TO FILE, 0=DO NOT WRITE TO',
     &' FILE'/I5,': 1=PRINT ITERATION INFORMATION TO SCREEN, 0=DO NOT',
     &' PRINT'/I5,': 0=REWRITE LATEST RESULTS TO FILE AFTER EACH TIME',
     &' STEP,'/'        1=WRITE RESULTS TO FILE EVERY NP TIME STEPS')
```

```
C
C  READ AND WRITE AQUIFER PARAMETERS LAYER BY LAYER
      DO 70 K=1,NNL
        IF(IOP(2).EQ.1)WRITE(IUN(23),80)K
        IF(IOP(2).EQ.1)WRITE(IUN(23),90)
        CALL READ(FKX,NNR,NNC,K,IUN(2),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),100)
        CALL READ(FKY,NNR,NNC,K,IUN(3),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),110)
        CALL READ(STORF,NNR,NNC,K,IUN(4),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),120)
        CALL READ(STORS,NNR,NNC,K,IUN(5),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),130)
        CALL READ(POR,NNR,NNC,K,IUN(6),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),140)
        CALL READ(THCK,NNR,NNC,K,IUN(7),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),150)
        CALL READ(ZBOT,NNR,NNC,K,IUN(8),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),160)
        CALL READ(PHIF,NNR,NNC,K,IUN(9),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),170)
        IF(NINT.EQ.0)CALL READ(ZINT,NNR,NNC,K,IUN(10),IUN(23),IOP(2))
C
        DEL=SGF/(SGS-SGF)
        C2=SGF/SGS
        C3=1./(1.+DEL)
        IF(NINT.GT.0)THEN
          DO 161 I=1,NNR
          DO 161 J=1,NNC
 161        ZINT(I,J,K)=-DEL*PHIF(I,J,K)
          DO 162 I=1,NNR
 162        IF(IOP(2).EQ.1)WRITE(IUN(23),174)I,(ZINT(I,J,K),J=1,NNC)
        END IF
        DO 171 I=1,NNR
        DO 171 J=1,NNC
 171      PHIS(I,J,K)=C2*PHIF(I,J,K)+C3*ZINT(I,J,K)
        IF(IOP(2).EQ.1)WRITE(IUN(23),172)
 172    FORMAT(/' INITIAL SALTWATER HEADS')
        DO 173 I=1,NNR
 173    IF(IOP(2).EQ.1)WRITE(IUN(23),174)I,(PHIS(I,J,K),J=1,NNC)
 174    FORMAT(I5,3X,10G11.4/(8X,10G11.4))
        IF(NCONT.GT.0)THEN
          IF(IOP(2).EQ.1)WRITE(IUN(23),181)
 181      FORMAT(/' FX')
          CALL READ(FX,NNR,NNC,K,IUN(11),IUN(23),IOP(2))
          IF(IOP(2).EQ.1)WRITE(IUN(23),182)
 182      FORMAT(/' FY')
          CALL READ(FY,NNR,NNC,K,IUN(12),IUN(23),IOP(2))
          IF(IOP(2).EQ.1)WRITE(IUN(23),183)
 183      FORMAT(/' SX')
          CALL READ(SX,NNR,NNC,K,IUN(13),IUN(23),IOP(2))
          IF(IOP(2).EQ.1)WRITE(IUN(23),184)
 184      FORMAT(/' SY')
          CALL READ(SY,NNR,NNC,K,IUN(14),IUN(23),IOP(2))
```

```
        END IF
        IF(IOP(2).EQ.1)WRITE(IUN(23),180)
        CALL READ(AQL,NNR,NNC,K,IUN(15),IUN(23),IOP(2))
   70 CONTINUE
C
      IF(IOP(2).EQ.1)WRITE(IUN(23),190)
      CALL READ1(HEAD,NNR,NNC,IUN(16),IUN(23),IOP(2))
      IF(IOP(2).EQ.1)WRITE(IUN(23),195)
      CALL READ1(BATH,NNR,NNC,IUN(17),IUN(23),IOP(2))
  195 FORMAT(/' BATHYMETRY')
      DO 210 I=1,NNR
  210   READ(IUN(18),30)(IWT(I,J),J=1,NNC)
      IF(IOP(2).EQ.1)THEN
        WRITE(IUN(23),220)
        DO 230 I=1,NNR
  230   WRITE(IUN(23),240)I,(IWT(I,J),J=1,NNC)
      END IF
C
      READ(IUN(19),250)(DX(J),J=1,NNC)
      IF(IOP(2).EQ.1)WRITE(IUN(23),260)(DX(J),J=1,NNC)
      READ(IUN(20),250)(DY(I),I=1,NNR)
      IF(IOP(2).EQ.1)WRITE(IUN(23),270)(DY(I),I=1,NNR)
C
      RETURN
C
C -------------------------------------
      ENTRY PUMPER(IP)
C -------------------------------------
C
C  READ AND WRITE SPECIFICATIONS FOR NEW PUMPING PERIOD
C
      DO 280 I=1,NNR
      DO 280 J=1,NNC
        IF(IWT(I,J).EQ.1.AND.BATH(I,J).LT.0.)WRITE(IUN(23),350)I,J
      DO 280 K=1,NNL
        WTOP(I,J,K)=0.0
        WBOT(I,J,K)=0.0
        PUMP(I,J,K)=0.0
  280 CONTINUE
C
      READ(IUN(21),290)DT,TFAC,TMAX,NTSP,NWELL
      WRITE(IUN(23),300)IP,DT,TFAC,TMAX,NTSP,NWELL
      TMAX=TMAX*86400.
      IF(DT.GT.TMAX)DT=TMAX
C
      IF(NWELL.NE.0)THEN
        IF(IOP(3).EQ.1)WRITE(IUN(23),310)
          DO 320 N=1,NWELL
            READ(IUN(21),330)I,J,K,PUMP(I,J,K),WTOP(I,J,K),WBOT(I,J,K)
            IF(IOP(3).EQ.1)WRITE(IUN(23),340)I,J,K,PUMP(I,J,K),
     &WTOP(I,J,K),WBOT(I,J,K)
  320     CONTINUE
      END IF
      IF(IOP(3).EQ.1)WRITE(IUN(23),200)
```

```
      CALL READ1(RECH,NNR,NNC,IUN(22),IUN(23),IOP(3))                   IN1870
C                                                                       IN1880
      RETURN                                                            IN1890
C                                                                       IN1900
   10 FORMAT(A70)                                                       IN1910
   20 FORMAT(/1X,79('-')/5X,A70/1X,79('-')/)                            IN1920
   30 FORMAT(25I5)                                                      IN1930
   40 FORMAT(' NUMBER OF ROWS=',I4/' NUMBER OF COLUMNS=',I4/' NUMBER OF IN1940
     1 AQUIFERS=',I4/' NUMBER OF TIME STEPS BETWEEN PRINTOUT=',I4/      IN1950
     2' MAXIMUM NUMBER OF ITERATIONS=',I4/' NUMBER OF ITERATION '       IN1960
     3'PARAMETERS=',I4/' NUMBER OF PUMPING PERIODS=',I4/                IN1970
     4' INTERFACE FIXED AFTER ',I4,' ITERATIONS'/' INPUT/OUTPUT OPTIONS'IN1980
     &' PARAMETER=',I4,' (0=USE DEFAULTS, 1=READ IN OPTIONS ARRAY)'/    IN1981
     &' LEAKAGE OPTION PARAMETER=',I4,' (0=RESTRICTED MIXING,'          IN1982
     &' 1=COMPLETE MIXING)')                                            IN1990
   41 FORMAT(/' ***WARNING-NO. OF ROWS GREATER THAN ARRAY DIMENSION')   IN1991
   42 FORMAT(/' ***WARNING-NO. OF COLUMNS GREATER THAN ARRAY DIMENSION')IN1992
   43 FORMAT(/' ***WARNING-NO. OF LAYERS GREATER THAN ARRAY DIMENSION') IN1993
   50 FORMAT(10G10.0)                                                   IN2000
   60 FORMAT(/' CONVERGENCE CRITERION=',G11.4/' STEADY STATE CRITERION='IN2010
     1,G11.4/' RELAXATION FACTOR=',G11.4/' WEIGHTING FACTOR=',G11.4/    IN2020
     1' ITERATION PARAMETER FACTOR=',G11.4/                             IN2030
     2' SPECIFIC GRAVITY OF FRESHWATER='                                IN2040
     2,G11.4/' SPECIFIC GRAVITY OF SALTWATER=',G11.4/                   IN2050
     3' VISCOSITY OF FRESHWATER=',G11.4/' VISCOSITY OF SALTWATER='      IN2060
     4,G11.4/)                                                          IN2070
   80 FORMAT(/1X,31('-')/' AQUIFER PARAMETERS FOR LAYER',I3/1X,31('-')) IN2080
   90 FORMAT(/' HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION')   IN2090
  100 FORMAT(/' HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION')   IN2100
  110 FORMAT(/' FRESHWATER SPECIFIC STORAGE')                           IN2110
  120 FORMAT(/' SALTWATER SPECIFIC STORAGE')                            IN2120
  130 FORMAT(/' EFFECTIVE POROSITY')                                    IN2130
  140 FORMAT(/' AQUIFER THICKNESS')                                     IN2140
  150 FORMAT(/' ELEVATION OF BASE OF AQUIFER')                          IN2150
  160 FORMAT(/' INITIAL FRESHWATER HEAD')                               IN2160
  170 FORMAT(/' INITIAL INTERFACE ELEVATION')                           IN2170
  180 FORMAT(/' AQUITARD LEAKANCES (K"/B")')                            IN2180
  190 FORMAT(/' HEAD IN OVERLYING AQUIFER')                             IN2190
  200 FORMAT(/' RECHARGE')                                              IN2200
  220 FORMAT(/'CODE FOR UPPER LAYER (1-UNCONFINED NODE,'                IN2210
     2'0-CONFINED NODE)')                                               IN2220
  240 FORMAT(I5,3X,25I5/(8X,25I5))                                      IN2230
  250 FORMAT(10G10.0)                                                   IN2240
  260 FORMAT(/' DELTA X'//(1H ,10G11.4))                                IN2250
  270 FORMAT(/' DELTA Y'//(1H ,10G11.4))                                IN2260
  290 FORMAT(3G10.0,4I5)                                                IN2270
  300 FORMAT(//1X,79('-')/30X,' PUMPING PERIOD',I3/1X,79('-')//         IN2280
     120X,'INITIAL TIME STEP(SEC)=',G11.4/20X,'MULTIPLICATION FACTOR ', IN2290
     2'FOR DELTA T=',G11.4/20X,'LENGTH OF PUMPING PERIOD(DAYS)=',G11.4/ IN2300
     320X,'MAXIMUM NUMBER OF TIME STEPS=',I3/                           IN2310
     420X,'NUMBER OF ACTIVE WELLS=',I3)                                 IN2320
  310 FORMAT(/33X,' PUMPING NODES:'/34X,14('-')//19X,'I',4X,'J',        IN2330
     14X,'K',3X,'PUMPAGE',3X,'SCREEN TOP',3X,'SCREEN BOTTOM'/           IN2340
     217X,52('-'))                                                      IN2350
```

```
 330  FORMAT(3I5,3G10.4)
 340  FORMAT(15X,3I5,G13.4,G12.4,G14.4)
 350  FORMAT(/' ***WARNING-UNCONFINED BLOCK WITH BATHYMETRY LESS THAN ',
     &'ZERO AT:',I3,',',I3)
      END
C
C ---------------------------------------------------------------------
      SUBROUTINE READ(DUM,IN,JN,K,IR,IW,IO)
C ---------------------------------------------------------------------
C
C  A SUBROUTINE TO READ AND WRITE DATA ARRAYS
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
C
      DIMENSION DUM(NR,NC,NL),DUM1(NR,NC)
C
C  THREE DIMENSIONAL ARRAYS
      READ(IR,100)M,DUMMY
C
      IF(M.EQ.1)THEN
        DO 10 I=1,IN
        DO 10 J=1,JN
          DUM(I,J,K)=DUMMY
  10    CONTINUE
        IF(IO.EQ.1)WRITE(IW,140)DUMMY
      ELSE
        DO 20 I=1,IN
          READ(IR,110)(DUM(I,J,K),J=1,JN)
  20    CONTINUE
        DO 30 I=1,IN
        DO 30 J=1,JN
          DUM(I,J,K)=DUM(I,J,K)*DUMMY
  30    CONTINUE
        IF(IO.EQ.1)THEN
          DO 40 I=1,IN
            WRITE(IW,130)I,(DUM(I,J,K),J=1,JN)
  40      CONTINUE
        END IF
      END IF
C
      RETURN
C
C -------------------------------------
      ENTRY READ1(DUM1,IN,JN,IR,IW,IO)
C -------------------------------------
C
C TWO DIMENSIONAL ARRAYS
      READ(IR,100)M,DUMMY
C
      IF(M.EQ.1)THEN
        DO 60 I=1,IN
        DO 60 J=1,JN
          DUM1(I,J)=DUMMY
```

```
   60    CONTINUE
         IF(IO.EQ.1)WRITE(IW,140)DUMMY
       ELSE
         DO 70 I=1,IN
           READ(IR,110)(DUM1(I,J),J=1,JN)
   70    CONTINUE
         DO 80 I=1,IN
         DO 80 J=1,JN
           DUM1(I,J)=DUM1(I,J)*DUMMY
   80    CONTINUE
         IF(IO.EQ.1)THEN
           DO 90 I=1,IN
             WRITE(IW,130)I,(DUM1(I,J),J=1,JN)
   90      CONTINUE
         END IF
       END IF
C
       RETURN
C
  100  FORMAT(I5,G10.0)
  110  FORMAT(10G10.0)
  130  FORMAT(I5,3X,10G11.4/(8X,10G11.4))
  140  FORMAT(/1H ,G11.4)
       END
C
C -----------------------------------------------------------------------
       SUBROUTINE IPARAM
C -----------------------------------------------------------------------
C
C  A SUBROUTINE TO CALCULATE ITERATION PARAMETERS
C
       IMPLICIT REAL*8 (A-H,O-Z)
       PARAMETER (NR=40,NC=47,NL=5)
       CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
       COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
      1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
      2LW,IW(10),JW(10),KW(10),NUP,NLK
C
       COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
       COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
      1,TPUMP,STST,WFAC,WITER
C
       COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
      1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
      2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
      3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
      4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
      5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
      6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
      7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
      8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
      9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
```

```
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
      SNR=DBLE(NNR*NNR)
      SNC=DBLE(NNC*NNC)
      X1=DBLE(NITP-1)
      WF=0.
      WS=1.
      C1=(VIF*SGS)/(VIS*SGF)
C
      DO 10 K=1,NNL
      DO 10 I=1,NNR
      DO 10 J=1,NNC
        IF(FKX(I,J,K).EQ.0.)GO TO 10
        IF(FKY(I,J,K).EQ.0.)WRITE(IUN(23),40)
        DX2=DX(J)**2
        DY2=DY(I)**2
          RHOF=(FKY(I,J,K)*DX2)/(FKX(I,J,K)*DY2)
          FMAX=DMAX1(SNC*(1.+RHOF),SNR*(1.+1./RHOF))
          IF(FMAX.GT.WF)WF=FMAX
   10 CONTINUE
C
      WF=3.141592654**2/(2.*WF)
      WOPTF(1)=0.D0
      DO 20 I=2,NITP
        X2=DBLE(I-1)
        WOPTF(I)=1.-(WF*WITER)**(X2/X1)
   20 CONTINUE
C
      WRITE(IUN(23),30)(WOPTF(I),I=1,NITP)
      RETURN
C
   30 FORMAT(/' ITERATION PARAMETERS:'/'   FRESHWATER EQUATION:'
     &,10G9.4/(24X,10G9.4))
   40 FORMAT(/' ***WARNING-FKY(',I3,',',I3,',',I3,') =0 AT AN ACTIVE ',
     &'BLOCK')
      END
C
C -----------------------------------------------------------------------
      SUBROUTINE KMEAN
C -----------------------------------------------------------------------
C
C  A SUBROUTINE TO CALCULATE MEAN CONDUCTIVITY TERMS AT BLOCK BOUNDARIES
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
```

```
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),
     6ZI(10,200),FAR(10,200),SAR(10,200)
C
C  CALCULATE HARMONIC MEANS
      DO 30 K=1,NNL
C
C  X DIRECTION
        DO 10 I=1,NNR
        DO 10 J=1,NNC-1
          J2=J+1
          TFX(I,J,K)=0.0
          IF(FKX(I,J,K).EQ.0.) GO TO 10
          T1=2*FKX(I,J2,K)*FKX(I,J,K)
          B1=FKX(I,J2,K)*DX(J)+FKX(I,J,K)*DX(J2)
          TFX(I,J,K)=T1/B1
   10   CONTINUE
C
C  Y DIRECTION
        DO 20 I=1,NNR-1
        DO 20 J=1,NNC
          I2=I+1
          TFY(I,J,K)=0.0
          IF(FKX(I,J,K).EQ.0.) GO TO 20
          T1=2*FKY(I2,J,K)*FKY(I,J,K)
          B1=FKY(I2,J,K)*DY(I)+FKY(I,J,K)*DY(I2)
          TFY(I,J,K)=T1/B1
   20   CONTINUE
   30 CONTINUE
C
      RETURN
      END
C
C ------------------------------------------------------------------
      SUBROUTINE SIP(*)
C ------------------------------------------------------------------
```

```
C
C  A SUBROUTINE TO SOLVE THE FRESHWATER AND SALTWATER FLOW EQUATIONS
C    USING THE STRONGLY IMPLICIT PROCEDURE
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /XNEW/FXN(NR,NC,NL),FYN(NR,NC,NL),SXN(NR,NC,NL),
     1SYN(NR,NC,NL)
C
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),
     6ZI(10,200),FAR(10,200),SAR(10,200)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
C  INITIALIZE VARIABLES
  5   NIT=0
      ITP=0
      DO 10 K=1,NNL
      DO 10 I=1,NNR
      DO 10 J=1,NNC
        VF(I,J,K)=0.0
        VS(I,J,K)=0.0
        DPHIF(I,J,K)=0.0
        DPHIS(I,J,K)=0.0
      DO 10 L=1,4
        E(I,J,K,L)=0.
        F(I,J,K,L)=0.
```

```
      G(I,J,K,L)=0.
 10   CONTINUE
C
C  BEGIN NEW ITERATION
 100  NIT=NIT+1
      DFMAX=0.0
      DSMAX=0.0
C
C  STOP IF MAXIMUM NUMBER OF ITERATIONS IS EXCEEDED
      IF(NIT.GT.ITMAX)THEN
          WRITE(IUN(24),20)
          CALL OUTPUT(1)
          RETURN 1
      END IF
C
C  SELECT ITERATION PARAMETER
      IF(MOD(NIT,NITP))30,30,40
  30  ITP=0
  40  ITP=ITP+1
      W=WOPTF(ITP)
C
C  UPDATE TRANSMISSIVITY COEFFICIENTS AND INTERFACE TRACKING
      IF(NIT.LE.NUP)CALL TCOEF
C
C  SELECT NORMAL OR REVERSE ALGORITHM
      IF(MOD(NIT,2))300,300,200
C
C  NORMAL ALGORITHM
 200  IFLAG=0
C
C  FACTOR COEFFICIENT MATRIX (A+B)
      DO 50 K=1,NNL
      DO 50 I=2,NNR-1
      DO 50 J=2,NNC-1
        IF(FKX(I,J,K).EQ.0.)GO TO 50
        AL=0.0
        IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)AL=1.0
        CALL FACTOR(I,J,K,IFLAG,AL,W)
  50  CONTINUE
C
C  BACK SUBSTITUTION FOR CHANGES IN FRESHWATER AND SALTWATER HEADS
      DO 60 KK=1,NNL
        K=NNL-KK+1
      DO 60 II=1,NNR-2
        I=NNR-II
      DO 60 JJ=1,NNC-2
        J=NNC-JJ
        I2=I+1
        J2=J+1
        K2=K+1
        DFK2=0.
        DSK2=0.
        IF(K2.LE.NNL)THEN
          DFK2=DPHIF(I,J,K2)
```

```
          DSK2=DPHIS(I,J,K2)
        END IF
        DPHIF(I,J,K)=VF(I,J,K)-(E(I,J,K,1)*DPHIF(I,J2,K)+E(I,J,K,2)*
     1DPHIS(I,J2,K)+F(I,J,K,1)*DPHIF(I2,J,K)+F(I,J,K,2)*DPHIS(I2,J,K)
     2+G(I,J,K,1)*DFK2+G(I,J,K,2)*DSK2)
        DPHIS(I,J,K)=VS(I,J,K)-(E(I,J,K,3)*DPHIF(I,J2,K)+E(I,J,K,4)*
     1DPHIS(I,J2,K)+F(I,J,K,3)*DPHIF(I2,J,K)+F(I,J,K,4)*DPHIS(I2,J,K)
     2+G(I,J,K,3)*DFK2+G(I,J,K,4)*DSK2)
   60 CONTINUE
      GO TO 400
C
C REVERSE ALGORITHM
  300 IFLAG=1
C  FACTOR COEFFICIENT MATRIX A
      DO 70 KK=1,NNL
        K=NNL-KK+1
      DO 70 II=1,NNR-2
        I=NNR-II
      DO 70 J=2,NNC-1
        IF(FKX(I,J,K).EQ.0.)GO TO 70
        AL=0.0
        IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)AL=1.0
        CALL FACTOR(I,J,K,IFLAG,AL,W)
   70 CONTINUE
C
C  BACK SUBSTITUTE FOR FRESHWATER AND SALTWATER HEAD CHANGES
      DO 80 K=1,NNL
      DO 80 I=2,NNR-1
      DO 80 JJ=1,NNC-2
        J=NNC-JJ
        I1=I-1
        J2=J+1
        K1=K-1
        DFK1=0.
        DSK1=0.
        IF(K1.GE.1)THEN
          DFK1=DPHIF(I,J,K1)
          DSK1=DPHIS(I,J,K1)
        END IF
        DPHIF(I,J,K)=VF(I,J,K)-(E(I,J,K,1)*DPHIF(I,J2,K)+E(I,J,K,2)*
     1DPHIS(I,J2,K)+F(I,J,K,1)*DPHIF(I1,J,K)+F(I,J,K,2)*DPHIS(I1,J,K)
     2+G(I,J,K,1)*DFK1+G(I,J,K,2)*DSK1)
        DPHIS(I,J,K)=VS(I,J,K)-(E(I,J,K,3)*DPHIF(I,J2,K)+E(I,J,K,4)*
     1DPHIS(I,J2,K)+F(I,J,K,3)*DPHIF(I1,J,K)+F(I,J,K,4)*DPHIS(I1,J,K)
     2+G(I,J,K,3)*DFK1+G(I,J,K,4)*DSK1)
   80 CONTINUE
C
  400 CONTINUE
C
C  DETERMINE LARGEST FRESHWATER AND SALTWATER HEAD CHANGE OVER
C     ITERATION AND UPDATE VALUES
      DO 90 K=1,NNL
      DO 90 I=2,NNR-1
      DO 90 J=2,NNC-1
```

```
         IF(FKX(I,J,K).EQ.0.)GO TO 90
         FMULT=1-INT(1.-FAREA(I,J,K))
         SMULT=1-INT(1.-SAREA(I,J,K))
         APHIF=DABS(FMULT*DPHIF(I,J,K))
         APHIS=DABS(SMULT*DPHIS(I,J,K))
         IF(APHIF.GT.DFMAX)THEN
           DFMAX=APHIF
           IF=I
           JF=J
           KF=K
         END IF
         IF(APHIS.GT.DSMAX)THEN
           DSMAX=APHIS
           IS=I
           JS=J
           KS=K
         END IF
         PHIF(I,J,K)=PHIF(I,J,K)+DPHIF(I,J,K)
         PHIS(I,J,K)=PHIS(I,J,K)+DPHIS(I,J,K)
   90  CONTINUE
       DMAXF(NIT)=DFMAX
       DMAXS(NIT)=DSMAX
C
C  WRITE ITERATION INFORMATION TO SCREEN
       IF(IOP(11).GT.0)THEN
       WRITE(1,'((A),I4,(A),I4,(A),G12.4,3I3,A3,(A),G12.4,3I3,A3))')
     &  'TS:',NT,' IT:',NIT,' DFMAX:',DPHIF(IF,JF,KF),IF,JF,KF,
     &  ICODE(IF,JF,KF),' DSMAX:',DPHIS(IS,JS,KS),IS,JS,KS,
     &  ICODE(IS,JS,KS)
       END IF
C
C  BEGIN NEW ITERATION IF CONVERGENCE HAS NOT BEEN ACHIEVED
       IF(DFMAX.GT.ERR.OR.DSMAX.GT.ERR) GO TO 100
C
C  STORE VALUES AT OBSERVATION NODES
       N=NT+1
       TIME(N)=TSEC/31557600.
       DO 110 L=1,LW
         I=IW(L)
         J=JW(L)
         K=KW(L)
         FWH(L,N)=PHIF(I,J,K)
         SWH(L,N)=PHIS(I,J,K)
         ZI(L,N)=ZINT(I,J,K)
         IC(L,N)=ICODE(I,J,K)
         FAR(L,N)=FAREA(I,J,K)
         SAR(L,N)=SAREA(I,J,K)
  110  CONTINUE
C
       RETURN
C
   20  FORMAT(/1X,37('*')/' MAXIMUM NUMBER OF ITERATIONS EXCEEDED'/
      11X,37('*'))
       END
```

```
C
C ----------------------------------------------------------------------
      SUBROUTINE TCOEF
C ----------------------------------------------------------------------
C
C  A SUBROUTINE TO CALCULATE FRESHWATER AND SALTWATER TRANSMISSIVITY
C    COEFFICIENTS
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /XNEW/FXN(NR,NC,NL),FYN(NR,NC,NL),SXN(NR,NC,NL),
     1SYN(NR,NC,NL)
C
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),
     6ZI(10,200),FAR(10,200),SAR(10,200)

      COMMON /IUNITS/IUN(32),IOP(12)
C
C CALCULATE FRESHWATER AND SALTWATER THICKNESSES
      C1=(VIF*SGS)/(VIS*SGF)
      C2=SGF/SGS
      C3=1./(1.+DEL)
      DO 10 K=1,NNL
      DO 10 I=1,NNR
      DO 10 J=1,NNC
        IF(FKX(I,J,K).EQ.0.) GO TO 10
C
```

```
C  CALCULATE NEW INTERFACE ELEVATION
        ZINT(I,J,K)=(1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)
        IF(IWT(I,J).EQ.1.AND.K.EQ.NNL)THEN
          ZTOP(I,J,K)=PHIF(I,J,K)
          IF(ZTOP(I,J,K).GT.(ZBOT(I,J,K)+THCK(I,J,K)))WRITE(IUN(23),170)
     &      I,J,K
        END IF
        TOP=ZTOP(I,J,K)
        THICK=TOP-ZBOT(I,J,K)
        FAREA(I,J,K)=0.
        SAREA(I,J,K)=0.
        FXN(I,J,K)=0.
        FYN(I,J,K)=0.
        SXN(I,J,K)=0.
        SYN(I,J,K)=0.
C
C  DETERMINE TYPE OF NODE
          IF((ZINT(I,J,K)-ZBOT(I,J,K)).LE.(.01*THICK))THEN
          ZINT(I,J,K)=ZBOT(I,J,K)
          ICODE(I,J,K)=FR
          FAREA(I,J,K)=1.
          FXN(I,J,K)=1.
          FYN(I,J,K)=1.
         ELSE IF((ZTOP(I,J,K)-ZINT(I,J,K)).LE.(.01*THICK))THEN
          ZINT(I,J,K)=TOP
          ICODE(I,J,K)=S
          SAREA(I,J,K)=1.
          SXN(I,J,K)=1.
          SYN(I,J,K)=1.
        ELSE
          ICODE(I,J,K)=M
          FAREA(I,J,K)=1.
          SAREA(I,J,K)=1.
          FXN(I,J,K)=1.
          FYN(I,J,K)=1.
          SXN(I,J,K)=1.
          SYN(I,J,K)=1.
        END IF
C
C  CALCULATE FRESHWATER AND SALTWATER THICKNESSES
        THS(I,J,K)=ZINT(I,J,K)-ZBOT(I,J,K)
        IF(THS(I,J,K).LT.0.0)THS(I,J,K)=0.0
        THF(I,J,K)=ZTOP(I,J,K)-ZINT(I,J,K)
        IF(THF(I,J,K).LT.0.0)THF(I,J,K)=0.0
C
   10 CONTINUE
C
C  CALCULATE TRANSMISSIVITY COEFFICIENTS
      DO 40 K=1,NNL
C
C     X DIRECTION
        DO 20 I=1,NNR
        DO 20 J=1,NNC-1
          IF(FKX(I,J,K).EQ.0.)GO TO 20
```

```
          J2=J+1
          FACT=DX(J)/(DX(J2)+DX(J))
          THIC=THF(I,J,K)+FACT*(THF(I,J2,K)-THF(I,J,K))
          TTFX(I,J,K)=TFX(I,J,K)*THIC
          THIC=THS(I,J,K)+FACT*(THS(I,J2,K)-THS(I,J,K))
          TTSX(I,J,K)=TFX(I,J,K)*THIC*C1
  20    CONTINUE
C
C     Y DIRECTION
        DO 30 I=1,NNR-1
        DO 30 J=1,NNC
          IF(FKX(I,J,K).EQ.0.)GO TO 30
          I2=I+1
          FACT=DY(I)/(DY(I2)+DY(I))
          THIC=THF(I,J,K)+FACT*(THF(I2,J,K)-THF(I,J,K))
          TTFY(I,J,K)=TFY(I,J,K)*THIC
          THIC=THS(I,J,K)+FACT*(THS(I2,J,K)-THS(I,J,K))
          TTSY(I,J,K)=TFY(I,J,K)*THIC*C1
  30    CONTINUE
C
C  INTERFACE TIP TRACKING
C    X DIRECTION PROJECTION
        DO 50 I=2,NNR-1
        DO 50 J=2,NNC-1
          IF(FKX(I,J,K).EQ.0.)GO TO 50
          IF(ICODE(I,J,K).EQ.S)GO TO 50
            JP=J+1
            JM=J-1
            DX2=DX(J)/2
C
C  HEAD DERIVATIVES IN X DIRECTION
            DXM=0.5*(DX(J)+DX(JM))
            DXP=0.5*(DX(JP)+DX(J))
            DSM=(PHIS(I,J,K)-PHIS(I,JM,K))/DXM
            DSP=(PHIS(I,JP,K)-PHIS(I,J,K))/DXP
            DFM=(PHIF(I,J,K)-PHIF(I,JM,K))/DXM
            DFP=(PHIF(I,JP,K)-PHIF(I,J,K))/DXP
C
C  PROJECTION IN POSITIVE X DIRECTION
          IF(ICODE(I,JP,K).EQ.S)THEN
            IF(ICODE(I,JM,K).EQ.'.'.OR.ICODE(I,JM,K).EQ.S)THEN
              DSM=DSP
              DFM=DFP
            END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF TOP OF AQUIFER
            XLOLD=0.
            IF(FX(I,J,K).GE.1.0)THEN
              XLOLD=(FX(I,J,K)-0.5)*DX(J)+FX(I,JP,K)*DX(JP)
            ELSE IF(FX(I,J,K).GT.0.5)THEN
              XLOLD=(FX(I,J,K)-0.5)*DX(J)
            END IF
            FP=2.*FX(I,JP,K)
            IF(FP.GT.1.)FP=1.
```

```
          DZINT=(1.+DEL)*((1.-FP)*DSM+FP*DSP)-DEL*
     1((1.-FP)*DFM+FP*DFP)
          DZTOP=(ZTOP(I,JP,K)-ZTOP(I,J,K))/DXP
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
        DEN=DZINT-DZTOP
        IF(DEN.NE.0.0)THEN
          XLNEW=THF(I,J,K)/(DZINT-DZTOP)
          IF(ICODE(I,J,K).EQ.FR)XLNEW=(ZTOP(I,J,K)-
     1((1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)))/(DZINT-DZTOP)
        ELSE
          XLNEW=XLOLD
        END IF
        AXL=WFAC*DABS(XLNEW)+(1.-WFAC)*XLOLD
        IF(AXL.LE.DX2)THEN
           FXN(I,J,K)=(AXL+DX2)/DX(J)
           TTSX(I,J,K)=TTSX(I,J,K)+TTFX(I,J,K)*C1
           TTFX(I,J,K)=0.
           IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)FXN(I,J,K)=1.
        ELSE
           FL=(AXL-DX2)/DX(JP)
           IF(FL.GT.1.0)FL=1.0
             FXN(I,JP,K)=FL
               TTFXN=THF(I,J,K)*(AXL-DX2)/AXL*TFX(I,J,K)
               TTSX(I,J,K)=TTSX(I,J,K)+(TTFX(I,J,K)-TTFXN)*C1
               TTFX(I,J,K)=TTFXN
         END IF
        END IF
C
C  PROJECTION IN THE NEGATIVE X DIRECTION
        IF(ICODE(I,JM,K).EQ.S)THEN
          IF(ICODE(I,JP,K).EQ.'.'.OR.ICODE(I,JP,K).EQ.S)THEN
            DSP=DSM
            DFP=DFM
          END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF TOP OF AQUIFER
          XLOLD=0.
          IF(FX(I,J,K).GE.1.0)THEN
            XLOLD=(FX(I,J,K)-0.5)*DX(J)+FX(I,JM,K)*DX(JM)
          ELSE IF(FX(I,J,K).GT.0.5)THEN
            XLOLD=(FX(I,J,K)-0.5)*DX(J)
          END IF
          FM=2.*FX(I,JM,K)
          IF(FM.GT.1.)FM=1.
          DZINT=(1.+DEL)*(FM*DSM+(1.-FM)*DSP)-DEL*
     1(FM*DFM+(1.-FM)*DFP)
          DZTOP=(ZTOP(I,J,K)-ZTOP(I,JM,K))/DXM
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
        DEN=DZINT-DZTOP
        IF(DEN.NE.0.0)THEN
          XLNEW=THF(I,J,K)/(DZINT-DZTOP)
          IF(ICODE(I,J,K).EQ.FR)XLNEW=(ZTOP(I,J,K)-
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     1((1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)))/(DZINT-DZTOP)
          ELSE
            XLNEW=XLOLD
          END IF
          AXL=WFAC*DABS(XLNEW)+(1.-WFAC)*XLOLD
          IF(AXL.LE.DX2)THEN
            IF(FXN(I,J,K).LT.1.)THEN
             FXN(I,J,K)=FXN(I,J,K)+(AXL+DX2)/DX(J)
            ELSE
             FXN(I,J,K)=(AXL+DX2)/DX(J)
            END IF
             IF(FXN(I,J,K).GT.1.)FXN(I,J,K)=1.0
             TTSX(I,JM,K)=TTSX(I,JM,K)+TTFX(I,JM,K)*C1
             TTFX(I,JM,K)=0.
             IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)FXN(I,J,K)=1.
          ELSE
             FL=(AXL-DX2)/DX(JM)
             IF(FL.GT.1.0)FL=1.0
              IF(FXN(I,J,K).LT.1.)THEN
               FXN(I,JM,K)=FXN(I,JM,K)+FL
              ELSE
               FXN(I,JM,K)=FL
              END IF
             IF(FXN(I,JM,K).GT.1.)FXN(I,JM,K)=1.0
               TTFXN=THF(I,J,K)*(AXL-DX2)/AXL*TFX(I,JM,K)
               TTSX(I,JM,K)=TTSX(I,JM,K)+(TTFX(I,JM,K)-TTFXN)*C1
               TTFX(I,JM,K)=TTFXN
           END IF
          END IF
C
C  Y DIRECTION PROJECTION
            IP=I+1
            IM=I-1
            DY2=DY(I)/2.
C
C  HEAD DERIVATIVES IN THE Y DIRECTION
            DYM=0.5*(DY(I)+DY(IM))
            DYP=0.5*(DY(IP)+DY(I))
            DSM=(PHIS(I,J,K)-PHIS(IM,J,K))/DYM
            DSP=(PHIS(IP,J,K)-PHIS(I,J,K))/DYP
            DFM=(PHIF(I,J,K)-PHIF(IM,J,K))/DYM
            DFP=(PHIF(IP,J,K)-PHIF(I,J,K))/DYP
C
C  PROJECTION IN THE POSITIVE Y DIRECTION
          IF(ICODE(IP,J,K).EQ.S)THEN
            IF(ICODE(IM,J,K).EQ.'.'.OR.ICODE(IM,J,K).EQ.S)THEN
              DSM=DSP
              DFM=DFP
            END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF TOP OF AQUIFER
            YLOLD=0.
            IF(FY(I,J,K).GE.1.0)THEN
              YLOLD=(FY(I,J,K)-0.5)*DY(I)+FY(IP,J,K)*DY(IP)
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          ELSE IF(FY(I,J,K).GT.0.5)THEN
            YLOLD=(FY(I,J,K)-0.5)*DY(I)
          END IF
          FP=2.*FY(IP,J,K)
          IF(FP.GT.1.)FP=1.
          DZINT=(1.+DEL)*((1.-FP)*DSM+FP*DSP)-DEL*
     1((1.-FP)*DFM+FP*DFP)
          DZTOP=(ZTOP(IP,J,K)-ZTOP(I,J,K))/DYP
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
        DEN=DZINT-DZTOP
        IF(DEN.NE.0.0)THEN
          YLNEW=THF(I,J,K)/(DZINT-DZTOP)
          IF(ICODE(I,J,K).EQ.FR)YLNEW=(ZTOP(I,J,K)-
     1((1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)))/(DZINT-DZTOP)
        ELSE
          YLNEW=YLOLD
        END IF
        AYL=WFAC*DABS(YLNEW)+(1.-WFAC)*YLOLD
        IF(AYL.LE.DY2)THEN
          FL=(AYL+DY2)/DY(I)
          FYN(I,J,K)=FL
          TTSY(I,J,K)=TTSY(I,J,K)+TTFY(I,J,K)*C1
          TTFY(I,J,K)=0.0
           IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)FYN(I,J,K)=1.
        ELSE
          FL=(AYL-DY2)/DY(IP)
          IF(FL.GT.1.0)FL=1.0
          FYN(IP,J,K)=FL
          TTFYN=THF(I,J,K)*(AYL-DY2)/AYL*TFY(I,J,K)
          TTSY(I,J,K)=TTSY(I,J,K)+(TTFY(I,J,K)-TTFYN)*C1
          TTFY(I,J,K)=TTFYN
        END IF
        END IF
C
C  PROJECTION IN THE NEGATIVE Y DIRECTION
        IF(ICODE(IM,J,K).EQ.S)THEN
          IF(ICODE(IP,J,K).EQ.'.'.OR.ICODE(IP,J,K).EQ.S)THEN
            DSP=DSM
            DFP=DFM
          END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF TOP OF AQUIFER
          YLOLD=0.
          IF(FY(I,J,K).GE.1.0)THEN
            YLOLD=(FY(I,J,K)-0.5)*DY(I)+FY(IM,J,K)*DY(IM)
          ELSE IF(FY(I,J,K).GT.0.5)THEN
            YLOLD=(FY(I,J,K)-0.5)*DY(I)
          END IF
          FM=2.*FY(IM,J,K)
          IF(FM.GT.1.)FM=1.
          DZINT=(1.+DEL)*(FM*DSM+(1.-FM)*DSP)-DEL*
     1(FM*DFM+(1.-FM)*DFP)
          DZTOP=(ZTOP(I,J,K)-ZTOP(IM,J,K))/DYM
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C                                                                       TC3160
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS      TC3170
          DEN=DZINT-DZTOP                                               TC3180
          IF(DEN.NE.0.0)THEN                                            TC3190
            YLNEW=THF(I,J,K)/(DZINT-DZTOP)                              TC3200
            IF(ICODE(I,J,K).EQ.FR)YLNEW=(ZTOP(I,J,K)-                   TC3210
     1((1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)))/(DZINT-DZTOP)             TC3220
          ELSE                                                          TC3230
            YLNEW=YLOLD                                                 TC3240
          END IF                                                        TC3250
          AYL=WFAC*DABS(YLNEW)+(1.-WFAC)*YLOLD                          TC3260
          IF(AYL.LE.DY2)THEN                                            TC3270
            FL=(AYL+DY2)/DY(I)                                          TC3280
           IF(FYN(I,J,K).LT.1.)THEN                                     TC3290
            FYN(I,J,K)=FYN(I,J,K)+FL                                    TC3300
           ELSE                                                         TC3310
            FYN(I,J,K)=FL                                               TC3320
           END IF                                                       TC3330
            IF(FYN(I,J,K).GT.1.)FYN(I,J,K)=1.0                          TC3340
            TTSY(IM,J,K)=TTSY(IM,J,K)+TTFY(IM,J,K)*C1                   TC3350
            TTFY(IM,J,K)=0.0                                            TC3360
             IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)FYN(I,J,K)=1.                TC3361
          ELSE                                                          TC3370
            FL=(AYL-DY2)/DY(IM)                                         TC3380
            IF(FL.GT.1.0)FL=1.0                                         TC3390
           IF(FYN(IM,J,K).LT.1.)THEN                                    TC3400
            FYN(IM,J,K)=FYN(IM,J,K)+FL                                  TC3410
           ELSE                                                         TC3420
            FYN(IM,J,K)=FL                                              TC3430
           END IF                                                       TC3440
            IF(FYN(IM,J,K).GT.1.)FYN(IM,J,K)=1.0                        TC3450
            TTFYN=THF(I,J,K)*(AYL-DY2)/AYL*TFY(IM,J,K)                  TC3460
            TTSY(IM,J,K)=TTSY(IM,J,K)+(TTFY(IM,J,K)-TTFYN)*C1           TC3470
            TTFY(IM,J,K)=TTFYN                                          TC3480
          END IF                                                        TC3490
          END IF                                                        TC3500
  50    CONTINUE                                                        TC3510
C                                                                       TC3520
C  INTERFACE TOE TRACKING                                               TC3530
C    X DIRECTION  PROJECTION                                            TC3540
        DO 80 I=2,NNR-1                                                 TC3550
        DO 80 J=2,NNC-1                                                 TC3560
          IF(FKX(I,J,K).EQ.0.)GO TO 80                                  TC3570
          IF(ICODE(I,J,K).EQ.FR)GO TO 80                                TC3580
            JP=J+1                                                      TC3590
            JM=J-1                                                      TC3600
            DX2=DX(J)/2.                                                TC3610
C                                                                       TC3620
C  HEAD DERIVATIVES IN X DIRECTION                                      TC3630
            DXM=0.5*(DX(J)+DX(JM))                                      TC3640
            DXP=0.5*(DX(JP)+DX(J))                                      TC3650
            DSM=(PHIS(I,J,K)-PHIS(I,JM,K))/DXM                          TC3660
            DSP=(PHIS(I,JP,K)-PHIS(I,J,K))/DXP                          TC3670
            DFM=(PHIF(I,J,K)-PHIF(I,JM,K))/DXM                          TC3680
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          DFP=(PHIF(I,JP,K)-PHIF(I,J,K))/DXP
C
C  PROJECTION IN POSITIVE X DIRECTION
        IF(ICODE(I,JP,K).EQ.FR)THEN
          IF(ICODE(I,JM,K).EQ.'.'.OR.ICODE(I,JM,K).EQ.FR)THEN
            DSM=DSP
            DFM=DFP
          END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF BOTTOM OF AQUIFER
          XLOLD=0.
          IF(SX(I,J,K).GE.1.0)THEN
            XLOLD=(SX(I,J,K)-0.5)*DX(J)+SX(I,JP,K)*DX(JP)
          ELSE IF(SX(I,J,K).GT.0.5)THEN
            XLOLD=(SX(I,J,K)-0.5)*DX(J)
          END IF
          SP=XLOLD/DXP
          IF(SP.GT.1.)SP=1.
          DZINT=(1.+DEL)*((1.-SP)*DSM+SP*DSP)-DEL*
     1((1.-SP)*DFM+SP*DFP)
          DZBOT=(ZBOT(I,JP,K)-ZBOT(I,J,K))/DXP
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
        DEN=DZBOT-DZINT
        IF(DEN.NE.0.0)THEN
          XLNEW=THS(I,J,K)/(DZBOT-DZINT)
          IF(ICODE(I,J,K).EQ.S)XLNEW=(((1.+DEL)*PHIS(I,J,K)-
     1DEL*PHIF(I,J,K))-ZBOT(I,J,K))/(DZBOT-DZINT)
        ELSE
          XLNEW=XLOLD
        END IF
        AXL=WFAC*DABS(XLNEW)+(1.-WFAC)*XLOLD
        IF(AXL.LE.DX2)THEN
           SXN(I,J,K)=(AXL+DX2)/DX(J)
           IF (ICODE(I,J,K).NE.S) THEN
             TTFX(I,J,K)=TTFX(I,J,K)+TTSX(I,J,K)/C1
             TTSX(I,J,K)=0.
           ENDIF
        ELSE
           SL=(AXL-DX2)/DX(JP)
           IF(SL.GT.1.0)SL=1.0
             SXN(I,JP,K)=SL
             IF (ICODE(I,J,K).NE.S) THEN
               TTSXN=THS(I,J,K)*(AXL-DX2)/AXL*TFX(I,J,K)*C1
               TTFX(I,J,K)=TTFX(I,J,K)+(TTSX(I,J,K)-TTSXN)/C1
               TTSX(I,J,K)=TTSXN
             ENDIF
         END IF
        END IF
C
C  PROJECTION IN NEGATIVE X DIRECTION
        IF(ICODE(I,JM,K).EQ.FR)THEN
          IF(ICODE(I,JP,K).EQ.'.'.OR.ICODE(I,JP,K).EQ.FR)THEN
            DSP=DSM
```

```
            DFP=DFM
          END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF BOTTOM OF AQUIFER
          XLOLD=0.
          IF(SX(I,J,K).GE.1.0)THEN
            XLOLD=(SX(I,J,K)-0.5)*DX(J)+SX(I,JM,K)*DX(JM)
          ELSE IF(SX(I,J,K).GT.0.5)THEN
            XLOLD=(SX(I,J,K)-0.5)*DX(J)
          END IF
         SM=XLOLD/DXM
          IF(SM.GT.1.)SM=1.
          DZINT=(1.+DEL)*(SM*DSM+(1.-SM)*DSP)-DEL*
     1(SM*DFM+(1.-SM)*DFP)
          DZBOT=(ZBOT(I,J,K)-ZBOT(I,JM,K))/DXM
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
        DEN=DZBOT-DZINT
        IF(DEN.NE.0.0)THEN
          XLNEW=THS(I,J,K)/(DZBOT-DZINT)
          IF(ICODE(I,J,K).EQ.S)XLNEW=(((1.+DEL)*PHIS(I,J,K)-
     1DEL*PHIF(I,J,K))-ZBOT(I,J,K))/(DZBOT-DZINT)
        ELSE
          XLNEW=XLOLD
        END IF
        AXL=WFAC*DABS(XLNEW)+(1.-WFAC)*XLOLD
        IF(AXL.LE.DX2)THEN
          IF(SXN(I,J,K).LT.1.)THEN
           SXN(I,J,K)=SXN(I,J,K)+(AXL+DX2)/DX(J)
          ELSE
           SXN(I,J,K)=(AXL+DX2)/DX(J)
          END IF
          IF(SXN(I,J,K).GT.1.)SXN(I,J,K)=1.
           IF(ICODE(I,J,K).NE.S) THEN
             TTFX(I,JM,K)=TTFX(I,JM,K)+TTSX(I,JM,K)/C1
             TTSX(I,JM,K)=0.
           ENDIF
        ELSE
           SL=(AXL-DX2)/DX(JM)
           IF(SL.GT.1.0)SL=1.0
            IF(SXN(I,JM,K).LT.1.)THEN
             SXN(I,JM,K)=SXN(I,JM,K)+SL
            ELSE
             SXN(I,JM,K)=SL
            END IF
            IF(SXN(I,JM,K).GT.1.)SXN(I,JM,K)=1.0
             IF(ICODE(I,J,K).EQ.S) THEN
               FACT=DX(JM)/(DX(J)+DX(JM))
               THIC=THCK(I,JM,K)+FACT*(THCK(I,J,K)-THCK(I,JM,K))
             ELSE
               TTSXN=THS(I,J,K)*(AXL-DX2)/AXL*TFX(I,JM,K)*C1
               TTFX(I,JM,K)=TTFX(I,JM,K)+(TTSX(I,JM,K)-TTSXN)/C1
               TTSX(I,JM,K)=TTSXN
             END IF
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          END IF
         END IF
C
C  Y DIRECTION PROJECTION
           IP=I+1
           IM=I-1
           DY2=DY(I)/2.
C
C  HEAD DERIVATIVES IN Y DIRECTION
           DYM=0.5*(DY(I)+DY(IM))
           DYP=0.5*(DY(IP)+DY(I))
           DSM=(PHIS(I,J,K)-PHIS(IM,J,K))/DYM
           DSP=(PHIS(IP,J,K)-PHIS(I,J,K))/DYP
           DFM=(PHIF(I,J,K)-PHIF(IM,J,K))/DYM
           DFP=(PHIF(IP,J,K)-PHIF(I,J,K))/DYP
C
C  PROJECTION IN POSITIVE Y DIRECTION
         IF(ICODE(IP,J,K).EQ.FR)THEN
           IF(ICODE(IM,J,K).EQ.'.'.OR.ICODE(IM,J,K).EQ.FR)THEN
             DSM=DSP
             DFM=DFP
           END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF BASE OF AQUIFER
           YLOLD=0.
           IF(SY(I,J,K).GE.1.0)THEN
             YLOLD=(SY(I,J,K)-0.5)*DY(I)+SY(IP,J,K)*DY(IP)
           ELSE IF(SX(I,J,K).GT.0.5)THEN
             YLOLD=(SY(I,J,K)-0.5)*DY(I)
           END IF
          SP=YLOLD/DYP
           IF(SP.GT.1.)SP=1.
           DZINT=(1.+DEL)*((1.-SP)*DSM+SP*DSP)-DEL*
    1((1.-SP)*DFM+SP*DFP)
           DZBOT=(ZBOT(IP,J,K)-ZBOT(I,J,K))/DYP
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
         DEN=DZBOT-DZINT
         IF(DEN.NE.0.0)THEN
           YLNEW=THS(I,J,K)/(DZBOT-DZINT)
           IF(ICODE(I,J,K).EQ.S)YLNEW=(((1.+DEL)*PHIS(I,J,K)-
    1DEL*PHIF(I,J,K))-ZBOT(I,J,K))/(DZBOT-DZINT)
         ELSE
           YLNEW=YLOLD
         END IF
         AYL=WFAC*DABS(YLNEW)+(1.-WFAC)*YLOLD
         IF(AYL.LE.DY2)THEN
           SL=(AYL+DY2)/DY(I)
           SYN(I,J,K)=SL
           IF (ICODE(I,J,K).NE.S) THEN
             TTFY(I,J,K)=TTFY(I,J,K)+TTSY(I,J,K)/C1
             TTSY(I,J,K)=0.0
           ENDIF
         ELSE
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          SL=(AYL-DY2)/DY(IP)
          IF(SL.GT.1.0)SL=1.0
          SYN(IP,J,K)=SL
          IF (ICODE(I,J,K).NE.S) THEN
            TTSYN=THS(I,J,K)*(AYL-DY2)/AYL*TFY(I,J,K)*C1
            TTFY(I,J,K)=TTFY(I,J,K)+(TTSY(I,J,K)-TTSYN)/C1
            TTSY(I,J,K)=TTSYN
          ENDIF
        END IF
        END IF
C
C  PROJECTION IN NEGATIVE Y DIRECTION
        IF(ICODE(IM,J,K).EQ.FR)THEN
          IF(ICODE(IP,J,K).EQ.'.'.OR.ICODE(IP,J,K).EQ.FR)THEN
            DSP=DSM
            DFP=DFM
          END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF BASE OF AQUIFER
          YLOLD=0.
          IF(SY(I,J,K).GE.1.0)THEN
            YLOLD=(SY(I,J,K)-0.5)*DY(I)+SY(IM,J,K)*DY(IM)
          ELSE IF(SY(I,J,K).GT.0.5)THEN
            YLOLD=(SY(I,J,K)-0.5)*DY(I)
          END IF
          SM=YLOLD/DYM
          IF(SM.GT.1.)SM=1.
          DZINT=(1.+DEL)*(SM*DSM+(1.-SM)*DSP)-DEL*
     1(SM*DFM+(1.-SM)*DFP)
          DZBOT=(ZBOT(I,J,K)-ZBOT(IM,J,K))/DYM
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
        DEN=DZBOT-DZINT
        IF(DEN.NE.0.0)THEN
          YLNEW=THS(I,J,K)/(DZBOT-DZINT)
          IF(ICODE(I,J,K).EQ.S)YLNEW=(((1.+DEL)*PHIS(I,J,K)-
     1DEL*PHIF(I,J,K))-ZBOT(I,J,K))/(DZBOT-DZINT)
        ELSE
          YLNEW=YLOLD
        END IF
        AYL=WFAC*DABS(YLNEW)+(1.-WFAC)*YLOLD
        IF(AYL.LE.DY2)THEN
          SL=(AYL+DY2)/DY(I)
         IF(SYN(I,J,K).LT.1.)THEN
          SYN(I,J,K)=SYN(I,J,K)+SL
         ELSE
          SYN(I,J,K)=SL
         END IF
         IF(SYN(I,J,K).GT.1.)SYN(I,J,K)=1.
          IF (ICODE(I,J,K).NE.S) THEN
            TTFY(IM,J,K)=TTFY(IM,J,K)+TTSY(IM,J,K)/C1
            TTSY(IM,J,K)=0.0
          ENDIF
        ELSE
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          SL=(AYL-DY2)/DY(IM)
          IF(SL.GT.1.0)SL=1.0
         IF(SYN(IM,J,K).LT.1.)THEN
          SYN(IM,J,K)=SYN(IM,J,K)+SL
         ELSE
          SYN(IM,J,K)=SL
         END IF
         IF(SYN(IM,J,K).GT.1.)SYN(IM,J,K)=1.0
          IF (ICODE(I,J,K).NE.S) THEN
            TTSYN=THS(I,J,K)*(AYL-DY2)/AYL*TFY(IM,J,K)*C1
            TTFY(IM,J,K)=TTFY(IM,J,K)+(TTSY(IM,J,K)-TTSYN)/C1
            TTSY(IM,J,K)=TTSYN
          ENDIF
        END IF
        END IF
 80   CONTINUE
C
C  CALCULATE NEW FRESHWATER AND SALTWATER AREA FACTORS
      DO 100 I=2,NNR-1
      DO 100 J=2,NNC-1
        IF(FKX(I,J,K).EQ.0.)GO TO 100
        IF(FXN(I,J,K).EQ.0.0.OR.FXN(I,J,K).EQ.1.0)THEN
          FAREA(I,J,K)=FYN(I,J,K)
        ELSE IF(FYN(I,J,K).EQ.0.0.OR.FYN(I,J,K).EQ.1.0)THEN
          FAREA(I,J,K)=FXN(I,J,K)
        ELSE IF(FXN(I,J,K).LE.0.5)THEN
          FAREA(I,J,K)=(1.-DSQRT(FXN(I,J,K)*FYN(I,J,K)))*
     1(FXN(I,J,K)+FYN(I,J,K))
        ELSE IF(FYN(I,J,K).LE.0.5)THEN
          FAREA(I,J,K)=(1.-DSQRT(FXN(I,J,K)*FYN(I,J,K)))*
     1(FXN(I,J,K)+FYN(I,J,K))
        ELSE
          FL=FXN(I,J,K)*FYN(I,J,K)
          FAREA(I,J,K)=FL*(1.+(1./((FL+.75)**7)))
          IF(FAREA(I,J,K).GT.1.0)FAREA(I,J,K)=1.0
        END IF
        IF(SXN(I,J,K).EQ.0.0.OR.SXN(I,J,K).EQ.1.0)THEN
          SAREA(I,J,K)=SYN(I,J,K)
        ELSE IF(SYN(I,J,K).EQ.0.0.OR.SYN(I,J,K).EQ.1.0)THEN
          SAREA(I,J,K)=SXN(I,J,K)
        ELSE IF(SXN(I,J,K).LE.0.5)THEN
          SAREA(I,J,K)=(1.-DSQRT(SXN(I,J,K)*SYN(I,J,K)))*
     1(SXN(I,J,K)+SYN(I,J,K))
        ELSE IF(SYN(I,J,K).LE.0.5)THEN
          SAREA(I,J,K)=(1.-DSQRT(SXN(I,J,K)*SYN(I,J,K)))*
     1(SXN(I,J,K)+SYN(I,J,K))
        ELSE
          SL=SXN(I,J,K)*SYN(I,J,K)
          SAREA(I,J,K)=SL*(1.+(1./((SL+.75)**7)))
          IF(SAREA(I,J,K).GT.1.0)SAREA(I,J,K)=1.0
        END IF
        FX(I,J,K)=FXN(I,J,K)
        FY(I,J,K)=FYN(I,J,K)
        SX(I,J,K)=SXN(I,J,K)
```

```
         SY(I,J,K)=SYN(I,J,K)
 100    CONTINUE
C
  40  CONTINUE
C
 170  FORMAT(/' ***WARNING: WATER TABLE ABOVE LAND SURFACE AT BLOCK:',
     &I3,2X,I3,2X,I3)
C
      RETURN
      END
C
C -----------------------------------------------------------------------
      SUBROUTINE FACTOR(I,J,K,IFLAG,AL,W)
C -----------------------------------------------------------------------
C
C  A SUBROUTINE TO CALCULATE COEFFICIENTS OF MATRIX (A) AND FACTOR
C    MODIFIED COEFFICIENT MATRIX (A+B)
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),
     6ZI(10,200),FAR(10,200),SAR(10,200)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
      DIMENSION G1(4)
C
```

```
      I1=I-1
      I2=I+1
      J1=J-1
      J2=J+1
      K1=K-1
      K2=K+1
      AREA=DX(J)*DY(I)
C
      DO 5 L=1,4
        BB(L)=0.
        DD(L)=0.
        EE(L)=0.
        FF(L)=0.
        HH(L)=0.
        SS(L)=0.
        ZZ(L)=0.
        EK1(L)=0.
        FK1(L)=0.
        A(L)=0.0
    5 CONTINUE
C
C  ASSIGN VALUES OF TRANSMISSIVITY COEFFICIENTS
        BB(1)=TTFY(I1,J,K)*DX(J)
        DD(1)=TTFX(I,J1,K)*DY(I)
        FF(1)=TTFX(I,J,K)*DY(I)
        HH(1)=TTFY(I,J,K)*DX(J)
        BB(4)=TTSY(I1,J,K)*DX(J)
        DD(4)=TTSX(I,J1,K)*DY(I)
        FF(4)=TTSX(I,J,K)*DY(I)
        HH(4)=TTSY(I,J,K)*DX(J)
C
C  CALCULATE LEAKAGE COEFFICIENTS
      AQLTOP=(1.-AL)*AQL(I,J,K)*AREA
      AQLBOT=0.0
      SGR=SGS/SGF
      IF(K.NE.1)AQLBOT=AQL(I,J,K1)*AREA
      QF2=0.
      QS2=0.
      QF1=0.
      QS1=0.
      QFL=0.
      QSL=0.
      ZZ1=0.
      E5=0.
      WT1=1.0
      WT2=1.0
      WT3=0.0
      RT3=1.0
      WT4=1.0
      WT5=1.0
        IF(NLK.EQ.0)THEN
          WT2=0.0
          WT3=FAREA(I,J,K)
          WT4=0.0
```

```
          IF(K.NE.NNL)THEN
            DIRP=(SGR*PHIS(I,J,K+1)-PHIF(I,J,K))-(ZBOT(I,J,K2)+
     &ZTOP(I,J,K))/(2.*DEL)
            IF(DIRP.GT.0.0)WT1=0.0
            IF(ICODE(I,J,K2).EQ.'.')THEN
              WT1=1.0
              WT2=1.0
              IF(PHIF(I,J,K2).GT.PHIF(I,J,K).AND.BATH(I,J).LT.0.)WT5=0.0
            END IF
          END IF
          IF(K.NE.1)THEN
            DIRM=(PHIF(I,J,K1)-SGR*PHIS(I,J,K))+(ZBOT(I,J,K)+
     &ZTOP(I,J,K1))/(2.*DEL)
            IF(DIRM.LT.0.0)RT3=0.0
          END IF
        END IF
      IF(K.EQ.NNL)THEN
        PHTOPF=(1.-AL)*HEAD(I,J)
        PHTOPS=(1.-AL)*(HEAD(I,J)/SGR+BATH(I,J)/(DEL+1.))
        QF1=FAREA(I,J,K)*AQLTOP*PHTOPF
        QS1=(1.-FAREA(I,J,K))*AQLTOP*PHTOPS
        QF2=FAREA(I,J,K)*AQLTOP
        QS2=(1.-FAREA(I,J,K))*AQLTOP
        IF(NLK.EQ.0)THEN
          IF(HEAD(I,J).GT.PHIF(I,J,K).AND.BATH(I,J).LT.0.)THEN
            QF1=0.0
            QF2=0.0
          END IF
        END IF
C
       ELSE
         IF(FAREA(I,J,K).GE.(1.-SAREA(I,J,K2)))THEN
           SS(1)=(1.-SAREA(I,J,K2))*AQLTOP
           SS(2)=(FAREA(I,J,K)-(1.-SAREA(I,J,K2)))*AQLTOP*SGR*WT1
           SS(4)=(1.-FAREA(I,J,K))*AQLTOP
           QFL=-SS(2)/SGR*(ZBOT(I,J,K2)+ZTOP(I,J,K))/(2.*DEL)
         ELSE
           SS(1)=FAREA(I,J,K)*AQLTOP*WT5
           SS(3)=((1.-FAREA(I,J,K))-SAREA(I,J,K2))*AQLTOP*
     &WT2
           SS(4)=SAREA(I,J,K2)*AQLTOP
           QSL=SS(3)*(ZBOT(I,J,K2)+ZTOP(I,J,K))/(2.*DEL)
         END IF
       END IF
       IF(K.NE.1)THEN
         IF(FAREA(I,J,K1).GT.(1.-SAREA(I,J,K)))THEN
           ZZ1=RT3*WT3*(FAREA(I,J,K1)-(1.-SAREA(I,J,K)))*AQLBOT
           E5=ZZ1*SGR
           ZZ(1)=(1.-SAREA(I,J,K))*AQLBOT+ZZ1
           ZZ(3)=(FAREA(I,J,K1)-(1.-SAREA(I,J,K)))*AQLBOT*(1.-
     &WT3)*RT3
           ZZ(4)=(1.-FAREA(I,J,K1))*AQLBOT
           QFL=QFL+ZZ1*(ZBOT(I,J,K)+ZTOP(I,J,K1))/(2.*DEL)
           QSL=QSL+ZZ(3)*(ZBOT(I,J,K)+ZTOP(I,J,K1))/(2.*DEL)
```

```
         ELSE
           ZZ(1)=FAREA(I,J,K1)*AQLBOT
           ZZ(2)=WT4*((1.-FAREA(I,J,K1))-SAREA(I,J,K))*AQLBOT*SGR
           ZZ(4)=SAREA(I,J,K)*AQLBOT
           QFL=QFL-ZZ(2)/SGR*(ZBOT(I,J,K)+ZTOP(I,J,K1))/(2.*DEL)
        END IF
       END IF
C
       E2=SS(1)+SS(2)/SGR+(ZZ(1)-ZZ1)+ZZ(2)/SGR+QF2
       E4=SS(3)*SGR+SS(4)+ZZ(3)*SGR+ZZ(4)+QS2
C
C  CALCULATE REMAINING COEFFICIENTS
       APROP=FAREA(I,J,K)+SAREA(I,J,K)-1.
       ARDT=AREA/DT
       IF(APROP.GT.0.)THEN
         E1=(POR(I,J,K)*DEL*APROP+(POR(I,J,K)*AL+STORF(I,J,K)*
     1THF(I,J,K))*FAREA(I,J,K))*ARDT
         EE(2)=POR(I,J,K)*(1.+DEL)*APROP*ARDT
         EE(3)=POR(I,J,K)*DEL*APROP*ARDT
         E3=(POR(I,J,K)*(1.+DEL)*APROP+STORS(I,J,K)*THS(I,J,K)*
     1SAREA(I,J,K))*ARDT
       ELSE
         E1=SAREA(I,J,K)+(STORF(I,J,K)*THF(I,J,K)+AL*POR(I,J,K))*
     1FAREA(I,J,K)*ARDT
         EE(2)=(1.-FAREA(I,J,K))*SGR
         EE(3)=(1.-SAREA(I,J,K))/SGR
         E3=FAREA(I,J,K)+STORS(I,J,K)*THS(I,J,K)*SAREA(I,J,K)*ARDT
       END IF
C
       EE(1)=-(BB(1)+DD(1)+FF(1)+HH(1)+E1+E2)
       EE(2)=EE(2)-E5
       EE(4)=-(BB(4)+DD(4)+FF(4)+HH(4)+E3+E4)
C
C  CALCULATE FRESHWATER AND SALTWATER PUMPAGES
      PUMPF(I,J,K)=0.0
      PUMPS=0.0
      IF(PUMP(I,J,K).EQ.0.) GO TO 10
        TOP=WTOP(I,J,K)
        BOT=WBOT(I,J,K)
        IF(WTOP(I,J,K).GT.ZTOP(I,J,K))TOP=ZTOP(I,J,K)
        IF(TOP.LE.WBOT(I,J,K))THEN
          PUMP(I,J,K)=0.
          WRITE(IUN(24),20)I,J,K
          GO TO 10
        END IF
C
        IF(TOP.GT.ZINT(I,J,K))THEN
          IF(BOT.LT.ZINT(I,J,K))THEN
            THICF=TOP-ZINT(I,J,K)
            THICS=ZINT(I,J,K)-BOT
          ELSE
            THICF=TOP-BOT
            THICS=0.0
          END IF
```

```
      ELSE
        THICF=0.0
        THICS=TOP-BOT
      END IF
C
      THICK=THICF+THICS
      PUMPF(I,J,K)=THICF*PUMP(I,J,K)/THICK
      PUMPS=PUMP(I,J,K)-PUMPF(I,J,K)
C
C  ZERO COEFFICIENTS AT CONSTANT HEAD NODES
 10   IF(STORF(I,J,K).LT.0.)THEN
        BB(1)=0.
        DD(1)=0.
        FF(1)=0.
        HH(1)=0.
        SS(1)=0.
        SS(2)=0.
        ZZ(1)=0.
        ZZ(2)=0.
        QF1=0.
        QF2=0.
        EE(1)=1.0E+06
        EE(2)=0.
        QFL=0.
        E5=0.
      END IF
      IF(STORS(I,J,K).LT.0.)THEN
        BB(4)=0.
        DD(4)=0.
        FF(4)=0.
        HH(4)=0.
        SS(3)=0.
        SS(4)=0.
        ZZ(3)=0.
        ZZ(4)=0.
        QS1=0.
        QS2=0.
        EE(3)=0.
        EE(4)=1.0E+06
        QSL=0.
      END IF
C
C  CALCULATE FRESHWATER AND SALTWATER RESIDUALS
      QF=(EE(2)+E5)*PHISP(I,J,K)-E1*PHIFP(I,J,K)
    1-AL*RECH(I,J)*AREA+PUMPF(I,J,K)-QF1-QFL
      Z1=0.
      S1=0.
      IF(K.NE.1)Z1=ZZ(1)*PHIF(I,J,K1)+ZZ(2)*PHIS(I,J,K1)
      IF(K.NE.NNL)S1=SS(1)*PHIF(I,J,K2)+SS(2)*PHIS(I,J,K2)
      RESF=QF-(BB(1)*PHIF(I1,J,K)+DD(1)*PHIF(I,J1,K)+EE(1)*PHIF(I,J,K)
    1+EE(2)*PHIS(I,J,K)+FF(1)*PHIF(I,J2,K)+HH(1)*PHIF(I2,J,K)+Z1+S1)
      IF(FAREA(I,J,K).LE.0.)RESF=0.
      QS=EE(3)*PHIFP(I,J,K)-E3*PHISP(I,J,K)
    1+PUMPS-QS1-QSL
```

```
      Z2=0.
      S2=0.
      IF(K.NE.1)Z2=ZZ(3)*PHIF(I,J,K1)+ZZ(4)*PHIS(I,J,K1)
      IF(K.NE.NNL)S2=SS(3)*PHIF(I,J,K2)+SS(4)*PHIS(I,J,K2)
      RESS=QS-(BB(4)*PHIS(I1,J,K)+DD(4)*PHIS(I,J1,K)+EE(3)*PHIF(I,J,K)
     1+EE(4)*PHIS(I,J,K)+FF(4)*PHIS(I,J2,K)+HH(4)*PHIS(I2,J,K)+Z2+S2)
      IF(SAREA(I,J,K).LE.0.)RESS=0.
      IF(STORF(I,J,K).LT.0.)THEN
        RESF=0.
      END IF
      IF(STORS(I,J,K).LT.0.)THEN
        RESS=0.
      END IF
C
C  PICK COEFFICIENTS FOR NORMAL OR REVERSE FACTORIZATION
    IF(IFLAG.EQ.0)THEN
      II=I1
      KK=K1
    ELSE
      DO 7 L=1,4
        BBB(L)=HH(L)
        HH(L)=BB(L)
        BB(L)=BBB(L)
        ZZZ(L)=SS(L)
        SS(L)=ZZ(L)
        ZZ(L)=ZZZ(L)
  7   CONTINUE
      II=I2
      KK=K2
    ENDIF
C
C  CALCULATION OF MODIFIED COEFFICIENT MATRIX (A+B) AND FACTORIZATION
C
    IF(KK.GE.1.AND.KK.LE.NNL)THEN
      CALL ASSIGN(E,EK1,I,J,KK)
      CALL ASSIGN(F,FK1,I,J,KK)
      CALL MAT1(EK1,FK1,ARRAY,W)
      CALL INV(ARRAY,ARRAY)
      CALL MULT(ZZ,ARRAY,A)
    END IF
C
    CALL ASSIGN(E,EI1,II,J,K)
    CALL ASSIGN(G,GI1,II,J,K)
    CALL MAT1(EI1,GI1,ARRAY,W)
    CALL INV(ARRAY,ARRAY)
    CALL MULT(BB,ARRAY,B)
C
    CALL ASSIGN(F,FJ1,I,J1,K)
    CALL ASSIGN(G,GJ1,I,J1,K)
    CALL MAT1(FJ1,GJ1,ARRAY,W)
    CALL INV(ARRAY,ARRAY)
    CALL MULT(DD,ARRAY,C)
C
    CALL MULT(A,EK1,AA)
```

```
      CALL MULT(B,EI1,CC)
      CALL MULT(C,FJ1,GG)
      CALL MULT(C,GJ1,WW)
      CALL MULT(A,FK1,TT)
      CALL MULT(B,GI1,UU)
C
      DO 100 L=1,4
        D(L)=EE(L)+W*(CC(L)+GG(L)+AA(L)+WW(L)+TT(L)+UU(L))
 100  CONTINUE
C
      IF(KK.LT.1.OR.KK.GT.NNL)THEN
        DO 150 L=1,4
          G1(L)=0.
          A(L)=0.
 150    CONTINUE
        VF1=0.
        VS1=0.
      ELSE
        DO 160 L=1,4
          G1(L)=G(I,J,KK,L)
 160    CONTINUE
        VF1=VF(I,J,KK)
        VS1=VS(I,J,KK)
      END IF
C
      D(1)=D(1)-(A(1)*G1(1)+A(2)*G1(3)+B(1)*F(II,J,K,1)
     1+B(2)*F(II,J,K,3)+C(1)*E(I,J1,K,1)+C(2)*E(I,J1,K,3))
      D(2)=D(2)-(A(1)*G1(2)+A(2)*G1(4)+B(1)*F(II,J,K,2)
     1+B(2)*F(II,J,K,4)+C(1)*E(I,J1,K,2)+C(2)*E(I,J1,K,4))
      D(3)=D(3)-(A(3)*G1(1)+A(4)*G1(3)+B(3)*F(II,J,K,1)
     1+B(4)*F(II,J,K,3)+C(3)*E(I,J1,K,1)+C(4)*E(I,J1,K,3))
      D(4)=D(4)-(A(3)*G1(2)+A(4)*G1(4)+B(3)*F(II,J,K,2)
     1+B(4)*F(II,J,K,4)+C(3)*E(I,J1,K,2)+C(4)*E(I,J1,K,4))
C
      CALL MAT2(FF,CC,AA,ARRAY,W)
      CALL INV(D,D)
      CALL MULT(D,ARRAY,EIJK)
C
      CALL MAT2(HH,GG,TT,ARRAY,W)
      CALL MULT(D,ARRAY,FIJK)
C
      CALL MAT2(SS,WW,UU,ARRAY,W)
      CALL MULT(D,ARRAY,GIJK)
C
      DO 200 L=1,4
        E(I,J,K,L)=EIJK(L)
        F(I,J,K,L)=FIJK(L)
        G(I,J,K,L)=GIJK(L)
 200  CONTINUE
C
C  FORWARD SUBSTITUTION FOR VECTOR (V)
      XF=RFAC*RESF-(A(1)*VF1+A(2)*VS1+B(1)*VF(II,J,K)
     1+B(2)*VS(II,J,K)+C(1)*VF(I,J1,K)+C(2)*VS(I,J1,K))
      XS=RFAC*RESS-(A(3)*VF1+A(4)*VS1+B(3)*VF(II,J,K)
```

```
     1+B(4)*VS(II,J,K)+C(3)*VF(I,J1,K)+C(4)*VS(I,J1,K))
C
      VF(I,J,K)=D(1)*XF+D(2)*XS
      VS(I,J,K)=D(3)*XF+D(4)*XS
C
      RETURN
C
   20 FORMAT(' WELL(',I2,',',I2,',',I2,') GOES DRY')
      END
C
C-----------------------------------------------------------------------
      SUBROUTINE MULT(A,B,C)
C-----------------------------------------------------------------------
C
C  A SUBROUTINE TO MULTIPLY MATRIX A TIMES MATRIX B
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION A(4),B(4),C(4)
C
      C(1)=A(1)*B(1)+A(2)*B(3)
      C(2)=A(1)*B(2)+A(2)*B(4)
      C(3)=A(3)*B(1)+A(4)*B(3)
      C(4)=A(3)*B(2)+A(4)*B(4)
C
      RETURN
      END
C
C-----------------------------------------------------------------------
      SUBROUTINE INV(A,AINV)
C-----------------------------------------------------------------------
C
C  A SUBROUTINE TO TAKE THE INVERSE OF MATRIX A
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION A(4),AINV(4)
C
      DET=A(1)*A(4)-A(2)*A(3)
      A1=A(1)
      AINV(1)=A(4)/DET
      AINV(2)=-A(2)/DET
      AINV(3)=-A(3)/DET
      AINV(4)=A1/DET
C
      RETURN
      END
C
C-----------------------------------------------------------------------
      SUBROUTINE MAT1(A,B,C,W)
C-----------------------------------------------------------------------
C
C  A SUBROUTINE TO DO MATRIX CALCULATIONS USED IN FACTORIZATION
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION A(4),B(4),C(4)
C
      DO 10 I=1,4,3
        C(I)=1.+W*(A(I)+B(I))
```

```
   10  CONTINUE
       DO 20 I=2,3
         C(I)=W*(A(I)+B(I))
   20  CONTINUE
C
       RETURN
       END
C
C-----------------------------------------------------------------------
       SUBROUTINE MAT2(A,B,C,D,W)
C-----------------------------------------------------------------------
C
C  A SUBROUTINE TO DO MATRIX CALCULATIONS USED IN FACTORIZATION
       IMPLICIT REAL*8 (A-H,O-Z)
       DIMENSION A(4),B(4),C(4),D(4)
C
       DO 10 I=1,4
         D(I)=A(I)-W*(B(I)+C(I))
   10  CONTINUE
C
       RETURN
       END
C
C-----------------------------------------------------------------------
       SUBROUTINE ASSIGN(A,B,I,J,K)
C-----------------------------------------------------------------------
C
C  A SUBROUTINE TO ASSIGN MATRIX ELEMENTS
       IMPLICIT REAL*8 (A-H,O-Z)
       PARAMETER (NR=40,NC=47,NL=5)
       DIMENSION A(NR,NC,NL,4),B(4)
C
       DO 10 L=1,4
         B(L)=A(I,J,K,L)
   10  CONTINUE
C
       RETURN
       END
C
C-----------------------------------------------------------------------
       SUBROUTINE RESULTS
C-----------------------------------------------------------------------
C
C  A SUBROUTINE TO WRITE TIME STEP RESULTS TO FILE
C
       IMPLICIT REAL*8 (A-H,O-Z)
       PARAMETER (NR=40,NC=47,NL=5)
       CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
       COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
       COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
```

```
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
      DO 130 K=1,NNL
      WRITE(IUN(25),81)K,TSEC
   81 FORMAT('     0         1.0     PHIF LAYER',I3,', T (SEC)=',G20.10)
      DO 110 I=1,NNR
  110 WRITE(IUN(25),80)(PHIF(I,J,K),J=1,NNC)
      DO 115 I=1,NNR
      DO 115 J=1,NNC
        ZINT(I,J,K)=(1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)
  115 CONTINUE
      WRITE(IUN(26),82)K,TSEC
   82 FORMAT('     0         1.0     ZINT LAYER',I3,', T (SEC)=',G20.10)
      DO 120 I=1,NNR
  120 WRITE(IUN(26),80)(ZINT(I,J,K),J=1,NNC)
      WRITE(IUN(27),83)K,TSEC
   83 FORMAT('     0         1.0     FX LAYER',I3,', T (SEC)=',G20.10)
      DO 121 I=1,NNR
  121 WRITE(IUN(27),80)(FX(I,J,K),J=1,NNC)
      WRITE(IUN(28),84)K,TSEC
   84 FORMAT('     0         1.0     FY LAYER',I3,', T (SEC)=',G20.10)
      DO 122 I=1,NNR
  122 WRITE(IUN(28),80)(FY(I,J,K),J=1,NNC)
      WRITE(IUN(29),85)K,TSEC
   85 FORMAT('     0         1.0     SX LAYER',I3,', T (SEC)=',G20.10)
      DO 123 I=1,NNR
  123 WRITE(IUN(29),80)(SX(I,J,K),J=1,NNC)
      WRITE(IUN(30),86)K,TSEC
   86 FORMAT('     0         1.0     SY LAYER',I3,', T (SEC)=',G20.10)
      DO 124 I=1,NNR
  124 WRITE(IUN(30),80)(SY(I,J,K),J=1,NNC)
  130 CONTINUE
C
   80 FORMAT(10F10.3)
C
      RETURN
      END
C
C -----------------------------------------------------------------
```

```
      SUBROUTINE OUTPUT(KWRITE)
C -----------------------------------------------------------------------
C
C  A SUBROUTINE TO PRINT MODEL SOLUTION
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /BAL/FIN(7),FOUT(5),SSIN(7),SOUT(5),CFIN(7,NL),CFOUT(5,NL),
     1CSIN(7,NL),CSOUT(5,NL),FFLOW(200),SFLOW(200),IFL(200),
     2JFL(200),ISL(200),JSL(200),FLKT(NR,NC),SLKT(NR,NC),FLKB(NR,NC),
     3SLKB(NR,NC),FSTOR,CFSTR(10),SSTOR,CSSTR(10),TFIN,TCFIN,TSSIN,
     4TCSIN,TFOUT,TCFOUT,TSOUT,TCSOUT,FSLKT(NR,NC),SFLKT(NR,NC),
     5FDIF,CFDIF,SDIF,CSDIF,FRERF,FRERS,FSLKB(NR,NC),SFLKB(NR,NC),
     6CFRERF,CFRERS,SRERF,SRERS,CSRERF,CSRERS
C
      COMMON /WHEAD/WPHIF(NR,NC),WPHIS(NR,NC),WZINT(NR,NC)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
C  PRINT TIME STEP INFORMATION
      DTHRS=DT/3600.
      DTDAYS=DTHRS/24.
      DTYRS=DTDAYS/365.25
      THRS=TSEC/3600.
      TDAYS=THRS/24.
      TYRS=TDAYS/365.25
      PHRS=TPUMP/3600.
      PDAYS=PHRS/24.
      PYRS=PDAYS/365.25
      WRITE(IUN(24),10)NT,DT,DTHRS,DTDAYS,DTYRS,TPUMP,PHRS,PDAYS,PYRS,
     1TSEC,THRS,TDAYS,TYRS
      WRITE(IUN(24),20)(DMAXF(I),I=1,NIT)
      WRITE(IUN(24),30)(DMAXS(I),I=1,NIT)
```

```
C
C  IF NUMBER OF TIME STEPS BETWEEN PRINTOUTS HAS NOT BEEN REACHED,
C    CALCULATE MASS BALANCE AND BEGIN NEW TIME STEP
      IF(KWRITE.EQ.0)THEN
        DO 199 K=1,NNL
  199   CALL MASBAL(NFH,NSH,K)
        RETURN
      ELSE
      DO 200 K=1,NNL
        WRITE(IUN(24),40)K
        WRITE(IUN(32),45)NT,K
C
C  CALCULATE AND PRINT AQUIFER MASS BALANCE
        CALL MASBAL(NFH,NSH,K)
        WRITE(IUN(24),50)
        WRITE(IUN(24),60)FSTOR,CFSTR(K),SSTOR,CSSTR(K),FIN(1),CFIN(1,K)
        WRITE(IUN(24),70)(FIN(I),CFIN(I,K),SSIN(I),CSIN(I,K),I=2,7),
     1TFIN,TCFIN,TSSIN,TCSIN
        WRITE(IUN(24),80)(FOUT(I),CFOUT(I,K),SOUT(I),CSOUT(I,K),I=2,5),
     1TFOUT,TCFOUT,TSOUT,TCSOUT,FDIF,CFDIF,SDIF,CSDIF,FRERF,
     1CFRERF,SRERF,CSRERF,FRERS,CFRERS,SRERS,CSRERS
C
        DO 99 I=1,NNR
        DO 99 J=1,NNC
          WPHIF(I,J)=PHIF(I,J,K)
          WPHIS(I,J)=PHIS(I,J,K)
          WZINT(I,J)=11111.
          IF(FAREA(I,J,K).LE.0.)THEN
            WPHIF(I,J)=11111.
          END IF
          IF(SAREA(I,J,K).LE.0.)THEN
            WPHIS(I,J)=11111.
          END IF
        IF(ICODE(I,J,K).EQ.M)THEN
          WZINT(I,J)=ZINT(I,J,K)
        END IF
   99   CONTINUE
C
C  PRINT AQUIFER POTENTIALS AND INTERFACE ELEVATIONS
        IF(IOP(4).EQ.1)THEN
          WRITE(IUN(24),90)
          DO 100 I=1,NNR
 100        WRITE(IUN(24),110)I,(WPHIF(I,J),J=1,NNC)
        END IF
        IF(IOP(5).EQ.1)THEN
          WRITE(IUN(24),120)
          DO 130 I=1,NNR
 130        WRITE(IUN(24),110)I,(WPHIS(I,J),J=1,NNC)
        END IF
        IF(IOP(6).EQ.1)THEN
          WRITE(IUN(24),140)
          DO 150 I=1,NNR
 150        WRITE(IUN(24),110)I,(WZINT(I,J),J=1,NNC)
        END IF
```

```
      IF(IOP(7).EQ.1)THEN
        WRITE(IUN(24),220)
        DO 190 I=1,NNR
190       WRITE(IUN(24),240)I,(FAREA(I,J,K),J=1,NNC)
      END IF
      IF(IOP(8).EQ.1)THEN
        WRITE(IUN(24),230)
        DO 195 I=1,NNR
195       WRITE(IUN(24),240)I,(SAREA(I,J,K),J=1,NNC)
      END IF
      IF(IOP(9).EQ.1)THEN
        WRITE(IUN(24),160)
        DO 170 I=1,NNR
170       WRITE(IUN(24),180)I,(ICODE(I,J,K),J=1,NNC)
      END IF
      IF(IOP(10).EQ.1)THEN
        WRITE(IUN(32),250)
        DO 196 I=1,NNR
 196    WRITE(IUN(32),111)I,(FLKT(I,J),J=1,NNC)
        WRITE(IUN(32),251)
        DO 296 I=1,NNR
 296    WRITE(IUN(32),111)I,(FSLKT(I,J),J=1,NNC)
        WRITE(IUN(32),260)
        DO 197 I=1,NNR
 197    WRITE(IUN(32),111)I,(FLKB(I,J),J=1,NNC)
        WRITE(IUN(32),261)
        DO 297 I=1,NNR
 297    WRITE(IUN(32),111)I,(FSLKB(I,J),J=1,NNC)
        WRITE(IUN(32),270)
        DO 198 I=1,NNR
 198    WRITE(IUN(32),111)I,(SLKT(I,J),J=1,NNC)
        WRITE(IUN(32),271)
        DO 298 I=1,NNR
 298    WRITE(IUN(32),111)I,(SFLKT(I,J),J=1,NNC)
        WRITE(IUN(32),280)
        DO 201 I=1,NNR
 201    WRITE(IUN(32),111)I,(SLKB(I,J),J=1,NNC)
        WRITE(IUN(32),281)
        DO 301 I=1,NNR
 301    WRITE(IUN(32),111)I,(SFLKB(I,J),J=1,NNC)
        IF(NFH.GT.0)THEN
          WRITE(IUN(32),290)
          WRITE(IUN(32),300)(IFL(I),JFL(I),FFLOW(I),I=1,NFH)
        END IF
        IF(NSH.GT.0)THEN
          WRITE(IUN(32),310)
          WRITE(IUN(32),300)(ISL(I),JSL(I),SFLOW(I),I=1,NSH)
        END IF
      END IF
200 CONTINUE
    END IF
C
    RETURN
C
```

```
 10  FORMAT(/1X,13('-')/' TIME STEP',I4/1X,13('-')/26X,'SECONDS',           OP1520
    16X,'HOURS',6X,'DAYS',7X,'YEARS'/'   TIME STEP SIZE:',7X,4G11.4/         OP1530
    2'    PUMPING PERIOD TIME:',2X,4G11.4/'   TOTAL SIMULATION TIME:',       OP1540
    44G11.4/)                                                                OP1550
 20  FORMAT(' MAXIMUM FRESHWATER HEAD CHANGE:',8G11.4                        OP1560
    1/(33X,8G11.4))                                                          OP1570
 30  FORMAT(' MAXIMUM SALTWATER HEAD CHANGE: ',8G11.4                        OP1580
    1/(33X,8G11.4))                                                          OP1590
 40  FORMAT(/' AQUIFER',I4/1X,11('-'))                                       OP1600
 45  FORMAT(//1X,13('-')/' TIME STEP',I4/1X,13('-')//                        OP1610
    1' AQUIFER',I4/1X,11('-'))                                               OP1620
 50  FORMAT(5X,' MASS BALANCE:')                                             OP1630
 60  FORMAT(38X,'  FRESHWATER ',21X,' SALTWATER'                             OP1640
    1/35X,'T.S. RATE',3X,'CUM. VOLUME',9X,'T.S. RATE',3X,                    OP1650
    2'CUM. VOLUME'/9X,' CHANGE IN STORAGE',7X,2G11.4,10X,2G11.4/             OP1660
    410X,' SOURCES'/10X,'   RECHARGE',14X,2G11.4)                            OP1670
 70  FORMAT(10X,'   CONSTANT HEAD NODES',3X,2G11.4,10X,2G11.4/               OP1680
    110X,'   INJECTION',13X,2G11.4,10X,2G11.4/                               OP1690
    210X,'   FW LEAKAGE ACROSS TOP',1X,2G11.4,10X,2G11.4/                    OP1700
    210X,'   FW LEAKAGE ACROSS BOT',1X,2G11.4,10X,2G11.4/                    OP1710
    210X,'   SW LEAKAGE ACROSS TOP',1X,2G11.4,10X,2G11.4/                    OP1711
    210X,'   SW LEAKAGE ACROSS BOT',1X,2G11.4,10X,2G11.4/                    OP1712
    310X,'   TOTAL',17X,2G11.4,10X,2G11.4)                                   OP1720
 80  FORMAT(10X,' SINKS'/10X,'   CONSTANT HEAD NODES',3X,2G11.4,10X,         OP1730
    12G11.4/10X,'   PUMPAGE',15X,2G11.4,10X,2G11.4/10X,'   LEAKAGE',         OP1740
    1' ACROSS TOP',4X,2G11.4,10X,2G11.4/10X,'   LEAKAGE ACROSS BOT',         OP1750
    24X,2G11.4,10X,2G11.4/10X,'   TOTAL',17X,2G11.4,10X,2G11.4/              OP1760
    310X,' SOURCES-SINKS',11X,2G11.4,10X,2G11.4/                             OP1770
    48X,' RELATIVE ERROR (%)'/                                               OP1780
    512X,' INFLUX',16X,2G11.4,10X,2G11.4/12X,' STORAGE',15X,2G11.4,10X,      OP1790
    62G11.4)                                                                 OP1800
 90  FORMAT(/' FRESHWATER HEADS')                                            OP1810
110  FORMAT(I5,3X,10G11.5/(8X,10G11.5))                                      OP1820
111  FORMAT(I5,3X,10G11.4/(8X,10G11.4))                                      OP1830
120  FORMAT(/' SALTWATER HEADS')                                             OP1840
140  FORMAT(/' INTERFACE ELEVATION')                                         OP1850
160  FORMAT(/' MAP OF EXTENT OF INTRUSION',                                  OP1860
    1' (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)'/)                 OP1870
180  FORMAT(I5,3X,50A2/(8X,50A2))                                            OP1880
210  FORMAT(/' CUMULATIVE MASS BALANCE:')                                    OP1890
220  FORMAT(//' FAREA'/)                                                     OP1900
230  FORMAT(//' SAREA'/)                                                     OP1910
240  FORMAT(I5,3X,30F4.1/(8X,30F4.1))                                        OP1920
250  FORMAT(/' FRESHWATER LEAKAGE ACROSS TOP FROM OVERLYING ',               OP1930
    &'FRESHWATER')                                                           OP1931
251  FORMAT(/' FRESHWATER LEAKAGE ACROSS TOP FROM OVERLYING SALTWATER')      OP1932
260  FORMAT(/' FRESHWATER LEAKAGE ACROSS BOT FROM UNDERLYING ',              OP1940
    &'FRESHWATER')                                                           OP1941
261  FORMAT(/' FRESHWATER LEAKAGE ACROSS BOT FROM UNDERLYING ',              OP1942
    &'SALTWATER')                                                            OP1943
270  FORMAT(/' SALTWATER LEAKAGE ACROSS TOP FROM OVERLYING SALTWATER')       OP1950
271  FORMAT(/' SALTWATER LEAKAGE ACROSS TOP FROM OVERLYING FRESHWATER')      OP1951
280  FORMAT(/' SALTWATER LEAKAGE ACROSS BOT FROM UNDERLYING ',               OP1960
    &'SALTWATER')                                                            OP1961
```

```
 281  FORMAT(/' SALTWATER LEAKAGE ACROSS BOT FROM UNDERLYING ',
     &'FRESHWATER')
 290  FORMAT(/' FLOW RATES TO FRESHWATER CONSTANT HEAD NODES:'/
     19X,'I',4X,'J',7X,'RATE',3(14X,'I',4X,'J',7X,'RATE'))
 300  FORMAT(4(5X,2I5,3X,G11.4))
 310  FORMAT(/' FLOW RATES TO SALTWATER CONSTANT HEAD NODES:'/
     19X,'I',4X,'J',5X,'RATE',3(14X,'I',4X,'J',5X,'RATE'))
      END
C
C ----------------------------------------------------------------------
      SUBROUTINE MASBAL(NFH,NSH,K)
C ----------------------------------------------------------------------
C
C  A SUBROUTINE TO CALCULATE AQUIFER AND CUMULATIVE MASS BALANCES
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /BAL/FIN(7),FOUT(5),SSIN(7),SOUT(5),CFIN(7,NL),CFOUT(5,NL),
     1CSIN(7,NL),CSOUT(5,NL),FFLOW(200),SFLOW(200),IFL(200),
     2JFL(200),ISL(200),JSL(200),FLKT(NR,NC),SLKT(NR,NC),FLKB(NR,NC),
     3SLKB(NR,NC),FSTOR,CFSTR(10),SSTOR,CSSTR(10),TFIN,TCFIN,TSSIN,
     4TCSIN,TFOUT,TCFOUT,TSOUT,TCSOUT,FSLKT(NR,NC),SFLKT(NR,NC),
     5FDIF,CFDIF,SDIF,CSDIF,FRERF,FRERS,FSLKB(NR,NC),SFLKB(NR,NC),
     6CFRERF,CFRERS,SRERF,SRERS,CSRERF,CSRERS
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
C  INITIALIZE VARIABLES
      IF(NFLAG.EQ.1)THEN
        DO 11 L=1,NNL
        CFSTR(L)=0.0
        CSSTR(L)=0.0
```

```
          DO 10 I=1,5                                                     MB 440
            CFIN(I,L)=0.                                                  MB 450
            CFOUT(I,L)=0.                                                 MB 460
            CSIN(I,L)=0.                                                  MB 470
            CSOUT(I,L)=0.                                                 MB 480
   10     CONTINUE                                                        MB 490
          CFIN(6,L)=0.0                                                   MB 491
          CFIN(7,L)=0.0                                                   MB 492
          CSIN(6,L)=0.0                                                   MB 493
          CSIN(7,L)=0.0                                                   MB 494
   11     CONTINUE                                                        MB 495
        END IF                                                            MB 500
        DO 20 I=1,5                                                       MB 510
          FIN(I)=0.                                                       MB 520
          FOUT(I)=0.                                                      MB 530
          SSIN(I)=0.                                                      MB 540
          SOUT(I)=0.                                                      MB 550
 20     CONTINUE                                                          MB 560
        FIN(6)=0.                                                         MB 561
        FIN(7)=0.                                                         MB 562
        SSIN(6)=0.                                                        MB 563
        SSIN(7)=0.                                                        MB 564
        NFLAG=0                                                           MB 570
        FSTOR=0.0                                                         MB 580
        SSTOR=0.0                                                         MB 590
        FRERF=0.0                                                         MB 600
        SRERF=0.0                                                         MB 610
        FRERS=0.0                                                         MB 620
        SRERS=0.0                                                         MB 630
        CFRERF=0.0                                                        MB 640
        CSRERF=0.0                                                        MB 650
        CFRERS=0.0                                                        MB 660
        CSRERS=0.0                                                        MB 670
        NFH=0                                                             MB 680
        NSH=0                                                             MB 690
C                                                                         MB 700
        DO 199 I=1,NNR                                                    MB 710
        DO 199 J=1,NNC                                                    MB 720
          FLKT(I,J)=0.                                                    MB 730
          FSLKT(I,J)=0.                                                   MB 731
          FLKB(I,J)=0.                                                    MB 740
          FSLKB(I,J)=0.                                                   MB 741
          SLKT(I,J)=0.                                                    MB 750
          SFLKT(I,J)=0.                                                   MB 751
          SLKB(I,J)=0.                                                    MB 760
          SFLKB(I,J)=0.                                                   MB 761
 199    CONTINUE                                                          MB 770
C  BEGIN CALCULATIONS                                                     MB 780
        DO 200 I=2,NNR-1                                                  MB 790
        DO 200 J=2,NNC-1                                                  MB 800
        IF (FKX(I,J,K).EQ.0.) GO TO 200                                   MB 810
          AREA=DX(J)*DY(I)                                                MB 820
          AL=0.0                                                          MB 830
          IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)AL=1.0                            MB 840
```

```
C
C  COMPUTE FRESHWATER AND SALTWATER RATE CHANGES FOR TIME STEP
C  CONSTANT FRESHWATER HEAD NODES
        IF(STORF(I,J,K).GE.0.) GO TO 50
          NFH=NFH+1
          IFL(NFH)=I
          JFL(NFH)=J
          FFLOW(NFH)=0.0
          IF(STORF(I,J-1,K).GE.0..AND.FAREA(I,J-1,K).GT.0.)FFLOW(NFH)=
     1FFLOW(NFH)+(PHIF(I,J,K)-PHIF(I,J-1,K))*TTFX(I,J-1,K)*DY(I)
          IF(STORF(I,J+1,K).GE.0..AND.FAREA(I,J+1,K).GT.0.)FFLOW(NFH)=
     1FFLOW(NFH)+(PHIF(I,J,K)-PHIF(I,J+1,K))*TTFX(I,J,K)*DY(I)
          IF(STORF(I-1,J,K).GE.0..AND.FAREA(I-1,J,K).GT.0.)FFLOW(NFH)=
     1FFLOW(NFH)+(PHIF(I,J,K)-PHIF(I-1,J,K))*TTFY(I-1,J,K)*DX(J)
          IF(STORF(I+1,J,K).GE.0..AND.FAREA(I+1,J,K).GT.0.)FFLOW(NFH)=
     1FFLOW(NFH)+(PHIF(I,J,K)-PHIF(I+1,J,K))*TTFY(I,J,K)*DX(J)
        IF(FFLOW(NFH).GE.0.)THEN
          FIN(2)=FIN(2)+FFLOW(NFH)
        ELSE
          FOUT(2)=FOUT(2)-FFLOW(NFH)
        END IF
C
C  CONSTANT SALTWATER HEAD NODES
 50     IF(STORS(I,J,K).GE.0.) GO TO 80
          NSH=NSH+1
          ISL(NSH)=I
          JSL(NSH)=J
          SFLOW(NSH)=0.0
          IF(STORS(I,J-1,K).GE.0..AND.SAREA(I,J-1,K).GT.0.)SFLOW(NSH)=
     1SFLOW(NSH)+(PHIS(I,J,K)-PHIS(I,J-1,K))*TTSX(I,J-1,K)*DY(I)
          IF(STORS(I,J+1,K).GE.0..AND.SAREA(I,J+1,K).GT.0.)SFLOW(NSH)=
     1SFLOW(NSH)+(PHIS(I,J,K)-PHIS(I,J+1,K))*TTSX(I,J,K)*DY(I)
          IF(STORS(I-1,J,K).GE.0..AND.SAREA(I-1,J,K).GT.0.)SFLOW(NSH)=
     1SFLOW(NSH)+(PHIS(I,J,K)-PHIS(I-1,J,K))*TTSY(I-1,J,K)*DX(J)
          IF(STORS(I+1,J,K).GE.0..AND.SAREA(I+1,J,K).GT.0.)SFLOW(NSH)=
     1SFLOW(NSH)+(PHIS(I,J,K)-PHIS(I+1,J,K))*TTSY(I,J,K)*DX(J)
        IF(SFLOW(NSH).GE.0.)THEN
          SSIN(2)=SSIN(2)+SFLOW(NSH)
        ELSE
          SOUT(2)=SOUT(2)-SFLOW(NSH)
        END IF
C
C  RECHARGE
 80     FIN(1)=FIN(1)+AL*RECH(I,J)*AREA
C
C  PUMPAGE
        IF(PUMP(I,J,K).EQ.0.)GO TO 140
          PUMPS=PUMP(I,J,K)-PUMPF(I,J,K)
          IF(PUMPF(I,J,K).LE.0.)THEN
            FIN(3)=FIN(3)-PUMPF(I,J,K)
          ELSE
            FOUT(3)=FOUT(3)+PUMPF(I,J,K)
          END IF
          IF(PUMPS.LE.0.)THEN
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          SSIN(3)=SSIN(3)-PUMPS                                        MB1390
        ELSE                                                           MB1400
          SOUT(3)=SOUT(3)+PUMPS                                        MB1410
        END IF                                                         MB1420
C                                                                      MB1430
C  STORAGE                                                             MB1440
 140  APROP=FAREA(I,J,K)+SAREA(I,J,K)-1.                               MB1450
      IF(APROP.GT.0.)THEN                                              MB1460
        FST=AREA*((POR(I,J,K)*DEL*APROP+(POR(I,J,K)*AL                 MB1470
     1+STORF(I,J,K)*THF(I,J,K))*FAREA(I,J,K))*(PHIF(I,J,K)             MB1480
     2-PHIFP(I,J,K))-POR(I,J,K)*(1.+DEL)*APROP*(PHIS(I,J,K)            MB1490
     3-PHISP(I,J,K)))                                                  MB1500
        SST=AREA*((POR(I,J,K)*(1.+DEL)*APROP+STORS(I,J,K)              MB1510
     1*THS(I,J,K)*SAREA(I,J,K))*(PHIS(I,J,K)-PHISP(I,J,K))             MB1520
     2-POR(I,J,K)*DEL*APROP*(PHIF(I,J,K)-PHIFP(I,J,K)))                MB1530
      ELSE                                                             MB1540
        FST=AREA*(STORF(I,J,K)*THF(I,J,K)+AL*POR(I,J,K))               MB1550
     1*FAREA(I,J,K)*(PHIF(I,J,K)-PHIFP(I,J,K))                         MB1560
        SST=AREA*STORS(I,J,K)*THS(I,J,K)*SAREA(I,J,K)                  MB1570
     1*(PHIS(I,J,K)-PHISP(I,J,K))                                      MB1580
      END IF                                                           MB1590
C                                                                      MB1600
      IF(STORF(I,J,K).LT.0.)FST=0.                                     MB1610
      IF(STORS(I,J,K).LT.0.)SST=0.                                     MB1620
      FSTOR=FSTOR+FST/DT                                               MB1630
      SSTOR=SSTOR+SST/DT                                               MB1640
      CFSTR(K)=CFSTR(K)+FST                                            MB1650
      CSSTR(K)=CSSTR(K)+SST                                            MB1660
C                                                                      MB1670
C  LEAKAGE                                                             MB1680
      K1=K-1                                                           MB1690
      K2=K+1                                                           MB1700
C                                                                      MB1710
C  ACROSS TOP                                                          MB1720
      AQLTOP=(1.-AL)*AQL(I,J,K)*AREA                                   MB1730
      AQLBOT=0.0                                                       MB1740
      SGR=SGS/SGF                                                      MB1750
      IF(K.NE.1)AQLBOT=AQL(I,J,K1)*AREA                                MB1760
     WT1=1.0                                                           MB1770
     WT2=1.0                                                           MB1780
     WT3=0.0                                                           MB1790
     RT3=1.0                                                           MB1800
     WT4=1.0                                                           MB1810
     WT5=1.0                                                           MB1811
      IF(NLK.EQ.0)THEN                                                 MB1820
        WT2=0.0                                                        MB1860
        WT3=FAREA(I,J,K)                                               MB1870
        WT4=0.0                                                        MB1910
        IF(K.NE.NNL)THEN                                               MB1821
          DIRP=(SGR*PHIS(I,J,K+1)-PHIF(I,J,K))-(ZBOT(I,J,K2)+          MB1830
     &ZTOP(I,J,K))/(2.*DEL)                                            MB1840
          IF(DIRP.GT.0.0)WT1=0.0                                       MB1850
          IF(ICODE(I,J,K2).EQ.'.')THEN                                 MB1860
            WT1=1.0                                                    MB1870
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          WT2=1.0                                                       MB1880
          IF(PHIF(I,J,K2).GT.PHIF(I,J,K).AND.BATH(I,J).LT.0.)WT5=0.0    MB1890
        END IF                                                          MB1900
      END IF                                                            MB1910
      IF(K.NE.1)THEN                                                    MB1920
        DIRM=(PHIF(I,J,K1)-SGR*PHIS(I,J,K))+(ZBOT(I,J,K)+               MB1930
&ZTOP(I,J,K1))/(2.*DEL)                                                 MB1940
        IF(DIRM.LT.0.0)RT3=0.0                                          MB1950
      END IF                                                            MB1960
    END IF                                                              MB1965
    IF(K.EQ.NNL)THEN                                                    MB1970
      FLKT(I,J)=(1.-AL)*FAREA(I,J,K)*AQLTOP*(HEAD(I,J)-PHIF(I,J,K))     MB1980
      IF(BATH(I,J).LT.0.0)THEN                                          MB1981
        IF(FLKT(I,J).GT.0.)THEN                                         MB1982
          IF(NLK.EQ.0)THEN                                              MB1983
            FLKT(I,J)=0.D0                                              MB1984
          ELSE                                                          MB1985
            FSLKT(I,J)=FLKT(I,J)                                        MB1986
            FLKT(I,J)=0.D0                                              MB1987
          END IF                                                        MB1988
        END IF                                                          MB1989
      END IF                                                            MB1990
      SLKT(I,J)=(1.-AL)*(1.-FAREA(I,J,K))*AQLTOP*(HEAD(I,J)/SGR+        MB1991
1BATH(I,J)/(DEL+1.)-PHIS(I,J,K))                                        MB2000
    ELSE                                                                MB2010
      IF(FAREA(I,J,K).GE.(1.-SAREA(I,J,K2)))THEN                        MB2020
        FLKT(I,J)=(1.-SAREA(I,J,K2))*AQLTOP*(PHIF(I,J,K2)-              MB2030
1PHIF(I,J,K))                                                           MB2031
        FSLKT(I,J)=WT1*(FAREA(I,J,K)-(1.-SAREA(I,J,K2)))*AQLTOP*(       MB2032
2(SGR*PHIS(I,J,K+1)-PHIF(I,J,K))-(ZBOT(I,J,K2)+ZTOP(I,J,K))/            MB2033
3(2.*DEL))                                                              MB2040
        IF(FSLKT(I,J).LT.0.0)THEN                                       MB2041
          FLKT(I,J)=FLKT(I,J)+FSLKT(I,J)                                MB2042
          FSLKT(I,J)=0.0                                                MB2043
        END IF                                                          MB2040
        SLKT(I,J)=(1.-FAREA(I,J,K))*AQLTOP*(PHIS(I,J,K2)-               MB2050
1PHIS(I,J,K))                                                           MB2060
      ELSE                                                              MB2070
        FLKT(I,J)=FAREA(I,J,K)*AQLTOP*(PHIF(I,J,K2)-PHIF(I,J,K))*WT5    MB2080
        SLKT(I,J)=SAREA(I,J,K2)*AQLTOP*(PHIS(I,J,K2)-PHIS(I,J,K))       MB2090
        SFLKT(I,J)=WT2*((1.-FAREA(I,J,K))-                              MB2100
&SAREA(I,J,K2))*AQLTOP*                                                 MB2120
1(PHIF(I,J,K2)-SGR*PHIS(I,J,K)+(ZBOT(I,J,K2)+ZTOP(I,J,K))/              MB2130
2(2.*DEL))                                                              MB2140
        IF(ICODE(I,J,K2).EQ.'.'.AND.BATH(I,J).LT.0.0)THEN               MB2150
          IF(FLKT(I,J).GT.0.0)THEN                                      MB2151
            FSLKT(I,J)=FLKT(I,J)                                        MB2152
            FLKT(I,J)=0.0                                               MB2153
          END IF                                                        MB2154
          SLKT(I,J)=SLKT(I,J)+SFLKT(I,J)                                MB2155
          SFLKT(I,J)=0.0                                                MB2156
        END IF                                                          MB2157
      END IF                                                            MB2160
    END IF                                                              MB2170
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C                                                                       MB2180
C  ACROSS BOTTOM                                                        MB2190
        IF(K.NE.1)THEN                                                  MB2200
          IF(FAREA(I,J,K1).GT.(1.-SAREA(I,J,K)))THEN                    MB2210
            FLKB(I,J)=(1.-SAREA(I,J,K))*AQLBOT*(PHIF(I,J,K1)-           MB2220
     1PHIF(I,J,K))+RT3*WT3*(FAREA(I,J,K1)-(1.-SAREA(I,J,K)))*           MB2230
     1AQLBOT*(PHIF(I,J,K1)-SGR*PHIS(I,J,K)+(ZBOT(I,J,K)+ZTOP(I,J,K1))/  MB2240
     2(2.*DEL))                                                         MB2250
            SLKB(I,J)=(1.-FAREA(I,J,K1))*AQLBOT*(PHIS(I,J,K1)-          MB2251
     &PHIS(I,J,K))                                                      MB2252
            SFLKB(I,J)=RT3*(1.-WT3)*(FAREA(I,J,K1)-                     MB2260
     &(1.-SAREA(I,J,K)))*                                               MB2270
     1AQLBOT*(PHIF(I,J,K1)-SGR*PHIS(I,J,K)+(ZBOT(I,J,K)+ZTOP(I,J,K1))/  MB2280
     2(2.*DEL))                                                         MB2290
          ELSE                                                          MB2300
            FLKB(I,J)=FAREA(I,J,K1)*AQLBOT*(PHIF(I,J,K1)-               MB2310
     1PHIF(I,J,K))                                                      MB2311
            FSLKB(I,J)=WT4*((1.-FAREA(I,J,K1))-SAREA(I,J,K))*AQLBOT*    MB2320
     2(SGR*PHIS(I,J,K1)-PHIF(I,J,K)-(ZBOT(I,J,K)+ZTOP(I,J,K1))/(2.*DEL)) MB2330
            SLKB(I,J)=SAREA(I,J,K)*AQLBOT*(PHIS(I,J,K1)-PHIS(I,J,K))    MB2340
          END IF                                                        MB2350
        END IF                                                          MB2360
C                                                                       MB2370
        IF(STORF(I,J,K).LT.0.)THEN                                      MB2380
           FFLOW(NFH)=FFLOW(NFH)-FLKT(I,J)-FLKB(I,J)-FSLKT(I,J)         MB2390
     &-FSLKB(I,J)                                                       MB2410
           IF(FLKT(I,J).LE.0.)THEN                                      MB2420
             FIN(2)=FIN(2)-FLKT(I,J)                                    MB2430
           ELSE                                                         MB2440
             FOUT(2)=FOUT(2)+FLKT(I,J)                                  MB2450
           END IF                                                       MB2460
           IF(FLKB(I,J).LE.0.)THEN                                      MB2470
             FIN(2)=FIN(2)-FLKB(I,J)                                    MB2480
           ELSE                                                         MB2490
             FOUT(2)=FOUT(2)+FLKB(I,J)                                  MB2500
           END IF                                                       MB2510
           IF(FSLKT(I,J).LE.0.)THEN                                     MB2420
             FIN(2)=FIN(2)-FSLKT(I,J)                                   MB2430
           ELSE                                                         MB2440
             FOUT(2)=FOUT(2)+FSLKT(I,J)                                 MB2450
           END IF                                                       MB2460
           IF(FSLKB(I,J).LE.0.)THEN                                     MB2470
             FIN(2)=FIN(2)-FSLKB(I,J)                                   MB2480
           ELSE                                                         MB2490
             FOUT(2)=FOUT(2)+FSLKB(I,J)                                 MB2500
           END IF                                                       MB2510
        END IF                                                          MB2520
        IF(STORS(I,J,K).LT.0.)THEN                                      MB2530
           SFLOW(NSH)=SFLOW(NSH)-SLKT(I,J)-SLKB(I,J)-SFLKT(I,J)         MB2540
     &-SFLKB(I,J)                                                       MB2560
           IF(SLKT(I,J).LE.0.)THEN                                      MB2570
             SSIN(2)=SSIN(2)-SLKT(I,J)                                  MB2580
           ELSE                                                         MB2590
             SOUT(2)=SOUT(2)+SLKT(I,J)                                  MB2600
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            END IF                                                      MB2610
            IF(SLKB(I,J).LE.0.)THEN                                     MB2620
              SSIN(2)=SSIN(2)-SLKB(I,J)                                 MB2630
            ELSE                                                        MB2640
              SOUT(2)=SOUT(2)+SLKB(I,J)                                 MB2650
            END IF                                                      MB2660
            IF(SFLKT(I,J).LE.0.)THEN                                    MB2570
              SSIN(2)=SSIN(2)-SFLKT(I,J)                                MB2580
            ELSE                                                        MB2590
              SOUT(2)=SOUT(2)+SFLKT(I,J)                                MB2600
            END IF                                                      MB2610
            IF(SFLKB(I,J).LE.0.)THEN                                    MB2620
              SSIN(2)=SSIN(2)-SFLKB(I,J)                                MB2630
            ELSE                                                        MB2640
              SOUT(2)=SOUT(2)+SFLKB(I,J)                                MB2650
            END IF                                                      MB2660
         END IF                                                         MB2670
C                                                                       MB2680
C  SUM VALUES                                                           MB2690
         IF(FLKT(I,J).GE.0.)THEN                                        MB2700
           FIN(4)=FIN(4)+FLKT(I,J)                                      MB2710
         ELSE                                                           MB2720
           FOUT(4)=FOUT(4)-FLKT(I,J)                                    MB2730
         END IF                                                         MB2740
         IF(FSLKT(I,J).GE.0.)THEN                                       MB2741
           FIN(6)=FIN(6)+FSLKT(I,J)                                     MB2742
         ELSE                                                           MB2743
           FOUT(4)=FOUT(4)-FSLKT(I,J)                                   MB2744
         END IF                                                         MB2745
         IF(FLKB(I,J).GE.0.)THEN                                        MB2750
           FIN(5)=FIN(5)+FLKB(I,J)                                      MB2760
         ELSE                                                           MB2770
           FOUT(5)=FOUT(5)-FLKB(I,J)                                    MB2780
         END IF                                                         MB2790
         IF(FSLKB(I,J).GE.0.)THEN                                       MB2791
           FIN(7)=FIN(7)+FSLKB(I,J)                                     MB2792
         ELSE                                                           MB2793
           FOUT(5)=FOUT(5)-FSLKB(I,J)                                   MB2794
         END IF                                                         MB2795
         IF(SLKT(I,J).GE.0.)THEN                                        MB2800
           SSIN(6)=SSIN(6)+SLKT(I,J)                                    MB2810
         ELSE                                                           MB2820
           SOUT(4)=SOUT(4)-SLKT(I,J)                                    MB2830
         END IF                                                         MB2840
         IF(SFLKT(I,J).GE.0.)THEN                                       MB2841
           SSIN(4)=SSIN(4)+SFLKT(I,J)                                   MB2842
         ELSE                                                           MB2843
           SOUT(4)=SOUT(4)-SFLKT(I,J)                                   MB2845
         END IF                                                         MB2846
         IF(SLKB(I,J).GE.0.)THEN                                        MB2850
           SSIN(7)=SSIN(7)+SLKB(I,J)                                    MB2860
         ELSE                                                           MB2870
           SOUT(5)=SOUT(5)-SLKB(I,J)                                    MB2880
         END IF                                                         MB2890
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          IF(SFLKB(I,J).GE.0.)THEN
            SSIN(5)=SSIN(5)+SFLKB(I,J)
          ELSE
            SOUT(5)=SOUT(5)-SFLKB(I,J)
          END IF
  200 CONTINUE
C
C  COMPUTE CUMULATIVE FRESHWATER AND SALTWATER VOLUME CHANGES
        DO 210 I=1,5
          CFIN(I,K)=CFIN(I,K)+FIN(I)*DT
          CFOUT(I,K)=CFOUT(I,K)+FOUT(I)*DT
          CSIN(I,K)=CSIN(I,K)+SSIN(I)*DT
          CSOUT(I,K)=CSOUT(I,K)+SOUT(I)*DT
 210    CONTINUE
        CFIN(6,K)=CFIN(6,K)+FIN(6)*DT
        CFIN(7,K)=CFIN(7,K)+FIN(7)*DT
        CSIN(6,K)=CSIN(6,K)+SSIN(6)*DT
        CSIN(7,K)=CSIN(7,K)+SSIN(7)*DT
C
C  COMPUTE TOTALS FOR EACH AQUIFER
        TFIN=FIN(1)+FIN(2)+FIN(3)+FIN(4)+FIN(5)+FIN(6)+FIN(7)
        TCFIN=CFIN(1,K)+CFIN(2,K)+CFIN(3,K)+CFIN(4,K)+CFIN(5,K)+
       &CFIN(6,K)+CFIN(7,K)
        TSSIN=SSIN(1)+SSIN(2)+SSIN(3)+SSIN(4)+SSIN(5)+SSIN(6)+SSIN(7)
        TCSIN=CSIN(1,K)+CSIN(2,K)+CSIN(3,K)+CSIN(4,K)+CSIN(5,K)+
       &CSIN(6,K)+CSIN(7,K)
        TFOUT=FOUT(2)+FOUT(3)+FOUT(4)+FOUT(5)
        TCFOUT=CFOUT(2,K)+CFOUT(3,K)+CFOUT(4,K)+CFOUT(5,K)
        TSOUT=SOUT(2)+SOUT(3)+SOUT(4)+SOUT(5)
        TCSOUT=CSOUT(2,K)+CSOUT(3,K)+CSOUT(4,K)+CSOUT(5,K)
C
C  COMPUTE AQUIFER MASS BALANCE ERROR
        FDIF=TFIN-TFOUT
        SDIF=TSSIN-TSOUT
        CFDIF=TCFIN-TCFOUT
        CSDIF=TCSIN-TCSOUT
        FERR=FSTOR-FDIF
        SERR=SSTOR-SDIF
        CFERR=CFSTR(K)-CFDIF
        CSERR=CSSTR(K)-CSDIF
        IF(TFIN.NE.0.)FRERF=FERR/TFIN*100.
        IF(TSSIN.NE.0.)SRERF=SERR/TSSIN*100.
        IF(FSTOR.NE.0.)FRERS=FERR/FSTOR*100.
        IF(SSTOR.NE.0.)SRERS=SERR/SSTOR*100.
        IF(TCFIN.NE.0.)CFRERF=CFERR/TCFIN*100.
        IF(TCSIN.NE.0.)CSRERF=CSERR/TCSIN*100.
        IF(CFSTR(K).NE.0.)CFRERS=CFERR/CFSTR(K)*100.
        IF(CSSTR(K).NE.0.)CSRERS=CSERR/CSSTR(K)*100.
C
        RETURN
        END
```