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HYDRO GeoLogic INC.

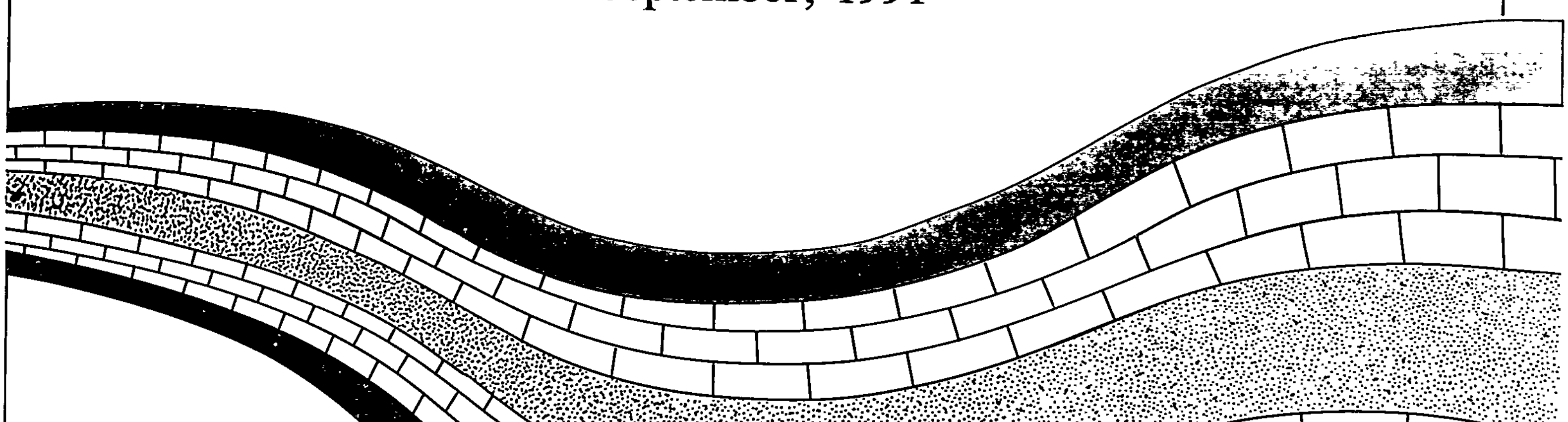
SAMFT3D

Single-phase and Multiphase Flow and Transport in 3 Dimensions

Version 1.0

DOCUMENTATION AND USER'S GUIDE

September, 1991



SAMFT3D.1.0

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DOCUMENTATION AND USER'S GUIDE

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ABSTRACT

SAMFT3D is a three-dimensional, finite element code designed to simulate single-phase and multiphase fluid flow and contaminant transport in porous media. This report documents the single-phase version of the code. The single-phase computational modules have been developed to simulate flow and solute transport in fully or variably saturated porous media. The formulation of the governing equations and the numerical procedures used in these modules are presented. The flow equation is approximated using the Galerkin finite element method. For variably saturated flow problems, nonlinearities due to unsaturated soil properties are treated using Picard or Newton-Raphson iterations. The contaminant transport simulation can account for advection, hydrodynamic dispersion, linear equilibrium sorption, and first-order degradation. Transport of a single component can be handled. The transport equation is approximated using a upstream weighted residual method. Several test problems are presented to verify the code and to demonstrate its utility. These problems range from single one-dimensional to complex three-dimensional problems.

This document has been produced as a user's manual. It contains brief information on the code structure along with detailed instructions for input data preparation and sample input and printed output for selected test problems. Also included are instructions for setting up a simulation run and restart procedures.

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1 INTRODUCTION

1.1 PURPOSE OF THE CODE

SAMFT3D is a three-dimensional, finite element code that simulates fluid flow and solute transport in variably saturated porous media. The code is intended to handle single-phase as well as two-phase and three-phase flow conditions using two integrated sets of computational modules. To date, the single-phase flow and transport computational modules have been completed and are documented herein. These modules are capable of simulating a wide range of practical conditions involving flow of water (aqueous phase) and single-species transport of dissolved contaminants. Both flow and transport simulations can be performed concurrently or sequentially. Material heterogeneities and anisotropy are handled by taking full advantage of the finite element approach. Efficient matrix computational and solution schemes are employed in conjunction with simple rectangular brick elements to analyze problems involving highly nonlinear soil moisture characteristics. Several types of boundary conditions can be accommodated including prescribed pressure and flux conditions, water-table conditions, recharge, infiltration, and sinks and sources.

1.2 OVERVIEW OF CODE CAPABILITIES AND SALIENT FEATURES

Multidimensional modeling of fluid flow and waste migration in variably saturated subsurface systems can be a formidable task unless one is equipped with a proper code that accommodates a wide range of field conditions. Recognizing this point, SAMFT3D was developed to have not only essential modeling capabilities but also salient features that facilitate practical use. An overview of these aspects of the code is presented below.

1. SAMFT3D can perform transient analyses or single step steady-state analyses of both variably saturated water flow and solute transport problems. If the flow and transport problems are associated, these problems can be solved sequentially in a single computer run.

2. The finite element formulation and nonlinear solution procedures in SAMFT3D are based on state-of-the-art technology designed to accommodate a wide range of field conditions including highly nonlinear moisture characteristics, material heterogeneity and anisotropy, and rapidly fluctuating transient flow boundary conditions.

3. The flow simulator of SAMFT3D can handle various boundary conditions and physical processes including infiltration, evaporation, well pumping and recharging, and varying water table conditions. Temporal variations of pressure and flux boundary conditions can be handled conveniently using either continuous piecewise linear representations or discontinuous (stepped) representations.

4. The transport simulator of SAMFT3D is designed to have upstream weighting capability to circumvent numerical oscillations. The scheme can accommodate first-order decay as well as linear equilibrium sorption. Both pulse and step releases of contaminants can be simulated.

1.3 APPLICABILITY OF THE CODE

The SAMFT3D code has many practical applications. Typical examples include the following:

- Investigation of moisture movement in variably saturated subsurface systems

- Investigation of groundwater flow in confined and unconfined aquifer systems
- Investigation of transport of dissolved contaminants in the subsurface soil or groundwater system
- Investigation of immiscible flow of NonAqueous Phase Liquids and miscible transport of dissolved constituents or components in the unsaturated and saturated zones of the subsurface system
- Investigation of leachate migration from land disposal units
- Investigation of potential for radionuclide migration from subsurface repositories or buried waste containers.

1.4 CODE USER REQUIREMENTS

In order to apply the SAMFT3D code effectively, the user will need:

- a thorough understanding of hydrogeological principles
- a basic understanding of numerical modeling techniques
- an awareness of the code's capabilities and limitations
- familiarity with the editor, operating system, and file handling concepts of the computer system used.

It is also recommended that the user run some of the test problems provided to gain confidence and understanding in using the code.

1.5 COMPUTER EQUIPMENT REQUIREMENTS

SAMFT3D is written in ANSI Standard FORTRAN 77 and can be compiled on any standard micro, mini, or mainframe system. The source code was developed and tested on personal computers using the FORTRAN 77 compiler developed by the University of Salford, United Kingdom. Installation of earlier versions of the code has also been made on VAX, MIPS and SUN computers with standard FORTRAN 77 compilers. With minor conversion (e.g., changing OPEN FILE statements), the source code can be made to compile and run on a PC 386 machine properly equipped with at least 2 megabytes of core memory, a protected mode FORTRAN 77 compiler, and a 80387 or Weitek math co-processor.

2 GOVERNING MATHEMATICAL MODELS

2.1 PROCESS AND GEOMETRY

The single-phase computational modules of SAMFT3D perform three-dimensional finite element simulations of water flow and/or solute transport in variably saturated and fully saturated porous media. These modules employ efficient numerical techniques to provide steady-state and transient solutions of practical problems encountered in the investigation, mitigation and remediation of soil and groundwater contamination due to disposal of hazardous wastes. The steady-state analysis is performed by disregarding all storage terms of the governing equations thus avoiding the necessity of time marching. The transient analysis is performed by time marching until the prescribed number of time steps is reached. For water flow simulations, the code can handle a variety of boundary conditions including infiltration, evaporation, and sinks and sources of water and solute. The code can also accommodate severely nonlinear soil moisture characteristics and anisotropy and heterogeneity of permeability. For solute transport simulations, SAMFT3D accounts for advection, hydrodynamic dispersion, equilibrium sorption, and first-order decay.

The user is permitted to employ the following right-handed coordinate system:

- three-dimensional Cartesian coordinates (x,y,z) with the (x-y) plane being horizontal.

2.2 GOVERNING AND SUPPLEMENTARY EQUATIONS FOR SINGLE-PHASE MODELS

The single-phase components of SAMFT3D are formulated based upon two governing equations, one describing flow of water (aqueous-phase) and the other describing single-species solute transport. These equations are described in this section together with initial and boundary conditions as well as other relevant supplementary constitutive relations.

2.2.1 Variably Saturated Flow

For single-phase, variably saturated flow analysis, the SAMFT3D code uses gauge pressure head of water (the aqueous phase) as the primary dependent variable. The governing equation for water flow in a variably saturated porous medium may be expressed in the form:

$$\frac{\partial}{\partial x_i}\left[\rho_w K_{ij} k_{rw} \left(\frac{\partial \psi}{\partial x_j} + e_j\right)\right] = \frac{\partial}{\partial t}(\rho_w \phi S_w) - \rho_w q \tag{2.1}$$

where ρ_w is the density of water, ψ is the gauge, water-pressure head, K_{ij} is the saturated hydraulic conductivity tensor, k_{rw} is the relative permeability with respect to the water phase, x_i ($i = 1, 2, 3$) are spatial coordinates, t is time, e_j is the unit vector assumed to be vertically upward, S_w is water-phase saturation, ϕ is the effective porosity, and q is the volumetric flow rate via sources (or sinks) per unit volume of the porous medium.

Note that ψ and K_{ij} are defined as

$$\psi = (p_w - p_{atm})/\rho_w g \tag{2.2a}$$

and

$$K_{ij} = k_{ij}\rho_w g/\mu_w \tag{2.2b}$$

where p_w is the water-phase pressure, p_{atm} is the atmospheric pressure, g is the gravitational acceleration constant, k_{ij} is the intrinsic permeability tensor, and μ_w is the dynamic viscosity of water.

For slightly compressible fluid, equation (2.1) can be written in the form:

$$\frac{\partial}{\partial x_i}\left[(K_{ij}k_{rw}\frac{\partial\psi}{\partial x_j} + e_j) \right] = \eta \frac{\partial\psi}{\partial t} - q \tag{2.3}$$

where η is a coefficient defined as:

$$\eta = S_w S_s + \phi \frac{dS_w}{d\psi} \tag{2.4}$$

The coefficient S_s in equation (2.4) is known as specific storage and is defined as $S_s = \rho_w g(\phi\beta_w+\beta_s)$, where g is the gravitational acceleration, and β_s and β_w are coefficients of compressibility of the porous medium and water, respectively.

The initial and boundary conditions of the variably saturated water flow problem are:

$$\psi(x_i,0) = \psi_o(x_i) \tag{2.5}$$

$$\psi(x_i,t) = \tilde{\psi} \; on \; B_1 \tag{2.6}$$

and

$$V_i n_i = -V_n \; on \; B_2 \tag{2.7}$$

where ψ_o is the initial head value, B_1 is the portion of the flow boundary where $\tilde{\psi}$ is prescribed as ψ, V_i is the Darcy velocity vector, B_2 is the portion of the flow boundary where the outward normal velocity is prescribed as $-V_n$, and n_i is the outward unit normal vector.

In order to solve the variably saturated flow problem, it is also necessary to specify the relationships of relative permeability versus water saturation, and pressure head versus water saturation. Two alternative function expressions are used to describe the relationship of relative permeability versus water saturation. These functions are given by (Brooks and Corey, 1966; van Genuchten, 1976):

$$k_{rw} = S_e^n \tag{2.8a}$$

and

$$k_{rw} = S_e^{1/2}\,[1-(1-S_e^{1/\gamma})^\gamma]^2 \tag{2.8b}$$

where n and γ are empirical parameters and S_e is the effective water saturation defined as $S_e = (S_w - S_{wr})/(1-S_{wr})$ with S_{wr} being referred to as the residual water saturation.

The relationship of pressure head versus water saturation is described by the following function (van Genuchten, 1977; Mualem, 1976):

$$\frac{S_w - S_{wr}}{1 - S_{wr}} = \begin{cases} \dfrac{1}{[1+(\alpha\,|\psi-\psi_a|)^\beta]^\gamma} & \mathit{for}\ \psi < \psi_a \\ 1 & \mathit{for}\ \psi \geq \psi_a \end{cases} \tag{2.9}$$

where α and β are empirical parameters, ψ_a is the air entry pressure head value, and S_{wr} is the residual water saturation. The parameters β and γ are usually related by $\gamma = 1-1/\beta$.

Equation (2.3) is solved numerically using the Galerkin finite element method subject to the initial and boundary conditions given in (2.5) through (2.7). After the distributions of ψ and S_w have been determined, Darcy velocity components are calculated from:

$$V_i = -K_{ij} k_{rw} \left(\frac{\partial \psi}{\partial x_j} + e_j\right) \tag{2.10}$$

2.2.2 Solute Transport with Single-Phase Flow

The governing equation for transport of a non-conservative single component in a variably saturated porous medium takes the form:

$$\begin{aligned} \frac{\partial}{\partial x_i} \left(D_{ij} \frac{\partial c}{\partial x_j}\right) - \frac{\partial}{\partial x_i} (V_i\, c) = \frac{\partial}{\partial t} \left[\phi\, S_w\, c + \rho_s\, (1-\phi)\, c_s\right] - q\, c^* \\ + \lambda \left[\phi\, S_w\, c + \rho_s\, (1-\phi)\;\; c_s\right] \end{aligned} \tag{2.11}$$

where D_{ij} is the apparent hydrodynamic dispersion tensor, c is solute concentration in the fluid, V_i is the Darcy velocity, ϕ is the effective porosity, ρ_s is the density of solid grains, c_s is the adsorbed concentration, λ is the first-order decay coefficient, and c^* is the solute concentration in the injected fluid.

Assuming that the relation between adsorbed and solution concentration is described by a linear equilibrium isotherm, equation (2.11) can be expressed as

$$\frac{\partial}{\partial x_i} (D_{ij} \frac{\partial c}{\partial x_j}) - \frac{\partial}{\partial x_i} (V_i \ c) = \frac{\partial}{\partial t} \left[\phi \ S_w \ (1 + \frac{\rho_s(1-\phi)k_d}{\phi S_w}) \ c \right] -qc^* + \lambda \phi S_w \left[1 + \frac{\rho_s(1-\phi)k_d}{\phi S_w} \right] c \tag{2.12}$$

where k_d is the distribution coefficient.

Equation (2.12) reduces to

$$\frac{\partial}{\partial x_i} (D_{ij} \frac{\partial c}{\partial x_j}) - \frac{\partial}{\partial x_i} (V_i c) = \frac{\partial}{\partial t} (\phi S_w Rc) + \lambda \phi S_w Rc - q \ c^* \tag{2.13}$$

where R is the retardation factor defined as

$$R = 1 + \frac{\rho_s(1-\phi)k_d}{\phi S_w} = 1 + \frac{\rho_B \ k_d}{\phi S_w} \tag{2.14}$$

with the bulk density ρ_B being defined as $(1-\phi)\rho_s$. Expanding the convective and mass accumulation terms of equation (2.13) and using the continuity equation of fluid flow, one obtains

$$\frac{\partial}{\partial x_i} (D_{ij} \frac{\partial c}{\partial x_j}) - V_i \frac{\partial c}{\partial x_i} = \phi S_w \ R \frac{\partial c}{\partial t} + c \frac{\partial}{\partial t} (\phi S_w) + c \frac{\partial}{\partial t} (\rho_B k_d) - c \frac{\partial}{\partial t} (\phi S_w) + q(c-c^*) + \lambda \phi S_w Rc \tag{2.15}$$

which, assuming that the time derivative of $(\rho_B k_d)$ is negligible, reduces to

$$\frac{\partial}{\partial x_i}\left(D_{ij}\frac{\partial c}{\partial x_j}\right) - V_i\frac{\partial c}{\partial x_i} = \phi S_w R\left(\frac{\partial c}{\partial t} + \lambda c\right) + q(c-c^*) \qquad (2.16)$$

Note that the term q(c-c*) is zero in the case where q corresponds to the specific discharge of a pumped well, because c≡c*. The hydrodynamic dispersion tensorial components are computed using the following constitutive relations (Scheidegger, 1961):

$$D_{ij} = \alpha_T |V| \delta_{ij} + (\partial_L - \partial_T)\frac{V_i V_j}{|V|} + D_w^* \delta_{ij} \qquad (2.17)$$

where α_L and α_T are longitudinal and transverse dispersivities, respectively, and D_w^* is the apparent molecular diffusion in the water-phase of the porous medium.

The apparent molecular diffusion coefficient of the water-phase is computed by the code using the following relation:

$$D_w^* = (\tau\phi S_w^n)\, D_{mw} \qquad (2.18)$$

where τ is a tortuosity factor, D_{mw} is the free-water molecular diffusion coefficient, and n is an exponent parameter. Note that equation (2.18) corresponds to the Millington-Quirk equation if τ and n are set equal to $\phi^{1/3}$ and 10/3, respectively.

Equation (2.16) is the required form of the transport equation and will be approximated using the upstream weighted residual finite element technique of Huyakorn and Nilkuha (1979). The initial and boundary conditions associated with equation (2.16) are as follows:

$$c(x_1, x_2, x_3, 0) = c_o \qquad (2.19)$$

$$c(x_1, x_2, t) = \tilde{c} \text{ on } B_1' \tag{2.20a}$$

$$D_{ij} \frac{\partial c}{\partial x_j} n_i = q_c^D \text{ on } B_2' \tag{2.20b}$$

$$D_{ij} \frac{\partial c}{\partial x_j} n_i - V_i n_i c = q_c^T \text{ on } B_3' \tag{2.20c}$$

where B_1' is the portion of the boundary where concentration is prescribed as $\tilde{c}$, and B_2' and B_3' are portions of the boundary where the dispersive and the total solute mass fluxes are prescribed as q_c^D and q_c^T, respectively.

2.3 GOVERNING AND SUPPLEMENTARY EQUATIONS FOR MULTIPHASE MODELS

The multiphase components of SAMFT3D are formulated based upon immiscible flow equations (one equation for each active fluid phase), and a single-species solute transport equation. These equations are described in this section together with initial and boundary conditions as well as other relevant supplementary constitutive relations.

2.3.1 Multiphase Flow

Consider a general situation involving flow of three active fluid phases, water, NAPL (Nonaqueous Phase Liquid), and air or vapor. The governing equations may be expressed as

$$\frac{\partial}{\partial x_i}\left[k_{ij}\,\tau_\ell\,\frac{\partial \Phi_\ell}{\partial x_j}\right] = \frac{\partial}{\partial t}\,(\theta \rho_\ell S_\ell) - \dot{M}_\ell,\ \ell = w,\ n,\ a \tag{2.21}$$

where subscript ℓ refers to the three fluid phases: water (w), NAPL (n) and air (a), k_{ij} is the intrinsic permeability tensor, τ_ℓ and Φ_ℓ are the mobility and fluid potential of phase ℓ, respectively, θ is effective porosity, ρ_ℓ and S_ℓ are density and phase saturation, $\dot{M}_\ell$ is the mass flow rate of phase ℓ via sources or sinks per unit volume of the porous medium.

The phase mobility and fluid potential are defined as

$$\tau_\ell = k_{r\ell}\,\rho_\ell/\mu_\ell \tag{2.22a}$$

and

$$\frac{\partial \Phi_\ell}{\partial x_j} = \frac{\partial p_\ell}{\partial x_j} + \rho_\ell\, g\,\frac{\partial z}{\partial x_j} \tag{2.22b}$$

where $k_{r\ell}$ is the relative permeability, μ_ℓ is the dynamic viscosity, and z is the elevation above a given datum, and p^* is the reference pressure.

Note that for the two liquid phase w and n, equation (2.22b) reduces to

$$\Phi_\ell = p_\ell + \rho_\ell\, gz - p^* \tag{2.23}$$

The initial and boundary conditions of the multiphase flow problem may be represented by

$$p_\ell\ (x_i,\ 0)\ = p_\ell^o\ (x_i) \tag{2.24}$$

$$p_\ell\ (x_i,\ t)\ = \tilde{p}_\ell\ on\ B_1 \tag{2.25a}$$

and

$$V_{i\ell}\ n_i\ = -\tilde{V}_\ell\ on\ B_2 \tag{2.25b}$$

where p_ℓ^o is the initial phase pressure value, B_1 is the portion of the flow boundary where p_ℓ is prescribed as $\tilde{p}_\ell$, $V_{i\ell}$ is the Darcy velocity vector for phase ℓ, B_2 is the boundary portion where the outward normal velocity of phase ℓ is prescribed as $-\tilde{V}_\ell$, and n_i is the outward unit normal vector.

In addition to the three governing equations, there are supplementary equations given by:

$$S_w + S_n + S_a\ = 1 \tag{2.26a}$$

$$p_n - p_w = \bar{P}_{cnw}\ (S_w,\ S_n) \tag{2.26b}$$

$$p_a - p_n = \bar{P}_{can}\ (S_w,\ S_n) \tag{2.26c}$$

$$p_a - p_w = \bar{P}_{can} + \bar{P}_{cnw} \tag{2.26d}$$

Typical relations for $\bar{P}_{cnw}$ and $\bar{P}_{can}$ are given by (Forsyth, 1990):

$$\bar{P}_{cnw} = \alpha \bar{P}_{cnw}(S_w) + (1-\alpha)\, \bar{P}_{cnw}(S_w=1) \qquad (2.27a)$$

$$\bar{P}_{can} = \alpha \bar{P}_{can}(S_w) + (1-\alpha)\, [\bar{P}_{caw}(S_a) - \bar{P}_{cnw}(S_w=1)] \qquad (2.27b)$$

with either $\alpha = \min(1, S_n/S_n^*)$ or $\alpha = 1$, S_n^* being critical NAPL saturation.

2.3.2 Solute Transport with Multiphase Flow

2.3.2.1 Transport Equations

The equation describing transport of a non-conservative solute component in a fluid phase ℓ (ℓ = w,n,a) may be written in the form:

$$\frac{\partial}{\partial x_i}\left[D_{\ell ij}\frac{\partial}{\partial x_j}(\rho_\ell c_\ell)\right] - \frac{\partial}{\partial x_i}(V_{\ell i}\rho_\ell c_\ell) = \frac{\partial}{\partial t}(\phi S_\ell \rho_\ell c_\ell) + \lambda_\ell \phi S_\ell \rho_\ell c_\ell + Q_\ell \rho_\ell (c_\ell - c_\ell^*) - \Gamma_\ell \qquad (2.28)$$

where c_ℓ is mass fraction concentration of the component concerned in fluid phase ℓ (defined as mass of the solute per unit mass of fluid phase ℓ), ρ_ℓ is the fluid density, $D_{\ell ij}$ is the apparent hydrodynamic dispersion coefficient with respect to fluid phase ℓ, $V_{\ell i}$ is the Darcy velocity of fluid phase ℓ, λ_ℓ is the decay coefficient in fluid phase ℓ, Q_ℓ is the volumetric rate of fluid injection per unit bulk volume of the porous medium, and c_ℓ^* is the injected solute concentration in phase ℓ, and Γ_ℓ is the net rate of solute mass transfer into or out of phase ℓ per unit volume of the porous medium.

The net mass transfer rate, Γ_ℓ, accounts for the component mass transfer between phase ℓ and each of the remaining fluid phases as well as the component mass transfer between phase

ℓ and a "precipitated phase" of the solute component. The "precipitated phase" is an immobile (liquid or solid) phase allowed to occur when the dissolved concentration exceeds the solubility limit. In treating the multiphase flow equations, we have assumed that the effect of contaminant mass transfer between various fluid phases is negligible. This assumption is valid if the component concerned is slightly soluble.

By expanding the advection and mass accumulation terms and enforcing the continuity requirement for fluid flow, equation (2.28) may be expressed in the form:

$$\frac{\partial}{\partial x_i}\left[D_{\ell ij}\rho_\ell \frac{\partial c_\ell}{\partial x_j}\right] - V_{\ell i}\rho_\ell \frac{\partial c_\ell}{\partial x_i} = \phi S_\ell \rho_\ell \frac{\partial c_\ell}{\partial t} + \lambda_\ell \phi S_\ell \rho_\ell c_\ell + Q_\ell \rho_\ell (c_\ell - c_\ell^*) - \Gamma_\ell \qquad (2.29)$$

where the term $\frac{\partial}{\partial x_i}\left[D_{\ell ij} c_\ell \frac{\partial \rho_\ell}{\partial x_j}\right]$ has been neglected, and the following flow continuity equation has been used:

$$-\frac{\partial}{\partial t}(V_{\ell i}\rho_\ell) = \frac{\partial}{\partial t}(\phi S_\ell \rho_\ell) \qquad (2.30)$$

The mass balance equation for the precipitated phase is given by

$$\frac{\partial}{\partial t}(\rho_p S_p \phi) + \lambda_p S_p = \Gamma_p \qquad (2.31)$$

where ρ_p and S_p are density and saturation of the precipitated contaminant phase, and Γ_p is the net rate of mass transfer between the precipitated phase and all other remaining fluid and solid phases.

The equation describing solute mass distribution in the porous matrix is given by

$$\frac{\partial}{\partial t}\left[(1-\phi)\,\rho_s\,c_s\right] + \lambda_s c_s = \Gamma_s \tag{2.32}$$

where c_s and λ_s are the solute concentration and the coefficient of decay in the solid phase, respectively, and Γ_s is the rate of solute mass transfer between the soil matrix and all other phases. Equation (2.28) may be summed with respect to all fluid phases (w,n,a) and combined with (2.30) and (2.31) to give

$$\begin{aligned}
\sum_{\ell}\left[\frac{\partial}{\partial x_i}\left[D_{\ell ij}\rho_\ell\frac{\partial c_\ell}{\partial x_j}\right] - V_{\ell i}\rho_\ell\frac{\partial c_\ell}{\partial x_i}\right] &= \sum_{\ell}\,(\phi S_\ell\rho_\ell\frac{\partial c_\ell}{\partial t}\\
&+ \lambda_\ell\phi S_\ell\rho_\ell c_\ell) + (1-\phi)\,\rho_s\left[\frac{\partial c_s}{\partial t} + \lambda_s c_s\right] + \sum_{\ell}\rho_\ell Q_\ell\,(c_\ell - c_\ell^{\,*})\\
&+ \frac{\partial}{\partial t}\left[\rho_p\,S_p\,\phi\right] + \lambda_p\,\phi\,\rho_p\,S_p
\end{aligned} \tag{2.33}$$

where the following mass-conservation constraint has been applied:

$$\Gamma_w + \Gamma_n + \Gamma_a + \Gamma_s + \Gamma_p = 0 \tag{2.34}$$

and the component concentration in the precipitated phase is considered to be unity.

The partitioning of solute mass between different phases is described by means of linear equilibrium isotherms. Since these isotherms are linear, the partitioning relations required for transport in three-phase flow may be expressed using water as the reference phase as follows:

$$c_n = \kappa_n c_w \tag{2.35a}$$

$$c_a = \kappa_a c_w \tag{2.35b}$$

$$c_s = k_d \rho_w c_w \tag{2.35c}$$

where κ_n, κ_a and k_d are partitioning coefficients relating concentration in the water phase to concentrations in the nonaqueous phase, the air phase and the solid phase, respectively. Note that κ_n and κ_a are dimensionless and k_d is a distribution coefficient having a dimension of volume per unit mass.

The air-water partitioning coefficient, κ_a, is generally known as Henry's constant. The NAPL-water partitioning coefficient, κ_n, may be expressed as

$$\kappa_n = \kappa_a / \kappa_a^* \tag{2.36}$$

where κ_a^* is the air-NAPL partitioning coefficient known as Raoult's constant.

Equation (2.33) can be combined with (2.35a)-(2.35c) to give the following equation:

$$\begin{aligned}
&\frac{\partial}{\partial x_i}\left[(D_{wij}\rho_w + \kappa_n \rho_n D_{nij} + \kappa_a \rho_a D_{aij})\frac{\partial c_w}{\partial x_j}\right] \\
&- (V_{wi}\rho_w + \kappa_n \rho_n V_{ni} + \kappa_a \rho_a V_{ai})\frac{\partial c_w}{\partial x_i} = \phi(RS_w\rho_w + \kappa_n S_n \rho_n + \kappa_a S_a \rho_a)\frac{\partial c_w}{\partial t} \\
&\qquad + \phi\lambda(RS_w\rho_w + \kappa_n S_n \rho_n + \kappa_a S_a \rho_a) c_w \\
&\qquad + \sum_\ell \rho_\ell Q_\ell (c_\ell - c_\ell^*) + \frac{\partial}{\partial t}\left[\rho_p \phi S_p\right] \\
&\qquad + \lambda_p \phi \rho_p S_p
\end{aligned} \tag{2.37}$$

where R is given by

$$R = 1 + \frac{(1-\phi)\rho_s k_d}{\phi S_w} \tag{2.38}$$

and it has been assumed that $\lambda_\ell = \lambda_s = \lambda$.

We now introduce the following definitions:

$$D_{Tij} = \rho_w D_{wij} + \rho_n \kappa_n D_{nij} + \rho_a \kappa_a D_{aij} \tag{2.39}$$

$$V_{Ti} = \rho_w V_{wi} + \rho_n \kappa_n V_{ni} + \rho_a \kappa_a V_{ai} \tag{2.40}$$

$$R_T = R\rho_w S_w + \kappa_n \rho_n S_n + \kappa_a \rho_a S_a \tag{2.41}$$

$$Q_T = \rho_w Q_w + \rho_n Q_n \kappa_n + \rho_a Q_a \kappa_a \tag{2.42}$$

$$(Qc)_T^* = \rho_w Q_w C_w^* + \rho_n Q_n C_n^* + \rho_a Q_a C_a^* \tag{2.43}$$

Equation (2.37) may be combined with (2.39) - (2.43) to give the following governing equation:

$$\begin{aligned} \frac{\partial}{\partial x_i}\left[D_{Tij}\frac{\partial c_w}{\partial x_j}\right] - V_{Ti}\frac{\partial c_w}{\partial x_i} &= \phi R_T\left(\frac{\partial c_w}{\partial t} + \lambda c_w\right) + \\ &\frac{\partial}{\partial t}[m_p] + \lambda_p m_p + Q_T c_w - (Qc)_T^* \end{aligned} \tag{2.44}$$

where $m_p = \rho_p S_p \phi$.

Equation (2.44) needs to be solved numerically subject to the following constraints:

$$c_w \leq c_{ws} \tag{2.45}$$

and

$$m_p \geq 0 \tag{2.46}$$

where c_{ws} is the water-solubility limit (maximum dissolved concentration) of the component concerned.

2.3.2.2 Supplementary Equations

The Darcy velocity and hydrodynamic dispersion for each fluid phase are computed using the following relations:

$$V_{\ell i} = - \frac{k_{ij} k_{r\ell}}{\mu_\ell} \frac{\partial \Phi_\ell}{\partial x_j} \tag{2.47}$$

$$D_{\ell ij} = \alpha_T |V_\ell| \delta_{ij} + (\alpha_L - \alpha_T) \frac{V_{\ell i} V_{\ell j}}{|V_\ell|} + (\phi \, \tau^* \, S_\ell^N) D_{m\ell} \, \delta_{ij} \tag{2.48}$$

where α_L and α_T are longitudinal and transverse dispersivities, $D_{m\ell}$ is free-fluid molecular diffusion coefficient for fluid phase ℓ, τ^* is tortuosity factor, and n is an exponent. If the Millington-Quirk expression is to be used, then N and τ are set equal to 10/3 and $\phi^{1/3}$, respectively. For a passive fluid phase, it is assumed that $V_{\ell i} = 0$.

2.3.2.3 Initial and Boundary Conditions

The initial and boundary conditions associated with the solute transport equation may be expressed as

$$c_w\ (x_i,\ 0)\ =\ c_w\ (x_i) \tag{2.49}$$

$$c_w\ (x_i,\ t)\ =\ \tilde{c}_w\ on\ B_1^{'} \tag{2.50}$$

$$\sum_{\ell}\ (D_{ij\ell}\ \frac{\partial c_\ell}{\partial x_j}\ n_i)\ =\ \dot{m}_D\ on\ B_2^{'} \tag{2.51}$$

$$\sum_{\ell}\ (D_{ij\ell}\ \frac{\partial c_\ell}{\partial x_j}\ -\ V_{i\ell})\ n_i\ =\ \dot{m}_T\ on\ B_3^{'} \tag{2.52}$$

where $B_1^{'}$ is the boundary portion where the solute concentration in the water phase is prescribed $\tilde{c}_w$, $B_2^{'}$ is the boundary portion where dispersive mass flux of solute is prescribed as $\dot{m}_D$, and $B_3^{'}$ is the boundary portion where the total solute mass flux is prescribed as $\dot{m}_T$. Note that the sign convention for $\dot{m}_D$ and $\dot{m}_T$ is positive for influx and negative for efflux.

2.4 ASSUMPTIONS

In this section, major assumptions incorporated into the single-phase and multiphase mathematical models are provided.

2.4.1 Single-phase Models

Major assumptions of the multiphase flow model of SAMFT3D are as follows:

- Water is the only active phase (i.e., other fluid phases assumed to be passive)

- Flow of the water-phase is considered isothermal and governed by Darcy's law

- The active fluid phase is slightly compressible and homogeneous

- The soil or rock medium may be represented by a single-continuum porous medium.

Major assumptions of the single-phase solute transport model are as follows:

- Transport in the porous medium system is governed by Fick's law. The hydrodynamic dispersion coefficient is defined as the sum of the coefficients of mechanical dispersion and molecular diffusion. The medium dispersivity is assumed to correspond to that of an isotropic porous medium and hence related to two constants, α_L and α_T, which are the longitudinal and transverse dispersivities

- Adsorption and decay of the solute may be described by a linear equilibrium isotherms and first order decay constants.

2.4.2 Multiphase Models

Major assumptions of the multiphase flow model are as follows:

- Flow of each phase may be treated as isothermal and governed by Darcy's law

- Both liquid phases (water and NAPL) are slightly compressible and homogeneous

- The compressible air phase may be treated as an ideal gas

- The soil or rock medium may be represented by a single-continuum porous medium.

Major assumptions of the multiphase solute transport model are as follows:

- Transport in the porous medium system is governed by Fick's law. For each fluid phase, the hydrodynamic dispersion coefficient is defined as the sum of the coefficients of mechanical dispersion and molecular diffusion. The medium dispersivity is assumed to correspond to that of an isotropic porous medium and hence related to two constants, α_L and α_T, which are the longitudinal and transverse dispersivities

- Adsorption and decay of the solute in the solid and fluid phases may be described by linear equilibrium isotherms and first order decay constants.

2.5 LIMITATIONS

The SAMFT3D code has the following limitations:

- In performing single-phase or multiphase flow analysis, the code neglects effects of temperature variation and non-Darcian flow or non-Newtonian behavior of the fluids

- The code considers only single-porosity soil or aquifer media. It does not rigorously handle fractured media or structured soils

- In performing solute transport analysis, the code does not take into account sorption nonlinearity or kinetic effects which, in some instances, can be important. Furthermore, effects of changes in fluid properties due to variations in solute concentrations are neglected. Solute mass transfer between fluid phases are also neglected.

2.6 INPUT DATA

Input data and parameters required by the single-phase and multiphase models of SAMFT3D are summarized below.

2.6.1 Single-phase Models

Input data and parameters for variably saturated flow simulations include the following:

(1) System Geometry

- Horizontal and vertical dimensions including layering and other heterogeneities (L)

(2) Porous Medium Properties

- Intrinsic permeability components, k_{xx}, k_{yy} and k_{zz} (L^2)
- Volume compressibility, β_s (LT^2/M)
- Effective porosity, ϕ

(3) Fluid Properties

- Density of water, ρ_w (ML^{-3})
- Dynamic viscosity of water, μ_w ($ML^{-1}\,T^{-1}$)
- Volume compressibility of water, β_w (LT^2/M)

(4) Initial and Boundary Conditions

- Initial distribution of water-phase pressure, p_w^o ($ML^{-1}\,T^{-2}$)
- Prescribed values of p_w at specified Dirichlet boundary nodes, $\tilde{p}_w$ ($ML^{-1}\,T^{-2}$)
- Prescribed values of water fluxes at specified flux nodes, q_w ($ML^{-1}\,T^{-1}$)

Input data and parameters for the transport model include the following:

(1) System Geometry

- Horizontal and vertical dimensions including layering and other heterogeneities (L)

(2) Porous Medium Properties

- Longitudinal dispersivity, α_L (L)
- Transverse dispersivity, α_T (L)

- Apparent molecular diffusion coefficient, D^* — $(L^2 T^{-1})$
- Effective porosity, ϕ
- Bulk density, ρ_B — (ML^{-3})

(3) Properties of Solute Species

- Decay coefficient, λ — (T^{-1})
- Distribution coefficient, k_d — $(L^3 M^{-1})$

(4) Darcy velocity components, V_1 and V_2 — (LT^{-1})

(5) Water-phase saturation, S_w

(6) Initial and boundary conditions

- Initial distribution of concentration, c_o — (ML^{-3})
- Prescribed values of concentration, $\bar{c}$ — (ML^{-3})
- Prescribed values of solute flux, $\dot{m}$ — $(ML^{-1} T^{-1})$

(7) Boundary geometry and fluid flux data at the boundary nodes — $(L^3 T^{-1})$

2.6.2 Multiphase Models

Input data and parameters for multiphase flow and transport simulations are similar to those for single-phase flow and transport except that reference is now made to each active fluid phase. Functional or tabulated relationships are used to describe the relative permeabilities of various fluid phases and capillary behavior. A full description of data requirements is provided in Section 8.3 of Chapter 8.

2.7 OUTPUT

2.7 OUTPUT

For a single-phase flow simulation, the primary line printer output includes nodal values of pressure head and element centroidal values of Darcy velocity components and water-phase saturation at specified time levels. To enable the user to use results from the flow model to run the transport model, SAMFT3D also provides the main link of the two models by writing the linking information on FORTRAN Unit 9. This information includes computed element centroidal values of Darcy velocities and water saturation, nodal fluid storage terms, and boundary nodal flux values. A restart option for the flow model is provided in the code. This is facilitated by writing the nodal values of pressure head computed at the final time step of the current run on FORTRAN Unit 8.

The primary line printer output of the transport model SAMFT3D includes nodal values (at user-selected time levels) of solute concentration. A restart option for the transport model is also provided in the code. This is facilitated by writing the nodal values of concentration computed at the final time step of the current run on FORTRAN Unit 8.

The SAMFT3D code is also capable of performing sequential simulations of flow and transport. In the sequential simulation approach, the flow problem is solved for the entire time period of simulation. In order to solve the associated transport problem after running the flow problem, the user should select an option that directs the code to write values of element velocities and water saturation obtained by solving the flow problem onto FORTRAN Unit 9. The information written on Unit 9 should then be supplied to the code as supplementary input data for the transport calculation.

3 NUMERICAL SOLUTION TECHNIQUES

3.1 GENERAL

In this chapter, numerical techniques for approximating the variably saturated water flow equation and the non-conservative solute transport equation are described. The flow equation is treated using the Galerkin finite element method. The transport equation is treated using the upstream-weighted finite element method designed to circumvent numerical oscillations. For both flow and transport problems, spatial discretization is performed using simple linear rectangular elements. Element matrices are computed using highly efficient influence coefficient matrix formulas (Huyakorn et al., 1986). The systems of algebraic equations resulting from the finite element approximations of the flow and transport equations are solved using SSR (slice successive relaxation) solvers for symmetric and asymmetric matrices, respectively.

3.2 NUMERICAL TREATMENT OF SINGLE-PHASE FLOW AND TRANSPORT PROBLEMS

3.2.1 Variably Saturated Flow

Equation (2.3) is solved by the Galerkin finite element method. In the Galerkin procedure, the pressure head function is represented by a trial function of the form

$$\psi(x_i,\ t) = N_J(x_i)\phi_J(t) \quad ,\ J = 1,2,\ldots,n \tag{3.1}$$

where $N_J(x_i)$ and $\psi_J(t)$ are basis functions and nodal values of pressure head at time t, respectively, n is the number of nodes in the finite element network, and repeated indices imply nodal summation. Applying the Galerkin criterion to (2.3) and transforming the second-order derivative term, one obtains

$$\int_R K_{ij}\, k_{rw} \frac{\partial N_I}{\partial x_i} \frac{\partial N_J}{\partial x_j} \psi_J \, dR + \int_R K_{ij}\, k_{rw} \frac{\partial N_I}{\partial x_i} e_j \, dR$$

$$+ \int_R \eta \, N_I \, N_J \frac{d\psi_J}{dt} dR - \int_B K_{ij}\, k_{rw} \left(\frac{\partial \psi}{\partial x_j} + e_j\right) n_i dB \tag{3.2}$$

$$- \int_R N_I \, q \, dR = 0 \; , \quad I = 1,2,\ldots,n$$

where R is the solution domain with boundary B, and n is the number of nodes in the finite element network.

Equation (3.2) can be written more concisely as

$$A_{IJ} \, \psi_J + B_{IJ} \frac{d\psi_J}{dt} = F_I \; , \; I = 1,2,\ldots,n \tag{3.3}$$

where

$$A_{IJ} = \sum_e \int_{R^e} K_{ij}\, k_{rw} \frac{\partial N_I}{\partial x_i} \frac{\partial N_J}{\partial x_j} dR \tag{3.4a}$$

$$B_{IJ} = \sum_e \int_{R^e} \eta \, N_I \, N_J \;\; dR \tag{3.4b}$$

$$F_I = \sum_e \left(\int_{R^e} - K_{ij}\, k_{rw} \frac{\partial N_I}{\partial x_i} e_j \, dR\right)$$

$$+ \int_R N_I \, q \, dR + \sum_e \left(\int_{B^e} V_n \, N_I \, dB\right) \tag{3.4c}$$

in which R^e is the element subdomain with boundary B^e, and V_n denotes the normal velocity at the boundary. The sign convention for V_n is the same as for q. That is, V_n is positive for inward flow and negative for outward flow.

3.2.2 Picard and Newton-Raphson Schemes

Equation (3.3) represents a system of n nonlinear ordinary differential equations. Time integration of these equations is performed using a fully implicit finite difference approximation. Two alternative nonlinear treatment procedures are provided in SAMFT3D. The first scheme is a Picard scheme that leads to a system of algebraic equations with symmetric coefficient matrix. The second scheme is a Newton-Raphson scheme that leads to a system of algebraic equations with asymmetric coefficient matrix. Both schemes are presented briefly in this section.

In the Picard scheme, equation (3.3) is approximated by the following equation:

$$\omega\, A_{IJ}^{k+\omega}\, \psi_J^{k+1} + (1-\omega)\, A_{IJ}^{k+\omega}\, \psi_J^{k} + \frac{B_{IJ}^{k+\omega}}{\Delta t_k} (\psi_J^{k+1} - \psi_J^{k}) = F_I^{k+\omega} \quad , \quad I = 1,2\ldots,n \tag{3.5}$$

where ω is a time-weighting factor, superscripts k and k + 1 are used to denote the previous and current time level respectively, and $\Delta t_k = t_{k+1} - t_k$. To obtain a fully implicit time-stepping scheme, the value of ω is set equal to 1. Equation (3.5) thus becomes:

$$\left(A_{IJ}^{k+1} + \frac{B_{IJ}^{k+1}}{\Delta t_k}\right) \psi_J^{k+1} = F_I^{k+1} + \frac{B_{IJ}^{k+1}}{\Delta t_k} \psi_J^k \tag{3.6}$$

which represents a symmetric matrix equation in view of the fact that both [A] and [B] are symmetric matrices. Nonlinear iterations are performed within each time step to achieve a stable numerical solution. The use of fully implicit (backward) difference time stepping combined with lumping (diagonalization) of storage matrix [B] proves to be advantageous for highly nonlinear situations where damping of oscillatory convergence behavior of the numerical solution is desirable.

In the Newton-Raphson scheme, equation (3.3) is replaced by the following integrated fully-implicit finite difference approximation:

$$\begin{aligned} G_I \equiv\; & A_{IJ}\, \psi_J^{k+1} + B'_{IJ}\, (\psi_J^{k+1} - \psi_J^k)/\Delta t_k \\ & + E_{IJ}\, (S_{wJ}^{k+1} - S_{wJ}^k)/\Delta t \;=\; 0,\; I=1,2\ldots,n \end{aligned} \tag{3.7}$$

where G_I is the nonlinear (vector array) function of the nodal head values, and B'_{IJ} and E_{IJ} are defined as

$$B'_{IJ} = \int_R S_s S_w N_I N_J \, dR \tag{3.8a}$$

$$E_{II} = \int_R \phi N_I dR \tag{3.8b}$$

$$E_{IJ} = 0 \;\; for\; J \neq I \tag{3.8c}$$

Application of the Newton-Raphson procedure to (3.7) yields (see Huyakorn and Pinder, 1983):

$$G_I^{r+1} = G_I^r + \left(\frac{\partial G_I}{\partial \psi_J}\right)^r \Delta\psi_J^{r+1} = 0 \quad , I=1,2,\ldots,n \tag{3.9}$$

where r and r+1 denote previous and present iteration levels at the current time value, $\Delta\psi_J^{r+1}$ is an iteration displacement vector defined as

$$\Delta\psi_J^{r+1} = \psi_J^{r+1} - \psi_J^r \tag{3.10}$$

and $(\partial G_I/\partial\psi_J)^r$ is the Jacobian of the Newton-Raphson iteration.

Equation (3.8) can be written in the form

$$H_{IJ}^r \, \psi_J^{r+1} = H_{IJ}^r \, \psi_J^r - G_I^r \, , \; I=1,2,\ldots,n \tag{3.11}$$

where $H_{IJ} = (\partial G_I/\partial\psi_J)^r$.

Owing to the fact that [H] is an asymmetric matrix, (3.11) thus represents an asymmetric matrix equation. As in the Picard scheme, it is necessary to perform nonlinear iterations within the time step to achieve a stable numerical solution. Iterations are performed until the successive change in pressure head values is within a prescribed tolerance. For each iteration, the Newton-Raphson scheme requires more than twice the computational effort compared with the Picard scheme. However, experience has indicated that the Newton-Raphson scheme with lumping of the storage matrix is more robust than the Picard scheme when dealing with highly nonlinear soil moisture characteristics.

Several convergence enhancement features have been implemented into the code and used in conjunction with both the Picard and the Newton-Raphson techniques. The first of such features is the use of extrapolation formulas for estimating nodal values, ψ_J^{k+1} thereby enhancing convergence of the iterative process. At the start of a new time level, an initial estimate of ψ_J^{k+1} is obtained from:

$$
\begin{aligned}
\psi_J^{k+1} &= \psi_J^k &&, \ if\ k = 1 \\
\psi_J^{k+1} &= \psi_J^k + (\psi_J^k - \psi_J^{k-1})\ \Delta t_k / 2\Delta t_{k-1} &&, \ if\ k = 2 \qquad (3.12) \\
\psi_J^{k+1} &= \psi_J^k + (\psi_J^k - \psi_J^{k-1})\ \frac{log(t_{k+1}/t_k)}{log(t_k/t_{k-1})} &&, \ if\ k > 2
\end{aligned}
$$

During subsequent iterations, improved estimates of ψ_J^{k+1} are obtained from

$$\psi_J^{k+1} = (1-\gamma)\ \psi_J^r + \gamma\ \psi_J^{r+1} \qquad (3.13)$$

where γ is an underrelaxation factor ($0 < \gamma < 1$), and ψ_J^r and ψ_J^{r+1} are the current and previous iterations of nodal values of pressure head at the current time level, $k + 1$, respectively.

Another salient feature is the use of an automatic underrelaxation procedure to cope with oscillatory convergence behavior of the numerical solution. Via this procedure, the value of the underrelaxation factor, γ, is computed as the iterations progress. The algorithm used to compute γ is adapted from Cooley (1983), and is given as

Step 1

$$S = \begin{cases} \dfrac{e_{r+1}}{e_r \gamma_{old}} & if\ \ r > 1 \\ 1 & if\ \ r = 1 \end{cases} \qquad (3.14)$$

Step 2

$$\gamma_{new} = \begin{cases} \dfrac{3+s}{3+|s|} & \text{if } s \geq -1 \\ \dfrac{1}{2|s|} & \text{if } s < -1 \end{cases} \tag{3.15}$$

where r and r + 1 denote previous and current iteration levels, respectively, γ_{old} and γ_{new} are old and new values of the underrelaxation factor, and e is the absolute value of the largest difference between head values at two successive iteration levels ($e_r = \text{Max} \mid \psi_I^r - \psi_I^{r-1} \mid$).

3.2.3 Spatial Discretization and the SSOR Scheme

In SAMFT3D, discretization of a three-dimensional solution region is performed using 8-node rectangular brick elements. Such elements are selected because their element matrices are simple and inexpensive to compute.

In essence, the discretization is achieved in a simple manner by dividing a given region into vertical blocks, each of which is subdivided into a number of brick elements. Nodes are numbered sequentially within each vertical slice starting from the first to the last slice. Note that a right-handed Cartesian coordinate system is adopted. The x-y plane corresponds to the projected plane of each slice. The z-axis is normal to this plane and the sense of direction for z-coordinate is obtained by making a counter-clockwise rotation from x to y. With this discretization approach it is simple to use the Slice Successive Over-Relaxation (SSOR) scheme to perform matrix solution. The matrix solution strategy can be described as follows:

- Estimate current values of the nodal unknowns for the entire solution region. Use this estimate to compute element matrices and right-hand side vectors.
- Assemble element matrix equations using an appropriate matrix partitioning technique that leads to subsets of algebraic equations each of which correspond to the individual slices. The unknowns in a particular subset of equations are the unknown values of the head (or concentration as the case may be) at the nodes in the individual slice.
- Perform a slice-by-slice solution of the global matrix equation starting from the first to the last slice. For each slice, the subset of algebraic equations is solved using a direct Gauss solver. The solution from the solver routine is modified by applying the following over-relaxation formula:

$$\chi_I^* = \chi_I^{old} + \Omega \, (\chi_I^{old})$$

where X_I^{old} and X_I are the old value of the nodal unknown and the value obtained from the solver, Ω is the over-relaxation factor, and X_I^* is the new value of the unknown. For computational efficiency, the Gauss solver should take advantage of the banded feature of the coefficient matrix as well as the symmetric property which arises when dealing with fluid flow. In addition, the solver subroutine should be coded such that matrix reduction and back substitution are done separately. Note that matrix reduction needs to be performed only once in the first stage of this SSOR scheme.

- Check to determine if the solution has converged. If convergence to within a prescribed tolerance is not achieved, use the updated values of the nodal unknown to recompute the right-hand side vector of the matrix equation. Repeat the slice-by-slice solution of the global matrix equation. This time the solution is obtained by performing backward substitution. Once again, update values of the nodal unknown by applying the over-relaxation formula, and check convergence. If need be, perform successive iterations until a satisfactory result is obtained.

3.2.4 Solute Transport

For the contaminant transport simulation, SAMFT3D solves (2.16) using an upstream-weighted residual finite element method. To illustrate the application of the technique, consider equation (2.15) and a trial solution for concentration be written in the form:

$$c(x_i,t) = N_J(x_i)c_J(t) \tag{3.16}$$

where $N_J(x_i)$ and $c_J(t)$ are the basis functions and nodal values of concentration at time t, respectively.

In the upstream weighted residual technique, the weighted residual integral equation is obtained using asymmetric (upstream) weighting functions (see Huyakorn and Nilkuha, 1979) to weight the spatial derivative terms of the transport equation, and the standard basis functions to weight the remaining mass accumulation term. Application of this procedure to (2.15) yields

$$\int_R W_I \left[\frac{\partial}{\partial x_i} (D_{ij} \frac{\partial c}{\partial x_j} - V_i \frac{\partial c}{\partial x_i}) \right]$$
$$- \int_R N_I \left[\phi S_w R (\frac{\partial c}{\partial t} + \lambda c) + q(c-c^*) \right] dR = 0 \tag{3.17}$$

where W_I are the upstream weighting functions.

Using Green's theorem to remove the second derivative and substituting for c, one obtains

$$\int_R (D_{ij} \frac{\partial W_I}{\partial x_i} \frac{\partial N_J}{\partial x_j} + V_i W_I \frac{\partial N_J}{\partial x_i}) c_J dR$$
$$+ \int_R \phi S_w R N_I N_J (\frac{dc_J}{dt} + \lambda c_J) dR + \int N_I q (c* - N_J c_J) dR \tag{3.18}$$
$$- \int_B W_I (D_{ij} \frac{\partial c}{\partial x_j} n_i) dB = 0$$

Equation (3.18) can be expressed in the form

$$(E_{IJ} + B_{IJ}^*) c_J + \tilde{B}_{IJ} \frac{dc_J}{dt} = \tilde{F}_I \tag{3.19}$$

where

$$\tilde{F}_I = - \int_R N_I q (c* - N_J c_J) dR + \int_B W_I (D_{ij} \frac{\partial c}{\partial x_j}) n_i dB \tag{3.20}$$

$$E_{ij} = \int_R (D_{ij} \frac{\partial W_I}{\partial x_i} \frac{\partial N_J}{\partial x_j} + V_i W_I \frac{\partial N_J}{\partial x_i}) dR \tag{3.21}$$

$$\tilde{B}_{IJ} = \int_R (\phi S_w R) N_I N_J dR \tag{3.22}$$

$$B_{IJ}^* = \int_R (\lambda \phi S_w R) N_I N_J dR \tag{3.23}$$

Once all of the element matrices have been computed and assembled into global matrices, the system of ordinary differential equations (3.19) can be integrated with respect to time. This leads to the following system of algebraic equations:

$$\left[\omega(E_{IJ} + B_{IJ}^{*}) + \frac{\tilde{B}_{IJ}}{\Delta t_k}\right] c_J^{k+1} = (\omega-1)\ (E_{IJ} + B_{IJ}^{*})\ c_J^{k} + \frac{\tilde{B}_{IJ}}{\Delta t_k}\ c_J^{k} + \omega\ \tilde{F}_I^{k+1} + (1-\omega)\ \tilde{F}_I^{k} \tag{3.24}$$

where ω is the time weighting factor.

Equation (3.24) can be rearranged in the form

$$G_{IJ}\ c_J^{k+1} = R_I^{k+1} \tag{3.25}$$

where

$$R_I^{k+1} = (\omega-1)\ (E_{IJ} + B_{IJ}^{*})\ c_J^{k} + \frac{\tilde{B}_{IJ}}{\Delta t_k}\ c + \omega\ \tilde{F}_I^{k+1} + (1-\omega)\ \tilde{F}_I^{k} \tag{3.26a}$$

and

$$G_{IJ} = \omega(E_{IJ} + B_{IJ}^{*}) + \tilde{B}_{IJ}/\Delta t_k \tag{3.26b}$$

To obtain a second-order accuracy in time approximation, ω is chosen to be 0.5 thus yielding the Crank-Nicholson time stepping scheme. Equation (3.25) represents a system of linear algebraic equations with an asymmetric banded coefficient matrix.

3.2.5 Treatment of Boundary Conditions

The first-type boundary condition (2.20a) is treated by setting current concentration values at the boundary nodes to the prescribed concentration $\tilde{c}$. Physically, the first-type boundary condition may apply to inflow boundary segments where the concentration of the incoming fluid is assumed to be approximately the same as the resident nodal concentration in the porous medium. Nodal points representing injection wells or contaminant sources may also be subject to the first type boundary condition if the stated equilibrium assumption is adopted.

The second-type boundary condition (2.20b) is treated by adding the integrated value of the prescribed dispersive flux to the right hand side of the discretized finite element equations. Physically, the second-type boundary condition may apply to impermeable boundary segments where the fluxes and normal concentration gradients are zero. It may also apply to certain contaminant sources placed in an undisturbed flow field wherein the mass of waste material is leaching at a prescribed rate, q_c^D.

The third-type boundary condition (2.20c) generally applies to inlet boundary segments and/or injection wells when the concentration of incoming or injected fluid c* may be unequal to the resident nodal concentration values. In this case, the integrated nodal values of the flux q_c^T are added to the right side of the finite element equations, and the integrated advective flux term corresponding to $V_i n_i c$ of (2.20c) is incorporated into the coefficient matrix. For the special case of pumping wells and outflow boundary, the outflow concentration c* usually takes the same value as the resident nodal concentration, c. The boundary condition (2.20c) then reduces to that of (2.20b) with zero dispersive flux. This corresponds to the natural boundary condition of the finite element formulation used in the code and no treatment is needed.

A temporal variation of the boundary condition at any given node may be accommodated in a convenient manner by using either a continuous piecewise linear approximation or discontinuous (stepped) approximation of the actual graph of concentration or solute flux versus time.

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4 EXAMPLE VERIFICATION AND APPLICATION PROBLEMS

4.1 GENERAL

Two sets of test problems were used for verification of numerical schemes and demonstration of major capabilities of the single-phase flow and transport components of the SAMFT3D code. Specific purposes of the example problems presented in this chapter are described below.

- Simulation of water flow under variably saturated (or saturated-unsaturated) conditions

- Sequential simulation of flow and transport problems with various types of boundary conditions

- Verification of the SAMFT3D code against analytical solutions and other finite element variably saturated flow and transport codes UNSAT2 (Davis and Neuman, 1983) FEMWATER and FEMWASTE (Yeh and Ward, 1981) and VADOFT (Huyakorn et al. 1988)

- Demonstration of the ability of SAMFT3D to handle realistic three-dimensional problems.

The first problem set consists of three transient flow problems with different features of boundary conditions. These problems are as follows:

- One-dimensional horizontal flow in a soil slab

- Two-dimensional flow in a vertical section of a soil slab

- Three-dimensional flow in an unconfined aquifer with a pumping well.

The second problem set consists of four transient transport problems. Three of these problems are associated with three of the flow problems just mentioned. The transport problems considered are listed as follows:

- One-dimensional horizontal transport in a soil slab
- Two-dimensional transport in a soil slab
- Three-dimensional transport in an unconfined aquifer with a pumping well
- Three-dimensional transport in uniform groundwater flow.

A detailed description of all test problems, values of the physical parameters used in the simulation, and numerical results are presented in the following sections.

4.2 SINGLE-PHASE FLOW PROBLEMS

4.2.1 Horizontal Flow in a Soil Slab

The purpose of this problem is to test the implementation of the Galerkin finite element formulation and the nonlinear iterative schemes for a simple one-dimensional case in which there is no gravity effect. The problem, presented in an earlier paper by Huyakorn et al. (1984), is depicted schematically in Figure 4.1. As illustrated, a slab of soil has an initial pressure head of -83.33 cm. Wetting occurs at the left boundary (x = 0) where the pressure head is increased to 0.0 and maintained constant. The pressure head at the right boundary (x = 20 cm) is kept constant at -83.33 cm. For convenience, the soil was assumed to be homogeneous and isotropic with a saturated hydraulic conductivity of 1 cm/d and porosity of 0.45. The soil moisture characteristics used in the simulation are

$$k_{rw} = (S_w - S_{wr})/(1 - S_{wr})$$

and

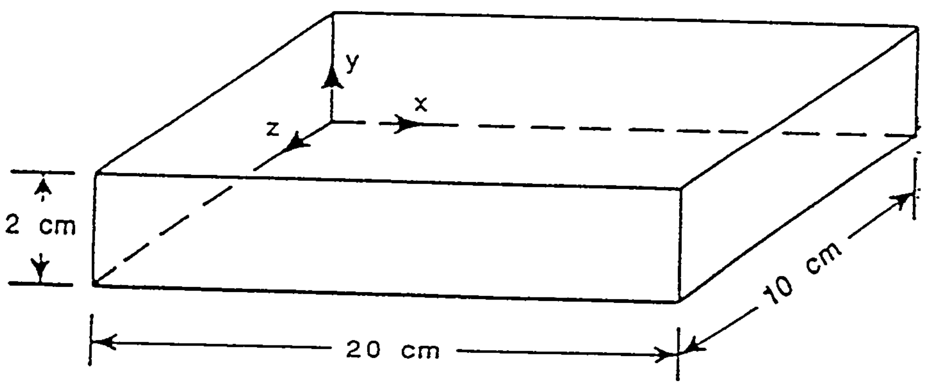


Figure 4.1. Geometry and boundary conditions used in the simulation of unsaturated flow in a soil slab.

$$\frac{1-S_w}{1-S_{wr}} = \frac{\psi-\psi_a}{-100-\psi_a}$$

where $S_{wr} = 0.3333$ and $\psi_a = 0.0$ cm. The selected relative permeability function corresponds to the Brooks-Corey equation with $n = 1$. The selected water saturation function corresponds to the van Genuchten equation with $\alpha = -0.01$ cm^{-1}, $\beta = 1$ and $\gamma = -1$.

To apply the SAMFT3D code to the stated problem, some physical parameters and initial and boundary conditions need to be converted. Table 4.1 provides the result of this conversion. Note that compressibilities of water and soil matrix are assumed to be zero. Numerical solutions were obtained using equal mesh spacings, $\Delta x = 1$ cm, $\Delta y = 2$ cm, $\Delta z = 10$ cm, and constant time increments, $\Delta t = 864$ s (0.01 d). Computed pressure head and water saturation profiles are plotted in Figures 4.2 and 4.3, respectively. In Figure 4.2, the pressure head profiles computed by SAMFT3D are compared with those computed by UNSAT2, the two-dimensional Galerkin finite element code, documented by Davis and Neuman (1983). It can be seen that there is good agreement between the two numerical solutions.

4.2.2 Two-Dimensional Flow in a Cross Section of Soil Slab

The purpose of this problem is to test the implementation of the Galerkin finite element formulation and the nonlinear iterative schemes for a two-dimensional case involving gravity effect. The problem, solved previously using the UNSAT2 code, three other codes (VAM2D and UNSAT2), is described schematically in Figure 4.3. As illustrated, a rectangular soil slab, with sectional dimensions in the x-y plane of 15 cm by 10 cm and a width of 10 cm, had an initial

Table 4.1. Converted input parameters and initial and boundary conditions for the SAMFT3D computer run.

Intrinsic permeability, k	1.157E-10	cm^2
Dynamic viscosity of water, μ_w	9.8 E-3	g/(cm.s)
Gravitational acceleration, g	980.5	cm/s^2
Initial gauge pressure value, p_w^o	-81705	$dyne/cm^2$
Gauge pressure value at x=0, $p_w(x=0)$	0.0	$dyne/cm^2$
Gauge pressure value at x=20 cm, $p_w(x=20)$	-81705	$dyne/cm^2$

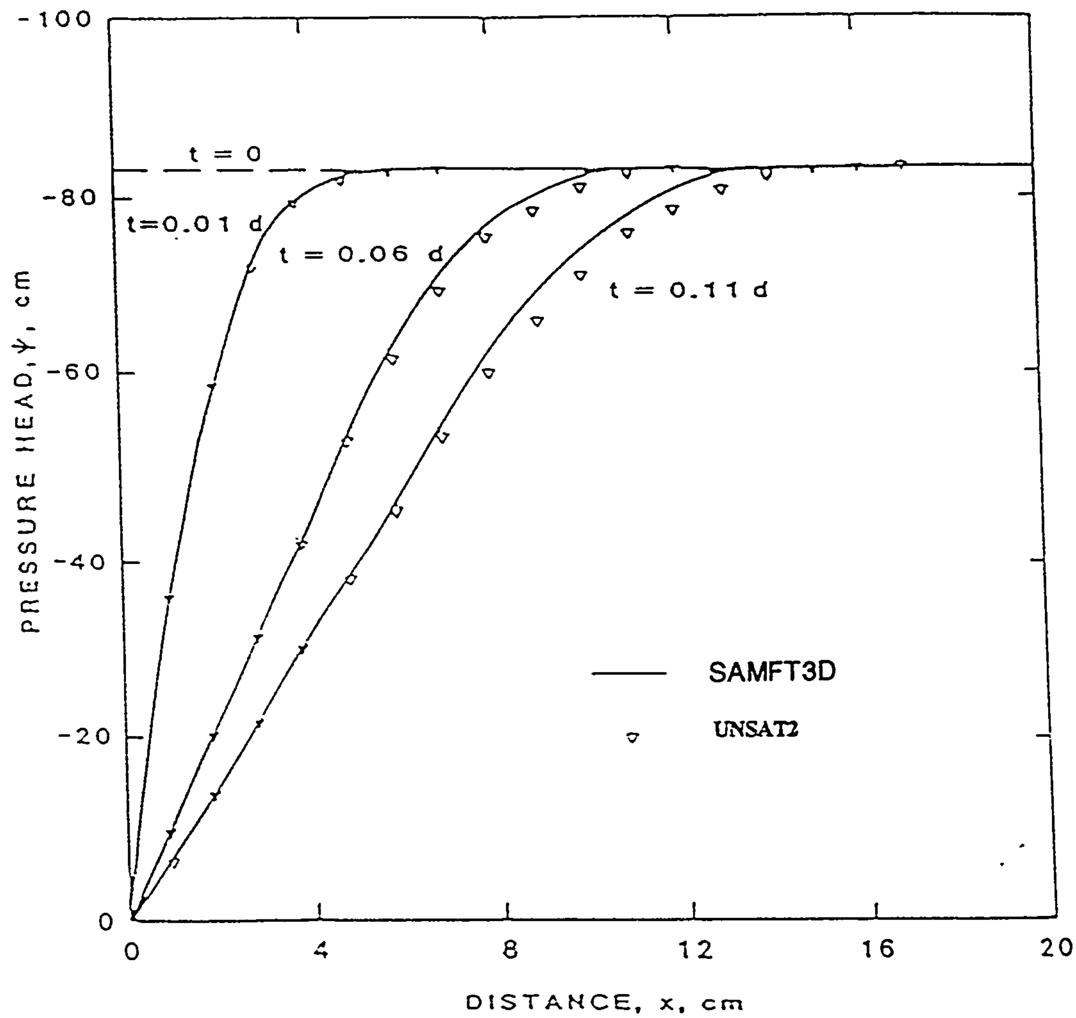


Figure 4.2. Pressure head distributions along the base and the top of the flow region.

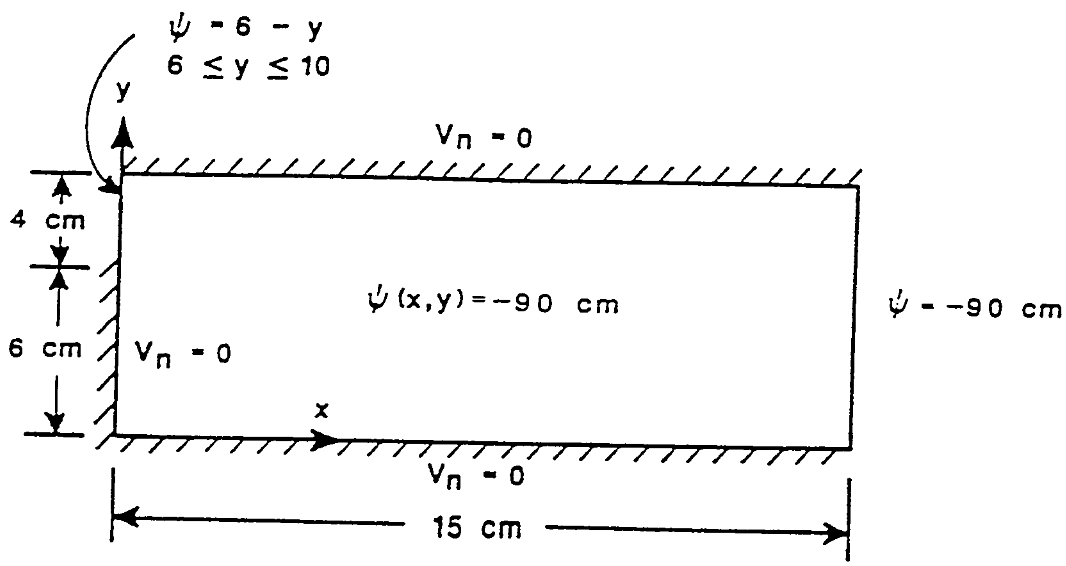


Figure 4.3. Geometry and boundary conditions used in the simulation of unsaturated flow in a soil slab.

pressure head of -90 cm. The boundary conditions depicted in Figure 4.3 were then applied and maintained thereafter. The soil properties used in the simulation are the same as those presented in Section 4.2.1 for the horizontal flow problem.

The flow region was discretized using a rectangular grid consisting of 150 elements and 352 nodes. A constant nodal spacing was used along each coordinate axis. The nodal spacings in the x and y directions were $\Delta x = 1$ cm, $\Delta y = 1$ cm, and $\Delta z = 10$ cm, respectively. The simulation was performed for 15 time steps. Time-step values were generated within the code using the algorithm: $\Delta t_1 = 864$ s (0.01 d), $\Delta t_k = 1.2\Delta t_{k-1} \leq 4320$ s (0.05 d) for $k = 2, \ldots, 15$.

The number of nonlinear iterations required for convergence (within the prescribed tolerance of 0.01 cm) varies from 3 to 6 over the 15 time steps of simulation. Computed values of pressure head on the base and the top of the flow region are plotted in Figure 4.4 for a time value of 43200 s (0.508 d). Also included in the numerical solution obtained from UNSAT2, the two-dimensional Galerkin finite element code, documented in Neuman et al. (1974) and Davis and Neuman (1983). It can be seen that there is good agreement between the two numerical solutions.

4.2.3 Three-Dimensional Flow in an Unconfined Aquifer With a Pumping Well

This problem concerns saturated-unsaturated flow in an anisotropic unconfined aquifer subjected to well pumping. Geometry and boundary conditions of the problem are depicted in Figure 4.5. Because of symmetry only half of the flow region needs to be considered.

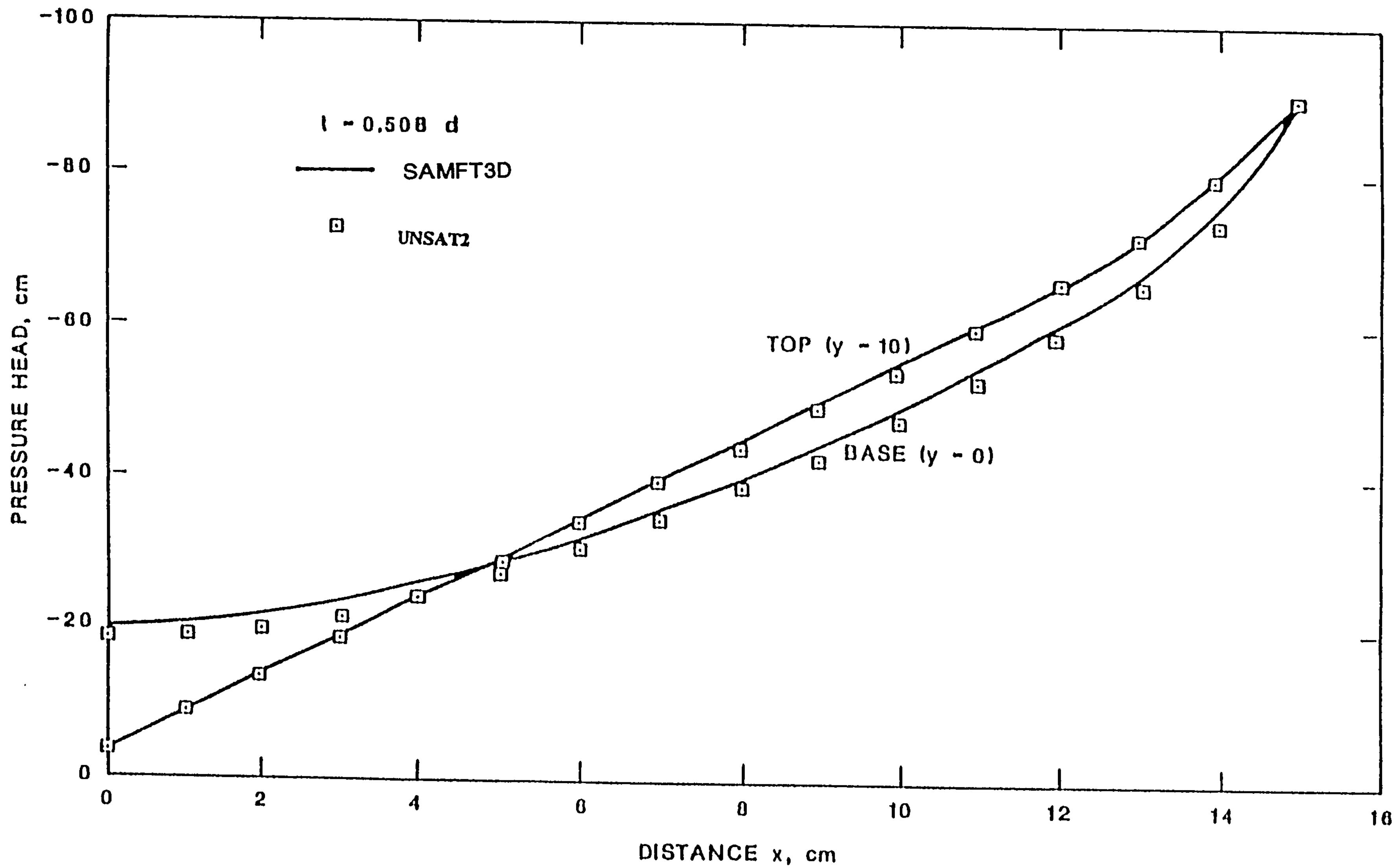


Figure 4.4. Pressure head distributions along the base and the top of the flow region.

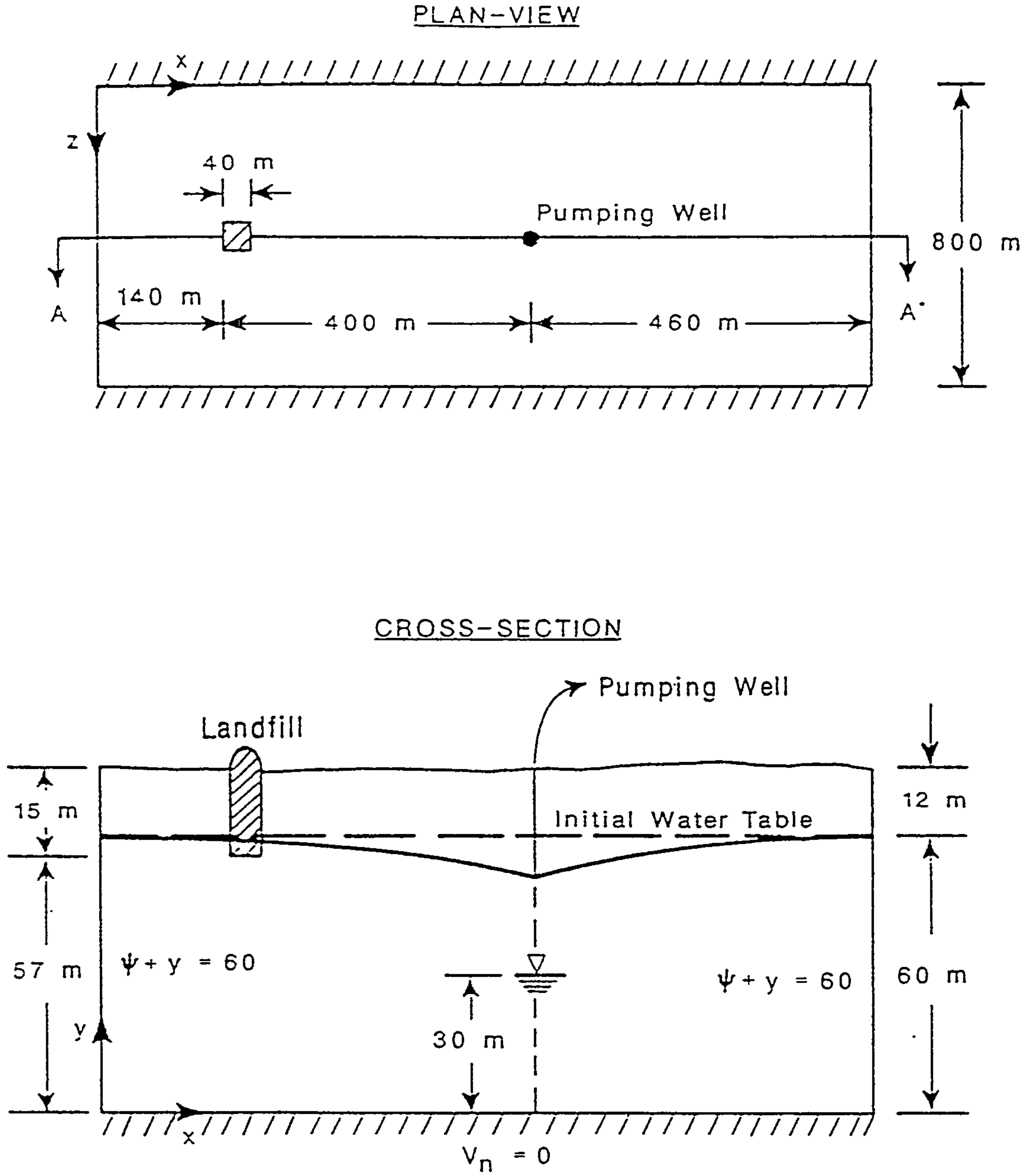


Figure 4.5. Geometry and boundary conditions for the problem of three-dimensional flow in a pumped unconfined aquifer (from Huyakorn et al., 1986).

Initially, the water table was assumed to be located at a height of 60 m above the base of the aquifer. The water level in the well was then lowered to a height of 30 m, and this height was maintained until a steady-state condition was established. A prescribed hydraulic head condition (ψ+y = 60 m) was assumed on two vertical boundary portions located at x = 0, 0 $\leq$ y $\leq$ 60 m, and at x = 1000 m, 0 $\leq$ y $\leq$ 60 m, respectively. No-flow condition was assumed on other boundary portions of the flow region. A steady-state analysis of the stated flow problem was performed. Values of the physical parameters used in the analysis are given in Table 4.2.

The region defined by 0 $\leq$ x $\leq$ 1000, 0 $\leq$ y $\leq$ 72, and 0 $\leq$ z $\leq$ 400 m was discretized using a rectangular grid comprised of 1600 elements and 2079 nodes. The nodal spacings of this grid are given in Table 4.3. The steady flow problem was solved in one step with the head tolerance specified as 0.01 m. It took six nonlinear iterations to reach the desired degree of convergence. Within each of these iterations, the SSOR matrix subiterations were performed using an over-relaxation value of 1.5. The number of subiterations necessary to converge to the tolerance of 0.01 m varies from 3 to 15. Computed water table elevations versus distances are plotted in Figures 4.6 and 4.7 for longitudinal and transverse sections through the pumping well, respectively. Note that the length of the seepage face and the well discharge were determined to be approximately 4 meters and 1838.4 m^3/day, respectively.

Table 4.2. Values of Physical Parameters Used in the Simulation of Three-Dimensional Flow in an Unconfined Aquifer With a Pumping Well and Three-Dimensional Flow in a Drained Field.

Hydraulic conductivity, K_{xx}	5 m/d
Hydraulic conductivity, K_{yy}	2 m/d
Hydraulic conductivity, K_{zz}	0.5 m/d
Air entry value, ψ_a	0
Residual water saturation, S_{wr}	0.05

<u>Constitutive relations</u>:

$$S_e = \frac{1}{1 + (\alpha \mid \psi - \psi_a \mid)^{\beta}}$$

and

$$k_{rw} = S_e^2$$

where

$$\alpha = 0.5 \text{ m}^{-1}, \beta = 2, \text{ and}$$

$$S_a = (S_w - S_{wr})/(1 - S_{wr}).$$

Table 4.3. Coordinates of the Rectangular Grid Used in Simulating Three-Dimensional Flow in an Unconfined Aquifer Subjected to well Pumping.

x_i, $i=1$ to 21	0, 70, 120, 160, 200, 275, 350, 400, 450, 500, 540, 570, 600, 650, 700, 750, 900, 850, 900, 950, 1000 m.
y_j, $j=1$ to 11	0, 15, 30, 35, 40, 45, 50, 55, 60, 66, 72 m.
z_k, $k=1$ to 9	0, 50, 100, 150, 200, 250, 300, 350, 400 m.

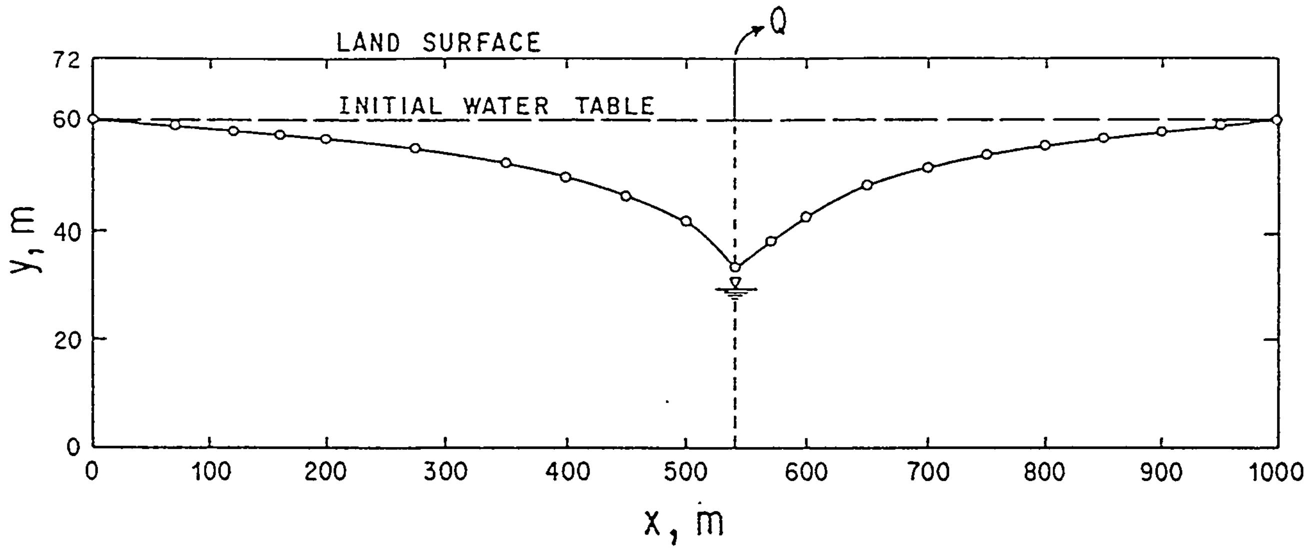


Figure 4.6. Longitudinal profile of the steady-state water table.

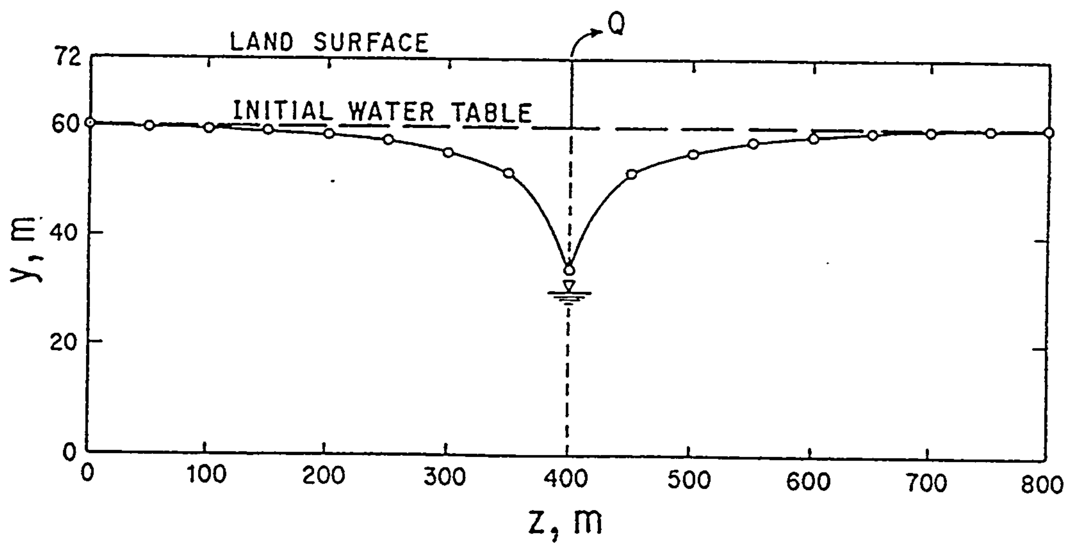


Figure 4.7. Transverse profile of the steady-state water table.

4.3 SINGLE-PHASE TRANSPORT PROBLEMS

4.3.1 One-Dimensional Transport in a Soil Slab

The purpose of this problem is to test the coding of the finite element formulation for a one-dimensional case involving advective-dispersive transport in an unsaturated porous medium. The problem concerns one-dimensional transport of a non-conservative species in an unsaturated soil slab identical to that described in Section 4.2.1. Velocities obtained by solving the corresponding unsaturated flow problem were used as input data for the current transport problem. Initial and boundary conditions required by the model are depicted in Figure 4.8 together with values of the physical parameters used.

The numerical solution was obtained using the same mesh previously used for the corresponding flow problem. The transport simulation was performed for 20 time steps with a constant value of $\Delta t=864$ s (0.01 days). Typical velocity profiles used in the transport calculation are illustrated in Figure 4.9. It is important to recognize that for the unsaturated flow case considered, the velocity distribution is time-dependent and this fact must be taken into account in the mass balance calculation to avoid obtaining an incorrect result. Computed concentration profiles at 0.04 and 0.2 days are depicted in Figure 4.10.

4.3.2 Two-Dimensional Transport in a Soil Slab

This problem concerns transport of a non-conservative solute in a rectangular cross section of an unsaturated soil. It corresponds to the 2-D unsaturated flow problem described in Section 4.2.2. As illustrated in Figure 4.11, the soil is initially dry and water and solute are allowed to enter the system at the upper portion of the left-hand boundary, $x=0$ and

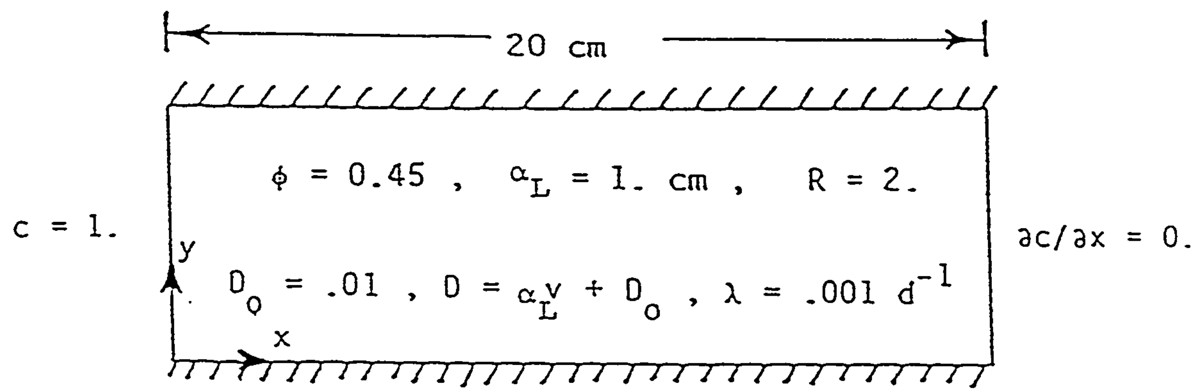


Figure 4.8. Schematic description and data for the problem of transport in a soil slab.

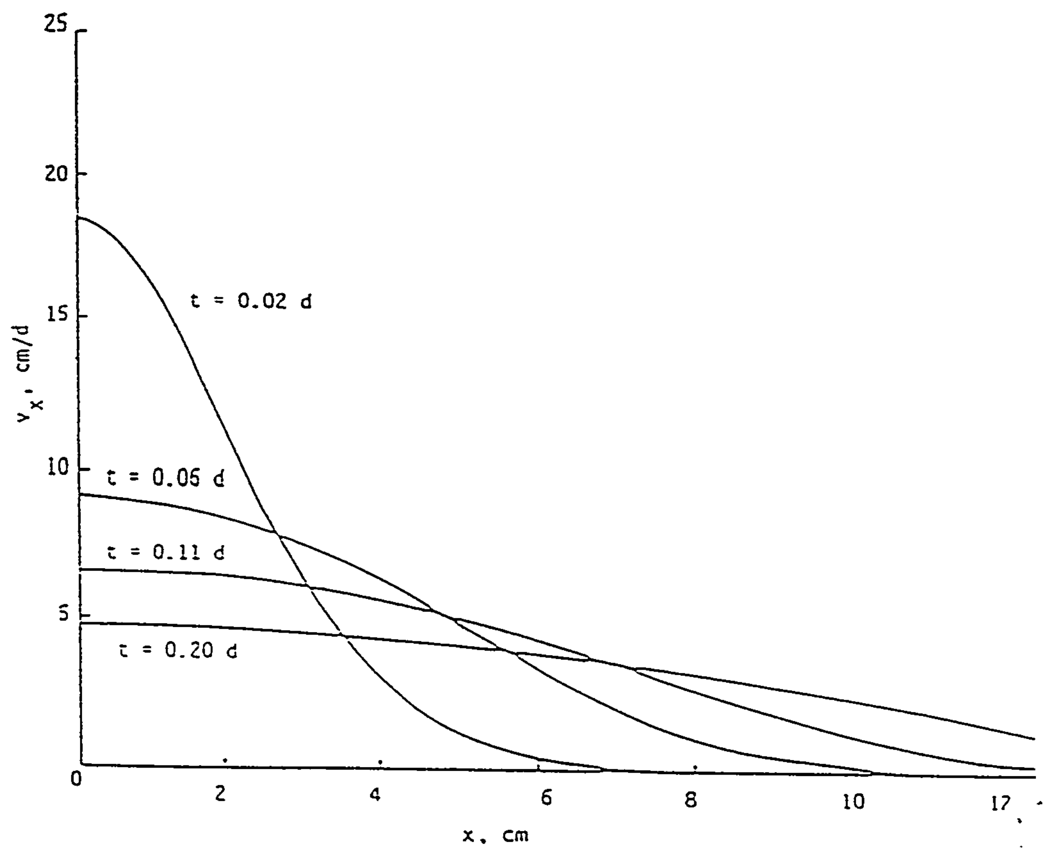


Figure 4.9. Simulated saturation profiles and velocity field.

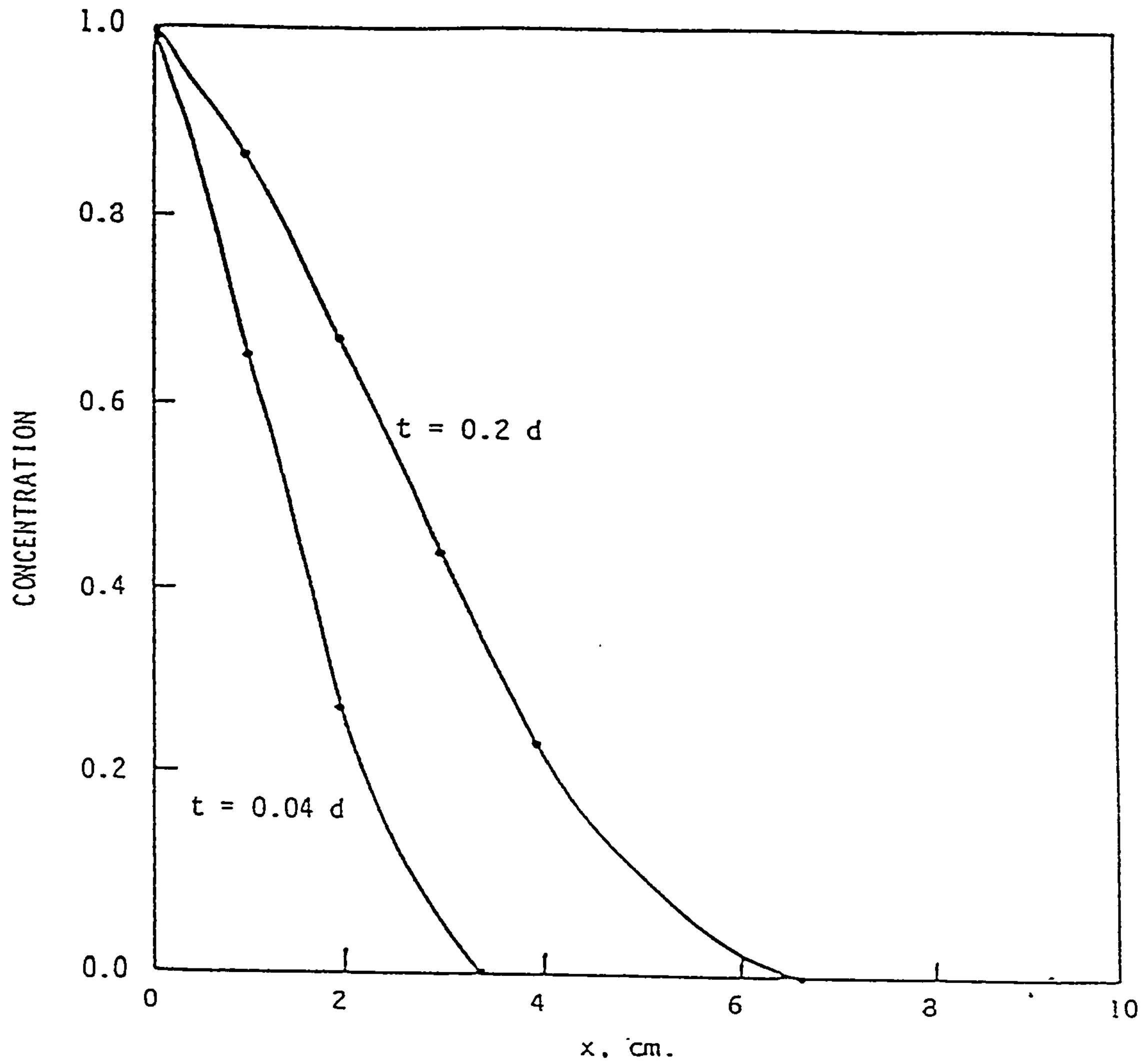


Figure 4.10. Simulated concentration profiles for the one-dimensional transport problem.

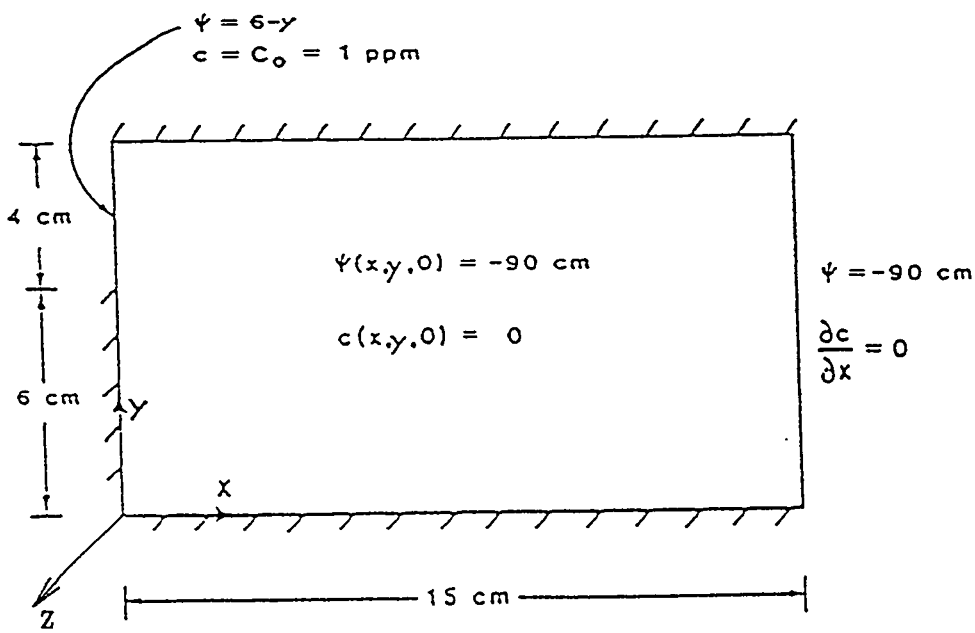


Figure 4.11. Schematic description and data for the problem of two-dimensional transport in a soil slab.

$6 \le y \le 10$ cm. The right-hand boundary, which corresponds to the outlet, is maintained at the same initial pressure head value. At the inlet, the pressure head is maintained at $\psi = 6 - y$, and the solute concentration is assumed to be 1 ppm. No flow and zero normal concentration gradients are applied to the remaining portions of the entire boundary.

Values of the physical parameters required are given in Table 4.4. Values of water saturation and Darcy velocities at different times were determined by analyzing the associated flow problem. Both flow and transport were simulated using a medium rectangular grid. The grid was a uniform 11 x 16 x 2 grid comprised of 352 nodes and 150 elements. The nodal spacings were $\Delta x = \Delta y = 1$ cm, and $\Delta z = 10$ cm. Time increment values were generated within the code using the algorithm: $\Delta t_1 = 864$ s (0.01 days), $\Delta t_k = 1.2\Delta t_{k-1} \le 4320$ s (0.05 days).

The transport simulation was performed for 15 time steps using the Galerkin scheme. (Upstream weighting was not applied in this case because the cell Peclet number, $Pe = \Delta x/\alpha_L$, was not large enough to create numerical oscillations.) For verification purposes, the solution obtained using the present finite element model is compared in Figures 4.12 and 4.13 with the corresponding Galerkin solution obtained using the FEMWASTE code. Evidently, the overall agreement between the two numerical solutions is reasonable. The horizontal concentration distributions depicted in Figure 4.12 are all smooth, although the profile predicted by the present model appears to be slightly ahead of that predicted by FEMWASTE. Note, however, that at the two later time values the vertical concentration distributions computed by FEMWASTE exhibit numerical oscillations and incorrect representation of the zero normal gradient boundary

Table 4.4. Values of physical parameters used in the simulation of 2-D transport in a soil slab.

Parameter	Value
Hydraulic conductivity, K	1 cm/d
Porosity, ϕ	0.45
Initial pressure head, ψ_o	-90 cm
Initial concentration, c_o	0
Longitudinal dispersivity, α_L	1 cm
Transverse dispersivity, α_T	0
Apparent molecular diffusion, D_o	0.01 cm^2/d
Decay coefficient, λ	0.001 d^{-1}
Bulk density, ρ_B	1.46 g/cm^3
Distribution coefficient, k_d	0.308 cm^3/g

Soil moisture relations used are the same as those given in Section 4.2.1.

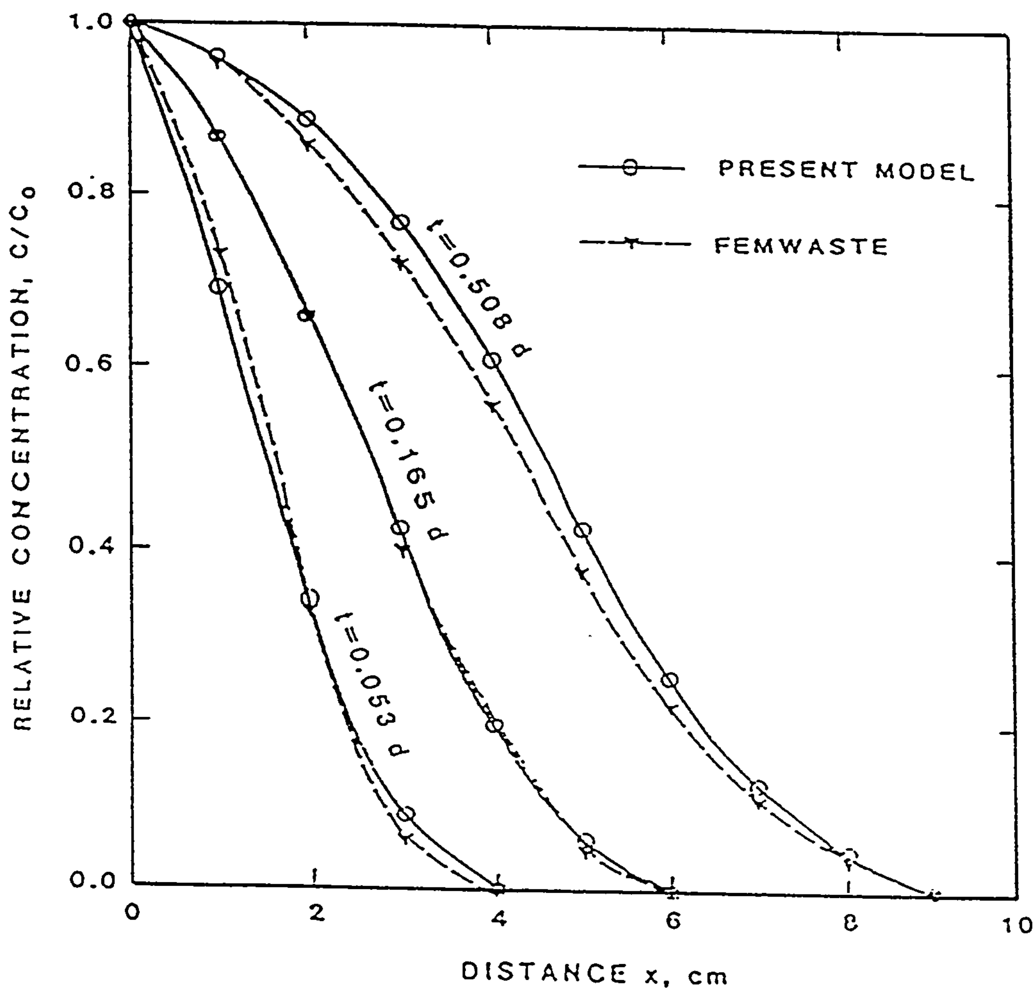


Figure 4.12. Computed horizontal profiles for typical time values.

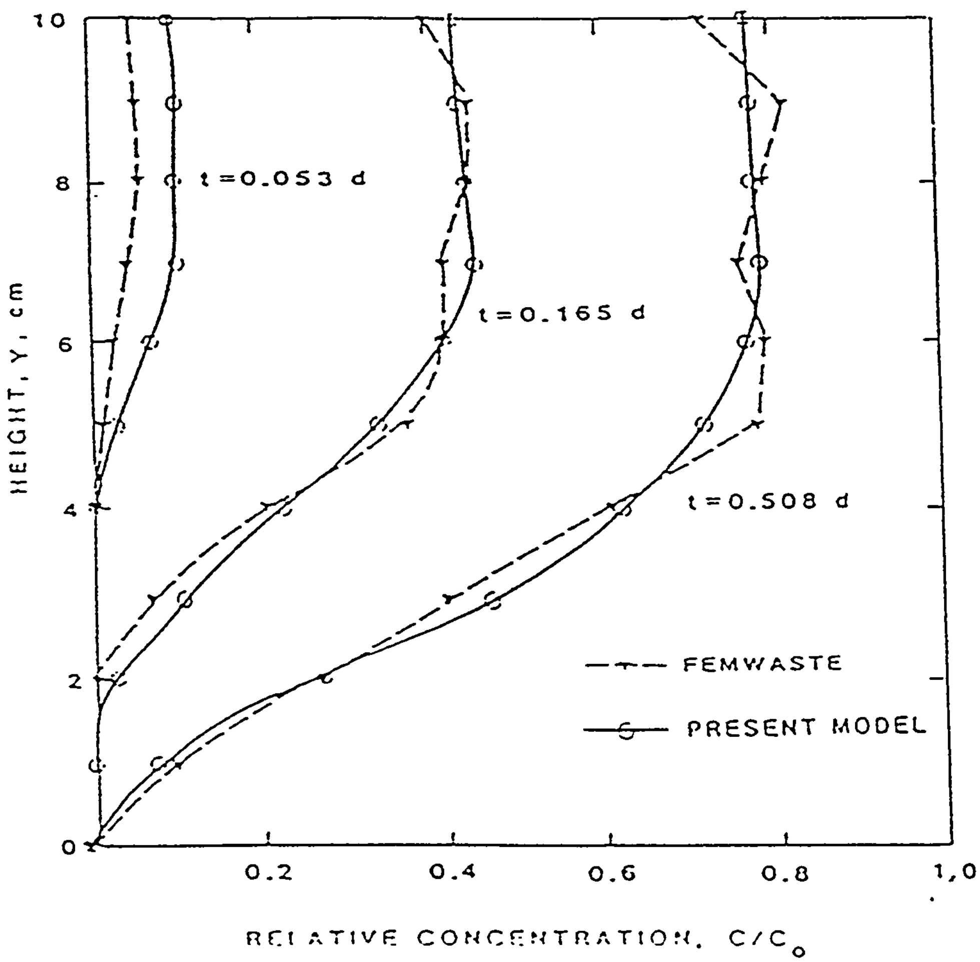


Figure 4.13. Computed vertical profiles for typical time values.

condition at the top boundary, $y = 10$ cm. In contrast, the vertical concentration profiles computed by the present model are smooth. Furthermore, the zero normal gradient condition at $y = 10$ cm is very well duplicated.

4.3.3 Three-Dimensional Transport in an Unconfined Aquifer With a Pumping Well

This problem is related to the steady three-dimensional flow problem described in Section 4.2.3. It concerns contaminant transport in an unconfined aquifer subjected to well pumping. As depicted in Figure 4.14, the contaminants originate from a surface landfill and enter the groundwater system through an unsaturated zone above the water table. The problem was selected to test the finite element formulation for fully three-dimensional transport in variably saturated porous media. Values of the transport parameters used in the simulation are given in Table 4.5. We elected to simulate the transport of a nonconservative species having retardation and decay coefficients equal to 2 and 10^{-5} d^{-1}, respectively. The velocity field and the distribution of water saturation needed for the transport simulation were detrmined from the steady-state saturated-unsaturated flow simulation described in Section 4.2.3. Initially, the flow system was assumed to be free of contamination. Using the rectangular grid with coordinates given in Table 4.3, the transient transport problem was solved for 40 time steps with constant $\Delta t = 250$ d. Concentration at the nodes representing the landfill was prescribed as 100 mg/m^3. At other boundary nodes, zero normal concentration gradient was prescribed. Within each time step, the SSR matrix subiterations were performed using a relaxation factor of 1. On the average, it took four subiterations to converge to the concentration tolerance of 0.01 mg/m^3.

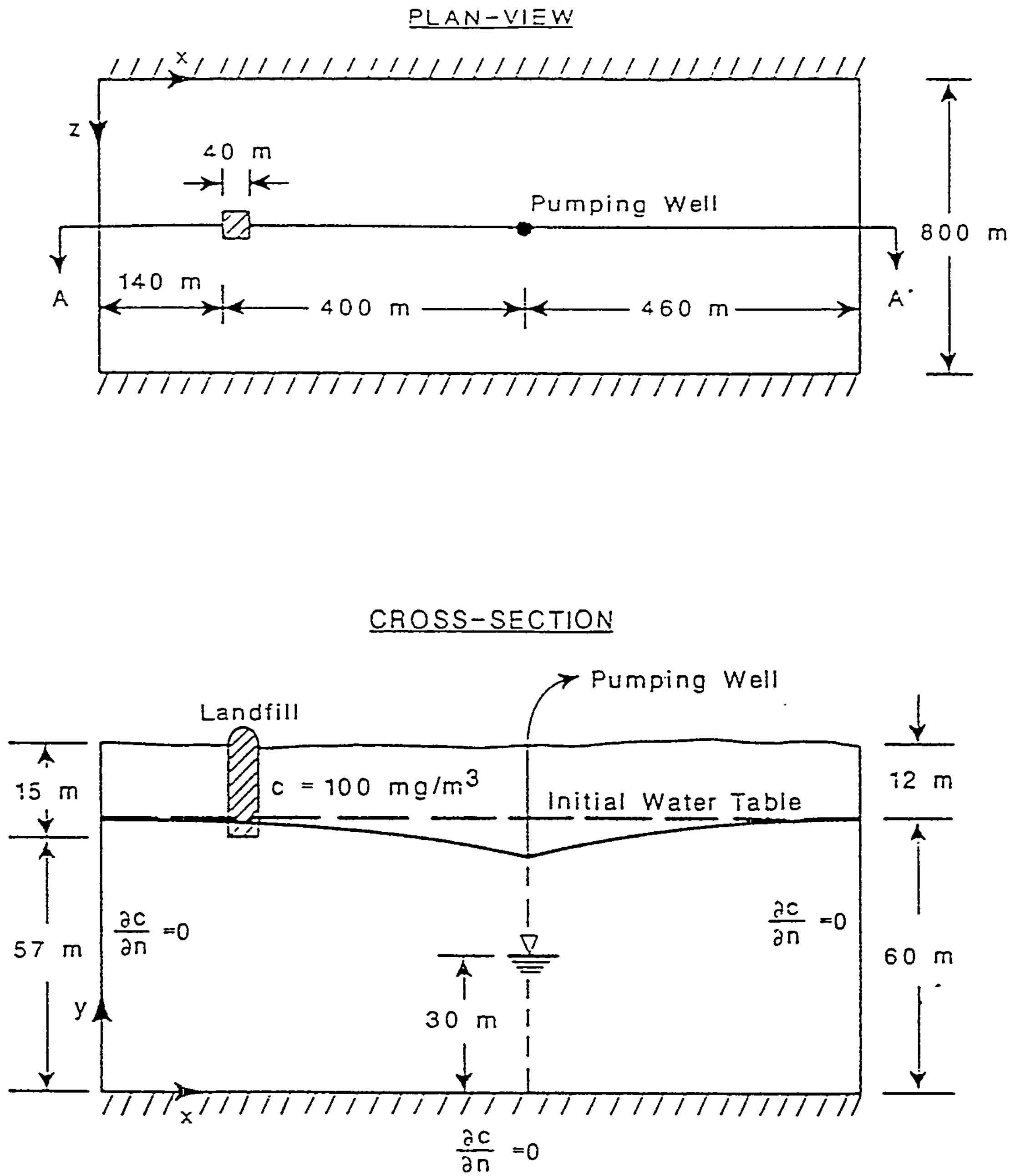


Figure 4.14. Geometry and boundary conditions for the problem of three-dimensional transport in a pumped unconfined aquifer.

Table 4.5. Values of Transport Parameters Used in the Simulation of Contaminant Migration in a Pumped Aquifer.

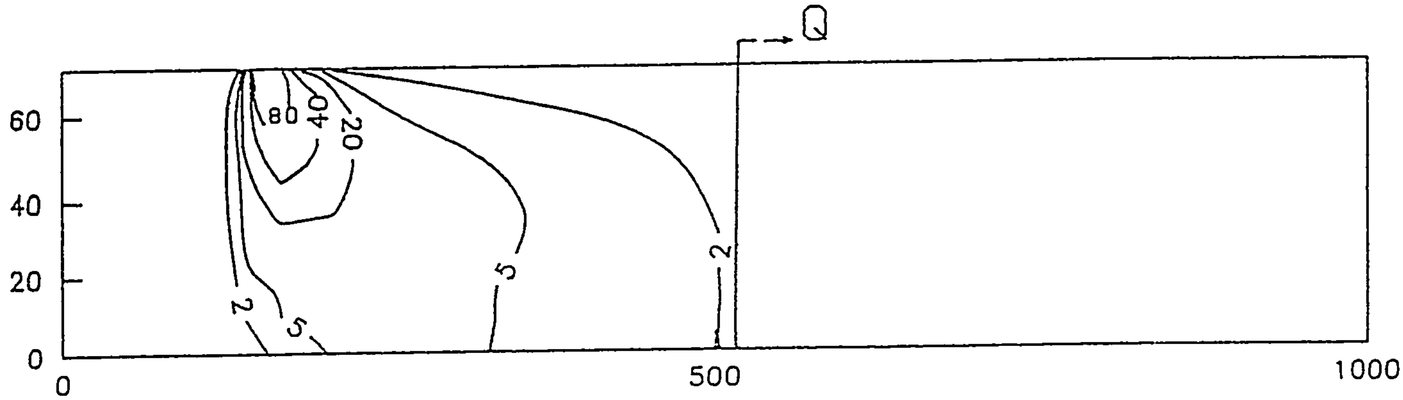
Longitudinal dispersivity, α_L	20 m
Lateral dispersivity, α_T	4 m
Molecular diffusion, D^*	0
Decay constant, λ	10^{-5} d^{-1}
Retardation coefficient, R	2
Porosity, ϕ	0.35

The numerical results obtained are displayed in Figures 4.15-4.17. Shown in Figures 4.15a and 4.15b are concentration contours in the vertical plane located at $z = 400$ m, for time values of 4,000 and 10,000 days, respectively. It is evident that the contaminant plume spreads through both saturated and unsaturated zones. At $t = 10{,}000$ days, the plume has already intercepted the pumping well. Vertical profiles of concentration at various locations downstream from the landfill and in the vertical plane AA′ are presented in Figures 4.16 and 4.17. As can be seen, the concentration profile undergoes considerable change in shape and peak location as it moves from the landfill position ($x=160$ m) through the well location ($x=540$ m) and toward the tail end of the plume ($x=570$ m).

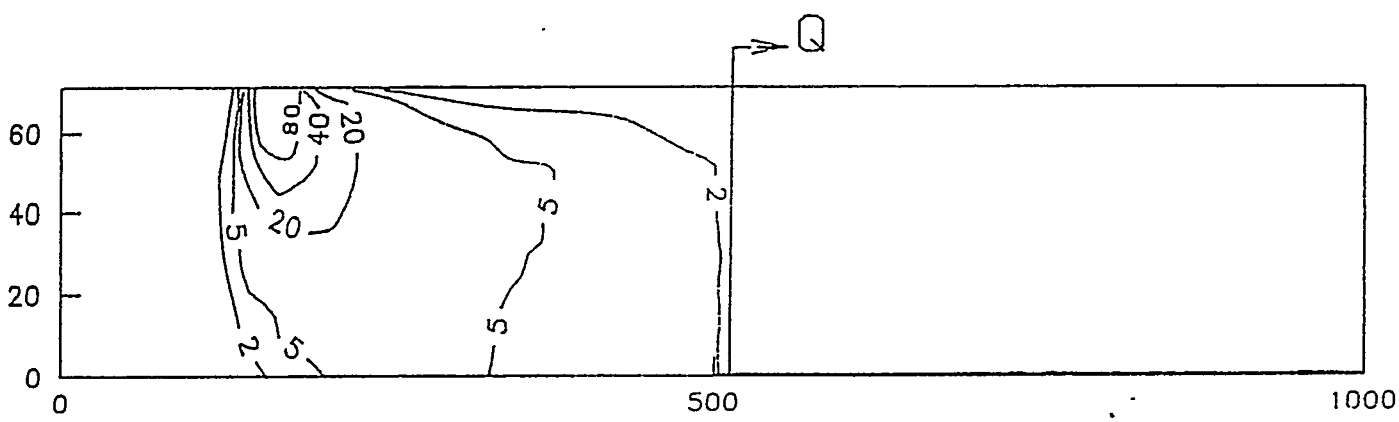
4.3.4 Three-Dimensional Transport in an Unconfined Aquifer

This example is included to demonstrate the ability of the present numerical model to handle a fully three-dimensional transport problem requiring the use of a grid with a few thousand nodes to avoid numerical difficulties.

As depicted in Figure 4.18, the problem concerns contaminant transport from a small volume source (land disposal) situated on top of a shallow unconfined aquifer. The transport occurs in steady uniform groundwater flow. We assumed a case involving an initially clean aquifer being contaminated by a continuous release of contaminant mass flux at a rate of 140.8 g/d. The aquifer was treated as isotropic and homogeneous and Darcy velocity flow was assumed to be equal to 1.61×10^{-2} m/d parallel to the horizontal x-axis. Other transport parameter values used in the simulation were porosity of 0.35, and longitudinal and lateral dispersivities of 4.0 and 0.8 m, respectively. For such a case, a general analytical solution can

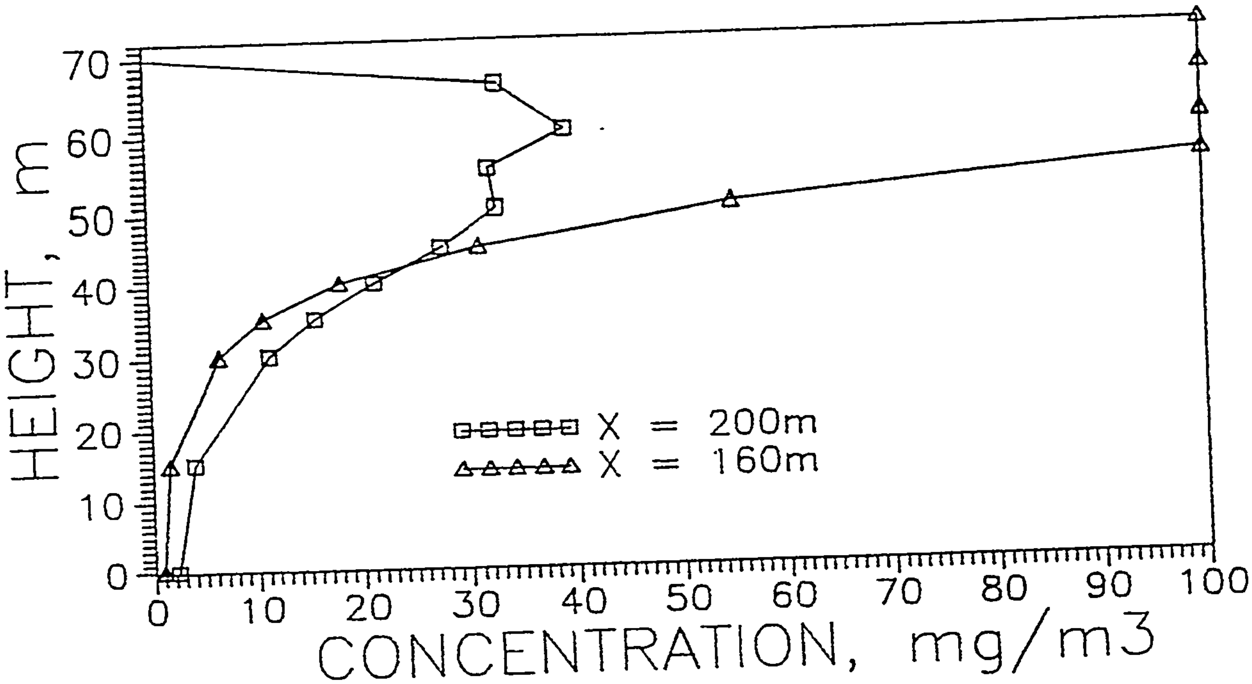


(a) t=4,000 days



(b) t=10,000 days

Figure 4.15. Concentration contours in the vertical plane located at z = 400 m.



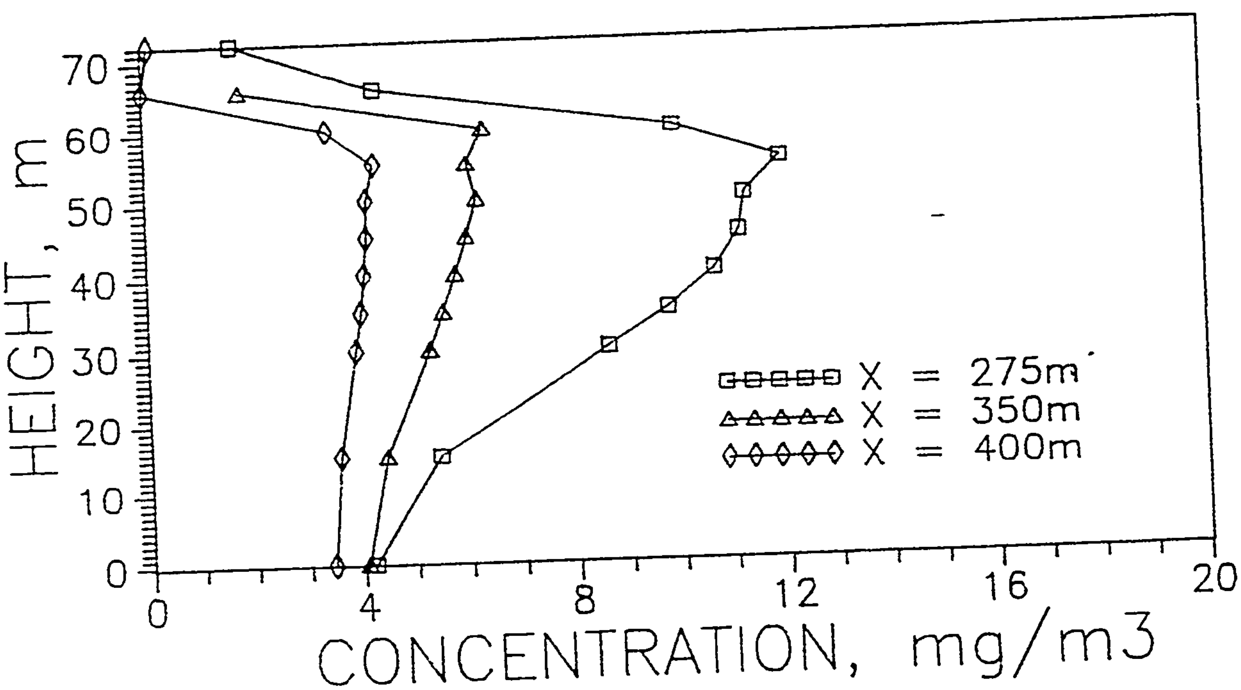
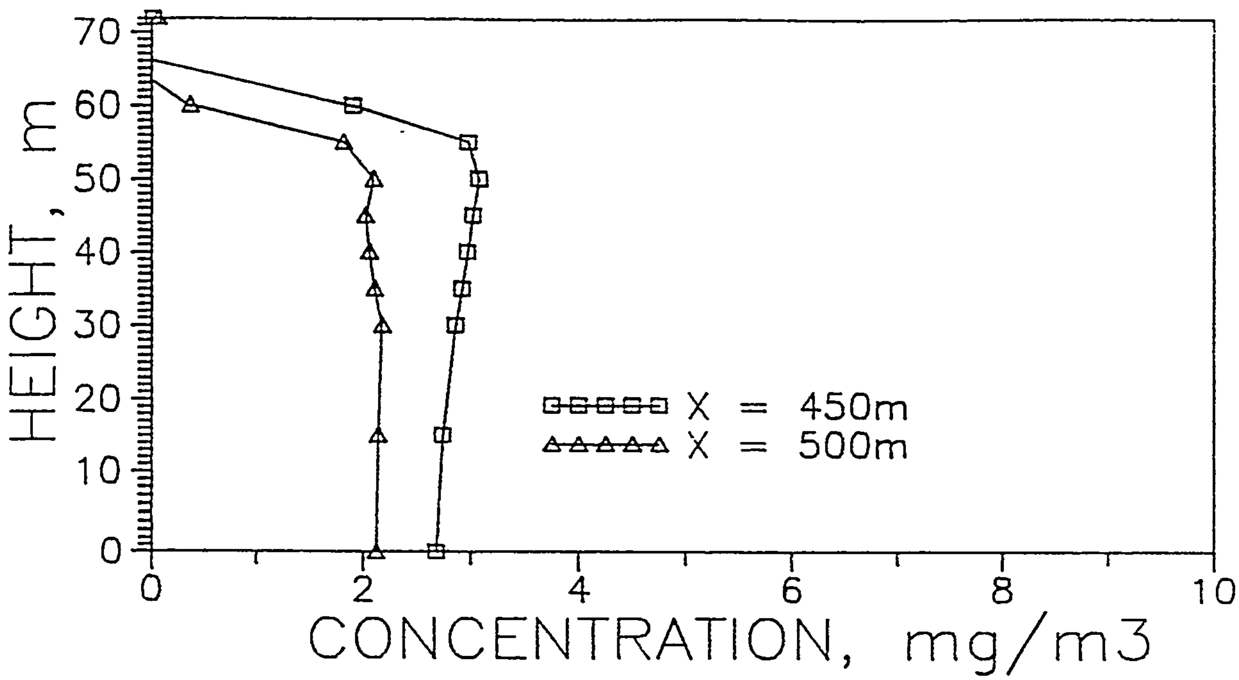


Figure 4.16. Concentration profiles in the vertical plane corresponding to Section AA′ for t=10,000 days and x between 160 and 400 m.



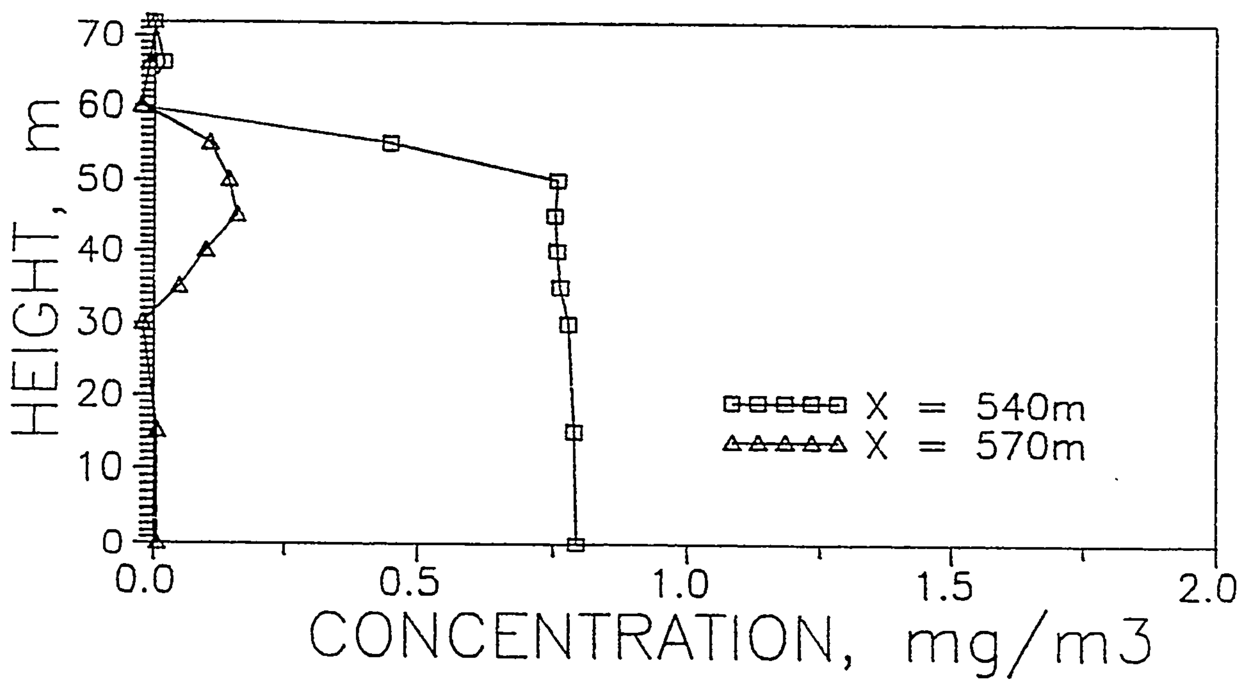


Figure 4.17. Concentration profiles in the vertical plane corresponding to Section AA′ for t=10,000 days and x between 450 and 570 m.

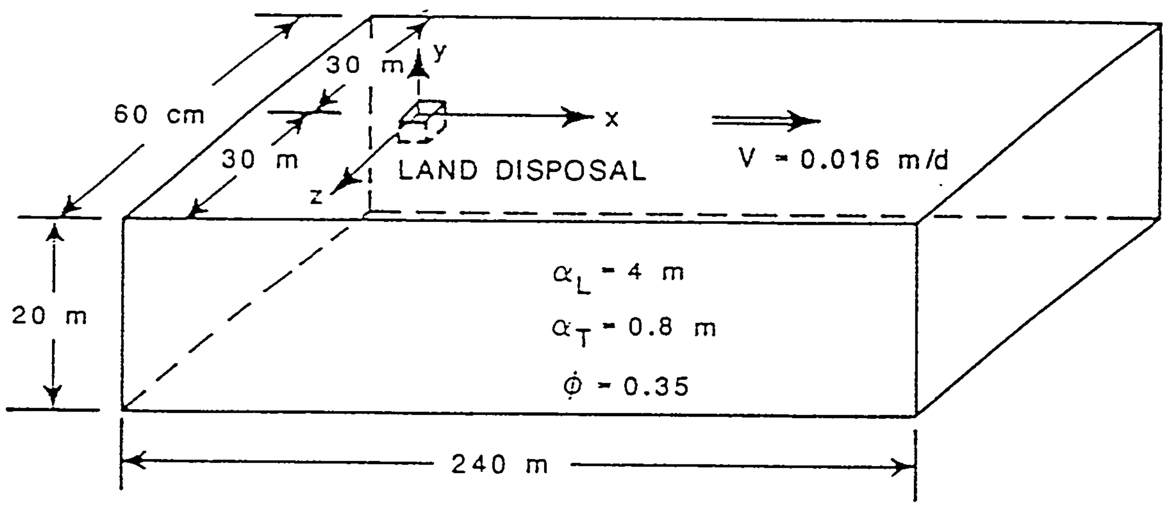


Figure 4.18. Contaminant transport from a land disposal.

be found in Yeh and Ward (1981). The solution was implemented into a computer code referred to as the AT123D analytical model.

To obtain a finite element solution, we employed the Slice Successive Relaxation (SSR) algorithm described earlier. Boundary conditions used are zero concentration upstream of the source, and zero normal concentration gradient elsewhere. Because of symmetry of the flow region about the horizontal x-axis, only one-half portion was represented. The grid selected was a rectangular grid comprised of 2430 (30x9x9) nodes. Variable nodal spacings were used in the x-direction. The x-coordinates of grid lines 1 through 30 are -36, -19, -10, -4, 0, 4, 10 ,17, 24, 31, 38, 46, 54, 62, 70, 78, 87, 96, 105, 114, 123, 132, 141, 150, 159, 168, 177, 186, 195, and 204 m, respectively. Constant nodal spacings were used in the y and z directions. The values of Δy and Δz are 2.5 and 3.75 m, respectively. The simulation was performed for 20 time steps with $\Delta t = 100$ days. The relaxation factor and concentration tolerance for the matrix subiterations were specified as 1 and 0.01, respectively. It took on the average of 5 subiterations per time step to obtain the required degree of convergence.

Longitudinal profiles of concentration at $y = 0$, $z = 0$ are plotted in Figure 4.19 for three typical time values. Similar plots of transverse and vertical concentration profiles at $x = 54$ m are presented in Figure 4.20. Also included in these plots are the analytical solution obtained using the AT123D code and numerical solutions obtained using two additional three-dimensional finite element codes, MAST3D and STACE3D. As can be seen, these numerical solutions exhibit reasonable agreement with the analytical solution.

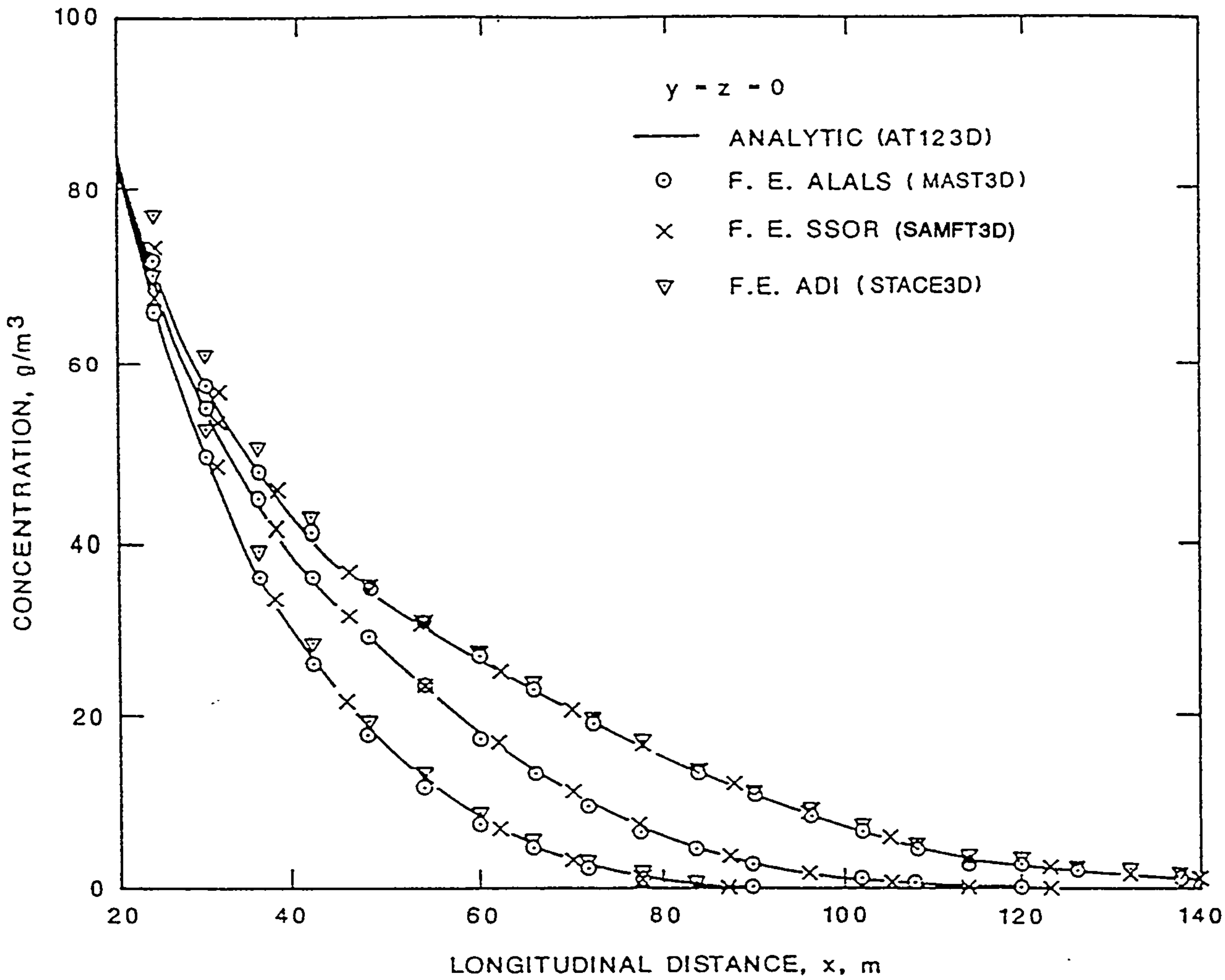


Figure 4.19. Longitudinal profiles of concentration at y = z = 0, for t = 1000, 1400, and 2000 days.

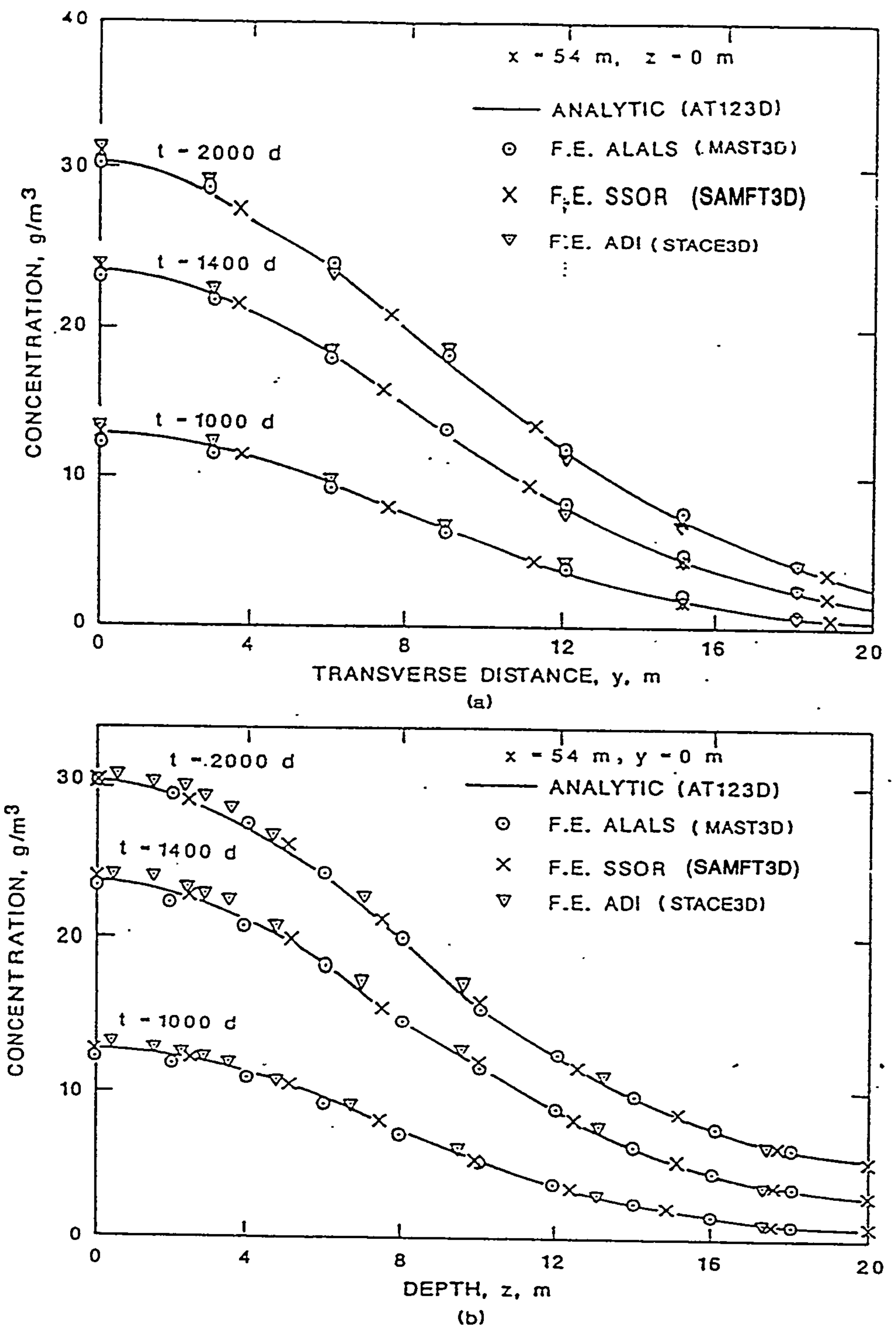


Figure 4.20. Transverse and vertical profiles of concentration at x = 54 m, for t = 1000, 1500, and 2000 days, (a) z = 0, and (b) y = 0.

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5 PROBLEM DEFINITION AND SIMULATION PROCEDURE

5.1 TYPES OF PROBLEMS

The SAMFT3D code can be used in several types of investigation of fluid flow and contaminant transport in the subsurface. For demonstrative purposes, four typical examples are described. The first example (Figure 5.1) has application to the conceptual design and risk assessment for a low-level radioactive waste disposal site. It involves variably saturated flow around gravel and wick layers surrounding a low-level radioactive waste container placed in the unsaturated zone above a water table (Frind et al., 1977). For this study, SAMFT3D can be used to predict the flow pattern resulting from vertical recharge at the soil surface. The velocity field determined from flow simulations can be used as input to subsequent contaminant transport simulations. For the investigation or risk analysis of the potential for migration of radionuclides, SAMFT3D can be used to perform single-species transport simulations.

The second example (Figure 5.2) applies to drainage or mine dewatering problems involving analyses of seepage into a drain or mine pit. For this example, SAMFT3D can be used to perform saturated-unsaturated flow simulations taking into account groundwater recharge and seepage boundary conditions.

The third example applies to a landfill above an unconfined groundwater system intercepting a river (Figure 5.3). To evaluate the environmental impact of a land disposal unit (landfill or surface impoundment), it is essential to predict water flow and contaminant migration in both unsaturated and saturated zones between the landfill and the river.

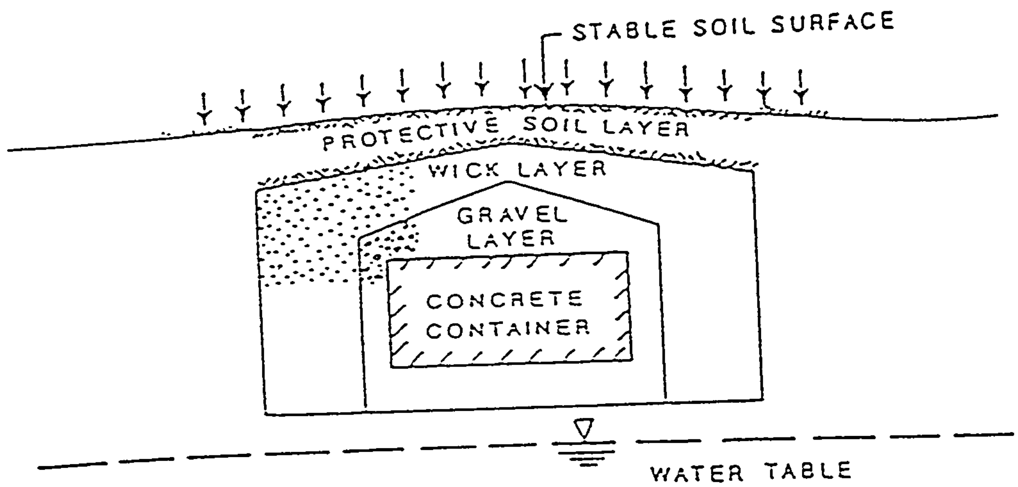


Figure 5.1. Basic geologic environment for a low-level waste container (Frind et al., 1977).

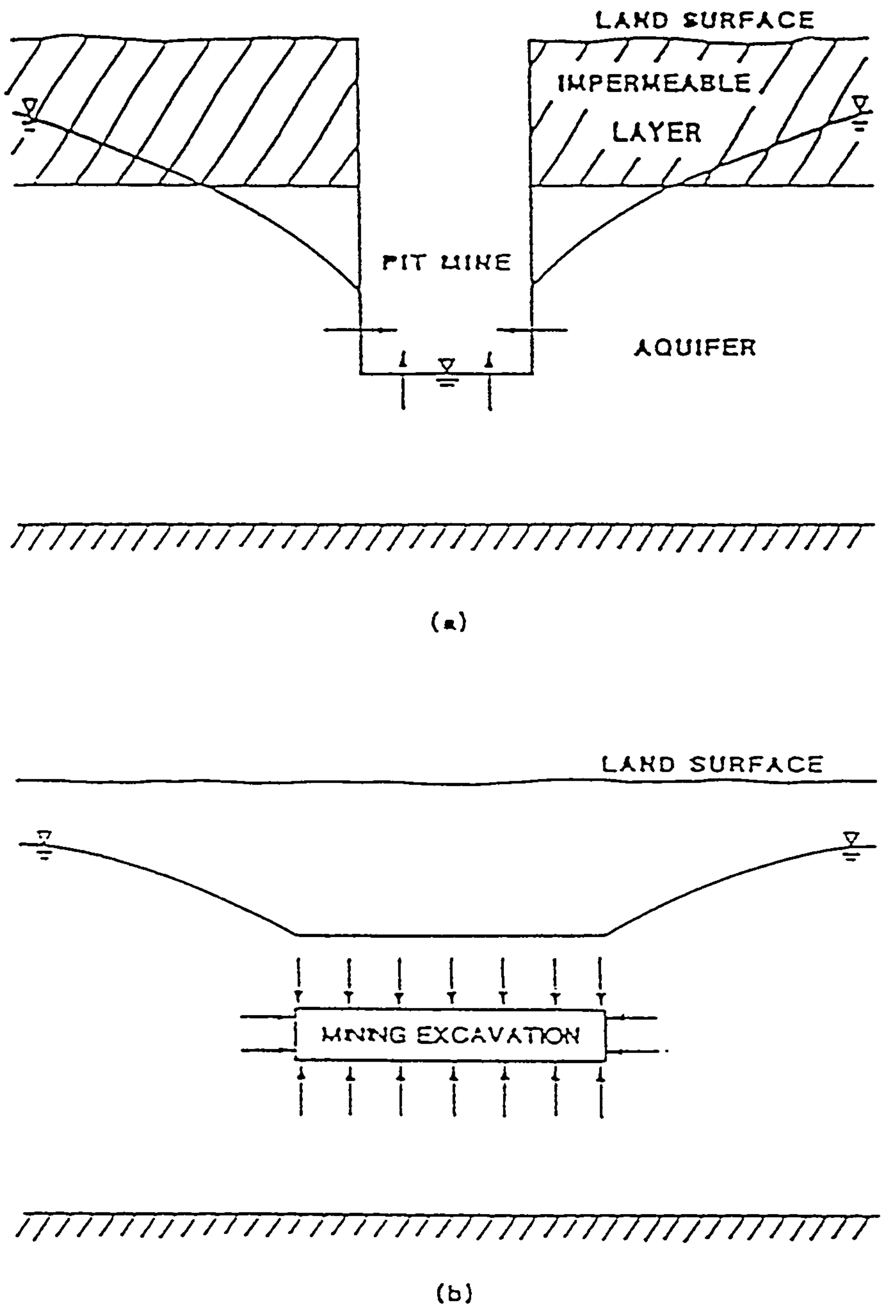


Figure 5.2. Groundwater seepage due to mine dewatering or underground drainage operations.

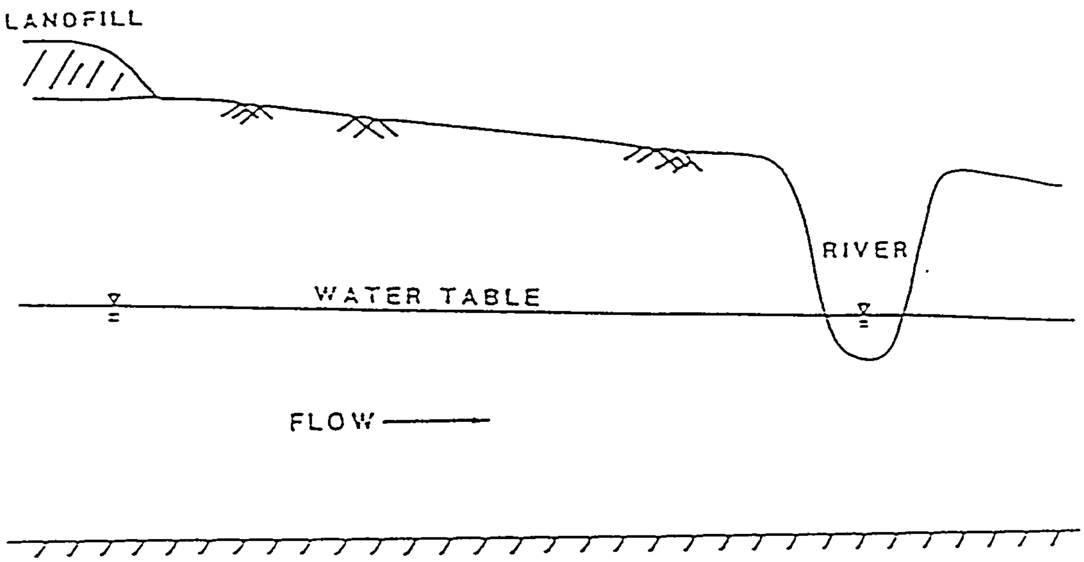


Figure 5.3. Groundwater contamination caused by a landfill.

SAMFT3D can be used to perform both the flow and transport simulations.

The fourth example concerns subsurface contamination due to disposal, leakage or accidental spillage of NAPL (NonAqueous Phase Liquid) chemicals. Shown in Figure 5.4 is a common scenario involving light NAPL with density less than that of water. For such a situation, the multiphase computational modules of SAMFT3D (expected to be completed during 1992) can be utilized. The multiphase flow module will predict the distribution of NAPL mass in the unsaturated and saturated zones of the unconfined system. The corresponding multiphase transport module will predict the rate of plume migration and concentration distributions of dissolved chemical components.

5.2 DATA REQUIREMENTS

Data required for the simulation of variably saturated, single-phase or multiphase flow include intrinsic permeability and compressibility of the porous medium, fluid properties, the geometry and configuration of the flow region, as well as initial and boundary conditions of the problem. Additionally, data pertaining to fluid retention characteristics of the porous medium needs to be supplied to the code either in a functional form or tabulation.

Data required for the simulation of solute transport includes longitudinal and transverse dispersivities of the porous media, solute properties (i.e., distribution and decay coefficients), information on groundwater recharge and withdrawal, as well as contaminant source characteristics (source location, geometry, concentration, and fluxes) Darcy velocity components and saturation of each active fluid phase, and initial and boundary conditions associated with the single-species transport equation.

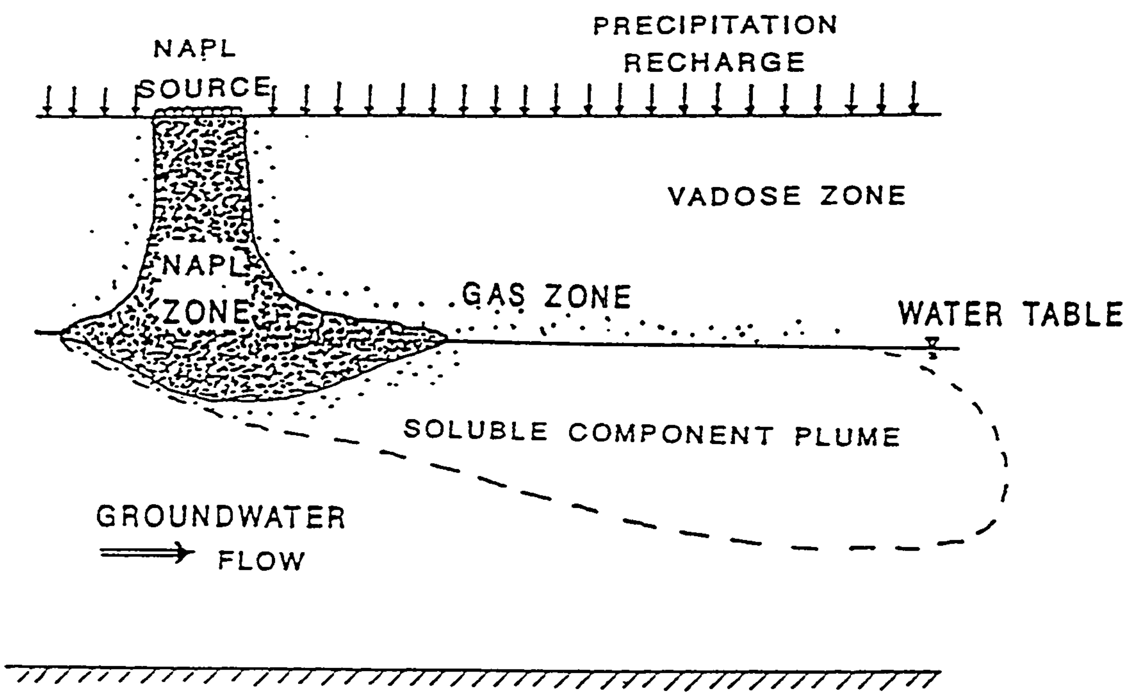


Figure 5.4. Schematic description of the distribution of nonaqueous phase liquid with density less than water and the soluble component plume.

5.3 SIMULATION PROCEDURE

The general procedure for using SAMFT3D to simulate fluid flow and/or solute transport in subsurface systems is outlined below.

- Prepare a diagrammatic description of the problem such as those shown in Figures 5.1 through 5.4. The diagram should depict the solution region together with a description of the zones of different material properties and boundary conditions.

- Prepare a list of material numbers and properties to be supplied to the code.

- Prepare a sketch of a given region showing the orientation of the coordinate axes and sequential numbers of the nodes and the elements (Figure 5.5).

- Prepare steady-state boundary condition data. These data are classified into two sets. The first set consists of global node numbers and prescribed values of dependent variables to be determined. The second set consists of global node numbers and prescribed values of integrated nodal fluxes. If there are no steady-state boundary conditions, this step of the simulation procedure may be omitted.

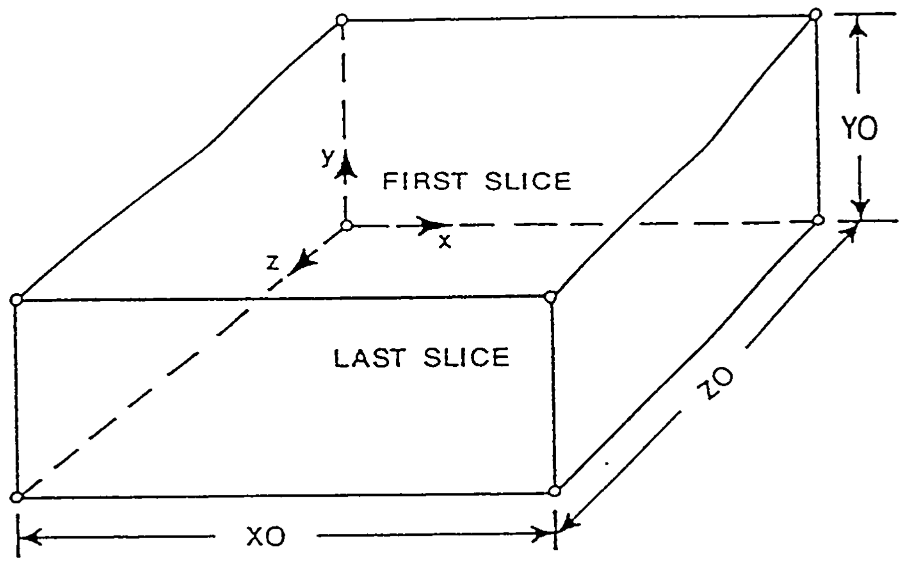
- Prepare transient boundary condition data. The data are also classified into two sets. The first set consists of global node numbers and the time graph of prescribed values of dependent variables to be determined. The second set consists of global node numbers and the time graph of prescribed values of integrated nodal fluxes.

- Follow the input data preparation instructions given in Chapter 8 and supply the required input to the code.

- Run the code and interpret the output using the guide provided in Chapter 9.

5.4 SPECIFICATION OF MESH PARAMETERS

A rectangular mesh is used by SAMFT3D and the mesh is automatically generated by the code when the following mesh parameters are specified:



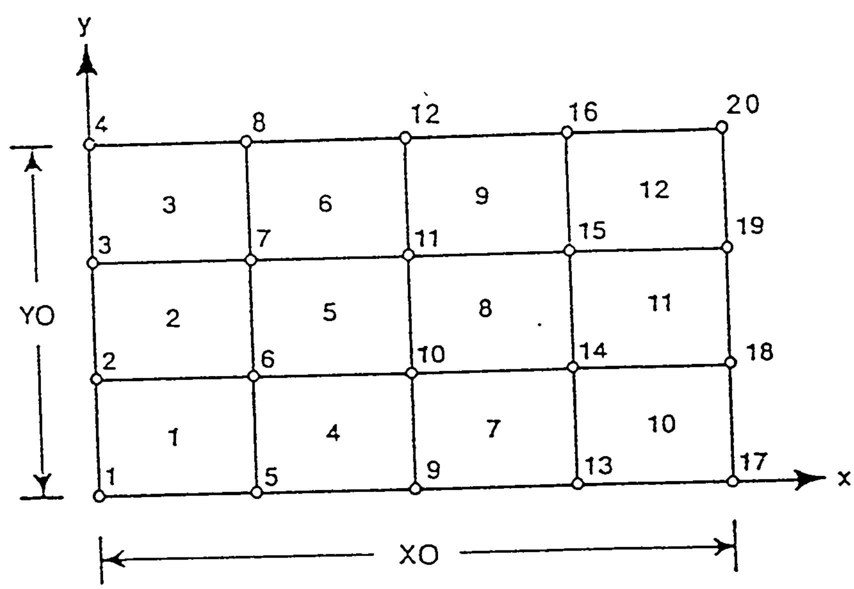


Figure 5.5. Typical rectangular meshes generated automatically by the SAMFT3D code using the option of IXYZRD = 0.

Record type 11 (see Chapter 8)

NRROWS: Number of grid lines parallel to x-axis.

NCOLS: Number of grid lines parallel to y-axis.

NPLANE: Number of planes to be used in the 3-D grid generation.

DXMAX: Maximum value of spatial increment allowed in x-direction.

DYMAX: Maximum value of spatial increment allowed in y-direction.

DZMAX: Maximum value of spatial increment allowed in z-direction.

IXYZRD: Parameter for indicating if the grid line coordinates are to be input or generated by the code.
- = 0 if coordinates are to be computed using generated values of spatial increments,
- = 1 if coordinate input is needed,

Note how the nodes are sequentially numbered in Figure 5.5 to achieve a minimum matrix bandwidth. The parameter that specifies how the nodes are to be numbered is ISWAP in record group 3, cols. 66-70.

Although SAMFT3D requires the use of rectangular mesh, the code allows an irregular region to be treated in a convenient manner. To achieve this, the user needs to overlay the selected regular and the modeled region. Elements that are outside the interested region can then be blocked out by setting IPROP values that correspond to such elements to zero.

5.5 INITIAL AND BOUNDARY CONDITION SPECIFICATIONS

To perform a transient flow or transport analysis or a steady-state flow analysis, an initial distribution of each primary dependent variable to be solved must be applied to the code. If the initial distribution is uniform, it is sufficient to supply constant default values to the code.

In a fluid flow simulation, a uniform initial condition may also be specified (see record group 7 in Section 8.3).

For a general case of nonuniform initial distribution, it is necessary to supply initial nodal values to the code. The number of nodes where initial values differ from the default value (NPIN) may be less than or equal to the total number of nodes (NP). The input initial values are used by the code to override the default values.

Boundary conditions can be given in terms of either the Dirichlet prescribed values of the dependent variables, or in terms of the fluid or solute flux at boundary nodes. Specification of a Dirichlet first-type boundary condition is very straightforward and requires no further explanation. Specifying the nodal boundary condition value in the case of a flux-type boundary condition is described below.

For a fluid flow analysis, the fluid flux at a node corresponds to the flow rate of the concerned fluid over the effective flow area covered by the node. The sign convention for flux adopted by the code is positive for influx and negative for efflux.

For a solute transport analysis, the solute flux at a node corresponds to the rate of solute mass entering the node over the effective flow area covered by the node.

Steady-state boundary conditions are handled simply by specifying the node numbers and prescribed values of the dependent variables or mass fluxes of fluid or solute. Transient boundary conditions are also handled in a convenient manner by specifying the node numbers and relationships of time versus the prescribed values. The code admits both continuous and discontinuous (stepped) temporal variations (Figure 5.6). A continuous variation is represented using the piecewise linear approximation passing through a number of control points. A discontinuous variation is represented using a stepped approximation passing through control points. The total number of control points is equal to the number of steps plus one.

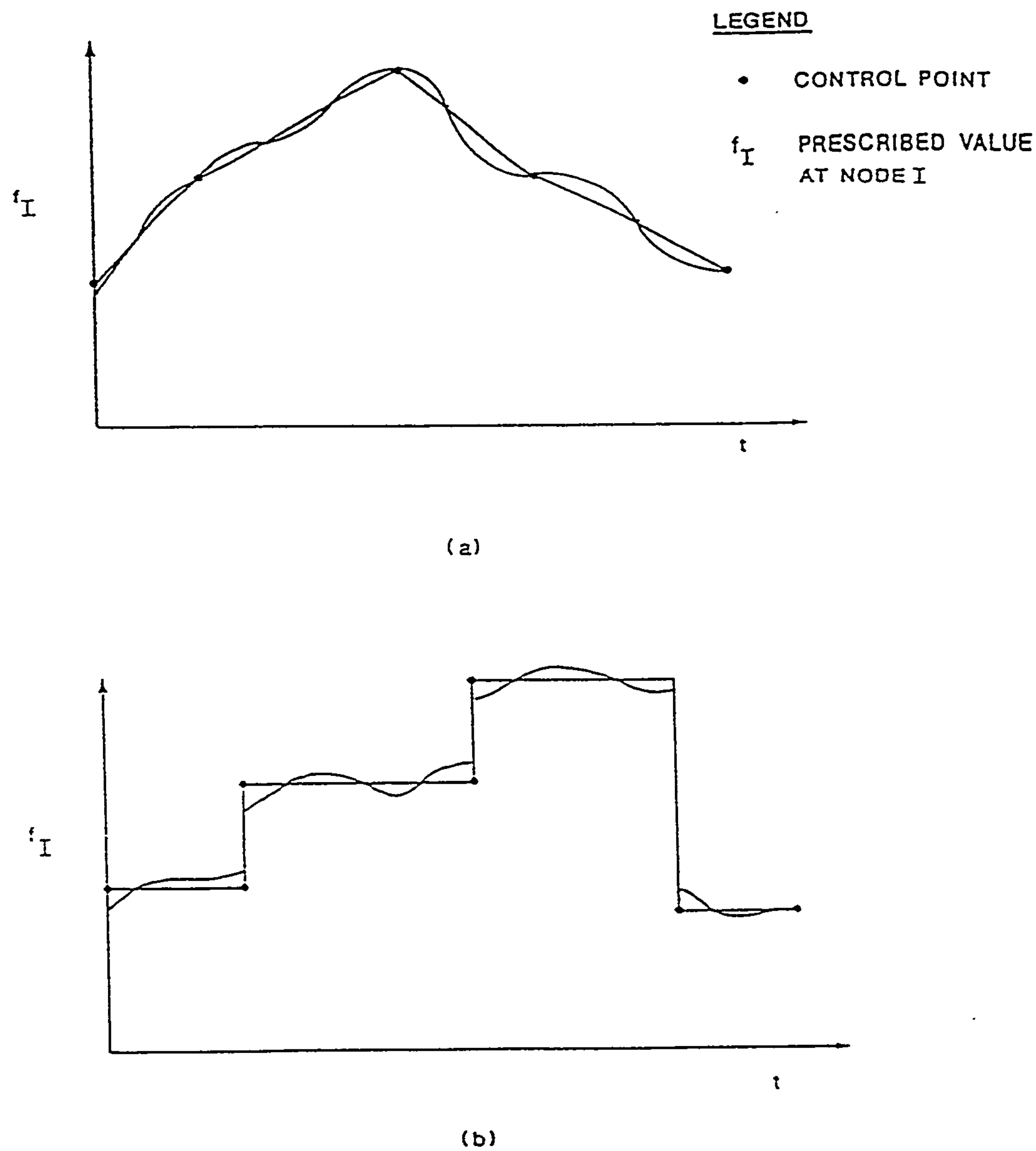


Figure 5.6. Modeled approximations for continuous and discontinuous variations of prescribed function at node I.

6 CODE STRUCTURE

6.1 CODE ORGANIZATION AND MODULE DESCRIPTION

The SAMFT3D code is structured to accommodate two sets of computational modules designed to perform single-phase and multiphase analyses, respectively. The single-phase modules, which have been incorporated into the current version of the code, are described herein.

Shown in Figure 6.1 is a schematic flow chart depicting major computational steps for single-phase, variably saturated flow and transport analysis. Note that two modeling options (IMODL=1 and 0) are provided. With these options, the user may instruct the code to perform: water flow simulation or, solute transport simulation. A grid consisting of linear rectangular elements is generated and used by the code to represent the region of interest. The solutions of the matrix equations resulting from finite element discretizations of the flow and transport equations are performed using SSR (Slice Successive Relaxation) solvers. Nonlinear treatment of the variably saturated flow problem is performed using the Picard or Newton-Raphson scheme described in Chapter 3. An option of mass balance computation is available for both flow and transport analyses.

6.2 INTERNAL DATA STRUCTURE

Data necessary for the finite element analysis performed by the code is classified as follows:

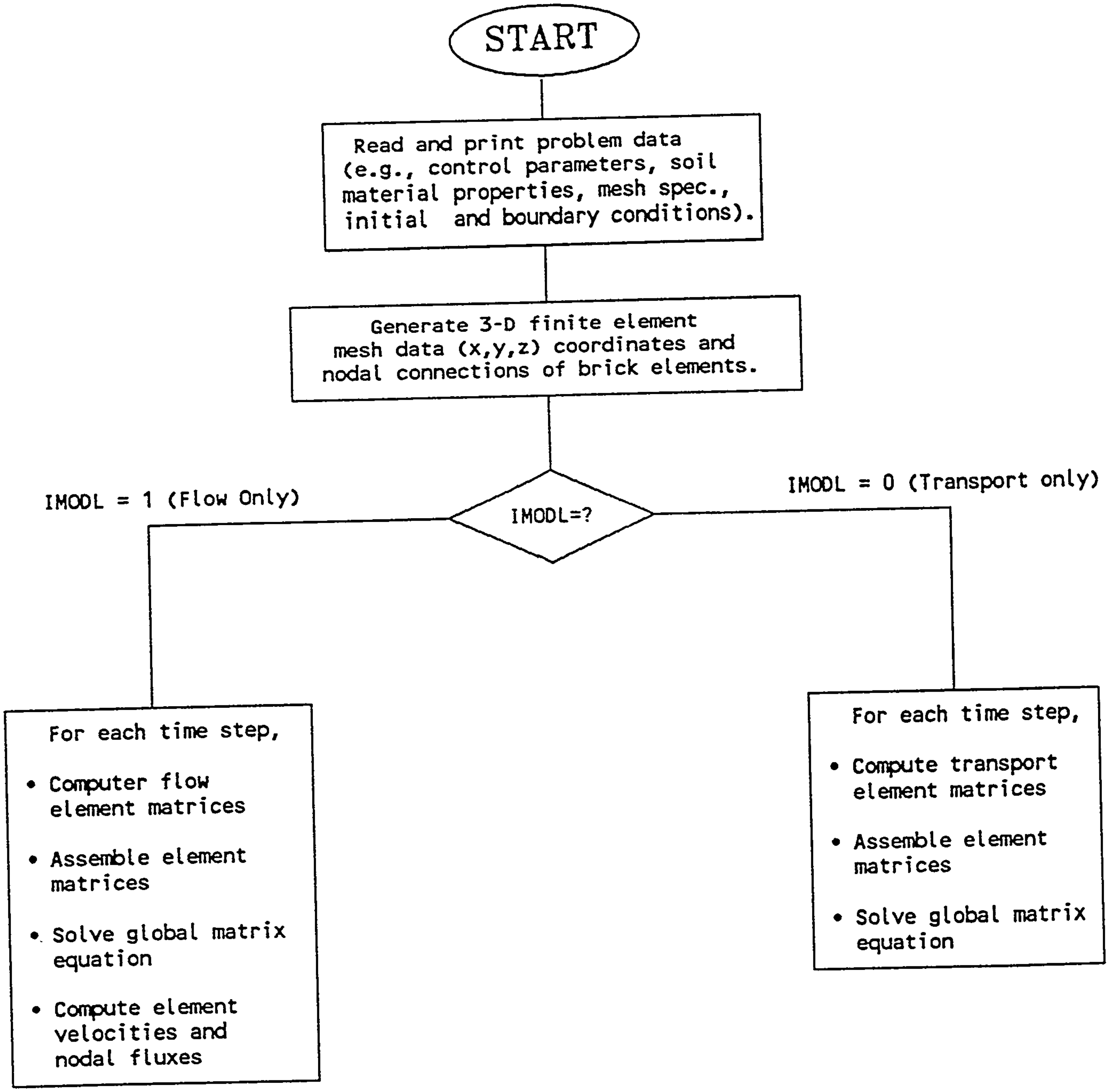


Figure 6.1. Flow chart for the SAMFT3D computational module.

(1) Material properties. The material properties pertaining to single or multiphase flow and transport analyses are read in and stored in three common blocks labeled MDATA, RDATA and SWHDA, respectively.

(2) Mesh data and element material numbers. The mesh data generated by the code and the element material numbers are stored in a common block labeled MSHDAT.

(3) Boundary condition data. Steady-state Dirichlet and prescribed flux conditions are read in and stored in two common blocks labeled BDATA and FDATA. The block BDATA contains arrays that store node numbers and prescribed values of the dependent variables to be solved. The block FDATA contains arrays that store node numbers and values of nodal fluxes.

(4) Initial condition data and computed nodal values of the dependent variables. These are stored in a common block labeled WAVE.

(5) Element geometrical and storage properties. These are stored in a common block labeled ESTORE.

(6) Global coefficient matrix. This matrix is generated and modified during simulation. It is stored in a common block labeled WDUM.

6.3 DIMENSION LIMITS

No dynamic dimensioning is employed in the code. All of the important arrays are stored in labeled common blocks. The dimension limits of the principal arrays are summarized below. These must be observed by the user when applying the code to practical problems.

Maximum total number of nodal points	= 12021
Maximum total number of elements	= 10701

Maximum number of time steps	=	200
Maximum number of different sets of material properties	=	52
Maximum number of slices	=	31
Maximum number of nodes per slice	=	999
Maximum number of elements per slice	=	800
Maximum number of steady-state Dirichlet boundary conditions	=	899
Maximum number of steady-state flux boundary conditions	=	899
Maximum bandwidth of global coefficient matrix	=	161
Maximum number of time-dependent, Dirichlet boundary nodes	=	100
Maximum number of time-dependent, flux boundary nodes	=	100
Maximum number of nodes for which flux computation is required	=	1441
Maximum number of observation nodes	=	50

7 DATA FILES

7.1 MAIN INPUT AND OUTPUT FILES

There are two major input and output files used by the SAMFT3D code on units 5 and 6, respectively. These files are described as follows:

1. File number 5. This is the input file containing the essential input data for each run of the code. The content of this file as well as the description of input variables are provided in Section 8.3 of Chapter 8.

2. File number 6. This is the output file containing the line printer output from the code. The content of this file as well as the description of output variables are provided in Chapter 9.

In addition to the major files on units 5 and 6, several backup files may be needed by the code to perform a restart run or, two consecutive runs of flow and related transport problems, and to create output for plotting purposes.

7.2 BACKUP FILES

There are 4 backup files that may be used by the code. Two of these files contain binary (unformatted) records written on units 8 and 9, and the other two contain formatted records written on units 10 and 13. These files are described below.

1. File number 8. This is the output file containing nodal values of the dependent variables which correspond to the final time step of the current run. Information in this file can be used as the initial condition for the next restart run. File number 8 is written only when the

control input variable NOWRIT is set equal to 1.

The purpose of file number 8 is to create a data file for a subsequent restart run. The restart procedures are described in Section 8.2.

2. File number 9. This file is written (by subroutine BTAPE9) when the flow simulation is performed and the value of the output control parameter NVWRIT = 1. The file contains centroidal values of element Darcy velocity components and water saturation.

The output file from the flow simulation may be used as a direct input into the transient transport simulation. The data file on Unit 9 will be read by the code when the input control parameter NVREAD is set equal to 1.

3. File number 10. This file is written in binary records by subroutine BTAP10, when the value of the output control parameter NPLOT is greater than 0. The file is written for every nth time step, where n = NPLOT.

The output in file number 10 contains computed output for each time step of the flow or transport simulation. This output consists of the following:

- Time step number and time value written in binary.
- Values of head or concentration written in binary.

4. File number 13. This file contains mesh data consisting of the following:

- List of node numbers and their x and y coordinates. This information is written in FORMAT (3(I5, 2F10.3)).
- List of element numbers and their nodal connections. For each element, the information is written in FORMAT (5I5).

- List of element numbers and x and y coordinates of the element centroids.

  This information is written in FORMAT (3(I5, 2F10.3)).

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8 INPUT DATA PREPARATION

8.1 GENERAL CONSIDERATIONS

SAMFT3D is designed to perform the numerical solution of one problem or several consecutive problems in a single computer run. The code is intended to handle three-dimensional single-phase and multiphase fluid flow and single component transport problems. Although the multiphase computational modules have not been incorporated into the current version 1.0, a general input data organization for single-phase and multiphase simulations is contained in the code. The complete input preparation guide is provided in section 8.3.

Several features are incorporated into SAMFT3D for automatic generation of a substantial portion of input required for the finite element analysis of a single-phase or multiphase problem. These are summarized below.

(1) Mesh generation option. A rectangular finite element grid is generated automatically by the code. The grid has a constant number of nodal rows and columns. Nodal spacings along the x, y and z axes may be uniform or variable. The complete mesh data generated by the code consists of nodal coordinates and element nodal connections.

(2) Default initial value option. This option may be invoked by setting an input control parameter NONU=0. When this is the case, all nodal values of the primary dependent variables will be set equal to the default initial values.

(3) Time step generation option. Time steps to be used in the finite element analysis of a transient problem can also be generated automatically. This option may be invoked by setting an input control parameter ITSGN=1.

(4) Default values for element Darcy velocity and phase saturation. For a solute transport simulation, default values of Darcy velocity components and saturation are used to generate element velocities

and phase saturation values. If desired, the generated data can be overridden by the correct data supplied to the code.

8.2 RESTART PROCEDURE

A restart option is provided in the code for continuation of the solution of a time-dependent problem. To use this option, the user must provide data pertaining to initial nodal values of the dependent variables. These nodal values are to be supplied as input data on a FORTRAN data file on Unit 8. If the restart option is selected, the user should adopt the following procedure:

(1) Before restarting, a provision must be made in the preceding run for the code to write the last set of nodal values (computed at the final time step) on file unit 8. This is achieved by setting the value of the input variable NOWRIT to 1.

(2) Prepare input data for unit 5 of the restart run in the usual manner but keeping in mind that the initial conditions of the new problem can be derived from information contained in file unit 8. Note also that the variable NONU must be set to 2 and NOWRIT must be set to 0.

8.3 INPUT DATA PREPARATION GUIDE

The main stream of input data required for a flow simulation or a transport simulation is to be supplied from a FORTRAN input file on unit 5. To facilitate data entry, the input data for each problem is divided into 22 groups and arranged as follows:

1. Problem control record
2. Problem title record

3. Simulation control record
4. General and time stepping control record
5. Input/output control record
6. Temporal discretization data
7. Default initial condition data
8. Element material numbers
9. Material properties for flow simulation
10. Material properties for transport simulation
11. Mesh parameter specification
12. Grid line coordinates
13. Coordinate generation parameters
14. Boundary condition data
15. Transient Dirichlet boundary condition data
16. Transient flux boundary condition data
17. Initial condition data
18. Transport simulation control data
19. Default velocity and phase saturation data
20. Boundary nodal data
21. Observation node data

The above sequence must be strictly followed in the preparation of a data file. Following are descriptions of the input variables and data formats.

0. Specification of number of problems (I5)

One record.

Col. 1-5	NPROB:	Number of problems to be solved.

** The following record groups are to be repeated for each problem.

1. Problem control record (2I5)

One record.

Col. 1-5	IDPROB:	Problem identification number.
6-10	IEXEC:	Parameter indicating if the code needs to be fully executed after setting up the problem, = 1 if yes, = 0 if no.

2. Problem title (A80)

One record.

Col. 1-80	TITLE:	Title of problem.

3. Simulation control parameters (14I5)

One record.

Col. 1-5	IMODL:	Parameter indicating the type of modeling required; = 0 for solute transport modeling, = 1 for flow modeling.
6-10	NTPHAS:	Total number of fluid phases that may exist in the flow system.

11-15	NMPHAS:	Number of active fluid phases whose governing equations need to be solved. Note that NMPHAS $\leq$ NTPHAS. For a single-phase flow problem, set NMPHAS = 1.
16-20	IMNUMR:	Parameter indicating if data concerning porous material number specification (group 8) is to be input; = 1 if yes, = 0 if no. Set IMNUMR = 0 if dealing with a rectangular flow domain with entirely homogeneous material properties.
21-25	NVAR:	Number of primary variables for which nodal values are to be computed; = 1 if IMODL = 0, = NMPHAS if IMODL = 1, = NMPHAS + 1 if IMODL = 2.
26-30	ISSTA:	Parameter indicating a steady-state analysis of the problem is to be performed; = 1 if yes, = 0 if no. Set ISSTA = 0 if performing a multiphase simulation.
31-35	ITSGN:	Parameter indicating if simulation time values are to be generated by the code; = 0 if no and simulation time values are to be supplied to the code, = 1 if yes.
36-40	NTS:	Number of time steps. Set NTS = 1 if a steady-state analysis is required.
41-45	NP:	Total number of nodal points in the finite element grid.
46-50	NE:	Total number of elements in the grid.
51-55	NMAT:	Number of different porous materials.

56-60	KPROP:	Parameter indicating the form of relative permeability and capillary pressure data; = 0 for functional form, = 1 for tabulated form. KPROP must be set to 0 when dealing with single-phase flow problem.
61-65	NONU:	Parameter indicating if the initial condition differs from the default initial condition data described in record group 7; = 0 if no, = 1 if yes and initial condition data are to be supplied to the code as part of this input file (see group 17), = 2 if yes and initial condition data are to be read from a file on unit 8.
66-70	ISWAP:	Parameter indicating the sequential numbering of the nodes in each gridding plane of the mesh; = 1 if the nodes are sequentially numbered in the x-direction, = 0 if the nodes are sequentially numbered in the y-direction.

4. <u>Time stepping, iteration control and gravitational parameters</u> (2I5,5E10.3, I5, E10.3)

One record.

Col. 1-5	IKALL:	Parameter indicating the type of time stepping scheme for the solute transport simulation; = 1 for backward difference scheme, = 0 for central difference scheme. Note that IKALL is automatically set to 1 for a steady-state transport analysis. For the fluid flow simulation, the code automatically selects the backward difference scheme.

6-10	NITMAX:	Maximum number of nonlinear iterations allowed per time step of the flow simulation. Suggested values of NITMAX = 5 and 20 for transient and steady-state simulations, respectively.
11-20	HTOL:	Equivalent freshwater head tolerance to be used in the solution of nonlinear flow equations. Suggested value is $0.0 < \text{HTOL} \leq 0.01$ m.
21-30	STOL:	Saturation tolerance to be used in the solution of nonlinear flow equations. Suggested value is $0.0 < \text{STOL} \leq 0.005$.
31-40	CTOL:	Concentration tolerance to be used in the solution of multiphase transport equation.
41-50	GCONST:	Gravitational acceleration constant.
51-60	PATM:	Atmospheric pressure.
61-65	IRESOL:	Maximum number of refinements of time steps allowed if the solution of the variably saturated flow equation does not converge (recommended value is 3 or 4). Leave blank if transport simulation only is required (IMODL=0).
66-75	ORELAX:	Relaxation factor of the slice successive relaxation (SSR) scheme for matrix solution. Default value=1. Recommended values of ORELAX for flow and transport problems are 15 and 0.9, respectively.

5. Input and output control parameters (14I5)

One record.

Col. 1-5	NVREAD:	Parameter specifying if element velocity data for each fluid phase are to be input;

= 0 if no velocity input is needed (this option is used for a flow run or for transport in uniform flow),
= 1 if the velocity data is to be input using a separate data file unit number 9. Note the NVREAD is set to 0 if IMODL = 1 OR 2.

6-10	IOUTLT:	Parameter indicating if boundary node data (see group 20) are to be input: = 1 if yes, = 0 if no. IOUTLT is automatically set by the code to 1 if IMBAL = 1 (group 5, col. 46-50).
11-15	NPIN:	Number of nodes for which initial values of the dependent variables are to be input as part of this input file. NPIN is automatically set to 0 unless NONU = 1.
16-20	IPRD:	Parameter indicating output requirement; = 0 if complete mesh data printout is required, = 1 if element connection data printout is not needed, = 2 if the whole mesh data printout is not needed, = 3 if mesh and initial condition data printouts are not needed.
21-25	NVWRIT:	Parameter specifying if the computed values of element velocities for each fluid phase are to be written on file unit 9; = 0 if no, = 1 if yes and output is to be written for selected time steps as specified in record group 22b. Note: set NVWRIT = 0 if IMODL = 2.
26-30	NVPR:	Parameter controlling the printout of computed element velocities;

		= 0 if no output is to be written, = n if the output is to be written for each n time step.
31-35	NPLOT:	Parameter indicating if time and computed nodal values of the dependent variables are to be written on file unit 10 for use in subsequent plotting; = 0 if no output is to be written, = n if the output is to be written for each n time step. For flow simulation (IMODL = 1 or 2) values of velocity components at element centroids are also written on file unit 11.
36-40	NSTEP:	Parameter controlling the printout for computed nodal values of dependent variables; = 0 if no output is to be written, = n if the output is to be written for each n time step.
41-45	IOBSND:	Parameter indicating if the values of dependent variables at some specified nodes are to be recorded for all the time steps (see group 21); = 1 if yes, = 0 if no.
46-50	IMBAL:	Parameter specifying if mass balance calculation is required. Set = 0
51-55	NOWRIT:	Parameter indicating if the computed nodal values of the dependent variables at the final time level are to be written on file unit 8; = 1 if yes, = 0 if no.
56-60	IPRCHK:	Matrix computation print check parameter (used for debugging purposes); = 0 if print-check is not needed, = 1 if print check is needed.

6. <u>Temporal discretization data</u>

*** Omit this group if a steady-state analysis is required, ISSTA = 1 (group 3, col. 26-30).

(a) <u>Specified time values</u> (8E10.3)

*** Omit <u>unless</u> ITSGN = 0 (group 3, col. 31-35).

Number of records = NTS/8 + 0 or 1.

Col. 1-10 11-20 etc.	TMVEC(I): I=1, NTS	Time values at the end of time steps 1 through NTS.

(b) <u>Time discretization parameters</u> (4E10.3)

*** Omit <u>unless</u> ITSGN = 1 (group 3, col. 31-35).

One record.

Col. 1-10	TIMA:	Starting time value of the simulation.
11-20	TIN:	Value of the first time step.
21-30	TFAC:	Time step multiplier
31-40	TMAX:	Maximum allowed time step size.

7. <u>Default initial values</u> (4E10.3)

One record.

Col.	1-10 11-20 etc.	HINV(I) I = 1, NVAR	Default initial values of the dependent variable(s) to be computed. For a single-phase flow simulation, the dependent variable corresponds to pressure head of water. For a transport simulation, the dependent variable corresponds to dissolved concentration in the water phase. For a multiphase flow problem, the dependent variables

correspond to the selected primary variables.

8. Material number specification

*** Omit this group if IMNUMR = 0 (group 3, col. 16-20).
Follow the instruction in parts (a) and (b) for single-phase and multiphase simulations, respectively.

(a) Single-Phase Simulation (5I5)

For single-phase flow and/or transport simulation, input the following data:

Number of records = as many as needed. Each record contains:

Col. 1-5	IMATNO:	Soil material number to be assigned to elements whose element numbers are in the range specified in this record.
6-10	IELST:	Starting element number.
11-15	IELEND:	Ending element number.
16-20	IELINC:	Element number increment for IMATNO assignment.
21-25	IPAUSE:	Parameter indicating if this is the last record of group 8; = 1 if yes, = 0 if no.
		Note: Elements that are outside the flow domain or in the impermeable zone need not be specified. The code automatically assigns their IMATNO as zero.

(b) Multiphase Simulation (5I5)

For multiphase flow and/or transport simulation, input the following data:

Number of records = as many as needed. Each record contains:

Col. 1-5	IMATNO:	Soil material number to be assigned to nodes whose node numbers are in the range specified in this record,
6-10	INDST:	Starting node number.
11-15	INDEND:	Ending node number.
16-20	INDINC:	Node-number increment for IMATNO assignment.
21-25	IPAUSE:	Parameter indicating if this if the last record of group 8; = 1 if yes, = 0 if no.

Note: Nodes that are outside the flow domain or in the impermeable zone need not be specified. The code automatically assigns their IMATNO as zero.

9. Material properties for flow simulation

*** Omit this group if IMODL = 0 (group 3, col. 1-5).

(a) Soil properties (8E10.3)

Number of records = NMAT (group 3, col. 51-55)

Col. 1-10	PROP(I,1):	Intrinsic permeability component k_{xx} of material I.
11-20	PROP(I,2):	Intrinsic permeability component k_{yy} of material I.
21-30	PROP(I,3):	Intrinsic permeability component k_{zz} of material I.
31-40	PROP(I,4):	Volume compressibility of material I.
41-50	PROP(I,5):	Effective porosity of material I at reference pressure.

51-60 PROP(I,6): Air-entry pressure head for the water-air (w-a) system, $\psi_a = 0$.

61-70 SNIRWN(I): Irreducible NAPL saturation for the water-NAPL (w-n) fluid system.

71-80 SNSTR(I): Threshold (critical) NAPL saturation beyond which air-water interface ceases to exist. Default value of SNSTR(I) is equal to that of SNIRWN(I).

Note: For an isotropic soil material, set $k_{xx} = k_{yy} = k_{zz}$. For single phase flow simulation, leave col. 51-70 blank.

(b) Fluid Properties (3E10.3)

Number of records = NMPHAS (group 3, col. 6-10). The numbering of fluid phases is described in Table 8.1 for the various situations considered by the code.

Col. 1-10 FPROP(I,1): Reference density of fluid phase I.

11-20 FPROP(I,2): Reference dynamic viscosity of fluid phase I.

21-30 FPROP(I,3): Compressibility of fluid phase I (see definition on page 2-18).

(c) Relative Permeability and Capillary Functional Parameters for water-air (w-a) fluid system

*** Omit if KPROP = 1 (group 3, col. 51-55) or NTPHAS = 1 (group 3, col. 6-10).

Number of records = NMAT. Typically record I contains parameters for soil material I.

Col. 1-10 PROP(I,7): Residual water saturation (S_{wr}).

11-20 PROP(I,8): Exponent (N) of the Brooks-Corey relative permeability versus phase saturation function. Set PROP(I,8) = 0 if the van Genuchten k_{rw} function is to be used instead of the Brooks-Corey function. For single-phase flow problem, the Brooks-Corey k_{rw} function is expressed as $k_{rw} = (\bar{S}_w)^N$ where $\bar{S}_w$ is the effective water-phase saturation. For multiphase flow problem, k_{rw} is expressed as $k_{rw} = (\bar{S}_w)^{N+2}$.

21-30	PROP(I,9):	Leading coefficient (α) of the van Genuchten function: $\bar{S}_w = [1 + (\alpha\lvert\psi - \psi_a\rvert^{\beta})]^{-\gamma}$ where $\psi = (p_w - p_a)/\rho_w g$.
31-40	PROP(I,10):	Power index (β) of the van Genuchten function.
41-50	PROP(I,11):	Power index (γ) of the van Genuchten function. If PROP(I,11) is left blank, the code will assume that $\gamma = 1-1/\beta$.
51-60	PROP(I,12):	Interfacial surface tension (σ_{aw}) between fluid phases a and w.
61-70	PROP(I,13):	Interfacial surface tension (σ_{nw}) between fluid phases n and w.
71-80	PROP(I,14):	Interfacial surface tension (σ_{an}) between fluid phases a and n.

Note: If performing single-phase flow simulation, col. 61-80 should be left blank.

(d) Tabulated Relative Permeability and Capillary Pressure Data

*** Omit if KPROP = 0 (group 3, col. 56-60) or NTPHAS = 1 (group 3, col. 6-10).

Number of record sets = NMAT (group 3, col. 51-55). Typically, record set I contains the following data for soil material I:

(i) Control Record (2I5,3E10.3)

One record.

Col.	1-5	NRPH12(I):	Number of row entries required to define the constitutive relationships for fluid phase 1 versus 2. See Table 8.1 for fluid phase numbering convention.
	6-10	NRPH23(I):	Number of row entries required to define the constitutive relationships for fluid phase 2 versus 3 and phase 3 versus 1. Set NRPH23(I) = 0 if dealing with a two-phase flow system.
	11-20	PROP(I,7):	Irreducible water-phase saturation (S_{wr}).
	21-30	AKSTAR(I):	Relative permeability of NAPL at the residual saturation of water in the water-NAPL (w-n) fluid system.
	31-40	PCNWS1(I):	Capillary pressure between fluid phases n and w at $S_w = 1$.
			Note: Omit col. 21-40 if the total number of fluid phases (NTPHAS) is less than 3.

(ii) Constitutive relationships for phase 1 versus 2 (4E10.3)

Number of records = NRPH12(I). Typical record for entry J is as follows:

Col.	1-10	SPH1(J,I):	Saturation of phase 1 (the wetting aqueous phase). Values of SPH1(J,I) must be arranged in ascending order with the maximum value equal to 1.
	11-20	RKPH1(J,I):	Relative permeability of phase 1.
	21-30	RKPH21(J,I):	Relative permeability of phase 2 with respect to phase 1.
	31-40	PCPH21(J,I):	Capillary pressure between phases 2 and 1. Leave blank if capillary pressure effects are to be neglected.

(iii) Constitutive relationships for phase 2 versus phase 3 (5E10.3)

*** Omit if NRPH23(I) = 0.

Number of records = NRPH23(I). Typical record for entry J is as follows:

Col.	1-10	SPH3(J,I):	Saturation of phase 3. Values of SPH3(I,J) must be arranged in ascending order.
	11-20	RKPH3(J,I):	Relative permeability of phase 3.
	21-30	RKPH23(J,I):	Relative permeability of phase 2 with respect to phase 3.
	31-40	PCPH32(J,I):	Capillary pressure between phases 3 and 2. Leave blank if capillary effects are to be neglected.
	41-50	PCPH31(J,I):	Capillary pressure between phases 3 and 1. Leave blank if capillary effects are to be neglected.

10. Soil-solute transport parameters

*** Omit if group if IMODL = 1 (group 3, col. 1-5).

(a) Soil physical transport parameter (6E10.3)

Number of records = NMAT (group 3, col. 51-55)

Col.	1-10	PROPJ(I,1):	Longitudinal dispersivity, α_L, of soil material I.
	11-20	PROPJ(I,2):	Transverse dispersivity, α_T, of soil material I.
	21-30	PROPJ(I,3):	Tortuosity factor, τ, of material I.
	31-40	PROPJ(I,4):	Exponent n of the equation: $D_\ell^* = (\phi \tau S_\ell^n) D_{m\ell}$ is used to compute the apparent

molecular diffusion of solute in fluid phase ℓ. If the Millington-Quirk diffusion coefficient expression is to be used, then set n=10/3, and $\tau=\phi^{1/3}$.

41-50	PROPJ(I,5):	Effective porosity, ϕ, of soil material I.
51-60	PROPJ(I,6):	Bulk density, ρ_b, of soil material I.

(b) Molecular diffusion coefficients (3E10.3)

One record.

Col. 1-10 11-20 etc.	DMPHAS(I): I=1, NTPHAS	Molecular diffusion, D_{mI}, of solute in fluid phase I. See Table 8.1 for fluid phase numbering convention

(c) Soil-solute transport parameters (5E10.3)

Number of records = NMAT (group 3, col. 51-55).

Col. 1-10	RPROP(I,1):	Solute decay coefficient, λ, of soil material I. For a conservative solute species set RPROP(I,1) = 0.0. Note: $\lambda = \ln 2/t_{1/2}$, where $t_{1/2}$ = half life.
11-20	RPROP(I,2):	Distribution coefficient (solute partitioning coefficient between fluid phase 1 and soil material I), k_d. Note: the units for k_d must be the reciprocal of the units for bulk density. For a non-adsorbed solute species set RPROP(I,2) = 0.

(d) Fluid Densities (3E10.3)

*** Omit if NMPHAS = 1 (group 3, col. 11-15)

One record.

Col. 1-10 11-20 etc.	FPROP(I,1): I=1, NTPHAS	Density of fluid phase I.

(e) Fluid-pair partitioning coefficients and solubility limit (3E10.3)

*** Omit if NMPHAS = 1 (group 3, col. 11-15).

One record.

Col. 1-10	PCOEF(1):	Solute partitioning coefficient between fluid phases 1 and 2.
11-20	PCOEF(2):	Solute partitioning coefficient between fluid phases 1 and 3.
21-30	PCOEF(3):	Water-phase solubility limit (maximum dissolved concentration of the contaminant component in water. If PCOEF(I) is left blank, the code will assume unlimited solubility.

11. Mesh parameter specification (3I5,3F10.3,3I5)

One record.

Col. 1-5	NROWS:	Number of grid lines parallel to the x-direction. NROWS must not be less than 2.
6-10	NCOLS:	Number of grid line parallel to the y-direction. NCOLS must not be less than 2.
11-15	NPLANE:	Number of planes (slices) to be used in the mesh generation, NPLANE must not be less than 2.
16-25	DXMAX:	Maximum value of spatial increment allowed in the x-direction.
26-35	DYMAX:	Maximum value of spatial increment allowed in the y-direction.
36-45	DZMAX:	Maximum value of spatial increment allowed in the z-direction.

46-50	IXYZRD:	Parameter indicating if x, and y coordinates of the grid lines are to be input or generated by the code; = 0 if coordinates are to be computed using generated values of spatial increments, = 1 if coordinate input is needed,
51-55	IHORGR:	Parameter indicating if gravity effect is to be neglected in the flow simulation, = 1 if yes, = 0 if no.
56-60	NSLICE:	Number of slices or gridding planes for which nodal unknowns are to be determined. For a two-dimensional problem, set NSLICE=1.

12. Grid line coordinates

*** Omit if IXYZRD = 0 or 2 (group 11, col. 31-35).

(a) Grid line x-coordinates (8F10.3)

Number of records = NCOLS/8+0 or 1 (group 11, col. 6-10).

Col. 1-10 11-20 etc.	XW(J) : J=1, NCOLS	x-coordinates of grid lines 1 through NCOLS.

(b) Grid line y-coordinates (8F10.3)

Number of records = NROWS/8 = 0 or 1 (group 11, col. 1-5).

Col. 1-10 11-20 etc.	YW(I) : I=1, NROWS	y-coordinates of grid lines 1 through NROWS.

(c) Grid line z-coordinates (8F10.3)

Number of records = NPLANE/8 + 0 or 1 (group 11, col. 11-15).

Col. 1-10 11-20 etc.	ZW(K): K = 1, NPLANE	z-coordinates of grid lines 1 through NPLANE.

13. Coordinate generation parameters

*** Omit if IXYZRD = 1 (group 11, col. 31-35).

(a) x-y coordinate parameters (8F10.3)

One record.

Col. 1-10	DX:	Nodal spacing in the x-direction of the first grid block.
11-20	DY:	Nodal spacing in the y-direction of the first grid block.
21-30	XO:	Maximum value of x-coordinate.
31-40	YO:	Maximum value of y-coordinate.
41-50	SCFX:	Mesh grading factor in the x-direction.
51-60	SCFY:	Mesh grading factor in the y-direction.
61-70	XSTART:	Minimum value of x-coordinate.
71-80	YSTART:	Minimum value of y-coordinate.

(b) z-coordinate parameters (4F10.3)

One record.

Col. 1-10	DZ:	Nodal spacing in the z-direction of the first grid block.
11-20	ZO:	Maximum value of z-coordinate.
21-30	SCFZ:	Scale factor in the z-direction.
31-40	ZSTART:	Minimum value of z-coordinate.

14. <u>Boundary condition data</u>

(a) <u>Boundary condition control record</u> (4I5)

One record.

Col.	1-5	NBTO:	Number of steady-state Dirichlet boundary conditions.
	6-10	NDFLUX:	Number of steady-state prescribed flux boundary conditions.
	11-15	NBHVAR:	Number of transient Dirichlet boundary conditions.
	16-20	NBFVAR:	Number of transient flux boundary conditions.

(b) <u>Steady-state Dirichlet boundary condition data</u> (2I5,E10.3,I5)

*** Omit if NBTO = 0 (group 14a, col. 1-5).

Number of records = NBTO.

Col.	1-5	NODV(I):	Node number concerned with a Dirichlet boundary condition.
	6-10	MDEGB(I):	For the fluid flow problem, MDEGB(I) corresponds to the identification number of the fluid phase for which the pressure is prescribed. For the solute transport problem, MDEGB(I)corresponds to the governing equation number of the transport equation. For single-phase flow or transport problem, set MDEGB(I)=1.
	11-20	VALVO(I):	Prescribed value of the concerned variable (fluid phase pressure or solute concentration) at the specified node.

(c) <u>Steady-state flux boundary condition data</u> (2I5,2E10.3)

*** Omit if NDFLUX = 0 (group 14a, col. 6-10).

Number of records = NDFLUX. Note that the outward flux is taken to be negative and the inward flux is taken to be positive.

Col.	1-5	NODF(I):	Node number concerned with a constant flux boundary condition of a particular governing flow or transport equation.
	6-10	MDEGF(I):	For the fluid flow equation, MDEGF(I) corresponds to the identification number of fluid phase for which the flux is prescribed. For the solute transport problem, MDEGF(I) corresponds to the governing equation number of the transport equation. For single-phase flow or transport problem, set MDEGF(I)=1.
	11-20	FLUXVO(I):	For the fluid flow equation, FLUXVO(I) denotes fluid flux at the specified node. This flux corresponds to the flux of the specified fluid phase. For the transport equation, FLUXVO(I) corresponds to the solute mass flux injected at the node.
	21-30	QVALV(I):	For the fluid flow equation, QVALV(I) is to be left blank. For the transport equation, QVALV(I) corresponds to the total fluid flux at the specified node. For a single phase simulation, this flux corresponds to water volumetric flux, Q_{WI}. For a multiphase simulation, the flux corresponds to the total partitioned fluid mass flux, Q_{TI}, defined below.

Note:

(1) The sign convention for fluid and solute mass fluxes is positive for influxes and negative for effluxes. In performing solute transport simulation, the code automatically treats the withdrawal well nodes and efflux boundary nodes. Hence such nodes can be excluded from group 14c.

(2) The total partitioned fluid mass flux at node I (Q_{TI}) is defined as
$$Q_{TI} = \rho_w Q_{wI} + \rho_n Q_{nI} \kappa_n + \rho_a Q_{aI} \kappa_a$$
where $\rho_w Q_{wI}$, $\rho_n Q_{nI}$, and $\rho_a Q_{aI}$ denote mass fluxes of water, NAPL and air, respectively, and κ_n and κ_a are the partitioning coefficients for the NAPL and air phase.

15. <u>Transient Dirichlet boundary condition data</u>

*** Omit if NBHVAR = 0 (group 14a, col. 11-15).

Number of record sets = NBHVAR.

Each set contains the following records:

(a) <u>Control record</u> (5I5)

One record.

Col. 1-5	NDHVAR(I):	Node number concerned with a time-dependent Dirichlet boundary condition of a particular governing flow or transport equation.
6-10	MDEGBT(I):	For the fluid flow problem, MDEGBT(I) corresponds to the identification number of the fluid phase for which the pressure is prescribed. For the solute transport problem, MDEGBT(I) corresponds to the governing equation number of the transport equation.
11-15	NTSNDH(I):	Number of control points on the time graph of the boundary condition at the node.
16-20	ITVARH(I):	Parameter indicating the time variation of the prescribed function data; = 0 for continuous variation, = 1 for discontinuous (stepped) variation.
21-25	ITPBC(I):	Multiphase flow boundary conditions identifier, = -1 if the node is to be treated outflow node for the specified fluid phase, = 1 if the node is to be treated as an inflow node, = 0 otherwise.

(b) Time value records (8E10.3)

Number of records = NTSNDH(I)/8 + 0 or 1 (group 15a, col. 11-15).

Col. 1-10 11-20 etc.	TMHV(I,J): J=1, NTSNDH(I)	Sequential time values corresponding to the control points on the time graph depicting temporal variation of the prescribed dependent variable (fluid phase pressure or solute concentration).

(c) Functional value records (8E10.3)

Number of records = NTSNDH(I)/8 + 0 or 1 (group 15a, col. 11-15).

Col. 1-10 11-20 etc.	HVTM(K,J): J=1, NTSNDH(I)	Prescribed values of the concerned variable (fluid phase pressure or solute concentration at the corresponding time values, TMHV(I,J).

16. Transient flux boundary condition data

*** Omit if NBFVAR = 0 (group 14a, col. 16-20).

Number of record sets = NBFVAR.

Each set contains the following records:

(a) Control records (4I5)

One record.

Col. 1-5	NDFVAR(I):	Node number concerned with a time-dependent flux boundary condition.
6-10	MDEGFT(I):	For the fluid flow problem, MDEGFT(I) corresponds to the identification number of fluid phase for which the flux is prescribed. For the solute transport problem, MDEGFT(I) corresponds to the governing equation number of the transport equation.

11-15	NTSNDF(I):	Number of control points on the time graph of the flux boundary condition at the node.
16-20	ITVARF(I):	Parameter indicating the time variation of the prescribed nodal flux data; = 0 for continuous variation, = 1 for stepped variation.

(b) <u>Time value records</u> (8E10.3)

Number of records = NTSNDF(I)/8 + 0 or (group 16a, col. 11-15).

Col. 1-10 11-20 etc.	TMHF(I,J): J=1, NTSNDF(I)	Sequential time values corresponding to the control points on the graph depicting temporal variation of the flux boundary condition at the node.

(c) <u>Flux value records</u> (8E10.3)

Number of records = NTSNDF(I)/8 + 0 or 1 (group 16a, col. 11-15).

Col. 1-10 11-20 etc.	FVTM(I,J): J=1, NTSNDF(I)	For the fluid flow problem, FVTM(I,J) denotes nodal fluid flux of the specified fluid phase. For the transport equation, FVTM(I,J) corresponds to the solute mass flux injected at the node.

(d) <u>Fluid flux value records</u> (8E10.3)

*** Omit if performing flow simulation only, IMODL = 1 (group 3, col. 1-5). Also omit if performing combined flow-transport simulation (IMODL = 2) and MDEGFT(I) is less than NVAR (Group 3, Col. 21-25).

Number of records = NTSNDF(I)/8 + 0 or 1 (group 16a, col. 11-15).

Col. 1-10 11-20 etc.	QVTM(I,J): J=1, TNSNDF(I)	Fluid flux values corresponding to TMHF(I,J). For a single phase simulation, this flux corresponds to volumetric water flux, Q_{wI}. For multiphase simulation, the flux corresponds to the total

partitioned fluid flux, Q_{TI}, defined at the end of group 14.

17. Initial condition data

*** Omit if NONU = 0 or 2 (group 3, col. 61-65). Also omit if NPIN = 0 (group 5, col. 11-15).

Supply the initial condition data to the code according to one of the following formats:

(a) Format type 1 (I5,4E15.6)

To be used only when NPIN (group 5, col. 11-15) is less than NP (group 3, col. 41-45).

(Note: NP = total number of nodes, and NPIN = number of nodes for which initial nodal values are to be read).

Number of records to be supplied = NPIN (group 5, col. 11-15).

Col.	1-5	N:	Node number.
	6-15	HINT(N,J):	Initial value of primary dependent
	16-25	J=1,NVAR	variable number 1 through NVAR (group
	etc.		3, col. 21-25).

(b) Format type 2 (5E15.6)

To be used only for a restart run where initial values to be read correspond to the final set of nodal values obtained from a previous run. This set of nodal values can be obtained from file unit 8.

For record sets 1 through NVAR,

Number of records in each set = NP/5 + 0 or 1. Record set J contains:

Col.	1-10	HINT(I,J):	Initial values of primary dependent
	11-20	I=1,NP	variable J at nodes 1 through NP.
	etc.		

18. Transport simulation control data (I5,3F10.3)

*** Omit if IMODL = 1 (group 3, col. 1-5).

One record.

Col.	1-5	IVSTED:	Parameter indicating if the velocity field is steady state; = 1 if yes, = 0 if no.
	6-15	WFAC:	Default value of transport upstream weighing factor in the x-direction. Leave blank if upstream weighing is not required.
	16-25	YFAC:	Default value of transport upstream weighing factor in the y-direction. Leave blank if upstream weighing is not required.
	26-35	ZFAC:	Default value of transport upstream weighing factor in the z-direction. Leave blank if upstream weighing is not required.

19. Default velocity and phase saturation data (I5,4E10.3)

*** Omit if IMODL = 1 (group 3, col. 1-5).

Number of records = NMPHAS (group 3, col. 11-15).

Col.	1-5	IPHAS:	Fluid phase number.
	6-15	SDFPH(IPHAS):	Default value of saturation of fluid IPHAS.
	16-25	VXDFPH(IPHAS):	Default value of Darcy velocity component of fluid IPHAS in the x-direction.
	26-35	VYDFPH(IPHAS):	Default value of Darcy velocity component of fluid IPHAS in the y-direction.
	36-45	VZDFPH(IPHAS):	Default value of Darcy velocity component of fluid IPHAS in the z-direction.

20. Boundary nodal data

*** This record type is to be omitted if IOUTLT (group 5, col. 6-10) and IMBAL (group 5, col. 46-50) = 0 (i.e. flux and mass balance calculation is not required).

(a) Control record (I5)

One record.

Col. 1-5	NBOUT:	Number of nodes where integrated nodal flux values are to be computed.

(b) Nodal numbers for flux computation (16I5)

*** Omit if NBOUT = 0.

Number of records = NBOUT/16 + 0 or 1.

Col. 1-5 6-10 etc.	NDOUT(I): I=1, NBOUT	Node numbers of the nodes for which integrated nodal flux values are to be computed.

21. Observation node data

*** Omit if IOBSND = 0 (group 5, col. 41-45).

(a) Control record (I5)

One record.

Col. 1-5	NNOBS:	Number of nodes for which time history of computed values of dependent variable(s) is to be recorded.

(b) Observation node numbers (16I5)

Number of records = NNOBS/16 + 0 or 1.

Col. 1-5 6-10 etc.	NDOBS(I): I=1, NNOBS	Node numbers of observation nodes.

9 OUTPUT

9.1 GENERAL CONSIDERATIONS

Line printer output from the single-phase modules of SAMFT3D is organized for each problem into various categories of information. For the user's convenience, the different categories of information are summarized as follows:

- Listing of general control input data supplied to the code by the user
- Listing of the generated mesh data or user supplied mesh data
- Listing of boundary condition data
- Listing of initial condition data
- Listing of the user-supplied steady-state values of element velocities and saturation
- Listing of user-supplied data pertaining to the non-zero flux nodes and flux values
- Listing of element numbers and centroidal coordinates
- Listing of the input data supplied from file unit 9 for each time step
- Listing of information pertaining to the computation of element matrices and incorporation of boundary conditions performed by the code
- Listing of node numbers and values of head or concentration computed by the code. This listing is given for every nth time step, where n is the value of NSTEP
- Listing of element numbers and water saturation values for the elements that become unsaturated. This listing is given for every nth time step, where n is the

value of NSTEP

- Listing of element numbers and the x, y and z components of Darcy velocity. This listing is given for every nth time step, where n is the value of NVPR.

9.2. OUTPUT CONTROL

Output streams are controlled by several control parameters; the values of which must be supplied to the code. Table 9.1 provides a summary of the procedures used to control various categories of output. It is up to the user to decide how much printed output is really needed for the problem simulated. For example, the mesh data and the boundary conditions are normally not needed in the restart run of the same problem.

Table 9.1. Printer Output Control Parameters.

CONTROL PARAMETER	VALUE	MEANING
IPRD	3	Suppress the printout of the entire mesh data as well as the initial condition.
IPRD	2	Suppress the printout of the entire mesh data.
IPRD	1	Suppress the printout of the element and node connection.
NSTEP	n	For each nth time step, print computed values of head or concentration (as the case may be), and print computed values of element water saturation (if variably saturated flow analysis is performed). Note: When the value of NSTEP is greater than NTS (the total number of time steps of the simulation) or equal to zero, the mentioned printout will be suppressed.
NVPR	n	For each nth time step, print element numbers and computed values of Darcy velocity components at the element centroids. NOTE: When the value of NVPR is greater than NTS or equal to zero, the mentioned printout will be suppressed.

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10 INPUT AND OUTPUT FOR SAMPLE PROBLEMS

10.1 GENERAL CONSIDERATIONS

To demonstrate how the code is used, two sample input data sets and computer output listings are provided. These input and output correspond to the two-dimensional unsaturated flow problem and the associated contaminant transport problem described in Section 4.2.2 and 4.3.2, respectively.

The first set of input data and output are chosen to exercise several major options pertaining to variably saturated flow modeling. These options include: (1) automatic mesh generation, (2) entry of functional relationships of relative permeability versus water saturation and pressure head versus water saturation, (3) default initial pressure values, (4) specification of prescribed boundary conditions, (5) computation of Darcy velocity components and water saturation at element centroids, and (6) printout control options.

The second set of input data and output are chosen to exercise various options pertaining to solute transport modeling. These options include: (1) automatic mesh generation, (2) default initial concentration value, (3) option to read velocity and water saturated data from Unit 9, and (4) specification of prescribed boundary conditions and printout control options.

10.2 EXAMPLE 1: TWO-DIMENSIONAL FLOW IN A RECTANGULAR SOIL SLAB

10.2.1 Input Data

This problem is described in Section 4.2.2. The input data file corresponding to the problem is displayed in Table 10.1. Note that the automatic mesh generation option is exercised by setting the control variable ITSGN = 1. Because the output control parameter IPRD is set equal to 0, a complete printout of mesh data, as well as initial condition data will be given as part of the printed output. Also evident in the depicted input data is the specification of KPROP = 0. Accordingly, functional values of water saturation versus relative permeability and water saturation versus pressure head must also be part of the input. The input data also include 32 prescribed pressure boundary conditions. Note how vertical slices are used thus there are 16 boundary conditions per slice.

Table 10.1 Input data file for the two-dimensional flow in a soil slab.

```
    1    1                                                                          GROUP 1
    Two-dimensional flow in soil slab (test problem 10.1)                           GROUP 2
    1    2    1    0    1    0    1    5  352  150    1    0    0    0              GROUP 3
    1   10       .01       .01       .01 9.8050e02        .0    5        1.0        GROUP 4
    0    0    0    0    1    0    0    1    0    0    0    0                        GROUP 5
       0.     .864E3       1.2   .432E04                                            GROUP 6
-8.8245e04                                                                          GROUP 7
 1.157e-10 1.157e-10 1.157e-10        0.     0.450        0.        0.       .00    GROUP 8
       1.0   0.98E-2        .0                                                      GROUP 9A
     0.333      1.00      -.01       1.0       -1.        .0        .0        .0    GROUP 9B
   11   16    2         1.        1.       10.    0    0    2                       GROUP 11
        1.        1.       15.       10.        1.        1.        0.        0.    GROUP 13A
       10.       10.        1.        0.                                            GROUP 13B
   32    0    0    0                                                                GROUP 14A
    7    1        0.                                                                GROUP 14B
    8    1 -9.805E02                                                                GROUP 14B
    9    1 -1.961E03                                                                GROUP 14B
   10    1-2.9415E03                                                                GROUP 14B
   11    1-3.9220E03                                                                GROUP 14B
  166    1-8.8245E04                                                                GROUP 14B
  167    1-8.8245E04                                                                GROUP 14B
  168    1-8.8245E04                                                                GROUP 14B
  169    1-8.8245E04                                                                GROUP 14B
  170    1-8.8245E04                                                                GROUP 14B
  171    1-8.8245E04                                                                GROUP 14B
  172    1-8.8245E04                                                                GROUP 14B
  173    1-8.8245E04                                                                GROUP 14B
  174    1-8.8245E04                                                                GROUP 14B
  175    1-8.8245E04                                                                GROUP 14B
  176    1-8.8245E04                                                                GROUP 14B
  183    1        0.                                                                GROUP 14B
  184    1 -9.805E02                                                                GROUP 14B
  185    1 -1.961E03                                                                GROUP 14B
  186    1-2.9415E03                                                                GROUP 14B
  187    1-3.9220E03                                                                GROUP 14B
  342    1-8.8245E04                                                                GROUP 14B
  343    1-8.8245E04                                                                GROUP 14B
  344    1-8.8245E04                                                                GROUP 14B
  345    1-8.8245E04                                                                GROUP 14B
  346    1-8.8245E04                                                                GROUP 14B
  347    1-8.8245E04                                                                GROUP 14B
  348    1-8.8245E04                                                                GROUP 14B
  349    1-8.8245E04                                                                GROUP 14B
  350    1-8.8245E04                                                                GROUP 14B
  351    1-8.8245E04                                                                GROUP 14B
  352    1-8.8245E04                                                                GROUP 14B
```

10.2.2 Sample Output

The printed output file on Unit 6 is displayed in Table 10.2. This output consists of the following categories of information:

1. Problem specification parameters
2. Simulation control parameters
3. Time-stepping and iteration control parameters
4. Input/Output control parameters
5. Time-stepping data
6. Default initial values
7. Constitutive relations of saturation vs. relative permeability and pressure head
8. Porous material data
9. Mesh data
10. Prescribed boundary condition data
11. Initial condition data
12. Maximum matrix bandwidth for each slice
13. Time step number and time value
14. Print check information pertaining to the boundary conditions prescribed and convergence of the nonlinear iterations, and SSOR subiterations
15. Node numbers and nodal pressure head values corresponding to the given time value
16. List of unsaturated elements and centroidal values of water saturation

** Note that information in categories 13 through 16 are repeated for each time step.

Table 10.2. Output for the two-dimensional flow in a soil slab.

```
********************************************************************************

                              THIS OUTPUT GENERATED BY SAMFT3D
                              INPUT FILE NAME = P10-4.DAT

********************************************************************************


        PROBLEM IDENTIFICATION NUMBER =     1

        PROBLEM EXECUTION INDEX........(IEXEC) =     1

        PROBLEM TITLE
        ------------------------------------------------------------------------

            Two-dimensional flow in soil slab (test problem 10.1)

        ------------------------------------------------------------------------


        PROBLEM SPECIFICATION PARAMETERS
        --------------------------------
        MODEL OPTION PARAMETER ....................(IMODL) =    1
          NOTE:  IMODL = 0 FOR SOLUTE TRANSPORT ONLY
                       = 1 FOR FLUID FLOW ONLY
                       = 2 FOR COUPLED FLOW AND TRANSPORT
        TOTAL NUMBER OF FLUID PHASES............ (NTPHAS) =    2
        NUMBER OF ACTIVE FLUID PHASES........... (NMPHAS) =    1
        MATERIAL NUMBER INPUT  ? (1=YES,0=NO)(IMNUMR).... =    0
        TOTAL NUMBER OF DEPENDENT VARIABLES........(NVAR) =    1
        STEADY STATE SIMULATION(1=YES, 0=NO)......(ISSTA) =    0
        TIME STEP GENERATION INDEX (1=YES, 0=NO) .(ITSGN) =    1
        NUMBER OF TIME STEPS ........................(NTS) =    5
        TOTAL NUMBER OF NODES ........................(NP) =  352
        TOTAL NUMBER OF ELEMENTS .....................(NE) =  150
        NUMBER OF POROUS MATERIALS ................(NMAT) =    1
        SOIL CONSTITUTIVE DATA(0=FUNCTION,1=TABLE)(KPROP) =    0
        INITIAL CONDITION NON-UNIFORMITY INDEX ....(NONU) =    0
        SEQUENCE OF NODE NUMBERING (0=Y-,1=X-DIR).(ISWAP) =    0


        INPUT / OUTPUT CONTROL PARAMETERS
        ---------------------------------
        VELOCITY/INPUT............................(NVREAD) =    0
        BOUNDARY NODE DATA READ (1=YES, 0=NO)....(IOUTLT) =    0
        NUMBER OF NODES FOR WHICH I.C. ARE READ....(NPIN) =    0
        OUTPUT REQUIREMENT INDICATOR:
         (0=ALL DATA, 1=NO ELEMENT DATA,
          2=NO MESH DATA, 3=NO MESH AND I.C. DATA..(IPRD) =    0
        UNIT 9 OUTPUT (1=YES, 0=NO)..............(NVWRIT) =    1
        VELOCITY PRINTOUT CONTROL INDEX............(NVPR) =    0
        UNIT 10 OUTPUT (0=NONE, N=NTH)............(NPLOT) =    0
        NODAL VALUE PRINTOUT CONTROL INDEX........(NSTEP) =    1
        OBSERVATION NODE INDEX...................(IOBSND) =    0
        UNIT 8 OUTPUT (1=YES, 0=NO)..............(NOWRIT) =    0
        PRINT CHECK OPTION INDEX.................(IPRCHK) =    0

        MAX. NUMBER OF NONLINEAR FLOW ITERATIONS..(NITMAX) =   10
        EQUIVALENT FRESHWATER HEAD TOLERANCE........(HTOL) =  0.1000E-01
        SATURATION TOLERANCE........................(STOL) =  0.1000E-01
```

```
GRAVITATIONAL ACCELERATION................(GCONST) =  0.9805E+03
ATMOSPERIC PRESSURE.........................(PATM) =  0.0000E+00
MAXIMUM NUMBER OF TIME STEP REQUIREMENTS..(IRESOL) =    5
SSOR RELAXATION FACTOR (DEFAULT=1)........(ORELAX) =  0.1000E+01


TIME STEPPING DATA
------------------
INITIAL TIME VALUE .........................(TIMA) =  0.0000E+00
VALUE OF FIRST TIME STEP ....................(TIN) =  0.8640E+03
TIME STEP MULTIPLIER .......................(TFAC) =  0.1200E+01
MAXIMUM TIME STEP SIZE .....................(TMAX) =  0.4320E+04


DEFAULT INITIAL VALUES OF VARIABLES TO BE SOLVED
------------------------------------------------

         -8.8245E+04


HYDRAULIC PROPERTIES OF POROUS MEDIA
------------------------------------


MATERIAL NUMBER:    1  (I)

PERMEABILITY COMPONENT kxx.............(PROP(I,1)) =  0.1157E-09
PERMEABILITY COMPONENT kyy.............(PROP(I,2)) =  0.1157E-09
PERMEABILITY COMPONENT kzz.............(PROP(I,3)) =  0.1157E-09
POROUS MATRIX COMPRESSIBILITY ........ (PROP(I,4)) =  0.0000E+00
EFFECTIVE POROSITY............. ...... (PROP(I,5)) =  0.4500E+00
AIR ENTRY PRESSURE HEAD............... (PROP(I,6)) =  0.0000E+00

FLUID PROPERTIES
----------------

FLUID PHASE NUMBER:    1

REFERENCE DENSITY................................. =  0.1000E+01
REFERENCE DYNAMIC VISCOSITY....................... =  0.9800E-02
COMPRESSIBILITY .................................. =  0.0000E+00

FLUID RETENTION FUNCTIONAL PARAMETERS
-------------------------------------

SOIL MATERIAL NUMBER:    1  (I)

IRREDUCIBLE WETTING PHASE SATURATION.....PROP(I,7) =  0.3330E+00
EXPONENT INDEX OF REL. PERM. FUNCTION....PROP(I,8) =  0.1000E+01
COEFF. ALPHA.............................PROP(I,9) = -0.1000E-01
POWER INDEX BETA........................PROP(I,10) =  0.1000E+01
POWER INDEX GAMMA.......................PROP(I,11) = -0.1000E+01
SURFACE TENSION BETWEEN AIR AND WATER....PROP(I,12)=  0.0000E+00
SURFACE TENSION BETWEEN NAPL AND WATER...PROP(I,13)=  0.0000E+00
SURFACE TENSION BETWEEN AIR AND NAPL.....PROP(I,14)=  0.0000E+00



MESH GENERATION PARAMETERS
--------------------------
NUMBER OF GRID LINES PARALLEL TO X-AXIS  (NROWS)  =     11
NUMBER OF GRID LINES PARALLEL TO Y-AXIS  (NCOLS)  =     16
NUMBER OF PLANES USED IN THE MESH ......(NPLANE)  =      2
MAXIMUM ALLOWABLE VALUE OF X-INCREMENT ..(DXMAX)  = 0.100E+01
MAXIMUM ALLOWABLE VALUE OF Y-INCREMENT ..(DYMAX)  = 0.100E+01
MAXIMUM ALLOWABLE VALUE OF Z-INCREMENT ..(DZMAX)  = 0.100E+02
GRID LINE COORDINATE INPUT CODE  .......(IXYZRD)  =      0
```

```
HORIZONTAL PLANE DOMAIN INDICATOR.......(IHORGR)  =    0
NUMBER OF SLICES .......................(NSLICE)  =    2

X-INCREMENT OF THE FIRST GRID BLOCK ........(DX)  =    1.000
Y-INCREMENT OF THE FIRST GRID BLOCK ........(DY)  =    1.000
MAXIMUM VALUE OF X-COORDINATE ..............(XO)  =   15.000
MAXIMUM VALUE OF Y-COORDINATE ..............(YO)  =   10.000
X-INCREMENT MULTIPLIER ...................(SCFX)  =    1.000
Y-INCREMENT MULTIPLIER ...................(SCFY)  =    1.000
MINIMUM VALUE OF X-COORDINATE ..........(XSTART)  =    0.000
MINIMUM VALUE OF Y-COORDINATE ..........(YSTART)  =    0.000

Z-INCREMENT OF THE FIRST GRID BLOCK ........(DZ)  =   10.000
MAXIMUM VALUE OF Z-COORDINATE ..............(ZO)  =   10.000
Z-INCREMENT MULTIPLIER ...................(SCFZ)  =    1.000
MINIMUM VALUE OF Z-COORDINATE ..........(ZSTART)  =    0.000
```

*** X-COORDINATES OF GRID LINES ***

0.000	1.000	2.000	3.000	4.000	5.000	6.000	7.000
8.000	9.000	10.000	11.000	12.000	13.000	14.000	15.000

*** Y-COORDINATES OF GRID LINES ***

0.000	1.000	2.000	3.000	4.000	5.000	6.000	7.000
8.000	9.000	10.000					

*** Z-COORDINATES OF GRID LINES ***

0.000	10.000

LIST OF ELEMENT NUMBERS AND NODAL CONNECTION DATA

ELEMENT #	NODAL CONNECTIONS							
1	1	12	13	2	177	188	189	178
3	3	14	15	4	179	190	191	180
5	5	16	17	6	181	192	193	182
7	7	18	19	8	183	194	195	184
9	9	20	21	10	185	196	197	186
11	12	23	24	13	188	199	200	189
13	14	25	26	15	190	201	202	191
15	16	27	28	17	192	203	204	193
17	18	29	30	19	194	205	206	195
19	20	31	32	21	196	207	208	197
21	23	34	35	24	199	210	211	200
23	25	36	37	26	201	212	213	202
25	27	38	39	28	203	214	215	204
27	29	40	41	30	205	216	217	206
29	31	42	43	32	207	218	219	208
31	34	45	46	35	210	221	222	211
33	36	47	48	37	212	223	224	213
35	38	49	50	39	214	225	226	215
37	40	51	52	41	216	227	228	217
39	42	53	54	43	218	229	230	219
41	45	56	57	46	221	232	233	222

ELEMENT #	NODAL CONNECTIONS							
2	2	13	14	3	178	189	190	179
4	4	15	16	5	180	191	192	181
6	6	17	18	7	182	193	194	183
8	8	19	20	9	184	195	196	185
10	10	21	22	11	186	197	198	187
12	13	24	25	14	189	200	201	190
14	15	26	27	16	191	202	203	192
16	17	28	29	18	193	204	205	194
18	19	30	31	20	195	206	207	196
20	21	32	33	22	197	208	209	198
22	24	35	36	25	200	211	212	201
24	26	37	38	27	202	213	214	203
26	28	39	40	29	204	215	216	205
28	30	41	42	31	206	217	218	207
30	32	43	44	33	208	219	220	209
32	35	46	47	36	211	222	223	212
34	37	48	49	38	213	224	225	214
36	39	50	51	40	215	226	227	216
38	41	52	53	42	217	228	229	218
40	43	54	55	44	219	230	231	220
42	46	57	58	47	222	233	234	223

43	47	58	59	48	223	234	235	224	44	48	59	60	49	224	235	236	225
45	49	60	61	50	225	236	237	226	46	50	61	62	51	226	237	238	227
47	51	62	63	52	227	238	239	228	48	52	63	64	53	228	239	240	229
49	53	64	65	54	229	240	241	230	50	54	65	66	55	230	241	242	231
51	56	67	68	57	232	243	244	233	52	57	68	69	58	233	244	245	234
53	58	69	70	59	234	245	246	235	54	59	70	71	60	235	246	247	236
55	60	71	72	61	236	247	248	237	56	61	72	73	62	237	248	249	238
57	62	73	74	63	238	249	250	239	58	63	74	75	64	239	250	251	240
59	64	75	76	65	240	251	252	241	60	65	76	77	66	241	252	253	242
61	67	78	79	68	243	254	255	244	62	68	79	80	69	244	255	256	245
63	69	80	81	70	245	256	257	246	64	70	81	82	71	246	257	258	247
65	71	82	83	72	247	258	259	248	66	72	83	84	73	248	259	260	249
67	73	84	85	74	249	260	261	250	68	74	85	86	75	250	261	262	251
69	75	86	87	76	251	262	263	252	70	76	87	88	77	252	263	264	253
71	78	89	90	79	254	265	266	255	72	79	90	91	80	255	266	267	256
73	80	91	92	81	256	267	268	257	74	81	92	93	82	257	268	269	258
75	82	93	94	83	258	269	270	259	76	83	94	95	84	259	270	271	260
77	84	95	96	85	260	271	272	261	78	85	96	97	86	261	272	273	262
79	86	97	98	87	262	273	274	263	80	87	98	99	88	263	274	275	264
81	89	100	101	90	265	276	277	266	82	90	101	102	91	266	277	278	267
83	91	102	103	92	267	278	279	268	84	92	103	104	93	268	279	280	269
85	93	104	105	94	269	280	281	270	86	94	105	106	95	270	281	282	271
87	95	106	107	96	271	282	283	272	88	96	107	108	97	272	283	284	273
89	97	108	109	98	273	284	285	274	90	98	109	110	99	274	285	286	275
91	100	111	112	101	276	287	288	277	92	101	112	113	102	277	288	289	278
93	102	113	114	103	278	289	290	279	94	103	114	115	104	279	290	291	280
95	104	115	116	105	280	291	292	281	96	105	116	117	106	281	292	293	282
97	106	117	118	107	282	293	294	283	98	107	118	119	108	283	294	295	284
99	108	119	120	109	284	295	296	285	100	109	120	121	110	285	296	297	286
101	111	122	123	112	287	298	299	288	102	112	123	124	113	288	299	300	289
103	113	124	125	114	289	300	301	290	104	114	125	126	115	290	301	302	291
105	115	126	127	116	291	302	303	292	106	116	127	128	117	292	303	304	293
107	117	128	129	118	293	304	305	294	108	118	129	130	119	294	305	306	295
109	119	130	131	120	295	306	307	296	110	120	131	132	121	296	307	308	297
111	122	133	134	123	298	309	310	299	112	123	134	135	124	299	310	311	300
113	124	135	136	125	300	311	312	301	114	125	136	137	126	301	312	313	302
115	126	137	138	127	302	313	314	303	116	127	138	139	128	303	314	315	304
117	128	139	140	129	304	315	316	305	118	129	140	141	130	305	316	317	306
119	130	141	142	131	306	317	318	307	120	131	142	143	132	307	318	319	308
121	133	144	145	134	309	320	321	310	122	134	145	146	135	310	321	322	311
123	135	146	147	136	311	322	323	312	124	136	147	148	137	312	323	324	313
125	137	148	149	138	313	324	325	314	126	138	149	150	139	314	325	326	315
127	139	150	151	140	315	326	327	316	128	140	151	152	141	316	327	328	317
129	141	152	153	142	317	328	329	318	130	142	153	154	143	318	329	330	319
131	144	155	156	145	320	331	332	321	132	145	156	157	146	321	332	333	322
133	146	157	158	147	322	333	334	323	134	147	158	159	148	323	334	335	324
135	148	159	160	149	324	335	336	325	136	149	160	161	150	325	336	337	326
137	150	161	162	151	326	337	338	327	138	151	162	163	152	327	338	339	328
139	152	163	164	153	328	339	340	329	140	153	164	165	154	329	340	341	330
141	155	166	167	156	331	342	343	332	142	156	167	168	157	332	343	344	333
143	157	168	169	158	333	344	345	334	144	158	169	170	159	334	345	346	335
145	159	170	171	160	335	346	347	336	146	160	171	172	161	336	347	348	337
147	161	172	173	162	337	348	349	338	148	162	173	174	163	338	349	350	339
149	163	174	175	164	339	350	351	340	150	164	175	176	165	340	351	352	341

LIST OF NODE NUMBERS AND THEIR X,Y AND Z-COORDINATES

NODE	X-COORD.	Y-COORD.	Z-COORD.	NODE	X-COORD.	Y-COORD.	Z-COORD.	NODE	X-COORD.	Y-COORD.	Z-COORD.
1	0.00	0.00	0.00	2	0.00	1.00	0.00	3	0.00	2.00	0.00
4	0.00	3.00	0.00	5	0.00	4.00	0.00	6	0.00	5.00	0.00
7	0.00	6.00	0.00	8	0.00	7.00	0.00	9	0.00	8.00	0.00
10	0.00	9.00	0.00	11	0.00	10.00	0.00	12	1.00	0.00	0.00
13	1.00	1.00	0.00	14	1.00	2.00	0.00	15	1.00	3.00	0.00

16	1.00	4.00	0.00	17	1.00	5.00	0.00	18	1.00	6.00	0.00
19	1.00	7.00	0.00	20	1.00	8.00	0.00	21	1.00	9.00	0.00
22	1.00	10.00	0.00	23	2.00	0.00	0.00	24	2.00	1.00	0.00
25	2.00	2.00	0.00	26	2.00	3.00	0.00	27	2.00	4.00	0.00
28	2.00	5.00	0.00	29	2.00	6.00	0.00	30	2.00	7.00	0.00
31	2.00	8.00	0.00	32	2.00	9.00	0.00	33	2.00	10.00	0.00
34	3.00	0.00	0.00	35	3.00	1.00	0.00	36	3.00	2.00	0.00
37	3.00	3.00	0.00	38	3.00	4.00	0.00	39	3.00	5.00	0.00
40	3.00	6.00	0.00	41	3.00	7.00	0.00	42	3.00	8.00	0.00
43	3.00	9.00	0.00	44	3.00	10.00	0.00	45	4.00	0.00	0.00
46	4.00	1.00	0.00	47	4.00	2.00	0.00	48	4.00	3.00	0.00
49	4.00	4.00	0.00	50	4.00	5.00	0.00	51	4.00	6.00	0.00
52	4.00	7.00	0.00	53	4.00	8.00	0.00	54	4.00	9.00	0.00
55	4.00	10.00	0.00	56	5.00	0.00	0.00	57	5.00	1.00	0.00
58	5.00	2.00	0.00	59	5.00	3.00	0.00	60	5.00	4.00	0.00
61	5.00	5.00	0.00	62	5.00	6.00	0.00	63	5.00	7.00	0.00
64	5.00	8.00	0.00	65	5.00	9.00	0.00	66	5.00	10.00	0.00
67	6.00	0.00	0.00	68	6.00	1.00	0.00	69	6.00	2.00	0.00
70	6.00	3.00	0.00	71	6.00	4.00	0.00	72	6.00	5.00	0.00
73	6.00	6.00	0.00	74	6.00	7.00	0.00	75	6.00	8.00	0.00
76	6.00	9.00	0.00	77	6.00	10.00	0.00	78	7.00	0.00	0.00
79	7.00	1.00	0.00	80	7.00	2.00	0.00	81	7.00	3.00	0.00
82	7.00	4.00	0.00	83	7.00	5.00	0.00	84	7.00	6.00	0.00
85	7.00	7.00	0.00	86	7.00	8.00	0.00	87	7.00	9.00	0.00
88	7.00	10.00	0.00	89	8.00	0.00	0.00	90	8.00	1.00	0.00
91	8.00	2.00	0.00	92	8.00	3.00	0.00	93	8.00	4.00	0.00
94	8.00	5.00	0.00	95	8.00	6.00	0.00	96	8.00	7.00	0.00
97	8.00	8.00	0.00	98	8.00	9.00	0.00	99	8.00	10.00	0.00
100	9.00	0.00	0.00	101	9.00	1.00	0.00	102	9.00	2.00	0.00
103	9.00	3.00	0.00	104	9.00	4.00	0.00	105	9.00	5.00	0.00
106	9.00	6.00	0.00	107	9.00	7.00	0.00	108	9.00	8.00	0.00
109	9.00	9.00	0.00	110	9.00	10.00	0.00	111	10.00	0.00	0.00
112	10.00	1.00	0.00	113	10.00	2.00	0.00	114	10.00	3.00	0.00
115	10.00	4.00	0.00	116	10.00	5.00	0.00	117	10.00	6.00	0.00
118	10.00	7.00	0.00	119	10.00	8.00	0.00	120	10.00	9.00	0.00
121	10.00	10.00	0.00	122	11.00	0.00	0.00	123	11.00	1.00	0.00
124	11.00	2.00	0.00	125	11.00	3.00	0.00	126	11.00	4.00	0.00
127	11.00	5.00	0.00	128	11.00	6.00	0.00	129	11.00	7.00	0.00
130	11.00	8.00	0.00	131	11.00	9.00	0.00	132	11.00	10.00	0.00
133	12.00	0.00	0.00	134	12.00	1.00	0.00	135	12.00	2.00	0.00
136	12.00	3.00	0.00	137	12.00	4.00	0.00	138	12.00	5.00	0.00
139	12.00	6.00	0.00	140	12.00	7.00	0.00	141	12.00	8.00	0.00
142	12.00	9.00	0.00	143	12.00	10.00	0.00	144	13.00	0.00	0.00
145	13.00	1.00	0.00	146	13.00	2.00	0.00	147	13.00	3.00	0.00
148	13.00	4.00	0.00	149	13.00	5.00	0.00	150	13.00	6.00	0.00
151	13.00	7.00	0.00	152	13.00	8.00	0.00	153	13.00	9.00	0.00
154	13.00	10.00	0.00	155	14.00	0.00	0.00	156	14.00	1.00	0.00
157	14.00	2.00	0.00	158	14.00	3.00	0.00	159	14.00	4.00	0.00
160	14.00	5.00	0.00	161	14.00	6.00	0.00	162	14.00	7.00	0.00
163	14.00	8.00	0.00	164	14.00	9.00	0.00	165	14.00	10.00	0.00
166	15.00	0.00	0.00	167	15.00	1.00	0.00	168	15.00	2.00	0.00
169	15.00	3.00	0.00	170	15.00	4.00	0.00	171	15.00	5.00	0.00
172	15.00	6.00	0.00	173	15.00	7.00	0.00	174	15.00	8.00	0.00
175	15.00	9.00	0.00	176	15.00	10.00	0.00	177	0.00	0.00	10.00
178	0.00	1.00	10.00	179	0.00	2.00	10.00	180	0.00	3.00	10.00
181	0.00	4.00	10.00	182	0.00	5.00	10.00	183	0.00	6.00	10.00
184	0.00	7.00	10.00	185	0.00	8.00	10.00	186	0.00	9.00	10.00
187	0.00	10.00	10.00	188	1.00	0.00	10.00	189	1.00	1.00	10.00
190	1.00	2.00	10.00	191	1.00	3.00	10.00	192	1.00	4.00	10.00
193	1.00	5.00	10.00	194	1.00	6.00	10.00	195	1.00	7.00	10.00
196	1.00	8.00	10.00	197	1.00	9.00	10.00	198	1.00	10.00	10.00
199	2.00	0.00	10.00	200	2.00	1.00	10.00	201	2.00	2.00	10.00
202	2.00	3.00	10.00	203	2.00	4.00	10.00	204	2.00	5.00	10.00
205	2.00	6.00	10.00	206	2.00	7.00	10.00	207	2.00	8.00	10.00
208	2.00	9.00	10.00	209	2.00	10.00	10.00	210	3.00	0.00	10.00
211	3.00	1.00	10.00	212	3.00	2.00	10.00	213	3.00	3.00	10.00
214	3.00	4.00	10.00	215	3.00	5.00	10.00	216	3.00	6.00	10.00
217	3.00	7.00	10.00	218	3.00	8.00	10.00	219	3.00	9.00	10.00
220	3.00	10.00	10.00	221	4.00	0.00	10.00	222	4.00	1.00	10.00

223	4.00	2.00	10.00	224	4.00	3.00	10.00	225	4.00	4.00	10.00
226	4.00	5.00	10.00	227	4.00	6.00	10.00	228	4.00	7.00	10.00
229	4.00	8.00	10.00	230	4.00	9.00	10.00	231	4.00	10.00	10.00
232	5.00	0.00	10.00	233	5.00	1.00	10.00	234	5.00	2.00	10.00
235	5.00	3.00	10.00	236	5.00	4.00	10.00	237	5.00	5.00	10.00
238	5.00	6.00	10.00	239	5.00	7.00	10.00	240	5.00	8.00	10.00
241	5.00	9.00	10.00	242	5.00	10.00	10.00	243	6.00	0.00	10.00
244	6.00	1.00	10.00	245	6.00	2.00	10.00	246	6.00	3.00	10.00
247	6.00	4.00	10.00	248	6.00	5.00	10.00	249	6.00	6.00	10.00
250	6.00	7.00	10.00	251	6.00	8.00	10.00	252	6.00	9.00	10.00
253	6.00	10.00	10.00	254	7.00	0.00	10.00	255	7.00	1.00	10.00
256	7.00	2.00	10.00	257	7.00	3.00	10.00	258	7.00	4.00	10.00
259	7.00	5.00	10.00	260	7.00	6.00	10.00	261	7.00	7.00	10.00
262	7.00	8.00	10.00	263	7.00	9.00	10.00	264	7.00	10.00	10.00
265	8.00	0.00	10.00	266	8.00	1.00	10.00	267	8.00	2.00	10.00
268	8.00	3.00	10.00	269	8.00	4.00	10.00	270	8.00	5.00	10.00
271	8.00	6.00	10.00	272	8.00	7.00	10.00	273	8.00	8.00	10.00
274	8.00	9.00	10.00	275	8.00	10.00	10.00	276	9.00	0.00	10.00
277	9.00	1.00	10.00	278	9.00	2.00	10.00	279	9.00	3.00	10.00
280	9.00	4.00	10.00	281	9.00	5.00	10.00	282	9.00	6.00	10.00
283	9.00	7.00	10.00	284	9.00	8.00	10.00	285	9.00	9.00	10.00
286	9.00	10.00	10.00	287	10.00	0.00	10.00	288	10.00	1.00	10.00
289	10.00	2.00	10.00	290	10.00	3.00	10.00	291	10.00	4.00	10.00
292	10.00	5.00	10.00	293	10.00	6.00	10.00	294	10.00	7.00	10.00
295	10.00	8.00	10.00	296	10.00	9.00	10.00	297	10.00	10.00	10.00
298	11.00	0.00	10.00	299	11.00	1.00	10.00	300	11.00	2.00	10.00
301	11.00	3.00	10.00	302	11.00	4.00	10.00	303	11.00	5.00	10.00
304	11.00	6.00	10.00	305	11.00	7.00	10.00	306	11.00	8.00	10.00
307	11.00	9.00	10.00	308	11.00	10.00	10.00	309	12.00	0.00	10.00
310	12.00	1.00	10.00	311	12.00	2.00	10.00	312	12.00	3.00	10.00
313	12.00	4.00	10.00	314	12.00	5.00	10.00	315	12.00	6.00	10.00
316	12.00	7.00	10.00	317	12.00	8.00	10.00	318	12.00	9.00	10.00
319	12.00	10.00	10.00	320	13.00	0.00	10.00	321	13.00	1.00	10.00
322	13.00	2.00	10.00	323	13.00	3.00	10.00	324	13.00	4.00	10.00
325	13.00	5.00	10.00	326	13.00	6.00	10.00	327	13.00	7.00	10.00
328	13.00	8.00	10.00	329	13.00	9.00	10.00	330	13.00	10.00	10.00
331	14.00	0.00	10.00	332	14.00	1.00	10.00	333	14.00	2.00	10.00
334	14.00	3.00	10.00	335	14.00	4.00	10.00	336	14.00	5.00	10.00
337	14.00	6.00	10.00	338	14.00	7.00	10.00	339	14.00	8.00	10.00
340	14.00	9.00	10.00	341	14.00	10.00	10.00	342	15.00	0.00	10.00
343	15.00	1.00	10.00	344	15.00	2.00	10.00	345	15.00	3.00	10.00
346	15.00	4.00	10.00	347	15.00	5.00	10.00	348	15.00	6.00	10.00
349	15.00	7.00	10.00	350	15.00	8.00	10.00	351	15.00	9.00	10.00
352	15.00	10.00	10.00								

BOUNDARY CONDITION DATA

NUMBER OF STEADY DIRICHLET BOUNDARIES .... (NBTO) = 32
NUMBER OF STEADY FLUX BOUNDARIES .... (NDFLUX) = 0
NUMBER OF TRANSIENT DIRICHLET BOUNDARIES.... (NBHVAR) = 0
NUMBER OF TRANSIENT FLUX BOUNDARIES.... .... (NBFVAR) = 0

STEADY-STATE DIRICHLET BOUNDARY CONDITIONS

INDEX	NODE NO.	D.V. NO.	PRESCRIBED VALUE
1	7	1	0.000000E+00
2	8	1	-980.500
3	9	1	-1961.00
4	10	1	-2941.50
5	11	1	-3922.00
6	166	1	-88245.0
7	167	1	-88245.0
8	168	1	-88245.0

9	169	1	-88245.0
10	170	1	-88245.0
11	171	1	-88245.0
12	172	1	-88245.0
13	173	1	-88245.0
14	174	1	-88245.0
15	175	1	-88245.0
16	176	1	-88245.0
17	183	1	0.000000E+00
18	184	1	-980.500
19	185	1	-1961.00
20	186	1	-2941.50
21	187	1	-3922.00
22	342	1	-88245.0
23	343	1	-88245.0
24	344	1	-88245.0
25	345	1	-88245.0
26	346	1	-88245.0
27	347	1	-88245.0
28	348	1	-88245.0
29	349	1	-88245.0
30	350	1	-88245.0
31	351	1	-88245.0
32	352	1	-88245.0

INITIAL CONDITION DATA

NODE	PRESSURE	NODE	PRESSURE	NODE	PRESSURE	NODE	PRESSURE	NODE	PRESSURE
1	-88245.0	2	-88245.0	3	-88245.0	4	-88245.0	5	-88245.0
6	-88245.0	7	-88245.0	8	-88245.0	9	-88245.0	10	-88245.0
11	-88245.0	12	-88245.0	13	-88245.0	14	-88245.0	15	-88245.0
16	-88245.0	17	-88245.0	18	-88245.0	19	-88245.0	20	-88245.0
21	-88245.0	22	-88245.0	23	-88245.0	24	-88245.0	25	-88245.0
26	-88245.0	27	-88245.0	28	-88245.0	29	-88245.0	30	-88245.0
31	-88245.0	32	-88245.0	33	-88245.0	34	-88245.0	35	-88245.0
36	-88245.0	37	-88245.0	38	-88245.0	39	-88245.0	40	-88245.0
41	-88245.0	42	-88245.0	43	-88245.0	44	-88245.0	45	-88245.0
46	-88245.0	47	-88245.0	48	-88245.0	49	-88245.0	50	-88245.0
51	-88245.0	52	-88245.0	53	-88245.0	54	-88245.0	55	-88245.0
56	-88245.0	57	-88245.0	58	-88245.0	59	-88245.0	60	-88245.0
61	-88245.0	62	-88245.0	63	-88245.0	64	-88245.0	65	-88245.0
66	-88245.0	67	-88245.0	68	-88245.0	69	-88245.0	70	-88245.0
71	-88245.0	72	-88245.0	73	-88245.0	74	-88245.0	75	-88245.0
76	-88245.0	77	-88245.0	78	-88245.0	79	-88245.0	80	-88245.0
81	-88245.0	82	-88245.0	83	-88245.0	84	-88245.0	85	-88245.0
86	-88245.0	87	-88245.0	88	-88245.0	89	-88245.0	90	-88245.0
91	-88245.0	92	-88245.0	93	-88245.0	94	-88245.0	95	-88245.0
96	-88245.0	97	-88245.0	98	-88245.0	99	-88245.0	100	-88245.0
101	-88245.0	102	-88245.0	103	-88245.0	104	-88245.0	105	-88245.0
106	-88245.0	107	-88245.0	108	-88245.0	109	-88245.0	110	-88245.0
111	-88245.0	112	-88245.0	113	-88245.0	114	-88245.0	115	-88245.0
116	-88245.0	117	-88245.0	118	-88245.0	119	-88245.0	120	-88245.0
121	-88245.0	122	-88245.0	123	-88245.0	124	-88245.0	125	-88245.0
126	-88245.0	127	-88245.0	128	-88245.0	129	-88245.0	130	-88245.0
131	-88245.0	132	-88245.0	133	-88245.0	134	-88245.0	135	-88245.0
136	-88245.0	137	-88245.0	138	-88245.0	139	-88245.0	140	-88245.0
141	-88245.0	142	-88245.0	143	-88245.0	144	-88245.0	145	-88245.0
146	-88245.0	147	-88245.0	148	-88245.0	149	-88245.0	150	-88245.0
151	-88245.0	152	-88245.0	153	-88245.0	154	-88245.0	155	-88245.0
156	-88245.0	157	-88245.0	158	-88245.0	159	-88245.0	160	-88245.0
161	-88245.0	162	-88245.0	163	-88245.0	164	-88245.0	165	-88245.0

166	-88245.0	167	-88245.0	168	-88245.0	169	-88245.0	170	-88245.0
171	-88245.0	172	-88245.0	173	-88245.0	174	-88245.0	175	-88245.0
176	-88245.0	177	-88245.0	178	-88245.0	179	-88245.0	180	-88245.0
181	-88245.0	182	-88245.0	183	-88245.0	184	-88245.0	185	-88245.0
186	-88245.0	187	-88245.0	188	-88245.0	189	-88245.0	190	-88245.0
191	-88245.0	192	-88245.0	193	-88245.0	194	-88245.0	195	-88245.0
196	-88245.0	197	-88245.0	198	-88245.0	199	-88245.0	200	-88245.0
201	-88245.0	202	-88245.0	203	-88245.0	204	-88245.0	205	-88245.0
206	-88245.0	207	-88245.0	208	-88245.0	209	-88245.0	210	-88245.0
211	-88245.0	212	-88245.0	213	-88245.0	214	-88245.0	215	-88245.0
216	-88245.0	217	-88245.0	218	-88245.0	219	-88245.0	220	-88245.0
221	-88245.0	222	-88245.0	223	-88245.0	224	-88245.0	225	-88245.0
226	-88245.0	227	-88245.0	228	-88245.0	229	-88245.0	230	-88245.0
231	-88245.0	232	-88245.0	233	-88245.0	234	-88245.0	235	-88245.0
236	-88245.0	237	-88245.0	238	-88245.0	239	-88245.0	240	-88245.0
241	-88245.0	242	-88245.0	243	-88245.0	244	-88245.0	245	-88245.0
246	-88245.0	247	-88245.0	248	-88245.0	249	-88245.0	250	-88245.0
251	-88245.0	252	-88245.0	253	-88245.0	254	-88245.0	255	-88245.0
256	-88245.0	257	-88245.0	258	-88245.0	259	-88245.0	260	-88245.0
261	-88245.0	262	-88245.0	263	-88245.0	264	-88245.0	265	-88245.0
266	-88245.0	267	-88245.0	268	-88245.0	269	-88245.0	270	-88245.0
271	-88245.0	272	-88245.0	273	-88245.0	274	-88245.0	275	-88245.0
276	-88245.0	277	-88245.0	278	-88245.0	279	-88245.0	280	-88245.0
281	-88245.0	282	-88245.0	283	-88245.0	284	-88245.0	285	-88245.0
286	-88245.0	287	-88245.0	288	-88245.0	289	-88245.0	290	-88245.0
291	-88245.0	292	-88245.0	293	-88245.0	294	-88245.0	295	-88245.0
296	-88245.0	297	-88245.0	298	-88245.0	299	-88245.0	300	-88245.0
301	-88245.0	302	-88245.0	303	-88245.0	304	-88245.0	305	-88245.0
306	-88245.0	307	-88245.0	308	-88245.0	309	-88245.0	310	-88245.0
311	-88245.0	312	-88245.0	313	-88245.0	314	-88245.0	315	-88245.0
316	-88245.0	317	-88245.0	318	-88245.0	319	-88245.0	320	-88245.0
321	-88245.0	322	-88245.0	323	-88245.0	324	-88245.0	325	-88245.0
326	-88245.0	327	-88245.0	328	-88245.0	329	-88245.0	330	-88245.0
331	-88245.0	332	-88245.0	333	-88245.0	334	-88245.0	335	-88245.0
336	-88245.0	337	-88245.0	338	-88245.0	339	-88245.0	340	-88245.0
341	-88245.0	342	-88245.0	343	-88245.0	344	-88245.0	345	-88245.0
346	-88245.0	347	-88245.0	348	-88245.0	349	-88245.0	350	-88245.0
351	-88245.0	352	-88245.0						

MATRIX BANDWIDTH FOR EACH SLICE = 12

==

**** TIME STEP NUMBER : 1 ELAPSED SIMULATION TIME : 0.8640E+03 TIME STEP SIZE : 0.864E+03 ****

==

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	273	0.6577E+02
2	236	0.1308E+02

3	97	0.1110E+01
4	33	0.9898E-01
5	14	0.9035E-02
6	0	0.8402E-03

NONLINEAR ITERATION #. 1 NO. OF NON-CONVERGENT NODES = 226 MAX. ERROR = 51.52 AT NODE 20 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	234	0.1861E+02
2	149	0.2995E+01
3	71	0.2144E+00
4	33	0.2370E-01
5	14	0.3534E-02
6	0	0.5059E-03

NONLINEAR ITERATION #. 2 NO. OF NON-CONVERGENT NODES = 132 MAX. ERROR = 15.40 AT NODE 32 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	159	0.3177E+01
2	123	0.4420E+00
3	54	0.5294E-01
4	22	0.6736E-02
5	0	0.9179E-03

NONLINEAR ITERATION #. 3 NO. OF NON-CONVERGENT NODES = 122 MAX. ERROR = 2.707 AT NODE 43 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	143	0.4993E+00
2	89	0.9117E-01
3	27	0.6549E-02

4	0	0.6093E-03

NONLINEAR ITERATION #. 4 NO. OF NON-CONVERGENT NODES = 100 MAX. ERROR =-.4010 AT NODE 33 RELAX. FACTOR =0.9059

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	99	0.1069E+00
2	54	0.1666E-01
3	8	0.1245E-02
4	0	0.1735E-03

NONLINEAR ITERATION #. 5 NO. OF NON-CONVERGENT NODES = 44 MAX. ERROR =-.8898E-01 AT NODE 209 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	72	0.1763E-01
2	13	0.2456E-02
3	0	0.3040E-03

NONLINEAR ITERATION #. 6 NO. OF NON-CONVERGENT NODES = 10 MAX. ERROR =-.1501E-01 AT NODE 43 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	29	0.2951E-02
2	0	0.5224E-03

NONLINEAR ITERATION #. 7 NO. OF NON-CONVERGENT NODES = 0 MAX. ERROR =0.2429E-02 AT NODE 33 RELAX. FACTOR =0.8976

*** NODAL HEAD VALUES ***

NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE
1	-89.5084	2	-89.7862	3	-89.3908	4	-87.2524	5	-79.3860
6	-61.2225	7	-1.345082E-23	8	-1.00000	9	-2.00000	10	-3.00000
11	-4.00000	12	-89.5126	13	-89.7984	14	-89.4623	15	-87.6304
16	-81.2588	17	-64.0245	18	-49.5630	19	-39.0982	20	-38.1214
21	-38.4713	22	-39.2255	23	-89.5230	24	-89.8284	25	-89.6270
26	-88.5193	27	-84.7899	28	-78.4472	29	-71.3546	30	-66.4881
31	-64.2322	32	-64.0356	33	-64.5899	34	-89.5352	35	-89.8614
36	-89.7941	37	-89.3151	38	-88.0989	39	-85.9762	40	-83.4555
41	-81.3297	42	-80.1322	43	-79.8207	44	-80.2364	45	-89.5454
46	-89.8864	47	-89.9034	48	-89.7660	49	-89.4439	50	-88.9109
51	-88.2444	52	-87.6256	53	-87.2249	54	-87.1387	55	-87.4997
56	-89.5519	57	-89.9006	58	-89.9554	59	-89.9296	60	-89.8568
61	-89.7422	62	-89.6023	63	-89.4710	64	-89.3915	65	-89.4263
66	-89.7726	67	-89.5552	68	-89.9070	69	-89.9742	70	-89.9788
71	-89.9651	72	-89.9424	73	-89.9157	74	-89.8932	75	-89.8907
76	-89.9562	77	-90.2961	78	-89.5566	79	-89.9093	80	-89.9800
81	-89.9921	82	-89.9914	83	-89.9875	84	-89.9830	85	-89.9816
86	-89.9941	87	-90.0652	88	-90.4033	89	-89.5571	90	-89.9101
91	-89.9816	92	-89.9954	93	-89.9976	94	-89.9974	95	-89.9972
96	-89.9998	97	-90.0149	98	-90.0870	99	-90.4247	100	-89.5573
101	-89.9103	102	-89.9820	103	-89.9962	104	-89.9989	105	-89.9995
106	-90.0002	107	-90.0035	108	-90.0191	109	-90.0913	110	-90.4289
111	-89.5574	112	-89.9104	113	-89.9822	114	-89.9964	115	-89.9993
116	-89.9999	117	-90.0008	118	-90.0042	119	-90.0199	120	-90.0922
121	-90.4297	122	-89.5576	123	-89.9106	124	-89.9823	125	-89.9965
126	-89.9994	127	-90.0000	128	-90.0009	129	-90.0043	130	-90.0200
131	-90.0922	132	-90.4297	133	-89.5588	134	-89.9116	135	-89.9829
136	-89.9968	137	-89.9994	138	-90.0001	139	-90.0008	140	-90.0040
141	-90.0194	142	-90.0913	143	-90.4288	144	-89.5656	145	-89.9165
146	-89.9854	147	-89.9974	148	-89.9995	149	-90.0000	150	-90.0006
151	-90.0033	152	-90.0167	153	-90.0866	154	-90.4229	155	-89.6016
156	-89.9465	157	-89.9912	158	-89.9985	159	-89.9997	160	-90.0000
161	-90.0004	162	-90.0019	163	-90.0101	164	-90.0563	165	-90.3906
166	-90.0000	167	-90.0000	168	-90.0000	169	-90.0000	170	-90.0000
171	-90.0000	172	-90.0000	173	-90.0000	174	-90.0000	175	-90.0000
176	-90.0000	177	-89.5084	178	-89.7862	179	-89.3908	180	-87.2524
181	-79.3860	182	-61.2225	183	-1.345082E-23	184	-1.00000	185	-2.00000
186	-3.00000	187	-4.00000	188	-89.5126	189	-89.7984	190	-89.4623
191	-87.6304	192	-81.2588	193	-64.0246	194	-49.5630	195	-39.0982
196	-38.1214	197	-38.4713	198	-39.2255	199	-89.5230	200	-89.8284
201	-89.6270	202	-88.5193	203	-84.7899	204	-78.4472	205	-71.3547
206	-66.4882	207	-64.2322	208	-64.0356	209	-64.5900	210	-89.5352
211	-89.8614	212	-89.7941	213	-89.3151	214	-88.0989	215	-85.9762
216	-83.4555	217	-81.3296	218	-80.1322	219	-79.8207	220	-80.2364
221	-89.5454	222	-89.8864	223	-89.9034	224	-89.7660	225	-89.4439
226	-88.9109	227	-88.2444	228	-87.6256	229	-87.2249	230	-87.1387
231	-87.4997	232	-89.5519	233	-89.9006	234	-89.9554	235	-89.9296
236	-89.8568	237	-89.7422	238	-89.6024	239	-89.4710	240	-89.3915
241	-89.4263	242	-89.7726	243	-89.5552	244	-89.9070	245	-89.9742
246	-89.9788	247	-89.9651	248	-89.9424	249	-89.9157	250	-89.8932
251	-89.8907	252	-89.9562	253	-90.2961	254	-89.5566	255	-89.9093
256	-89.9800	257	-89.9921	258	-89.9914	259	-89.9875	260	-89.9830
261	-89.9816	262	-89.9941	263	-90.0652	264	-90.4033	265	-89.5571
266	-89.9101	267	-89.9816	268	-89.9954	269	-89.9976	270	-89.9974
271	-89.9972	272	-89.9998	273	-90.0149	274	-90.0870	275	-90.4247
276	-89.5573	277	-89.9103	278	-89.9820	279	-89.9962	280	-89.9989
281	-89.9995	282	-90.0002	283	-90.0035	284	-90.0191	285	-90.0913
286	-90.4289	287	-89.5574	288	-89.9104	289	-89.9822	290	-89.9964
291	-89.9993	292	-89.9999	293	-90.0008	294	-90.0042	295	-90.0199
296	-90.0922	297	-90.4297	298	-89.5576	299	-89.9106	300	-89.9823
301	-89.9965	302	-89.9994	303	-90.0000	304	-90.0009	305	-90.0043

306	-90.0200	307	-90.0922	308	-90.4297	309	-89.5588	310	-89.9116
311	-89.9829	312	-89.9968	313	-89.9994	314	-90.0001	315	-90.0008
316	-90.0040	317	-90.0194	318	-90.0913	319	-90.4288	320	-89.5656
321	-89.9165	322	-89.9854	323	-89.9974	324	-89.9995	325	-90.0000
326	-90.0006	327	-90.0033	328	-90.0167	329	-90.0866	330	-90.4229
331	-89.6016	332	-89.9465	333	-89.9912	334	-89.9985	335	-89.9997
336	-90.0000	337	-90.0004	338	-90.0019	339	-90.0101	340	-90.0563
341	-90.3906	342	-90.0000	343	-90.0000	344	-90.0000	345	-90.0000
346	-90.0000	347	-90.0000	348	-90.0000	349	-90.0000	350	-90.0000
351	-90.0000	352	-90.0000								

*** LIST OF UNSATURATED ELEMENTS ***

ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE
1	0.4020	2	0.4023	3	0.4101	4	0.4405	5	0.5233
6	0.7085	7	0.8505	8	0.8662	9	0.8639	10	0.8588
11	0.4019	12	0.4018	13	0.4076	14	0.4294	15	0.4855
16	0.5608	17	0.6223	18	0.6533	19	0.6584	20	0.6560
21	0.4018	22	0.4012	23	0.4043	24	0.4152	25	0.4375
26	0.4677	27	0.4954	28	0.5128	29	0.5194	30	0.5186
31	0.4017	32	0.4006	33	0.4017	34	0.4053	35	0.4123
36	0.4221	37	0.4320	38	0.4392	39	0.4425	40	0.4419
41	0.4016	42	0.4003	43	0.4004	44	0.4014	45	0.4031
46	0.4055	47	0.4081	48	0.4102	49	0.4111	50	0.4100
51	0.4015	52	0.4001	53	0.4000	54	0.4001	55	0.4005
56	0.4010	57	0.4016	58	0.4020	59	0.4019	60	0.4006
61	0.4015	62	0.4001	63	0.3998	64	0.3998	65	0.3999
66	0.4000	67	0.4001	68	0.4001	69	0.3999	70	0.3985
71	0.4015	72	0.4001	73	0.3998	74	0.3997	75	0.3997
76	0.3998	77	0.3998	78	0.3997	79	0.3994	80	0.3981
81	0.4015	82	0.4001	83	0.3998	84	0.3997	85	0.3997
86	0.3997	87	0.3997	88	0.3996	89	0.3993	90	0.3980
91	0.4015	92	0.4001	93	0.3998	94	0.3997	95	0.3997
96	0.3997	97	0.3997	98	0.3996	99	0.3993	100	0.3980
101	0.4015	102	0.4001	103	0.3998	104	0.3997	105	0.3997
106	0.3997	107	0.3997	108	0.3996	109	0.3993	110	0.3980
111	0.4015	112	0.4001	113	0.3998	114	0.3997	115	0.3997
116	0.3997	117	0.3997	118	0.3996	119	0.3993	120	0.3980
121	0.4014	122	0.4000	123	0.3998	124	0.3997	125	0.3997
126	0.3997	127	0.3997	128	0.3996	129	0.3993	130	0.3980
131	0.4013	132	0.4000	133	0.3997	134	0.3997	135	0.3997
136	0.3997	137	0.3997	138	0.3996	139	0.3994	140	0.3981
141	0.4005	142	0.3998	143	0.3997	144	0.3997	145	0.3997
146	0.3997	147	0.3997	148	0.3997	149	0.3996	150	0.3990

***** TIME STEP NO. 1 COMPLETED *****

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**** TIME STEP NUMBER : 2 ELAPSED SIMULATION TIME : 0.1901E+04 TIME STEP SIZE : 0.104E+04 ****

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SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	306	0.2184E+02
2	228	0.5502E+01
3	109	0.9177E+00
4	53	0.1530E+00
5	25	0.2596E-01
6	17	0.4464E-02
7	0	0.7749E-03

NONLINEAR ITERATION #. 1 NO. OF NON-CONVERGENT NODES = 272 MAX. ERROR =-15.27 AT NODE 20 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	218	0.3563E+01
2	167	0.7045E+00
3	93	0.6514E-01
4	36	0.7669E-02
5	2	0.1058E-02
6	0	0.1608E-03

NONLINEAR ITERATION #. 2 NO. OF NON-CONVERGENT NODES = 168 MAX. ERROR =-2.785 AT NODE 31 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	176	0.6477E+00
2	109	0.9864E-01
3	50	0.1132E-01
4	5	0.1761E-02
5	0	0.2733E-03

NONLINEAR ITERATION #. 3 NO. OF NON-CONVERGENT NODES = 138 MAX. ERROR =-.5400 AT NODE 44 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	122	0.9134E-01
2	84	0.1885E-01
3	10	0.1889E-02
4	0	0.2141E-03

NONLINEAR ITERATION #. 4 NO. OF NON-CONVERGENT NODES = 78 MAX. ERROR =-.7584E-01 AT NODE 55 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	109	0.1917E-01
2	24	0.3030E-02
3	0	0.2804E-03

NONLINEAR ITERATION #. 5 NO. OF NON-CONVERGENT NODES = 24 MAX. ERROR =0.1592E-01 AT NODE 5 RELAX. FACTOR =0.8692

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	44	0.3882E-02
2	0	0.6105E-03

NONLINEAR ITERATION #. 6 NO. OF NON-CONVERGENT NODES = 0 MAX. ERROR =0.3324E-02 AT NODE 40 RELAX. FACTOR = 1.000

*** NODAL HEAD VALUES ***

NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE
1	-88.7056	2	-88.7381	3	-86.4019	4	-79.4791	5	-65.5184
6	-44.5166	7	-1.226964E-23	8	-1.00000	9	-2.00000	10	-3.00000
11	-4.00000	12	-88.7445	13	-88.8310	14	-86.7646	15	-80.5714

16	-68.3608	17	-48.7479	18	-33.9384	19	-24.7864	20	-23.5092
21	-23.7012	22	-24.4869	23	-88.8432	24	-89.0613	25	-87.6448
26	-83.3267	27	-74.7334	28	-64.1247	29	-54.3998	30	-48.1819
31	-45.3003	32	-44.8288	33	-45.4172	34	-88.9610	35	-89.3228
36	-88.6079	37	-86.3011	38	-81.9814	39	-76.2806	40	-70.7367
41	-66.5781	42	-64.2875	43	-63.5842	44	-64.0589	45	-89.0612
46	-89.5299	47	-89.3089	48	-88.4030	49	-86.6623	50	-84.2156
51	-81.5827	52	-79.3887	53	-78.0214	54	-77.5807	55	-78.0455
56	-89.1281	57	-89.6557	58	-89.6871	59	-89.4156	60	-88.8624
61	-88.0550	62	-87.1257	63	-86.2868	64	-85.7419	65	-85.6429
66	-86.1548	67	-89.1647	68	-89.7179	69	-89.8479	70	-89.8020
71	-89.6575	72	-89.4417	73	-89.1910	74	-88.9651	75	-88.8436
76	-88.9404	77	-89.4770	78	-89.1816	79	-89.7439	80	-89.9067
81	-89.9296	82	-89.9020	83	-89.8522	84	-89.7959	85	-89.7540
86	-89.7657	87	-89.9221	88	-90.4616	89	-89.1885	90	-89.7536
91	-89.9262	92	-89.9682	93	-89.9711	94	-89.9626	95	-89.9535
96	-89.9559	97	-89.9990	98	-90.1678	99	-90.7063	100	-89.1911
101	-89.7570	102	-89.9322	103	-89.9792	104	-89.9897	105	-89.9910
106	-89.9927	107	-90.0049	108	-90.0546	109	-90.2256	110	-90.7636
111	-89.1923	112	-89.7584	113	-89.9342	114	-89.9824	115	-89.9946
116	-89.9981	117	-90.0022	118	-90.0165	119	-90.0675	120	-90.2388
121	-90.7765	122	-89.1939	123	-89.7598	124	-89.9355	125	-89.9836
126	-89.9960	127	-89.9999	128	-90.0044	129	-90.0188	130	-90.0698
131	-90.2410	132	-90.7786	133	-89.1995	134	-89.7646	135	-89.9384
136	-89.9850	137	-89.9967	138	-90.0003	139	-90.0044	140	-90.0181
141	-90.0677	142	-90.2376	143	-90.7747	144	-89.2235	145	-89.7830
146	-89.9483	147	-89.9880	148	-89.9975	149	-90.0003	150	-90.0036
151	-90.0147	152	-90.0575	153	-90.2207	154	-90.7540	155	-89.3191
156	-89.8630	157	-89.9693	158	-89.9932	159	-89.9986	160	-90.0002
161	-90.0020	162	-90.0084	163	-90.0344	164	-90.1412	165	-90.6660
166	-90.0000	167	-90.0000	168	-90.0000	169	-90.0000	170	-90.0000
171	-90.0000	172	-90.0000	173	-90.0000	174	-90.0000	175	-90.0000
176	-90.0000	177	-88.7056	178	-88.7381	179	-86.4019	180	-79.4791
181	-65.5184	182	-44.5165	183	-1.226961E-23	184	-1.00000	185	-2.00000
186	-3.00000	187	-4.00000	188	-88.7445	189	-88.8310	190	-86.7646
191	-80.5714	192	-68.3609	193	-48.7478	194	-33.9383	195	-24.7863
196	-23.5091	197	-23.7012	198	-24.4869	199	-88.8432	200	-89.0613
201	-87.6448	202	-83.3266	203	-74.7334	204	-64.1247	205	-54.3998
206	-48.1819	207	-45.3003	208	-44.8288	209	-45.4172	210	-88.9610
211	-89.3228	212	-88.6079	213	-86.3011	214	-81.9814	215	-76.2807
216	-70.7367	217	-66.5781	218	-64.2875	219	-63.5843	220	-64.0589
221	-89.0612	222	-89.5299	223	-89.3089	224	-88.4030	225	-86.6622
226	-84.2156	227	-81.5826	228	-79.3887	229	-78.0214	230	-77.5807
231	-78.0455	232	-89.1281	233	-89.6557	234	-89.6871	235	-89.4156
236	-88.8624	237	-88.0550	238	-87.1257	239	-86.2868	240	-85.7418
241	-85.6428	242	-86.1548	243	-89.1647	244	-89.7179	245	-89.8479
246	-89.8021	247	-89.6575	248	-89.4417	249	-89.1910	250	-88.9651
251	-88.8436	252	-88.9404	253	-89.4770	254	-89.1816	255	-89.7439
256	-89.9067	257	-89.9296	258	-89.9020	259	-89.8522	260	-89.7959
261	-89.7540	262	-89.7657	263	-89.9221	264	-90.4616	265	-89.1885
266	-89.7536	267	-89.9262	268	-89.9682	269	-89.9711	270	-89.9626
271	-89.9535	272	-89.9559	273	-89.9990	274	-90.1678	275	-90.7063
276	-89.1911	277	-89.7570	278	-89.9322	279	-89.9792	280	-89.9897
281	-89.9910	282	-89.9927	283	-90.0049	284	-90.0546	285	-90.2256
286	-90.7636	287	-89.1923	288	-89.7584	289	-89.9342	290	-89.9824
291	-89.9946	292	-89.9981	293	-90.0022	294	-90.0165	295	-90.0675
296	-90.2388	297	-90.7765	298	-89.1939	299	-89.7598	300	-89.9355
301	-89.9836	302	-89.9960	303	-89.9999	304	-90.0044	305	-90.0188
306	-90.0698	307	-90.2410	308	-90.7786	309	-89.1995	310	-89.7646
311	-89.9384	312	-89.9850	313	-89.9967	314	-90.0003	315	-90.0044
316	-90.0181	317	-90.0677	318	-90.2376	319	-90.7747	320	-89.2235
321	-89.7830	322	-89.9483	323	-89.9880	324	-89.9975	325	-90.0003
326	-90.0036	327	-90.0147	328	-90.0575	329	-90.2207	330	-90.7540
331	-89.3191	332	-89.8630	333	-89.9693	334	-89.9932	335	-89.9986
336	-90.0002	337	-90.0020	338	-90.0084	339	-90.0344	340	-90.1412
341	-90.6660	342	-90.0000	343	-90.0000	344	-90.0000	345	-90.0000
346	-90.0000	347	-90.0000	348	-90.0000	349	-90.0000	350	-90.0000
351	-90.0000	352	-90.0000						

*** LIST OF UNSATURATED ELEMENTS ***

ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE
1	0.4080	2	0.4151	3	0.4444	4	0.5099	5	0.6212
6	0.7879	7	0.9004	8	0.9145	9	0.9129	10	0.9080
11	0.4072	12	0.4125	13	0.4359	14	0.4881	15	0.5732
16	0.6645	17	0.7310	18	0.7636	19	0.7710	20	0.7692
21	0.4061	22	0.4086	23	0.4232	24	0.4558	25	0.5046
26	0.5572	27	0.6000	28	0.6259	29	0.6365	30	0.6367
31	0.4049	32	0.4051	33	0.4120	34	0.4275	35	0.4512
36	0.4784	37	0.5026	38	0.5193	39	0.5273	40	0.5276
41	0.4041	42	0.4027	43	0.4050	44	0.4108	45	0.4201
46	0.4314	47	0.4424	48	0.4507	49	0.4547	50	0.4540
51	0.4036	52	0.4015	53	0.4018	54	0.4035	55	0.4063
56	0.4100	57	0.4138	58	0.4166	59	0.4178	60	0.4160
61	0.4034	62	0.4010	63	0.4006	64	0.4009	65	0.4016
66	0.4026	67	0.4035	68	0.4042	69	0.4039	70	0.4017
71	0.4033	72	0.4008	73	0.4001	74	0.4001	75	0.4002
76	0.4004	77	0.4006	78	0.4006	79	0.3999	80	0.3976
81	0.4032	82	0.4008	83	0.4000	84	0.3999	85	0.3998
86	0.3999	87	0.3999	88	0.3997	89	0.3990	90	0.3966
91	0.4032	92	0.4007	93	0.4000	94	0.3998	95	0.3997
96	0.3997	97	0.3997	98	0.3995	99	0.3987	100	0.3964
101	0.4032	102	0.4007	103	0.4000	104	0.3998	105	0.3997
106	0.3997	107	0.3996	108	0.3994	109	0.3987	110	0.3963
111	0.4032	112	0.4007	113	0.4000	114	0.3998	115	0.3997
116	0.3997	117	0.3996	118	0.3994	119	0.3987	120	0.3963
121	0.4031	122	0.4006	123	0.3999	124	0.3998	125	0.3997
126	0.3997	127	0.3996	128	0.3994	129	0.3987	130	0.3964
131	0.4027	132	0.4004	133	0.3999	134	0.3997	135	0.3997
136	0.3997	137	0.3997	138	0.3995	139	0.3989	140	0.3967
141	0.4011	142	0.4000	143	0.3998	144	0.3997	145	0.3997
146	0.3997	147	0.3997	148	0.3996	149	0.3994	150	0.3984

***** TIME STEP NO. 2 COMPLETED *****

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**** TIME STEP NUMBER : 3 ELAPSED SIMULATION TIME : 0.3145E+04 TIME STEP SIZE : 0.124E+04 ****

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SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	313	0.7192E+01
2	243	0.1394E+01
3	123	0.1980E+00

4	58	0.2975E-01
5	21	0.4737E-02
6	0	0.7857E-03

NONLINEAR ITERATION #. 1 NO. OF NON-CONVERGENT NODES = 284 MAX. ERROR = 6.220 AT NODE 231 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	243	0.1305E+01
2	193	0.2213E+00
3	101	0.1421E-01
4	14	0.1775E-02
5	0	0.3391E-03

NONLINEAR ITERATION #. 2 NO. OF NON-CONVERGENT NODES = 194 MAX. ERROR =-1.068 AT NODE 29 RELAX. FACTOR =0.8917

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	209	0.2710E+00
2	151	0.3765E-01
3	46	0.4686E-02
4	0	0.7501E-03

NONLINEAR ITERATION #. 3 NO. OF NON-CONVERGENT NODES = 168 MAX. ERROR =-.2307 AT NODE 55 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	153	0.4613E-01
2	90	0.9935E-02
3	0	0.9700E-03

NONLINEAR ITERATION #. 4 NO. OF NON-CONVERGENT NODES = 98 MAX. ERROR =-.3892E-01 AT NODE 66 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	119	0.9359E-02
2	14	0.1387E-02
3	0	0.1530E-03

NONLINEAR ITERATION #. 5 NO. OF NON-CONVERGENT NODES = 0 MAX. ERROR =0.7874E-02 AT NODE 16 RELAX. FACTOR =0.8737

*** NODAL HEAD VALUES ***

NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE
1	-86.4924	2	-85.5726	3	-80.3070	4	-70.1973	5	-55.4308
6	-36.7328	7	-9.314678E-24	8	-1.00000	9	-2.00000	10	-3.00000
11	-4.00000	12	-86.6596	13	-85.8717	14	-81.0340	15	-71.6411
16	-58.1916	17	-40.5642	18	-27.5143	19	-19.5349	20	-18.1891
21	-18.2851	22	-19.0403	23	-87.0942	24	-86.6450	25	-82.9240
26	-75.5042	27	-64.8900	28	-53.7372	29	-44.2564	30	-38.2386
31	-35.3533	32	-34.7403	33	-35.2829	34	-87.6369	35	-87.5946
36	-85.2726	37	-80.3623	38	-73.4436	39	-65.9230	40	-59.3483
41	-54.6314	42	-52.0013	43	-51.1082	44	-51.5387	45	-88.1271
46	-88.4260	47	-87.3166	48	-84.7006	49	-80.7666	50	-76.2183
51	-71.9521	52	-68.6613	53	-66.6508	54	-65.9204	55	-66.3507
56	-88.4783	57	-88.9932	58	-88.6620	59	-87.5527	60	-85.7326
61	-83.4513	62	-81.1362	63	-79.2190	64	-77.9960	65	-77.6096
66	-78.1191	67	-88.6871	68	-89.3100	69	-89.3613	70	-89.0103
71	-88.3417	72	-87.4451	73	-86.4757	74	-85.6337	75	-85.1129
76	-85.0774	77	-85.6739	78	-88.7937	79	-89.4615	80	-89.6678
81	-89.6201	82	-89.4269	83	-89.1463	84	-88.8366	85	-88.5769
86	-88.4685	87	-88.6441	88	-89.2884	89	-88.8420	90	-89.5262
91	-89.7873	92	-89.8435	93	-89.8105	94	-89.7399	95	-89.6635
96	-89.6184	97	-89.6654	98	-89.9155	99	-90.5717	100	-88.8622
101	-89.5518	102	-89.8305	103	-89.9190	104	-89.9342	105	-89.9252
106	-89.9164	107	-89.9329	108	-90.0229	109	-90.2906	110	-90.9476
111	-88.8711	112	-89.5622	113	-89.8460	114	-89.9436	115	-89.9722
116	-89.9799	117	-89.9889	118	-90.0210	119	-90.1211	120	-90.3920
121	-91.0484	122	-88.8783	123	-89.5693	124	-89.8534	125	-89.9525
126	-89.9840	127	-89.9956	128	-90.0085	129	-90.0437	130	-90.1452
131	-90.4159	132	-91.0719	133	-88.8944	134	-89.5834	135	-89.8631
136	-89.9586	137	-89.9884	138	-89.9998	139	-90.0124	140	-90.0459
141	-90.1444	142	-90.4118	143	-91.0665	144	-88.9470	145	-89.6254
146	-89.8871	147	-89.9676	148	-89.9917	149	-90.0007	150	-90.0107
151	-90.0380	152	-90.1220	153	-90.3753	154	-91.0222	155	-89.1151
156	-89.7669	157	-89.9339	158	-89.9818	159	-89.9955	160	-90.0005
161	-90.0061	162	-90.0218	163	-90.0722	164	-90.2362	165	-90.8643
166	-90.0000	167	-90.0000	168	-90.0000	169	-90.0000	170	-90.0000
171	-90.0000	172	-90.0000	173	-90.0000	174	-90.0000	175	-90.0000
176	-90.0000	177	-86.4924	178	-85.5726	179	-80.3070	180	-70.1973
181	-55.4309	182	-36.7328	183	-9.314659E-24	184	-1.00000	185	-2.00000

186	-3.00000	187	-4.00000	188	-86.6596	189	-85.8717	190	-81.0339
191	-71.6411	192	-58.1916	193	-40.5642	194	-27.5142	195	-19.5349
196	-18.1891	197	-18.2851	198	-19.0403	199	-87.0942	200	-86.6450
201	-82.9240	202	-75.5041	203	-64.8900	204	-53.7373	205	-44.2564
206	-38.2386	207	-35.3533	208	-34.7403	209	-35.2828	210	-87.6369
211	-87.5946	212	-85.2726	213	-80.3623	214	-73.4436	215	-65.9231
216	-59.3484	217	-54.6314	218	-52.0014	219	-51.1082	220	-51.5388
221	-88.1271	222	-88.4260	223	-87.3166	224	-84.7006	225	-80.7666
226	-76.2183	227	-71.9521	228	-68.6613	229	-66.6508	230	-65.9204
231	-66.3508	232	-88.4783	233	-88.9932	234	-88.6620	235	-87.5527
236	-85.7326	237	-83.4513	238	-81.1362	239	-79.2190	240	-77.9960
241	-77.6095	242	-78.1191	243	-88.6871	244	-89.3100	245	-89.3613
246	-89.0103	247	-88.3417	248	-87.4451	249	-86.4757	250	-85.6337
251	-85.1129	252	-85.0775	253	-85.6739	254	-88.7937	255	-89.4615
256	-89.6678	257	-89.6201	258	-89.4269	259	-89.1463	260	-88.8366
261	-88.5769	262	-88.4685	263	-88.6441	264	-89.2884	265	-88.8420
266	-89.5262	267	-89.7873	268	-89.8435	269	-89.8105	270	-89.7399
271	-89.6635	272	-89.6184	273	-89.6654	274	-89.9155	275	-90.5717
276	-88.8622	277	-89.5518	278	-89.8305	279	-89.9190	280	-89.9342
281	-89.9252	282	-89.9164	283	-89.9329	284	-90.0229	285	-90.2906
286	-90.9476	287	-88.8711	288	-89.5622	289	-89.8460	290	-89.9436
291	-89.9722	292	-89.9799	293	-89.9889	294	-90.0210	295	-90.1211
296	-90.3920	297	-91.0484	298	-88.8783	299	-89.5693	300	-89.8534
301	-89.9525	302	-89.9840	303	-89.9956	304	-90.0085	305	-90.0437
306	-90.1452	307	-90.4159	308	-91.0719	309	-88.8944	310	-89.5834
311	-89.8631	312	-89.9586	313	-89.9884	314	-89.9998	315	-90.0124
316	-90.0459	317	-90.1444	318	-90.4118	319	-91.0665	320	-88.9470
321	-89.6254	322	-89.8871	323	-89.9676	324	-89.9917	325	-90.0007
326	-90.0107	327	-90.0380	328	-90.1220	329	-90.3753	330	-91.0222
331	-89.1151	332	-89.7669	333	-89.9339	334	-89.9818	335	-89.9955
336	-90.0005	337	-90.0061	338	-90.0218	339	-90.0722	340	-90.2362
341	-90.8643	342	-90.0000	343	-90.0000	344	-90.0000	345	-90.0000
346	-90.0000	347	-90.0000	348	-90.0000	349	-90.0000	350	-90.0000
351	-90.0000	352	-90.0000								

*** LIST OF UNSATURATED ELEMENTS ***

ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE
1	0.4254	2	0.4451	3	0.4944	4	0.5740	5	0.6816
6	0.8252	7	0.9199	8	0.9321	9	0.9308	10	0.9261
11	0.4226	12	0.4389	13	0.4812	14	0.5494	15	0.6375
16	0.7231	17	0.7840	18	0.8144	19	0.8223	20	0.8210
21	0.4181	22	0.4290	23	0.4596	24	0.5094	25	0.5698
26	0.6277	27	0.6724	28	0.6995	29	0.7112	30	0.7121
31	0.4134	32	0.4187	33	0.4370	34	0.4676	35	0.5058
36	0.5440	37	0.5755	38	0.5966	39	0.6070	40	0.6083
41	0.4097	42	0.4107	43	0.4193	44	0.4351	45	0.4561
46	0.4785	47	0.4981	48	0.5122	49	0.5195	50	0.5198
51	0.4073	52	0.4058	53	0.4087	54	0.4153	55	0.4248
56	0.4355	57	0.4456	58	0.4531	59	0.4567	60	0.4556
61	0.4059	62	0.4034	63	0.4036	64	0.4057	65	0.4091
66	0.4132	67	0.4172	68	0.4201	69	0.4209	70	0.4186
71	0.4053	72	0.4023	73	0.4015	74	0.4019	75	0.4028
76	0.4041	77	0.4052	78	0.4058	79	0.4052	80	0.4023
81	0.4051	82	0.4019	83	0.4007	84	0.4005	85	0.4007
86	0.4010	87	0.4011	88	0.4010	89	0.3999	90	0.3968
91	0.4050	92	0.4017	93	0.4005	94	0.4001	95	0.4000
96	0.4000	97	0.3999	98	0.3995	99	0.3983	100	0.3952
101	0.4049	102	0.4016	103	0.4004	104	0.3999	105	0.3998
106	0.3997	107	0.3996	108	0.3991	109	0.3979	110	0.3948
111	0.4048	112	0.4016	113	0.4003	114	0.3999	115	0.3998
116	0.3997	117	0.3995	118	0.3991	119	0.3978	120	0.3948
121	0.4046	122	0.4014	123	0.4002	124	0.3999	125	0.3997
126	0.3997	127	0.3995	128	0.3991	129	0.3979	130	0.3949
131	0.4039	132	0.4010	133	0.4001	134	0.3998	135	0.3997

136	0.3997	137	0.3996	138	0.3993	139	0.3984	140	0.3955
141	0.4016	142	0.4002	143	0.3998	144	0.3997	145	0.3997
146	0.3997	147	0.3997	148	0.3995	149	0.3992	150	0.3979

***** TIME STEP NO. 3 COMPLETED *****

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**** TIME STEP NUMBER : 4 ELAPSED SIMULATION TIME : 0.4638E+04 TIME STEP SIZE : 0.149E+04 ****

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SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	317	0.4247E+01
2	271	0.6552E+00
3	144	0.5061E-01
4	49	0.5362E-02
5	0	0.6974E-03

NONLINEAR ITERATION #. 1 NO. OF NON-CONVERGENT NODES = 292 MAX. ERROR = 3.838 AT NODE 253 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	265	0.7801E+00
2	225	0.1122E+00
3	100	0.7585E-02
4	5	0.1267E-02
5	0	0.2045E-03

NONLINEAR ITERATION #. 2 NO. OF NON-CONVERGENT NODES = 224 MAX. ERROR =-.6597 AT NODE 55 RELAX. FACTOR =0.8916

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	238	0.1623E+00
2	153	0.2266E-01
3	29	0.2518E-02
4	0	0.3206E-03

NONLINEAR ITERATION #. 3 NO. OF NON-CONVERGENT NODES = 184 MAX. ERROR =-.1379 AT NODE 66 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	160	0.2361E-01
2	58	0.4466E-02
3	0	0.3109E-03

NONLINEAR ITERATION #. 4 NO. OF NON-CONVERGENT NODES = 86 MAX. ERROR =-.1886E-01 AT NODE 77 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	112	0.4668E-02
2	0	0.6864E-03

NONLINEAR ITERATION #. 5 NO. OF NON-CONVERGENT NODES = 0 MAX. ERROR =0.3982E-02 AT NODE 66 RELAX. FACTOR =0.8685

*** NODAL HEAD VALUES ***

NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE

1	-81.4076	2	-79.6226	3	-72.7724	4	-62.1551	5	-48.5483
6	-32.1646	7	-8.353959E-24	8	-1.00000	9	-2.00000	10	-3.00000
11	-4.00000	12	-81.8030	13	-80.1623	14	-73.6871	15	-63.6064
16	-50.9902	17	-35.4922	18	-23.9294	19	-16.8173	20	-15.5398
21	-15.6203	22	-16.3642	23	-82.8730	24	-81.6274	25	-76.1848
26	-67.6100	27	-57.0981	28	-46.7050	29	-38.0511	30	-32.5151
31	-29.8004	32	-29.1744	33	-29.7012	34	-84.3142	35	-83.6085
36	-79.6190	37	-73.0913	38	-65.3017	39	-57.5896	40	-51.1196
41	-46.5251	42	-43.9258	43	-43.0064	44	-43.4186	45	-85.7595
46	-85.5975	47	-83.1340	48	-78.7844	49	-73.3639	50	-67.8360
51	-63.0152	52	-59.4172	53	-57.2252	54	-56.3926	55	-56.7951
56	-86.9274	57	-87.1935	58	-85.9992	59	-83.5275	60	-80.1943
61	-76.5820	62	-73.2686	63	-70.6831	64	-69.0604	65	-68.4806
66	-68.9487	67	-87.7129	68	-88.2476	69	-87.8874	70	-86.7555
71	-85.0464	72	-83.0463	73	-81.0970	74	-79.5129	75	-78.5246
76	-78.2751	77	-78.8398	78	-88.1655	79	-88.8374	80	-88.9179
81	-88.5435	82	-87.8446	83	-86.9567	84	-86.0453	85	-85.2927
86	-84.8722	87	-84.9334	88	-85.5896	89	-88.3960	90	-89.1278
91	-89.4021	92	-89.3709	93	-89.1568	94	-88.8465	95	-88.5213
96	-88.2745	97	-88.2162	98	-88.4739	99	-89.1839	100	-88.5036
101	-89.2585	102	-89.6072	103	-89.7079	104	-89.6823	105	-89.6032
106	-89.5218	107	-89.4925	108	-89.5902	109	-89.9259	110	-90.6528
111	-88.5530	112	-89.3158	113	-89.6899	114	-89.8355	115	-89.8737
116	-89.8724	117	-89.8727	118	-89.9152	119	-90.0619	120	-90.4180
121	-91.1469	122	-88.5825	123	-89.3467	124	-89.7267	125	-89.8842
126	-89.9407	127	-89.9621	128	-89.9857	129	-90.0474	130	-90.2052
131	-90.5638	132	-91.2917	133	-88.6210	134	-89.3821	135	-89.7554
136	-89.9088	137	-89.9656	138	-89.9906	139	-90.0177	140	-90.0795
141	-90.2335	142	-90.5862	143	-91.3114	144	-88.7139	145	-89.4592
146	-89.8037	147	-89.9321	148	-89.9783	149	-89.9989	150	-90.0212
151	-90.0718	152	-90.2021	153	-90.5313	154	-91.2438	155	-88.9602
156	-89.6686	157	-89.8870	158	-89.9627	159	-89.9890	160	-90.0005
161	-90.0130	162	-90.0419	163	-90.1194	164	-90.3297	165	-91.0120
166	-90.0000	167	-90.0000	168	-90.0000	169	-90.0000	170	-90.0000
171	-90.0000	172	-90.0000	173	-90.0000	174	-90.0000	175	-90.0000
176	-90.0000	177	-81.4076	178	-79.6226	179	-72.7724	180	-62.1552
181	-48.5483	182	-32.1644	183	-8.353915E-24	184	-1.00000	185	-2.00000
186	-3.00000	187	-4.00000	188	-81.8030	189	-80.1623	190	-73.6871
191	-63.6065	192	-50.9902	193	-35.4921	194	-23.9293	195	-16.8172
196	-15.5397	197	-15.6203	198	-16.3641	199	-82.8730	200	-81.6274
201	-76.1848	202	-67.6101	203	-57.0982	204	-46.7050	205	-38.0510
206	-32.5150	207	-29.8003	208	-29.1743	209	-29.7012	210	-84.3143
211	-83.6085	212	-79.6189	213	-73.0914	214	-65.3017	215	-57.5897
216	-51.1197	217	-46.5251	218	-43.9258	219	-43.0064	220	-43.4186
221	-85.7596	222	-85.5975	223	-83.1340	224	-78.7844	225	-73.3639
226	-67.8361	227	-63.0153	228	-59.4173	229	-57.2253	230	-56.3926
231	-56.7952	232	-86.9274	233	-87.1935	234	-85.9992	235	-83.5274
236	-80.1943	237	-76.5819	238	-73.2687	239	-70.6831	240	-69.0605
241	-68.4807	242	-68.9488	243	-87.7129	244	-88.2476	245	-87.8874
246	-86.7555	247	-85.0464	248	-83.0463	249	-81.0970	250	-79.5128
251	-78.5246	252	-78.2751	253	-78.8397	254	-88.1655	255	-88.8374
256	-88.9179	257	-88.5435	258	-87.8446	259	-86.9567	260	-86.0453
261	-85.2927	262	-84.8722	263	-84.9334	264	-85.5896	265	-88.3960
266	-89.1278	267	-89.4021	268	-89.3709	269	-89.1568	270	-88.8465
271	-88.5213	272	-88.2745	273	-88.2162	274	-88.4739	275	-89.1839
276	-88.5036	277	-89.2585	278	-89.6072	279	-89.7079	280	-89.6823
281	-89.6032	282	-89.5218	283	-89.4925	284	-89.5902	285	-89.9259
286	-90.6528	287	-88.5530	288	-89.3158	289	-89.6899	290	-89.8355
291	-89.8737	292	-89.8724	293	-89.8727	294	-89.9152	295	-90.0619
296	-90.4180	297	-91.1469	298	-88.5825	299	-89.3467	300	-89.7267
301	-89.8842	302	-89.9407	303	-89.9621	304	-89.9857	305	-90.0474
306	-90.2052	307	-90.5638	308	-91.2917	309	-88.6210	310	-89.3821
311	-89.7554	312	-89.9088	313	-89.9656	314	-89.9906	315	-90.0177
316	-90.0795	317	-90.2335	318	-90.5862	319	-91.3114	320	-88.7139
321	-89.4592	322	-89.8037	323	-89.9321	324	-89.9783	325	-89.9989
326	-90.0212	327	-90.0718	328	-90.2021	329	-90.5313	330	-91.2438
331	-88.9602	332	-89.6686	333	-89.8870	334	-89.9627	335	-89.9890
336	-90.0005	337	-90.0130	338	-90.0419	339	-90.1194	340	-90.3297
341	-91.0120	342	-90.0000	343	-90.0000	344	-90.0000	345	-90.0000

346	-90.0000	347	-90.0000	348	-90.0000	349	-90.0000	350	-90.0000
351	-90.0000	352	-90.0000						

*** LIST OF UNSATURATED ELEMENTS ***

ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE
1	0.4614	2	0.4893	3	0.5461	4	0.6243	5	0.7212
6	0.8473	7	0.9304	8	0.9410	9	0.9397	10	0.9350
11	0.4556	12	0.4803	13	0.5313	14	0.6010	15	0.6827
16	0.7596	17	0.8144	18	0.8421	19	0.8497	20	0.8485
21	0.4457	22	0.4647	23	0.5056	24	0.5613	25	0.6220
26	0.6774	27	0.7195	28	0.7453	29	0.7567	30	0.7577
31	0.4343	32	0.4465	33	0.4754	34	0.5155	35	0.5596
36	0.6005	37	0.6330	38	0.6547	39	0.6656	40	0.6671
41	0.4239	42	0.4298	43	0.4473	44	0.4733	45	0.5031
46	0.5319	47	0.5558	48	0.5725	49	0.5812	50	0.5821
51	0.4162	52	0.4175	53	0.4261	54	0.4405	55	0.4583
56	0.4764	57	0.4921	58	0.5035	59	0.5092	60	0.5088
61	0.4114	62	0.4099	63	0.4129	64	0.4194	65	0.4282
66	0.4378	67	0.4465	68	0.4527	69	0.4554	70	0.4537
71	0.4088	72	0.4059	73	0.4060	74	0.4082	75	0.4117
76	0.4158	77	0.4195	78	0.4220	79	0.4222	80	0.4194
81	0.4076	82	0.4040	83	0.4029	84	0.4032	85	0.4042
86	0.4055	87	0.4067	88	0.4071	89	0.4060	90	0.4026
91	0.4070	92	0.4032	93	0.4016	94	0.4012	95	0.4013
96	0.4016	97	0.4017	98	0.4013	99	0.3997	100	0.3961
101	0.4067	102	0.4029	103	0.4011	104	0.4005	105	0.4003
106	0.4002	107	0.4000	108	0.3993	109	0.3976	110	0.3940
111	0.4065	112	0.4027	113	0.4009	114	0.4002	115	0.3999
116	0.3998	117	0.3995	118	0.3988	119	0.3971	120	0.3934
121	0.4061	122	0.4024	123	0.4007	124	0.4001	125	0.3998
126	0.3997	127	0.3994	128	0.3987	129	0.3971	130	0.3936
131	0.4050	132	0.4017	133	0.4004	134	0.3999	135	0.3998
136	0.3996	137	0.3995	138	0.3990	139	0.3977	140	0.3945
141	0.4020	142	0.4004	143	0.4000	144	0.3998	145	0.3997
146	0.3997	147	0.3996	148	0.3994	149	0.3990	150	0.3975

***** TIME STEP NO. 4 COMPLETED *****

**** TIME STEP NUMBER : 5 ELAPSED SIMULATION TIME : 0.6430E+04 TIME STEP SIZE : 0.179E+04 ****

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR

1	318	0.3706E+01
2	287	0.3935E+00
3	165	0.2335E-01
4	18	0.1989E-02
5	0	0.1913E-03

NONLINEAR ITERATION #. 1 NO. OF NON-CONVERGENT NODES = 296 MAX. ERROR = 3.424 AT NODE 177 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	294	0.5312E+00
2	251	0.8412E-01
3	99	0.6604E-02
4	0	0.6727E-03

NONLINEAR ITERATION #. 2 NO. OF NON-CONVERGENT NODES = 248 MAX. ERROR =-.4554 AT NODE 66 RELAX. FACTOR =0.9151

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	265	0.1006E+00
2	175	0.1422E-01
3	11	0.1366E-02
4	0	0.1697E-03

NONLINEAR ITERATION #. 3 NO. OF NON-CONVERGENT NODES = 188 MAX. ERROR =-.8525E-01 AT NODE 77 RELAX. FACTOR = 1.000

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	175	0.1412E-01
2	45	0.2202E-02
3	0	0.1588E-03

NONLINEAR ITERATION #. 4 NO. OF NON-CONVERGENT NODES = 24 MAX. ERROR =0.1179E-01 AT NODE 52 RELAX. FACTOR =0.9119

SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	80	0.2907E-02
2	0	0.4310E-03

NONLINEAR ITERATION #. 5 NO. OF NON-CONVERGENT NODES = 0 MAX. ERROR =0.2476E-02 AT NODE 62 RELAX. FACTOR = 1.000

*** NODAL HEAD VALUES ***

NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE	NODE	HEAD VALUE
1	-73.4454	2	-71.6633	3	-65.1440	4	-55.4946	5	-43.4378
6	-28.9359	7	-8.847753E-24	8	-1.00000	9	-2.00000	10	-3.00000
11	-4.00000	12	-74.0387	13	-72.3537	14	-66.0911	15	-56.8376
16	-45.5858	17	-31.8705	18	-21.4950	19	-15.0728	20	-13.9099
21	-14.0152	22	-14.7621	23	-75.7026	24	-74.2933	25	-68.7471
26	-60.5926	27	-51.0125	28	-41.6401	29	-33.8290	30	-28.7894
31	-26.2965	32	-25.7243	33	-26.2602	34	-78.1140	35	-77.1130
36	-72.6180	37	-65.9422	38	-58.4371	39	-51.2209	40	-45.2221
41	-40.9571	42	-38.5268	43	-37.6689	44	-38.0927	45	-80.8156
46	-80.2887	47	-77.0101	48	-71.9498	49	-66.1842	50	-60.6100
51	-55.8786	52	-52.3819	53	-50.2518	54	-49.4416	55	-49.8490
56	-83.3370	57	-83.2700	58	-81.1994	59	-77.6989	60	-73.5231
61	-69.3588	62	-65.7301	63	-62.9741	64	-61.2588	65	-60.6308
66	-61.0854	67	-85.3359	68	-85.6434	69	-84.6015	70	-82.4950
71	-79.7756	72	-76.9198	73	-74.3387	74	-72.3339	75	-71.0936
76	-70.7175	77	-71.2489	78	-86.6943	79	-87.2547	80	-86.9473
81	-85.9188	82	-84.4151	83	-82.7222	84	-81.1231	85	-79.8612
86	-79.1207	87	-79.0266	88	-79.6478	89	-87.4988	90	-88.2010
91	-88.3242	92	-87.9773	93	-87.3130	94	-86.4942	95	-85.6899
96	-85.0661	97	-84.7734	98	-84.9373	99	-85.6404	100	-87.9263
101	-88.6958	102	-89.0288	103	-89.0306	104	-88.8242	105	-88.5180
106	-88.2124	107	-88.0106	108	-88.0215	109	-88.3564	110	-89.1105
111	-88.1403	112	-88.9374	113	-89.3579	114	-89.5083	115	-89.5035
116	-89.4315	117	-89.3621	118	-89.3646	119	-89.5204	120	-89.9296
121	-90.7021	122	-88.2555	123	-89.0613	124	-89.5107	125	-89.7133
126	-89.7820	127	-89.7970	128	-89.8155	129	-89.8919	130	-90.0959
131	-90.5242	132	-91.2984	133	-88.3504	134	-89.1539	135	-89.6004
136	-89.8086	137	-89.8938	138	-89.9328	139	-89.9748	140	-90.0664
141	-90.2736	142	-90.6959	143	-91.4657	144	-88.5026	145	-89.2862
146	-89.6951	147	-89.8710	148	-89.9439	149	-89.9802	150	-90.0189
151	-90.0968	152	-90.2722	153	-90.6610	154	-91.4127	155	-88.8325
156	-89.5708	157	-89.8289	158	-89.9325	159	-89.9743	160	-89.9954
161	-90.0178	162	-90.0625	163	-90.1660	164	-90.4109	165	-91.1216
166	-90.0000	167	-90.0000	168	-90.0000	169	-90.0000	170	-90.0000
171	-90.0000	172	-90.0000	173	-90.0000	174	-90.0000	175	-90.0000
176	-90.0000	177	-73.4454	178	-71.6632	179	-65.1440	180	-55.4947
181	-43.4377	182	-28.9358	183	-8.847716E-24	184	-1.00000	185	-2.00000

186	-3.00000	187	-4.00000	188	-74.0387	189	-72.3536	190	-66.0912
191	-56.8377	192	-45.5858	193	-31.8704	194	-21.4949	195	-15.0727
196	-13.9098	197	-14.0151	198	-14.7621	199	-75.7026	200	-74.2932
201	-68.7471	202	-60.5927	203	-51.0126	204	-41.6400	205	-33.8289
206	-28.7893	207	-26.2964	208	-25.7242	209	-26.2601	210	-78.1140
211	-77.1130	212	-72.6180	213	-65.9423	214	-58.4371	215	-51.2209
216	-45.2221	217	-40.9571	218	-38.5268	219	-37.6689	220	-38.0927
221	-80.8156	222	-80.2886	223	-77.0101	224	-71.9498	225	-66.1843
226	-60.6101	227	-55.8786	228	-52.3820	229	-50.2518	230	-49.4416
231	-49.8491	232	-83.3371	233	-83.2700	234	-81.1994	235	-77.6989
236	-73.5231	237	-69.3589	238	-65.7301	239	-62.9742	240	-61.2589
241	-60.6308	242	-61.0855	243	-85.3359	244	-85.6434	245	-84.6014
246	-82.4950	247	-79.7755	248	-76.9198	249	-74.3387	250	-72.3339
251	-71.0937	252	-70.7175	253	-71.2489	254	-86.6943	255	-87.2548
256	-86.9473	257	-85.9188	258	-84.4151	259	-82.7222	260	-81.1231
261	-79.8611	262	-79.1206	263	-79.0266	264	-79.6478	265	-87.4988
266	-88.2010	267	-88.3242	268	-87.9774	269	-87.3130	270	-86.4942
271	-85.6899	272	-85.0661	273	-84.7734	274	-84.9373	275	-85.6404
276	-87.9263	277	-88.6958	278	-89.0288	279	-89.0306	280	-88.8242
281	-88.5180	282	-88.2124	283	-88.0106	284	-88.0215	285	-88.3564
286	-89.1105	287	-88.1403	288	-88.9374	289	-89.3579	290	-89.5083
291	-89.5035	292	-89.4315	293	-89.3621	294	-89.3646	295	-89.5204
296	-89.9296	297	-90.7021	298	-88.2555	299	-89.0613	300	-89.5107
301	-89.7133	302	-89.7820	303	-89.7970	304	-89.8155	305	-89.8919
306	-90.0959	307	-90.5242	308	-91.2984	309	-88.3504	310	-89.1539
311	-89.6004	312	-89.8086	313	-89.8938	314	-89.9328	315	-89.9748
316	-90.0664	317	-90.2736	318	-90.6959	319	-91.4657	320	-88.5026
321	-89.2862	322	-89.6951	323	-89.8710	324	-89.9439	325	-89.9802
326	-90.0189	327	-90.0968	328	-90.2722	329	-90.6610	330	-91.4127
331	-88.8325	332	-89.5708	333	-89.8289	334	-89.9325	335	-89.9743
336	-89.9954	337	-90.0178	338	-90.0625	339	-90.1660	340	-90.4109
341	-91.1216	342	-90.0000	343	-90.0000	344	-90.0000	345	-90.0000
346	-90.0000	347	-90.0000	348	-90.0000	349	-90.0000	350	-90.0000
351	-90.0000	352	-90.0000						

*** LIST OF UNSATURATED ELEMENTS ***

ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE	ELEM.	SAT. VALUE
1	0.5139	2	0.5410	3	0.5939	4	0.6642	5	0.7502
6	0.8628	7	0.9374	8	0.9467	9	0.9451	10	0.9403
11	0.5058	12	0.5306	13	0.5793	14	0.6431	15	0.7163
16	0.7852	17	0.8346	18	0.8598	19	0.8667	20	0.8653
21	0.4910	22	0.5118	23	0.5533	24	0.6065	25	0.6626
26	0.7133	27	0.7519	28	0.7756	29	0.7862	30	0.7870
31	0.4725	32	0.4880	33	0.5206	34	0.5623	35	0.6057
36	0.6449	37	0.6758	38	0.6963	39	0.7067	40	0.7081
41	0.4535	42	0.4635	43	0.4866	44	0.5175	45	0.5503
46	0.5805	47	0.6049	48	0.6217	49	0.6305	50	0.6315
51	0.4371	52	0.4419	53	0.4564	54	0.4773	55	0.5005
56	0.5225	57	0.5408	58	0.5537	59	0.5603	60	0.5603
61	0.4248	62	0.4256	63	0.4331	64	0.4454	65	0.4600
66	0.4746	67	0.4870	68	0.4957	69	0.4998	70	0.4987
71	0.4170	72	0.4152	73	0.4178	74	0.4237	75	0.4315
76	0.4397	77	0.4468	78	0.4517	79	0.4533	80	0.4510
81	0.4125	82	0.4093	83	0.4091	84	0.4111	85	0.4145
86	0.4182	87	0.4214	88	0.4233	89	0.4229	90	0.4196
91	0.4102	92	0.4063	93	0.4048	94	0.4049	95	0.4059
96	0.4072	97	0.4081	98	0.4082	99	0.4067	100	0.4029
101	0.4090	102	0.4049	103	0.4029	104	0.4022	105	0.4022
106	0.4024	107	0.4023	108	0.4016	109	0.3996	110	0.3956
111	0.4083	112	0.4042	113	0.4020	114	0.4010	115	0.4007
116	0.4005	117	0.4001	118	0.3992	119	0.3970	120	0.3931
121	0.4075	122	0.4035	123	0.4014	124	0.4005	125	0.4001
126	0.3999	127	0.3994	128	0.3985	129	0.3965	130	0.3926
131	0.4060	132	0.4024	133	0.4008	134	0.4002	135	0.3999

136	0.3997	137	0.3994	138	0.3987	139	0.3972	140	0.3937
141	0.4024	142	0.4007	143	0.4001	144	0.3999	145	0.3998
146	0.3997	147	0.3996	148	0.3993	149	0.3987	150	0.3971

***** TIME STEP NO. 5 COMPLETED *****

==

***** SAMFT3D HAS SOLVED THE PROBLEM *****

****
*** CPU TIME USED: 396.7 SECS. ***
****

10.3 EXAMPLE 2: TWO-DIMENSIONAL TRANSPORT IN A RECTANGULAR SOIL SLAB

10.3.1 Input Data

This problem is described in Section 4.3.2. It is associated with the unsaturated flow problem described in Section 4.2.2. The input data file corresponding to the problem is displayed in Table 10.3. This file is on Unit 5 and is used in conjunction with the file in Unit 9. The latter contains centroidal values of element Darcy velocity and water saturation produced by the flow simulation run.

Table 10.3 Input data for the two-dimensional transport problem in a soil slab.

```
 1    1                                                                                     GROUP 1
 Two-dimensional transport in soil slab (test problem 10.2)                                 GROUP 2
 0    2    1    0    1    0    1    5  352  150    1    0    0    0                         GROUP 3
 0    1       .01       .01       .10        1.        .0    5       1.0                    GROUP 4
 1    0    0    0    0    0    0    1    0    0    0    0                                   GROUP 5
      0.   .864E3       1.2   .432E04                                                       GROUP 6
   0.00                                                                                     GROUP 7
      1.        0.        1.        0.     0.450      1.46                                  GROUP 10A
2.55E-7       .01                                                                           GROUP 10B
1.15E-7     .3082                                                                           GROUP 10C
11   16    2         1.        1.      10.    0    0    2                                   GROUP 11
      1.        1.       15.       10.        1.        1.        0.        0.              GROUP 13A
     10.       10.        1.        0.                                                      GROUP 13B
10    0    0    0                                                                           GROUP 14A
 7    1        1.                                                                           GROUP 14B
 8    1        1.                                                                           GROUP 14B
 9    1        1.                                                                           GROUP 14B
10    1        1.                                                                           GROUP 14B
11    1        1.                                                                           GROUP 14B
183   1        1.                                                                           GROUP 14B
184   1        1.                                                                           GROUP 14B
185   1        1.                                                                           GROUP 14B
186   1        1.                                                                           GROUP 14B
187   1        1.                                                                           GROUP 14B
 0        0.        0.        0.                                                            GROUP 18
 1        1.        1.        1.        1.                                                  GROUP 19
```

10.3.2. Sample Output

The printed output file on Unit 6 is displayed in Table 10.4. This output consists of the following categories of information:

1. Problem specification parameters
2. Simulation control parameters
3. Time-stepping and iteration control parameters
4. Input/Output control parameters
5. Time stepping data
6. Default initial values
7. Solute property information
8. Porous material data
9. Mesh data
10. Prescribed boundary condition data
11. Initial condition data
12. Maximum matrix bandwidth for each slice
13. Time step number and time value
14. Matrix subiteration summary data
15. Node numbers and concentration values corresponding to the given time value

** Note that information in categories 13 through 15 are repeated for each time step.

Table 10.4 Output for the two-dimensional transport problem in a soil slab.

```
*******************************************************************************

                              THIS OUTPUT GENERATED BY SAMFT3D
                              INPUT FILE NAME = P10-5.DAT

*******************************************************************************


      PROBLEM IDENTIFICATION NUMBER =     1

      PROBLEM EXECUTION INDEX........(IEXEC) =     1


      PROBLEM TITLE
      --------------------------------------------------------------------------------

         Two-dimensional transport in soil slab (test problem 10.2)

      --------------------------------------------------------------------------------



      PROBLEM SPECIFICATION PARAMETERS
      --------------------------------
      MODEL OPTION PARAMETER ....................(IMODL) =     0
        NOTE:  IMODL = 0 FOR SOLUTE TRANSPORT ONLY
                     = 1 FOR FLUID FLOW ONLY
                     = 2 FOR COUPLED FLOW AND TRANSPORT
      TOTAL NUMBER OF FLUID PHASES............ (NTPHAS) =     2
      NUMBER OF ACTIVE FLUID PHASES........... (NMPHAS) =     1
      MATERIAL NUMBER INPUT  ? (1=YES,0=NO)(IMNUMR).... =     0
      TOTAL NUMBER OF DEPENDENT VARIABLES........(NVAR) =     1
      STEADY STATE SIMULATION(1=YES, 0=NO)......(ISSTA) =     0
      TIME STEP GENERATION INDEX (1=YES, 0=NO) .(ITSGN) =     1
      NUMBER OF TIME STEPS ........................(NTS) =     5
      TOTAL NUMBER OF NODES ........................(NP) =   352
      TOTAL NUMBER OF ELEMENTS .....................(NE) =   150
      NUMBER OF POROUS MATERIALS ................(NMAT) =     1
      SOIL CONSTITUTIVE DATA(0=FUNCTION,1=TABLE)(KPROP) =     0
      INITIAL CONDITION NON-UNIFORMITY INDEX ....(NONU) =     0
      SEQUENCE OF NODE NUMBERING (0=Y-,1=X-DIR).(ISWAP) =     0


      INPUT / OUTPUT CONTROL PARAMETERS
      ---------------------------------
      VELOCITY/INPUT............................(NVREAD) =     1
      BOUNDARY NODE DATA READ (1=YES, 0=NO)....(IOUTLT) =     0
      NUMBER OF NODES FOR WHICH I.C. ARE READ....(NPIN) =     0
      OUTPUT REQUIREMENT INDICATOR:
       (0=ALL DATA, 1=NO ELEMENT DATA,
        2=NO MESH DATA, 3=NO MESH AND I.C. DATA..(IPRD) =     0
      UNIT 9 OUTPUT (1=YES, 0=NO)..............(NVWRIT) =     0
      VELOCITY PRINTOUT CONTROL INDEX............(NVPR) =     0
      UNIT 10 OUTPUT (0=NONE, N=NTH)............(NPLOT) =     0
      NODAL VALUE PRINTOUT CONTROL INDEX........(NSTEP) =     1
      OBSERVATION NODE INDEX...................(IOBSND) =     0
      UNIT 8 OUTPUT (1=YES, 0=NO)..............(NOWRIT) =     0
      PRINT CHECK OPTION INDEX.................(IPRCHK) =     0

      TIME STEP. PARAMETER FOR TRANSPORT SIMULATION.(IKALL) =     0
      CONC. TOLERANCE FOR TRANSPORT MATRIX SOLTN..(CTOL) =  0.1000E+00
```

```
TIME STEPPING DATA
------------------
INITIAL TIME VALUE .........................(TIMA) =  0.0000E+00
VALUE OF FIRST TIME STEP ...................(TIN) =  0.8640E+03
TIME STEP MULTIPLIER .......................(TFAC) =  0.1200E+01
MAXIMUM TIME STEP SIZE .....................(TMAX) =  0.4320E+04


DEFAULT INITIAL VALUES OF VARIABLES TO BE SOLVED
------------------------------------------------

          0.0000E+00


TRANSPORT PROPERTIES OF POROUS MEDIA
------------------------------------


MATERIAL NUMBER:    1  (I)

LONGITUDINAL DISPERSIVITY.............(PROPJ(I,1)) =  0.1000E+01
TRANSVERSE DISPERSIVITY...............(PROPJ(I,2)) =  0.0000E+00
TORTUIOSITY FACTOR................. ..(PROPJ(I,3)) =  0.1000E+01
DIFFUSION COEFFICIENT PARAMETER.......(PROPJ(I,4)) =  0.0000E+00
EFFECTIVE POROSITY....................(PROPJ(I,5)) =  0.4500E+00
BULK DENSITY .........................(PROPJ(I,6)) =  0.1460E+01

MOLECULAR DIFFUSION COEFFICIENT OF PHASE 1 THROUGH NTPHAS

0.2550E-06     0.1000E-01


SOLUTE PROPERTIES
-----------------

MATERIAL NUMBER:    1  (I)
DECAY COEFFICIENT .................... (RPROP(I,1)) =  0.1150E-06
DISTRIBUTION COEFFICIENT ............ (RPROP(I,2)) =  0.3082E+00


MESH GENERATION PARAMETERS
--------------------------
NUMBER OF GRID LINES PARALLEL TO X-AXIS  (NROWS)  =    11
NUMBER OF GRID LINES PARALLEL TO Y-AXIS  (NCOLS)  =    16
NUMBER OF PLANES USED IN THE MESH ......(NPLANE)  =     2
MAXIMUM ALLOWABLE VALUE OF X-INCREMENT ..(DXMAX)  = 0.100E+01
MAXIMUM ALLOWABLE VALUE OF Y-INCREMENT ..(DYMAX)  = 0.100E+01
MAXIMUM ALLOWABLE VALUE OF Z-INCREMENT ..(DZMAX)  = 0.100E+02
GRID LINE COORDINATE INPUT CODE  .......(IXYZRD)  =     0
HORIZONTAL PLANE DOMAIN INDICATOR.......(IHORGR)  =     0
NUMBER OF SLICES ........................(NSLICE) =     2

X-INCREMENT OF THE FIRST GRID BLOCK ........(DX)  =     1.000
Y-INCREMENT OF THE FIRST GRID BLOCK ........(DY)  =     1.000
MAXIMUM VALUE OF X-COORDINATE ..............(X0)  =    15.000
MAXIMUM VALUE OF Y-COORDINATE ..............(Y0)  =    10.000
X-INCREMENT MULTIPLIER ....................(SCFX)  =     1.000
Y-INCREMENT MULTIPLIER ....................(SCFY)  =     1.000
MINIMUM VALUE OF X-COORDINATE ..........(XSTART)  =     0.000
MINIMUM VALUE OF Y-COORDINATE ..........(YSTART)  =     0.000

Z-INCREMENT OF THE FIRST GRID BLOCK ........(DZ)  =    10.000
MAXIMUM VALUE OF Z-COORDINATE ..............(Z0)  =    10.000
Z-INCREMENT MULTIPLIER ....................(SCFZ)  =     1.000
MINIMUM VALUE OF Z-COORDINATE ..........(ZSTART)  =     0.000
```

*** X-COORDINATES OF GRID LINES ***

0.000	1.000	2.000	3.000	4.000	5.000	6.000	7.000
8.000	9.000	10.000	11.000	12.000	13.000	14.000	15.000

*** Y-COORDINATES OF GRID LINES ***

0.000	1.000	2.000	3.000	4.000	5.000	6.000	7.000
8.000	9.000	10.000					

*** Z-COORDINATES OF GRID LINES ***

0.000	10.000

LIST OF ELEMENT NUMBERS AND NODAL CONNECTION DATA

ELEMENT #	NODAL CONNECTIONS							
1	1	12	13	2	177	188	189	178
3	3	14	15	4	179	190	191	180
5	5	16	17	6	181	192	193	182
7	7	18	19	8	183	194	195	184
9	9	20	21	10	185	196	197	186
11	12	23	24	13	188	199	200	189
13	14	25	26	15	190	201	202	191
15	16	27	28	17	192	203	204	193
17	18	29	30	19	194	205	206	195
19	20	31	32	21	196	207	208	197
21	23	34	35	24	199	210	211	200
23	25	36	37	26	201	212	213	202
25	27	38	39	28	203	214	215	204
27	29	40	41	30	205	216	217	206
29	31	42	43	32	207	218	219	208
31	34	45	46	35	210	221	222	211
33	36	47	48	37	212	223	224	213
35	38	49	50	39	214	225	226	215
37	40	51	52	41	216	227	228	217
39	42	53	54	43	218	229	230	219
41	45	56	57	46	221	232	233	222
43	47	58	59	48	223	234	235	224
45	49	60	61	50	225	236	237	226
47	51	62	63	52	227	238	239	228
49	53	64	65	54	229	240	241	230
51	56	67	68	57	232	243	244	233
53	58	69	70	59	234	245	246	235
55	60	71	72	61	236	247	248	237
57	62	73	74	63	238	249	250	239
59	64	75	76	65	240	251	252	241
61	67	78	79	68	243	254	255	244
63	69	80	81	70	245	256	257	246
65	71	82	83	72	247	258	259	248
67	73	84	85	74	249	260	261	250
69	75	86	87	76	251	262	263	252
71	78	89	90	79	254	265	266	255
73	80	91	92	81	256	267	268	257
75	82	93	94	83	258	269	270	259
77	84	95	96	85	260	271	272	261

ELEMENT #	NODAL CONNECTIONS							
2	2	13	14	3	178	189	190	179
4	4	15	16	5	180	191	192	181
6	6	17	18	7	182	193	194	183
8	8	19	20	9	184	195	196	185
10	10	21	22	11	186	197	198	187
12	13	24	25	14	189	200	201	190
14	15	26	27	16	191	202	203	192
16	17	28	29	18	193	204	205	194
18	19	30	31	20	195	206	207	196
20	21	32	33	22	197	208	209	198
22	24	35	36	25	200	211	212	201
24	26	37	38	27	202	213	214	203
26	28	39	40	29	204	215	216	205
28	30	41	42	31	206	217	218	207
30	32	43	44	33	208	219	220	209
32	35	46	47	36	211	222	223	212
34	37	48	49	38	213	224	225	214
36	39	50	51	40	215	226	227	216
38	41	52	53	42	217	228	229	218
40	43	54	55	44	219	230	231	220
42	46	57	58	47	222	233	234	223
44	48	59	60	49	224	235	236	225
46	50	61	62	51	226	237	238	227
48	52	63	64	53	228	239	240	229
50	54	65	66	55	230	241	242	231
52	57	68	69	58	233	244	245	234
54	59	70	71	60	235	246	247	236
56	61	72	73	62	237	248	249	238
58	63	74	75	64	239	250	251	240
60	65	76	77	66	241	252	253	242
62	68	79	80	69	244	255	256	245
64	70	81	82	71	246	257	258	247
66	72	83	84	73	248	259	260	249
68	74	85	86	75	250	261	262	251
70	76	87	88	77	252	263	264	253
72	79	90	91	80	255	266	267	256
74	81	92	93	82	257	268	269	258
76	83	94	95	84	259	270	271	260
78	85	96	97	86	261	272	273	262

79	86	97	98	87	262	273	274	263	80	87	98	99	88	263	274	275	264
81	89	100	101	90	265	276	277	266	82	90	101	102	91	266	277	278	267
83	91	102	103	92	267	278	279	268	84	92	103	104	93	268	279	280	269
85	93	104	105	94	269	280	281	270	86	94	105	106	95	270	281	282	271
87	95	106	107	96	271	282	283	272	88	96	107	108	97	272	283	284	273
89	97	108	109	98	273	284	285	274	90	98	109	110	99	274	285	286	275
91	100	111	112	101	276	287	288	277	92	101	112	113	102	277	288	289	278
93	102	113	114	103	278	289	290	279	94	103	114	115	104	279	290	291	280
95	104	115	116	105	280	291	292	281	96	105	116	117	106	281	292	293	282
97	106	117	118	107	282	293	294	283	98	107	118	119	108	283	294	295	284
99	108	119	120	109	284	295	296	285	100	109	120	121	110	285	296	297	286
101	111	122	123	112	287	298	299	288	102	112	123	124	113	288	299	300	289
103	113	124	125	114	289	300	301	290	104	114	125	126	115	290	301	302	291
105	115	126	127	116	291	302	303	292	106	116	127	128	117	292	303	304	293
107	117	128	129	118	293	304	305	294	108	118	129	130	119	294	305	306	295
109	119	130	131	120	295	306	307	296	110	120	131	132	121	296	307	308	297
111	122	133	134	123	298	309	310	299	112	123	134	135	124	299	310	311	300
113	124	135	136	125	300	311	312	301	114	125	136	137	126	301	312	313	302
115	126	137	138	127	302	313	314	303	116	127	138	139	128	303	314	315	304
117	128	139	140	129	304	315	316	305	118	129	140	141	130	305	316	317	306
119	130	141	142	131	306	317	318	307	120	131	142	143	132	307	318	319	308
121	133	144	145	134	309	320	321	310	122	134	145	146	135	310	321	322	311
123	135	146	147	136	311	322	323	312	124	136	147	148	137	312	323	324	313
125	137	148	149	138	313	324	325	314	126	138	149	150	139	314	325	326	315
127	139	150	151	140	315	326	327	316	128	140	151	152	141	316	327	328	317
129	141	152	153	142	317	328	329	318	130	142	153	154	143	318	329	330	319
131	144	155	156	145	320	331	332	321	132	145	156	157	146	321	332	333	322
133	146	157	158	147	322	333	334	323	134	147	158	159	148	323	334	335	324
135	148	159	160	149	324	335	336	325	136	149	160	161	150	325	336	337	326
137	150	161	162	151	326	337	338	327	138	151	162	163	152	327	338	339	328
139	152	163	164	153	328	339	340	329	140	153	164	165	154	329	340	341	330
141	155	166	167	156	331	342	343	332	142	156	167	168	157	332	343	344	333
143	157	168	169	158	333	344	345	334	144	158	169	170	159	334	345	346	335
145	159	170	171	160	335	346	347	336	146	160	171	172	161	336	347	348	337
147	161	172	173	162	337	348	349	338	148	162	173	174	163	338	349	350	339
149	163	174	175	164	339	350	351	340	150	164	175	176	165	340	351	352	341

LIST OF NODE NUMBERS AND THEIR X,Y AND Z-COORDINATES

NODE	X-COORD.	Y-COORD.	Z-COORD.	NODE	X-COORD.	Y-COORD.	Z-COORD.	NODE	X-COORD.	Y-COORD.	Z-COORD.
1	0.00	0.00	0.00	2	0.00	1.00	0.00	3	0.00	2.00	0.00
4	0.00	3.00	0.00	5	0.00	4.00	0.00	6	0.00	5.00	0.00
7	0.00	6.00	0.00	8	0.00	7.00	0.00	9	0.00	8.00	0.00
10	0.00	9.00	0.00	11	0.00	10.00	0.00	12	1.00	0.00	0.00
13	1.00	1.00	0.00	14	1.00	2.00	0.00	15	1.00	3.00	0.00
16	1.00	4.00	0.00	17	1.00	5.00	0.00	18	1.00	6.00	0.00
19	1.00	7.00	0.00	20	1.00	8.00	0.00	21	1.00	9.00	0.00
22	1.00	10.00	0.00	23	2.00	0.00	0.00	24	2.00	1.00	0.00
25	2.00	2.00	0.00	26	2.00	3.00	0.00	27	2.00	4.00	0.00
28	2.00	5.00	0.00	29	2.00	6.00	0.00	30	2.00	7.00	0.00
31	2.00	8.00	0.00	32	2.00	9.00	0.00	33	2.00	10.00	0.00
34	3.00	0.00	0.00	35	3.00	1.00	0.00	36	3.00	2.00	0.00
37	3.00	3.00	0.00	38	3.00	4.00	0.00	39	3.00	5.00	0.00
40	3.00	6.00	0.00	41	3.00	7.00	0.00	42	3.00	8.00	0.00
43	3.00	9.00	0.00	44	3.00	10.00	0.00	45	4.00	0.00	0.00
46	4.00	1.00	0.00	47	4.00	2.00	0.00	48	4.00	3.00	0.00
49	4.00	4.00	0.00	50	4.00	5.00	0.00	51	4.00	6.00	0.00
52	4.00	7.00	0.00	53	4.00	8.00	0.00	54	4.00	9.00	0.00
55	4.00	10.00	0.00	56	5.00	0.00	0.00	57	5.00	1.00	0.00
58	5.00	2.00	0.00	59	5.00	3.00	0.00	60	5.00	4.00	0.00
61	5.00	5.00	0.00	62	5.00	6.00	0.00	63	5.00	7.00	0.00
64	5.00	8.00	0.00	65	5.00	9.00	0.00	66	5.00	10.00	0.00
67	6.00	0.00	0.00	68	6.00	1.00	0.00	69	6.00	2.00	0.00

70	6.00	3.00	0.00	71	6.00	4.00	0.00	72	6.00	5.00	0.00
73	6.00	6.00	0.00	74	6.00	7.00	0.00	75	6.00	8.00	0.00
76	6.00	9.00	0.00	77	6.00	10.00	0.00	78	7.00	0.00	0.00
79	7.00	1.00	0.00	80	7.00	2.00	0.00	81	7.00	3.00	0.00
82	7.00	4.00	0.00	83	7.00	5.00	0.00	84	7.00	6.00	0.00
85	7.00	7.00	0.00	86	7.00	8.00	0.00	87	7.00	9.00	0.00
88	7.00	10.00	0.00	89	8.00	0.00	0.00	90	8.00	1.00	0.00
91	8.00	2.00	0.00	92	8.00	3.00	0.00	93	8.00	4.00	0.00
94	8.00	5.00	0.00	95	8.00	6.00	0.00	96	8.00	7.00	0.00
97	8.00	8.00	0.00	98	8.00	9.00	0.00	99	8.00	10.00	0.00
100	9.00	0.00	0.00	101	9.00	1.00	0.00	102	9.00	2.00	0.00
103	9.00	3.00	0.00	104	9.00	4.00	0.00	105	9.00	5.00	0.00
106	9.00	6.00	0.00	107	9.00	7.00	0.00	108	9.00	8.00	0.00
109	9.00	9.00	0.00	110	9.00	10.00	0.00	111	10.00	0.00	0.00
112	10.00	1.00	0.00	113	10.00	2.00	0.00	114	10.00	3.00	0.00
115	10.00	4.00	0.00	116	10.00	5.00	0.00	117	10.00	6.00	0.00
118	10.00	7.00	0.00	119	10.00	8.00	0.00	120	10.00	9.00	0.00
121	10.00	10.00	0.00	122	11.00	0.00	0.00	123	11.00	1.00	0.00
124	11.00	2.00	0.00	125	11.00	3.00	0.00	126	11.00	4.00	0.00
127	11.00	5.00	0.00	128	11.00	6.00	0.00	129	11.00	7.00	0.00
130	11.00	8.00	0.00	131	11.00	9.00	0.00	132	11.00	10.00	0.00
133	12.00	0.00	0.00	134	12.00	1.00	0.00	135	12.00	2.00	0.00
136	12.00	3.00	0.00	137	12.00	4.00	0.00	138	12.00	5.00	0.00
139	12.00	6.00	0.00	140	12.00	7.00	0.00	141	12.00	8.00	0.00
142	12.00	9.00	0.00	143	12.00	10.00	0.00	144	13.00	0.00	0.00
145	13.00	1.00	0.00	146	13.00	2.00	0.00	147	13.00	3.00	0.00
148	13.00	4.00	0.00	149	13.00	5.00	0.00	150	13.00	6.00	0.00
151	13.00	7.00	0.00	152	13.00	8.00	0.00	153	13.00	9.00	0.00
154	13.00	10.00	0.00	155	14.00	0.00	0.00	156	14.00	1.00	0.00
157	14.00	2.00	0.00	158	14.00	3.00	0.00	159	14.00	4.00	0.00
160	14.00	5.00	0.00	161	14.00	6.00	0.00	162	14.00	7.00	0.00
163	14.00	8.00	0.00	164	14.00	9.00	0.00	165	14.00	10.00	0.00
166	15.00	0.00	0.00	167	15.00	1.00	0.00	168	15.00	2.00	0.00
169	15.00	3.00	0.00	170	15.00	4.00	0.00	171	15.00	5.00	0.00
172	15.00	6.00	0.00	173	15.00	7.00	0.00	174	15.00	8.00	0.00
175	15.00	9.00	0.00	176	15.00	10.00	0.00	177	0.00	0.00	10.00
178	0.00	1.00	10.00	179	0.00	2.00	10.00	180	0.00	3.00	10.00
181	0.00	4.00	10.00	182	0.00	5.00	10.00	183	0.00	6.00	10.00
184	0.00	7.00	10.00	185	0.00	8.00	10.00	186	0.00	9.00	10.00
187	0.00	10.00	10.00	188	1.00	0.00	10.00	189	1.00	1.00	10.00
190	1.00	2.00	10.00	191	1.00	3.00	10.00	192	1.00	4.00	10.00
193	1.00	5.00	10.00	194	1.00	6.00	10.00	195	1.00	7.00	10.00
196	1.00	8.00	10.00	197	1.00	9.00	10.00	198	1.00	10.00	10.00
199	2.00	0.00	10.00	200	2.00	1.00	10.00	201	2.00	2.00	10.00
202	2.00	3.00	10.00	203	2.00	4.00	10.00	204	2.00	5.00	10.00
205	2.00	6.00	10.00	206	2.00	7.00	10.00	207	2.00	8.00	10.00
208	2.00	9.00	10.00	209	2.00	10.00	10.00	210	3.00	0.00	10.00
211	3.00	1.00	10.00	212	3.00	2.00	10.00	213	3.00	3.00	10.00
214	3.00	4.00	10.00	215	3.00	5.00	10.00	216	3.00	6.00	10.00
217	3.00	7.00	10.00	218	3.00	8.00	10.00	219	3.00	9.00	10.00
220	3.00	10.00	10.00	221	4.00	0.00	10.00	222	4.00	1.00	10.00
223	4.00	2.00	10.00	224	4.00	3.00	10.00	225	4.00	4.00	10.00
226	4.00	5.00	10.00	227	4.00	6.00	10.00	228	4.00	7.00	10.00
229	4.00	8.00	10.00	230	4.00	9.00	10.00	231	4.00	10.00	10.00
232	5.00	0.00	10.00	233	5.00	1.00	10.00	234	5.00	2.00	10.00
235	5.00	3.00	10.00	236	5.00	4.00	10.00	237	5.00	5.00	10.00
238	5.00	6.00	10.00	239	5.00	7.00	10.00	240	5.00	8.00	10.00
241	5.00	9.00	10.00	242	5.00	10.00	10.00	243	6.00	0.00	10.00
244	6.00	1.00	10.00	245	6.00	2.00	10.00	246	6.00	3.00	10.00
247	6.00	4.00	10.00	248	6.00	5.00	10.00	249	6.00	6.00	10.00
250	6.00	7.00	10.00	251	6.00	8.00	10.00	252	6.00	9.00	10.00
253	6.00	10.00	10.00	254	7.00	0.00	10.00	255	7.00	1.00	10.00
256	7.00	2.00	10.00	257	7.00	3.00	10.00	258	7.00	4.00	10.00
259	7.00	5.00	10.00	260	7.00	6.00	10.00	261	7.00	7.00	10.00
262	7.00	8.00	10.00	263	7.00	9.00	10.00	264	7.00	10.00	10.00
265	8.00	0.00	10.00	266	8.00	1.00	10.00	267	8.00	2.00	10.00
268	8.00	3.00	10.00	269	8.00	4.00	10.00	270	8.00	5.00	10.00
271	8.00	6.00	10.00	272	8.00	7.00	10.00	273	8.00	8.00	10.00
274	8.00	9.00	10.00	275	8.00	10.00	10.00	276	9.00	0.00	10.00

277	9.00	1.00	10.00	278	9.00	2.00	10.00	279	9.00	3.00	10.00
280	9.00	4.00	10.00	281	9.00	5.00	10.00	282	9.00	6.00	10.00
283	9.00	7.00	10.00	284	9.00	8.00	10.00	285	9.00	9.00	10.00
286	9.00	10.00	10.00	287	10.00	0.00	10.00	288	10.00	1.00	10.00
289	10.00	2.00	10.00	290	10.00	3.00	10.00	291	10.00	4.00	10.00
292	10.00	5.00	10.00	293	10.00	6.00	10.00	294	10.00	7.00	10.00
295	10.00	8.00	10.00	296	10.00	9.00	10.00	297	10.00	10.00	10.00
298	11.00	0.00	10.00	299	11.00	1.00	10.00	300	11.00	2.00	10.00
301	11.00	3.00	10.00	302	11.00	4.00	10.00	303	11.00	5.00	10.00
304	11.00	6.00	10.00	305	11.00	7.00	10.00	306	11.00	8.00	10.00
307	11.00	9.00	10.00	308	11.00	10.00	10.00	309	12.00	0.00	10.00
310	12.00	1.00	10.00	311	12.00	2.00	10.00	312	12.00	3.00	10.00
313	12.00	4.00	10.00	314	12.00	5.00	10.00	315	12.00	6.00	10.00
316	12.00	7.00	10.00	317	12.00	8.00	10.00	318	12.00	9.00	10.00
319	12.00	10.00	10.00	320	13.00	0.00	10.00	321	13.00	1.00	10.00
322	13.00	2.00	10.00	323	13.00	3.00	10.00	324	13.00	4.00	10.00
325	13.00	5.00	10.00	326	13.00	6.00	10.00	327	13.00	7.00	10.00
328	13.00	8.00	10.00	329	13.00	9.00	10.00	330	13.00	10.00	10.00
331	14.00	0.00	10.00	332	14.00	1.00	10.00	333	14.00	2.00	10.00
334	14.00	3.00	10.00	335	14.00	4.00	10.00	336	14.00	5.00	10.00
337	14.00	6.00	10.00	338	14.00	7.00	10.00	339	14.00	8.00	10.00
340	14.00	9.00	10.00	341	14.00	10.00	10.00	342	15.00	0.00	10.00
343	15.00	1.00	10.00	344	15.00	2.00	10.00	345	15.00	3.00	10.00
346	15.00	4.00	10.00	347	15.00	5.00	10.00	348	15.00	6.00	10.00
349	15.00	7.00	10.00	350	15.00	8.00	10.00	351	15.00	9.00	10.00
352	15.00	10.00	10.00								

BOUNDARY CONDITION DATA

NUMBER OF STEADY DIRICHLET BOUNDARIES .... (NBTO) = 10
NUMBER OF STEADY FLUX BOUNDARIES .... (NDFLUX) = 0
NUMBER OF TRANSIENT DIRICHLET BOUNDARIES.... (NBHVAR) = 0
NUMBER OF TRANSIENT FLUX BOUNDARIES.... .... (NBFVAR) = 0

STEADY-STATE DIRICHLET BOUNDARY CONDITIONS

INDEX	NODE NO.	D.V. NO.	PRESCRIBED VALUE
1	7	1	1.00000
2	8	1	1.00000
3	9	1	1.00000
4	10	1	1.00000
5	11	1	1.00000
6	183	1	1.00000
7	184	1	1.00000
8	185	1	1.00000
9	186	1	1.00000
10	187	1	1.00000

INITIAL CONDITION DATA

NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE
1	0.000000E+00	2	0.000000E+00	3	0.000000E+00	4	0.000000E+00	5	0.000000E+00
6	0.000000E+00	7	0.000000E+00	8	0.000000E+00	9	0.000000E+00	10	0.000000E+00

11	0.000000E+00	12	0.000000E+00	13	0.000000E+00	14	0.000000E+00	15	0.000000E+00
16	0.000000E+00	17	0.000000E+00	18	0.000000E+00	19	0.000000E+00	20	0.000000E+00
21	0.000000E+00	22	0.000000E+00	23	0.000000E+00	24	0.000000E+00	25	0.000000E+00
26	0.000000E+00	27	0.000000E+00	28	0.000000E+00	29	0.000000E+00	30	0.000000E+00
31	0.000000E+00	32	0.000000E+00	33	0.000000E+00	34	0.000000E+00	35	0.000000E+00
36	0.000000E+00	37	0.000000E+00	38	0.000000E+00	39	0.000000E+00	40	0.000000E+00
41	0.000000E+00	42	0.000000E+00	43	0.000000E+00	44	0.000000E+00	45	0.000000E+00
46	0.000000E+00	47	0.000000E+00	48	0.000000E+00	49	0.000000E+00	50	0.000000E+00
51	0.000000E+00	52	0.000000E+00	53	0.000000E+00	54	0.000000E+00	55	0.000000E+00
56	0.000000E+00	57	0.000000E+00	58	0.000000E+00	59	0.000000E+00	60	0.000000E+00
61	0.000000E+00	62	0.000000E+00	63	0.000000E+00	64	0.000000E+00	65	0.000000E+00
66	0.000000E+00	67	0.000000E+00	68	0.000000E+00	69	0.000000E+00	70	0.000000E+00
71	0.000000E+00	72	0.000000E+00	73	0.000000E+00	74	0.000000E+00	75	0.000000E+00
76	0.000000E+00	77	0.000000E+00	78	0.000000E+00	79	0.000000E+00	80	0.000000E+00
81	0.000000E+00	82	0.000000E+00	83	0.000000E+00	84	0.000000E+00	85	0.000000E+00
86	0.000000E+00	87	0.000000E+00	88	0.000000E+00	89	0.000000E+00	90	0.000000E+00
91	0.000000E+00	92	0.000000E+00	93	0.000000E+00	94	0.000000E+00	95	0.000000E+00
96	0.000000E+00	97	0.000000E+00	98	0.000000E+00	99	0.000000E+00	100	0.000000E+00
101	0.000000E+00	102	0.000000E+00	103	0.000000E+00	104	0.000000E+00	105	0.000000E+00
106	0.000000E+00	107	0.000000E+00	108	0.000000E+00	109	0.000000E+00	110	0.000000E+00
111	0.000000E+00	112	0.000000E+00	113	0.000000E+00	114	0.000000E+00	115	0.000000E+00
116	0.000000E+00	117	0.000000E+00	118	0.000000E+00	119	0.000000E+00	120	0.000000E+00
121	0.000000E+00	122	0.000000E+00	123	0.000000E+00	124	0.000000E+00	125	0.000000E+00
126	0.000000E+00	127	0.000000E+00	128	0.000000E+00	129	0.000000E+00	130	0.000000E+00
131	0.000000E+00	132	0.000000E+00	133	0.000000E+00	134	0.000000E+00	135	0.000000E+00
136	0.000000E+00	137	0.000000E+00	138	0.000000E+00	139	0.000000E+00	140	0.000000E+00
141	0.000000E+00	142	0.000000E+00	143	0.000000E+00	144	0.000000E+00	145	0.000000E+00
146	0.000000E+00	147	0.000000E+00	148	0.000000E+00	149	0.000000E+00	150	0.000000E+00
151	0.000000E+00	152	0.000000E+00	153	0.000000E+00	154	0.000000E+00	155	0.000000E+00
156	0.000000E+00	157	0.000000E+00	158	0.000000E+00	159	0.000000E+00	160	0.000000E+00
161	0.000000E+00	162	0.000000E+00	163	0.000000E+00	164	0.000000E+00	165	0.000000E+00
166	0.000000E+00	167	0.000000E+00	168	0.000000E+00	169	0.000000E+00	170	0.000000E+00
171	0.000000E+00	172	0.000000E+00	173	0.000000E+00	174	0.000000E+00	175	0.000000E+00
176	0.000000E+00	177	0.000000E+00	178	0.000000E+00	179	0.000000E+00	180	0.000000E+00
181	0.000000E+00	182	0.000000E+00	183	0.000000E+00	184	0.000000E+00	185	0.000000E+00
186	0.000000E+00	187	0.000000E+00	188	0.000000E+00	189	0.000000E+00	190	0.000000E+00
191	0.000000E+00	192	0.000000E+00	193	0.000000E+00	194	0.000000E+00	195	0.000000E+00
196	0.000000E+00	197	0.000000E+00	198	0.000000E+00	199	0.000000E+00	200	0.000000E+00
201	0.000000E+00	202	0.000000E+00	203	0.000000E+00	204	0.000000E+00	205	0.000000E+00
206	0.000000E+00	207	0.000000E+00	208	0.000000E+00	209	0.000000E+00	210	0.000000E+00
211	0.000000E+00	212	0.000000E+00	213	0.000000E+00	214	0.000000E+00	215	0.000000E+00
216	0.000000E+00	217	0.000000E+00	218	0.000000E+00	219	0.000000E+00	220	0.000000E+00
221	0.000000E+00	222	0.000000E+00	223	0.000000E+00	224	0.000000E+00	225	0.000000E+00
226	0.000000E+00	227	0.000000E+00	228	0.000000E+00	229	0.000000E+00	230	0.000000E+00
231	0.000000E+00	232	0.000000E+00	233	0.000000E+00	234	0.000000E+00	235	0.000000E+00
236	0.000000E+00	237	0.000000E+00	238	0.000000E+00	239	0.000000E+00	240	0.000000E+00
241	0.000000E+00	242	0.000000E+00	243	0.000000E+00	244	0.000000E+00	245	0.000000E+00
246	0.000000E+00	247	0.000000E+00	248	0.000000E+00	249	0.000000E+00	250	0.000000E+00
251	0.000000E+00	252	0.000000E+00	253	0.000000E+00	254	0.000000E+00	255	0.000000E+00
256	0.000000E+00	257	0.000000E+00	258	0.000000E+00	259	0.000000E+00	260	0.000000E+00
261	0.000000E+00	262	0.000000E+00	263	0.000000E+00	264	0.000000E+00	265	0.000000E+00
266	0.000000E+00	267	0.000000E+00	268	0.000000E+00	269	0.000000E+00	270	0.000000E+00
271	0.000000E+00	272	0.000000E+00	273	0.000000E+00	274	0.000000E+00	275	0.000000E+00
276	0.000000E+00	277	0.000000E+00	278	0.000000E+00	279	0.000000E+00	280	0.000000E+00
281	0.000000E+00	282	0.000000E+00	283	0.000000E+00	284	0.000000E+00	285	0.000000E+00
286	0.000000E+00	287	0.000000E+00	288	0.000000E+00	289	0.000000E+00	290	0.000000E+00
291	0.000000E+00	292	0.000000E+00	293	0.000000E+00	294	0.000000E+00	295	0.000000E+00
296	0.000000E+00	297	0.000000E+00	298	0.000000E+00	299	0.000000E+00	300	0.000000E+00
301	0.000000E+00	302	0.000000E+00	303	0.000000E+00	304	0.000000E+00	305	0.000000E+00
306	0.000000E+00	307	0.000000E+00	308	0.000000E+00	309	0.000000E+00	310	0.000000E+00
311	0.000000E+00	312	0.000000E+00	313	0.000000E+00	314	0.000000E+00	315	0.000000E+00
316	0.000000E+00	317	0.000000E+00	318	0.000000E+00	319	0.000000E+00	320	0.000000E+00
321	0.000000E+00	322	0.000000E+00	323	0.000000E+00	324	0.000000E+00	325	0.000000E+00
326	0.000000E+00	327	0.000000E+00	328	0.000000E+00	329	0.000000E+00	330	0.000000E+00
331	0.000000E+00	332	0.000000E+00	333	0.000000E+00	334	0.000000E+00	335	0.000000E+00
336	0.000000E+00	337	0.000000E+00	338	0.000000E+00	339	0.000000E+00	340	0.000000E+00
341	0.000000E+00	342	0.000000E+00	343	0.000000E+00	344	0.000000E+00	345	0.000000E+00
346	0.000000E+00	347	0.000000E+00	348	0.000000E+00	349	0.000000E+00	350	0.000000E+00
351	0.000000E+00	352	0.000000E+00						

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TRANSPORT SIMULATION CONTROL DATA
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STEADY-STATE VELOCITY FIELD (0=NO,1=YES)..(IVSTED) =    0
UPSTREAM FACTOR IN X-DIRECTION..............(WFAC) =  0.00E+00
UPSTREAM FACTOR IN Y-DIRECTION..............(YFAC) =  0.00E+00
UPSTREAM FACTOR IN Z-DIRECTION..............(ZFAC) =  0.00E+00


DEFAULT PHASE SATURATION AND DARCY VELOCITY VALUES
--------------------------------------------------

FLUID PHASE NUMBER    1
----------------------
PHASE SATURATION (DEFAULT VALUE).................. =  0.1000E+01
X-COMPONENT OF DARCY VELOCITY (DEFAULT VALUE)..... =  0.1000E+01
Y-COMPONENT OF DARCY VELOCITY (DEFAULT VALUE)..... =  0.1000E+01
Z-COMPONENT OF DARCY VELOCITY (DEFAULT VALUE)..... =  0.1000E+01


MATRIX BANDWIDTH FOR EACH SLICE =     12


==========================================================================================================================

****  TIME STEP NUMBER :    1           ELAPSED SIMULATION TIME :  0.8640E+03          TIME STEP SIZE : 0.864E+03  ****

==========================================================================================================================


SSR MATRIX SUBITERATION SUMMARY
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SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	28	0.4979E+00
2	15	0.1245E+00
3	11	0.3112E-01
4	0	0.7779E-02

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*** NODAL CONCENTRATION VALUES ***
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NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE
1	-4.399933E-05	2	8.944535E-05	3	-3.224174E-04	4	1.272405E-03	5	-5.766960E-03
6	9.318091E-02	7	1.00000	8	1.00000	9	1.00000	10	1.00000
11	1.00000	12	-1.752312E-04	13	3.562379E-04	14	-1.284434E-03	15	5.066129E-03
16	-2.324506E-02	17	0.201930	18	0.221278	19	0.334500	20	0.274602
21	0.282189	22	0.273886	23	8.267735E-05	24	-1.679690E-04	25	6.034145E-04
26	-2.329170E-03	27	9.366708E-03	28	-1.933083E-02	29	7.981676E-03	30	2.240476E-02
31	2.705930E-02	32	2.546002E-02	33	2.387060E-02	34	-2.470584E-05	35	5.015304E-05

36	-1.794711E-04	37	6.794332E-04	38	-2.492635E-03	39	4.128790E-03	40	-7.698406E-04
41	-2.655522E-03	42	-2.788569E-03	43	-2.498616E-03	44	-2.446448E-03	45	6.875659E-06
46	-1.394936E-05	47	4.979459E-05	48	-1.865823E-04	49	6.630292E-04	50	-1.037646E-03
51	1.540995E-04	52	6.017299E-04	53	6.113165E-04	54	5.391775E-04	55	5.338208E-04
56	-1.869444E-06	57	3.791442E-06	58	-1.351726E-05	59	5.045840E-05	60	-1.776330E-04
61	2.740693E-04	62	-3.753668E-05	63	-1.559351E-04	64	-1.577035E-04	65	-1.383411E-04
66	-1.382338E-04	67	5.030373E-07	68	-1.020051E-06	69	3.635076E-06	70	-1.355436E-05
71	4.759961E-05	72	-7.321309E-05	73	9.795430E-06	74	4.153868E-05	75	4.204593E-05
76	3.677678E-05	77	3.705406E-05	78	-1.348886E-07	79	2.735064E-07	80	-9.745488E-07
81	3.632606E-06	82	-1.274912E-05	83	1.959610E-05	84	-2.608174E-06	85	-1.111410E-05
86	-1.125419E-05	87	-9.836997E-06	88	-9.935416E-06	89	3.613194E-08	90	-7.326086E-08
91	2.610284E-07	92	-9.728968E-07	93	3.414029E-06	94	-5.246802E-06	95	6.975137E-07
96	2.975665E-06	97	3.013389E-06	98	2.633591E-06	99	2.661268E-06	100	-9.677198E-09
101	1.962112E-08	102	-6.990847E-08	103	2.605531E-07	104	-9.142170E-07	105	1.404939E-06
106	-1.867306E-07	107	-7.967839E-07	108	-8.068987E-07	109	-7.051821E-07	110	-7.126647E-07
111	2.591513E-09	112	-5.254384E-09	113	1.872064E-08	114	-6.977170E-08	115	2.448071E-07
116	-3.762073E-07	117	4.999959E-08	118	2.133572E-07	119	2.160665E-07	120	1.888285E-07
121	1.908363E-07	122	-6.940082E-10	123	1.407097E-09	124	-5.013207E-09	125	1.868389E-08
126	-6.555530E-08	127	1.007415E-07	128	-1.338894E-08	129	-5.713285E-08	130	-5.785832E-08
131	-5.056440E-08	132	-5.110250E-08	133	1.859073E-10	134	-3.769057E-10	135	1.342814E-09
136	-5.004499E-09	137	1.755999E-08	138	-2.698530E-08	139	3.586479E-09	140	1.530392E-08
141	1.549815E-08	142	1.354417E-08	143	1.368861E-08	144	-5.002231E-11	145	1.013939E-10
146	-3.612710E-10	147	1.346489E-09	148	-4.724589E-09	149	7.260482E-09	150	-9.649678E-10
151	-4.117587E-09	152	-4.169728E-09	153	-3.643620E-09	154	-3.682788E-09	155	1.428148E-11
156	-2.894425E-11	157	1.031504E-10	158	-3.844444E-10	159	1.348918E-09	160	-2.072936E-09
161	2.755401E-10	162	1.175562E-09	163	1.190738E-09	164	1.039685E-09	165	1.050813E-09
166	-7.175950E-12	167	1.447383E-11	168	-5.155521E-11	169	1.921216E-10	170	-6.740831E-10
171	1.035881E-09	172	-1.376671E-10	173	-5.875826E-10	174	-5.947386E-10	175	-5.217023E-10
176	-5.222551E-10	177	-4.348765E-05	178	8.840515E-05	179	-3.186679E-04	180	1.257608E-03
181	-5.699894E-03	182	9.209744E-02	183	1.00000	184	1.00000	185	1.00000
186	1.00000	187	1.00000	188	-1.731936E-04	189	3.520955E-04	190	-1.269499E-03
191	5.007219E-03	192	-2.297476E-02	193	0.199582	194	0.218705	195	0.330611
196	0.271410	197	0.278908	198	0.270701	199	8.171600E-05	200	-1.660159E-04
201	5.963982E-04	202	-2.302087E-03	203	9.257796E-03	204	-1.910605E-02	205	7.888902E-03
206	2.214430E-02	207	2.674471E-02	208	2.516403E-02	209	2.359309E-02	210	-2.441857E-05
211	4.956988E-05	212	-1.773843E-04	213	6.715330E-04	214	-2.463651E-03	215	4.080778E-03
216	-7.608935E-04	217	-2.624649E-03	218	-2.756147E-03	219	-2.469566E-03	220	-2.418005E-03
221	6.795711E-06	222	-1.378716E-05	223	4.921560E-05	224	-1.844128E-04	225	6.553197E-04
226	-1.025580E-03	227	1.523087E-04	228	5.947343E-04	229	6.042089E-04	230	5.329087E-04
231	5.276142E-04	232	-1.847706E-06	233	3.747356E-06	234	-1.336008E-05	235	4.987169E-05
236	-1.755675E-04	237	2.708823E-04	238	-3.710047E-05	239	-1.541222E-04	240	-1.558699E-04
241	-1.367326E-04	242	-1.366266E-04	243	4.971881E-07	244	-1.008190E-06	245	3.592809E-06
246	-1.339675E-05	247	4.704614E-05	248	-7.236172E-05	249	9.681602E-06	250	4.105576E-05
251	4.155707E-05	252	3.634918E-05	253	3.662325E-05	254	-1.333202E-07	255	2.703262E-07
256	-9.632170E-07	257	3.590368E-06	258	-1.260088E-05	259	1.936823E-05	260	-2.577865E-06
261	-1.098489E-05	262	-1.112334E-05	263	-9.722625E-06	264	-9.819901E-06	265	3.571181E-08
266	-7.240901E-08	267	2.579932E-07	268	-9.615843E-07	269	3.374332E-06	270	-5.185789E-06
271	6.894082E-07	272	2.941071E-06	273	2.978353E-06	274	2.602971E-06	275	2.630327E-06
276	-9.564674E-09	277	1.939297E-08	278	-6.909560E-08	279	2.575235E-07	280	-9.035867E-07
281	1.388601E-06	282	-1.845607E-07	283	-7.875206E-07	284	-7.975171E-07	285	-6.969831E-07
286	-7.043788E-07	287	2.561379E-09	288	-5.193287E-09	289	1.850296E-08	290	-6.896042E-08
291	2.419606E-07	292	-3.718326E-07	293	4.941856E-08	294	2.108768E-07	295	2.135543E-07
296	1.866330E-07	297	1.886175E-07	298	-6.859385E-10	299	1.390736E-09	300	-4.954915E-09
301	1.846664E-08	302	-6.479304E-08	303	9.957005E-08	304	-1.323335E-08	305	-5.646863E-08
306	-5.718562E-08	307	-4.997650E-08	308	-5.050835E-08	309	1.837456E-10	310	-3.725231E-10
311	1.327200E-09	312	-4.946308E-09	313	1.735581E-08	314	-2.667150E-08	315	3.544802E-09
316	1.512600E-08	317	1.531796E-08	318	1.338670E-08	319	1.352946E-08	320	-4.944066E-11
321	1.002149E-10	322	-3.570703E-10	323	1.330832E-09	324	-4.669653E-09	325	7.176053E-09
326	-9.537543E-10	327	-4.069716E-09	328	-4.121248E-09	329	-3.601257E-09	330	-3.639969E-09
331	1.411542E-11	332	-2.860770E-11	333	1.019510E-10	334	-3.799742E-10	335	1.333234E-09
336	-2.048830E-09	337	2.723382E-10	338	1.161895E-09	339	1.176894E-09	340	1.027597E-09
341	1.038596E-09	342	-7.092510E-12	343	1.430553E-11	344	-5.095574E-11	345	1.898877E-10
346	-6.662451E-10	347	1.023835E-09	348	-1.360674E-10	349	-5.807515E-10	350	-5.878237E-10
351	-5.156366E-10	352	-5.161831E-10						

***** TIME STEP NO. 1 COMPLETED *****

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**** TIME STEP NUMBER : 2 ELAPSED SIMULATION TIME : 0.1901E+04 TIME STEP SIZE : 0.104E+04 ****

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SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	31	0.3755E+00
2	27	0.9421E-01
3	4	0.2355E-01
4	0	0.5888E-02

*** NODAL CONCENTRATION VALUES ***

NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE
1	1.171342E-05	2	-2.116695E-05	3	5.250653E-05	4	4.938881E-05	5	-4.163228E-03
6	0.400953	7	1.00000	8	1.00000	9	1.00000	10	1.00000
11	1.00000	12	2.970928E-04	13	-5.911167E-04	14	2.054154E-03	15	-7.471470E-03
16	2.199191E-02	17	0.352022	18	0.511356	19	0.630622	20	0.544167
21	0.551410	22	0.541866	23	7.038105E-05	24	-1.471189E-04	25	5.716691E-04
26	-2.658497E-03	27	1.529350E-02	28	2.608783E-02	29	7.276376E-02	30	0.125975
31	0.116775	32	0.115462	33	0.110489	34	-3.185671E-05	35	6.538622E-05
36	-2.410723E-04	37	9.601911E-04	38	-3.478279E-03	39	-6.345023E-03	40	-5.364303E-03
41	-6.606710E-03	42	-2.628123E-03	43	-2.142989E-03	44	-2.510692E-03	45	9.789151E-06
46	-1.995059E-05	47	7.193520E-05	48	-2.677317E-04	49	8.062583E-04	50	1.707061E-03
51	9.385919E-04	52	9.086003E-04	53	7.199475E-05	54	-2.368966E-05	55	5.735710E-05
56	-2.765766E-06	57	5.615759E-06	58	-2.003517E-05	59	7.250985E-05	60	-2.039838E-04
61	-4.575704E-04	62	-2.202542E-04	63	-1.923277E-04	64	1.217843E-05	65	3.567942E-05
66	1.479199E-05	67	7.568754E-07	68	-1.534048E-06	69	5.449376E-06	70	-1.952561E-05
71	5.369040E-05	72	1.227258E-04	73	5.692364E-05	74	4.840052E-05	75	-4.935298E-06
76	-1.134291E-05	77	-5.541610E-06	78	-2.042691E-07	79	4.137033E-07	80	-1.467242E-06
81	5.239948E-06	82	-1.430962E-05	83	-3.291291E-05	84	-1.511846E-05	85	-1.280166E-05
86	1.389803E-06	87	3.150167E-06	88	1.556618E-06	89	5.482538E-08	90	-1.110043E-07
91	3.934705E-07	92	-1.403738E-06	93	3.825455E-06	94	8.823223E-06	95	4.041556E-06
96	3.419896E-06	97	-3.758025E-07	98	-8.525542E-07	99	-4.189591E-07	100	-1.468673E-08
101	2.973287E-08	102	-1.053729E-07	103	3.758138E-07	104	-1.023425E-06	105	-2.364880E-06
106	-1.081896E-06	107	-9.148828E-07	108	1.014549E-07	109	2.294336E-07	110	1.127789E-07
111	3.932615E-09	112	-7.960980E-09	113	2.821142E-08	114	-1.006039E-07	115	2.738560E-07
116	6.338202E-07	117	2.897028E-07	118	2.448093E-07	119	-2.739852E-08	120	-6.166999E-08
121	-3.039386E-08	122	-1.052886E-09	123	2.131216E-09	124	-7.551983E-09	125	2.692858E-08
126	-7.328383E-08	127	-1.698745E-07	128	-7.758175E-08	129	-6.551122E-08	130	7.399204E-09
131	1.657236E-08	132	8.193061E-09	133	2.819981E-10	134	-5.706648E-10	135	2.022012E-09
136	-7.209323E-09	137	1.961664E-08	138	4.554372E-08	139	2.078326E-08	140	1.753637E-08
141	-1.998780E-09	142	-4.454491E-09	143	-2.208865E-09	144	-7.590408E-11	145	1.534615E-10
146	-5.437779E-10	147	1.938810E-09	148	-5.274232E-09	149	-1.226459E-08	150	-5.592322E-09
151	-4.715096E-09	152	5.424437E-10	153	1.202738E-09	154	5.980407E-10	155	2.168364E-11
156	-4.377606E-11	157	1.551777E-10	158	-5.532798E-10	159	1.504697E-09	160	3.505039E-09

161	1.596860E-09	162	1.345204E-09	163	-1.558963E-10	164	-3.450526E-10	165	-1.728625E-10
166	-1.097300E-11	167	2.191059E-11	168	-7.756467E-11	169	2.764078E-10	170	-7.514844E-10
171	-1.752872E-09	172	-7.980153E-10	173	-6.721595E-10	174	7.888471E-11	175	1.694108E-10
176	9.207946E-11	177	8.599052E-06	178	-1.491001E-05	179	3.029745E-05	180	1.352968E-04
181	-4.521964E-03	182	0.397605	183	1.00000	184	1.00000	185	1.00000
186	1.00000	187	1.00000	188	2.857824E-04	189	-5.684255E-04	190	1.973980E-03
191	-7.166934E-03	192	2.083423E-02	193	0.350236	194	0.508170	195	0.628164
196	0.541532	197	0.548805	198	0.539229	199	7.116146E-05	200	-1.486001E-04
201	5.760226E-04	202	-2.665710E-03	203	1.522409E-02	204	2.491086E-02	205	7.106213E-02
206	0.123319	207	0.114538	208	0.113194	209	0.108302	210	-3.188004E-05
211	6.541220E-05	212	-2.409878E-04	213	9.587380E-04	214	-3.472867E-03	215	-6.085284E-03
216	-5.229713E-03	217	-6.484278E-03	218	-2.613967E-03	219	-2.133252E-03	220	-2.490468E-03
221	9.778608E-06	222	-1.992529E-05	223	7.181951E-05	224	-2.672781E-04	225	8.072931E-04
226	1.640311E-03	227	9.144151E-04	228	8.950664E-04	229	8.065145E-05	230	-1.429468E-05
231	6.457264E-05	232	-2.761004E-06	233	5.605377E-06	234	-1.999471E-05	235	7.238783E-05
236	-2.045059E-04	237	-4.398937E-04	238	-2.145205E-04	239	-1.898789E-04	240	9.221541E-06
241	3.255898E-05	242	1.220772E-05	243	7.553727E-07	244	-1.530852E-06	245	5.437455E-06
246	-1.949241E-05	247	5.385063E-05	248	1.180014E-04	249	5.543584E-05	250	4.781786E-05
251	-4.107204E-06	252	-1.046840E-05	253	-4.809903E-06	254	-2.038441E-07	255	4.128070E-07
256	-1.463947E-06	257	5.230990E-06	258	-1.435414E-05	259	-3.164749E-05	260	-1.472277E-05
261	-1.264932E-05	262	1.166592E-06	263	2.913431E-06	264	1.358682E-06	265	5.470993E-08
266	-1.107614E-07	267	3.925819E-07	268	-1.401343E-06	269	3.837535E-06	270	8.484189E-06
271	3.935733E-06	272	3.379281E-06	273	-3.159592E-07	274	-7.889540E-07	275	-3.658993E-07
276	-1.465581E-08	277	2.966790E-08	278	-1.051354E-07	279	3.751763E-07	280	-1.026684E-06
281	-2.274044E-06	282	-1.053564E-06	283	-9.040257E-07	284	8.541235E-08	285	2.123769E-07
286	9.855744E-08	287	3.924360E-09	288	-7.943637E-09	289	2.814807E-08	290	-1.004343E-07
291	2.747341E-07	292	6.094830E-07	293	2.821156E-07	294	2.419057E-07	295	-2.309752E-08
296	-5.709735E-08	297	-2.658132E-08	298	-1.050684E-09	299	2.126593E-09	300	-7.535100E-09
301	2.688348E-08	302	-7.352031E-08	303	-1.633538E-07	304	-7.554981E-08	305	-6.473462E-08
306	6.246063E-09	307	1.534657E-08	308	7.170910E-09	309	2.814103E-10	310	-5.694326E-10
311	2.017514E-09	312	-7.197343E-09	313	1.968034E-08	314	4.379608E-08	315	2.023890E-08
316	1.732860E-08	317	-1.689513E-09	318	-4.125801E-09	319	-1.934745E-09	320	-7.574577E-11
321	1.531319E-10	322	-5.425745E-10	323	1.935612E-09	324	-5.291470E-09	325	-1.179412E-08
326	-5.445839E-09	327	-4.659261E-09	328	4.591297E-10	329	1.114215E-09	330	5.242050E-10
331	2.163836E-11	332	-4.368287E-11	333	1.548364E-10	334	-5.523746E-10	335	1.509649E-09
336	3.370631E-09	337	1.555031E-09	338	1.329283E-09	339	-1.320820E-10	340	-3.197507E-10
341	-1.517422E-10	342	-1.094848E-11	343	2.186360E-11	344	-7.739415E-11	345	2.759580E-10
346	-7.539711E-10	347	-1.685674E-09	348	-7.771100E-10	349	-6.642064E-10	350	6.696668E-11
351	1.568009E-10	352	8.144087E-11								

***** TIME STEP NO. 2 COMPLETED *****

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**** TIME STEP NUMBER : 3 ELAPSED SIMULATION TIME : 0.3145E+04 TIME STEP SIZE : 0.124E+04 ****

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SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	45	0.1829E+00

2	32	0.4555E-01
3	2	0.1139E-01
4	0	0.2847E-02

*** NODAL CONCENTRATION VALUES ***

NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE
1	3.944371E-04	2	-8.163893E-04	3	3.252720E-03	4	-1.664096E-02	5	0.119998
6	0.548201	7	1.00000	8	1.00000	9	1.00000	10	1.00000
11	1.00000	12	2.129614E-04	13	-4.599069E-04	14	2.114908E-03	15	-1.370331E-02
16	0.118364	17	0.495597	18	0.636494	19	0.731287	20	0.652069
21	0.656771	22	0.647970	23	-1.030396E-05	24	6.699094E-06	25	1.351820E-04
26	-2.644179E-03	27	4.372575E-02	28	0.118702	29	0.222420	30	0.288441
31	0.262291	32	0.259753	33	0.251587	34	-3.153488E-05	35	6.781157E-05
36	-2.845021E-04	37	1.410181E-03	38	-4.784973E-03	39	-5.929384E-03	40	7.765474E-03
41	2.387536E-02	42	2.721094E-02	43	2.921286E-02	44	2.696632E-02	45	1.322713E-05
46	-2.725811E-05	47	1.016113E-04	48	-3.808315E-04	49	5.587533E-04	50	6.699192E-04
51	-1.823914E-03	52	-4.442786E-03	53	-3.864036E-03	54	-3.886573E-03	55	-3.706734E-03
56	-4.076688E-06	57	8.246198E-06	58	-2.920256E-05	59	9.673196E-05	60	-8.092661E-05
61	-8.110606E-05	62	4.240096E-04	63	9.476614E-04	64	7.166885E-04	65	6.894006E-04
66	6.672419E-04	67	1.157949E-06	68	-2.319851E-06	69	8.027005E-06	70	-2.523696E-05
71	1.539149E-05	72	1.227961E-05	73	-1.067893E-04	74	-2.311677E-04	75	-1.645167E-04
76	-1.549976E-04	77	-1.510325E-04	78	-3.182795E-07	79	6.346478E-07	80	-2.174640E-06
81	6.699054E-06	82	-3.541744E-06	83	-2.545856E-06	84	2.790497E-05	85	6.006674E-05
86	4.192930E-05	87	3.922175E-05	88	3.833113E-05	89	8.611096E-08	90	-1.713455E-07
91	5.848733E-07	92	-1.788571E-06	93	8.936395E-07	94	6.350979E-07	95	-7.402568E-06
96	-1.596372E-05	97	-1.109716E-05	98	-1.035463E-05	99	-1.013387E-05	100	-2.313639E-08
101	4.599741E-08	102	-1.567835E-07	103	4.782206E-07	104	-2.336031E-07	105	-1.672419E-07
106	1.977223E-06	107	4.269931E-06	108	2.967266E-06	109	2.764546E-06	110	2.713384E-06
111	6.200746E-09	112	-1.232275E-08	113	4.197904E-08	114	-1.279179E-07	115	6.178047E-08
116	4.448999E-08	117	-5.293607E-07	118	-1.143615E-06	119	-7.947312E-07	120	-7.399867E-07
121	-7.274786E-07	122	-1.660644E-09	123	3.298916E-09	124	-1.123473E-08	125	3.421735E-08
126	-1.639162E-08	127	-1.186473E-08	128	1.418236E-07	129	3.063841E-07	130	2.128958E-07
131	1.981914E-07	132	1.949382E-07	133	4.450181E-10	134	-8.832733E-10	135	3.007036E-09
136	-9.155091E-09	137	4.353593E-09	138	3.166712E-09	139	-3.801704E-08	140	-8.211354E-08
141	-5.704972E-08	142	-5.310208E-08	143	-5.223579E-08	144	-1.199725E-10	145	2.374921E-10
146	-8.082500E-10	147	2.460244E-09	148	-1.161342E-09	149	-8.489299E-10	150	1.023659E-08
151	2.210548E-08	152	1.535508E-08	153	1.428757E-08	154	1.404885E-08	155	3.434691E-11
156	-6.771275E-11	157	2.305011E-10	158	-7.014776E-10	159	3.284183E-10	160	2.415572E-10
161	-2.925361E-09	162	-6.315193E-09	163	-4.387568E-09	164	-4.076243E-09	165	-3.997588E-09
166	-1.752344E-11	167	3.394551E-11	168	-1.152516E-10	169	3.502625E-10	170	-1.629073E-10
171	-1.203987E-10	172	1.462862E-09	173	3.158106E-09	174	2.194269E-09	175	2.043146E-09
176	1.982869E-09	177	3.891897E-04	178	-8.052086E-04	179	3.203605E-03	180	-1.633943E-02
181	0.117213	182	0.547191	183	1.00000	184	1.00000	185	1.00000
186	1.00000	187	1.00000	188	2.226173E-04	189	-4.783063E-04	190	2.165819E-03
191	-1.373048E-02	192	0.116352	193	0.493343	194	0.635610	195	0.731007
196	0.651235	197	0.655974	198	0.647123	199	-9.135853E-06	200	4.486724E-06
201	1.413736E-04	202	-2.635792E-03	203	4.299291E-02	204	0.116602	205	0.219102
206	0.285110	207	0.259179	208	0.256657	209	0.248527	210	-3.163568E-05
211	6.794888E-05	212	-2.843099E-04	213	1.403212E-03	214	-4.760992E-03	215	-6.100759E-03
216	7.208064E-03	217	2.274579E-02	218	2.617458E-02	219	2.812305E-02	220	2.593786E-02
221	1.322027E-05	222	-2.723191E-05	223	1.014137E-04	224	-3.796693E-04	225	5.652461E-04
226	7.403679E-04	227	-1.715954E-03	228	-4.255165E-03	229	-3.734079E-03	230	-3.758632E-03
231	-3.581770E-03	232	-4.071840E-06	233	8.234590E-06	234	-2.914976E-05	235	9.658364E-05
236	-8.365398E-05	237	-1.025809E-04	238	3.995768E-04	239	9.089643E-04	240	6.943441E-04
241	6.685788E-04	242	6.464283E-04	243	1.156245E-06	244	-2.316177E-06	245	8.013132E-06
246	-2.521593E-05	247	1.620292E-05	248	1.828934E-05	249	-1.006545E-04	250	-2.218278E-04
251	-1.595771E-04	252	-1.505329E-04	253	-1.465059E-04	254	-3.177699E-07	255	6.335931E-07
256	-2.170944E-06	257	6.695353E-06	258	-3.766815E-06	259	-4.177550E-06	260	2.629854E-05
261	5.764621E-05	262	4.068620E-05	263	3.811185E-05	264	3.719858E-05	265	8.596897E-08
266	-1.710564E-07	267	5.838895E-07	268	-1.787780E-06	269	9.547220E-07	270	1.073840E-06
271	-6.975541E-06	272	-1.532076E-05	273	-1.076912E-05	274	-1.006311E-05	275	-9.835570E-06
276	-2.309796E-08	277	4.591968E-08	278	-1.565218E-07	279	4.780315E-07	280	-2.500474E-07
281	-2.849191E-07	282	1.863079E-06	283	4.097986E-06	284	2.879602E-06	285	2.686829E-06

286	2.633555E-06	287	6.190449E-09	288	-1.230198E-08	289	4.190944E-08	290	-1.278705E-07
291	6.619521E-08	292	7.603578E-08	293	-4.987988E-07	294	-1.097571E-06	295	-7.712590E-07
296	-7.191963E-07	297	-7.060790E-07	298	-1.657893E-09	299	3.293384E-09	300	-1.121624E-08
301	3.420531E-08	302	-1.757591E-08	303	-2.032021E-08	304	1.336368E-07	305	2.940512E-07
306	2.066099E-07	307	1.926251E-07	308	1.892052E-07	309	4.442809E-10	310	-8.817998E-10
311	3.002123E-09	312	-9.152038E-09	313	4.671326E-09	314	5.433752E-09	315	-3.582299E-08
316	-7.880891E-08	317	-5.536580E-08	318	-5.161114E-08	319	-5.070000E-08	320	-1.197719E-10
321	2.370984E-10	322	-8.069414E-10	323	2.459471E-09	324	-1.246962E-09	325	-1.459455E-09
326	9.645952E-09	327	2.121604E-08	328	1.490199E-08	329	1.388656E-08	330	1.363595E-08
331	3.428872E-11	332	-6.760179E-11	333	2.301320E-10	334	-7.012725E-10	335	3.529060E-10
336	4.160407E-10	337	-2.756618E-09	338	-6.061151E-09	339	-4.258127E-09	340	-3.961901E-09
341	-3.880228E-09	342	-1.749054E-11	343	3.388897E-11	344	-1.150669E-10	345	3.501654E-10
346	-1.751605E-10	347	-2.076595E-10	348	1.378498E-09	349	3.031079E-09	350	2.129559E-09
351	1.985715E-09	352	1.924899E-09								

***** TIME STEP NO. 3 COMPLETED *****

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**** TIME STEP NUMBER : 4 ELAPSED SIMULATION TIME : 0.4638E+04 TIME STEP SIZE : 0.149E+04 ****

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SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	43	0.7843E-01
2	12	0.1970E-01
3	0	0.4925E-02

*** NODAL CONCENTRATION VALUES ***

NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE
1	-6.827304E-04	2	1.379795E-03	3	-4.769139E-03	4	1.075546E-02	5	0.249966
6	0.644763	7	1.00000	8	1.00000	9	1.00000	10	1.00000
11	1.00000	12	-6.758510E-04	13	1.387452E-03	14	-5.047923E-03	15	1.314542E-02
16	0.235417	17	0.592674	18	0.719380	19	0.793996	20	0.725369
21	0.727035	22	0.718891	23	-2.395328E-04	24	5.059411E-04	25	-2.029801E-03
26	6.894168E-03	27	0.104016	28	0.232077	29	0.349981	30	0.409310
31	0.375191	32	0.371972	33	0.362070	34	-3.654599E-06	35	1.920773E-05
36	-2.117621E-04	37	2.130239E-03	38	3.141761E-03	39	2.614777E-02	40	6.994791E-02
41	0.101196	42	9.873312E-02	43	0.101951	44	9.712429E-02	45	1.682222E-05
46	-3.623689E-05	47	1.508412E-04	48	-5.708701E-04	49	-1.466695E-03	50	-3.448708E-03
51	-4.185162E-03	52	-2.614507E-03	53	2.124591E-04	54	1.461373E-03	55	1.063074E-03
56	-6.404328E-06	57	1.294456E-05	58	-4.527028E-05	59	1.155434E-04	60	3.971915E-04
61	7.017170E-04	62	3.163617E-04	63	-4.300176E-04	64	-8.279435E-04	65	-1.066485E-03
66	-9.694811E-04	67	1.931257E-06	68	-3.789388E-06	69	1.222408E-05	70	-2.538151E-05

71	-1.010928E-04	72	-1.639382E-04	73	-2.591599E-05	74	1.821005E-04	75	2.405508E-04
76	2.855138E-04	77	2.643656E-04	78	-5.448745E-07	79	1.052545E-06	80	-3.269958E-06
81	6.151886E-06	82	2.625451E-05	83	4.118714E-05	84	1.847749E-06	85	-5.355503E-05
86	-6.410487E-05	87	-7.410158E-05	88	-6.905455E-05	89	1.497216E-07	90	-2.867753E-07
91	8.758913E-07	92	-1.578102E-06	93	-6.944661E-06	94	-1.075921E-05	95	-5.516897E-08
96	1.470186E-05	97	1.704994E-05	98	1.956274E-05	99	1.827211E-05	100	-4.058779E-08
101	7.740025E-08	102	-2.346760E-07	103	4.154137E-07	104	1.853064E-06	105	2.859343E-06
106	-1.768520E-08	107	-3.960734E-06	108	-4.550696E-06	109	-5.217855E-06	110	-4.871462E-06
111	1.092338E-08	112	-2.078527E-08	113	6.282513E-08	114	-1.104143E-07	115	-4.960501E-07
116	-7.643709E-07	117	6.864645E-09	118	1.062338E-06	119	1.217683E-06	120	1.396559E-06
121	1.304132E-06	122	-2.931399E-09	123	5.569542E-09	124	-1.680858E-08	125	2.943911E-08
126	1.329285E-07	127	2.046465E-07	128	-2.021602E-09	129	-2.847362E-07	130	-3.261766E-07
131	-3.740637E-07	132	-3.495749E-07	133	7.870037E-10	134	-1.491865E-09	135	4.496708E-09
136	-7.857442E-09	137	-3.564562E-08	138	-5.482851E-08	139	5.667206E-10	140	7.633445E-08
141	8.741598E-08	142	1.002363E-07	143	9.369527E-08	144	-2.127769E-10	145	4.012231E-10
146	-1.207653E-09	147	2.106139E-09	148	9.602474E-09	149	1.475635E-08	150	-1.575035E-10
151	-2.055447E-08	152	-2.353234E-08	153	-2.697320E-08	154	-2.520492E-08	155	6.101265E-11
156	-1.142717E-10	157	3.438533E-10	158	-5.985778E-10	159	-2.745505E-09	160	-4.214598E-09
161	4.625873E-11	162	5.873081E-09	163	6.724002E-09	164	7.698352E-09	165	7.186890E-09
166	-3.126543E-11	167	5.729931E-11	168	-1.717796E-10	169	2.980435E-10	170	1.373472E-09
171	2.106787E-09	172	-2.338152E-11	173	-2.936508E-09	174	-3.362718E-09	175	-3.851004E-09
176	-3.587284E-09	177	-6.023812E-04	178	1.214695E-03	179	-4.145419E-03	180	8.338094E-03
181	0.246561	182	0.644562	183	1.00000	184	1.00000	185	1.00000
186	1.00000	187	1.00000	188	-6.265289E-04	189	1.281974E-03	190	-4.601930E-03
191	1.114979E-02	192	0.231625	193	0.592090	194	0.719123	195	0.794092
196	0.724943	197	0.726694	198	0.718520	199	-2.291662E-04	200	4.822486E-04
201	-1.915544E-03	202	6.294411E-03	203	0.101148	204	0.228161	205	0.347321
206	0.407533	207	0.373151	208	0.369917	209	0.359974	210	-5.092617E-06
211	2.184605E-05	212	-2.171622E-04	213	2.104697E-03	214	2.561132E-03	215	2.397498E-02
216	6.619386E-02	217	9.701056E-02	218	9.490089E-02	219	9.808700E-02	220	9.336267E-02
221	1.674170E-05	222	-3.599819E-05	223	1.491851E-04	224	-5.641686E-04	225	-1.351290E-03
226	-3.228215E-03	227	-4.165840E-03	228	-2.996552E-03	229	-2.601828E-04	230	8.984329E-04
231	5.470805E-04	232	-6.326591E-06	233	1.278649E-05	234	-4.472157E-05	235	1.152550E-04
236	3.739709E-04	237	6.704732E-04	238	3.562878E-04	239	-2.816626E-04	240	-6.884954E-04
241	-9.138958E-04	242	-8.255297E-04	243	1.904415E-06	244	-3.738831E-06	245	1.208555E-05
246	-2.552304E-05	247	-9.595904E-05	248	-1.585733E-04	249	-3.945959E-05	250	1.411771E-04
251	2.057997E-04	252	2.488863E-04	253	2.294382E-04	254	-5.369099E-07	255	1.038094E-06
256	-3.234715E-06	257	6.216062E-06	258	2.500290E-05	259	4.006586E-05	260	5.700751E-06
261	-4.258500E-05	262	-5.516549E-05	263	-6.482822E-05	264	-6.016600E-05	265	1.474672E-07
266	-2.827674E-07	267	8.666248E-07	268	-1.598191E-06	269	-6.622056E-06	270	-1.048838E-05
271	-1.104600E-06	272	1.176503E-05	273	1.469072E-05	274	1.712820E-05	275	1.593351E-05
276	-3.996589E-08	277	7.630613E-08	278	-2.322013E-07	279	4.210815E-07	280	1.767864E-06
281	2.789213E-06	282	2.644427E-07	283	-3.174286E-06	284	-3.921538E-06	285	-4.569394E-06
286	-4.248063E-06	287	1.075462E-08	288	-2.048992E-08	289	6.216326E-08	290	-1.119620E-07
291	-4.733414E-07	292	-7.457760E-07	293	-6.876419E-08	294	8.516703E-07	295	1.049318E-06
296	1.223075E-06	297	1.137215E-06	298	-2.885931E-09	299	5.490246E-09	300	-1.663172E-08
301	2.985745E-08	302	1.268574E-07	303	1.996852E-07	304	1.824681E-08	305	-2.282937E-07
306	-2.810790E-07	307	-3.276049E-07	308	-3.048380E-07	309	7.747552E-10	310	-1.470608E-09
311	4.449485E-09	312	-7.970265E-09	313	-3.402040E-08	314	-5.350228E-08	315	-4.867103E-09
316	6.120673E-08	317	7.533096E-08	318	8.778843E-08	319	8.170594E-08	320	-2.094485E-10
321	3.955048E-10	322	-1.195009E-09	323	2.136705E-09	324	9.165343E-09	325	1.440010E-08
326	1.305762E-09	327	-1.648190E-08	328	-2.027951E-08	329	-2.362390E-08	330	-2.198033E-08
331	6.005631E-11	332	-1.126478E-10	333	3.402750E-10	334	-6.073836E-10	335	-2.620732E-09
336	-4.113038E-09	337	-3.719307E-10	338	4.709604E-09	339	5.794585E-09	340	6.742719E-09
341	6.268510E-09	342	-3.077179E-11	343	5.648549E-11	344	-1.699998E-10	345	3.024827E-10
346	1.311134E-09	347	2.056087E-09	348	1.857381E-10	349	-2.354723E-09	350	-2.897920E-09
351	-3.372489E-09	352	-3.130369E-09						

***** TIME STEP NO. 4 COMPLETED *****

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**** TIME STEP NUMBER : 5 ELAPSED SIMULATION TIME : 0.6430E+04 TIME STEP SIZE : 0.179E+04 ****

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SSR MATRIX SUBITERATION SUMMARY

SUBITERATION	NUMBER OF NON-CONVERGENT NODES	MAXIMUM ERROR
1	42	0.5989E-01
2	5	0.1555E-01
3	0	0.3887E-02

*** NODAL CONCENTRATION VALUES ***

NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE	NODE	CONC. VALUE
1	-2.955868E-04	2	8.894363E-04	3	-7.812867E-03	4	7.424977E-02	5	0.363152
6	0.717879	7	1.00000	8	1.00000	9	1.00000	10	1.00000
11	1.00000	12	-2.098035E-04	13	7.405071E-04	14	-7.361537E-03	15	7.331880E-02
16	0.342704	17	0.669020	18	0.780062	19	0.839023	20	0.779074
21	0.779025	22	0.771253	23	-6.523358E-05	24	2.863931E-04	25	-3.249265E-03
26	3.679307E-02	27	0.185385	28	0.338411	29	0.455847	30	0.506389
31	0.471406	32	0.466305	33	0.455748	34	4.110000E-05	35	-6.238116E-05
36	-1.756147E-04	37	7.665924E-03	38	3.148797E-02	39	8.741079E-02	40	0.152392
41	0.188361	42	0.179905	43	0.183465	44	0.176166	45	1.837523E-05
46	-4.616244E-05	47	2.592898E-04	48	-1.039774E-03	49	-2.180928E-03	50	2.186175E-03
51	1.375612E-02	52	2.377154E-02	53	2.715728E-02	54	3.028409E-02	55	2.854861E-02
56	-1.017246E-05	57	2.101207E-05	58	-7.331366E-05	59	8.723190E-05	60	2.145920E-04
61	-7.174003E-04	62	-2.499840E-03	63	-3.374186E-03	64	-2.740398E-03	65	-2.613530E-03
66	-2.546549E-03	67	3.206082E-06	68	-6.139855E-06	69	1.699495E-05	70	-1.721098E-06
71	-8.436196E-06	72	1.845692E-04	73	4.394588E-04	74	4.689419E-04	75	2.570875E-04
76	1.673207E-04	77	1.772042E-04	78	-8.995541E-07	79	1.654853E-06	80	-4.036087E-06
81	-1.750095E-06	82	-3.482412E-06	83	-4.849216E-05	84	-8.997854E-05	85	-7.626891E-05
86	-2.320431E-05	87	2.352514E-06	88	-2.033211E-06	89	2.458767E-07	90	-4.422669E-07
91	1.009743E-06	92	7.042288E-07	93	1.561253E-06	94	1.285017E-05	95	2.095665E-05
96	1.502947E-05	97	1.665338E-06	98	-5.090456E-06	99	-3.762157E-06	100	-6.672710E-08
101	1.184563E-07	102	-2.617749E-07	103	-2.154732E-07	104	-4.826140E-07	105	-3.415717E-06
106	-5.271578E-06	107	-3.472371E-06	108	-6.127033E-09	109	1.786747E-06	110	1.422391E-06
111	1.803477E-08	112	-3.175766E-08	113	6.908798E-08	114	6.095523E-08	115	1.353907E-07
116	9.103082E-07	117	1.377240E-06	118	8.800117E-07	119	-3.551921E-08	120	-5.165964E-07
121	-4.179000E-07	122	-4.858991E-09	123	8.509001E-09	124	-1.836685E-08	125	-1.675313E-08
126	-3.681162E-08	127	-2.433011E-07	128	-3.657270E-07	129	-2.319537E-07	130	1.198891E-08
131	1.414506E-07	132	1.145493E-07	133	1.308624E-09	134	-2.278868E-09	135	4.894464E-09
136	4.559002E-09	137	9.914452E-09	138	6.515305E-08	139	9.773261E-08	140	6.187451E-08
141	-3.354871E-09	142	-3.817447E-08	143	-3.075066E-08	144	-3.546635E-10	145	6.121554E-10
146	-1.308894E-09	147	-1.243525E-09	148	-2.673403E-09	149	-1.753749E-08	150	-2.628273E-08
151	-1.662707E-08	152	9.230598E-10	153	1.030406E-08	154	8.325399E-09	155	1.014630E-10
156	-1.735011E-10	157	3.701962E-10	158	3.606000E-10	159	7.640528E-10	160	5.010935E-09
161	7.506062E-09	162	4.744947E-09	163	-2.642717E-10	164	-2.963026E-09	165	-2.428267E-09
166	-5.191572E-11	167	8.652778E-11	168	-1.837451E-10	169	-1.826313E-10	170	-3.818536E-10
171	-2.505553E-09	172	-3.752838E-09	173	-2.374716E-09	174	1.308164E-10	175	1.470454E-09
176	1.267026E-09	177	-4.010949E-04	178	1.077359E-03	179	-8.050590E-03	180	6.990119E-02
181	0.360815	182	0.717551	183	1.00000	184	1.00000	185	1.00000
186	1.00000	187	1.00000	188	-3.068824E-04	189	9.145939E-04	190	-7.601499E-03
191	6.922356E-02	192	0.339909	193	0.668350	194	0.779988	195	0.839129
196	0.778966	197	0.778898	198	0.771123	199	-9.264883E-05	200	3.333931E-04

201	-3.266895E-03	202	3.455844E-02	203	0.181267	204	0.335379	205	0.454018
206	0.505116	207	0.469611	208	0.464583	209	0.453958	210	3.952435E-05
211	-5.942179E-05	212	-1.712727E-04	213	7.201486E-03	214	2.922960E-02	215	8.329786E-02
216	0.147983	217	0.184342	218	0.176074	219	0.179663	220	0.172416
221	1.842272E-05	222	-4.583708E-05	223	2.533027E-04	224	-1.010211E-03	225	-2.247516E-03
226	1.367527E-03	227	1.178807E-02	228	2.116082E-02	229	2.461792E-02	230	2.762254E-02
231	2.598975E-02	232	-1.002625E-05	233	2.067491E-05	234	-7.202637E-05	235	9.000762E-05
236	2.601044E-04	237	-5.371718E-04	238	-2.239027E-03	239	-3.174959E-03	240	-2.649192E-03
241	-2.573046E-03	242	-2.495140E-03	243	3.157162E-06	244	-6.049119E-06	245	1.684366E-05
246	-3.360945E-06	247	-2.298657E-05	248	1.432057E-04	249	4.031169E-04	250	4.701029E-04
251	2.817934E-04	252	2.075436E-04	253	2.128035E-04	254	-8.865075E-07	255	1.633634E-06
256	-4.028831E-06	257	-1.240962E-06	258	6.106935E-07	259	-3.829985E-05	260	-8.392236E-05
261	-8.218842E-05	262	-3.396140E-05	263	-1.224641E-05	264	-1.537178E-05	265	2.424328E-07
266	-4.371320E-07	267	1.012346E-06	268	5.615449E-07	269	4.480169E-07	270	1.022684E-05
271	1.973367E-05	272	1.720255E-05	273	4.932207E-06	274	-8.515665E-07	275	1.423239E-07
276	-6.580003E-08	277	1.171460E-07	278	-2.630365E-07	279	-1.765379E-07	280	-1.829479E-07
281	-2.725144E-06	282	-4.985549E-06	283	-4.113416E-06	284	-9.174474E-07	285	6.205395E-07
286	3.452163E-07	287	1.778287E-08	288	-3.141279E-08	289	6.949264E-08	290	5.043319E-08
291	5.499451E-08	292	7.266145E-07	293	1.304635E-06	294	1.057029E-06	295	2.116260E-07
296	-2.013272E-07	297	-1.264703E-07	298	-4.790612E-09	299	8.417255E-09	300	-1.848342E-08
301	-1.392282E-08	302	-1.526124E-08	303	-1.942112E-07	304	-3.466334E-07	305	-2.797867E-07
306	-5.442271E-08	307	5.674264E-08	308	3.624543E-08	309	1.290071E-09	310	-2.254414E-09
311	4.927003E-09	312	3.799064E-09	313	4.136736E-09	314	5.200795E-08	315	9.264725E-08
316	7.472724E-08	317	1.445610E-08	318	-1.545212E-08	319	-9.755389E-09	320	-3.495996E-10
321	6.056443E-10	322	-1.318013E-09	323	-1.038703E-09	324	-1.117516E-09	325	-1.399981E-08
326	-2.491711E-08	327	-2.009071E-08	328	-3.873288E-09	329	4.186732E-09	330	2.672153E-09
331	1.000272E-10	332	-1.717071E-10	333	3.729583E-10	334	3.020068E-10	335	3.194108E-10
336	4.000384E-09	337	7.116377E-09	338	5.735069E-09	339	1.106145E-09	340	-1.215187E-09
341	-8.114306E-10	342	-5.118042E-11	343	8.566006E-11	344	-1.852062E-10	345	-1.532927E-10
346	-1.595187E-10	347	-2.000339E-09	348	-3.558049E-09	349	-2.869586E-09	350	-5.544534E-10
351	5.973689E-10	352	4.547773E-10								

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*****                    TIME STEP NO.  5  COMPLETED                    *****
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          ***** SAMFT3D HAS SOLVED THE PROBLEM *****

     **************************************
     *** CPU TIME USED: 37.36    SECS. ***
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