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EVALUATION AND DOCUMENTATION OF THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT THREE-LAYER ANALYTICAL GROUNDWATER MODELS 3LAYSS AND 3LAYT FOR USE BY PERMIT APPLICANTS

EVALUATION AND DOCUMENTATION OF THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT THREE-LAYER ANALYTICAL GROUNDWATER MODEL FOR USE BY PERMIT APPLICANTS

(Draft Project Report)

by

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1.0 INTRODUCTION

1.1 Background and Objective

In permit applications to the St. Johns River Water Management District (District), applicants may be required to address drawdown impacts in the pumped aquifer and also in overlying and/or underlying unpumped aquifers. Extensive hydrogeological investigations that include numerical groundwater flow modeling may be required in some cases to address these issues. However, in other cases, analyses utilizing analytical modeling techniques may be sufficient to assess impacts. Also, analytical modeling techniques may be useful in screening for impacts and/or in conducting preliminary investigations that may indicate the need for more detailed investigations.

The District currently utilizes several models for this purpose, including a two-layer analytical model (Motz and Acar 2007) to analyze drawdowns in two aquifer layers that the University of Florida (University) developed for the District under a previous agreement (District Contract No. SJ398AA). In some cases, there exists the need to analyze drawdowns in three aquifer layers using the same analytical approach that is available in the two-layer model.

The objective of the investigation described in this report was to develop a three-layer analytical drawdown model by modifying and enhancing the capabilities of the District's existing two-layer analytical drawdown model. Documentation of new equations and the computer code for the three-layer model were written so that the documentation and executable code could be posted on the District's website.

1.2 Scope of Work

The investigation described in this draft report consisted of four tasks:

- Review and enhancement of the two-layer model;
- Development of source code and documentation for the three-layer model;
- Preparation of a draft final project report (user's manual); and
- Preparation of a final report (user's manual).

In the first task, the District's existing two-layer model (Motz and Acar 2007, based on Denis and Motz 1998) was reviewed, along with existing analytical solutions for pumping from multiple aquifers (e.g., Cheng 2000, Hemker 1984 and 1985, and Hunt 1985). Suitable solutions (i.e., Hemker 1984 and 1985 and Hemker and Maas 1987) were selected for application to three-layer hydrogeologic conditions in northeast Florida.

In the second task, software was created to calculate drawdowns due to pumping from a three-layer aquifer system. The software consists of two programs, i.e., 3LAYSS can be used to calculate steady-state drawdowns due to pumping from single or multiple wells, and 3LAYT can be used to calculate transient drawdowns due to pumping from single or multiple wells. In this task, FORTRAN source codes were written for the three-layer steady-state and transient drawdown solutions selected in the first task. Beta versions of the three-layer steady-state and transient codes were provided to the District for testing purposes. Also, beta versions of the three-layer drawdown models underwent benchmark testing by the University using selected analytical and numerical problems. Based on the benchmark testing by the University and review of the beta versions by the District, final versions of the steady-state and transient three-layer drawdown models were developed.

In the third task, this draft final project report (user's manual) has been prepared. Based on the first two tasks, this report includes a description of the problem, three-layer steady-state and transient solutions applicable to hydrogeologic conditions in northeast Florida, listings of the source codes for the steady-state and transient programs, the results of the benchmark testing, and example problems to illustrate how to use the software. Electronic copies of the source codes and input and output files for the benchmark and examples problems have been provided to the District.

In the fourth task, a final project report (user's manual) that incorporates the review comments and suggested revisions resulting from the District's review of the draft report will be prepared and submitted to the District. Also, a one-day training session will be provided to District staff at the District's Palatka office.

2.0 LITERATURE REVIEW

2.1 Two-Aquifer Systems

Polubarinova-Kochina (1962) described a solution for the steady-state case for drawdowns in two confined leaky aquifers in which pumpage from one aquifer is balanced by leakage from an overlying constant head source bed. Hantush (1967) described a transient solution for the case in which pumping occurs from one aquifer and drawdowns occur in the pumped aquifer and in an overlying unpumped aquifer. In Hantush's (1967) solution, the pumped water is balanced by water released from storage in the two aquifers, but a steady-state condition is not reached because a source term for recharge is not present. Neuman and Witherspoon (1969) also presented a transient solution in which drawdowns occur in the pumped aquifer, the overlying unpumped aquifer, and in the intermediate confining unit. In their solution, water is obtained from storage in the aquifers and the confining unit, but there is no source term for recharge and thus steady state is not reached in their solution. Motz (1978, 1981) described a steady-state solution in which drawdowns occur in the pumped aquifer and overlying unpumped aquifer. Pumpage is balanced by a drawdown-dependent source term that represents the reduction in evapotranspiration caused by lowering the water table. Motz (1996) developed a nonsteady coupled aquifer solution in which transient drawdowns occur in the pumped and unpumped aquifers. Steady state is reached when pumpage is balanced by the source term that represents evapotranspiration reduction caused by lowering the water table. Confining unit storage is not included in Motz's (1996) solution. Denis and Motz (1998) developed a nonsteady solution in which both aquifers can be pumped and in which confining unit storage and the drawdown-dependent source term representing evapotranspiration reduction are both included in the differential equations that are solved. Steady-state conditions are reached when pumpage is balanced by the source term that represents evapotranspiration reduction caused by lowering the water table. Motz and Denis (2000) used this solution to confirm results obtained by Stewart and Langevin (1999) using a numerical model that the time for the surficial aquifer in Cross Bar wellfield in Pasco County, Florida, to respond fully to pumping from the underlying Floridan aquifer was on the order of at least several years. Hunt and Scott (2007) published an approximate solution for drawdowns due to pumping from a well in a two-aquifer system. In their solution, pumping occurs from one aquifer, steady-state conditions are not reached, and confining unit storage is not considered. The Denis and Motz (1998) solution is more general in that it can be used to consider the additional effects of pumping from both aquifers, evapotranspiration reduction, and confining unit storage and to calculate drawdowns in the confining unit (Motz 2007).

2.2 Multiple-Aquifer Systems

Herrera and Figueroa (1969) and Herrera (1970) considered storage in the confining unit for single and multiple aquifers and developed solutions based on transforming the leaky aquifer equations to corresponding nonleaky aquifer equations. Hemker (1984) developed a general eigenvalue method for the analytical solution of steady flow problems in leaky multiple-aquifer systems comprising any number of aquifers. Also, Hemker (1985) used the eigenvalue approach to derive exact solutions for transient well flow problems in leaky and confined systems comprising any number of aquifers. Hunt (1985) utilized solutions to generalized eigenvalue problems to calculate drawdowns for both steady and unsteady flow to a well in an aquifer system with multiple horizontal aquifers. Maas (1986) demonstrated how boundary value problems for multiple-aquifer flow can be formulated in terms of matrix differential equations and solved in terms of matrix functions. Maas (1987a and 1987b) presented solutions to the problem of steady and nonsteady flow to a partially screened well in a stratified porous medium, in which both horizontal and vertical flows are taken into account. Hemker and Maas (1987) developed solutions for the calculation of drawdowns in leaky and confined multi-aquifer systems, pumped by a well of constant discharge penetrating one or more of the aquifers, in which confining unit storage is accounted for. Two equivalent solutions in terms of matrix functions and an eigenvalue analysis are obtained. Cheng and Ou (1989) described a numerical algorithm that inverts a solution in Laplace space to the time domain for groundwater flow in multi-aquifer systems. Cheng and Morohunfola (1993) developed an analytical solution that utilizes influence and memory functions described by Herrera (1970) and matrix solution techniques. A numerical algorithm inverts from Laplace space to the time domain to solve for transient drawdowns due to pumping from a multi-layer leaky aquifer system. Their solution includes the effects of storage in multiple confining units. Hemker and Maas (1994) agreed that the solution of Cheng and Morohunfola (1993) represents a solution for transient well flow in leaky multiaquifer systems but argued that the same problem had been solved previously and more rigorously by Hemker and Maas (1987). Hemker (1999) obtained a solution for the general problem of computing well flow in vertically heterogeneous aquifers by integrating both analytical and numerical techniques. Also, Hemker (1999) obtained a solution for transient well flow in layered aquifer systems for the uniform well-face drawdown case. Meesters et al. (2004) obtained an analytical solution for the problem of steady groundwater flow toward a pumping well in an aquifer system consisting of aquifers with anisotropy of the horizontal conductivity.

3.0 ANALYTICAL SOLUTIONS FOR A THREE-LAYER AQUIFER SYSTEM

3.1 Steady-State Solution

3.1.1 Steady-State Solution for a Multi-Layer Aquifer System

The general method developed by Hemker (1984) for the analytical solution of steady-state flow in leaky multiple-aquifer systems comprising any number of aquifers was used as the basis for the steady-state three-layer solution developed for the District. In Hemker's (1984) solution, the multi-layer aquifer system consists of *n* aquifers and *n+1* confining units (see Figure 3-1). All of the layers are homogeneous, horizontal, and of infinite extent, and the aquifers are isotropic with respect to horizontal and vertical conductivity. Groundwater flow is induced by a well or multiple wells, completely penetrating one or more of the aquifers, with each screen pumped at a constant rate. Zero-drawdown boundaries are specified at the top and bottom of the system, and it is assumed that the system layers possess sufficiently contrasting conductivities so that horizontal flow in the confining units and resistance to vertical flow in the aquifers can be neglected.

The steady-state multi-aquifer well flow problem can be formulated in terms of a system of *n* simultaneous ordinary differential equations with boundary conditions for the unknown drawdowns (Hemker 1984). When the radial component in the aquifers is considered, the drawdown s(r) satisfies the equation:

$$\frac{d^2 s_i}{dr^2} + \frac{1}{r}\frac{ds_i}{dr} = \frac{s_i - s_{i-1}}{T_i c_i} + \frac{s_i - s_{i+1}}{T_i c_{i+1}} \qquad i = 1, 2, ..., n \qquad \text{(3-1)}$$

subject to the boundary conditions:

$$s_i = 0 \text{ at } r \to \infty \qquad \text{(3-2)}$$

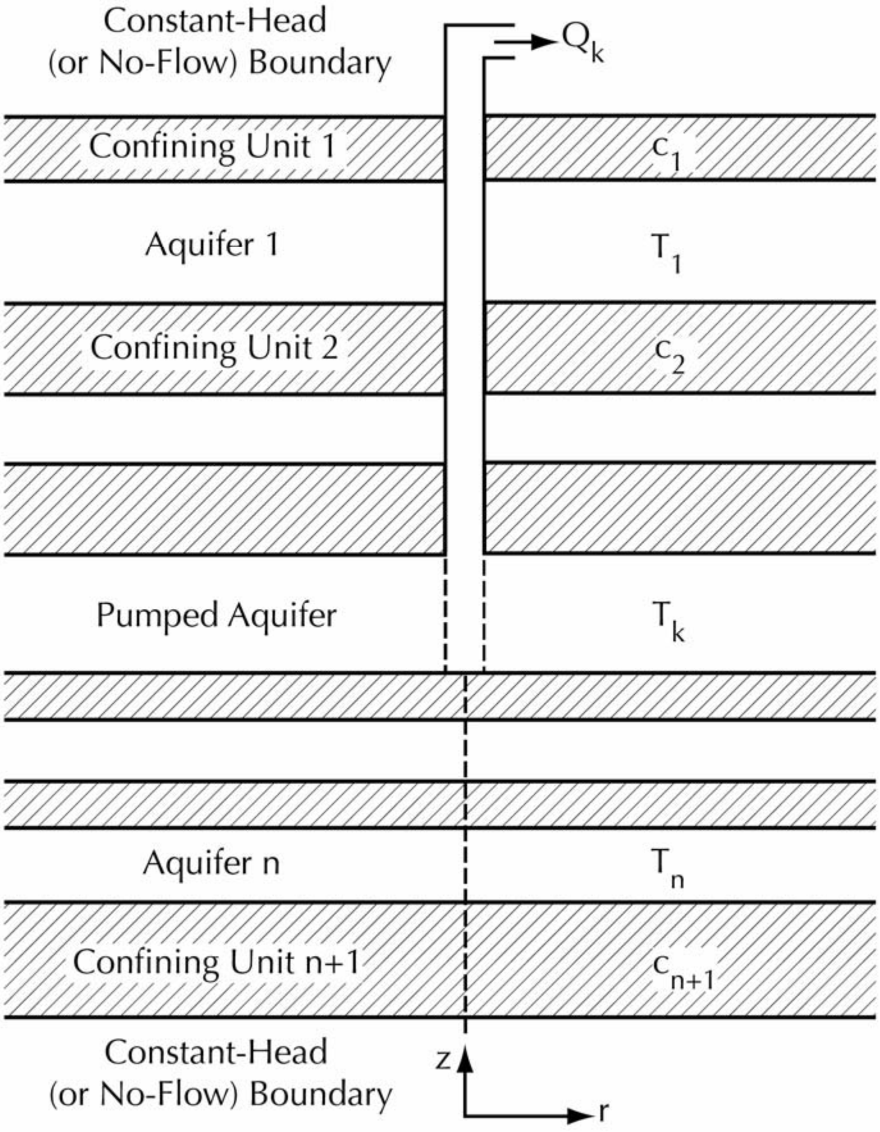


Figure 3-1. Definition sketch for a well in a steady-state leaky multiple-aquifer system (modified from Hemker 1984)

and:

$$\lim_{r\to 0} r\frac{ds_i}{dr} = -\frac{Q_i}{2\pi T_i} \tag{3-3}$$

where s_i = drawdown in the ith aquifer [L]; T_i = transmissivity of the ith aquifer [L^2T^{-1}]; c_i = hydraulic resistance (1/leakance) of the ith confining unit [T]; and Q_i = discharge rate from the ith aquifer [L^3T^{-1}]. The indices indicate the succession of layers from top to bottom. When a leaky aquifer system is considered with recharge at the top and bottom, $s_0 = 0$ and $s_{n+1} = 0$. If top and/or bottom of the system are impervious, no-flow boundary conditions are specified at the top and/or bottom instead.

This system of equations can be written in the form of a matrix:

$$\mathcal{L}\mathbf{s} = \mathbf{A}\mathbf{s} \tag{3-4}$$

with the Laplace operator $\mathcal{L}$ defined for radial flow as:

$$\mathcal{L} = \frac{d^2}{dr^2} + \frac{1}{r}\frac{d}{dr} \tag{3-5}$$

and where **A** is a non-symmetric tridiagonal n x n matrix defined as:

$$\mathbf{A} = \begin{bmatrix} a_1+b_1 & -b_1 & 0 & \cdots & 0 & 0 \\ -a_2 & a_2+b_2 & -b_2 & \cdots & 0 & 0 \\ 0 & -a_3 & a_3+b_3 & \cdots & 0 & 0 \\ \vdots & & & & & \\ 0 & 0 & 0 & \cdots & -a_n & a_n+b_n \end{bmatrix} \tag{3-6}$$

with:

$a_i = 1/T_i c_i$;

$b_i = 1/T_i c_{i+1}$;

T_i = transmissivity of *ith* aquifer [L^2T^{-1}];

c_i = vertical hydraulic resistance (1/leakance) of *ith* confining unit [T]; and

s is the drawdown vector defined by:

$$\mathbf{s} = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_n \end{bmatrix}$$

3.1.2 Steady-State Solution for a Three-Layer Aquifer System

In the steady-state three-layer solution developed for the District (see Figure 3-2), a slightly different approach from Hemker's (1984) steady-state solution is used. In order to benefit fully from the nearly symmetric property of matrix **A**, a symmetric tridiagonal matrix **D** is defined, and then its n eigenvalues and eigenvectors are calculated. This is similar to the procedure followed by Hemker and Maas (1987) in their transient multi-layer solution. Using this approach, a matrix **D** is defined as:

$$\mathbf{D} = \mathbf{T}^{1/2}\mathbf{A}\mathbf{T}^{-1/2} \tag{3-7}$$

where **T** is a diagonal matrix with T_i along the main diagonal. Matrix **D** can be represented in terms of its eigenvalues and eigenvectors as:

$$\mathbf{D} = \mathbf{R}\mathbf{W}\mathbf{R}^{-1} \tag{3-8}$$

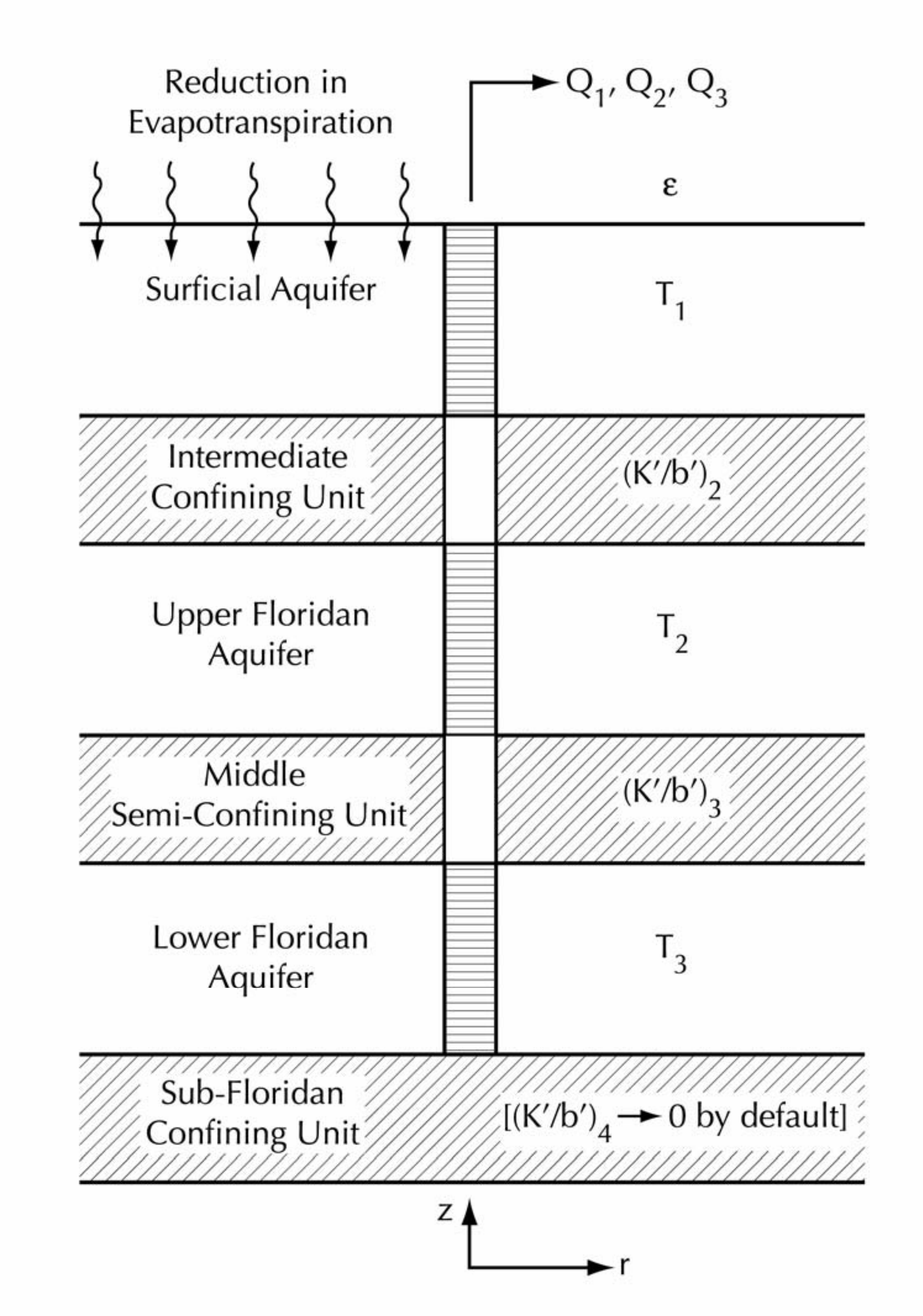


Figure 3-2. Definition sketch for a well in a steady-state leaky three-aquifer system with evapotranspiration reduction at the top boundary

where **W** is an n x n diagonal matrix with the eigenvalues w_i, and **R** is an n x n matrix containing the corresponding eigenvectors in its columns. Since **D** is symmetric, the eigenvectors can be normalized to obtain an orthonormal matrix **R**, and thus $\mathbf{R}^{-1} = \mathbf{R}^{T}$. Upon defining a matrix $\mathbf{V} = \mathbf{T}^{-1/2}\mathbf{R}$, then:

$$\mathbf{V}^{-1} = \mathbf{R}^{-1}\mathbf{T}^{1/2} = \mathbf{R}^{T}\mathbf{T}^{1/2} \tag{3-9}$$

Substituting equations (3-7), (3-8) and (3-9) into (3-4) leads to:

$$\mathcal{L}\mathbf{s} = \mathbf{V}\mathbf{W}\mathbf{V}^{-1}\mathbf{s} \tag{3-10}$$

This system of differential equations can be uncoupled and solved using the boundary conditions to obtain:

$$\mathbf{s} = \mathbf{V}\mathbf{K}\mathbf{V}^{-1}\mathbf{g} \tag{3-11}$$

where **K** is an n x n diagonal matrix with $K_0(r\sqrt{w_i})$ as non-zero elements; $K_0(\ )$ = modified Bessel function, second kind, zero order; and **g** is the discharge vector given by $Q_i / 2\pi T_i$, $i = 1, 2, \ldots, n$.

In the three-layer steady-state solution developed for the District, the top and bottom boundary conditions are written to reflect hydrogeologic conditions in the District. The source term at the top of the aquifer system is the reduction in evapotranspiration due to a decline in the water table, which is represented by the coefficient ε $[T^{-1}]$ (Denis and Motz, 1998). This term is included in the equation for aquifer one by setting $c_1 = 1/\varepsilon$ for the uppermost confining unit in the calculations. At the bottom of the aquifer system, the sub-Floridan aquifer confining unit is generally considered impermeable. This condition is represented in the three-layer solution by setting $c_4 = 1.0 \times 10^{38}$, which results in zero leakance for the bottom confining unit, or $(K'/b')_4 = 1/c_4 \rightarrow 0$.

3.2 Transient Solution

3.2.1 Transient Solution for a Multi-Layer Aquifer System

The transient solution for drawdowns in multiple aquifers obtained by Hemker and Maas (1987) was used as the basis for the transient three-layer solution developed for the District. In Hemker and Maas' (1987) solution, similar to the steady-state problem (Hemker 1984), the eigenvalue analysis approach is used to derive solutions for transient well flow problems in leaky and confined systems comprising any number of aquifers. Hemker and Maas (1987) include the effects of elastic storage in the separating and bounding confining units in this transient solution, which consists of n aquifers and $n+1$ confining units (see Figure 3-3). In the transient solution, it is assumed that all of the layers are homogeneous, horizontal, and of infinite extent and that the aquifers are isotropic with respect to horizontal and vertical conductivity. Groundwater flow is induced by a well or multiple wells that completely penetrate one or more of the aquifers, with each screen pumped at a constant rate from the same initial time. The hydraulic properties of aquifers and confining units remain constant in time, and it is assumed that the system layers possess sufficiently contrasting conductivities so that horizontal flow in the confining units and resistance to vertical flow in the aquifers can be neglected (Hemker 1985).

The transient multi-aquifer well flow problem can be formulated in terms of a system of $2n$ simultaneous partial differential equations with initial and boundary conditions for the unknown drawdown (Hemker and Maas 1987). When the radial component in the aquifers is considered, the drawdown s(r, t) satisfies the equation:

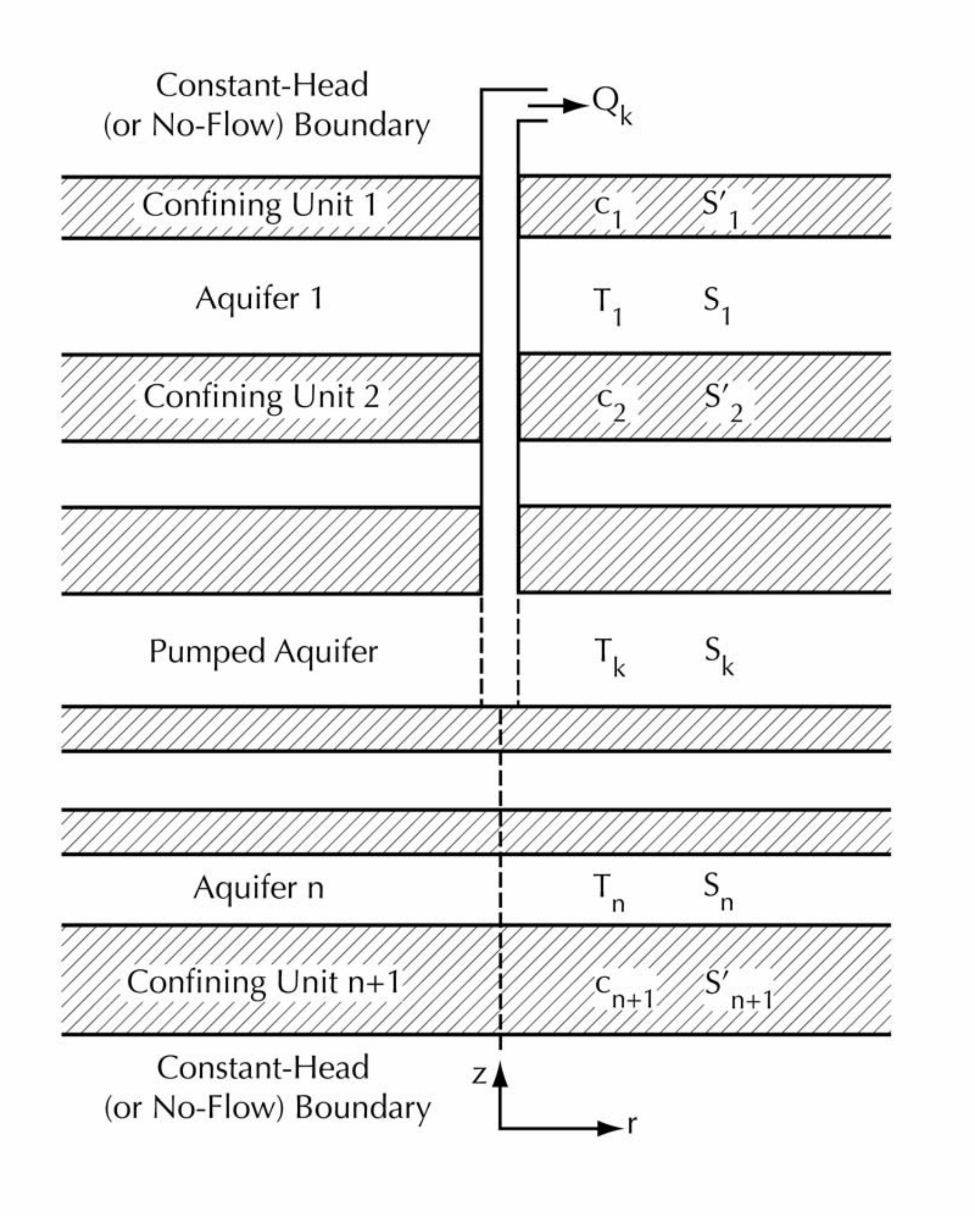


Figure 3-3. Definition sketch for a well in a transient leaky multiple-aquifer system with confining unit storage (modified from Hemker and Maas 1987)

$$\frac{\partial^2 s_i}{\partial r^2} + \frac{1}{r}\frac{\partial s_i}{\partial r} = -\frac{K_i^{'}}{T_i}\frac{\partial s_i^{'}}{\partial z}\bigg|_{z=z_i^{'}} + \frac{K_{i+1}^{'}}{T_i}\frac{\partial s_{i+1}^{'}}{\partial z}\bigg|_{z=z_{i+1}^{'}} + \frac{S_i}{T_i}\frac{\partial s_i}{\partial t} \qquad i=1,2,...,n \tag{3-12}$$

subject to the boundary conditions:

$$s_i(\infty, t) = 0 \tag{3-13}$$

$$\lim_{r \to 0} r\frac{\partial s_i}{\partial r} = -\frac{Q_i}{2\pi T_i} \tag{3-14}$$

and the initial condition:

$$s_i(r, 0) = 0 \tag{3-15}$$

Vertical flow in the confining units is governed by:

$$\frac{\partial^2 s_i^{'}}{\partial z^2} = \frac{S_{si}^{'}}{K_i^{'}}\frac{\partial s_i^{'}}{\partial t} \qquad i=1,2,...,n \tag{3-16}$$

subject to the boundary conditions:

$$s_i^{'}(r, z_{i-1}, t) = s_{i-1}(r, t) \tag{3-17}$$

$$s_i^{'}(r, z_i^{'}, t) = s_i(r, t) \tag{3-18}$$

and the initial condition:

$$s_i^{'}(r, z, 0) = 0 \tag{3-19}$$

where K = hydraulic conductivity [LT^{-1}]; S_s = specific storage[dimensionless]; T = aquifer transmissivity [$L^2\ T^{-1}$]; and S = storage coefficient [dimensionless]. The indices indicate the succession of layers, and the primes refer to confining units (Figure 3-3). When a leaky aquifer system with recharge at the top and bottom is considered, $s_0 = 0$ and $s_{n+1} = 0$. If the top and/or bottom of the system are impervious, no-flow boundary conditions are specified instead:

$$\frac{\partial}{\partial z} s_1^{'}(r, z_0, t) = 0 \tag{3-20}$$

and/or:

$$\frac{\partial}{\partial z} s_{n+1}^{'}(r, z_{n+1}^{'}, t) = 0 \tag{3-21}$$

Using Laplace transforms, the partial differential equations (3-12) and (3-16) can be transformed to ordinary differential equations, which can be expressed in matrix notation as:

$$\mathcal{L}\overline{\mathbf{s}} = \mathbf{A}\overline{\mathbf{s}} \tag{3-22}$$

where $\mathcal{L}$ is the Laplace operator $\frac{\partial^2}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial r}$, $\overline{\mathbf{s}}$ is the vector of the Laplace transformed drawdowns, and **A** is a non-symmetric tridiagonal n x n matrix defined as:

$$\mathbf{A} = \begin{bmatrix} e_{11} + e_{21} + d_1 & -f_{21} & 0 & \cdots & 0 & 0 \\ -f_{22} & e_{22} + e_{32} + d_2 & -f_{32} & & & \vdots \\ 0 & -f_{33} & e_{33} + e_{43} + d_3 & & & \vdots \\ \vdots & & & & & \\ \vdots & & & & & -f_{n,n-1} \\ 0 & 0 & 0 & 0 & -f_{nn} & e_{nn} + e_{n+1,n} + d_n \end{bmatrix} \tag{3-23}$$

with:

$$d_i = pS_i / T_i;$$

$$e_{ij} = (b_i \coth b_i) / c_i T_j;$$

$$f_{ij} = b_i / (c_i T_j \sinh b_i);$$

$$b_i = (pS_i^{'} c_i)^{1/2};$$

p = Laplace transform parameter [T^{-1}];

S_i = storage coefficient of *ith* aquifer [dimensionless];

T_i = transmissivity of *ith* aquifer [L^2T^{-1}];

c_i = hydraulic resistance of *ith* confining unit [T]; and

$S_i^{'}$ = storage coefficient of *ith* confining unit [dimensionless];

3.2.2 Transient Solution for a Three-Layer Aquifer System

The three-layer transient solution developed for the District (see Figure 3-4) is based on the method described by Hemker and Maas (1987). In order to benefit fully from the nearly symmetric property of **A**, a symmetric tridiagonal matrix **D** is defined, and then its n eigenvalues and eigenvectors are calculated using the QL method described by Wilkinson and Reinsch (1971). The matrix **D** is defined as:

$$\mathbf{D} = \mathbf{T}^{1/2}\mathbf{A}\mathbf{T}^{-1/2} \tag{3-24}$$

where **T** is a diagonal matrix with T_i along the main diagonal. Matrix **D** can be represented in terms of its eigenvalues and eigenvectors as:

$$\mathbf{D} = \mathbf{R}\mathbf{W}\mathbf{R}^{-1} \tag{3-25}$$

where **W** is an n x n diagonal matrix with the eigenvalues w_i, and **R** is an n x n matrix containing the corresponding eigenvectors in its columns. Since **D** is symmetric, the eigenvectors can be normalized to obtain an orthonormal matrix **R**, and thus $\mathbf{R}^{-1} = \mathbf{R}^{T}$. Upon defining a matrix $\mathbf{V} = \mathbf{T}^{-1/2}\mathbf{R}$, then:

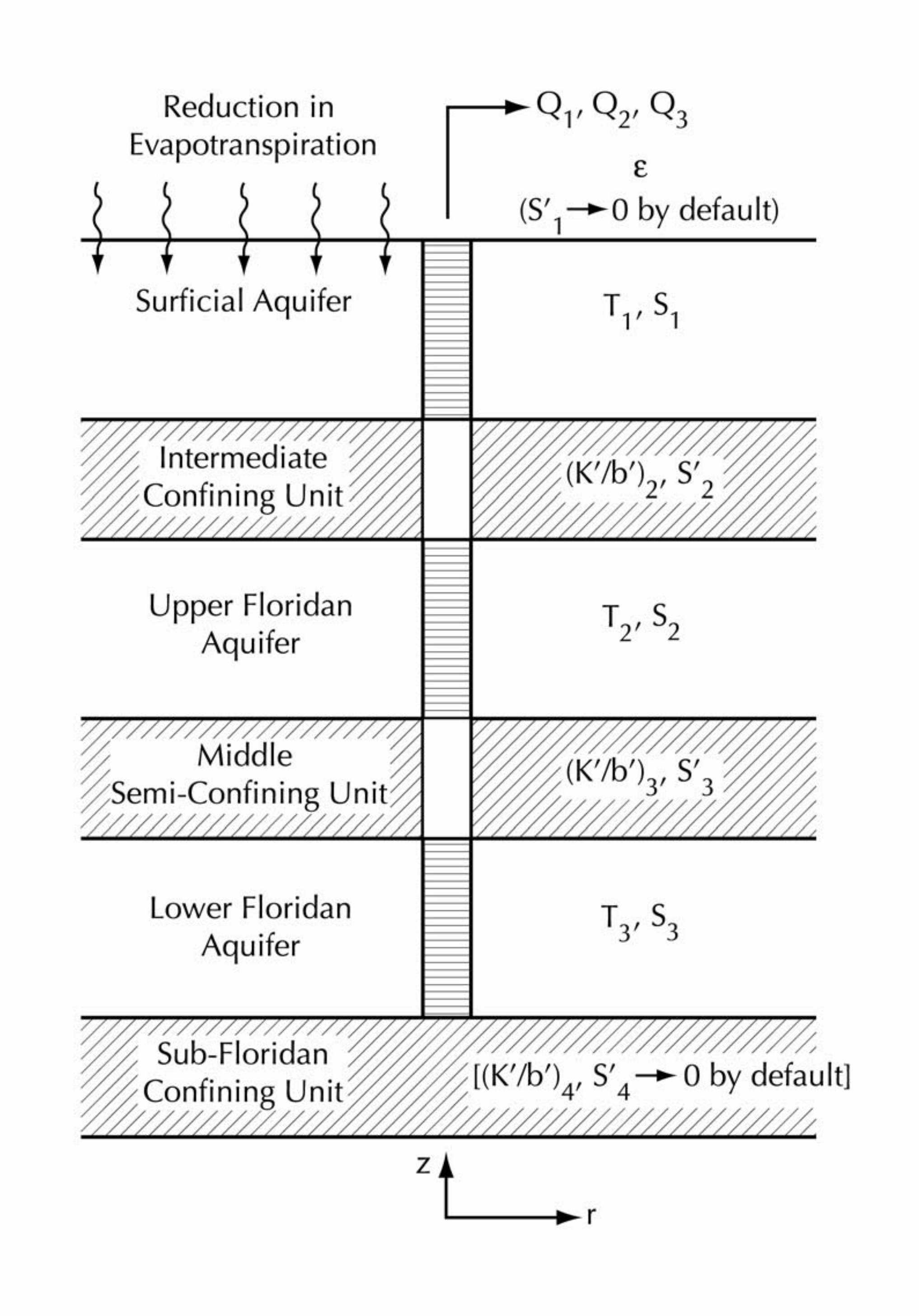


Figure 3-4. Definition sketch for a well in a transient leaky three-aquifer system with confining unit storage and evapotranspiration reduction at the top boundary

$$\mathbf{V}^{-1} = \mathbf{R}^{-1}\mathbf{T}^{1/2} = \mathbf{R}^{T}\mathbf{T}^{1/2} \tag{3-26}$$

Substituting equations (3-24), (3-25) and (3-26) into (3-22) leads to:

$$\mathcal{L}\overline{\mathbf{s}} = \mathbf{V}\mathbf{W}\mathbf{V}^{-1}\overline{\mathbf{s}} \tag{3-27}$$

Similar to the steady-state problem, this system of differential equations can be uncoupled and solved using the boundary conditions to obtain:

$$\overline{\mathbf{s}} = \frac{1}{p}\mathbf{V}\mathbf{K}\mathbf{V}^{-1}\mathbf{g} \tag{3-28}$$

where **K** is the n x n diagonal matrix with $K_0(r\sqrt{w_i})$ as non-zero elements; $K_0(\ )$ = modified Bessel function, second kind, zero order; and **g** is the discharge vector given by $Q_i / 2\pi T_i$, $i = 1, 2, \ldots, n$. Drawdowns in the time domain are obtained by inverting the Laplace-space solution given by Equation 3-28 using the Stehfest (1970a, b) numerical algorithm.

Similar to the three-layer steady-state solution (section 3.1.2), the top and bottom boundary conditions in the three-layer transient solution are written to reflect hydrogeologic conditions in the District. The source term at the top of the aquifer system is the reduction in evapotranspiration due to a decline in the water table, which is represented by ε (Denis and Motz, 1998) and written in the equation for aquifer one as $c_1 = 1/\varepsilon$. At the bottom of the aquifer system, the impermeable sub-Floridan confining unit is represented in the three-layer solution by setting $c_4 = 1.0 \times 10^{38}$, which results in zero leakance for the bottom confining unit, or $(K'/b')_4 = 1/c_4 \rightarrow 0$. In the three-layer transient model, there are no contributions of water from storage associated with the evapotranspiration reduction process or from the bottom impermeable confining unit, and, thus, both $S_1^{'}$ and $S_4^{'}$ = 0, which is achieved by setting these storage coefficients equal to 1.0 x 10^{-38}.

4.0 STEADY-STATE MODEL FOR A THREE-LAYER AQUIFER SYSTEM

4.1 Drawdowns Due to Single Well

4.1.1 Steady-State Single-Well Option

The single-well option in 3LAYSS uses Equations 3-6 through 3-11 to calculate drawdowns for aquifers one, two, and three. To start the program, the user clicks on the icon for the program and selects the single-well option. The program can be run interactively with the user inputting all data on the screen, or the user can prepare an input file and select the 'file' option when running the program. If the program is run interactively, drawdown results for each radial distance are printed on the screen, and the user is prompted to enter the names of two output files. One output file (filename.out) echoes the input data and prints the radial distance from the pumped well and the drawdown results at that distance, and the other file (filename.dat) prints the output results for radial distance and drawdowns in a format that can be readily used in a graphical package such as Grapher™ to plot drawdowns for a certain radial distance. If the 'file' option is selected, then the user is prompted to enter the input file name (filename.in), the name of the project ('project name'), and the names of the two output files (filename.out and filename.dat), which are the same as the output files written using the interactive option. Interactively on the screen or in the input file, the user inputs the pumping rates and transmissivity values for each aquifer, the rate at which evapotranspiration is reduced per unit of water-table drawdown, leakance values for each confining unit, the number of radial distances at which calculations are carried out, and values for the radial distances. Inside the program, c_1 is set by default equal to $1/\varepsilon$ to represent the effects of evapotranspiration reduction in the equation for aquifer one. Also, c_4 is set by default equal to $1.0\mathrm{x}10^{38}$ to approximate the impermeable boundary condition at the base of aquifer three, i.e., $(K'/b')_4 = 1/c_4 \rightarrow 0$.

The single-well option for 3LAYSS runs as follows. First, the non-symmetric tridiagonal matrix **A** is computed using Equation 3-6. Then, this matrix is converted to the symmetric tridiagonal matrix **D** using Equation 3-7. Eigenvalues and eigenvectors of **D** are calculated in subroutine 'tqli' using the QL method described by Wilkinson and Reinsch (1971). In the next step, matrix **V**, which is defined as $\mathbf{V} = \mathbf{T}^{-1/2}\mathbf{R}$, is calculated by matrix multiplication in subroutine 'Mmult'. The inverse of **V** is calculated in subroutine 'inversematrix'. Then, the discharge vector **g** is determined from $Q_i / 2\pi T_i,\ i = 1, 2, \ldots, n$. In order to use Equation 3-11 to calculate the drawdowns, the last step is to find matrix **K**. After this point, all the computations are done inside the radial distances loop. While finding matrix **K**, modified Bessel functions of the second kind, zero order [K_0( )] are calculated in subroutine 'BESSELKo'. This subroutine is linked to subroutine 'BESSELIo', which calculates modified Bessel functions of the first kind, zero order [I_0( )]. Finally, all the matrix and matrix-vector multiplications in Equation 3-11 involving **V**, **K**, $\mathbf{V}^{-1}$, and **g** are carried out in the subroutines 'Mmult' and 'MVmult'. When calculations for all of the radial distances have been performed, radius and drawdown results are written to both output files 'filename.out' and 'filename.dat'. At this point, the user is asked if more calculations are to be done.

4.1.2 Benchmark Problem for Single-Well Steady-State Model

The single-well steady-state option in 3LAYSS was tested using parameters based on Williams (1995) and Tibbals (1990) that are generally representative of the hydrogeologic system and parameters in the Titusville/Mims area in the northern part of Brevard County in east-central Florida. In this area, the hydrogeologic system generally consists of a surficial aquifer system that overlies a low permeability confining unit, which in turn overlies the Floridan aquifer system, a regionally extensive aquifer system (Miller 1986). The water table occurs in the uppermost part of the surficial aquifer system. The confining unit between the surficial and Floridan aquifer systems, called the intermediate confining unit, is the upper confining unit of the Floridan aquifer system. The Floridan aquifer system is comprised of two zones called the upper and lower Floridan aquifers, which are separated by a relatively low permeability unit called the middle semiconfining unit. Additionally, the sub-Floridan confining unit, generally considered impermeable, occurs at the base of the Floridan aquifer system. In the 3LAYSS steady-state solution, aquifer one represents the surficial aquifer, aquifer two represents the upper Floridan aquifer, and aquifer three represents the lower Floridan aquifer (see Table 4-1). Confining unit two overlying aquifer two represents the intermediate confining unit, and confining unit three overlying aquifer three represents the middle semiconfining unit. Values for $Q_1 = 0$ and $T_1 = 1{,}000$ ft^2/day were used for aquifer one, $Q_2 = 353{,}000$ ft^3/day and $T_2 =$

Table 4-1. Hydrogeologic units and parameters used in the steady-state 3LAYSS and MODFLOW solutions

Hydrogeologic Units and ET Reduction Process	3LAYSS		MODFLOW	
	Units	Parameters	Layers	Parameters
-	-	-	1	Constant head source bed
Evapotranspiration Reduction	Confining Unit One	$\varepsilon = 1.52 \times 10^{-4}$ day^{-1}	2	$(K_V/b)_2 = 1.52 \times 10^{-4}$ day^{-1}
Water-Table Aquifer	Aquifer One	$Q_1 = 0$; $T_1 = 1{,}000$ ft^2/day	3	$T_3 = 1{,}000$ ft^2/day
Intermediate Confining Unit	Confining Unit Two	$(K'/b')_2 = 1.0 \times 10^{-4}$ day^{-1}	4	$(K_V/b)_4 = 1.0 \times 10^{-4}$ day^{-1}
Upper Floridan Aquifer	Aquifer Two	$Q_2 = 353{,}000$ ft^3/day; $T_2 = 60{,}000$ ft^2/day	5	$Q_{5,70,70} = -353{,}000$ ft^3/day; $T_5 = 60{,}000$ ft^2/day
Middle Semi-Confining Unit	Confining Unit Three	$(K'/b')_3 = 5.0 \times 10^{-5}$ day^{-1}	6	$(K_V/b)_6 = 5.0 \times 10^{-5}$ day^{-1}
Lower Floridan Aquifer	Aquifer Three	$Q_3 = 0$; $T_3 = 60{,}000$ ft^2/day	7	$T_7 = 60{,}000$ ft^2/day
Sub-Floridan Confining Unit	Confining Unit Four	$(K'/b')_4 \rightarrow 0$ by default	-	No-flow boundary by default

- No data.

60,000 ft^2/day were used for aquifer two, and $Q_3 = 0$ and $T_3 = 60,000$ ft^2/day were used for aquifer three. A value for $\varepsilon = 1.52 \times 10^{-4}$ day^{-1} was used, based on Motz (1981). A value of $(K'/b')_2 = 1.0 \times 10^{-4}$ day^{-1} was used for confining unit two, and a value of $(K'/b')_3 = 5.0 \times 10^{-5}$ day^{-1} was used for confining unit three. Using 3LAYSS, drawdowns were calculated versus radial distance from the pumped well in layer two for layers one, two, and three (see Figure 4-1).

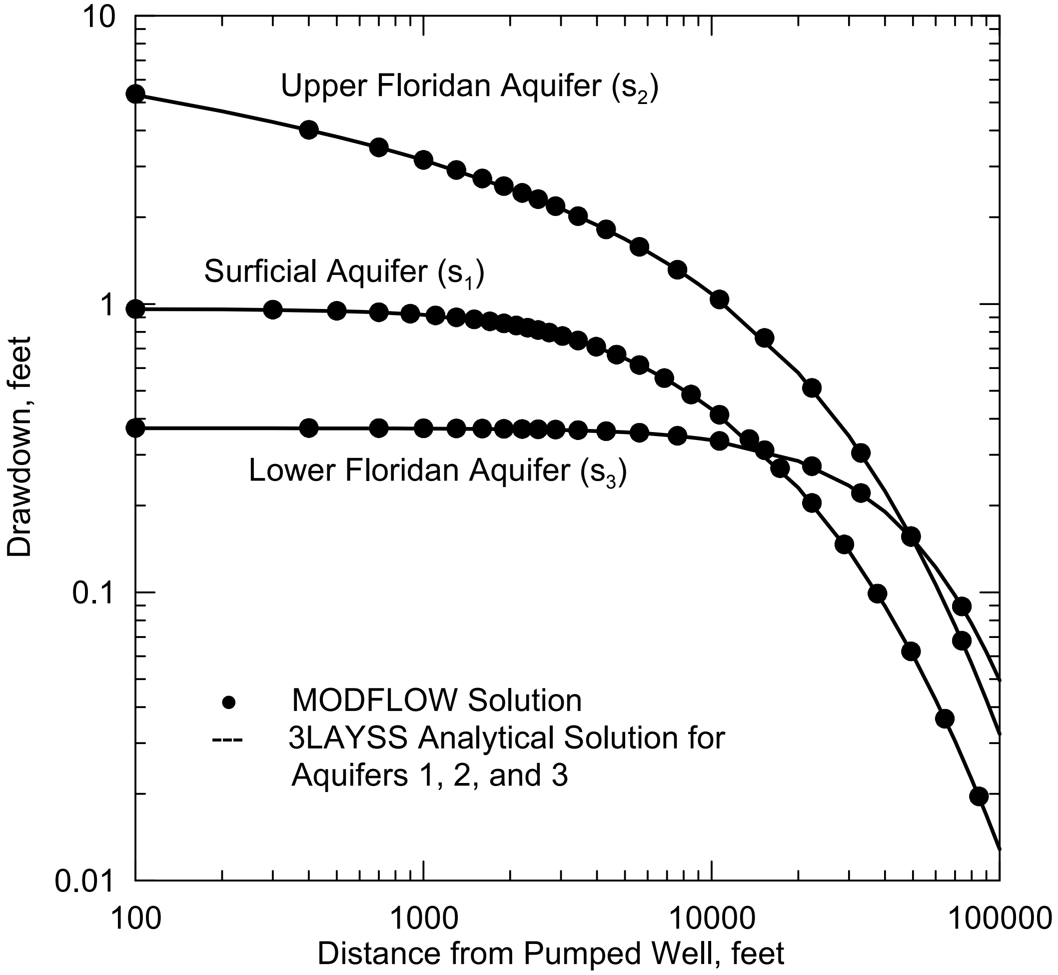


Figure 4-1. Benchmark problem for steady-state model: drawdowns versus radial distance for 3LAYSS and MOFLOW solutions

Files for the steady-state benchmark problem are in Tables 4-2 through 4-6. The screen capture for the interactive option is in Table 4-2, and the output files are in Tables 4-3 and 4-4. The screen capture for the input file option is in Table 4-5, and the input file for the file option is in Table 4-6. The input file option writes the same output files as the interactive option (Tables 4-3 and 4-4).

Table 4-2. Input on screen for interactive input for steady-state 3LAYSS benchmark problem

```
****************************************************************************
****************************************************************************
         3LAYSS: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
****************************************************************************
****************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
s
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
i
 NAME OF THE PROJECT: <write in single quotation marks>
'three-layer steady-state benchmark problem'
 PLEASE ENTER DATA IN CONSISTENT UNITS
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)=?
1000.0
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
353000.
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)=?
60000.0
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
0.0
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)=?
60000.0
 RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)=?
1.52e-4
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)=?
1.0e-4
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)=?
5.0e-5
 NUMBER OF r VALUES FOR WHICH CALCULATIONS ARE CARRIED OUT=?
29
RADIAL DISTANCE FROM THE PUMPED WELL (r) 1 (ft)=?
100
RADIAL DISTANCE FROM THE PUMPED WELL (r) 2 (ft)=?
200
RADIAL DISTANCE FROM THE PUMPED WELL (r) 3 (ft)=?
300
RADIAL DISTANCE FROM THE PUMPED WELL (r) 4 (ft)=?
400
RADIAL DISTANCE FROM THE PUMPED WELL (r) 5 (ft)=?
500
RADIAL DISTANCE FROM THE PUMPED WELL (r) 6 (ft)=?
600
RADIAL DISTANCE FROM THE PUMPED WELL (r) 7 (ft)=?
700
RADIAL DISTANCE FROM THE PUMPED WELL (r) 8 (ft)=?
800
RADIAL DISTANCE FROM THE PUMPED WELL (r) 9 (ft)=?
900
```

```
RADIAL DISTANCE FROM THE PUMPED WELL (r)10 (ft)=?
1000
RADIAL DISTANCE FROM THE PUMPED WELL (r)11 (ft)=?
2000
RADIAL DISTANCE FROM THE PUMPED WELL (r)12 (ft)=?
3000
RADIAL DISTANCE FROM THE PUMPED WELL (r)13 (ft)=?
4000
RADIAL DISTANCE FROM THE PUMPED WELL (r)14 (ft)=?
5000
RADIAL DISTANCE FROM THE PUMPED WELL (r)15 (ft)=?
6000
RADIAL DISTANCE FROM THE PUMPED WELL (r)16 (ft)=?
7000
RADIAL DISTANCE FROM THE PUMPED WELL (r)17 (ft)=?
8000
RADIAL DISTANCE FROM THE PUMPED WELL (r)18 (ft)=?
9000
RADIAL DISTANCE FROM THE PUMPED WELL (r)19 (ft)=?
10000
RADIAL DISTANCE FROM THE PUMPED WELL (r)20 (ft)=?
20000
RADIAL DISTANCE FROM THE PUMPED WELL (r)21 (ft)=?
30000
RADIAL DISTANCE FROM THE PUMPED WELL (r)22 (ft)=?
40000
RADIAL DISTANCE FROM THE PUMPED WELL (r)23 (ft)=?
50000
RADIAL DISTANCE FROM THE PUMPED WELL (r)24 (ft)=?
60000
RADIAL DISTANCE FROM THE PUMPED WELL (r)25 (ft)=?
70000
RADIAL DISTANCE FROM THE PUMPED WELL (r)26 (ft)=?
80000
RADIAL DISTANCE FROM THE PUMPED WELL (r)27 (ft)=?
90000
RADIAL DISTANCE FROM THE PUMPED WELL (r)28 (ft)=?
100000
RADIAL DISTANCE FROM THE PUMPED WELL (r)29 (ft)=?
128008
 ENTER OUTPUT FILE NAME: <filename.out>
benchmark.out
 ENTER DATA FILE NAME FOR GRAPHER INPUT: <filename.dat>
benchmark.dat

 r (ft) = 1.000E+02

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   9.590E-01   5.311E+00   3.706E-01


 r (ft) = 2.000E+02

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   9.568E-01   4.662E+00   3.706E-01


 r (ft) = 3.000E+02

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   9.536E-01   4.283E+00   3.705E-01


 r (ft) = 4.000E+02

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   9.498E-01   4.014E+00   3.704E-01
```

```
r (ft) = 5.000E+02

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  9.454E-01   3.805E+00   3.704E-01


r (ft) = 6.000E+02

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  9.404E-01   3.634E+00   3.703E-01


r (ft) = 7.000E+02

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  9.351E-01   3.490E+00   3.702E-01


r (ft) = 8.000E+02

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  9.294E-01   3.366E+00   3.701E-01


r (ft) = 9.000E+02

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  9.235E-01   3.256E+00   3.700E-01


r (ft) = 1.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  9.173E-01   3.157E+00   3.698E-01
r (ft) = 2.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  8.477E-01   2.513E+00   3.680E-01


r (ft) = 3.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  7.757E-01   2.140E+00   3.655E-01


r (ft) = 4.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  7.082E-01   1.878E+00   3.625E-01
```

```
r (ft) = 5.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  6.474E-01   1.678E+00   3.590E-01


r (ft) = 6.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  5.933E-01   1.517E+00   3.551E-01


r (ft) = 7.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  5.455E-01   1.384E+00   3.510E-01


r (ft) = 8.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  5.031E-01   1.270E+00   3.466E-01


r (ft) = 9.000E+03

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  4.656E-01   1.172E+00   3.420E-01
r (ft) = 1.000E+04

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  4.321E-01   1.085E+00   3.372E-01


r (ft) = 2.000E+04

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  2.305E-01   5.775E-01   2.853E-01


r (ft) = 3.000E+04

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  1.389E-01   3.483E-01   2.345E-01


r (ft) = 4.000E+04

  drawdown    drawdown    drawdown
  aquifer 1   aquifer 2   aquifer 3
 ----------  ----------  ----------
 ----------  ----------  ----------
  8.955E-02   2.247E-01   1.900E-01
```

```
 r (ft) = 5.000E+04

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   6.047E-02   1.518E-01   1.526E-01


 r (ft) = 6.000E+04

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   4.232E-02   1.063E-01   1.221E-01


 r (ft) = 7.000E+04

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   3.047E-02   7.654E-02   9.751E-02


 r (ft) = 8.000E+04

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   2.245E-02   5.641E-02   7.779E-02
 r (ft) = 9.000E+04

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   1.685E-02   4.235E-02   6.206E-02


 r (ft) = 1.000E+05

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   1.284E-02   3.227E-02   4.953E-02


 r (ft) = 1.280E+05

   drawdown    drawdown    drawdown
   aquifer 1   aquifer 2   aquifer 3
  ----------  ----------  ----------
  ----------  ----------  ----------
   6.343E-03   1.596E-02   2.649E-02

 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 4-3. Output file for steady-state 3LAYSS benchmark problem

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

            3LAYSS: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
       3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

            PROGRAMMED BY Ozlem Acar and Louis H. Motz
                          Department of Civil and Coastal Engineering
                          University of Florida
                          Gainesville, Florida
************************************************************************************
************************************************************************************

three-layer steady-state benchmark problem

DRAWDOWNS DUE TO SINGLE WELL PUMPING

INPUT DATA
----------
----------

ALL DATA ARE IN CONSISTENT UNITS

PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)                                : 1.000E+03
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 3.530E+05
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)                                : 6.000E+04
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)                                : 6.000E+04
RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)              : 1.520E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)                     : 1.000E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)                     : 5.000E-05

NUMBER OF WELL LOCATIONS AT WHICH DRAWDOWNS ARE CALCULATED               :        29
RADIAL DISTANCE FROM THE PUMPED WELL (r) 1 (ft)                          :   100.000
RADIAL DISTANCE FROM THE PUMPED WELL (r) 2 (ft)                          :   200.000
RADIAL DISTANCE FROM THE PUMPED WELL (r) 3 (ft)                          :   300.000
RADIAL DISTANCE FROM THE PUMPED WELL (r) 4 (ft)                          :   400.000
RADIAL DISTANCE FROM THE PUMPED WELL (r) 5 (ft)                          :   500.000
RADIAL DISTANCE FROM THE PUMPED WELL (r) 6 (ft)                          :   600.000
RADIAL DISTANCE FROM THE PUMPED WELL (r) 7 (ft)                          :   700.000
RADIAL DISTANCE FROM THE PUMPED WELL (r) 8 (ft)                          :   800.000
RADIAL DISTANCE FROM THE PUMPED WELL (r) 9 (ft)                          :   900.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)10 (ft)                          :  1000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)11 (ft)                          :  2000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)12 (ft)                          :  3000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)13 (ft)                          :  4000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)14 (ft)                          :  5000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)15 (ft)                          :  6000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)16 (ft)                          :  7000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)17 (ft)                          :  8000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)18 (ft)                          :  9000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)19 (ft)                          : 10000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)20 (ft)                          : 20000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)21 (ft)                          : 30000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)22 (ft)                          : 40000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)23 (ft)                          : 50000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)24 (ft)                          : 60000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)25 (ft)                          : 70000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)26 (ft)                          : 80000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)27 (ft)                          : 90000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)28 (ft)                          :100000.000
RADIAL DISTANCE FROM THE PUMPED WELL (r)29 (ft)                          :128008.000


DRAWDOWNS IN 3-LAYER AQUIFER SYSTEMS
OBTAINED BY ANALYTICAL MODEL
------------------------------------
------------------------------------

REF: Hemker,C.J.1984.Steady Groundwater Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,72(1984),355-374.
     Hemker,C.J.1985.Transient Well Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,81(1985),111-126.
     Hemker,C.J. and Maas,C.1987.Unsteady Flow to Wells in Layered and Fissured
     Aquifer Systems.J.of Hydrology,90(1987),231-249.
```

```
r (ft) = 1.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.590E-01        5.311E+00        3.706E-01


r (ft) = 2.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.568E-01        4.662E+00        3.706E-01


r (ft) = 3.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.536E-01        4.283E+00        3.705E-01


r (ft) = 4.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.498E-01        4.014E+00        3.704E-01


r (ft) = 5.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.454E-01        3.805E+00        3.704E-01


r (ft) = 6.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.404E-01        3.634E+00        3.703E-01


r (ft) = 7.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.351E-01        3.490E+00        3.702E-01


r (ft) = 8.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.294E-01        3.366E+00        3.701E-01


r (ft) = 9.000E+02

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     9.235E-01        3.256E+00        3.700E-01
```

```
r (ft) = 1.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     9.173E-01         3.157E+00         3.698E-01


r (ft) = 2.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     8.477E-01         2.513E+00         3.680E-01


r (ft) = 3.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     7.757E-01         2.140E+00         3.655E-01


r (ft) = 4.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     7.082E-01         1.878E+00         3.625E-01


r (ft) = 5.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     6.474E-01         1.678E+00         3.590E-01


r (ft) = 6.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     5.933E-01         1.517E+00         3.551E-01


r (ft) = 7.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     5.455E-01         1.384E+00         3.510E-01


r (ft) = 8.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     5.031E-01         1.270E+00         3.466E-01
r (ft) = 9.000E+03

     drawdown          drawdown          drawdown
  aquifer 1 (ft)    aquifer 2 (ft)    aquifer 3 (ft)
  --------------    --------------    --------------
  --------------    --------------    --------------
     4.656E-01         1.172E+00         3.420E-01
```

```
r (ft) = 1.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     4.321E-01        1.085E+00        3.372E-01


r (ft) = 2.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     2.305E-01        5.775E-01        2.853E-01


r (ft) = 3.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     1.389E-01        3.483E-01        2.345E-01


r (ft) = 4.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     8.955E-02        2.247E-01        1.900E-01


r (ft) = 5.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     6.047E-02        1.518E-01        1.526E-01


r (ft) = 6.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     4.232E-02        1.063E-01        1.221E-01


r (ft) = 7.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     3.047E-02        7.654E-02        9.751E-02
r (ft) = 8.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     2.245E-02        5.641E-02        7.779E-02


r (ft) = 9.000E+04

     drawdown          drawdown          drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     1.685E-02        4.235E-02        6.206E-02
```

```
r (ft) = 1.000E+05

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     1.284E-02        3.227E-02        4.953E-02


r (ft) = 1.280E+05

     drawdown         drawdown         drawdown
  aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
  --------------   --------------   --------------
  --------------   --------------   --------------
     6.343E-03        1.596E-02        2.649E-02
```

Table 4-4. Drawdown data output file for steady-state 3LAYSS benchmark problem

```
     r          s1          s2          s3
1.000E+02   9.590E-01   5.311E+00   3.706E-01
2.000E+02   9.568E-01   4.662E+00   3.706E-01
3.000E+02   9.536E-01   4.283E+00   3.705E-01
4.000E+02   9.498E-01   4.014E+00   3.704E-01
5.000E+02   9.454E-01   3.805E+00   3.704E-01
6.000E+02   9.404E-01   3.634E+00   3.703E-01
7.000E+02   9.351E-01   3.490E+00   3.702E-01
8.000E+02   9.294E-01   3.366E+00   3.701E-01
9.000E+02   9.235E-01   3.256E+00   3.700E-01
1.000E+03   9.173E-01   3.157E+00   3.698E-01
2.000E+03   8.477E-01   2.513E+00   3.680E-01
3.000E+03   7.757E-01   2.140E+00   3.655E-01
4.000E+03   7.082E-01   1.878E+00   3.625E-01
5.000E+03   6.474E-01   1.678E+00   3.590E-01
6.000E+03   5.933E-01   1.517E+00   3.551E-01
7.000E+03   5.455E-01   1.384E+00   3.510E-01
8.000E+03   5.031E-01   1.270E+00   3.466E-01
9.000E+03   4.656E-01   1.172E+00   3.420E-01
1.000E+04   4.321E-01   1.085E+00   3.372E-01
2.000E+04   2.305E-01   5.775E-01   2.853E-01
3.000E+04   1.389E-01   3.483E-01   2.345E-01
4.000E+04   8.955E-02   2.247E-01   1.900E-01
5.000E+04   6.047E-02   1.518E-01   1.526E-01
6.000E+04   4.232E-02   1.063E-01   1.221E-01
7.000E+04   3.047E-02   7.654E-02   9.751E-02
8.000E+04   2.245E-02   5.641E-02   7.779E-02
9.000E+04   1.685E-02   4.235E-02   6.206E-02
1.000E+05   1.284E-02   3.227E-02   4.953E-02
1.280E+05   6.343E-03   1.596E-02   2.649E-02
```

Table 4-5. Input on screen for file option for steady-state 3LAYSS benchmark problem

```
****************************************************************************
****************************************************************************
         3LAYSS: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
****************************************************************************
****************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
s
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
f
 ENTER INPUT FILE NAME: <filename.in>
benchmark.in
 NAME OF THE PROJECT: <write in single quotation marks>
'three-layer steady-state benchmark problem'
 ENTER OUTPUT FILE NAME: <filename.out>
benchmark.out
 ENTER DATA FILE NAME FOR GRAPHER INPUT: <filename.dat>
benchmark.dat

 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 4-6. Input file for file option for steady-state 3LAYSS benchmark problem

```
0.0  1000.0             Q1,T1
353000.  60000.0        Q2,T2
0.0  60000.0            Q3,T3
1.52E-4                 EP
1.0E-4                  K'/b' confining unit 2
5.0E-5                  K'/b' confining unit 3
29                      Number of observation wells
100                     Radial distances from pumped well to observation well
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
128008
```

To verify the 3LAYSS steady-state solution, drawdowns also were calculated for this problem using a seven-layer MODFLOW (McDonald and Harbaugh 1998) solution (see Table 4-1). The model area was discretized into 139 rows and 139 columns. In the center of the model area, where a discharging well was located in layer five, 51 rows and columns were equally spaced at 100 ft. From the center area, the 100-ft spacing was increased in each row and column by a factor of 1.15 so that the maximum discretization was 46,850 ft at the outermost rows and columns. The grid, which was approximately 7.22 x 10^5 ft x 7.22 x 10^5 ft, was made large enough to represent the infinite boundary conditions in the 3LAYSS analytical solution and the regionally extensive nature of the upper and lower Floridan aquifers. In this problem, layer one was a constant head source bed, and the vertical hydraulic conductivity divided by the thickness of layer two represented the evapotranspiration reduction coefficient. Layer three represented the unpumped surficial aquifer (aquifer one), and the vertical hydraulic conductivity divided by the thickness of layer four represented the leakance of the intermediate confining unit overlying the upper Floridan aquifer (confining unit two). Layer five represented the upper Floridan aquifer (aquifer two), which was pumped. The vertical hydraulic conductivity divided by the thickness of layer six represented the leakance of the middle semiconfining unit overlying the lower Floridan aquifer (confining unit three). Layer seven represented the lower Floridan aquifer (aquifer three), which was not pumped in this problem. All of the layers were specified as confined to match the linearized, i.e., small drawdown, assumptions implicit in Equation 3-1, and constant head boundary conditions were specified around layers five and seven. A steady-state simulation was run in MODFLOW using a data set equivalent to the parameters used in 3LAYSS to calculate drawdowns due to pumping. The drawdowns calculated using MODFLOW closely matched the drawdowns calculated using 3LAYSS (see Figure 4-1). In the mass balance calculated in MODFLOW, more than 99% of the pumped well discharge was derived from the evapotranspiration reduction simulated in layers one and two and less than 1% of the discharge was derived from the constant head boundaries in layers five and seven, indicating that the constant-head boundaries in the MODFLOW solution were set sufficiently far from the pumped well to have no significant effect on the solution and that the infinite boundaries in 3LAYSS were represented correctly.

4.2 Drawdowns Due to Multiple Wells

4.2.1 Steady-State Multiple-Well Option

Similar to the single-well option, the multiple-well option in 3LAYSS uses Equations 3-6 through 3-11 to calculate drawdowns for aquifers one, two, and three. To start the program, the user clicks on the icon for the program and selects the multiple-well option. The program can be run interactively with the user inputting all data on the screen, or the user can prepare an input file and select the 'file' option when running the program. If the program is run interactively, drawdowns and the sum of drawdowns at each grid location and then drawdowns and the sum of drawdowns at each well location are printed on the screen, and the user is prompted to enter the names of two output files. One output file (filename.out) echoes the input data and prints the drawdowns and sum of drawdowns at each grid location, followed by the drawdowns and sum of drawdowns at each well location. The other file (filename.dat) prints the sum of drawdowns in a format that can be readily used in a graphical package such as Surfer® to grid and plot drawdowns at each grid and/or well location. If the 'file' option is selected, then the user is prompted to enter the input file name (filename.in), the name of the project ('project name'), and the names of the two output files (filename.out and filename.dat), which are the same as the output files written using the interactive option. Interactively on the screen or in the input file, the user inputs the transmissivity values for each aquifer, the rate at which evapotranspiration is reduced per unit of water table drawdown, the leakance values for each confining unit, and the number of pumped wells. For each well, the well name or number, the x and y coordinates, the radius for each well, and the pumping rates from each aquifer are entered. Finally, the x and y coordinates for the lower left and upper right corners of the grid and the delta x and delta y spacings of the grid are entered. Inside the program, c_1 is set by default equal to $1/\varepsilon$ to represent the effects of evapotranspiration reduction in the equation for aquifer 1. Also, c_4 is set by default equal to $1.0\text{x}10^{38}$ to approximate the impermeable boundary condition at the base of aquifer 3, i.e., $(K'/b')_4 = 1/c_4 \rightarrow 0$.

The multiple-well option for 3LAYSS runs as follows. First, the non-symmetric tridiagonal matrix **A** is computed using Equation 3-6. Then, this matrix is converted to the symmetric tridiagonal matrix **D** using Equation 3-7. Eigenvalues and eigenvectors of **D** are calculated in subroutine 'tqli' using the QL method described by Wilkinson and Reinsch (1971). In the next step, matrix **V**, which is defined as $\mathbf{V} = \mathbf{T}^{-1/2}\mathbf{R}$, is calculated by matrix multiplication in subroutine 'Mmult'. The inverse of **V** is calculated in subroutine 'inversematrix'. Then, the discharge vector **g** is determined from $Q_i / 2\pi T_i,\ i = 1, 2, \ldots, n$. In order to calculate the drawdowns using Equation 3-11, the last step is to find matrix **K**. After this point, two separate rounds of calculations are performed. First, calculations are performed at the grid locations, and then they are performed at the well locations. (It is permissible, but not necessary, for a well to be location at a grid intersection.) Each round of calculations consists of two loops. For the computation of drawdowns at each grid location, the outer loop is the grid locations loop, and the inner loop is the well locations loop. For the computation of drawdowns at each well location, both the outer and inner loops are well locations loops. While finding matrix **K**, modified Bessel functions of the second kind, zero order [$K_0(\ )$] are calculated in subroutine 'BESSELKo'. This subroutine is linked to subroutine 'BESSELIo', which calculates modified Bessel functions of the first kind, zero order[$I_0(\ )$]. All the matrix and matrix-vector multiplications in Equation 3-11 involving $\mathbf{V}$, $\mathbf{K}$, $\mathbf{V}^{-1}$, and $\mathbf{g}$ are carried out in subroutines 'Mmult' and 'MVmult'. When calculations for all of the grid locations have been performed, the drawdown results (x and y grid locations, x and y well locations, radial distances between each grid location and well location, and drawdowns in layers 1, 2 and 3) are written to the output file 'filename.out'. After drawdowns due to each well at each grid location have been calculated, a sum of drawdowns loop is used to calculate the sum of drawdowns at each grid location due to all of the wells. These sums of drawdowns are printed in both output files 'filename.out' and 'filename.dat'. The same procedure applies to the second round of calculations for well locations. When calculations for all of the well locations are completed, the drawdown results (well i.d., x and y well locations, radial distances between each well location and the pumped well, and drawdowns in layers 1, 2 and 3) are written to the output file 'filename.out'. After these drawdown calculations for each well location are finished, a separate sum of drawdowns loop is used to calculate the sum of drawdowns at each well location due to all of the wells and these sum of drawdowns are printed in both files 'filename.out' and 'filename.dat'. When both rounds of computations (for grid locations and well locations) are complete, the user is asked if more calculations are to be done.

4.2.2 Example Problems

Three example problems were run using the multiple-well option in 3LAYSS. The first example, which was run using both the interactive and file input options, illustrates how drawdown values can be plotted for one pumped well for a rectangular grid. Similar to the benchmark problem (section 4.1.2), T_1 = 1,000 ft^2/day was used for aquifer one, T_2 = 60,000 ft^2/day was used for aquifer two, and T_3 = 60,000 ft^2/day was used for aquifer three. A value for ε = 1.52 x 10^{-4} day^{-1} was used, based on Motz (1981). A value of $(K'/b')_2$ = 1.0 x 10^{-4} day^{-1} was used for confining unit two, and a value of $(K'/b')_3$ = 5.0 x 10^{-5} day^{-1} was used for confining unit three. One well was specified and located at (x, y) = (0.0, 0.0) with a radius = 1.0 ft. The well was specified to pump only from layer two by inputting Q_1 = 0.0, Q_2 = 353,000 ft^3/day, and Q_3 = 0.0 for the well. Drawdowns were calculated in layers one, two, and three in a grid that ranged from x, y = (-12,500 ft; -12,500 ft) to x, y = (12,500 ft; 12,500 ft) at 2,601 evenly-spaced locations that were 500 ft apart in both the x and y directions (see Figures 4-2, 4-3, and 4-4)

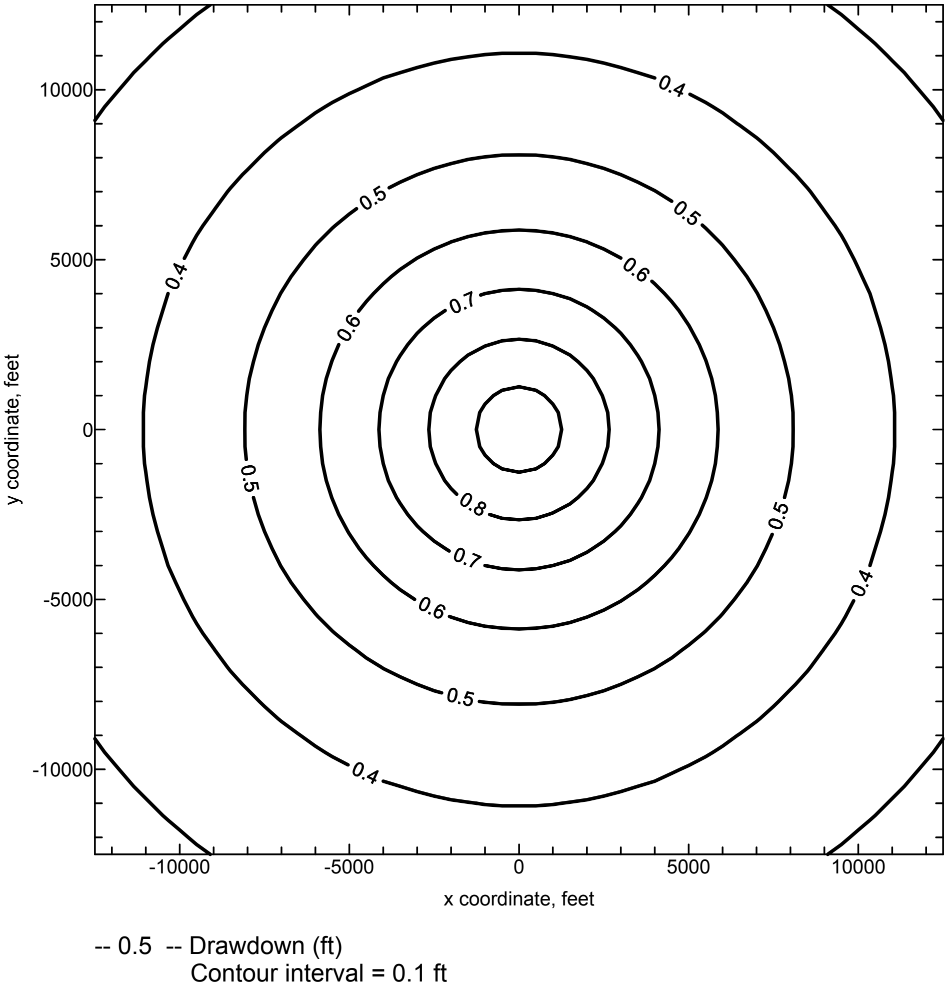


Figure 4-2. 3LAYSS multiple-well example one: drawdowns in the surficial aquifer due to pumping one well in the upper Floridan aquifer

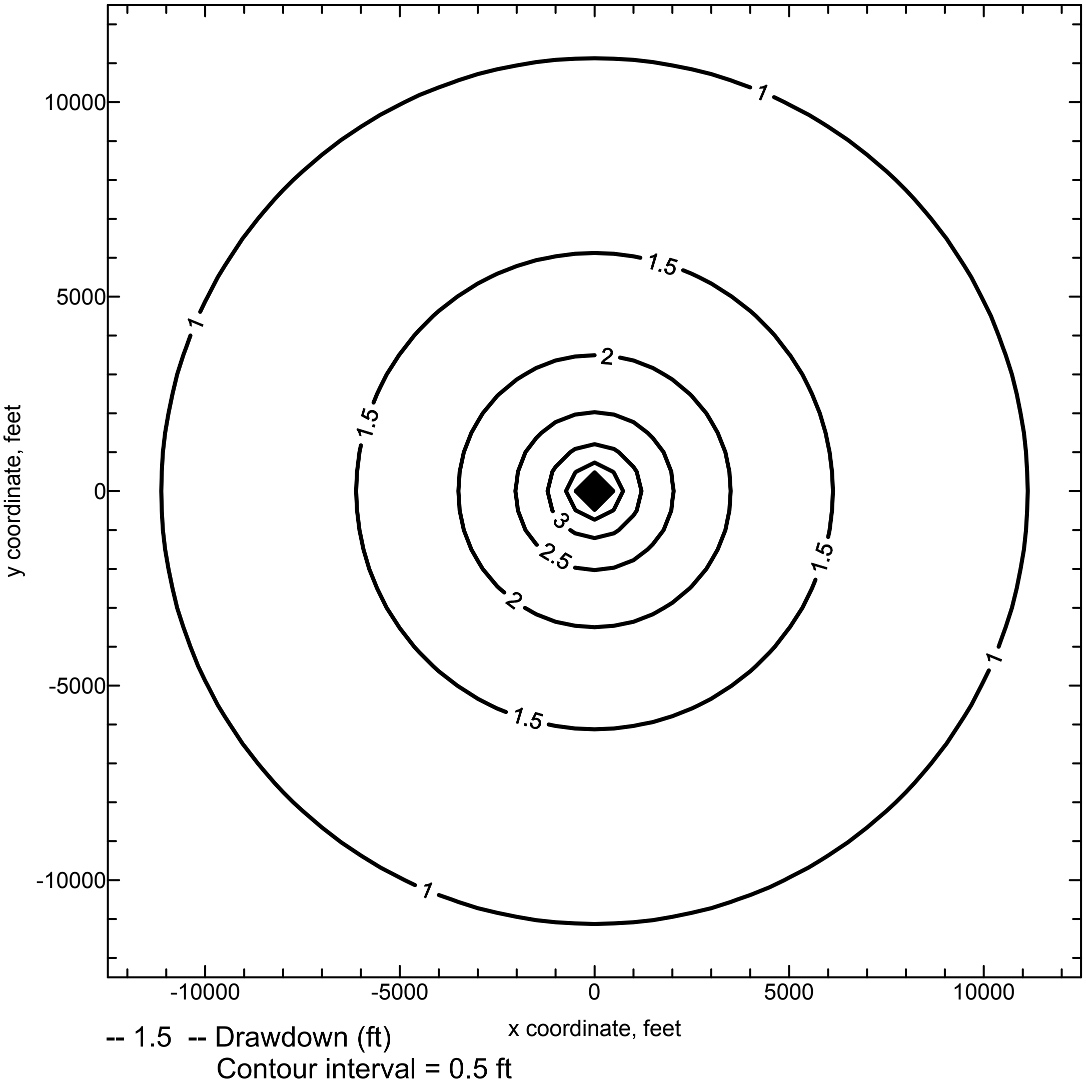


Figure 4-3. 3LAYSS multiple-well example one: drawdowns in the upper Floridan aquifer due to pumping one well in the upper Floridan aquifer

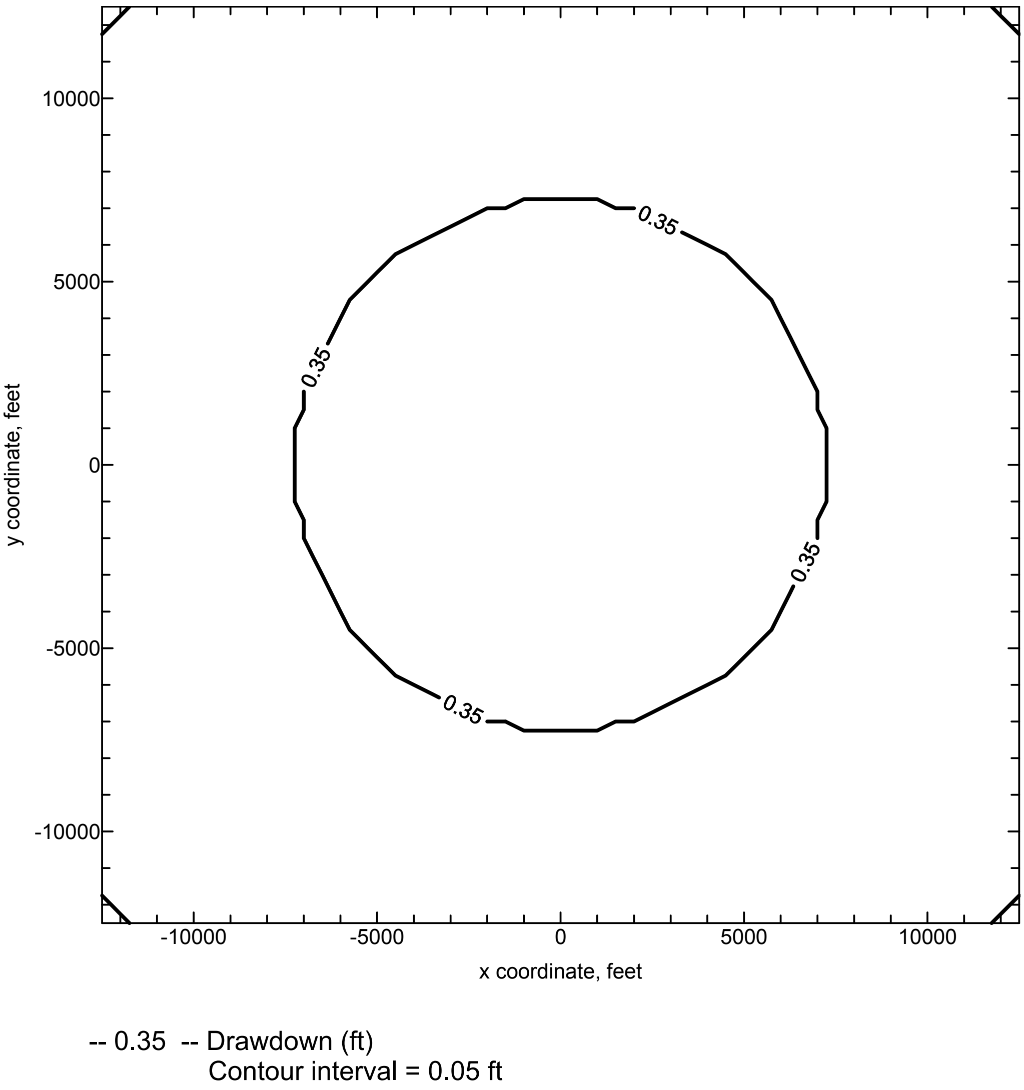


Figure 4-4. 3LAYSS multiple-well example one: drawdowns in the lower Floridan aquifer due to pumping one well in the upper Floridan aquifer

Files for the steady-state 3LAYSS multiple-well example one are in Tables 4-7 through 4-11. The screen capture for the interactive option is in Table 4-7, and the output files are in Tables 4-8 and 4-9. The screen capture for the input file option is in Table 4-10, and the input file for the file option is in Table 4-11. The input file option writes the same output files as the interactive option (Tables 4-8 and 4-9).

Table 4-7. Input on screen for interactive input for steady-state 3LAYSS multiple-well example one

```
***************************************************************************
***************************************************************************
         3LAYSS: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
***************************************************************************
***************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
m
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
i
 NAME OF THE PROJECT: <write in single quotation marks>
'3LAYSS multiple-well example-one'
 PLEASE ENTER DATA IN CONSISTENT UNITS
TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)=?
1000.0
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)=?
60000.0
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)=?
60000.0
 RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)=?
1.52e-4
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)=?
1.0e-4
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)=?
5.0e-5
 NUMBER OF WELLS=?
1
 WELL NUMBER OR NAME: <write in single quotation marks>
Well_1
 X COORDINATE OF WELL (ft)=?
0.0
 Y COORDINATE OF WELL (ft)=?
0.0
 RADIUS OF WELL (rw) (ft)=?
1.0
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
353000.0
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
0.0
 ENTER X COORDINATE FOR LOWER LEFT CORNER OF GRID
-12500.0
 ENTER Y COORDINATE FOR LOWER LEFT CORNER OF GRID
-12500.0
 ENTER X COORDINATE FOR UPPER RIGHT CORNER OF GRID
12500.0
 ENTER Y COORDINATE FOR UPPER RIGHT CORNER OF GRID
12500.0
 ENTER DELTA X SPACING FOR THE GRID
500.0
 ENTER DELTA Y SPACING FOR THE GRID
500.0
 ENTER OUTPUT FILE NAME: <filename.out>
3_layers_1_well.out
 ENTER DATA FILE NAME FOR SUM OF DRAWDOWNS: <filename.dat>
3_layers_1_well.dat
…
(Note: output on screen is not printed.)
PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 4-8. Output file for steady-state 3LAYSS multiple-well example one

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

            3LAYSS: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
       3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

            PROGRAMMED BY Ozlem Acar and Louis H. Motz
                          Department of Civil and Coastal Engineering
                          University of Florida
                          Gainesville, Florida
************************************************************************************
************************************************************************************

3LAYSS multiple-well example one

DRAWDOWNS DUE TO WELLFIELD PUMPING

INPUT DATA
----------
----------

ALL DATA ARE IN CONSISTENT UNITS

TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)                                : 1.000E+03
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)                                : 6.000E+04
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)                                : 6.000E+04
RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)              : 1.520E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)                     : 1.000E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)                     : 5.000E-05

NUMBER OF PUMPED WELLS                                                   :         1

Well_1
X COORDINATE OF WELL (ft)                                                :     0.000
Y COORDINATE OF WELL (ft)                                                :     0.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 3.530E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00

NUMBER OF GRIDS AT WHICH DRAWDOWNS ARE CALCULATED                        :      2601

GRID LOCATION :    1
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000

GRID LOCATION :    2
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12000.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000

GRID LOCATION :    3
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-11500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000

(Note: x- and y-coordinates for grid locations 4-2598 are not printed.)

GRID LOCATION : 2599
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 11500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000

GRID LOCATION : 2600
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12000.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000

GRID LOCATION : 2601
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000


DRAWDOWNS IN 3-LAYER AQUIFER SYSTEMS
OBTAINED BY ANALYTICAL MODEL
------------------------------------
------------------------------------

REF: Hemker,C.J.1984.Steady Groundwater Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,72(1984),355-374.
```

```
     Hemker,C.J.1985.Transient Well Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,81(1985),111-126.
     Hemker,C.J. and Maas,C.1987.Unsteady Flow to Wells in Layered and Fissured
     Aquifer Systems.J.of Hydrology,90(1987),231-249.


     Grid location =   1

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
-12500.000 -12500.000      0.000      0.000  17677.670    0.263    0.659    0.298


     Grid location =   2

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
-12000.000 -12500.000      0.000      0.000  17327.723    0.268    0.672    0.299


     Grid location =   3

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
-11500.000 -12500.000      0.000      0.000  16985.288    0.274    0.686    0.301

(Note: output for grid locations 4-2598 is not printed.)

     Grid location =2599

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
 11500.000  12500.000      0.000      0.000  16985.288    0.274    0.686    0.301


     Grid location =2600

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
 12000.000  12500.000      0.000      0.000  17327.723    0.268    0.672    0.299


     Grid location =2601

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
 12500.000  12500.000      0.000      0.000  17677.670    0.263    0.659    0.298


Grid loc.        xgrid       ygrid  sum of dd 1  sum of dd 2  sum of dd 3
---------   ----------  ----------  -----------  -----------  -----------
---------   ----------  ----------  -----------  -----------  -----------
       1    -12500.000  -12500.000        0.263        0.659        0.298
       2    -12000.000  -12500.000        0.268        0.672        0.299
       3    -11500.000  -12500.000        0.274        0.686        0.301

(Note: output for grid locations 4-2598 is not printed.)

    2599     11500.000   12500.000        0.274        0.686        0.301
    2600     12000.000   12500.000        0.268        0.672        0.299
    2601     12500.000   12500.000        0.263        0.659        0.298

     Well location = Well_1

 well id                xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
Well_1                 0.000      0.000      1.000    0.960    9.623    0.371


 Well id                xwell      ywell      rwell  sum of dd 1  sum of dd 2  sum of dd 3
------------------ ---------- ---------- ----------  -----------  -----------  -----------
------------------ ---------- ---------- ----------  -----------  -----------  -----------
Well_1                 0.000      0.000      1.000        0.960        9.623        0.371
```

Table 4-9. Drawdown data output file for steady-state 3LAYSS multiple-well example one

```
Grid/well                  x           y        sum1       sum2       sum3
       1             -12500.00   -12500.00      0.263      0.659      0.298
       2             -12000.00   -12500.00      0.268      0.672      0.299
       3             -11500.00   -12500.00      0.274      0.686      0.301

(Note: grid location and drawdowns are not printed for grid locations 4-2598.)

    2599              11500.00    12500.00      0.274      0.686      0.301
    2600              12000.00    12500.00      0.268      0.672      0.299
    2601              12500.00    12500.00      0.263      0.659      0.298
Well_1                    0.00        0.00      0.960      9.623      0.371
```

Table 4-10. Input on screen for file option for steady-state 3LAYSS multiple-well example one

```
****************************************************************************
****************************************************************************
         3LAYSS:AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
****************************************************************************
****************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
m
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
f
 ENTER INPUT FILE NAME: <filename.in>
3_layers_1_well.in
 NAME OF THE PROJECT: <write in single quotation marks>
'3LAYSS multiple-well example one'
 ENTER OUTPUT FILE NAME: <filename.out>
3_layers_1_well.out
 ENTER DATA FILE NAME FOR SUM OF DRAWDOWNS: <filename.dat>
3_layers_1_well.dat


 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 4-11. Input file for file option for steady-state 3LAYSS multiple-well example one

```
1000.0                              T1
60000.                              T2
60000.                              T3
1.52e-4                             EP
1.0e-4                              (K'/b') overlying layer 2
5.0e-5                              (K'/b') overlying layer 3
1                                   Number of pumped wells
Well_1         0.0  0.0  1.0        Well i.d.,xw,yw,rw
0.0  353000.0  0.0                  Q1,Q2,Q3
-12500.0  -12500.0                  Beginning x and y coordinates (at lower left corner)
 12500.0   12500.0                  Ending x and y coordinates (at upper right corner)
   500.0     500.0                  Spacing in x direction, spacing in y direction
```

The second example, which was run using the file input option, illustrates how drawdown values can be calculated and plotted for multiple wells in a rectangular grid. Similar to the benchmark problem (section 4.1.2) and example one, T_1 = 1,000 ft^2/day was used for aquifer one, T_2 = 60,000 ft^2/day was used for aquifer two, and T_3 = 60,000 ft^2/day was used for aquifer three. A value for $\varepsilon = 1.52 \times 10^{-4}$ day^{-1} was used, based on Motz (1981). A value of $(K'/b')_2 = 1.0 \times 10^{-4}$ day^{-1} was used for confining unit two, and a value of $(K'/b')_3 = 5.0 \times 10^{-5}$ day^{-1} was used for confining unit three. Six wells were specified, i.e., three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer. The three wells in the upper Floridan aquifer were uniformly spaced 1,000 ft apart through the center of the grid parallel to the x-axis at (x, y) = (-1,000 ft; 0 ft), (0 ft; 0 ft), and (1,000 ft; 0 ft). Each well was assigned a radius of 1.0 ft and pumping rates Q_1 = 0.0, Q_2 = 200,000 ft^3/day, and Q_3 = 0.0. In 3LAYSS (and 3LAYT), drawdowns are calculated at well locations in addition to the uniformly-spaced locations determined by the grid spacing, so it is not necessary for wells to be uniformly spaced or for a well to coincide with one of the uniformly-spaced grid locations. Also, well radiuses and pumping rates can be specified uniquely for each well. These important points are illustrated by the three wells in the lower Floridan aquifer. These wells were located at (x, y) = (-875 ft; -237 ft), (0 ft; 245 ft), and (900 ft; 0 ft) with radiuses = 0.75, 1.00, 1.25 ft, respectively. Pumping rates were Q_1 = 0.0, Q_2 = 0.0, and Q_3 = 133,500 ft^3/day; Q_1 = 0.0, Q_2 = 0.0, and Q_3 = 193,000 ft^3/day; and Q_1 = 0.0, Q_2 = 0.0, and Q_3 = 73,500 ft^3/day, respectively, for the three wells. Drawdowns were calculated in layers one, two, and three in a grid that ranged from x, y = (-12,500 ft; -12,500 ft) to x, y = (12,500 ft; 12,500 ft) at 2,601 evenly-spaced locations that were 500 ft apart in both the x and y directions (see Figures 4-5, 4-6, and 4-7).

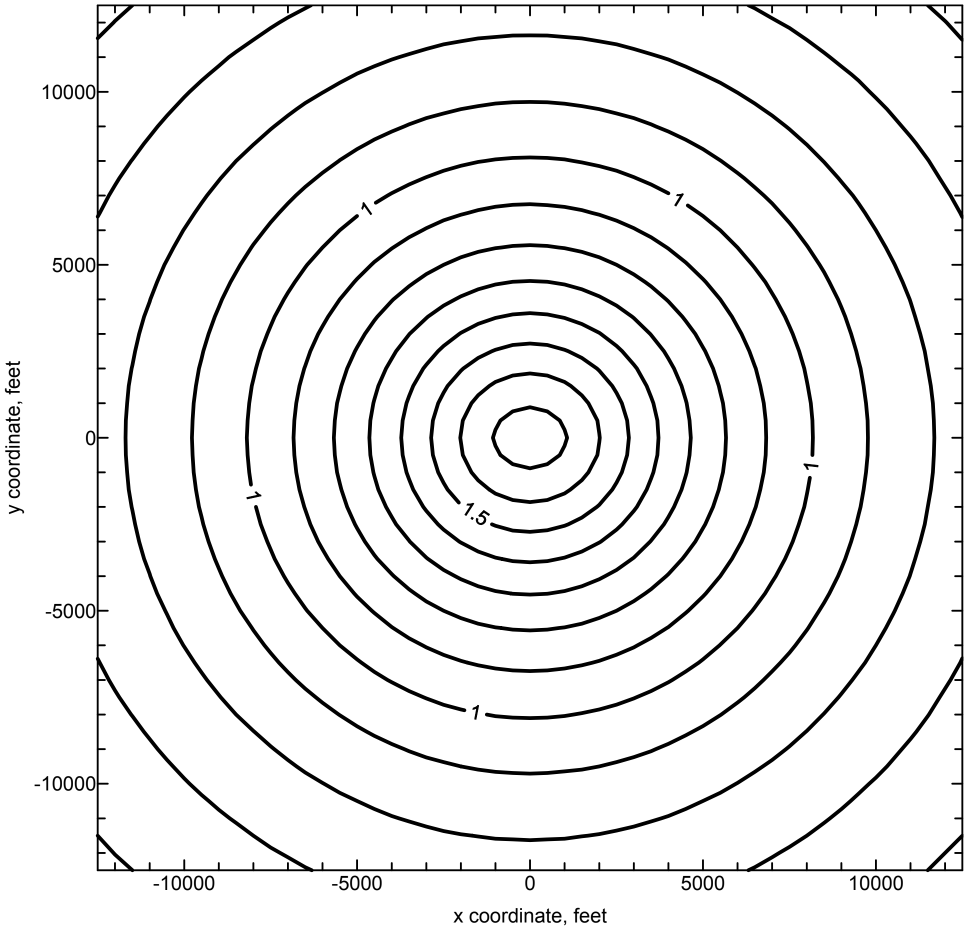


Figure 4-5. 3LAYSS multiple-well example two: drawdowns in the surficial aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer

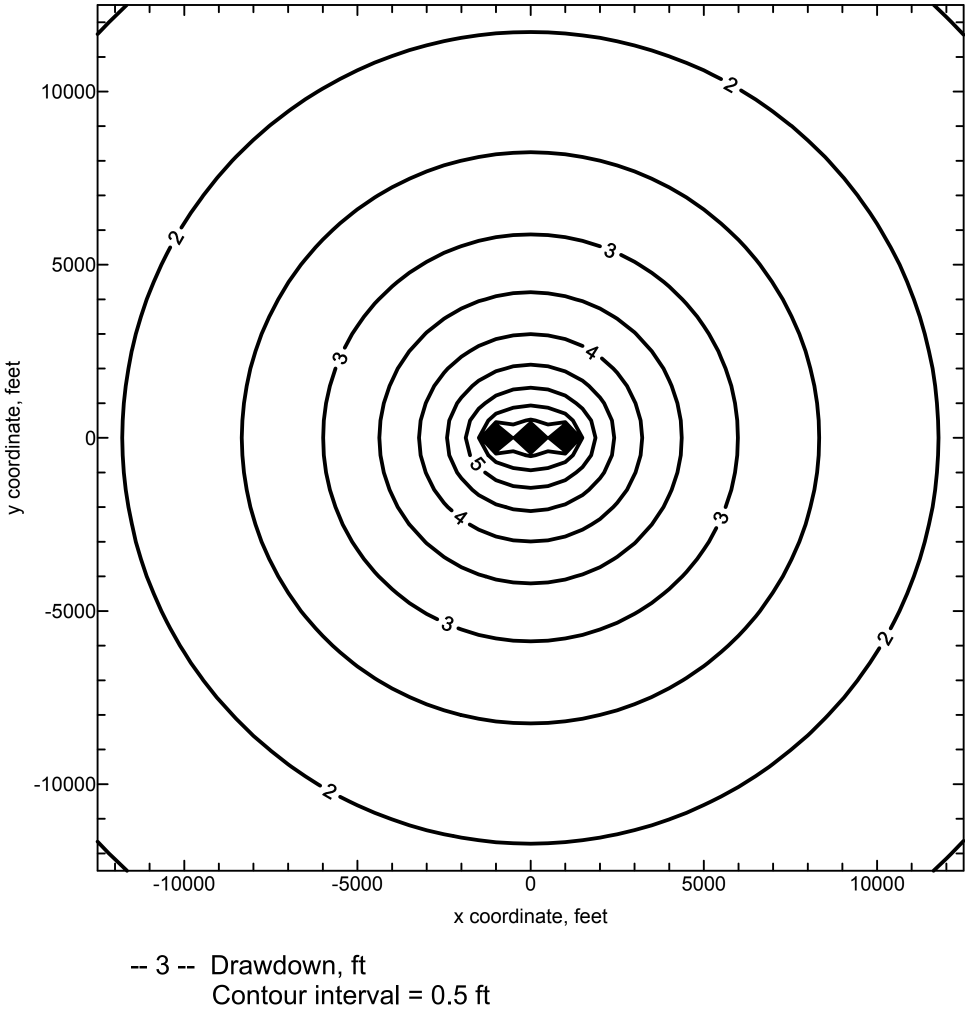


Figure 4-6. 3LAYSS multiple-well example two: drawdowns in the upper Floridan aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer

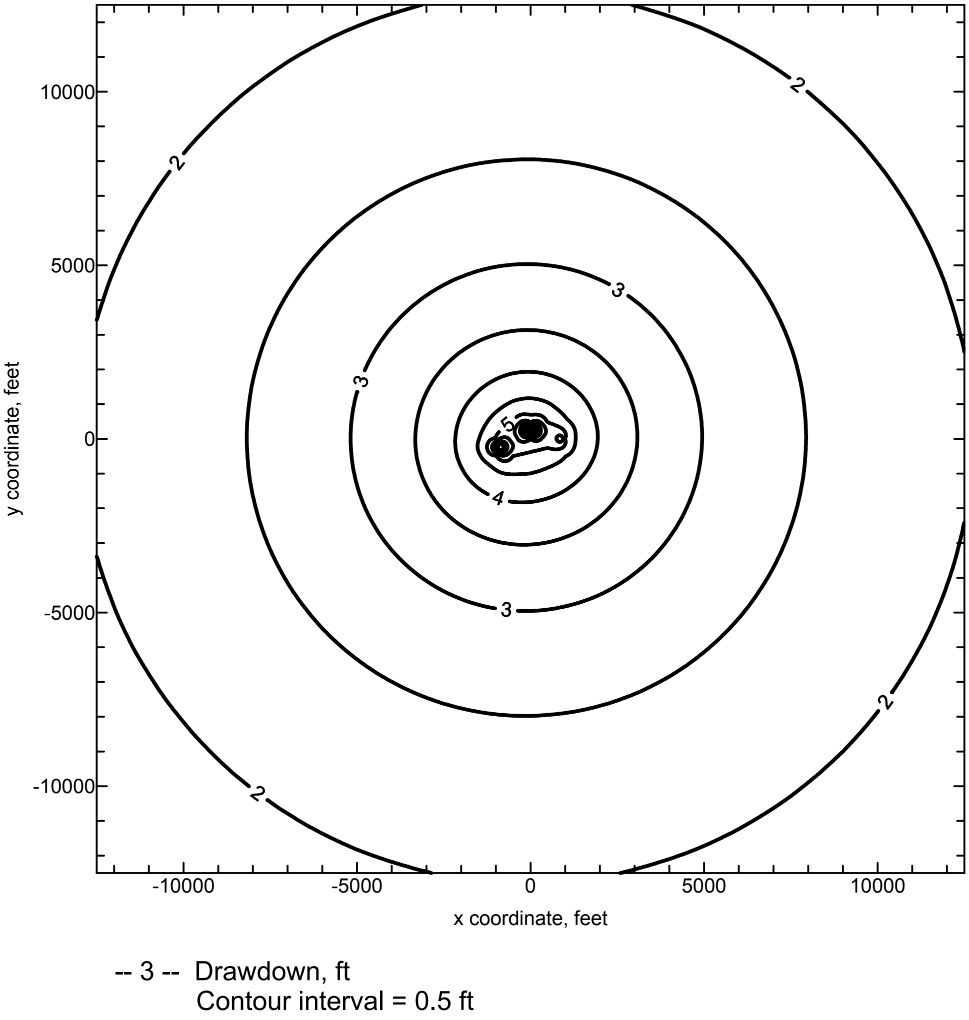


Figure 4-7. 3LAYSS multiple-well example two: drawdowns in the lower Floridan aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer

Files for the steady-state 3LAYSS multiple-well example two are in Tables 4-12 through 4-15. The screen capture for this example using the input file option is in Table 4-12. The input file for the file option is in Table 4-13, and the output files are in Tables 4-14 and 4-15.

Table 4-12. Input on screen for file option for steady-state 3LAYSS multiple-well example two

```
****************************************************************************
****************************************************************************
         3LAYSS: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
****************************************************************************
****************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
m
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
f
 ENTER INPUT FILE NAME: <filename.in>
6_wells_UFA_LFA.in
 NAME OF THE PROJECT: <write in single quotation marks>
'3LAYSS multiple-well example two'
 ENTER OUTPUT FILE NAME: <filename.out>
6_wells_UFA_LFA.out
 ENTER DATA FILE NAME FOR SUM OF DRAWDOWNS: <filename.dat>
6_wells_UFA_LFA.dat


 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 4-13. Input file for file option for steady-state 3LAYSS multiple-well example two

```
1000.0                                T1
60000.                                T2
60000.                                T3
1.52e-4                               EP
1.0e-4                                K'/b' overlying layer 2
5.0e-5                                K'/b' overlying layer 3
6                                     Number of pumped wells
UFA_1     -1000.0  0.0  1.0      Well i.d.,xw,yw,rw
0.0  200000.0  0.0                    Q1,Q2,Q3
UFA_2      0.0     0.0  1.0      Well i.d.,xw,yw,rw
0.0  200000.0  0.0                    Q1,Q2,Q3
UFA_3      1000.0  0.0  1.0      Well i.d.,xw,yw,rw
0.0  200000.0  0.0                    Q1,Q2,Q3
LFA_4     -875.0  -237.0  0.75   Well i.d.,xw,yw,rw
0.0       0.0  133500.0               Q1,Q2,Q3
LFA_5   0.0  245.0  1.0          Well i.d.,xw,yw,rw
0.0       0.0  193000.0               Q1,Q2,Q3
LFA_6  900.0  0.0  1.25          Well i.d.,xw,yw,rw
0.0       0.0  73500.0                Q1,Q2,Q3
-12500  -12500                        Beginning x and y coordinates (at lower left corner)
 12500   12500                        Ending x and y coordinates (at upper right corner)
   500     500                        Spacing in x direction, spacing in y direction
```

Table 4-14. Output file for steady-state 3LAYSS multiple-well example two

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

            3LAYSS: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
       3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

            PROGRAMMED BY Ozlem Acar and Louis H. Motz
                          Department of Civil and Coastal Engineering
                          University of Florida
                          Gainesville, Florida
************************************************************************************
************************************************************************************

3LAYSS multiple-well example two

DRAWDOWNS DUE TO WELLFIELD PUMPING

INPUT DATA
----------
----------

ALL DATA ARE IN CONSISTENT UNITS

TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)                                : 1.000E+03
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)                                : 6.000E+04
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)                                : 6.000E+04
RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)              : 1.520E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)                     : 1.000E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)                     : 5.000E-05

NUMBER OF PUMPED WELLS                                                   :         6

UFA_1
X COORDINATE OF WELL (ft)                                                : -1000.000
Y COORDINATE OF WELL (ft)                                                :     0.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 2.000E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00

UFA_2
X COORDINATE OF WELL (ft)                                                :     0.000
Y COORDINATE OF WELL (ft)                                                :     0.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 2.000E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00

UFA_3
X COORDINATE OF WELL (ft)                                                :  1000.000
Y COORDINATE OF WELL (ft)                                                :     0.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 2.000E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00

LFA_4
X COORDINATE OF WELL (ft)                                                :  -875.000
Y COORDINATE OF WELL (ft)                                                :  -237.000
RADIUS OF WELL (rw) (ft)                                                 :     0.750
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 1.335E+05

LFA_5
X COORDINATE OF WELL (ft)                                                :     0.000
Y COORDINATE OF WELL (ft)                                                :   245.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 1.930E+05

LFA_6
X COORDINATE OF WELL (ft)                                                :   900.000
Y COORDINATE OF WELL (ft)                                                :     0.000
RADIUS OF WELL (rw) (ft)                                                 :     1.250
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 0.000E+00
```

```
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 7.350E+04

NUMBER OF GRIDS AT WHICH DRAWDOWNS ARE CALCULATED                        :      2601

GRID LOCATION :    1
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000

GRID LOCATION :    2
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12000.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000

GRID LOCATION :    3
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-11500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000

…
(Note: x- and y-coordinates for grid locations 4-2598 are not printed.)

GRID LOCATION : 2599
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 11500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000

GRID LOCATION : 2600
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12000.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000

GRID LOCATION : 2601
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000


DRAWDOWNS IN 3-LAYER AQUIFER SYSTEMS
OBTAINED BY ANALYTICAL MODEL
------------------------------------
------------------------------------

REF: Hemker,C.J.1984.Steady Groundwater Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,72(1984),355-374.
     Hemker,C.J.1985.Transient Well Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,81(1985),111-126.
     Hemker,C.J. and Maas,C.1987.Unsteady Flow to Wells in Layered and Fissured
     Aquifer Systems.J.of Hydrology,90(1987),231-249.


     Grid location =   1

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
-12500.000 -12500.000  -1000.000      0.000  16985.288    0.155    0.389    0.171
-12500.000 -12500.000      0.000      0.000  17677.670    0.149    0.373    0.169
-12500.000 -12500.000   1000.000      0.000  18398.369    0.143    0.358    0.166
-12500.000 -12500.000   -875.000   -237.000  16897.390    0.045    0.114    0.399
-12500.000 -12500.000      0.000    245.000  17851.751    0.064    0.162    0.553
-12500.000 -12500.000    900.000      0.000  18325.119    0.024    0.061    0.206


     Grid location =   2

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
-12000.000 -12500.000  -1000.000      0.000  16650.826    0.158    0.396    0.172
-12000.000 -12500.000      0.000      0.000  17327.723    0.152    0.381    0.170
-12000.000 -12500.000   1000.000      0.000  18034.689    0.146    0.366    0.168
-12000.000 -12500.000   -875.000   -237.000  16557.379    0.045    0.115    0.405
-12000.000 -12500.000      0.000    245.000  17505.286    0.064    0.163    0.561
-12000.000 -12500.000    900.000      0.000  17962.739    0.024    0.062    0.209

     Grid location =   3

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
-11500.000 -12500.000  -1000.000      0.000  16324.828    0.161    0.404    0.173
-11500.000 -12500.000      0.000      0.000  16985.288    0.155    0.389    0.171
-11500.000 -12500.000   1000.000      0.000  17677.670    0.149    0.373    0.169
-11500.000 -12500.000   -875.000   -237.000  16225.652    0.046    0.115    0.411
-11500.000 -12500.000      0.000    245.000  17166.392    0.065    0.164    0.570
-11500.000 -12500.000    900.000      0.000  17607.101    0.025    0.062    0.213

(Note: output for grid locations 4-2598 is not printed.)
```

```
     Grid location =2599

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
 11500.000  12500.000  -1000.000      0.000  17677.670    0.149    0.373    0.169
 11500.000  12500.000      0.000      0.000  16985.288    0.155    0.389    0.171
 11500.000  12500.000   1000.000      0.000  16324.828    0.161    0.404    0.173
 11500.000  12500.000   -875.000   -237.000  17758.710    0.044    0.112    0.384
 11500.000  12500.000      0.000    245.000  16805.803    0.065    0.165    0.579
 11500.000  12500.000    900.000      0.000  16389.326    0.025    0.063    0.225


     Grid location =2600

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
 12000.000  12500.000  -1000.000      0.000  18034.689    0.146    0.366    0.168
 12000.000  12500.000      0.000      0.000  17327.723    0.152    0.381    0.170
 12000.000  12500.000   1000.000      0.000  16650.826    0.158    0.396    0.172
 12000.000  12500.000   -875.000   -237.000  18110.682    0.044    0.112    0.378
 12000.000  12500.000      0.000    245.000  17151.823    0.065    0.164    0.570
 12000.000  12500.000    900.000      0.000  16717.057    0.025    0.063    0.221


     Grid location =2601

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
 12500.000  12500.000  -1000.000      0.000  18398.369    0.143    0.358    0.166
 12500.000  12500.000      0.000      0.000  17677.670    0.149    0.373    0.169
 12500.000  12500.000   1000.000      0.000  16985.288    0.155    0.389    0.171
 12500.000  12500.000   -875.000   -237.000  18469.483    0.044    0.111    0.372
 12500.000  12500.000      0.000    245.000  17505.286    0.064    0.163    0.561
 12500.000  12500.000    900.000      0.000  17053.152    0.025    0.063    0.218


Grid loc.        xgrid       ygrid  sum of dd 1  sum of dd 2  sum of dd 3
---------   ----------  ----------  -----------  -----------  -----------
---------   ----------  ----------  -----------  -----------  -----------
       1    -12500.000  -12500.000        0.580        1.457        1.663
       2    -12000.000  -12500.000        0.590        1.482        1.684
       3    -11500.000  -12500.000        0.600        1.508        1.705

(Note: drawdown sums for grid locations 4-2598 are not printed.)


    2599     11500.000   12500.000        0.600        1.507        1.699
    2600     12000.000   12500.000        0.590        1.482        1.678
    2601     12500.000   12500.000        0.580        1.457        1.657


     Well location = UFA_1

 well id               xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000      1.000    0.544    5.452    0.210
UFA_2                   0.000      0.000   1000.000    0.520    1.789    0.210
UFA_3                1000.000      0.000   2000.000    0.480    1.424    0.209
LFA_4                -875.000   -237.000    267.944    0.055    0.140    1.831
LFA_5                   0.000    245.000   1029.575    0.079    0.202    1.958
LFA_6                 900.000      0.000   1900.000    0.030    0.077    0.627

     Well location = UFA_2

 well id               xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000   1000.000    0.520    1.789    0.210
UFA_2                   0.000      0.000      1.000    0.544    5.452    0.210
UFA_3                1000.000      0.000   1000.000    0.520    1.789    0.210
LFA_4                -875.000   -237.000    906.529    0.055    0.140    1.399
LFA_5                   0.000    245.000    245.000    0.079    0.203    2.693
LFA_6                 900.000      0.000    900.000    0.030    0.077    0.772

     Well location = UFA_3

 well id               xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000   2000.000    0.480    1.424    0.209
UFA_2                   0.000      0.000   1000.000    0.520    1.789    0.210
```

```
UFA_3                1000.000      0.000      1.000    0.544    5.452    0.210
LFA_4                -875.000   -237.000   1889.919    0.054    0.139    1.140
LFA_5                   0.000    245.000   1029.575    0.079    0.202    1.958
LFA_6                 900.000      0.000    100.000    0.030    0.077    1.200

     Well location = LFA_4

 well id                xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000    267.944    0.541    2.486    0.210
UFA_2                   0.000      0.000    906.529    0.523    1.841    0.210
UFA_3                1000.000      0.000   1889.919    0.485    1.453    0.209
LFA_4                -875.000   -237.000      0.750    0.055    0.140    3.912
LFA_5                   0.000    245.000    998.974    0.079    0.202    1.973
LFA_6                 900.000      0.000   1790.752    0.030    0.077    0.638

     Well location = LFA_5

 well id                xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000   1029.575    0.519    1.773    0.210
UFA_2                   0.000      0.000    245.000    0.541    2.534    0.210
UFA_3                1000.000      0.000   1029.575    0.519    1.773    0.210
LFA_4                -875.000   -237.000    998.974    0.055    0.140    1.365
LFA_5                   0.000    245.000      1.000    0.079    0.203    5.509
LFA_6                 900.000      0.000    932.751    0.030    0.077    0.765

     Well location = LFA_6

 well id                xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000   1900.000    0.484    1.451    0.209
UFA_2                   0.000      0.000    900.000    0.523    1.845    0.210
UFA_3                1000.000      0.000    100.000    0.543    3.009    0.210
LFA_4                -875.000   -237.000   1790.752    0.054    0.139    1.159
LFA_5                   0.000    245.000    932.751    0.079    0.202    2.009
LFA_6                 900.000      0.000      1.250    0.030    0.077    2.054

 Well id                xwell      ywell      rwell  sum of dd 1  sum of dd 2  sum of dd 3
------------------ ---------- ---------- ----------  -----------  -----------  -----------
------------------ ---------- ---------- ----------  -----------  -----------  -----------
UFA_1               -1000.000      0.000      1.000        1.707        9.084        5.044
UFA_2                   0.000      0.000      1.000        1.747        9.450        5.493
UFA_3                1000.000      0.000      1.000        1.707        9.084        4.926
LFA_4                -875.000   -237.000      0.750        1.712        6.200        7.152
LFA_5                   0.000    245.000      1.000        1.742        6.500        8.268
LFA_6                 900.000      0.000      1.250        1.714        6.723        5.850
```

Table 4-15. Drawdown data output file for steady-state 3LAYSS multiple-well example two

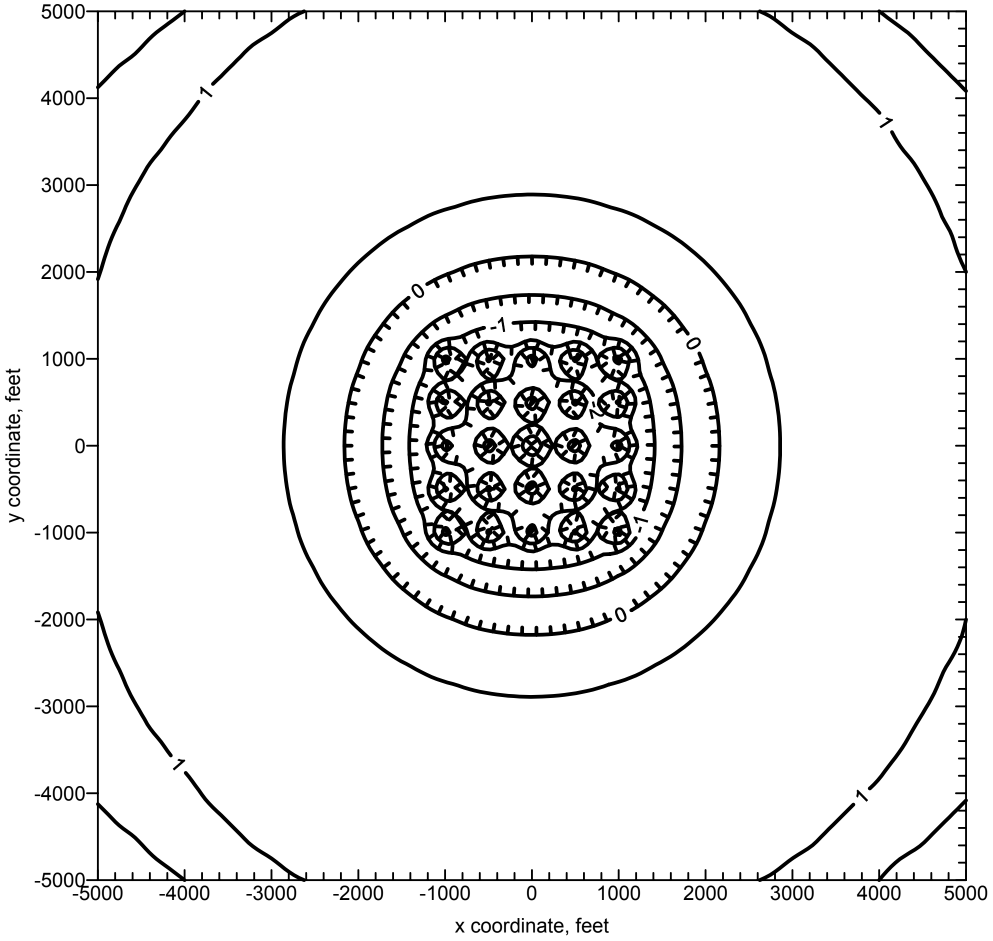
```
Grid/well                  x           y        sum1       sum2       sum3
       1             -12500.00   -12500.00      0.580      1.457      1.663
       2             -12000.00   -12500.00      0.590      1.482      1.684
       3             -11500.00   -12500.00      0.600      1.508      1.705
```

(Note: grid locations and drawdowns are not printed for grid locations 4-2598.)

```
    2599              11500.00    12500.00      0.600      1.507      1.699
    2600              12000.00    12500.00      0.590      1.482      1.678
    2601              12500.00    12500.00      0.580      1.457      1.657
UFA_1                 -1000.00        0.00      1.707      9.084      5.044
UFA_2                     0.00        0.00      1.747      9.450      5.493
UFA_3                  1000.00        0.00      1.707      9.084      4.926
LFA_4                  -875.00     -237.00      1.712      6.200      7.152
LFA_5                     0.00      245.00      1.742      6.500      8.268
LFA_6                   900.00        0.00      1.714      6.723      5.850
```

The third example, which also was run using the file input option, illustrates how recharge wells can be used to investigate whether drawdowns in the surficial aquifer due to pumping from underlying aquifers can be reduced. Similar to the benchmark problem (section 4.1.2) and examples one and two, T_1 = 1,000 ft^2/day was used for aquifer one, T_2 = 60,000 ft^2/day was used for aquifer two, and T_3 = 60,000 ft^2/day was used for aquifer three. A value for $\varepsilon = 1.52 \times 10^{-4}$ day^{-1} was used, based on Motz (1981). A value of $(K'/b')_2 = 1.0 \times 10^{-4}$ day^{-1} was used for confining unit two, and a value of $(K'/b')_3 = 5.0 \times 10^{-5}$ day^{-1} was used for confining unit three. Six wells with the same specifications as the six wells in example two were specified, i.e., three wells were located in the upper Floridan aquifer and three wells were located in the lower Floridan aquifer, with a total pumping rate of 1.0×10^6 ft^3/day. In this problem, an array of 25 recharging wells uniformly spaced at 500 ft in 5 rows of 5 wells each was added to the surficial aquifer. In the array, which was centered at (x, y) = (0, 0) and ranged from (x, y) = (-1,000 ft; -1,000 ft) to (1,000 ft; 1,000 ft), each well was assigned a radius of 0.5 ft and pumping rates Q_1 = -1,000 ft^3/day, Q_2 = 0.0, and Q_3 = 0.0, with a total pumping rate of – 25,000 ft^3/day (Note: negative sign for pumping indicates recharge). Drawdowns were calculated in layers one, two, and three in a grid that ranged from x, y = (-5,000 ft; -5,000 ft) to x, y = (5,000 ft; 5,000 ft) at 1,681 evenly-spaced locations that were 250 ft apart in both the x and y directions (see Figures 4-8, 4-9, and 4-10). The grid specified for example three covers a smaller area than the grid specified in examples one and two, thus providing more detailed coverage.

Files for the steady-state 3LAYSS multiple-well example three are in Tables 4-16 through 4-19. The screen capture for this example using the input file option is in Table 4-16. The input file for the file option is in Table 4-17, and the output files are in Tables 4-18 and 4-19.



-- 1 -- Drawdown, ft
Contour interval = 0.5 ft

Figure 4-8. 3LAYSS multiple-well example three: drawdowns in the surficial aquifer due to 25 recharge wells in the surficial aquifer and six pumping wells in the upper and lower Floridan aquifers

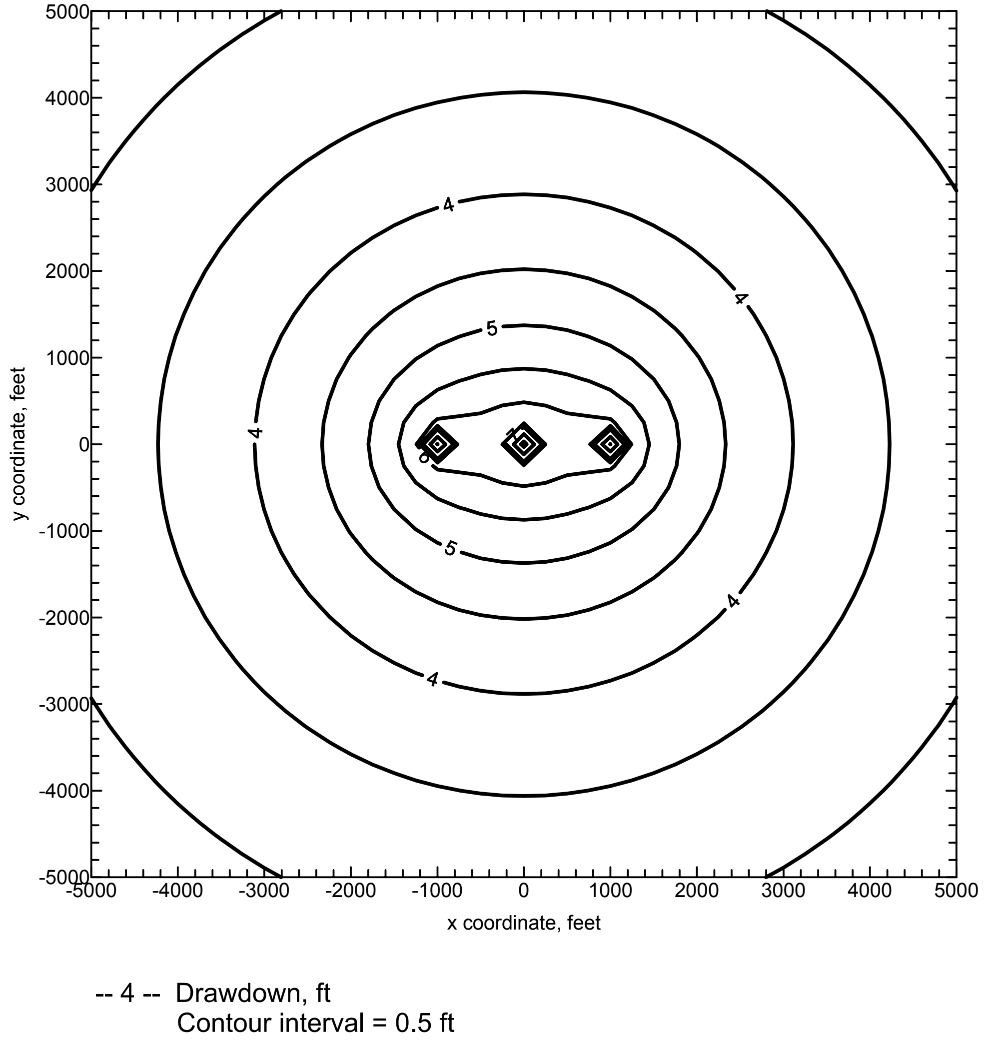


Figure 4-9. 3LAYSS multiple-well example three: drawdowns in the upper Floridan aquifer due to 25 recharge wells in the surficial aquifer and six pumping wells in the upper and lower Floridan aquifers

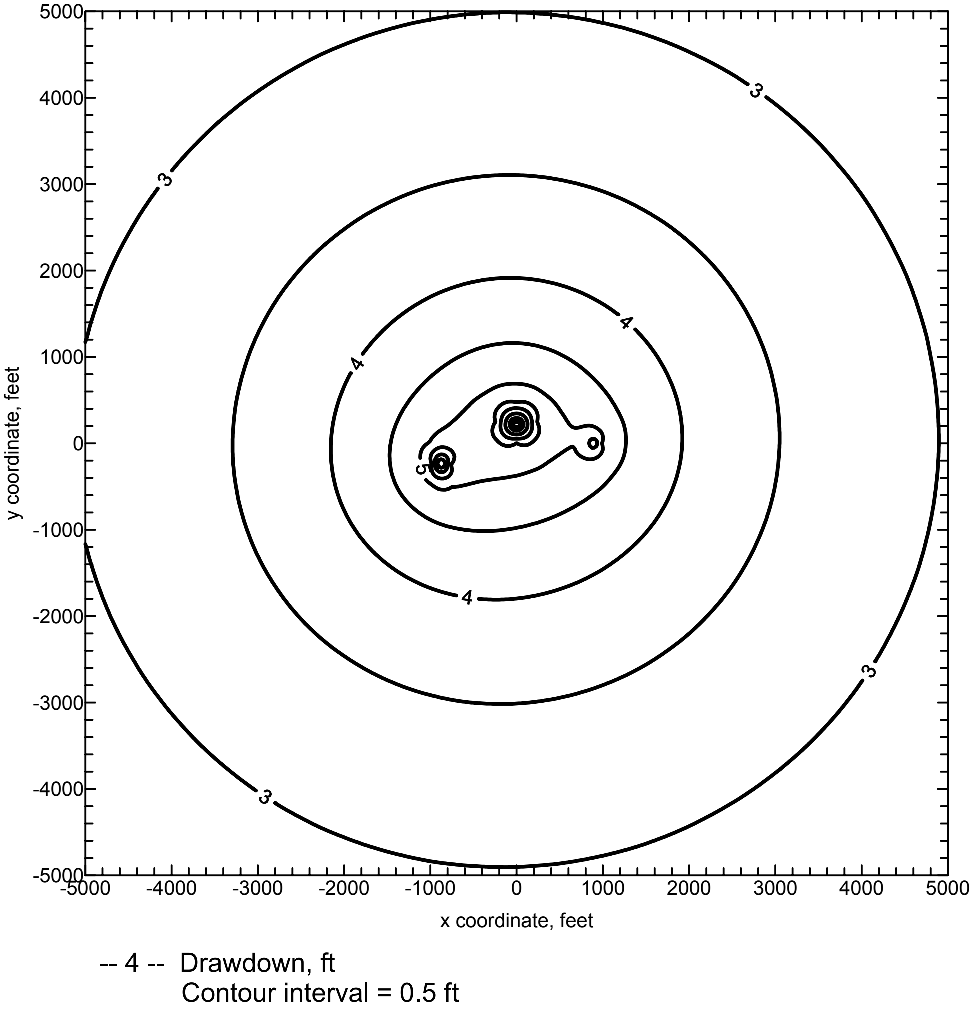


Figure 4-10. 3LAYSS multiple-well example three: drawdowns in the lower Floridan aquifer due to 25 recharge wells in the surficial aquifer and six pumping wells in the upper and lower Floridan aquifers

Table 4-16. Input on screen for file option for steady-state 3LAYSS multiple-well example three

```
****************************************************************************
****************************************************************************
         3LAYSS:AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
****************************************************************************
****************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
m
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
f
 ENTER INPUT FILE NAME: <filename.in>
31_wells_SAS_UFA_LFA_250.in
 NAME OF THE PROJECT: <write in single quotation marks>
'3LAYSS multiple-well example three'
 ENTER OUTPUT FILE NAME: <filename.out>
31_wells_SAS_UFA_LFA_250.out
 ENTER DATA FILE NAME FOR SUM OF DRAWDOWNS: <filename.dat>
31_wells_SAS_UFA_LFA_250.dat


 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 4-17. Input file for file option for steady-state 3LAYSS multiple-well example three

```
1000.0                                 T1
60000.                                 T2
60000.                                 T3
1.52e-4                                EP
1.0e-4                                 K'/b' overlying layer 2
5.0e-5                                 K'/b' overlying layer 3

31                                     Number of pumped wells
UFA_1     -1000.0  0.0  1.0         Well i.d.,xw,yw,rw
0.0  200000.0  0.0                     Q1,Q2,Q3
UFA_2      0.0     0.0  1.0         Well i.d.,xw,yw,rw
0.0  200000.0  0.0                     Q1,Q2,Q3
UFA_3      1000.0  0.0  1.0         Well i.d.,xw,yw,rw
0.0  200000.0  0.0                     Q1,Q2,Q3
LFA_4     -875.0  -237.0  0.75      Well i.d.,xw,yw,rw
0.0       0.0  133500.0                 Q1,Q2,Q3
LFA_5   0.0  245.0  1.0             Well i.d.,xw,yw,rw
0.0       0.0  193000.0                 Q1,Q2,Q3
LFA_6  900.0  0.0  1.25             Well i.d.,xw,yw,rw
0.0       0.0  73500.0                 Q1,Q2,Q3
SAS_7   -1000.0  1000.0  0.5        Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_8   -500.0  1000.0  0.5         Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_9   -0.0  1000.0  0.5           Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3


SAS_10   500.0  1000.0  0.5         Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_11   1000.0  1000.0  0.5        Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_12   -1000.0  500.0  0.5        Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3
```

```
SAS_13   -500.0  500.0  0.5         Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_14   0.0  500.0  0.5            Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_15   500.0  500.0  0.5          Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_16   1000.0  500.0  0.5         Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_17   -1000.0   0.0  0.5         Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_18   -500.0    0.0  0.5         Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_19    0.0      0.0  0.5         Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_20    500.0     0.0  0.5        Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_21    1000.0    0.0  0.5        Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_22   -1000.0  -500.0  0.5       Well i.d.,xw,yw,rw
-1000.0        0.0  0.0                 Q1,Q2,Q3

SAS_23   -500.0   -500.0  0.5       Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_24    0.0     -500.0  0.5       Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_25    500.0   -500.0  0.5       Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_26    1000.0  -500.0  0.5       Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_27   -1000.0  -1000.0  0.5      Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_28   -500.0   -1000.0  0.5      Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_29    0.0     -1000.0  0.5      Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_30    500.0    -1000.0  0.5     Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

SAS_31    1000.0   -1000.0  0.5     Well i.d.,xw,yw,rw
-1000.0       0.0  0.0                 Q1,Q2,Q3

-5000  -5000                        Beginning x and y coordinates (at lower left corner)
 5000   5000                        Ending x and y coordinates (at upper right corner)
  250    250                        Spacing in x direction, spacing in y direction
```

Table 4-18. Output file for steady-state 3LAYSS multiple-well example three

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

            3LAYSS:AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
       3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

            PROGRAMMED BY Ozlem Acar and Louis H. Motz
                          Department of Civil and Coastal Engineering
                          University of Florida
                          Gainesville, Florida
*********************************************************************************
*********************************************************************************

3LAYSS multiple-well example three

DRAWDOWNS DUE TO WELLFIELD PUMPING

INPUT DATA
----------
----------

ALL DATA ARE IN CONSISTENT UNITS

TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)                             : 1.000E+03
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)                             : 6.000E+04
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)                             : 6.000E+04
RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)           : 1.520E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)                  : 1.000E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)                  : 5.000E-05

NUMBER OF PUMPED WELLS                                                :        31

UFA_1
X COORDINATE OF WELL (ft)                                             : -1000.000
Y COORDINATE OF WELL (ft)                                             :     0.000
RADIUS OF WELL (rw) (ft)                                              :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                             : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                             : 2.000E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                             : 0.000E+00

UFA_2
X COORDINATE OF WELL (ft)                                             :     0.000
Y COORDINATE OF WELL (ft)                                             :     0.000
RADIUS OF WELL (rw) (ft)                                              :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                             : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                             : 2.000E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                             : 0.000E+00

(Note: x- and y-coordinates, radiuses and pumping rates for well locations 3-29 are not printed.)

SAS_30
X COORDINATE OF WELL (ft)                                             :   500.000
Y COORDINATE OF WELL (ft)                                             : -1000.000
RADIUS OF WELL (rw) (ft)                                              :     0.500
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                             :-1.000E+03
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                             : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                             : 0.000E+00

SAS_31
X COORDINATE OF WELL (ft)                                             :  1000.000
Y COORDINATE OF WELL (ft)                                             : -1000.000
RADIUS OF WELL (rw) (ft)                                              :     0.500
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                             :-1.000E+03
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                             : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                             : 0.000E+00

NUMBER OF GRIDS AT WHICH DRAWDOWNS ARE CALCULATED                     :      1681

GRID LOCATION :    1
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)       : -5000.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)       : -5000.000

GRID LOCATION :    2
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)       : -4750.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)       : -5000.000

…
(Note: x- and y-coordinates for grid locations 3-1679 are not printed.)
```

```
GRID LOCATION : 1680
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :  4750.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :  5000.000

GRID LOCATION : 1681
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :  5000.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :  5000.000

DRAWDOWNS IN 3-LAYER AQUIFER SYSTEMS
OBTAINED BY ANALYTICAL MODEL
------------------------------------
------------------------------------

REF: Hemker,C.J.1984.Steady Groundwater Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,72(1984),355-374.
     Hemker,C.J.1985.Transient Well Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,81(1985),111-126.
     Hemker,C.J. and Maas,C.1987.Unsteady Flow to Wells in Layered and Fissured
     Aquifer Systems.J.of Hydrology,90(1987),231-249.

     Grid location =   1

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------   -------  -------  -------
 -5000.000  -5000.000  -1000.000      0.000   6403.124    0.325    0.828    0.200
 -5000.000  -5000.000      0.000      0.000   7071.068    0.307    0.779    0.199
 -5000.000  -5000.000   1000.000      0.000   7810.250    0.289    0.731    0.197
 -5000.000  -5000.000   -875.000   -237.000   6300.936    0.053    0.134    0.720
 -5000.000  -5000.000      0.000    245.000   7246.380    0.075    0.191    0.973
 -5000.000  -5000.000    900.000      0.000   7733.693    0.028    0.072    0.358
 -5000.000  -5000.000  -1000.000   1000.000   7211.103   -0.003   -0.002    0.000
 -5000.000  -5000.000   -500.000   1000.000   7500.000   -0.003   -0.001    0.000
 -5000.000  -5000.000      0.000   1000.000   7810.250   -0.003   -0.001    0.000
 -5000.000  -5000.000    500.000   1000.000   8139.410   -0.002   -0.001    0.000
 -5000.000  -5000.000   1000.000   1000.000   8485.281   -0.002   -0.001    0.000
 -5000.000  -5000.000  -1000.000    500.000   6800.735   -0.004   -0.002    0.000
 -5000.000  -5000.000   -500.000    500.000   7106.335   -0.003   -0.002    0.000
 -5000.000  -5000.000      0.000    500.000   7433.034   -0.003   -0.001    0.000
 -5000.000  -5000.000    500.000    500.000   7778.175   -0.003   -0.001    0.000
 -5000.000  -5000.000   1000.000    500.000   8139.410   -0.002   -0.001    0.000
 -5000.000  -5000.000  -1000.000      0.000   6403.124   -0.005   -0.002    0.000
 -5000.000  -5000.000   -500.000      0.000   6726.812   -0.004   -0.002    0.000
 -5000.000  -5000.000      0.000      0.000   7071.068   -0.004   -0.002    0.000
 -5000.000  -5000.000    500.000      0.000   7433.034   -0.003   -0.001    0.000
 -5000.000  -5000.000   1000.000      0.000   7810.250   -0.003   -0.001    0.000
 -5000.000  -5000.000  -1000.000   -500.000   6020.797   -0.006   -0.002    0.000
 -5000.000  -5000.000   -500.000   -500.000   6363.961   -0.005   -0.002    0.000
 -5000.000  -5000.000      0.000   -500.000   6726.812   -0.004   -0.002    0.000
 -5000.000  -5000.000    500.000   -500.000   7106.335   -0.003   -0.002    0.000
 -5000.000  -5000.000   1000.000   -500.000   7500.000   -0.003   -0.001    0.000
 -5000.000  -5000.000  -1000.000  -1000.000   5656.854   -0.007   -0.002    0.000
 -5000.000  -5000.000   -500.000  -1000.000   6020.797   -0.006   -0.002    0.000
 -5000.000  -5000.000      0.000  -1000.000   6403.124   -0.005   -0.002    0.000
 -5000.000  -5000.000    500.000  -1000.000   6800.735   -0.004   -0.002    0.000
 -5000.000  -5000.000   1000.000  -1000.000   7211.103   -0.003   -0.002    0.000


     Grid location =   2

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------   -------  -------  -------
 -4750.000  -5000.000  -1000.000      0.000   6250.000    0.329    0.840    0.201
 -4750.000  -5000.000      0.000      0.000   6896.557    0.312    0.791    0.199

(Note: drawdowns due to wells 3-29 are not printed.)

 -4750.000  -5000.000    500.000  -1000.000   6600.189   -0.004   -0.002    0.000
 -4750.000  -5000.000   1000.000  -1000.000   7004.463   -0.004   -0.002    0.000

(Note: output for grid locations 3-1679 is not printed.)


     Grid location =1680

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------   -------  -------  -------
  4750.000   5000.000  -1000.000      0.000   7619.875    0.294    0.743    0.197
  4750.000   5000.000      0.000      0.000   6896.557    0.312    0.791    0.199

(Note: drawdowns due to wells 3-29 are not printed.)
```

```
  4750.000   5000.000    500.000  -1000.000   7352.721   -0.003   -0.002    0.000
  4750.000   5000.000   1000.000  -1000.000   7075.486   -0.004   -0.002    0.000

     Grid location =1681

     xgrid      ygrid      xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
---------- ---------- ---------- ---------- ----------  -------  -------  -------
  5000.000   5000.000  -1000.000      0.000   7810.250    0.289    0.731    0.197
  5000.000   5000.000      0.000      0.000   7071.068    0.307    0.779    0.199

(Note: drawdowns due to wells 3-29 are not printed.)

  5000.000   5000.000    500.000  -1000.000   7500.000   -0.003   -0.001    0.000
  5000.000   5000.000   1000.000  -1000.000   7211.103   -0.003   -0.002    0.000


Grid loc.        xgrid       ygrid  sum of dd 1  sum of dd 2  sum of dd 3
---------   ----------  ----------  -----------  -----------  -----------
---------   ----------  ----------  -----------  -----------  -----------
       1     -5000.000   -5000.000        0.984        2.697        2.637
       2     -4750.000   -5000.000        0.989        2.733        2.663

(Note: drawdown sums for grid locations 3-1679 are not printed.)

    1680      4750.000    5000.000        0.989        2.733        2.646
    1681      5000.000    5000.000        0.984        2.696        2.619


     Well location = UFA_1

 well id                xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000      1.000    0.544    5.452    0.210
UFA_2                   0.000      0.000   1000.000    0.520    1.789    0.210
UFA_3                1000.000      0.000   2000.000    0.480    1.424    0.209
LFA_4                -875.000   -237.000    267.944    0.055    0.140    1.831
LFA_5                   0.000    245.000   1029.575    0.079    0.202    1.958
LFA_6                 900.000      0.000   1900.000    0.030    0.077    0.627
SAS_7               -1000.000   1000.000   1000.000   -0.147   -0.003    0.000
SAS_8                -500.000   1000.000   1118.034   -0.133   -0.003    0.000
SAS_9                   0.000   1000.000   1414.214   -0.104   -0.003    0.000
SAS_10                500.000   1000.000   1802.776   -0.078   -0.002    0.000
SAS_11               1000.000   1000.000   2236.068   -0.057   -0.002    0.000
SAS_12              -1000.000    500.000    500.000   -0.246   -0.003    0.000
SAS_13               -500.000    500.000    707.107   -0.195   -0.003    0.000
SAS_14                  0.000    500.000   1118.034   -0.133   -0.003    0.000
SAS_15                500.000    500.000   1581.139   -0.092   -0.002    0.000
SAS_16               1000.000    500.000   2061.553   -0.065   -0.002    0.000
SAS_17              -1000.000      0.000      0.500   -1.339   -0.003    0.000
SAS_18               -500.000      0.000    500.000   -0.246   -0.003    0.000
SAS_19                  0.000      0.000   1000.000   -0.147   -0.003    0.000
SAS_20                500.000      0.000   1500.000   -0.098   -0.003    0.000
SAS_21               1000.000      0.000   2000.000   -0.067   -0.002    0.000
SAS_22              -1000.000   -500.000    500.000   -0.246   -0.003    0.000
SAS_23               -500.000   -500.000    707.107   -0.195   -0.003    0.000
SAS_24                  0.000   -500.000   1118.034   -0.133   -0.003    0.000
SAS_25                500.000   -500.000   1581.139   -0.092   -0.002    0.000
SAS_26               1000.000   -500.000   2061.553   -0.065   -0.002    0.000
SAS_27              -1000.000  -1000.000   1000.000   -0.147   -0.003    0.000
SAS_28               -500.000  -1000.000   1118.034   -0.133   -0.003    0.000
SAS_29                  0.000  -1000.000   1414.214   -0.104   -0.003    0.000
SAS_30                500.000  -1000.000   1802.776   -0.078   -0.002    0.000
SAS_31               1000.000  -1000.000   2236.068   -0.057   -0.002    0.000


     Well location = UFA_2

 well id                xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000   1000.000    0.520    1.789    0.210
UFA_2                   0.000      0.000      1.000    0.544    5.452    0.210

(Note: drawdowns due to wells 3-29 are not printed.)

SAS_30                500.000  -1000.000   1118.034   -0.133   -0.003    0.000
SAS_31               1000.000  -1000.000   1414.214   -0.104   -0.003    0.000

     (Note: output for well locations 3-29 is not printed.)
```

```
     Well location = SAS_30

 well id                xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000   1802.776    0.488    1.478    0.209
UFA_2                   0.000      0.000   1118.034    0.515    1.730    0.209

(Note: drawdowns due to wells 3-29 are not printed.)

SAS_30                500.000  -1000.000      0.500   -1.339   -0.003    0.000
SAS_31               1000.000  -1000.000    500.000   -0.246   -0.003    0.000

     Well location = SAS_31

 well id                xwell      ywell  rad.dist.     dd 1     dd 2     dd 3
------------------ ---------- ---------- ----------  -------  -------  -------
UFA_1               -1000.000      0.000   2236.068    0.471    1.365    0.208
UFA_2                   0.000      0.000   1414.214    0.504    1.606    0.209

(Note: drawdowns due to wells 3-29 are not printed.)

SAS_30                500.000  -1000.000    500.000   -0.246   -0.003    0.000
SAS_31               1000.000  -1000.000      0.500   -1.339   -0.003    0.000

 Well id                xwell      ywell      rwell  sum of dd 1  sum of dd 2  sum of dd 3
------------------ ---------- ---------- ----------  -----------  -----------  -----------
------------------ ---------- ---------- ----------  -----------  -----------  -----------
UFA_1               -1000.000      0.000      1.000       -2.689        9.021        5.033
UFA_2                   0.000      0.000      1.000       -3.426        9.385        5.483
UFA_3                1000.000      0.000      1.000       -2.689        9.020        4.916
LFA_4                -875.000   -237.000      0.750       -1.908        6.136        7.142
LFA_5                   0.000    245.000      1.000       -2.469        6.435        8.258
LFA_6                 900.000      0.000      1.250       -2.004        6.660        5.840
SAS_7               -1000.000   1000.000      0.500       -2.142        5.117        4.365
SAS_8                -500.000   1000.000      0.500       -2.571        5.294        4.561
SAS_9                   0.000   1000.000      0.500       -2.705        5.356        4.646
SAS_10                500.000   1000.000      0.500       -2.571        5.294        4.526
SAS_11               1000.000   1000.000      0.500       -2.142        5.116        4.304
SAS_12              -1000.000    500.000      0.500       -2.561        5.649        4.662
SAS_13               -500.000    500.000      0.500       -3.092        5.847        4.993
SAS_14                  0.000    500.000      0.500       -3.257        5.970        5.353
SAS_15                500.000    500.000      0.500       -3.092        5.846        4.932
SAS_16               1000.000    500.000      0.500       -2.561        5.649        4.574
SAS_17              -1000.000      0.000      0.500       -2.689        9.021        5.033
SAS_18               -500.000      0.000      0.500       -3.252        6.241        5.229
SAS_19                  0.000      0.000      0.500       -3.426        9.385        5.483
SAS_20                500.000      0.000      0.500       -3.252        6.241        5.068
SAS_21               1000.000      0.000      0.500       -2.689        9.020        4.916
SAS_22              -1000.000   -500.000      0.500       -2.561        5.649        4.899
SAS_23               -500.000   -500.000      0.500       -3.092        5.847        4.962
SAS_24                  0.000   -500.000      0.500       -3.257        5.970        4.884
SAS_25                500.000   -500.000      0.500       -3.092        5.846        4.731
SAS_26               1000.000   -500.000      0.500       -2.561        5.649        4.500
SAS_27              -1000.000  -1000.000      0.500       -2.142        5.116        4.409
SAS_28               -500.000  -1000.000      0.500       -2.571        5.294        4.508
SAS_29                  0.000  -1000.000      0.500       -2.705        5.356        4.484
SAS_30                500.000  -1000.000      0.500       -2.571        5.293        4.382
SAS_31               1000.000  -1000.000      0.500       -2.142        5.116        4.217
```

Table 4-19. Drawdown data output file for steady-state 3LAYSS multiple-well example three

```
Grid/well                  x           y        sum1       sum2       sum3
       1            -5000.00    -5000.00      0.984      2.697      2.637
       2            -4750.00    -5000.00      0.989      2.733      2.663

(Note: grid locations and drawdowns are not printed for grid locations 3-1679.)

    1680             4750.00     5000.00      0.989      2.733      2.646
    1681             5000.00     5000.00      0.984      2.696      2.619
UFA_1               -1000.00        0.00     -2.689      9.021      5.033
UFA_2                   0.00        0.00     -3.426      9.385      5.483
UFA_3                1000.00        0.00     -2.689      9.020      4.916
LFA_4                -875.00     -237.00     -1.908      6.136      7.142
LFA_5                   0.00      245.00     -2.469      6.435      8.258
LFA_6                 900.00        0.00     -2.004      6.660      5.840
SAS_7               -1000.00     1000.00     -2.142      5.117      4.365
SAS_8                -500.00     1000.00     -2.571      5.294      4.561
SAS_9                   0.00     1000.00     -2.705      5.356      4.646
SAS_10                500.00     1000.00     -2.571      5.294      4.526
SAS_11               1000.00     1000.00     -2.142      5.116      4.304
SAS_12              -1000.00      500.00     -2.561      5.649      4.662
SAS_13               -500.00      500.00     -3.092      5.847      4.993
SAS_14                  0.00      500.00     -3.257      5.970      5.353
SAS_15                500.00      500.00     -3.092      5.846      4.932
SAS_16               1000.00      500.00     -2.561      5.649      4.574
SAS_17              -1000.00        0.00     -2.689      9.021      5.033
SAS_18               -500.00        0.00     -3.252      6.241      5.229
SAS_19                  0.00        0.00     -3.426      9.385      5.483
SAS_20                500.00        0.00     -3.252      6.241      5.068
SAS_21               1000.00        0.00     -2.689      9.020      4.916
SAS_22              -1000.00     -500.00     -2.561      5.649      4.899
SAS_23               -500.00     -500.00     -3.092      5.847      4.962
SAS_24                  0.00     -500.00     -3.257      5.970      4.884
SAS_25                500.00     -500.00     -3.092      5.846      4.731
SAS_26               1000.00     -500.00     -2.561      5.649      4.500
SAS_27              -1000.00    -1000.00     -2.142      5.116      4.409
SAS_28               -500.00    -1000.00     -2.571      5.294      4.508
SAS_29                  0.00    -1000.00     -2.705      5.356      4.484
SAS_30                500.00    -1000.00     -2.571      5.293      4.382
SAS_31               1000.00    -1000.00     -2.142      5.116      4.217
```

5.0 TRANSIENT MODEL FOR A THREE-LAYER AQUIFER SYSTEM

5.1 Drawdowns Due to Single Well

5.1.1 Transient Single-Well Option

The single-well option in 3LAYT uses Equations 3-23 through 3-28 and the Stehfest (1970a, b) numerical algorithm to calculate drawdowns for aquifers one, two, and three. To start the program, the user clicks on the icon for the program and selects the single-well option. The program can be run interactively with the user inputting all of the data on the screen, or the user can prepare an input file and select the 'file' option when running the program. If the program is run interactively, time and drawdown results for each radial distance are printed on the screen, and the user is prompted to enter the names of two output files. One output file (filename.out) echoes the input data and prints the radial distance from the pumped well and the time and drawdown results at that distance, and the other file (filename.dat) prints the output results for time and drawdowns at specified radial distances in a format that can be readily used in a graphical package such as Grapher™ to plot drawdowns versus time. If the 'file' option is selected, then the user is prompted to enter the input file name (filename.in), the name of the project ('project name'), and the names of the two output files (filename.out and filename.dat), which are the same as the output files written using the interactive option. Interactively on the screen or in the input file, the user inputs the pumping rates, the transmissivity and storativity values for each aquifer, the rate at which evapotranspiration is reduced per unit of water-table drawdown, the leakance and storativity values for each confining unit, the number of observation wells, the radial distances at which the observation wells are located, and finally the total time of the simulation, the number of time steps, and the time step multiplier. The format of the time input data is similar to the input format for numerical models such as MODFLOW (McDonald and Harbaugh 1988), but unlike a numerical model, it is not necessary to discretize the time steps to perform a drawdown calculation. For example, drawdowns can be calculated for one desired time value by inputting the desired time as the total time of the simulation, the number of time steps equal to 1, and a time step multiplier equal to 1.0. Similarly, drawdowns at steady state can be calculated using a large value for time (i.e., 1 x 10^6 days), one time step, and a time step multiplier equal to 1.0.

Inside the program, c_1 is set by default equal to $1/\varepsilon$ to represent the effects of evapotranspiration reduction in the equation for aquifer one. Also, c_4 is set by default equal to 1.0 x 10^{38} to approximate the impermeable boundary condition at the base of aquifer three, i.e., $(K'/b')_4 = 1/c_4 \rightarrow 0$. In the three-layer transient model, there are no contributions of water from storage associated with the evapotranspiration reduction process or from the bottom impermeable confining unit, and, thus, both $S_1^{'}$ and $S_4^{'} = 0$, which is achieved by setting these storage coefficients by default equal to 1.0 x 10^{-38}.

The program 3LAYT for the single-well option runs as follows. At the beginning of the program, the number of terms in the Stehfest algorithm is set equal to 12, and factorials and summations of V_i for the Stehfest algorithm are calculated. Then, the time interval deltime is computed if the time step multiplier is 1.0; otherwise, the initial time is computed. After this point, all the calculations are carried out within three loops inside each other. The first, or outer, loop is the loop for the radial distances. The second loop is the time loop, and the third, or inner, loop is the Stehfest algorithm. Inside this innermost loop, the Laplace transform parameter p is found first. Then, the eigenvalue analysis computations follow in the same order as in the steady-state code. First, the non-symmetric tridiagonal matrix **A** is computed using Equation 3-23. In the next step, this matrix is converted to the symmetric tridiagonal matrix **D** using Equation 3-24. Eigenvalues and eigenvectors of **D** are calculated in subroutine 'tqli' using the QL method described by Wilkinson and Reinsch (1971). In the next step, the matrix **V**, which is defined as $\mathbf{V} = \mathbf{T}^{-1/2}\mathbf{R}$, is calculated by matrix multiplication in subroutine 'Mmult'. The inverse of **V** is calculated in the subroutine 'inversematrix.' Then, the discharge vector **g** is determined from $Q_i / 2\pi T_i$, $i = 1, 2, \ldots, n$. In order to find the drawdowns in Laplace space by Equation 3-28, the last step left involves finding matrix **K**. In this last step, modified Bessel functions of the second kind, zero order [K_0( )], are calculated in subroutine 'BESSELKo', which is linked to subroutine 'BESSELIo' in which modified Bessel functions of the first kind, zero order [I_0( )] are calculated. Finally, all the matrix and matrix-vector multiplications involving **V**, **K**, $\mathbf{V}^{-1}$, and **g** are carried out by calling the subroutines 'Mmult' and 'MVmult' using Equation 3-28. The innermost Stehfest loop, which runs for N values from 1 to 12, ends with the calculation of drawdowns in Laplace space (Equation 3-28). Then, inverse values of these Laplace transforms, i.e., the drawdowns in the time domain, are obtained using Equation 1 in Stehfest (1970a), and both the time loop and the loop for different radial distances are closed. Drawdowns within the range from $-1.0\text{x}10^{-5}$ to $1.0\text{x}10^{-5}$ are set equal to 0.0 to avoid problems with underflow. If the user has selected the interactive option, the drawdown results for each radial distance are written to the screen at the end of each time step. Regardless of the choice of interactive or file options, the drawdown results for each radial distance at each time step are written to both output files, i.e., filename.out and filename.dat. After all the calculations have been performed and all the results have been printed for the given input data set, the user is asked if more calculations are to be done.

5.1.2 Benchmark Problem for Single-Well Transient Model

Similar to the single-well steady-state option in 3LAYSS (section 4.1.2), the single-well transient option in 3LAYT was tested using aquifer and confining unit parameters based on Williams (1995) and Tibbals (1990) that are generally representative of the hydrogeologic system in the Titusville/Mims area in the northern part of Brevard County in northeast Florida. In this area, the hydrogeologic system generally consists of a surficial aquifer system that overlies a low permeability confining unit, which in turn overlies the Floridan aquifer system, a regionally extensive aquifer system (Miller 1986). The water table occurs in the uppermost part of the surficial aquifer system. The confining unit between the surficial and Floridan aquifer systems, called the intermediate confining unit, is the upper confining unit of the Floridan aquifer system. The Floridan aquifer system is comprised of two zones called the upper and lower Floridan aquifers, which are separated by a relatively low permeability unit called the middle semiconfining unit. In the 3LAYT transient solution, layer one represents the surficial aquifer, layer two represents the upper Floridan aquifer, and layer three represents the lower Floridan aquifer (see Table 5-1). Confining unit two overlying aquifer two represents the intermediate confining unit, and confining unit three overlying aquifer three represents the middle semi-confining unit. Values for $Q_1 = 0$, $T_1 = 1{,}000$ ft^2/ day, and $S_1 = 0.2$ were used for aquifer one, and $Q_2 = 353{,}000$ ft^3/day, $T_2 = 60{,}000$ ft^2/day, and $S_2 = 0.001$ were used for aquifer two. Values for $Q_3 = 0$, $T_3 = 60{,}000$ ft^2/day, and $S_3 = 0.001$ were used for aquifer three. A value of $\varepsilon = 1.52 \times 10^{-4}$ day^{-1} was used for the evapotranspiration reduction rate. Values of $K'/b'_2 = 1.0 \times 10^{-4}$ day^{-1} and $S'_2 = 0.01$ were used for confining unit two overlying aquifer two, and values of $K'/b'_3 = 5.0 \times 10^{-5}$ day^{-1} and $S'_3 = 0.01$ were used for confining unit three overlying aquifer three. The value for ε is based on Motz (1981), and the storage coefficients are based on Denis and Motz (1998). The transient solution was run to 10,000 days in 100 time steps with a time step multiplier = 1.2.

Drawdowns for layers one, two, and three were plotted versus time for a location 800 ft from the pumped well (see Figure 5-1). The 3LAYT solution predicts that the maximum drawdowns at r = 800 ft will be 0.929 ft in layer one (surficial aquifer), 3.366 ft in layer two (upper Floridan aquifer), and 0.370 ft in layer three (lower Floridan aquifer). A steady-state drawdown condition is reached in approximately 5,800 days (at a criterion of 0.01 ft).

Table 5-1. Hydrogeologic units and parameters used in the transient 3LAYT and seven-layer MODFLOW solutions

Hydrogeologic Units and ET Reduction Process	3LAYT		MODFLOW Seven-Layer Solution	
	Units	Parameters	Layers	Parameters
-	-	-	1	Constant head source bed
Evapotranspiration Reduction	Confining Unit One	ε = 1.52 x 10^{-4} day^{-1} ; $S'_1 \rightarrow 0$ by default	2	$(K_V/b)_2$ = 1.52 x 10^{-4} day^{-1}; S_2 = 1 x 10^{-10}
Surficial Aquifer	Aquifer One	$Q_1 = 0$; T_1 = 1,000 ft^2/day; $S_1 = 0.2$	3	T_3 = 1,000 ft^2/day; $S_3 = 0.2$
Intermediate Confining Unit	Confining Unit Two	$(K'/b')_2$ = 1. 0 x 10^{-4} day^{-1} ; $S'_2 = 0.01$	4	$(K_V/b)_4$ = 1.0 x 10^{-4} day^{-1}; $S_4 = 0.01$
Upper Floridan Aquifer	Aquifer Two	Q_2 = 353,000 ft^3/day; T_2 = 60,000 ft^2/day; $S_2 = 0.001$	5	$Q_{5, 70, 70}$ = -353,000 ft^3/day; T_5 = 60,000 ft^2/day; $S_5 = 0.001$
Middle Semi-Confining Unit	Confining Unit Three	$(K'/b')_3$ = 5. 0 x 10^{-5} day^{-1} ; $S'_3 = 0.01$	6	$(K_V/b)_6$ = 5.0 x 10^{-5} day^{-1}; $S_6 = 0.01$
Lower Floridan Aquifer	Aquifer Three	$Q_3 = 0$; T_3 = 60,000 ft^2/day; $S_3 = 0.001$	7	T_7 = 60,000 ft^2/day; $S_7 = 0.001$
Sub-Floridan Confining Unit	Confining Unit Four	$(K'/b')_4$ and $S'_4 \rightarrow 0$ by default	-	No-flow boundary by default

- No data.

Files for the transient single-well benchmark problem are in Tables 5-2 through 5-6. The screen capture for the interactive option is in Table 5-2, and the output files are in Tables 5-3 and 5-4. The screen capture for the input file option is in Table 5-5, and the input file for the file option is in Table 5-6. The input file option writes the same output files as the interactive option (Tables 5-3 and 5-4).

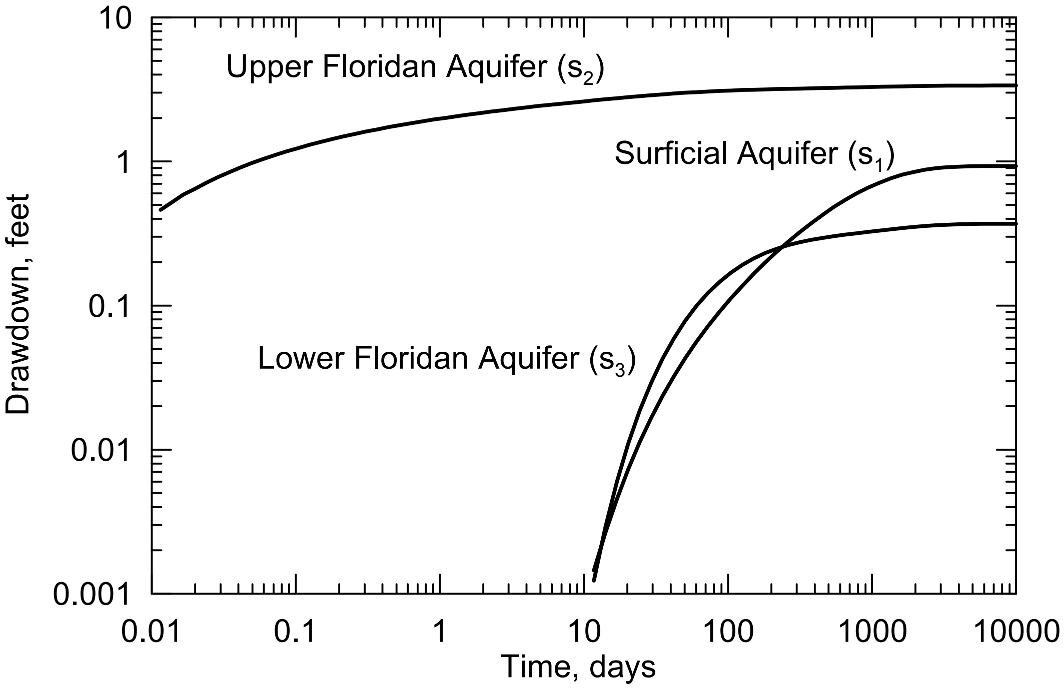


Figure 5-1. Benchmark problem for the transient solution: drawdowns versus time for 3LAYT solution

Table 5-2. Input on screen for interactive input for transient 3LAYT benchmark problem

```
***************************************************************************
***************************************************************************
         3LAYT: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
***************************************************************************
***************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
s
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
i
 NAME OF THE PROJECT: <write in single quotation marks>
'three-layer transient benchmark problem'
 PLEASE ENTER DATA IN CONSISTENT UNITS
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)=?
1000.0
STORATIVITY OF AQUIFER (S) 1=?
0.2
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
353000.
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)=?
60000.0
STORATIVITY OF AQUIFER (S) 2=?
0.001
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
0.0
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)=?
60000.0
STORATIVITY OF AQUIFER (S) 3=?
0.001
```

```
 RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)=?
1.52e-4
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)=?
1.0e-4
STORATIVITY OF THE CONFINING UNIT (Sprime) 2=?
0.01
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)=?
5.0e-5
STORATIVITY OF THE CONFINING UNIT (Sprime) 3=?
0.01
 NUMBER OF r VALUES FOR WHICH CALCULATIONS ARE CARRIED OUT=?
1
RADIAL DISTANCE FROM THE PUMPED WELL (r) 1 (ft)=?
800
 TOTAL TIME LENGTH FOR TRANSIENT SIMULATION (t) (days)=?
10000.
 NUMBER OF TIME STEPS FOR TRANSIENT SIMULATION=?
100.
 TIME STEP MULTIPLIER FOR TRANSIENT SIMULATION=?
1.2
 ENTER OUTPUT FILE NAME: <filename.out>
3_layer_transient_single_well.out
 ENTER DATA FILE NAME FOR GRAPHER INPUT: <filename.dat>
3_layer_transient_single_well.dat

 r (ft) = 8.000E+02

   time      drawdown    drawdown    drawdown
  (days)     aquifer 1   aquifer 2   aquifer 3
 ---------  ----------  ----------  ----------
 ---------  ----------  ----------  ----------
 1.449E-04   0.000E+00   0.000E+00   0.000E+00
 1.739E-04   0.000E+00   0.000E+00   0.000E+00
 2.087E-04   0.000E+00   0.000E+00   0.000E+00
 2.504E-04   0.000E+00   0.000E+00   0.000E+00
 3.005E-04   0.000E+00   1.058E-05   0.000E+00
 3.605E-04   0.000E+00   3.472E-05   0.000E+00
 4.327E-04   0.000E+00   1.251E-04   0.000E+00
 5.192E-04   0.000E+00   4.087E-04   0.000E+00
 6.230E-04   0.000E+00   1.139E-03   0.000E+00
 7.476E-04   0.000E+00   2.730E-03   0.000E+00
 8.972E-04   0.000E+00   5.766E-03   0.000E+00
 1.077E-03   0.000E+00   1.096E-02   0.000E+00
 1.292E-03   0.000E+00   1.908E-02   0.000E+00
 1.550E-03   0.000E+00   3.088E-02   0.000E+00
 1.860E-03   0.000E+00   4.697E-02   0.000E+00
 2.232E-03   0.000E+00   6.783E-02   0.000E+00
 2.679E-03   0.000E+00   9.371E-02   0.000E+00
 3.215E-03   0.000E+00   1.247E-01   0.000E+00
 3.858E-03   0.000E+00   1.606E-01   0.000E+00
 4.629E-03   0.000E+00   2.013E-01   0.000E+00
 5.555E-03   0.000E+00   2.462E-01   0.000E+00
 6.666E-03   0.000E+00   2.952E-01   0.000E+00
 7.999E-03   0.000E+00   3.477E-01   0.000E+00
 9.599E-03   0.000E+00   4.029E-01   0.000E+00
 1.152E-02   0.000E+00   4.611E-01   0.000E+00
 1.382E-02   0.000E+00   5.209E-01   0.000E+00
 1.659E-02   0.000E+00   5.891E-01   0.000E+00
 1.990E-02   0.000E+00   6.451E-01   0.000E+00
 2.389E-02   0.000E+00   7.106E-01   0.000E+00
 2.866E-02   0.000E+00   7.761E-01   0.000E+00
 3.439E-02   0.000E+00   8.418E-01   0.000E+00
 4.127E-02   0.000E+00   9.078E-01   0.000E+00
 4.953E-02   0.000E+00   9.739E-01   0.000E+00
 5.943E-02   0.000E+00   1.040E+00   0.000E+00
 7.132E-02   0.000E+00   1.106E+00   0.000E+00
 8.559E-02   0.000E+00   1.171E+00   0.000E+00
 1.027E-01   0.000E+00   1.236E+00   0.000E+00
 1.232E-01   0.000E+00   1.300E+00   0.000E+00
 1.479E-01   0.000E+00   1.364E+00   0.000E+00
 1.775E-01   0.000E+00   1.427E+00   0.000E+00
 2.130E-01   0.000E+00   1.489E+00   0.000E+00
 2.556E-01   0.000E+00   1.550E+00   0.000E+00
 3.067E-01   0.000E+00   1.611E+00   0.000E+00
 3.680E-01   0.000E+00   1.670E+00   0.000E+00
 4.416E-01   0.000E+00   1.729E+00   0.000E+00
 5.299E-01   0.000E+00   1.787E+00   0.000E+00
 6.359E-01   0.000E+00   1.843E+00   0.000E+00
 7.631E-01   0.000E+00   1.899E+00   0.000E+00
 9.157E-01   0.000E+00   1.955E+00   0.000E+00
```

```
 1.099E+00   0.000E+00   2.009E+00   0.000E+00
 1.319E+00   0.000E+00   2.062E+00   0.000E+00
 1.582E+00   0.000E+00   2.115E+00   0.000E+00
 1.899E+00   0.000E+00   2.167E+00   0.000E+00
 2.279E+00   0.000E+00   2.218E+00   0.000E+00
 2.734E+00   0.000E+00   2.269E+00   0.000E+00
 3.281E+00   0.000E+00   2.319E+00   0.000E+00
 3.937E+00   0.000E+00   2.368E+00   0.000E+00
 4.725E+00   1.540E-05   2.417E+00   0.000E+00
 5.670E+00   4.921E-05   2.465E+00   1.197E-05
 6.804E+00   1.370E-04   2.513E+00   3.749E-05
 8.165E+00   3.349E-04   2.560E+00   1.360E-04
 9.797E+00   7.312E-04   2.607E+00   4.460E-04
 1.176E+01   1.451E-03   2.654E+00   1.232E-03
 1.411E+01   2.658E-03   2.700E+00   2.905E-03
 1.693E+01   4.547E-03   2.746E+00   5.991E-03
 2.032E+01   7.343E-03   2.792E+00   1.107E-02
 2.438E+01   1.128E-02   2.836E+00   1.866E-02
 2.926E+01   1.661E-02   2.879E+00   2.915E-02
 3.511E+01   2.357E-02   2.920E+00   4.271E-02
 4.213E+01   3.237E-02   2.959E+00   5.926E-02
 5.055E+01   4.325E-02   2.995E+00   7.848E-02
 6.066E+01   5.642E-02   3.028E+00   9.983E-02
 7.280E+01   7.213E-02   3.057E+00   1.226E-01
 8.735E+01   9.063E-02   3.083E+00   1.460E-01
 1.048E+02   1.122E-01   3.106E+00   1.691E-01
 1.258E+02   1.372E-01   3.127E+00   1.913E-01
 1.509E+02   1.658E-01   3.145E+00   2.120E-01
 1.811E+02   1.985E-01   3.161E+00   2.308E-01
 2.174E+02   2.353E-01   3.176E+00   2.474E-01
 2.608E+02   2.763E-01   3.190E+00   2.619E-01
 3.130E+02   3.217E-01   3.203E+00   2.744E-01
 3.756E+02   3.712E-01   3.216E+00   2.851E-01
 4.507E+02   4.244E-01   3.229E+00   2.944E-01
 5.409E+02   4.807E-01   3.241E+00   3.027E-01
 6.491E+02   5.390E-01   3.255E+00   3.102E-01
 7.789E+02   5.979E-01   3.268E+00   3.173E-01
 9.346E+02   6.561E-01   3.282E+00   3.243E-01
 1.122E+03   7.115E-01   3.296E+00   3.312E-01
 1.346E+03   7.625E-01   3.309E+00   3.379E-01
 1.615E+03   8.073E-01   3.322E+00   3.444E-01
 1.938E+03   8.448E-01   3.333E+00   3.505E-01
 2.326E+03   8.744E-01   3.343E+00   3.559E-01
 2.791E+03   8.961E-01   3.351E+00   3.604E-01
 3.349E+03   9.110E-01   3.356E+00   3.639E-01
 4.019E+03   9.202E-01   3.361E+00   3.665E-01
 4.823E+03   9.253E-01   3.363E+00   3.682E-01
 5.787E+03   9.278E-01   3.365E+00   3.692E-01
 6.944E+03   9.289E-01   3.365E+00   3.697E-01
 8.333E+03   9.292E-01   3.365E+00   3.700E-01
 1.000E+04   9.293E-01   3.366E+00   3.700E-01

 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 5-3. Output file for transient 3LAYT benchmark problem

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

             3LAYT: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
       3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

             PROGRAMMED BY Ozlem Acar and Louis H. Motz
                           Department of Civil and Coastal Engineering
                           University of Florida
                           Gainesville, Florida
************************************************************************************
************************************************************************************

three-layer transient benchmark problem

DRAWDOWNS DUE TO SINGLE WELL PUMPING

INPUT DATA
----------
----------

ALL DATA ARE IN CONSISTENT UNITS

PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)                                : 1.000E+03
STORATIVITY OF AQUIFER (S) 1                                             : 2.000E-01
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 3.530E+05
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)                                : 6.000E+04
STORATIVITY OF AQUIFER (S) 2                                             : 1.000E-03
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)                                : 6.000E+04
STORATIVITY OF AQUIFER (S) 3                                             : 1.000E-03
RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)              : 1.520E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)                     : 1.000E-04
STORATIVITY OF THE CONFINING UNIT (Sprime) 2                             : 1.000E-02
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)                     : 5.000E-05
STORATIVITY OF THE CONFINING UNIT (Sprime) 3                             : 1.000E-02

NUMBER OF WELL LOCATIONS AT WHICH DRAWDOWNS ARE CALCULATED               :         1
RADIAL DISTANCE FROM THE PUMPED WELL (r) 1 (ft)                          :   800.000


TOTAL TIME LENGTH FOR TRANSIENT SIMULATION (t) (days)                    : 10000.000
NUMBER OF TIME STEPS FOR TRANSIENT SIMULATION                            :       100
TIME STEP MULTIPLIER FOR TRANSIENT SIMULATION                            :     1.200


DRAWDOWNS IN 3-LAYER AQUIFER SYSTEMS
OBTAINED BY ANALYTICAL MODEL
------------------------------------
------------------------------------

REF: Hemker,C.J.1984.Steady Groundwater Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,72(1984),355-374.
     Hemker,C.J.1985.Transient Well Flow in Leaky Multiple-Aquifer Systems
     J.of Hydrology,81(1985),111-126.
     Hemker,C.J. and Maas,C.1987.Unsteady Flow to Wells in Layered and Fissured
     Aquifer Systems.J.of Hydrology,90(1987),231-249.

 r (ft) = 8.000E+02

     time       drawdown         drawdown         drawdown
    (days)   aquifer 1 (ft)   aquifer 2 (ft)   aquifer 3 (ft)
 ---------   --------------   --------------   --------------
 ---------   --------------   --------------   --------------
 1.449E-04      0.000E+00        0.000E+00        0.000E+00
 1.739E-04      0.000E+00        0.000E+00        0.000E+00
 2.087E-04      0.000E+00        0.000E+00        0.000E+00
 2.504E-04      0.000E+00        0.000E+00        0.000E+00
 3.005E-04      0.000E+00        1.058E-05        0.000E+00
 3.605E-04      0.000E+00        3.472E-05        0.000E+00
 4.327E-04      0.000E+00        1.251E-04        0.000E+00
 5.192E-04      0.000E+00        4.087E-04        0.000E+00
 6.230E-04      0.000E+00        1.139E-03        0.000E+00
 7.476E-04      0.000E+00        2.730E-03        0.000E+00
 8.972E-04      0.000E+00        5.766E-03        0.000E+00
```

```
 1.077E-03      0.000E+00       1.096E-02       0.000E+00
 1.292E-03      0.000E+00       1.908E-02       0.000E+00
 1.550E-03      0.000E+00       3.088E-02       0.000E+00
 1.860E-03      0.000E+00       4.697E-02       0.000E+00
 2.232E-03      0.000E+00       6.783E-02       0.000E+00
 2.679E-03      0.000E+00       9.371E-02       0.000E+00
 3.215E-03      0.000E+00       1.247E-01       0.000E+00
 3.858E-03      0.000E+00       1.606E-01       0.000E+00
 4.629E-03      0.000E+00       2.013E-01       0.000E+00
 5.555E-03      0.000E+00       2.462E-01       0.000E+00
 6.666E-03      0.000E+00       2.952E-01       0.000E+00
 7.999E-03      0.000E+00       3.477E-01       0.000E+00
 9.599E-03      0.000E+00       4.029E-01       0.000E+00
 1.152E-02      0.000E+00       4.611E-01       0.000E+00
 1.382E-02      0.000E+00       5.209E-01       0.000E+00
 1.659E-02      0.000E+00       5.891E-01       0.000E+00
 1.990E-02      0.000E+00       6.451E-01       0.000E+00
 2.389E-02      0.000E+00       7.106E-01       0.000E+00
 2.866E-02      0.000E+00       7.761E-01       0.000E+00
 3.439E-02      0.000E+00       8.418E-01       0.000E+00
 4.127E-02      0.000E+00       9.078E-01       0.000E+00
 4.953E-02      0.000E+00       9.739E-01       0.000E+00
 5.943E-02      0.000E+00       1.040E+00       0.000E+00
 7.132E-02      0.000E+00       1.106E+00       0.000E+00
 8.559E-02      0.000E+00       1.171E+00       0.000E+00
 1.027E-01      0.000E+00       1.236E+00       0.000E+00
 1.232E-01      0.000E+00       1.300E+00       0.000E+00
 1.479E-01      0.000E+00       1.364E+00       0.000E+00
 1.775E-01      0.000E+00       1.427E+00       0.000E+00
 2.130E-01      0.000E+00       1.489E+00       0.000E+00
 2.556E-01      0.000E+00       1.550E+00       0.000E+00
 3.067E-01      0.000E+00       1.611E+00       0.000E+00
 3.680E-01      0.000E+00       1.670E+00       0.000E+00
 4.416E-01      0.000E+00       1.729E+00       0.000E+00
 5.299E-01      0.000E+00       1.787E+00       0.000E+00
 6.359E-01      0.000E+00       1.843E+00       0.000E+00
 7.631E-01      0.000E+00       1.899E+00       0.000E+00
 9.157E-01      0.000E+00       1.955E+00       0.000E+00
 1.099E+00      0.000E+00       2.009E+00       0.000E+00
 1.319E+00      0.000E+00       2.062E+00       0.000E+00
 1.582E+00      0.000E+00       2.115E+00       0.000E+00
 1.899E+00      0.000E+00       2.167E+00       0.000E+00
 2.279E+00      0.000E+00       2.218E+00       0.000E+00
 2.734E+00      0.000E+00       2.269E+00       0.000E+00
 3.281E+00      0.000E+00       2.319E+00       0.000E+00
 3.937E+00      0.000E+00       2.368E+00       0.000E+00
 4.725E+00      1.540E-05       2.417E+00       0.000E+00
 5.670E+00      4.921E-05       2.465E+00       1.197E-05
 6.804E+00      1.370E-04       2.513E+00       3.749E-05
 8.165E+00      3.349E-04       2.560E+00       1.360E-04
 9.797E+00      7.312E-04       2.607E+00       4.460E-04
 1.176E+01      1.451E-03       2.654E+00       1.232E-03
 1.411E+01      2.658E-03       2.700E+00       2.905E-03
 1.693E+01      4.547E-03       2.746E+00       5.991E-03
 2.032E+01      7.343E-03       2.792E+00       1.107E-02
 2.438E+01      1.128E-02       2.836E+00       1.866E-02
 2.926E+01      1.661E-02       2.879E+00       2.915E-02
 3.511E+01      2.357E-02       2.920E+00       4.271E-02
 4.213E+01      3.237E-02       2.959E+00       5.926E-02
 5.055E+01      4.325E-02       2.995E+00       7.848E-02
 6.066E+01      5.642E-02       3.028E+00       9.983E-02
 7.280E+01      7.213E-02       3.057E+00       1.226E-01
 8.735E+01      9.063E-02       3.083E+00       1.460E-01
 1.048E+02      1.122E-01       3.106E+00       1.691E-01
 1.258E+02      1.372E-01       3.127E+00       1.913E-01
 1.509E+02      1.658E-01       3.145E+00       2.120E-01
 1.811E+02      1.985E-01       3.161E+00       2.308E-01
 2.174E+02      2.353E-01       3.176E+00       2.474E-01
 2.608E+02      2.763E-01       3.190E+00       2.619E-01
 3.130E+02      3.217E-01       3.203E+00       2.744E-01
 3.756E+02      3.712E-01       3.216E+00       2.851E-01
 4.507E+02      4.244E-01       3.229E+00       2.944E-01
 5.409E+02      4.807E-01       3.241E+00       3.027E-01
 6.491E+02      5.390E-01       3.255E+00       3.102E-01
 7.789E+02      5.979E-01       3.268E+00       3.173E-01
 9.346E+02      6.561E-01       3.282E+00       3.243E-01
 1.122E+03      7.115E-01       3.296E+00       3.312E-01
 1.346E+03      7.625E-01       3.309E+00       3.379E-01
 1.615E+03      8.073E-01       3.322E+00       3.444E-01
 1.938E+03      8.448E-01       3.333E+00       3.505E-01
```

```
 2.326E+03      8.744E-01       3.343E+00       3.559E-01
 2.791E+03      8.961E-01       3.351E+00       3.604E-01
 3.349E+03      9.110E-01       3.356E+00       3.639E-01
 4.019E+03      9.202E-01       3.361E+00       3.665E-01
 4.823E+03      9.253E-01       3.363E+00       3.682E-01
 5.787E+03      9.278E-01       3.365E+00       3.692E-01
 6.944E+03      9.289E-01       3.365E+00       3.697E-01
 8.333E+03      9.292E-01       3.365E+00       3.700E-01
 1.000E+04      9.293E-01       3.366E+00       3.700E-01
```

Table 5-4. Time and drawdown data output file for transient 3LAYT benchmark problem

```
                r= 8.000E+02
     time          s1          s2          s3
  1.4490E-04  0.0000E+00  0.0000E+00  0.0000E+00
  1.7388E-04  0.0000E+00  0.0000E+00  0.0000E+00
  2.0865E-04  0.0000E+00  0.0000E+00  0.0000E+00
  2.5038E-04  0.0000E+00  0.0000E+00  0.0000E+00
  3.0046E-04  0.0000E+00  1.0579E-05  0.0000E+00
  3.6055E-04  0.0000E+00  3.4723E-05  0.0000E+00
  4.3266E-04  0.0000E+00  1.2513E-04  0.0000E+00
  5.1919E-04  0.0000E+00  4.0874E-04  0.0000E+00
  6.2303E-04  0.0000E+00  1.1386E-03  0.0000E+00
  7.4763E-04  0.0000E+00  2.7303E-03  0.0000E+00
  8.9716E-04  0.0000E+00  5.7663E-03  0.0000E+00
  1.0766E-03  0.0000E+00  1.0960E-02  0.0000E+00
  1.2919E-03  0.0000E+00  1.9082E-02  0.0000E+00
  1.5503E-03  0.0000E+00  3.0876E-02  0.0000E+00
  1.8603E-03  0.0000E+00  4.6973E-02  0.0000E+00
  2.2324E-03  0.0000E+00  6.7832E-02  0.0000E+00
  2.6789E-03  0.0000E+00  9.3714E-02  0.0000E+00
  3.2147E-03  0.0000E+00  1.2468E-01  0.0000E+00
  3.8576E-03  0.0000E+00  1.6061E-01  0.0000E+00
  4.6291E-03  0.0000E+00  2.0125E-01  0.0000E+00
  5.5550E-03  0.0000E+00  2.4625E-01  0.0000E+00
  6.6660E-03  0.0000E+00  2.9518E-01  0.0000E+00
  7.9992E-03  0.0000E+00  3.4767E-01  0.0000E+00
  9.5990E-03  0.0000E+00  4.0290E-01  0.0000E+00
  1.1519E-02  0.0000E+00  4.6111E-01  0.0000E+00
  1.3823E-02  0.0000E+00  5.2087E-01  0.0000E+00
  1.6587E-02  0.0000E+00  5.8910E-01  0.0000E+00
  1.9904E-02  0.0000E+00  6.4506E-01  0.0000E+00
  2.3885E-02  0.0000E+00  7.1062E-01  0.0000E+00
  2.8662E-02  0.0000E+00  7.7610E-01  0.0000E+00
  3.4395E-02  0.0000E+00  8.4181E-01  0.0000E+00
  4.1274E-02  0.0000E+00  9.0781E-01  0.0000E+00
  4.9529E-02  0.0000E+00  9.7391E-01  0.0000E+00
  5.9434E-02  0.0000E+00  1.0399E+00  0.0000E+00
  7.1321E-02  0.0000E+00  1.1057E+00  0.0000E+00
  8.5586E-02  0.0000E+00  1.1711E+00  0.0000E+00
  1.0270E-01  0.0000E+00  1.2360E+00  0.0000E+00
  1.2324E-01  0.0000E+00  1.3003E+00  0.0000E+00
  1.4789E-01  0.0000E+00  1.3640E+00  0.0000E+00
  1.7747E-01  0.0000E+00  1.4269E+00  0.0000E+00
  2.1296E-01  0.0000E+00  1.4890E+00  0.0000E+00
  2.5556E-01  0.0000E+00  1.5503E+00  0.0000E+00
  3.0667E-01  0.0000E+00  1.6108E+00  0.0000E+00
  3.6800E-01  0.0000E+00  1.6703E+00  0.0000E+00
  4.4160E-01  0.0000E+00  1.7289E+00  0.0000E+00
  5.2992E-01  0.0000E+00  1.7867E+00  0.0000E+00
  6.3591E-01  0.0000E+00  1.8435E+00  0.0000E+00
  7.6309E-01  0.0000E+00  1.8994E+00  0.0000E+00
  9.1571E-01  0.0000E+00  1.9545E+00  0.0000E+00
  1.0988E+00  0.0000E+00  2.0088E+00  0.0000E+00
  1.3186E+00  0.0000E+00  2.0622E+00  0.0000E+00
  1.5823E+00  0.0000E+00  2.1149E+00  0.0000E+00
  1.8988E+00  0.0000E+00  2.1668E+00  0.0000E+00
  2.2786E+00  0.0000E+00  2.2181E+00  0.0000E+00
  2.7343E+00  0.0000E+00  2.2687E+00  0.0000E+00
  3.2811E+00  0.0000E+00  2.3186E+00  0.0000E+00
  3.9374E+00  0.0000E+00  2.3680E+00  0.0000E+00
  4.7248E+00  1.5403E-05  2.4168E+00  0.0000E+00
  5.6698E+00  4.9209E-05  2.4652E+00  1.1967E-05
  6.8038E+00  1.3702E-04  2.5130E+00  3.7493E-05
  8.1645E+00  3.3491E-04  2.5604E+00  1.3597E-04
  9.7974E+00  7.3121E-04  2.6075E+00  4.4597E-04
```

```
  1.1757E+01  1.4512E-03  2.6541E+00  1.2325E-03
  1.4108E+01  2.6576E-03  2.7004E+00  2.9048E-03
  1.6930E+01  4.5472E-03  2.7463E+00  5.9911E-03
  2.0316E+01  7.3431E-03  2.7915E+00  1.1067E-02
  2.4379E+01  1.1284E-02  2.8359E+00  1.8659E-02
  2.9255E+01  1.6613E-02  2.8790E+00  2.9148E-02
  3.5106E+01  2.3567E-02  2.9202E+00  4.2706E-02
  4.2127E+01  3.2373E-02  2.9591E+00  5.9258E-02
  5.0553E+01  4.3251E-02  2.9950E+00  7.8481E-02
  6.0663E+01  5.6423E-02  3.0278E+00  9.9834E-02
  7.2796E+01  7.2130E-02  3.0572E+00  1.2260E-01
  8.7355E+01  9.0632E-02  3.0834E+00  1.4597E-01
  1.0483E+02  1.1222E-01  3.1065E+00  1.6913E-01
  1.2579E+02  1.3719E-01  3.1269E+00  1.9133E-01
  1.5095E+02  1.6581E-01  3.1450E+00  2.1201E-01
  1.8114E+02  1.9846E-01  3.1613E+00  2.3076E-01
  2.1737E+02  2.3526E-01  3.1762E+00  2.4739E-01
  2.6084E+02  2.7630E-01  3.1900E+00  2.6188E-01
  3.1301E+02  3.2169E-01  3.2031E+00  2.7437E-01
  3.7561E+02  3.7120E-01  3.2159E+00  2.8511E-01
  4.5073E+02  4.2443E-01  3.2286E+00  2.9442E-01
  5.4088E+02  4.8068E-01  3.2415E+00  3.0265E-01
  6.4905E+02  5.3896E-01  3.2546E+00  3.1019E-01
  7.7887E+02  5.9795E-01  3.2681E+00  3.1733E-01
  9.3464E+02  6.5606E-01  3.2818E+00  3.2429E-01
  1.1216E+03  7.1151E-01  3.2955E+00  3.3116E-01
  1.3459E+03  7.6247E-01  3.3089E+00  3.3793E-01
  1.6151E+03  8.0732E-01  3.3216E+00  3.4444E-01
  1.9381E+03  8.4482E-01  3.3330E+00  3.5050E-01
  2.3257E+03  8.7438E-01  3.3427E+00  3.5587E-01
  2.7908E+03  8.9615E-01  3.3506E+00  3.6039E-01
  3.3490E+03  9.1096E-01  3.3565E+00  3.6393E-01
  4.0188E+03  9.2015E-01  3.3605E+00  3.6650E-01
  4.8225E+03  9.2528E-01  3.3631E+00  3.6821E-01
  5.7870E+03  9.2781E-01  3.3645E+00  3.6921E-01
  6.9444E+03  9.2887E-01  3.3652E+00  3.6974E-01
  8.3333E+03  9.2924E-01  3.3655E+00  3.6997E-01
  1.0000E+04  9.2935E-01  3.3656E+00  3.7004E-01
```

Table 5-5. Input on screen for file option transient 3LAYT benchmark problem

```
****************************************************************************
****************************************************************************
         3LAYT: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
****************************************************************************
****************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
s
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
f
 ENTER INPUT FILE NAME: <filename.in>
3_layer_transient_single_well.in
 NAME OF THE PROJECT: <write in single quotation marks>
'three-layer transient benchmark problem'
 ENTER OUTPUT FILE NAME: <filename.out>
3_layer_transient_single_well.out
 ENTER DATA FILE NAME FOR GRAPHER INPUT: <filename.dat>
3_layer_transient_single_well.dat


 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 5-6. Input file for file option for transient 3LAYT benchmark problem

```
0.0  1000.0  0.2             Q1,T1,S1
353000.  60000.0  0.001      Q2,T2,S2
0.0  60000.0  0.001          Q3,T3,S3
1.52E-4                      EP
1.0E-4  0.01                 K'/b'2,S'2
5.0E-5  0.01                 K'/b'3,S'3
1                            Number of observation wells
800                          Radial distance from pumped well to observation well
10000.  100.  1.2            Total time, number of time steps, time-step multiplier
```

To verify the 3LAYT transient solution, drawdowns also were calculated for this problem using a transient MODFLOW solution similar to the seven-layer MODFLOW solution used to verify the analytical steady-state solution (section 4.1.2) (see Table 5-1). The model area was discretized into 139 rows and 139 columns. Layer one was a constant head source bed, and the vertical hydraulic conductivity divided by the thickness in layer two represented the evapotranspiration reduction coefficient. Layer three represented the unpumped water-table aquifer (aquifer one), and the vertical hydraulic conductivity divided by the thickness of layer four represented the leakance of the upper confining unit overlying the upper Floridan aquifer (confining unit two). Layer five represented the upper Floridan aquifer (aquifer two), in which a discharging well was located in row 70 and column 70. The vertical hydraulic conductivity divided by the thickness of layer six represented the leakance of the middle semiconfining unit overlying the lower Floridan aquifer (confining unit three). Layer seven represented the lower Floridan aquifer (aquifer three). All of the layers were specified as confined to match the linearized, i.e., small drawdown, assumptions implicit in Equations 3-12, and constant-head boundary conditions were specified around layers five and seven. A transient simulation was run in MODFLOW using a data set equivalent to the parameters used in 3LAYT to calculate drawdowns due to pumping. At a distance of 800 ft from the pumped well, the MODFLOW solution predicts that the maximum drawdowns will be 0.931 ft in layer one (surficial aquifer), 3.371 ft in layer two (upper Floridan aquifer), and 0.371 ft in layer three (lower Floridan aquifer) (see Figures 5-2 and 5-3). A steady-state drawdown condition is reached in approximately 5,800 days (at a criterion of 0.01 ft), i.e., approximately the same time as in the 3LAYT solution.

In a numerical model that represents an aquifer system in which pumpage is sustained partially by vertical flow of water released from a confining unit, it may be necessary to subdivide a low-conductivity confining unit into more than one layer in order to simulate accurately the effects that the transient release of water from storage in the confining unit has on the distribution of hydraulic heads and drawdowns in the aquifer system (McDonald and Harbaugh 1988 and Leake et al. 1994). This was explored for this problem using a nine-layer MODFLOW solution, in which each of the confining units was subdivided into two layers, and a thirteen-layer MODFLOW solution, in which each of the confining units was subdivided into four

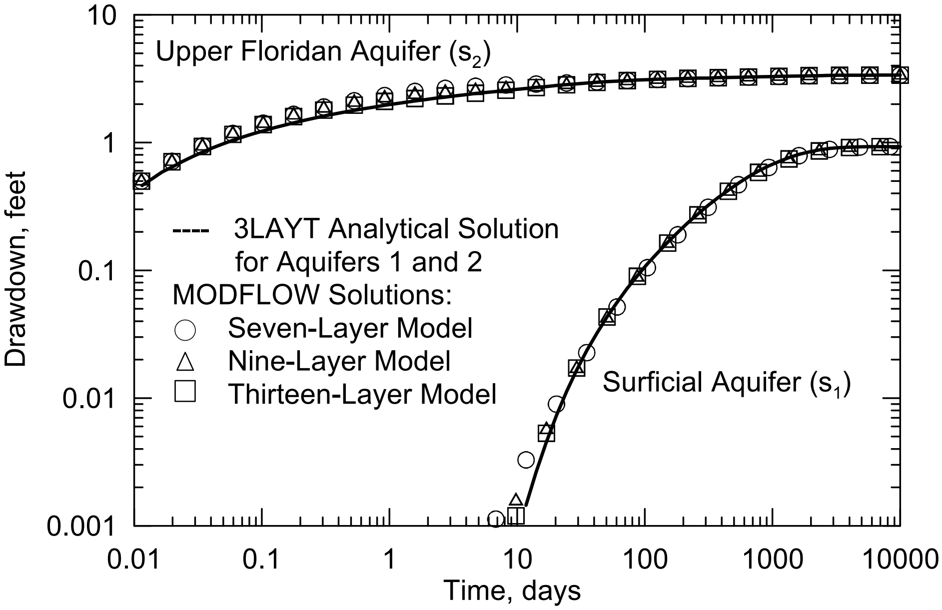


Figure 5-2. Comparison of 3LAYT analytical solution and seven-, nine-, and thirteen-layer MODFLOW solutions for the surficial and upper Floridan aquifers

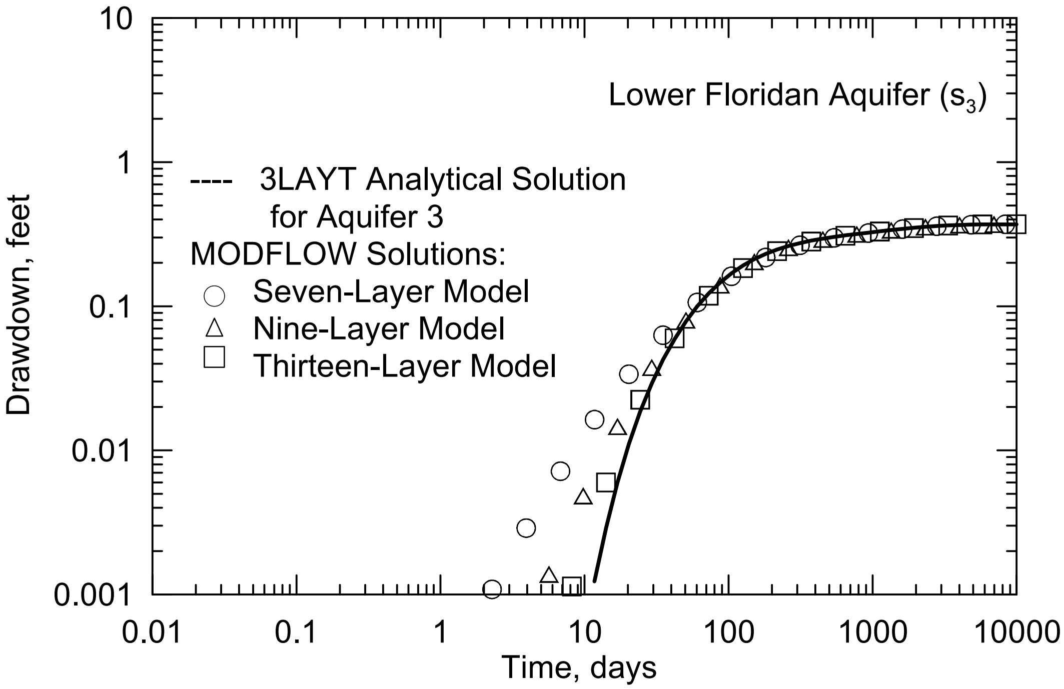


Figure 5-3 Comparison of 3LAYT analytical solution and seven-, nine-, and thirteen-layer MODFLOW solutions for the lower Floridan aquifer

layers. Transient simulations were run in MODFLOW using data sets otherwise equivalent to the parameters used in the 3LAYT and seven-layer MODFLOW solutions to calculate drawdowns due to pumping (see Table 5-7). At a distance of 800 ft from the pumped well in layers one and two, the seven-layer, nine-layer, and thirteen-layer MODFLOW solutions predict that the drawdowns and the time to reach steady-state conditions are the same as the drawdowns and time to steady state predicted by the 3LAYT analytical solution (see Figure 5-2). However, in layer three, the seven-layer and nine-layer solutions predict faster responses in the drawdowns compared to the thirteen-layer solution, which agrees more closely with the 3LAYT analytical solution (see Figure 5-3).

5.2 Drawdowns Due to Multiple Wells

5.2.1 Transient Multiple-Well Option

Similar to the single-well option, the multiple-well option in 3LAYT uses Equations 3-23 through 3-28 and the Stehfest (1970a, b) numerical algorithm to calculate drawdowns for aquifers one, two, and three. To start the program, the user clicks on the icon for the program and selects the multi-well option. The program can be run interactively with the user inputting all data on the screen, or the user can prepare an input file and select the 'file' option when running the program. If the program is run interactively, first drawdowns and the sum of drawdowns at each time step at each grid location and then drawdowns and the sum of drawdowns at each time step at each well location are printed on the screen, and the user is prompted to enter the names of two output files. One output file (filename.out) echoes the input data and prints the drawdowns and sum of drawdowns at each time step at each grid location, followed by the drawdowns and sum of drawdowns at each time step at each well location. The other file (filename.dat) prints the sum of drawdowns at each time step in a format that can be readily used in a graphical package such as Surfer® to grid and plot drawdowns versus time at each grid and/or well location. If the 'file' option is selected, then the user is prompted to enter the input file name (filename.in), the name of the project ('project name'), and the names of the two output files (filename.out and filename.dat), which are the same as the out put files written using the interactive option. Interactively on the screen or in the input file, the user inputs the transmissivity and storativity values for each aquifer, the rate at which evapotranspiration is reduced per unit of water table drawdown, the leakance and storativity values for each confining unit, the total time of the simulation, the number of time steps, the time step multiplier, and the

Table 5-7 Hydrogeologic units and parameters used in the transient 3LAYT and seven-, nine-, and thirteen-layer MODFLOW solutions

Hydro-geologic Units and ET Reduction Process	3LAYT		MODFLOW Solutions					
			Seven-Layer Solution		Nine-Layer Solution		Thirteen-Layer Solution	
	Units	Parameters	Layers	Parameters	Layers	Parameters	Layers	Parameters
-	-	-	1	Constant head source bed	1	Constant head source bed	1	Constant head source bed
Evapotran-spiration Reduction	Confining Unit One	$\varepsilon = 1.52 \times 10^{-4}$ day^{-1} ; $S'_1 \rightarrow 0$ by default	2	$(K_V/b)_2 = 1.52 \times 10^{-4}$ day^{-1}; $S_2 = 1 \times 10^{-10}$	2	$(K_V/b)_2 = 1.52 \times 10^{-4}$ day^{-1}; $S_2 = 1 \times 10^{-10}$	2	$(K_V/b)_2 = 1.52 \times 10^{-4}$ day^{-1}; $S_2 = 1 \times 10^{-10}$
Surficial Aquifer	Aquifer One	$Q_1 = 0$; $T_1 = 1,000$ ft^2/day; $S_1 = 0.2$	3	$T_3 = 1,000$ ft^2/day; $S_3 = 0.2$	3	$T_3 = 1,000$ ft^2/day; $S_3 = 0.2$	3	$T_3 = 1,000$ ft^2/day; $S_3 = 0.2$
Intermediate Confining Unit	Confining Unit Two	$(K'/b')_2 = 1.\ 0 \times 10^{-4}$ day^{-1} ; $S'_2 = 0.01$	4	$(K_V/b)_4 = 1.0 \times 10^{-4}$ day^{-1}; $S_4 = 0.01$	4	$(K_V/b)_4 = 2.0 \times 10^{-4}$ day^{-1}; $S_4 = 0.005$	4	$(K_V/b)_4 = 4.0 \times 10^{-4}$ day^{-1}; $S_4 = 0.0025$
					5	$(K_V/b)_5 = 2.0 \times 10^{-4}$ day^{-1}; $S_5 = 0.005$	5	$(K_V/b)_5 = 4.0 \times 10^{-4}$ day^{-1}; $S_5 = 0.0025$
							6	$(K_V/b)_6 = 4.0 \times 10^{-4}$ day^{-1}; $S_6 = 0.0025$
							7	$(K_V/b)_7 = 4.0 \times 10^{-4}$ day^{-1}; $S_7 = 0.0025$
Upper Floridan Aquifer	Aquifer Two	$Q_2 = 353,000$ ft^3/day; $T_2 = 60,000$ ft^2/day; $S_2 = 0.001$	5	$T_5 = 60,000$ ft^2/day; $S_5 = 0.001$	6	$T_6 = 60,000$ ft^2/day; $S_6 = 0.001$	8	$T_8 = 60,000$ ft^2/day; $S_8 = 0.001$
Middle Semi-Confining Unit	Confining Unit Three	$(K'/b')_3 = 5.\ 0 \times 10^{-5}$ day^{-1} ; $S'_3 = 0.01$	6	$(K_V/b)_6 = 5.0 \times 10^{-5}$ day^{-1}; $S_6 = 0.01$	7	$(K_V/b)_7 = 1.0 \times 10^{-4}$ day^{-1}; $S_7 = 0.005$	9	$(K_V/b)_9 = 2.0 \times 10^{-4}$ day^{-1}; $S_9 = 0.0025$
					8	$(K_V/b)_8 = 1.0 \times 10^{-4}$ day^{-1}; $S_8 = 0.005$	10	$(K_V/b)_{10} = 2.0 \times 10^{-4}$ day^{-1}; $S_{10} = 0.0025$
							11	$(K_V/b)_{11} = 2.0 \times 10^{-4}$ day^{-1}; $S_{11} = 0.0025$
							12	$(K_V/b)_{12} = 2.0 \times 10^{-4}$ day^{-1}; $S_{12} = 0.0025$
Lower Floridan Aquifer	Aquifer Three	$Q_3 = 0$; $T_3 = 60,000$ ft^2/day; $S_3 = 0.001$	7	$T_7 = 60,000$ ft^2/day; $S_7 = 0.001$	9	$T_9 = 60,000$ ft^2/day; $S_9 = 0.001$	13	$T_{13} = 60,000$ ft^2/day; $S_{13} = 0.001$
Sub-Floridan Confining Unit	Confining Unit Four	$(K'/b')_4$ and $S'_4 \rightarrow 0$ by default	-	No-flow boundary by default	-	No-flow boundary by default	-	No-flow boundary by default

- No data.

number of pumped wells. For each well, the well name or number, the x and y coordinates, the radius, and the pumping rates from each aquifer are entered. Finally, the x and y coordinates for the lower left and upper right corners of the grid and the delta x and delta y spacings of the grid are entered. The format of the time input data is similar to the input format for numerical models such as MODFLOW (McDonald and Harbaugh 1988), but unlike a numerical model, it is not necessary to discretize the time steps to perform a drawdown calculation. For example, the drawdowns can be calculated for one desired time value by inputting the desired time as the total time of the simulation, the number of time steps equal to 1, and a time step multiplier equal to 1.0. Similarly, drawdowns at steady state can be calculated using a large value for time (i.e., 1 x 10^6 days), one time step, and a time step multiplier equal to 1.0.

Inside the program, c_1 is set by default equal to $1/\varepsilon$ to represent the effects of evapotranspiration reduction in the equation for aquifer one. Also, c_4 is set by default equal to $1.0\text{x}10^{38}$ to approximate the impermeable boundary condition at the base of aquifer three, i.e., $(K'/b')_4 = 1/c_4 \rightarrow 0$. In the three-layer transient model, there are no contributions of water from storage associated with the evapotranspiration reduction process or from the bottom impermeable confining unit, and, thus, both $S_1^{'}$ and $S_4^{'}$ = 0, which is achieved by setting these storage coefficients equal by default to 1.0 x 10^{-38}.

The program 3LAYT for the multiple-well option runs as follows. At the beginning of the program, the number of terms in the Stehfest algorithm is set equal to 12, and factorials and summations of V_i for the Stehfest algorithm are calculated. Then, the time interval deltime is computed if the time step multiplier is 1.0; otherwise, initial time is computed. After this point, two separate rounds of drawdown calculations are performed. First, calculations are performed at the grid locations, and then they are performed at the well locations. (It is permissible, but not necessary, for a well to be location at a grid intersection.) Each round of calculations consists of four loops. For the computation of drawdowns at each grid location, the outermost loop is the grid locations loop, which encloses the well locations loop. A time loop and the Stehfest algorithm loop, which is the innermost loop, are located inside the well locations loop. For the second round of computation of drawdowns at each well location, both the outermost loop and the second outer loop enclosed by it are well locations loops. A time loop and the Stehfest algorithm loop, which is the innermost loop, are located inside the second well locations loop. For both rounds of drawdown computations, the path of calculations is the same as follows. Inside the innermost loop, the Laplace transform parameter p is found first. Then, the eigenvalue analysis computations follow in the same order as in the steady-state code. First, the non-symmetric tridiagonal matrix **A** is computed using Equation 3-23. In the next step, this matrix is converted to the symmetric tridiagonal matrix **D** using Equation 3-24. Eigenvalues and eigenvectors of **D** are calculated in subroutine ‘tqli’ using the QL method described by Wilkinson and Reinsch (1971). In the next step, matrix **V**, which is defined as $\mathbf{V} = \mathbf{T}^{-1/2}\mathbf{R}$, is calculated by matrix multiplication in subroutine ‘Mmult’. The inverse of **V** is calculated in subroutine ‘inversematrix’. Then, the discharge vector **g** is determined from $Q_i / 2\pi T_i,\ i = 1, 2, \ldots, n$. In order to find the drawdowns in Laplace space by Equation 3-28, the last step involves finding matrix **K**. In this last step, modified Bessel functions of the second kind, zero order [$K_0(\ )$], are calculated in subroutine ‘BESSELKo’ which is linked to subroutine ‘BESSELIo’in which modified Bessel functions of the first kind, zero order [$I_0(\ )$] are calculated. Finally, all the matrix and matrix-vector multiplications involving **V**, **K**, $\mathbf{V}^{-1}$, and **g** are carried out by calling the subroutines ‘Mmult’ and ‘MVmult’ using Equation 3-28. The innermost Stehfest loop, which runs for N values from 1 to 12, ends with the calculation of drawdowns in Laplace space (Equation 3-28). Then, inverse values of these Laplace transforms, i.e., drawdowns in the time domain, are obtained using Equation 1 from Stehfest (1970a, b), and all three outer loops, i.e., the time loop, the inner well locations loop, and the outermost loop for grid locations/well locations, are closed. Drawdowns within the range from -1.0 x 10^{-5} to 1.0 x 10^{-5} are set equal to 0.0 to avoid problems with underflow. After all of the drawdown calculations are finished, the next step is finding the sum of drawdowns at all grid/well locations. This is carried out again in two separate rounds, one for grid locations and the second for well locations. If the user has selected the interactive option, the drawdowns and the sum of drawdowns at each grid and well location are written to screen at the end of each time step. Regardless of the choice of interactive or file options, the drawdown results and sum of drawdowns for each grid location and well location at each time step are written to the output file, filename.out. Additionally, the sums of drawdowns are given in the second output file, filename.dat. After all the calculations have been performed and all the results have been printed for the given input data set, the user is asked if more calculations are to be done.

5.2.2 Example Problem

The example problem, which was run using both the interactive and file input options, illustrates how drawdown values can be calculated and plotted for multiple wells in a rectangular grid. Similar to the benchmark problem (section 5.1.2), T_1 = 1,000 ft^2/day was used for aquifer one, T_2 = 60,000 ft^2/day was used for aquifer two, and T_3 = 60,000 ft^2/day was used for aquifer three. A value for $\varepsilon = 1.52 \times 10^{-4}$ day^{-1} was used, based on Motz (1981). A value of $(K'/b')_2 = 1.0 \times 10^{-4}$ day^{-1} was used for confining unit two, and a value of $(K'/b')_3 = 5.0 \times 10^{-5}$ day^{-1} was used for confining unit three. Six wells were specified, i.e., three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer. The three wells in the upper Floridan aquifer were uniformly spaced 1,000 ft apart through the center of the grid parallel to the x-axis at (x, y) = (-1,000 ft; 0 ft), (0 ft; 0 ft), and (1,000 ft; 0 ft). Each well was assigned a radius of 1.0 ft and pumping rates Q_1 = 0.0, Q_2 = 200,000 ft^3/day, and Q_3 = 0.0. In 3LAYT (and 3LAYSS), drawdowns are calculated at well locations in addition to the uniformly-spaced locations determined by the grid spacing, so it is not necessary for wells to be uniformly spaced or for a well to coincide with one of the uniformly-spaced grid locations. Also, well radiuses and pumping rates can be specified uniquely for each well. These important points are illustrated by the three wells in the lower Floridan aquifer. These wells were located at (x, y) = (-875 ft; -237 ft), (0 ft; 245 ft), and (900 ft; 0 ft) with radiuses = 0.75, 1.00, 1.25 ft, respectively. Pumping rates were Q_1 = 0.0, Q_2 = 0.0, and Q_3 = 133,500 ft^3/day; Q_1 = 0.0, Q_2 = 0.0, and Q_3 = 193,000 ft^3/day; and Q_1 = 0.0, Q_2 = 0.0, and Q_3 = 73,500 ft^3/day, respectively, for the three wells. The transient solution was run to 10,000 days in 2 time steps with a time step multiplier = 100.0, which resulted in drawdowns being calculated at 100 days and 10,000 days. Drawdowns were calculated in layers one, two, and three in a grid that ranged from x, y = (-12,500 ft; -12,500 ft) to x, y = (12,500 ft; 12,500 ft) at 2,601 evenly-spaced locations that were 500 ft apart in both the x and y directions (see Figures 5-4 to 5-9).

Files for the transient 3LAYT multiple-well example are in Tables 5-8 through 5-12. The screen capture for the interactive option is in Table 5-8, and the output files are in Tables 5-9 and 5-10. The screen capture for the input file option is in Table 5-11, and the input file for the file option is in Table 5-12. The input file option writes the same output files as the interactive option (Tables 5-9 and 5-10).

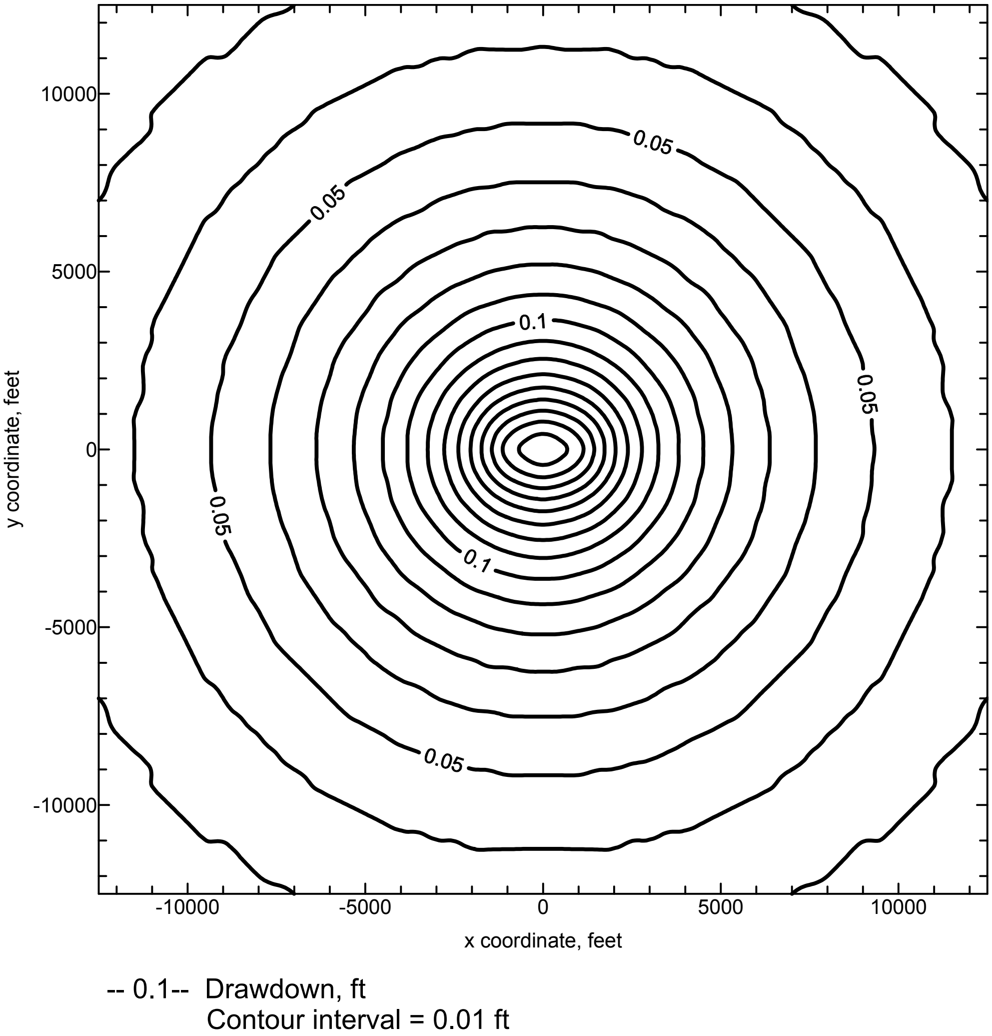


Figure 5-4. 3LAYT multiple-well example: drawdowns in the surficial aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer at time = 100 days

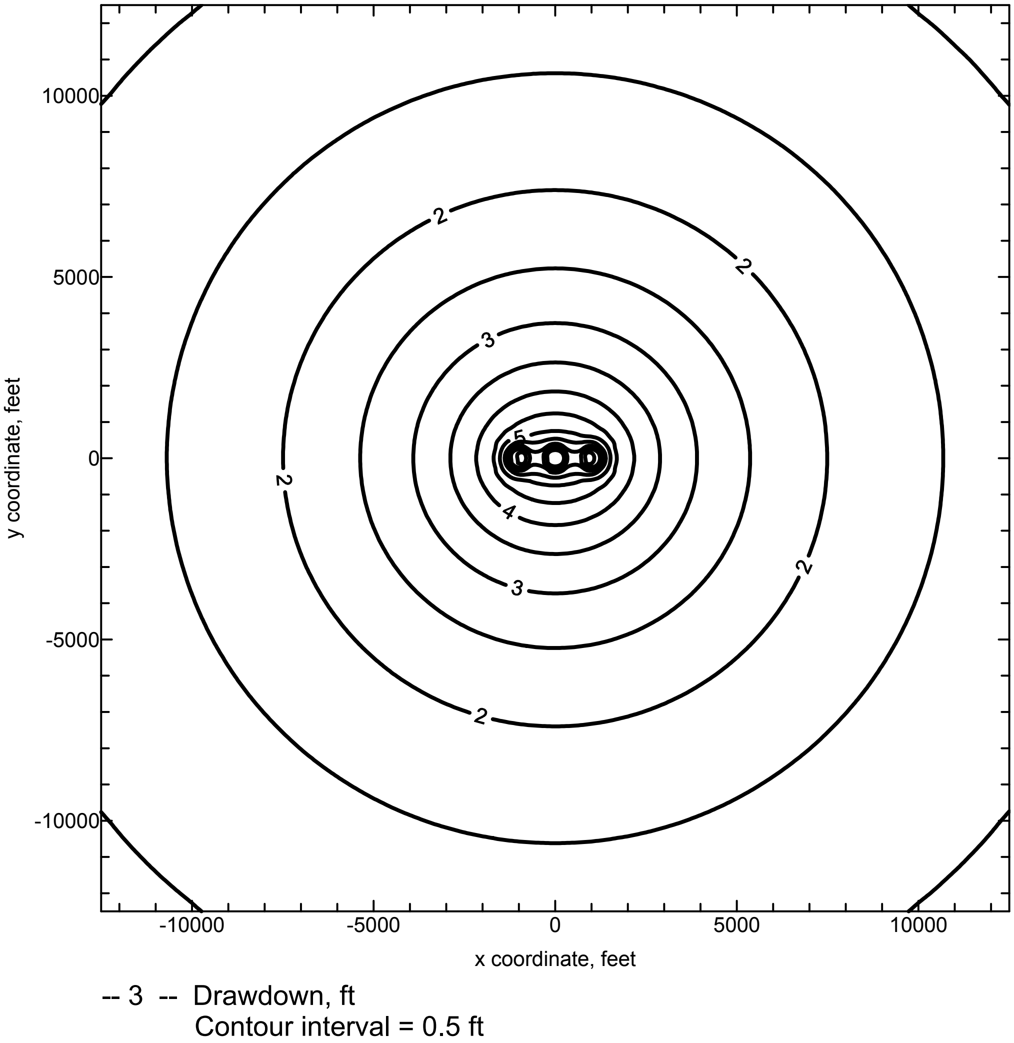


Figure 5-5. 3LAYT multiple-well example: drawdowns in the upper Floridan aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer at time = 100 days

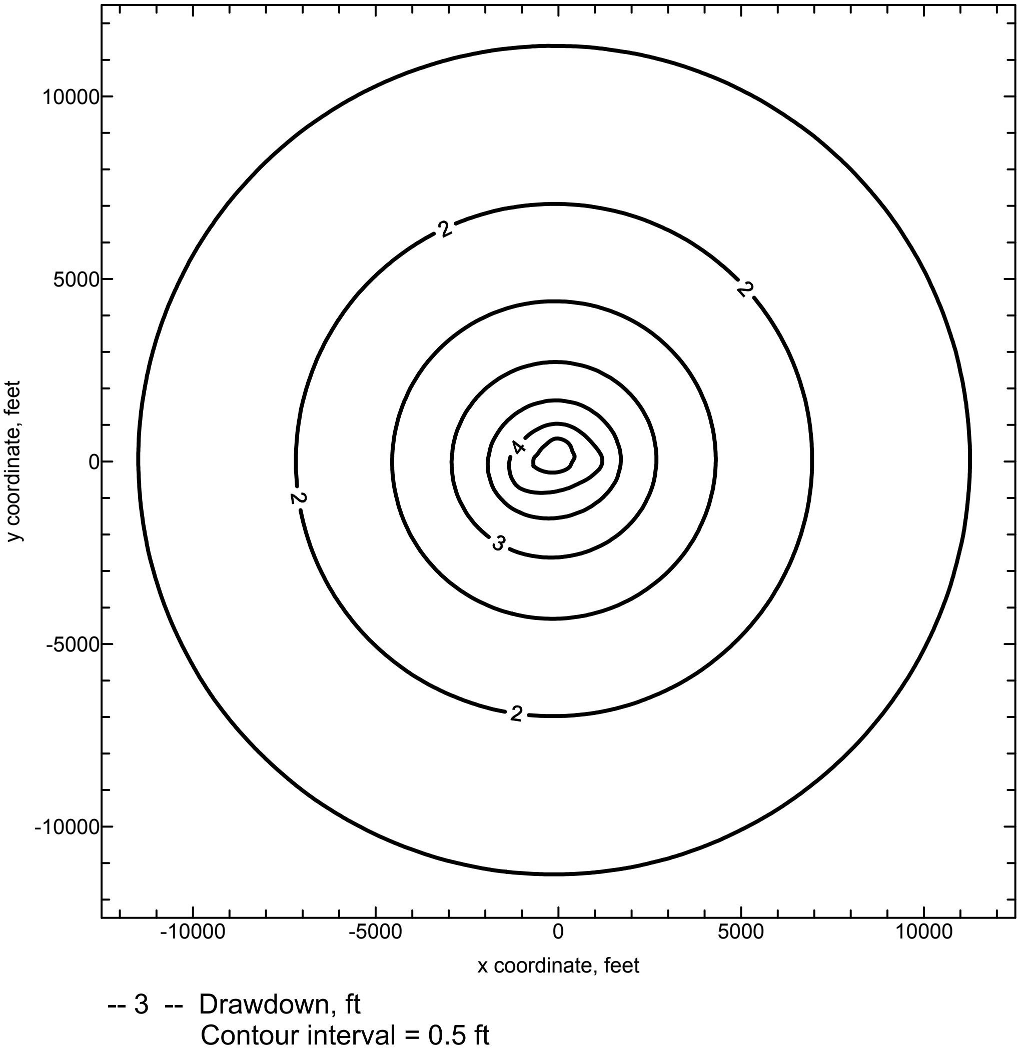


Figure 5-6. 3LAYT multiple-well example: drawdowns in the lower Floridan aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer at time = 100 days

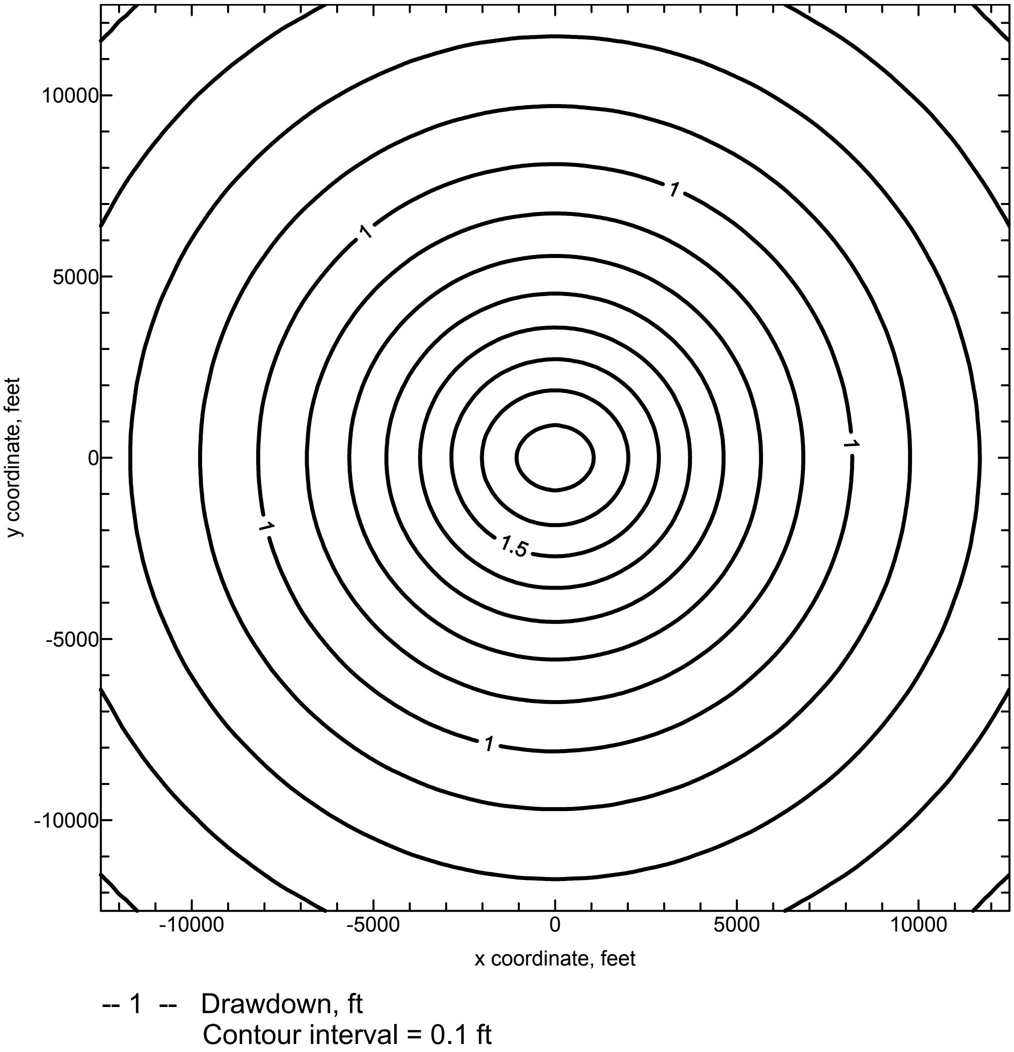


Figure 5-7. 3LAYT multiple-well example: drawdowns in the surficial aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer at time = 10,000 days

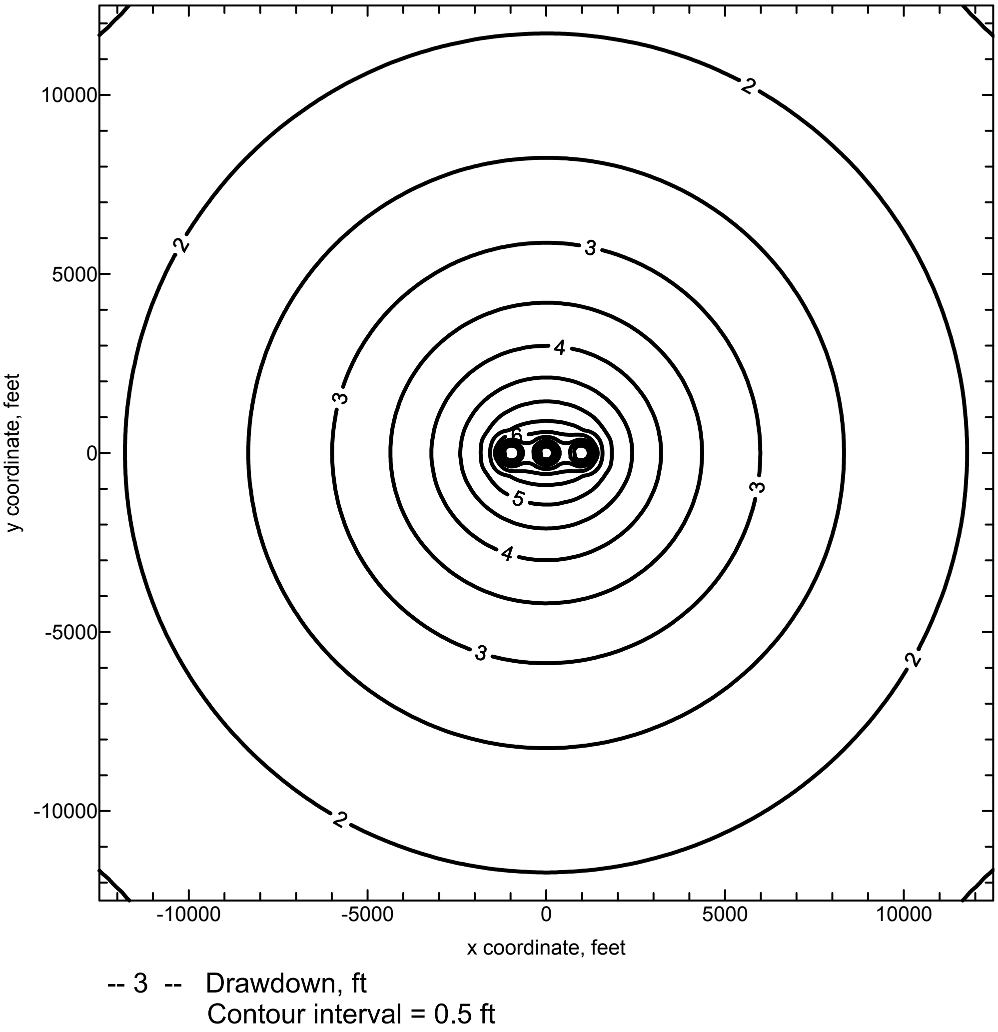


Figure 5-8. 3LAYT multiple-well example: drawdowns in the upper Floridan aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer at time = 10,000 days

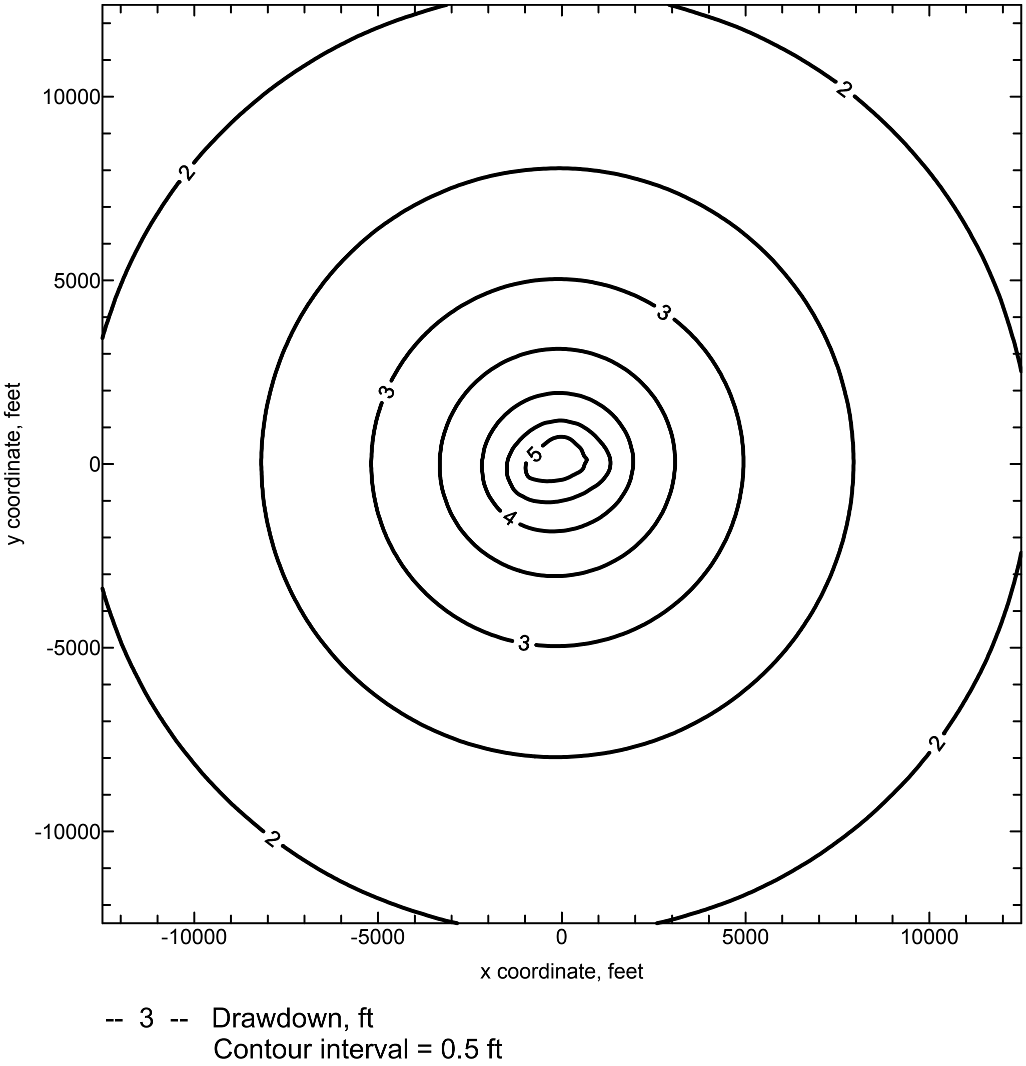


Figure 5-9. 3LAYT multiple-well example: drawdowns in the lower Floridan aquifer due to pumping three wells in the upper Floridan aquifer and three wells in the lower Floridan aquifer at time = 10,000 days

Table 5-8. Input on screen for interactive input for transient 3LAYT multiple-well example problem

```
******************************************************************************
******************************************************************************
         3LAYT: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
******************************************************************************
******************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
m
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
i
 NAME OF THE PROJECT: <write in single quotation marks>
'three-layer transient example problem'
 PLEASE ENTER DATA IN CONSISTENT UNITS
TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)=?
1000.0
STORATIVITY OF AQUIFER (S) 1=?
0.2
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)=?
60000.
STORATIVITY OF AQUIFER (S) 2=?
0.001
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)=?
60000.
STORATIVITY OF AQUIFER (S) 3=?
0.001
 RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)=?
1.52e-4
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)=?
1.0e-4
STORATIVITY OF THE CONFINING UNIT (Sprime) 2=?
0.01
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)=?
5.0e-5
STORATIVITY OF THE CONFINING UNIT (Sprime) 3=?
0.01
 TOTAL TIME LENGTH FOR TRANSIENT SIMULATION (t) (days)=?
1.0e4
 NUMBER OF TIME STEPS FOR TRANSIENT SIMULATION=?
2
 TIME STEP MULTIPLIER FOR TRANSIENT SIMULATION=?
100.0
 NUMBER OF WELLS=?
6
 WELL NUMBER OR NAME: <write in single quotation marks>
UFA_1
 X COORDINATE OF WELL (ft)=?
-1000.0
 Y COORDINATE OF WELL (ft)=?
0.0
 RADIUS OF WELL (rw) (ft)=?
1.0
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
200000.0
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
0.0
 WELL NUMBER OR NAME: <write in single quotation marks>
UFA_2
 X COORDINATE OF WELL (ft)=?
0.0
 Y COORDINATE OF WELL (ft)=?
0.0
 RADIUS OF WELL (rw) (ft)=?
1.0
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
200000.0
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
0.0
```

```
 WELL NUMBER OR NAME: <write in single quotation marks>
UFA_3
 X COORDINATE OF WELL (ft)=?
1000.0
 Y COORDINATE OF WELL (ft)=?
0.0
 RADIUS OF WELL (rw) (ft)=?
1.0
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
200000.0
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
0.0
 WELL NUMBER OR NAME: <write in single quotation marks>
LFA_4
 X COORDINATE OF WELL (ft)=?
-875.0
 Y COORDINATE OF WELL (ft)=?
-237.0
 RADIUS OF WELL (rw) (ft)=?
0.75
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
133500.0
 WELL NUMBER OR NAME: <write in single quotation marks>
LFA_5
 X COORDINATE OF WELL (ft)=?
0.0
 Y COORDINATE OF WELL (ft)=?
245.0
 RADIUS OF WELL (rw) (ft)=?
1.0
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
193000.0
 WELL NUMBER OR NAME: <write in single quotation marks>
LFA_6
 X COORDINATE OF WELL (ft)=?
900.0
 Y COORDINATE OF WELL (ft)=?
0.0
 RADIUS OF WELL (rw) (ft)=?
1.25
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)=?
0.0
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)=?
73500.0
 ENTER X COORDINATE FOR LOWER LEFT CORNER OF GRID
-12500
 ENTER Y COORDINATE FOR LOWER LEFT CORNER OF GRID
-12500
 ENTER X COORDINATE FOR UPPER RIGHT CORNER OF GRID
12500
 ENTER Y COORDINATE FOR UPPER RIGHT CORNER OF GRID
12500
 ENTER DELTA X SPACING FOR THE GRID
500
 ENTER DELTA Y SPACING FOR THE GRID
500
 ENTER OUTPUT FILE NAME: <filename.out>
3_layer_transient_example.out
 ENTER DATA FILE NAME FOR SUM OF DRAWDOWNS: <filename.dat>
3_layer_transient_example.dat

…
(Note: output on screen is not printed.)
 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 5-9. Output file for transient 3LAYT multiple-well example problem

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

             3LAYT: AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
       3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

             PROGRAMMED BY Ozlem Acar and Louis H. Motz
                           Department of Civil and Coastal Engineering
                           University of Florida
                           Gainesville, Florida
************************************************************************************
************************************************************************************

three layer transient example problem

DRAWDOWNS DUE TO WELLFIELD PUMPING

INPUT DATA
----------
----------

ALL DATA ARE IN CONSISTENT UNITS

TRANSMISSIVITY OF AQUIFER (T) 1 (ft2/day)                                : 1.000E+03
STORATIVITY OF AQUIFER (S) 1                                             : 2.000E-01
TRANSMISSIVITY OF AQUIFER (T) 2 (ft2/day)                                : 6.000E+04
STORATIVITY OF AQUIFER (S) 2                                             : 1.000E-03
TRANSMISSIVITY OF AQUIFER (T) 3 (ft2/day)                                : 6.000E+04
STORATIVITY OF AQUIFER (S) 3                                             : 1.000E-03
RATE AT WHICH ET IS REDUCED PER UNIT OF WT DRAWDOWN (1/day)              : 1.520E-04
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 2 (1/day)                     : 1.000E-04
STORATIVITY OF THE CONFINING UNIT (Sprime) 2                             : 1.000E-02
LEAKANCE OF CONFINING UNIT (Kprime/bprime) 3 (1/day)                     : 5.000E-05
STORATIVITY OF THE CONFINING UNIT (Sprime) 3                             : 1.000E-02

TOTAL TIME LENGTH FOR TRANSIENT SIMULATION (t) (days)                    : 1.000E+04
NUMBER OF TIME STEPS FOR TRANSIENT SIMULATION                            :         2
TIME STEP MULTIPLIER FOR TRANSIENT SIMULATION                            :   100.000

NUMBER OF PUMPED WELLS                                                   :         6

UFA_1
X COORDINATE OF WELL (ft)                                                : -1000.000
Y COORDINATE OF WELL (ft)                                                :     0.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 2.000E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00
UFA_2
X COORDINATE OF WELL (ft)                                                :     0.000
Y COORDINATE OF WELL (ft)                                                :     0.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 2.000E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00

UFA_3
X COORDINATE OF WELL (ft)                                                :  1000.000
Y COORDINATE OF WELL (ft)                                                :     0.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 2.000E+05
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 0.000E+00

LFA_4
X COORDINATE OF WELL (ft)                                                :  -875.000
Y COORDINATE OF WELL (ft)                                                :  -237.000
RADIUS OF WELL (rw) (ft)                                                 :     0.750
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                                : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                                : 1.335E+05

LFA_5
X COORDINATE OF WELL (ft)                                                :     0.000
Y COORDINATE OF WELL (ft)                                                :   245.000
RADIUS OF WELL (rw) (ft)                                                 :     1.000
```

```
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                              : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                              : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                              : 1.930E+05

LFA_6
X COORDINATE OF WELL (ft)                                              :   900.000
Y COORDINATE OF WELL (ft)                                              :     0.000
RADIUS OF WELL (rw) (ft)                                               :     1.250
PUMPING RATE FROM AQUIFER (Q) 1 (ft3/day)                              : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 2 (ft3/day)                              : 0.000E+00
PUMPING RATE FROM AQUIFER (Q) 3 (ft3/day)                              : 7.350E+04
NUMBER OF GRIDS AT WHICH DRAWDOWNS ARE CALCULATED                      :      2601

GRID LOCATION :    1
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000

GRID LOCATION :    2
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12000.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          :-12500.000

(Note: x- and y-coordinates for grid locations 3-2599 are not printed.)

GRID LOCATION : 2600
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12000.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000

GRID LOCATION : 2601
X COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000
Y COORDINATE OF LOCATION AT WHICH DRAWDOWNS ARE CALCULATED (ft)          : 12500.000

DRAWDOWNS IN 3-LAYER AQUIFER SYSTEMS
OBTAINED BY ANALYTICAL MODEL
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REF: Hemker,C.J.1984.Steady Groundwater Flow in Leaky Multiple-Aquifer Systems
     J. of Hydrology,72(1984),355-374.
     Hemker,C.J.1985.Transient Well Flow in Leaky Multiple-Aquifer Systems
     J. of Hydrology,81(1985),111-126.
     Hemker, C.J. and Maas,C.1987.Unsteady Flow to Wells in Layered and Fissured
     Aquifer Systems. J. of Hydrology,90(1987),231-249.
     Grid location =   1

     xgrid      ygrid     xwell     ywell rad.dist.    time     dd 1    dd 2    dd 3
---------- ---------- --------- --------- --------- --------- ------- ------- -------
-12500.000 -12500.000 -1000.000     0.000 16985.288 1.000E+02   0.007   0.265   0.062
-12500.000 -12500.000     0.000     0.000 17677.670 1.000E+02   0.007   0.251   0.060
-12500.000 -12500.000  1000.000     0.000 18398.369 1.000E+02   0.006   0.238   0.059
-12500.000 -12500.000  -875.000  -237.000 16897.390 1.000E+02   0.001   0.041   0.305
-12500.000 -12500.000     0.000   245.000 17851.751 1.000E+02   0.001   0.058   0.417
-12500.000 -12500.000   900.000     0.000 18325.119 1.000E+02   0.000   0.022   0.155

     Grid location =   2

     xgrid      ygrid     xwell     ywell rad.dist.    time     dd 1    dd 2    dd 3
---------- ---------- --------- --------- --------- --------- ------- ------- -------
-12000.000 -12500.000 -1000.000     0.000 16650.826 1.000E+02   0.008   0.272   0.062
-12000.000 -12500.000     0.000     0.000 17327.723 1.000E+02   0.007   0.258   0.061
-12000.000 -12500.000  1000.000     0.000 18034.689 1.000E+02   0.007   0.245   0.060
-12000.000 -12500.000  -875.000  -237.000 16557.379 1.000E+02   0.001   0.042   0.311
-12000.000 -12500.000     0.000   245.000 17505.286 1.000E+02   0.001   0.059   0.425
-12000.000 -12500.000   900.000     0.000 17962.739 1.000E+02   0.000   0.022   0.158

(Note: output for grid locations 3-2599 is not printed.)

     Grid location =2600

     xgrid      ygrid     xwell     ywell rad.dist.    time     dd 1    dd 2    dd 3
---------- ---------- --------- --------- --------- --------- ------- ------- -------
 12000.000  12500.000 -1000.000     0.000 18034.689 1.000E+02   0.007   0.245   0.060
 12000.000  12500.000     0.000     0.000 17327.723 1.000E+02   0.007   0.258   0.061
 12000.000  12500.000  1000.000     0.000 16650.826 1.000E+02   0.008   0.272   0.062
 12000.000  12500.000  -875.000  -237.000 18110.682 1.000E+02   0.001   0.040   0.285
 12000.000  12500.000     0.000   245.000 17151.823 1.000E+02   0.001   0.059   0.434
 12000.000  12500.000   900.000     0.000 16717.057 1.000E+02   0.000   0.023   0.169
```

```
     Grid location =2601

     xgrid      ygrid     xwell     ywell rad.dist.    time     dd 1    dd 2    dd 3
---------- ---------- --------- --------- --------- --------- ------- ------- -------
 12500.000  12500.000 -1000.000     0.000 18398.369 1.000E+02   0.006   0.238   0.059
 12500.000  12500.000     0.000     0.000 17677.670 1.000E+02   0.007   0.251   0.060
 12500.000  12500.000  1000.000     0.000 16985.288 1.000E+02   0.007   0.265   0.062
 12500.000  12500.000  -875.000  -237.000 18469.483 1.000E+02   0.000   0.039   0.279
 12500.000  12500.000     0.000   245.000 17505.286 1.000E+02   0.001   0.059   0.425
 12500.000  12500.000   900.000     0.000 17053.152 1.000E+02   0.000   0.023   0.166

Grid loc.       xgrid       ygrid      time    sum dd 1  sum dd 2  sum dd 3
---------  ----------  ----------  ----------  --------  --------  --------
---------  ----------  ----------  ----------  --------  --------  --------
       1   -12500.000  -12500.000   1.000E+02   0.022     0.875     1.058
       2   -12000.000  -12500.000   1.000E+02   0.023     0.898     1.077

(Note: drawdown sums for grid locations 3-2599 are not printed.)

    2600    12000.000   12500.000   1.000E+02   0.023     0.897     1.071
    2601    12500.000   12500.000   1.000E+02   0.022     0.875     1.052

     Well location = UFA_1

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000      1.000  1.000E+02   0.070   5.302   0.093
UFA_2         0.000      0.000   1000.000  1.000E+02   0.057   1.639   0.092
UFA_3      1000.000      0.000   2000.000  1.000E+02   0.045   1.274   0.091
LFA_4      -875.000   -237.000    267.944  1.000E+02   0.001   0.062   1.732
LFA_5         0.000    245.000   1029.575  1.000E+02   0.001   0.089   1.815
LFA_6       900.000      0.000   1900.000  1.000E+02   0.001   0.034   0.572

     Well location = UFA_2

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000   1000.000  1.000E+02   0.057   1.639   0.092
UFA_2         0.000      0.000      1.000  1.000E+02   0.070   5.302   0.093
UFA_3      1000.000      0.000   1000.000  1.000E+02   0.057   1.639   0.092
LFA_4      -875.000   -237.000    906.529  1.000E+02   0.001   0.062   1.300
LFA_5         0.000    245.000    245.000  1.000E+02   0.001   0.089   2.549
LFA_6       900.000      0.000    900.000  1.000E+02   0.001   0.034   0.717

     Well location = UFA_3

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000   2000.000  1.000E+02   0.045   1.274   0.091
UFA_2         0.000      0.000   1000.000  1.000E+02   0.057   1.639   0.092
UFA_3      1000.000      0.000      1.000  1.000E+02   0.070   5.302   0.093
LFA_4      -875.000   -237.000   1889.919  1.000E+02   0.001   0.061   1.041
LFA_5         0.000    245.000   1029.575  1.000E+02   0.001   0.089   1.815
LFA_6       900.000      0.000    100.000  1.000E+02   0.001   0.034   1.145

     Well location = LFA_4

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000    267.944  1.000E+02   0.068   2.336   0.093
UFA_2         0.000      0.000    906.529  1.000E+02   0.059   1.691   0.092
UFA_3      1000.000      0.000   1889.919  1.000E+02   0.046   1.304   0.092
LFA_4      -875.000   -237.000      0.750  1.000E+02   0.001   0.062   3.813
LFA_5         0.000    245.000    998.974  1.000E+02   0.001   0.089   1.830
LFA_6       900.000      0.000   1790.752  1.000E+02   0.001   0.034   0.583

     Well location = LFA_5

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000   1029.575  1.000E+02   0.057   1.623   0.092
UFA_2         0.000      0.000    245.000  1.000E+02   0.068   2.384   0.093
UFA_3      1000.000      0.000   1029.575  1.000E+02   0.057   1.623   0.092
LFA_4      -875.000   -237.000    998.974  1.000E+02   0.001   0.062   1.266
LFA_5         0.000    245.000      1.000  1.000E+02   0.001   0.089   5.365
LFA_6       900.000      0.000    932.751  1.000E+02   0.001   0.034   0.710
```

```
     Well location = LFA_6

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000   1900.000  1.000E+02   0.046   1.301   0.092
UFA_2         0.000      0.000    900.000  1.000E+02   0.059   1.695   0.092
UFA_3      1000.000      0.000    100.000  1.000E+02   0.070   2.859   0.093
LFA_4      -875.000   -237.000   1790.752  1.000E+02   0.001   0.061   1.060
LFA_5         0.000    245.000    932.751  1.000E+02   0.001   0.089   1.865
LFA_6       900.000      0.000      1.250  1.000E+02   0.001   0.091   1.995

 Well id      xwell      ywell      rwell      time  sum dd 1  sum dd 2  sum dd 3
-------- ---------- ---------- ---------- ---------  --------  --------  --------
-------- ---------- ---------- ---------- ---------  --------  --------  --------
UFA_1     -1000.000      0.000      1.000 1.000E+02     0.175     8.400     4.395
UFA_2         0.000      0.000      1.000 1.000E+02     0.187     8.765     4.844
UFA_3      1000.000      0.000      1.000 1.000E+02     0.175     8.400     4.277
LFA_4      -875.000   -237.000      0.750 1.000E+02     0.175     5.516     6.503
LFA_5         0.000    245.000      1.000 1.000E+02     0.185     5.816     7.619
LFA_6       900.000      0.000      1.250 1.000E+02     0.177     6.096     5.196


     Grid location =   1

     xgrid      ygrid     xwell     ywell rad.dist.    time     dd 1    dd 2    dd 3
---------- ---------- --------- --------- --------- --------- ------- ------- -------
-12500.000 -12500.000 -1000.000     0.000 16985.288 1.000E+04   0.155   0.389   0.171
-12500.000 -12500.000     0.000     0.000 17677.670 1.000E+04   0.149   0.373   0.169
-12500.000 -12500.000  1000.000     0.000 18398.369 1.000E+04   0.143   0.358   0.166
-12500.000 -12500.000  -875.000  -237.000 16897.390 1.000E+04   0.045   0.114   0.399
-12500.000 -12500.000     0.000   245.000 17851.751 1.000E+04   0.064   0.162   0.553
-12500.000 -12500.000   900.000     0.000 18325.119 1.000E+04   0.024   0.061   0.206

     Grid location =   2

     xgrid      ygrid     xwell     ywell rad.dist.    time     dd 1    dd 2    dd 3
---------- ---------- --------- --------- --------- --------- ------- ------- -------
-12000.000 -12500.000 -1000.000     0.000 16650.826 1.000E+04   0.158   0.396   0.172
-12000.000 -12500.000     0.000     0.000 17327.723 1.000E+04   0.152   0.381   0.170
-12000.000 -12500.000  1000.000     0.000 18034.689 1.000E+04   0.146   0.366   0.167
-12000.000 -12500.000  -875.000  -237.000 16557.379 1.000E+04   0.045   0.115   0.405
-12000.000 -12500.000     0.000   245.000 17505.286 1.000E+04   0.064   0.163   0.561
-12000.000 -12500.000   900.000     0.000 17962.739 1.000E+04   0.024   0.062   0.209

(Note: output for grid locations 3-2599 is not printed.)

     Grid location =2600

     xgrid      ygrid     xwell     ywell rad.dist.    time     dd 1    dd 2    dd 3
---------- ---------- --------- --------- --------- --------- ------- ------- -------
 12000.000  12500.000 -1000.000     0.000 18034.689 1.000E+04   0.146   0.366   0.167
 12000.000  12500.000     0.000     0.000 17327.723 1.000E+04   0.152   0.381   0.170
 12000.000  12500.000  1000.000     0.000 16650.826 1.000E+04   0.158   0.396   0.172
 12000.000  12500.000  -875.000  -237.000 18110.682 1.000E+04   0.044   0.112   0.378
 12000.000  12500.000     0.000   245.000 17151.823 1.000E+04   0.065   0.164   0.570
 12000.000  12500.000   900.000     0.000 16717.057 1.000E+04   0.025   0.063   0.221

     Grid location =2601

     xgrid      ygrid     xwell     ywell rad.dist.    time     dd 1    dd 2    dd 3
---------- ---------- --------- --------- --------- --------- ------- ------- -------
 12500.000  12500.000 -1000.000     0.000 18398.369 1.000E+04   0.143   0.358   0.166
 12500.000  12500.000     0.000     0.000 17677.670 1.000E+04   0.149   0.373   0.169
 12500.000  12500.000  1000.000     0.000 16985.288 1.000E+04   0.155   0.389   0.171
 12500.000  12500.000  -875.000  -237.000 18469.483 1.000E+04   0.044   0.111   0.372
 12500.000  12500.000     0.000   245.000 17505.286 1.000E+04   0.064   0.163   0.561
 12500.000  12500.000   900.000     0.000 17053.152 1.000E+04   0.025   0.063   0.218


Grid loc.       xgrid       ygrid      time    sum dd 1  sum dd 2  sum dd 3
---------  ----------  ----------  ----------  --------  --------  --------
---------  ----------  ----------  ----------  --------  --------  --------
       1   -12500.000  -12500.000   1.000E+04   0.580     1.457     1.663
       2   -12000.000  -12500.000   1.000E+04   0.590     1.482     1.684

(Note: drawdown sums for grid locations 3-2599 are not printed.)

    2600    12000.000   12500.000   1.000E+04   0.590     1.482     1.678
    2601    12500.000   12500.000   1.000E+04   0.580     1.456     1.657
```

```
     Well location = UFA_1

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000      1.000  1.000E+04   0.544   5.452   0.210
UFA_2         0.000      0.000   1000.000  1.000E+04   0.520   1.789   0.210
UFA_3      1000.000      0.000   2000.000  1.000E+04   0.480   1.424   0.209
LFA_4      -875.000   -237.000    267.944  1.000E+04   0.055   0.140   1.831
LFA_5         0.000    245.000   1029.575  1.000E+04   0.079   0.202   1.958
LFA_6       900.000      0.000   1900.000  1.000E+04   0.030   0.077   0.627

     Well location = UFA_2

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000   1000.000  1.000E+04   0.520   1.789   0.210
UFA_2         0.000      0.000      1.000  1.000E+04   0.544   5.452   0.210
UFA_3      1000.000      0.000   1000.000  1.000E+04   0.520   1.789   0.210
LFA_4      -875.000   -237.000    906.529  1.000E+04   0.055   0.140   1.399
LFA_5         0.000    245.000    245.000  1.000E+04   0.079   0.203   2.693
LFA_6       900.000      0.000    900.000  1.000E+04   0.030   0.077   0.772

     Well location = UFA_3

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000   2000.000  1.000E+04   0.480   1.424   0.209
UFA_2         0.000      0.000   1000.000  1.000E+04   0.520   1.789   0.210
UFA_3      1000.000      0.000      1.000  1.000E+04   0.544   5.452   0.210
LFA_4      -875.000   -237.000   1889.919  1.000E+04   0.054   0.139   1.140
LFA_5         0.000    245.000   1029.575  1.000E+04   0.079   0.202   1.958
LFA_6       900.000      0.000    100.000  1.000E+04   0.030   0.077   1.200

     Well location = LFA_4

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000    267.944  1.000E+04   0.541   2.486   0.210
UFA_2         0.000      0.000    906.529  1.000E+04   0.523   1.841   0.210
UFA_3      1000.000      0.000   1889.919  1.000E+04   0.485   1.453   0.209
LFA_4      -875.000   -237.000      0.750  1.000E+04   0.055   0.140   3.912
LFA_5         0.000    245.000    998.974  1.000E+04   0.079   0.202   1.973
LFA_6       900.000      0.000   1790.752  1.000E+04   0.030   0.077   0.638

     Well location = LFA_5

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000   1029.575  1.000E+04   0.519   1.773   0.209
UFA_2         0.000      0.000    245.000  1.000E+04   0.541   2.534   0.210
UFA_3      1000.000      0.000   1029.575  1.000E+04   0.519   1.773   0.209
LFA_4      -875.000   -237.000    998.974  1.000E+04   0.055   0.140   1.365
LFA_5         0.000    245.000      1.000  1.000E+04   0.079   0.203   5.509
LFA_6       900.000      0.000    932.751  1.000E+04   0.030   0.077   0.765

     Well location = LFA_6

 well id      xwell      ywell  rad.dist.      time    dd 1    dd 2    dd 3
-------- ---------- ---------- ---------- ---------- ------- ------- -------
UFA_1     -1000.000      0.000   1900.000  1.000E+04   0.484   1.451   0.209
UFA_2         0.000      0.000    900.000  1.000E+04   0.523   1.845   0.210
UFA_3      1000.000      0.000    100.000  1.000E+04   0.543   3.009   0.210
LFA_4      -875.000   -237.000   1790.752  1.000E+04   0.054   0.139   1.159
LFA_5         0.000    245.000    932.751  1.000E+04   0.079   0.202   2.009
LFA_6       900.000      0.000      1.250  1.000E+04   0.030   0.077   2.054

 Well id      xwell      ywell      rwell      time  sum dd 1  sum dd 2  sum dd 3
-------- ---------- ---------- ---------- ---------  --------  --------  --------
-------- ---------- ---------- ---------- ---------  --------  --------  --------
UFA_1     -1000.000      0.000      1.000 1.000E+04     1.707     9.084     5.043
UFA_2         0.000      0.000      1.000 1.000E+04     1.747     9.450     5.493
UFA_3      1000.000      0.000      1.000 1.000E+04     1.707     9.084     4.926
LFA_4      -875.000   -237.000      0.750 1.000E+04     1.712     6.200     7.152
LFA_5         0.000    245.000      1.000 1.000E+04     1.742     6.500     8.268
LFA_6       900.000      0.000      1.250 1.000E+04     1.714     6.723     5.850
```

Table 5-10. Time and drawdown data output file for transient 3LAYT multiple-well example problem

```
Grid/well        x           y        time      sum1    sum2    sum3
       1   -12500.00   -12500.00  1.000E+02   0.022   0.875   1.058
       2   -12000.00   -12500.00  1.000E+02   0.023   0.898   1.077

(Note: grid locations, time and drawdowns are not printed for grid locations 3-2599.)

    2600    12000.00    12500.00  1.000E+02   0.023   0.897   1.071
    2601    12500.00    12500.00  1.000E+02   0.022   0.875   1.052
UFA_1       -1000.00        0.00  1.000E+02   0.175   8.400   4.395
UFA_2           0.00        0.00  1.000E+02   0.187   8.765   4.844
UFA_3        1000.00        0.00  1.000E+02   0.175   8.400   4.277
LFA_4        -875.00     -237.00  1.000E+02   0.175   5.516   6.503
LFA_5           0.00      245.00  1.000E+02   0.185   5.816   7.619
LFA_6         900.00        0.00  1.000E+02   0.177   6.096   5.196
       1   -12500.00   -12500.00  1.000E+04   0.580   1.457   1.663
       2   -12000.00   -12500.00  1.000E+04   0.590   1.482   1.684

(Note: grid locations, time and drawdowns are not printed for grid locations 3-2599.)

    2600    12000.00    12500.00  1.000E+04   0.590   1.482   1.678
    2601    12500.00    12500.00  1.000E+04   0.580   1.456   1.657
UFA_1       -1000.00        0.00  1.000E+04   1.707   9.084   5.043
UFA_2           0.00        0.00  1.000E+04   1.747   9.450   5.493
UFA_3        1000.00        0.00  1.000E+04   1.707   9.084   4.926
LFA_4        -875.00     -237.00  1.000E+04   1.712   6.200   7.152
LFA_5           0.00      245.00  1.000E+04   1.742   6.500   8.268
LFA_6         900.00        0.00  1.000E+04   1.714   6.723   5.850
```

Table 5-11. Input on screen for file option for transient 3LAYT multiple-well example problem

```
****************************************************************************
****************************************************************************
         3LAYT:AN INTERACTIVE PROGRAM FOR CALCULATING DRAWDOWNS IN
    3-LAYER AQUIFER SYSTEMS WITH CONFINING UNIT STORAGE AND ET REDUCTION

         PROGRAMMED BY Ozlem Acar and Louis H. Motz
                       Department of Civil and Coastal Engineering
                       University of Florida
                       Gainesville, Florida
****************************************************************************
****************************************************************************
 SINGLE OR MULTIPLE WELLS? <s/m>
m
 Do you want to read an input FILE or enter data INTERACTIVELY? <f/i>
f
 ENTER INPUT FILE NAME: <filename.in>
3_layer_transient_example.in
 NAME OF THE PROJECT: <write in single quotation marks>
'three layer transient example problem'
 ENTER OUTPUT FILE NAME: <filename.out>
3_layer_transient_example.out
 ENTER DATA FILE NAME FOR SUM OF DRAWDOWNS: <filename.dat>
3_layer_transient_example.dat


 PROGRAM COMPLETED
 Do you want to do more calculations? <y/n>
n
```

Table 5-12. Input file for file option for transient 3LAYT multiple-well example problem

```
1000.0  0.2                           T1,S1
60000.  0.001                         T2,S2
60000.  0.001                         T3,S3
1.52e-4                               EP
1.0e-4  0.01                          K'/b'2,S'2
5.0e-5  0.01                          K'/b'3,S'3
1.0e4  2  100.0                       Total time, no. of time steps, time-step multiplier
6                                     Number of pumped wells
UFA_1     -1000.0  0.0  1.0      Well i.d., xw, yw, rw
0.0  200000.0  0.0                    Q1,Q2,Q3
UFA_2      0.0     0.0  1.0      Well i.d., xw, yw, rw
0.0  200000.0  0.0                    Q1,Q2,Q3
UFA_3      1000.0  0.0  1.0      Well i.d., xw, yw, rw
0.0  200000.0  0.0                    Q1,Q2,Q3
LFA_4     -875.0  -237.0  0.75   Well i.d., xw, yw, rw
0.0       0.0  133500.0               Q1,Q2,Q3
LFA_5   0.0  245.0  1.0          Well i.d., xw, yw, rw
0.0       0.0  193000.0               Q1,Q2,Q3
LFA_6  900.0  0.0  1.25          Well i.d., xw, yw, rw
0.0       0.0  73500.0                Q1,Q2,Q3
-12500  -12500                        Beginning x and y coordinates (at lower left corner)
 12500   12500                        Ending x and y coordinates (at upper right corner)
   500     500                        Spacing in x direction, spacing in y direction
```

6.0 DOCUMENTATION

The source codes for 3LAYSS and 3LAYT were written in Fortran 90 programming language using Compaq Visual Fortran Version 6.6. The executable codes for these programs, which were compiled in the Microsoft Visual C++™ development environment (also known as Microsoft Developer Studio), are compatible with the Microsoft Windows 2000, Windows NT, Windows me, Windows 95, and Windows 98 operating systems. The source codes can be run from the Microsoft Developer Studio environment, or the executable codes can be run from the command console. The executable codes, which should be copied to selected subdirectories, can be started using the command prompt from the Windows desktop by specifying the complete path of the selected executable code. Alternately, a selected code can be started from the command console by typing and entering the name of the program in the appropriate subdirectory or by double clicking on the program icon of the executable file using a program such as Windows Explorer. Input files, which are required if the file input option is selected, can be prepared and modified using a text editor such as Wordpad. Output files also can be read and printed using a text editor. Opening output files using Microsoft Word and changing the font to Courier regular 8-point font has been found to yield a reasonably good match to the format in the FORTRAN input and output files. Graphical user interfaces (GUI's) could be prepared so that the programs could be run directly from a Windows-based environment. It is recommended that the preparation of such GUI's, which was beyond the scope of the present investigation, be considered by the District.

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