

USERS MANUAL

RADFLOW:
A NUMERICAL MODEL FOR
PUMPING TEST ANALYSIS

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PURPOSE AND SCOPE

This document describes how to use the numerical model RADFLOW for pumping test analysis. The intent of this document is to provide users with a description of model operation, input preparation and output interpretation. More information on the computational aspects and application can be found in Johnson et al. (2001).

RADFLOW DESCRIPTION

RADFLOW is a two-dimensional (vertical and radial dimensions) finite difference ground-water flow model that has been developed specifically for the analysis of time-drawdown data from pumping tests. The model and spreadsheet interface were designed to make modeling sufficiently simple that it can become a routine practice for pumping test analysis. RADFLOW is operated from a spreadsheet interface (RADFLOW.XLS) that operates in Microsoft EXCEL 97 or more recent version.

RADFLOW uses a cylindrical coordinate system to simulate axially-symmetric flow to a well at the center of the model domain (figure 1). The model is capable of simulating flow in radial and vertical dimensions, and consequently is ideally suited to representing pumping tests in layered aquifers with no significant lateral heterogeneities or boundaries. RADFLOW will accommodate multiple layers of different characteristics, but not lateral heterogeneity. This constraint was imposed on the model because it is not realistic to expect heterogeneities to be symmetrical about the center of the pumping well (required condition of axially-symmetric flow).

RADFLOW is capable of representing confined conditions, unconfined conditions (moving phreatic surface), pumping wells screened over multiple intervals, leaky aquitards, and borehole storage. Many of the above conditions may be represented in the same simulation. The aquifers and aquitards are assumed to be of near-infinite lateral extent and well discharge must be represented as time constant.

Time-drawdown data from a pumping test (up to five observation wells) are entered into RADFLOW for the purpose of model calibration. Model calibration is performed on a trial and error basis. It is suggested that calibration be viewed as having two objectives: 1) refinement of the conceptual model, and 2) estimation of aquifer properties. The conceptual model should be based upon available hydrogeologic information including drillers' logs, geophysical logs, geologic maps, and previous pumping test analyses. The user should begin by formulating the most simple conceptual model plausible (minimum number of hydrogeologic layers) and developing initial estimates of storage and hydraulic conductivity properties of the individual layers. The application of analytical techniques may be helpful in providing the initial property estimates. The model is run and estimates are adjusted by the user in a trial-and-error fashion to achieve the best possible match to the time-drawdown data. If the simple conceptual model cannot be calibrated to reasonably fit the time-drawdown data, then incrementally more complex conceptual models may be developed. Users should use as simple of a representation of the real system as possible in order to minimize potential for non-unique property estimates. Graphs comparing simulated and measured values of time-drawdown data are prepared by RADFLOW to assist in the calibration.

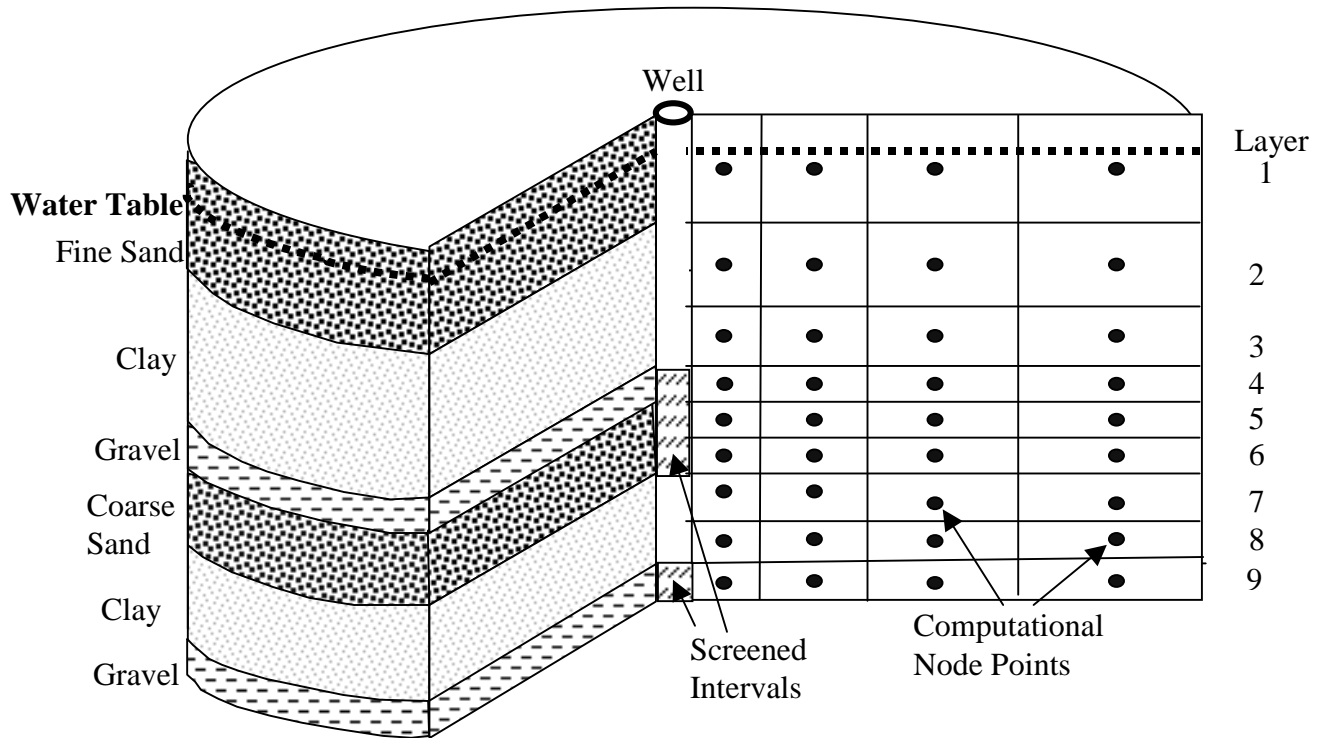


Figure 1. Model grid and conceptual representation (after Johnson et al, 2001).

HARDWARE AND SOFTWARE REQUIREMENTS

RADFLOW will run on most personal computers built since 1995. The only special requirements are that the user must be running in a MS Windows operating system and operation requires EXCEL 97 (or more recent version). The model is run from the spreadsheet, and the spreadsheet macros will likely not function in other spreadsheet software without modification.

The RADFLOW package consists of the following five files:

- 1) RADFLOW8.EXE (Fortran executable)
- 2) RADFLOW.XLS (Spreadsheet interface)
- 3) RUNRF.BAT (DOS batch file)
- 4) F77L3.EER (Compiler associated file)
- 5) RUN386.EXE (Compiler associated file)

Each of the above files must be loaded on the computer's C: drive as described in the following section.

LOADING RADFLOW

All five of the above listed files must be copied to the C: drive of the computer and placed in a directory RADFLOW immediately off the root directory (C:\Radflow). These files cannot be renamed or the package will not function. The directory is automatically created and the files copied by running (double click) INSTALL.BAT from the RADFLOW CD or by downloading from the web site <http://teton.if.uidaho.edu/~ifiwrri/radflow.html> and then running INSTALL.BAT.

After installation, check to ensure that installed files are not read-only, if they are turn off the read only switch found when displaying file properties. Using EXCEL97 or more recent version, open the file RADFLOW.XLS from the Radflow directory on C: drive. Test the installation by clicking the RUN button on the INPUT sheet (tab at bottom of screen). A DOS window should open and after a brief pause an EXECUTION COMPLETE message should appear in the window. Close the DOS window. Click the PLOT HYDROGRAPHS button and results should appear in the form of a hydrograph.

OPERATING RADFLOW

RADFLOW is run entirely from the EXCEL spreadsheet RADFLOW.XLS. The spreadsheet serves as the user interface. The spreadsheet is composed of multiple worksheets (indicated by tabs), some of which are hidden to the user because they contain computations that users need not be concerned with. Data describing aquifer conditions and pumping test results (time-drawdown data) are entered into two worksheets: 1) the INPUT sheet, and 2) the FIELD DATA sheet. Results are displayed in GRAPHS, DRAWDOWN CONTOURS, and MASS BALANCE worksheets, after the corresponding macros have been run by clicking the appropriate buttons on the INPUT sheet.

There are some standard practices that should be followed when using the RADFLOW spreadsheet:

- 1) When copying data from other spreadsheets, worksheets, or cells, use the “Paste Special” option of the Edit button and select “Paste Values”. This will avoid copying formulas or references for macros.
- 2) Never use a “Move” feature of EXCEL, it is likely to cause a macro or referencing malfunction.
- 3) Never have more than one spreadsheet open in EXCEL when running RADFLOW. This causes macro errors.
- 4) You must always run from the spreadsheet that has the name RADFLOW.XLS. A different name on the spreadsheet causes a failure of the spreadsheet macros.
- 5) If you wish to save a data set but continue calibration, perform a “Save As” command under the File option of the spreadsheet menu, and save to a name different than RADFLOW. Since this automatically opens that file in EXCEL, you will need to repeat the SAVE AS operation, now saving back to RADFLOW.XLS. The net result is two identical files one with the name RADFLOW.XLS which you can continue to run, and a second with a name of your choice that is not changed by your continued calibration in RADFLOW.
- 6) Use consistent units. The most common error is that the user has applied inconsistent time, distance, volume, or rate units in the input. For example, discharge rate must have distance (cubed) and time rates that are consistent with hydraulic conductivity and observation well distances.

INPUT DESCRIPTION

Input is entered into two worksheets of RADFLOW.XLS, the INPUT and FIELD DATA worksheets. Observation well characteristics and time-drawdown data are entered in the FIELD DATA sheet. Pumping well and estimated characteristics of aquifers and aquitards are entered in the INPUT sheet.

FIELD DATA Worksheet

Time-drawdown data from as many as five observation wells (potentially including the pumping well) must be entered into the FIELD DATA sheet and are used as model calibration targets. It is required that the user enter the radial distance of the observation well and the depth of the center of the observation well open interval in the FIELD DATA sheet. If observation wells are open over long intervals the user should simulate observation wells at multiple depths (same radial distance) and average the drawdown simulated at the multiple depths. If more than five observation wells have been used in a test, it will be necessary to iteratively calibrate the model to different sets of time-drawdown data copied into the FIELD DATA sheet.

The data entry fields are as follows:

For each observation well:

- a) **Well Name** (cells A3, C3, E3, G3, and I3) – Enter whatever well name is appropriate.
- b) **Radial Distance** (cells A5, C5, E5, G5, and I5) – Enter the distance from the center of the pumping well to the observation well. If one of the five observation wells is not used enter a value of zero for the distance. Make sure that the distance units are consistent with all other entered data involving length. If one of

the observation wells is the pumping well then the entered radius should be the radius of the pumping well or borehole.

- c) **Time** (cells A7:A204, C7:C204, E7:E204, G7:G204, and I7:I204) – Time data (at least two points) are required for at least one observation well. Times must progressively increase down each of the time columns. For each drawdown observation a corresponding time observation is required. Units must be consistent with all other entered data. Zeros should be used for blank cells.
- d) **Drawdown** (cells B7:B204, D7:D204, F7:F204, H7:H204, and J7:J204) – For each observation well used a drawdown value should be entered for each observation time. Units must be consistent with other entered data. Zeros should be used for blank cells.

Important considerations:

- 1) The depth of all observation wells must be within the model domain specified by the layers on the INPUT worksheet.
- 2) Time-drawdown data can be copied in from other spreadsheets. It is advisable to use the “Paste, Special – Values” feature under the “Edit” button.
- 3) Time-drawdown should be entered so that time values are continuously increasing.
- 4) All cells not being used on the FIELD DATA worksheet should be filled with zeros.
- 5) If no data are entered in the FIELD DATA worksheet the model will not run. It uses the entered times from this worksheet to establish model time discretization.
- 6) Time-drawdown data measured in the pumping well can be used for model calibration. The radius of the pumping well (or borehole) should be used as the radius of the corresponding observation well. RADFLOW makes no accommodation for well losses in the pumping well.
- 7) Drawdown adjustments for barometric pressure fluctuation and antecedent conditions must be made prior to entering the data into RADFLOW. No adjustment should be made for changing aquifer thickness in unconfined systems.
- 8) Again, one of the most common problems is using data that are not in consistent units. Be sure time and drawdown data are in units consistent with all other data on this and on the INPUT worksheets.

INPUT Worksheet

The INPUT sheet is used to enter the pumping well characteristics and the user’s estimates of aquifer and aquitard properties.

Simulation Time Settings. The INITIAL TIME STEP and SIMULATION LENGTH entries (gray colored cells) have default calculated values that may be over-written by the user. Under most conditions, the defaults will be adequate. In some cases, however, the user may choose to override default values. One example is if the user wishes to simulate drawdown for time periods longer than the data collection that appears in the FIELD DATA worksheet. If the default value is overwritten by the user, ultimately (after the analysis is complete) the formulas will need to be restored by clicking the RESTORE FORMULAS button. The following entries are part of the Simulation Time Settings:

- a) **Initial time step** (cell D7) – a default value is calculated as 0.1 times the earliest observation time entered in the FIELD DATA sheet. This value is normally adequate, however, under special circumstances the user may manually enter a different initial time step length.
- b) **Simulation length** (cell D8) – a default value is determined as 1.01 times the largest observation time. The simulation will actually run somewhat longer than this time, to a value dependent on the last timestep length.
- c) **Time step multiplier** (cell D9) – users may select values between 1 and 1.2 in the drop-down box. The length of each timestep progressively increases by the factor selected. More refined time interpolation and improved convergence can sometimes be achieved with smaller time step multipliers. Smaller time steps, however, result in longer run times and larger files. Excessively large files of simulation results may exceed the default plotting options in RADFLOW. Those settings can be adjusted if the user is familiar with EXCEL.

Pumping Well Characteristics.

Well Radius (cell D12) – pumping well radius must be entered by the user in units consistent with all other data entries involving length units. This value is used to set an inner boundary for the model grid or for calculation of the borehole storage if that option is selected.

Pump Discharge (cell D13) – The pump discharge (time constant) must be entered in time and length units consistent with all other data entries.

Borehole Storage Flag (cell G15) - If the borehole storage flag is set equal to one, then storage within the well radius is accounted for. Borehole storage may be significant with large diameter pumping wells in the early portion of the time-drawdown test. A flag equal to zero de-activates the computation of borehole storage.

Simulation Closure Setting.

Closure Criterion (cell D16) – The RADFLOW numerical model iterates to approximate solutions of drawdown at each time step. The iterations proceed until the absolute values of the head difference between iterations, summed for all cells, is less than the entered closure criterion. A closure criterion approximately equal to what is considered the required simulation accuracy may be appropriate. In some cases, the model may not converge (no EXECUTION COMPLETE message in the DOS window after clicking the RUN button) if the closure criterion is too small. Some trial and error may be involved in selecting an appropriate closure criterion.

Aquifer/Aquitard Characteristics.

The primary function of the spreadsheet is to allow the user to calibrate estimates of the aquifer and aquitard conceptual model and the corresponding property values. All aquifer and aquitard characteristics are entered as depths relative to a horizontal datum, normally land surface elevation, in units consistent with all other input data (including the time-drawdown data). Because data are entered as depths, larger positive values represent greater depths.

Static Water Level (cell D19) – The static water level is entered as depth below land surface (or other horizontal datum). It is used to set the initial (pre-pumping) position of the water table relative to hydrogeologic layers described in the Layer Characteristics table. Model layers above the static water level are inactive. The model layer in which the water table resides is assigned a storativity equal to the specific yield. In all deeper layers the storativity of a cell is the product of the layer thickness and specific storage. As pumping progresses the water table will decline, based on pumping rate and aquifer and aquitard characteristics. As the water table declines, dewatering deactivates cells above the water table. In cells containing the water table, the capability to horizontally transmit water is reduced in proportion to the ratio of saturated layer thickness to total layer thickness.

Upper Boundary of Model Domain (cell N2) – this value specifies the top of the uppermost layer to be simulated. It is specified relative to land surface and must be less than the depth of the bottom of the uppermost layer in the Layer Characteristics table. This value must also be less than the Static Water Level.

Depth of Bottom of Layer (cells J7:J30) – The depth (below land surface) of the bottom of each model layer is specified. The top of each layer corresponds to the bottom of the overlying layer (except the uppermost layer where the Upper Boundary of Model Domain forms the top of the layer). It is often desirable to use multiple model layers to represent a single hydrogeologic unit. This is accomplished by assigning identical property values to all model layers representing a single hydrogeologic unit (figure 2). In this way, the model layer thickness may be kept near constant to help limit model error. If thickness of model layers is varied, it is suggested that the thickness of adjacent layers not change by a factor greater than 1.5. A value of zero is entered for all cells in the table below the bottom of the desired model domain.

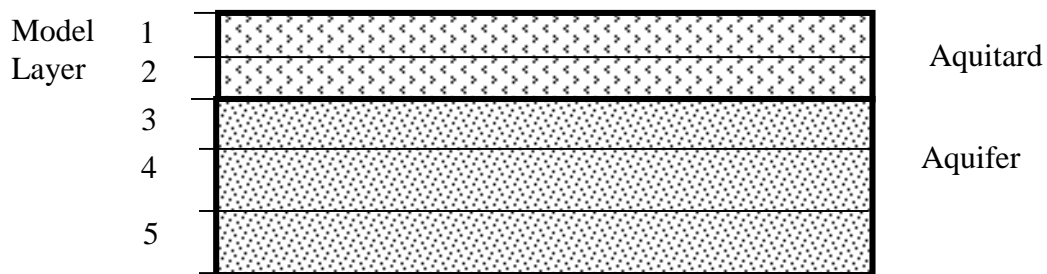


Figure 2. Using multiple model layers of near constant thickness to represent hydrogeologic units.

Layer Kh (cells K7:K30) – The estimated horizontal hydraulic conductivity of each model layer, in units consistent with all other input data. A value of zero is entered for all cells in the table below the bottom of the desired model domain.

Layer Kv (cells L7:L30) – The estimated vertical hydraulic conductivity of each model layer, in units consistent with all other input data. A value of zero is entered for all cells in the table below the bottom of the desired model domain.

Layer Ss (cells M7:M30) – The specific storage of each model layer, in length units consistent with all other input data. A value of zero is entered for all cells in the table below the bottom of the desired model domain.

Layer Sy (cells N7:N30) – The specific yield of each layer. Specific yield is used only if the phreatic surface is located within the specific layer. A value of zero is entered for all cells in the table below the bottom of the desired model domain.

Open or Cased Interval (cells O7:O30) – a binary switch indicating if the pumping well is open to the aquifer in the specific model layer. A value of 1 indicates the well is open to the aquifer, a value of 0 indicates it is cased off. A value of zero is entered for all cells in the table below the bottom of the desired model domain.

OUTPUT DESCRIPTION

All output is routed back to the RADFLOW spreadsheet at the request of the user. The output consists of 1) hydrograph data (simulated and measured time-drawdown graphs) for evaluating model calibration, 2) a surface (contour) plot of the drawdown profile (vertical section) at the end of the simulation period, and 3) a plot of mass balance for each time step of the simulation. The hydrograph data are used in model calibration, the drawdown contours are used for visualizing the distribution of drawdown in the vertical section, and the mass balance plot is used to quickly assess the level of numerical error. Each of these outputs can be viewed by clicking the corresponding button on the INPUT worksheet. The results are erased when the RUN button is executed.

Hydrograph Data

A time-drawdown plot is created by RADFLOW to contrast simulated and measured values of drawdown. Generally, adjustments would be made to the Layer Characteristics to improve the match to simulated and measured values. The simulated time-drawdown data are automatically plotted for locations corresponding to observation well locations entered by the user in the FIELD DATA worksheet. The plot is created by clicking on the GET HYDROGRAPH DATA button on the INPUT worksheet (figure 2). Graph characteristics, such as arithmetic or logarithmic axes, can be altered with the EXCEL chart options.

Quantitative measures of the goodness of fit between simulated and measured time-drawdown data are provided along with the graph. A table is displayed that gives the root mean squared (RMS) and mean absolute errors (MAE) for each of the observation wells. These values are computed based on the differences between measured drawdown values and values linearly interpolated from simulation results for the same pumping time. The linear interpolation will provide an adequate representation in most cases. The formulas for the RMS and MAE are as follows:

$$MAE = \sum |DD_{sim} - DD_{obs}| / n$$

$$RMS = \sqrt{\frac{\sum (DD_{sim} - DD_{obs})^2}{n}}$$

Where: DD_{obs} = observed drawdown at a given time,

DD_{sim} = simulated drawdown at time corresponding to the observation, and

n = number of observations.

Drawdown Contours

Drawdown in most systems will vary with depth and distance from the pumping well. RADFLOW produces a vertical profile of contours of drawdown indicating the distribution of drawdown with distance and depth (figure 3). The contours are prepared for a single time that corresponds to the end of the RADFLOW simulation. The contours are useful in gaining a conceptual understanding of the effectiveness of aquitards, and the propagation of drawdown in aquifers that are not fully penetrated by the pumping well. The contour plot can be obtained by clicking on the GET DRAWDOWN DATA button on the INPUT worksheet. The three-dimensional plotting options in EXCEL do not accurately represent irregularly spaced data on the axes, consequently, vertical and horizontal scales are distorted. The plot domain will need to be changed for each application, because each is set up with different grid dimensions. This can be accomplished by clicking on the graph and changing the plot domain to represent the full grid displayed in the upper right portion of the worksheet. Contour intervals and color coding can also be changed by right clicking on the legend and formatting the legend.

Mass Balance

Numerical models generally use a mass balance to describe the numerical precision of each model run. An imbalance indicates that all water is not being properly accounted for, and consequently simulated head values are in error. Ideally, mass balance errors should oscillate about zero, resulting in negative mass balance errors in one time step that are compensated by positive errors in a subsequent time step.

RADFLOW displays a graph of the variation in mass balance error in percent of well discharge when the user clicks the GET MASS BALANCE DATA button on the INPUT worksheet. Mass balance errors of a few percent, oscillating about zero generally do not cause significant errors in model calibration.

COUPLING WITH PARAMETER ESTIMATION ROUTINES

It is intended that RADFLOW be calibrated by trial-and-error procedure in most applications. In some cases, however, the user may wish to apply parameter estimation routines such as PEST (Doherty, 1998) or UCODE (Poeter and Hill, 1998) to the application. PEST has successfully been applied in an application with special accommodations including the development of DOS batch files to perform functions that are normally performed in the RADFLOW spreadsheet. An in-depth understanding of

the spreadsheet and model operations is necessary to successfully apply the parameter estimation routines and consequently it is currently not recommended for most users.

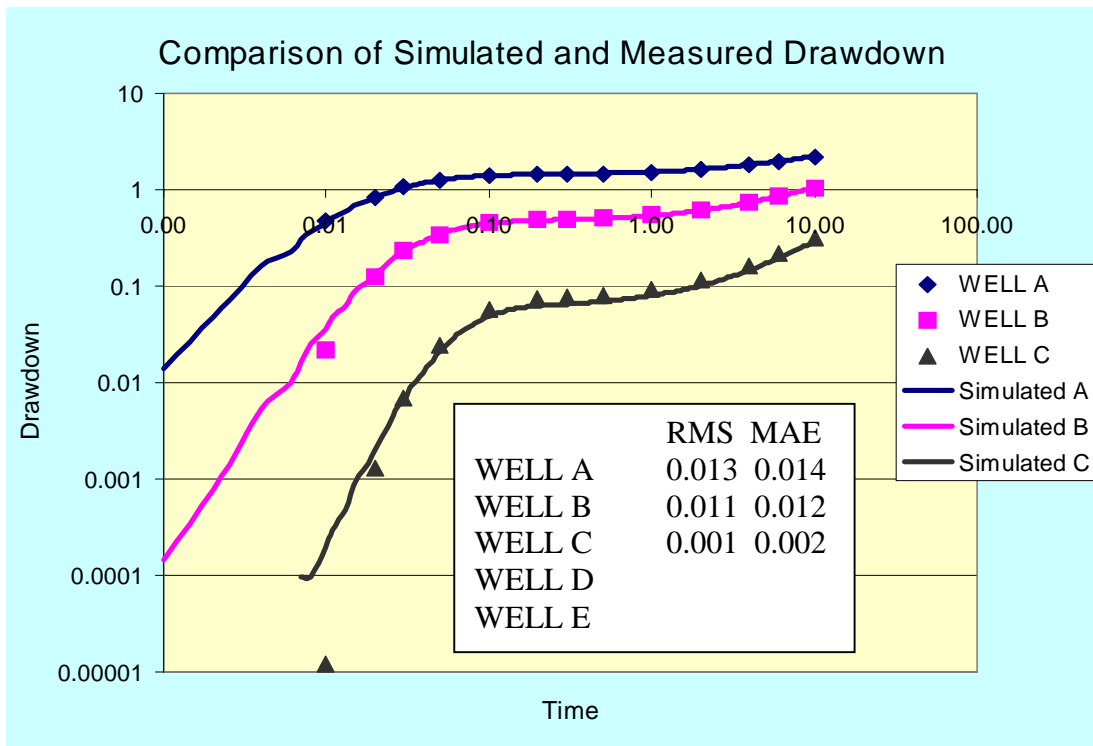


Figure 2. Example of hydrograph output.

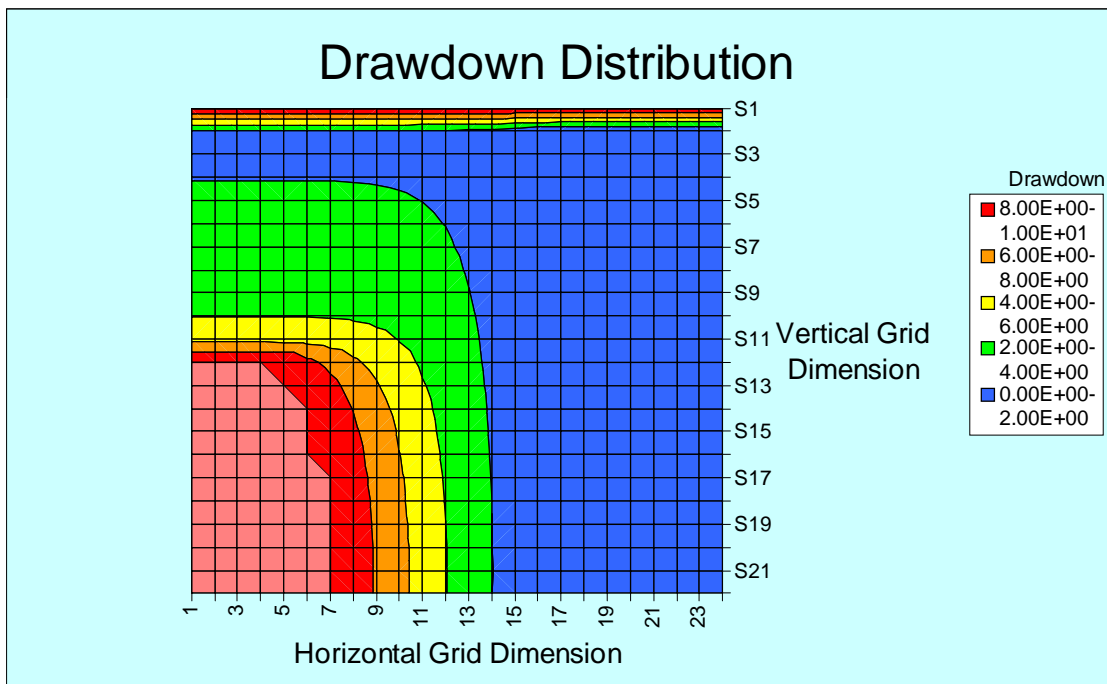


Figure 3. Example of drawdown contour plot.

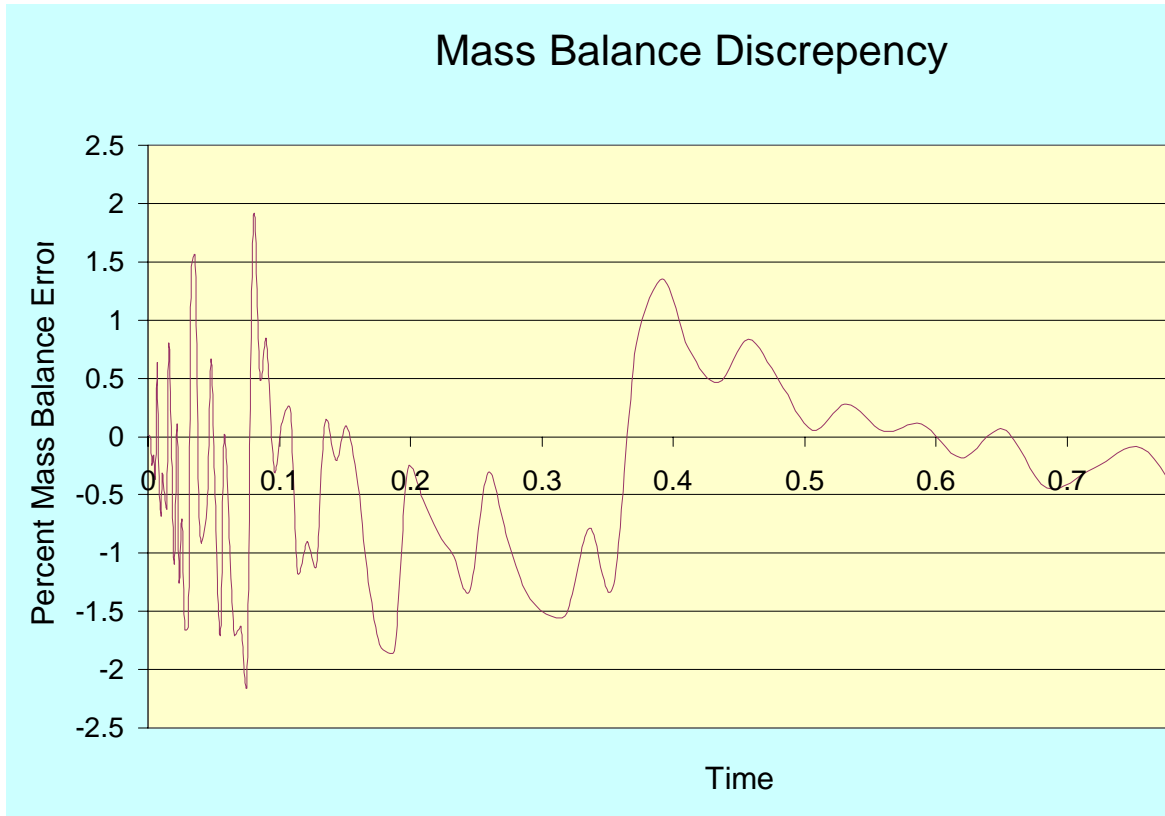


Figure 4. Example of mass balance output.

TUTORIAL

This tutorial is intended to provide the RADFLOW user with a basic understanding of how to operate RADFLOW. The following step by step instructions lead the user through changing inputs and evaluating simulation results. The instructions begin by changing the data set included on the provided RADFLOW spreadsheet. It is assumed that the reader has some familiarity with EXCEL.

Starting RADFLOW

- 1) If you have not already done so, open a window showing the files that came with RADFLOW. Double click the INSTALL.BAT file – this will install all the necessary files on a directory C:\RADFLOW.
- 2) In EXCEL, open the file C:\RADFLOW.XLS.

Getting Familiar With the Spreadsheet

The INPUT worksheet should be active. Initially, click the tabs for each of the worksheets.

- 1) The EXPLANATION sheet gives a brief explanation of how to run RADFLOW.
- 2) The INPUT sheet lays out the pumping test duration and discharge rate and estimates of properties of each model layer representing the aquifer. Moving the cursor to the small red triangles associated with the cell descriptions provides a more detailed description of a field. Notice that no units are specified in the worksheet. The user may choose whatever units they prefer (length and time), but they must be consistent throughout. This obviously excludes use of some units such as gallons.

For the provided worksheet notice that:

- a) The static water level (cell D19) is below the top of the model domain (cell N2). This is a requirement for all simulations.
- b) Borehole storage (cell G15) is zero, indicating that it is not active.
- c) The top of the model domain (cell N2) is equal to zero, meaning land surface.
- d) Model layers are established as uniform thickness of 20 units (meters or feet).
- e) The upper three model layers have consistent properties, indicating that they represent a single physical layer, an upper, unpumped aquifer.
- f) Layers four and five extend from 60 to 100 units below land surface and have a decreased vertical and horizontal hydraulic conductivity, indicating these layers form an aquitard.
- g) The producing aquifer exists from 100 units to 300 units below land surface (model layers 6-15) and is represented as vertically homogeneous and isotropic.
- h) The well is producing from 100 to 220 units below land surface (model layers 6-11) as indicated by column O. The discharge of 800 units (l^3/t) is divided equally among these six model layers since they all have the same horizontal hydraulic conductivity and thickness.

- i) Model layers 16-24 are filled with zeros, indicating they do not contribute to flow in the system, that is the bottom of the aquifer is at 300 units below land surface.
- 3) Click the FIELD DATA worksheet tab. Time-drawdown and observation well characteristics are entered in this sheet. In the example provided notice observation wells A, B, and C are used, wells D and E are not. Up to five observation wells can be represented. Observation well B, for example, is positioned at a distance of 75 units from the pumping well and is open to the aquifer at a depth of 125 units below land surface. This may represent an observation well with a short screened interval from 120 to 130 units below land surface. Zeros are used to fill cells without data since blank cells can distort plotting. Hydrographs for wells with large open intervals may be obtained by averaging drawdown from piezometers placed at several depths.
- 4) Click the GRAPHS worksheet tab. The displayed hydrograph shows both measured data (shown as symbols) from the FIELD DATA worksheet, and simulated results (shown as lines) for the corresponding location. The plot is shown on semi-log scale, but this can be changed by altering EXCELS chart characteristics. The goodness of fit of simulated and measured data are quantitatively expressed as the root mean squared error (RMS) and mean absolute error (MAE) in the table.
- 5) Click the DRAWDOWN CONTOURS worksheet tab. The displayed contour plot illustrates the drawdown pattern at the end of the simulation period in a vertical section with the well at the left boundary. The desired plotting range changes with each simulation set up and can be changed by selecting the chart and resizing the range in the data table at the top of the worksheet.
- 6) Click the MASS BALANCE worksheet tab. The graph shown displays the mass balance for each of the simulations time steps. The graph provides a visual measure of the numerical error in the simulation. Ideally, the mass balance error should be less than a few percent and should oscillate about zero.
- 7) Click the INPUT worksheet tab.

Running RADFLOW

RADFLOW was delivered with a data set included. This data set provides all the necessary information for RADFLOW to run. It also includes results of that run. We will run RADFLOW again, under the same conditions to generate the same results.

- 1) On the INPUT worksheet tab, click the button labeled RUN. A DOS window should appear. In the DOS window it will be apparent that previous output files (if they exist) are being deleted and that RADFLOW8.EXE is running. If errors occur during running of the Fortran program error messages will appear in the DOS window. Otherwise when the EXECUTION COMPLETE message appears the DOS window may be closed. At this point all graphs of the simulation results on the spreadsheet have been deleted and need to be reconstructed.
- 2) On the INPUT worksheet tab, click the button labeled PLOT HYDROGRAPHS. After a brief pause the model results have been plotted on the GRAPHS worksheet along with the measured data.
- 3) Return to the INPUT worksheet tab, and repeat the process for the MASS BALANCE, and CONTOUR DRAWDOWN buttons.

Changing RADFLOW Characteristics

Up to this point, we have only run the RADFLOW package with the existing data. We will now perform a few alterations to the data set to represent different conditions and create new simulations.

- 1) On the INPUT worksheet, in the cell labeled PUMP DISCHARGE (cell D13) change the discharge rate to 1600, and press enter. Click the RUN button. After the program has run, close the DOS window and click PLOT HYDROGRAPH. The new hydrograph should show simulated drawdown that is twice that estimated from the earlier run. Return the PUMP DISCHARGE to 800.
- 2) On the INPUT worksheet, reduce the vertical hydraulic conductivity of all layers to $1e-6$. This will allow essentially no vertical flow in the system and the aquifer will respond as a completely confined aquifer with a thickness equivalent to the open interval of the well. Click the RUN button, close the DOS window, and click the PLOT HYDROGRAPH button. When the graph appears, you notice only two graphs represented simulated conditions (Wells B and C) that appear as straight lines in late time, typical of completely confined conditions. The drawdown in Well A is plotted, but is zero at all times. This is because the well is only open (FIELD DATA sheet, cell B5) below the screened interval and vertical hydraulic conductivity is sufficiently small that pumping does not create drawdown at that depth.
- 3) On the INPUT worksheet, click on the CONTOUR DRAWDOWN button. You will notice that drawdown is now limited to the portion of the aquifer open to the pumping well, and that it extends radially further out into the aquifer.
- 4) On the FIELD DATA sheet, add a fourth well. In cell G3, rename Well D to NEW WELL by typing into the cell contents. Enter a well radius (cell G5) of 500 units and a depth (cell H5) of 150 units. Sequentially enter times of 0.1, 1.0, 10, 100, 1000, and 9000 (a value of 10000 exceeds field width constraints). Since we have extended the test duration, the simulation should automatically extend. The previous simulations had a duration of 1010 (cell D8 on the INPUT sheet) and should now show a value of 9090 (whatever time units you choose to use). We can run the simulation and plot the hydrograph, the simulation results will appear even though we did not enter any drawdown data for the new well.

In the same manner as described above estimates of aquifer properties, and well pumping and construction characteristics may be used to simulate drawdown at observation well locations. Comparison to measured time-drawdown data and subsequent adjustment of aquifer characteristics can result in an improved conceptual model of the system and improved estimates of aquifer properties.

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