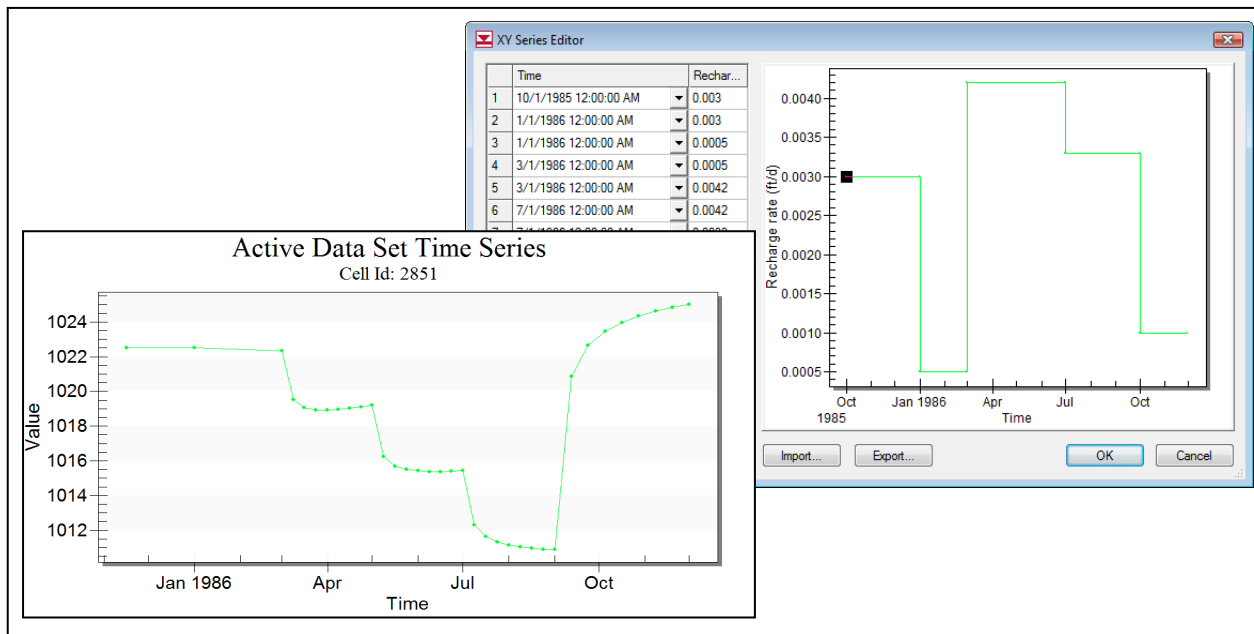


GMS 10.0 Tutorial

MODFLOW – Managing Transient Data

Creating transient MODFLOW models with time-varying inputs



Objectives

GMS provides a powerful suite of tools for inputting and managing transient data. These tools allow all data to be managed using a date/time format that eliminates much of the extra data processing that is often required with modeling projects. This tutorial illustrates how these tools are used.

Prerequisite Tutorials

- MODFLOW – Conceptual Model Approach I

Required Components

- Grid Module
- Map Module
- MODFLOW

Time

- 30-50 minutes



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1 Introduction

Building a transient simulation typically requires the management of large amounts of transient data from a variety of sources including pumping well data, recharge data, river stages, and water levels in observation wells. Gathering and formatting such data can be very tedious. GMS provides tools for importing time series data and converting that data to inputs for MODFLOW models.

1.1 Outline

Here are the steps of this tutorial:

1. Open a MODFLOW model and solution.
2. Enter transient data.
3. Import well pump data file.
4. Set up stress periods and define additional inputs.
5. Run MODFLOW.
6. Create an animation.

2 Description of Problem

The model that this tutorial will be using is the same model used in the “MODFLOW – Model Calibration” tutorial. This tutorial will use the computed heads from the steady-state calibrated flow model as the starting heads for our transient simulation. Transient recharge and pumping conditions will be modeled. The recharge rates will be manually entered but the pumping rates will be imported from a text file.


3 Getting Started

Do the following to get started:

1. If necessary, launch GMS.
2. If GMS is already running, select the *File* / **New** command to ensure that the program settings are restored to their default state.

4 Reading in the Project

First, it is necessary to read in the project:

1. Select the **Open**  button.
2. Locate and open the *Tutorials\MODFLOW\trans* directory.
3. Select the file entitled “start.gpr.”
4. Click the **Open** button.

The user should see a MODFLOW model with a solution and a set of map coverages. Two of the coverages are the source/sink and hydraulic conductivity coverages used to define the conceptual model. The active coverage is the recharge coverage.

5 Save the Project With a New Name

Before continuing, save the project with a new name.

1. Select the *File* | **Save As** command.
2. Change the name “trans1.gpr.”
3. Press the **Save** button.

It’s a good idea to save the work periodically.

6 Transient Data Strategy

When entering the time values associated with transient data, MODFLOW requires that the time be entered as scalar time values relative to a time value of zero at the beginning of the simulation. Furthermore, the times must be compatible with the time unit selected for the model. This approach can be time-consuming since transient data must be converted from a date/time format to relative time format. The strategy used in GMS for managing transient data makes it possible to enter all time values using a simple date/time format. Transient data are entered in the conceptual model using date/time values. The time at the beginning of the first MODFLOW stress period is the reference time. This represents the date/time corresponding to time=0.0 in the simulation. When the model is converted from the conceptual model to the grid model, the time values in the conceptual model are automatically mapped to the appropriate time values corresponding to the MODFLOW stress periods. When the MODFLOW model is saved to disk, the date/time values are converted to the appropriate relative time values.

In addition to ease of use, another advantage of the transient data strategy used in GMS is that both the spatial and temporal components of the conceptual model are defined independently of the discretization used in both the grid spacing and the stress period size. The user can change the stress period spacing and regenerate the model from the conceptual model in seconds.

7 Entering Transient Data in the Map Module

The first step in setting up our transient model is to associate our transient data with the feature objects in the Map Module.

7.1 Assigning the Transient Recharge Rate

First, it is necessary to assign the transient recharge rate for the recharge zones. The recharge zones are shown in Figure 1. There are four recharge zones defined by five polygons. The user will leave the recharge rate for zone 1 at zero. However, the user will assign a transient recharge rate to the other three zones.

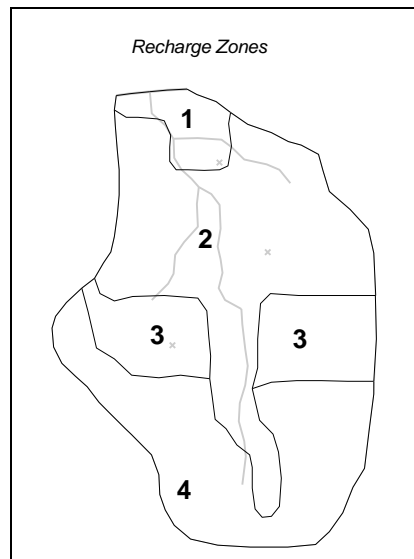








Figure 1 Recharge zones

Do the following to assign the recharge data:

1. Expand the “Map Data” folder.
2. Expand the “BigVal”  conceptual model item in the Project Explorer.
3. Select the “Recharge”  coverage to make it active.
4. Choose the **Select Polygon**  tool.
5. Select the polygon corresponding to recharge zone 2 in Figure 1.
6. Select **Properties**  button.
7. In the *Attribute Table* dialog, for the *Recharge rate*, click the down arrow  button and select the “<transient>” option from the drop down list.
8. Now click the  button for the *Recharge rate* to bring up the *XY Series Editor*.
9. Select the *Use dates/times* toggle.
10. Enter the following date/times and recharge rates:

Date/Time	Recharge (ft/day)	Rate
Oct 1, 1985 12:00:00 AM	0.001	
Jan 1, 1986 12:00:00 AM	0.001	
Jan 1, 1986 12:00:00 AM	0.0005	
Mar 1, 1986 12:00:00 AM	0.0005	
Mar 1, 1986 12:00:00 AM	0.006	
July 1, 1986 12:00:00 AM	0.006	
July 1, 1986 12:00:00 AM	0.005	
Oct 1, 1986 12:00:00 AM	0.005	
Oct 1, 1986 12:00:00 AM	0.001	
Dec 1, 1986 12:00:00 AM	0.001	

11. To change the time, select the drop-down calendar. Then click on each number (hours, minutes, seconds) and enter the new number(s).
12. Then use the up or down arrow key to change “PM” to “AM” where necessary.
13. Select the **OK** button to exit the *XY Series Editor*.
14. Select the **OK** button to exit the *Attribute Table* dialog.

See Figure 2 to see how the data should appear.

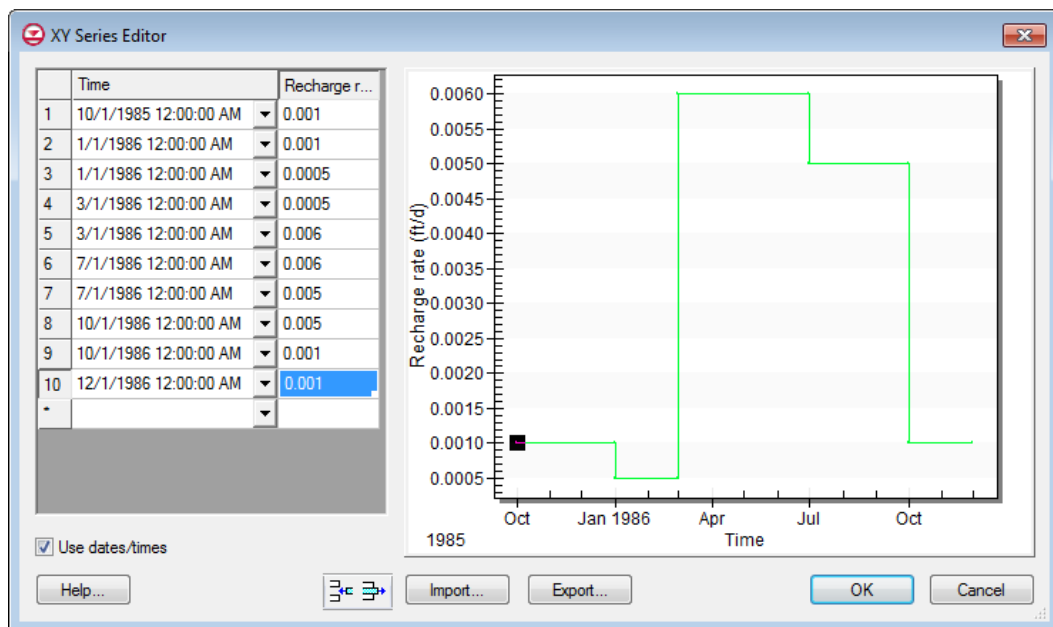


Figure 2 XY Series Editor showing recharge rate


NOTE: Depending on the user’s computer settings, the dates may be formatted differently than shown in the figure above. Those shown above are formatted *month/day/year*.

7.2 Importing Transient Recharge Data

Instead of repeating this same procedure for the other recharge zones, the data will be imported from a text file. Transient data can be imported for polygons, arcs, points, or nodes. The format for the text files is shown below.

Name	Date	Recharge
zone 3	Dec 3, 1999	0.0005
zone 3	Jan 30, 2000	0.001
zone 4	Mar 27, 2000	0.002
...		

In the case above, the user only has a date field; GMS also supports specifying both a date and a time. Later in this tutorial, the user will import pumping data that has both a date and a time specified. The *Name* column is used to match the *Date* data with a particular polygon.

1. Select the **Open**  button.
2. In the *Open* dialog, change the *Files of type* selection to “Text Files (*.txt).”
3. Go to the *Tutorials\MODFLOW\trans* directory.
4. Select the file named “trans_recharge.csv,” and click **Open**.

The user should now see the *Text Import Wizard*. It should look similar to the next figure. This wizard is used to import text data into a GMS project.

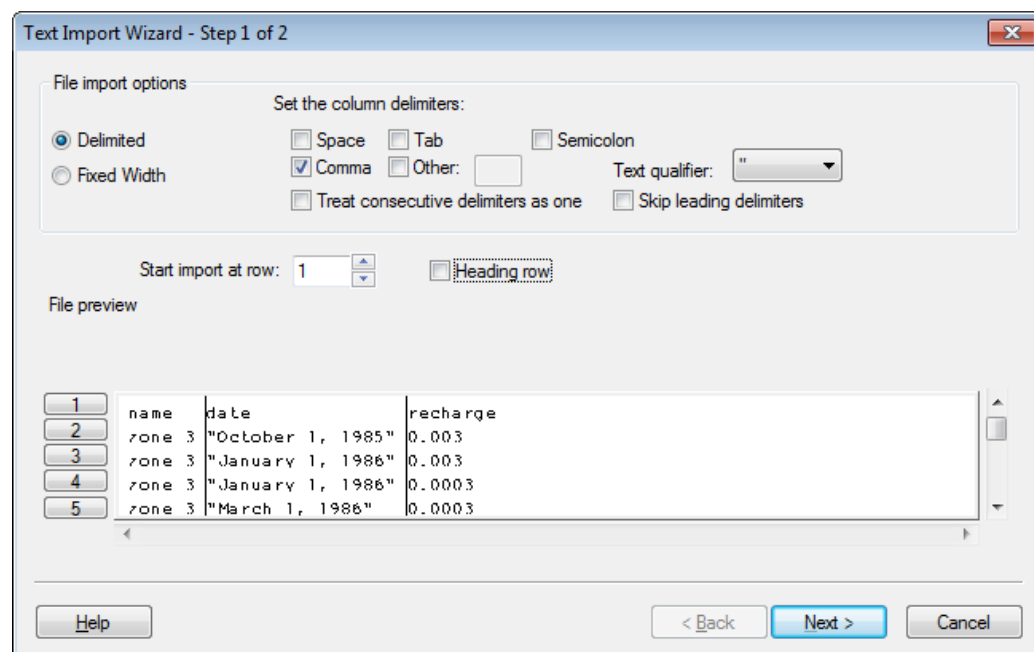


Figure 3 Text Import Wizard

5. Turn on the *Heading row* check box, and click the **Next** button.

- Near the top of the dialog, change the *GMS data type* in the drop-down menu to “Transient polygon data.” The dialog should look like the next figure.

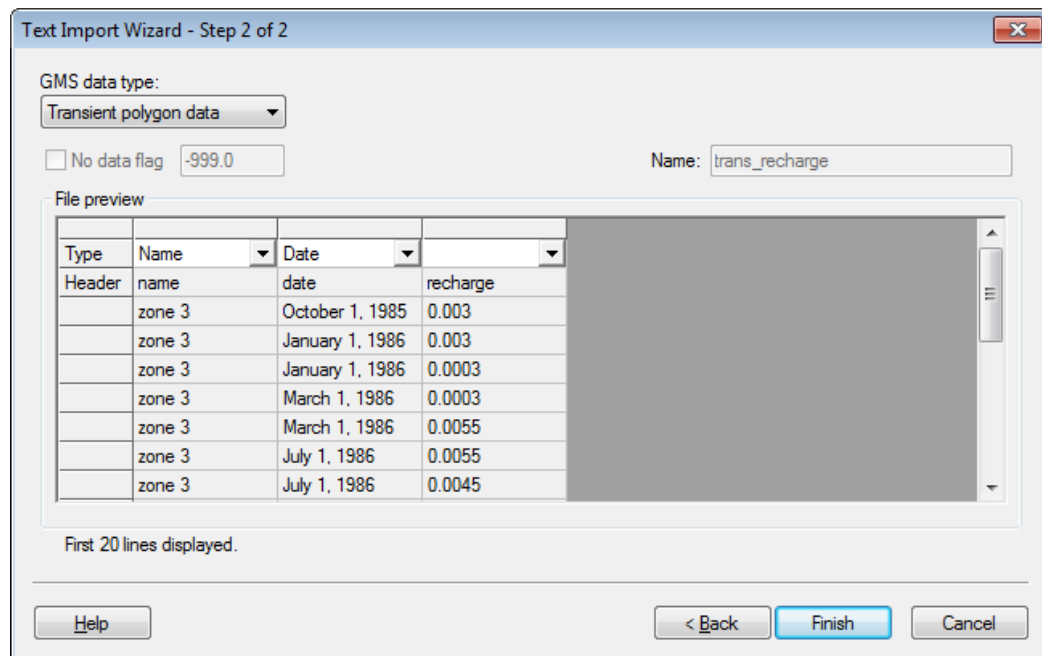



Figure 4 Step 2 of the Text Import Wizard

Notice that the Name and the Date columns were automatically recognized by GMS. Now it is necessary to specify the field for the third column of data.

- Select “Recharge rate TS” from the *Type* drop down box in the third column of the spreadsheet.
- Click on the **Finish** button.
- Select **No** at the prompt.
- Double-click on any of the polygons in zone 3 or zone 4.
- In the *Attribute Table* dialog, click the  button for the *Recharge rate* to bring up the *XY Series Editor*.

The user should see a time series curve of the imported data.

- Click **OK** to exit the *XY Series Editor* dialog.
- Click **OK** to exit the *Attribute Table* dialog.

7.3 Importing Pumping Well Data

In addition to the transient recharge data, our simulation will also contain a transient pumping schedule for the three wells in the model. Since our model only has three wells,





the transient pumping schedules could easily be entered by hand. However, the user will import the well data from a text file. This method is particularly useful for models with lots of wells and/or complicated pumping schedules.

Pumping well data is typically imported using two files. The first file contains the name, screen geometry, and xy coordinates of the wells. The second file contains the pumping schedules. Since the well locations are already defined, the user only needs to import the pumping schedules. The format for this file is as follows:

Name	date	time	Q
"well 1"	12/3/1999	18:00:00	625.0
"well 1"	1/30/2000	7:38:25	0.0
"well 1"	3/27/2000	18:00:00	200.0
"well 2"	12/3/1999	18:00:00	0.0
"well 2"	12/5/1999	14:48:32	100.0
...			



When importing text data for points, it is necessary to indicate to GMS which point matches with the date/time data. This can be done using a name, an id, or an x,y coordinate. In the case above, a name is being used. The first time an entry is found for a particular well, if the well is steady state, it is changed to transient and a pumping rate time series is created for the well. Each time a subsequent line is read in with the same well name, GMS adds a point to the time series. The dates and times can be in any standard format.

To import the well pumping data file:

1. Select the “Sources & Sinks”  coverage from the Project Explorer to make it the active coverage.
2. Select the **Open**  button.
3. In the *Open* dialog, change the *Files of type* selection to “Text Files (*.txt).”
4. Go to the Tutorials\MODFLOW\trans directory.
5. Select the file named “pumping.txt,” and click **Open**.
6. In the *Text Import Wizard*, turn on the *Heading row* option, and click **Next**.
7. Change the *GMS data type* to “Pumping data,” and click **Finish**. In this case GMS automatically recognized all of the fields in the file.
8. Select **Yes** at the prompt to import the pumping data as a step function.
9. Select the **Select Points/Nodes**  tool.
10. Double-click on any of the wells and note in the *Attribute Table* dialog that the *Flow rate* says “<transient>.” It may be desirable to click on the  button to see the curve.
11. Select **OK** to exit the dialog.

7.4 Assigning Specific Yield

Next, it is necessary to assign the storage coefficient to the aquifer. Since this is a one-layer unconfined aquifer, the user needs to assign the specific yield.

1. Double-click on the “Hydraulic Conductivity”  coverage in the Project Explorer to bring up the *Coverage Setup* dialog.
2. In the list of *Areal Properties*, turn on *Specific yield*.
3. Click **OK** to exit the dialog.
4. Select the **Select Polygon**  tool.
5. While holding down the *Shift* key, select the polygons labeled 1 and 2 in the figure below.

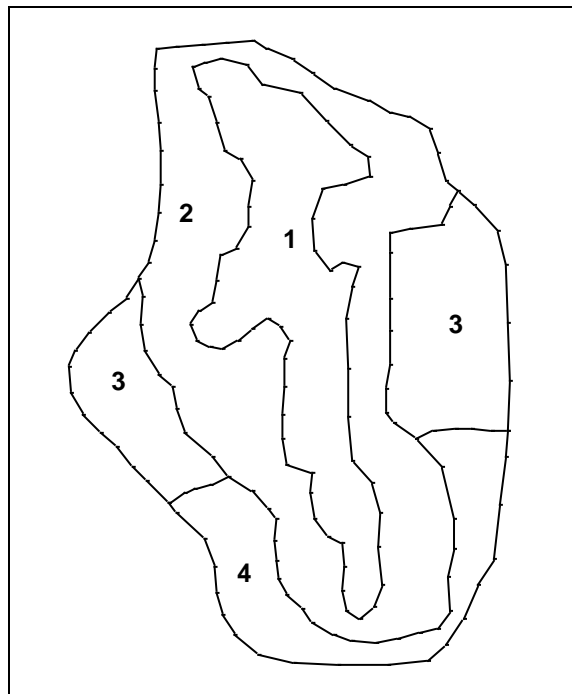



Figure 5 Hydraulic conductivity zones



6. Select **Properties**  button.
7. In the *Attribute Table* dialog, assign a *Specific yield* value of “0.20” to both polygons.
8. Select the **OK** button to exit the dialog.
9. Repeat the same procedure with the polygons labeled 3 and 4, except this time, assign a value of “0.15” for the *Specific yield* value.

8 Initializing MODFLOW Stress Periods

MODFLOW discretizes time using stress periods and time steps. A length of time is associated with each stress period, and boundary conditions (or stresses) can change at the beginning of a stress period. Stress periods are subdivided into time steps. Before converting our conceptual model, it is necessary to set up the stress periods.

8.1 Changing the MODFLOW Simulation to Transient

First, the user will change the current MODFLOW simulation from a steady-state simulation to a transient simulation.

1. In the Project Explorer, expand the *MODFLOW*  item located below the “3D Grid Data” folder under the “grid” item. .
2. In the Project Explorer, right-click on the “Global”  package.
3. Select the **Properties** command.
4. In the *MODFLOW Global/Basic Package* dialog, in the *Model type* section, select the *Transient* option.

8.2 Setting up the Stress Periods

Now the user will set up the stress period information for MODFLOW.

1. Select the **Stress Periods** button.
2. In the *Stress Periods* dialog, make sure the *Use dates/times* option is turned on.

When the *Use dates/times* option is used, all input fields in the MODFLOW interface in the *3D Grid* module expect the date/time format for input. The date/time format is used to display time values such as the time step values when post-processing. If the option is not used, scalar time values (e.g., 100, 120, etc.) are displayed.

3. Change the *Number of stress periods* to **7**.

The stress periods need to match the times where the input data in the map module changes. For example, the value for recharge changes at three different dates Jan 1, 1986, Mar 1, 1986, and July 1, 1986. Therefore, it is necessary to make sure that stress periods start at those times and at the time corresponding to changes in the pumping schedules.

4. Enter the following times and time steps for the stress periods.

	<i>Start</i>	<i>Num time steps</i>
1	Oct 1, 1985 12:00:00 AM	2
2	Jan 1, 1986 12:00:00 AM	1
3	Mar 1, 1986 12:00:00 AM	8
4	May 1, 1986 12:00:00 AM	4

5	June 1, 1986 12:00:00 AM	4
6	July 1, 1986 12:00:00 AM	8
7	Sept 1, 1986 12:00:00 AM	8
End	Dec 1, 1986 12:00:00 AM	

As the dates are entered, the stress period length is automatically calculated.


5. Make sure to uncheck the **Steady State** check box for the first stress period.

This check box is on by default so that our transient model starts from a steady state condition. The user can either do this, set the starting heads to the solution from a steady state run, or allow enough time at the beginning of the transient model for the heads to stabilize before applying any changes in stresses. Since the user already has a steady-state model and solution, the tutorial will use the solution as the starting heads for the transient model.

6. Select the **OK** button to exit the *Stress Periods* dialog.
7. Click **OK** if a prompt comes up.
8. Select the **OK** button to exit the *MODFLOW Global/Basic Package* dialog.



9 Converting the Conceptual Model



Now the user will convert our conceptual model data to MODFLOW input data.

1. Right-click on the “BigVal”  conceptual model in the Project Explorer.
2. Select the *Map to / MODFLOW/MODPATH* command.
3. In the *Map → Model* dialog click use *All applicable coverages* and select **OK**.
4. Select **OK** at the prompt to acknowledge that the xy series will be extrapolated to our numerical model.

10 Setting Starting Heads



As mentioned earlier, for transient models, it is necessary to either start off with a steady state stress period, set the starting heads equal to the solution generated from a steady state model, or allow some time in the beginning of the transient model for the heads to stabilize before applying any changes in stresses (pumping rates, recharge rates, etc.). The user will take the second approach.

1. In the Project Explorer, expand the “Global”  package.
2. Double-click on the “Starting Heads”  dataset.



3. In the *Starting Heads* dialog, click the **3D Dataset** → **Grid** button.
4. In the *Select Dataset* dialog, expand the “grid”  item.
5. Expand the “start (MODFLOW)”  solution and select the “Head” dataset.
6. Click **OK** to exit the *Select Dataset* dialog.
7. Click **OK** to exit the *Starting Heads* dialog.

11 Saving and Running MODFLOW

It is now possible to save the model and launch MODFLOW.

1. Select the **Save**  button.
2. Select the **Run MODFLOW**  button.
3. Once MODFLOW has finished, select the **Close** button to close the window and return to GMS.

The contours should change.


4. Expand the “trans1 (MODFLOW)”  item in the Project Explorer.
5. Select the “Head”  dataset.
6. Use the *Time Steps* window to cycle through the different time steps of the solution to see how the pumping schedules of the wells affect the computed heads.


12 Setting Up an Animation

Now the tutorial will illustrate how the head changes over time by generating an animation. To set up the animation:

1. Select the *Display* / **Animate** command.
2. In the *Animation Wizard* dialog, make sure the *Dataset* option is on, and click **Next**.
3. Make sure the *Display clock* option is on, and select the **Finish** button.


The user should see some images appear on the screen. These are the frames of the animation that are being generated.

4. After viewing the animation, select the **Stop**  button to stop the animation.

5. Select the **Step**  button to move the animation one frame at a time.
6. The user may wish to experiment with some of the other playback controls. When finished, close the window and return to GMS.

13 Conclusion

This concludes this tutorial. Here are the main components of this tutorial:

- When opening the *Properties* dialog for objects in the Map module, the user can enter transient data by using the  button.
- It is possible to import transient data for points, arcs, polygons, and nodes using the text import wizard. The points, arcs, polygons, and nodes must already exist in the active coverage.
- GMS can show dates and times as scalar values (0.0, 2.5, etc.) or in date/time format (12/03/2003).
- The user must define the MODFLOW stress periods before using the *Feature Objects / Map* → **MODFLOW / MODPATH** command with a transient simulation.