GMS 7.0 TUTORIALS

MODFLOW – Managing Transient Data

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. Fortunately, 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.

This tutorial is based on the MODFLOW model. It is recommended that you complete the *MODFLOW - Conceptual Model Approach* tutorial prior to beginning this tutorial. Although, this particular model is based on MODFLOW, the tools associated with transient data are designed as general-purpose tools and can be used with other models.

1.1 Contents

1.2 Outline

This is what you will do:

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 conditions.
5. Run MODFLOW.
6. Import transient observation data and create plots.

1.3 Required Modules/Interfaces

You will need the following components enabled to complete this tutorial:

- Grid
- Map
- MODFLOW

You can see if these components are enabled by selecting the *File* | *Register* command.

2 Description of Problem

The model we will be using in this tutorial is the same model used in the **MODFLOW - Model Calibration** tutorial. We 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. We will also import a set of transient-field-observed heads from observation wells.

3 Getting Started

Let's get started.

1. If necessary, launch GMS. 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, we will read in the project:

1. Select the *Open* button .
2. Locate and open the **tutfiles\MODFLOW\trans** directory.
3. Open the file entitled **start.gpr**.

You 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 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.

6 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.

6.1 Assigning the Transient Recharge Rate

First, we will 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. We will leave the recharge rate for zone 1 at zero. We will assign a transient recharge rate to the other three zones.

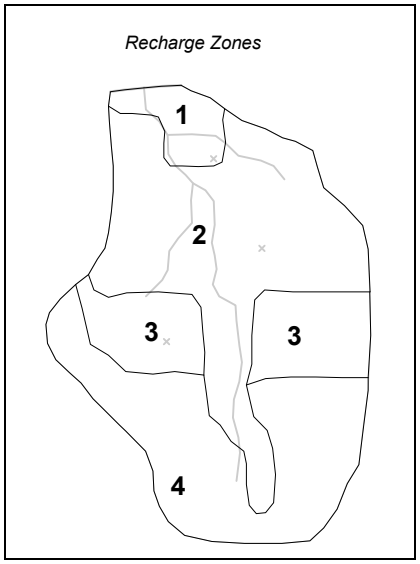

Figure 1. Recharge Zones

To assign the recharge data:

1. Expand the *BigVal* conceptual model item in the *Project Explorer*.
2. Select the *Recharge* coverage to make it active.
3. Choose the *Select Polygon* tool.
4. Select the polygon corresponding to recharge zone 2 in Figure 1.
5. Select *Properties* button.
6. For the *Recharge rate*, click the down arrow button and select the **<transient>** option from the drop down list.
7. Now click the button for the *Recharge rate* to bring up the *XY Series Editor*.
8. Select the *Use dates/times* toggle.

9. Enter the following date/times and recharge rates:

Date/Time	Recharge Rate (ft/day)
10/1/1985 12:00:00 AM	0.001
1/1/1986 12:00:00 AM	0.001
1/1/1986 12:00:00 AM	0.0005
3/1/1986 12:00:00 AM	0.0005
3/1/1986 12:00:00 AM	0.006
7/1/1986 12:00:00 AM	0.006
7/1/1986 12:00:00 AM	0.005
10/1/1986 12:00:00 AM	0.005
10/1/1986 12:00:00 AM	0.001
12/1/1986 12:00:00 AM	0.001

10. Select the *OK* button twice to exit both dialogs.

Instead of repeating this same procedure for the other recharge zones we will import previously generated time series curves. These curves were generated using this same editor and saved to text files using the *Export* button.

11. Select the two polygons that make up recharge zone 3 in Figure 1. Click on the first polygon and then hold down the *Shift* key while clicking on the second polygon.

12. Select *Properties* button .

13. In the *Recharge Rate* column for the *All* row, select the down arrow button and select the **<transient>** option from the drop down list. This will automatically bring up the *XY Series Editor*.

14. Select the *Import* button near the bottom of the dialog.

15. Select the file named **zone3.xys**.

16. Select the *Open* button. A time series curve should appear in the dialog. Click *OK*.

17. Select the *OK* button.

18. Repeat the same procedure with recharge zone 4 except import the file named *zone4.xys*.

6.2 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, we 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, we only need 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
…
```

The name column must be included. This tells GMS how to link the transient pumping data to the wells in the map module. 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 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. Select the file named **pumping.txt** and click *Open*.
5. In the *Import Wizard*, turn on the *Heading row* option and click *Next*.
6. Change the *GMS data type* to **Pumping data** and click *Finish*.
7. Select *Yes* at the prompt to import the pumping data as a step function.
8. Select the *Select Points/Nodes* tool.
9. Double-click on any of the wells and note that the *Flow rate* says **<transient>**. You may want to click on the button to see the curve.
10. Select *OK* to exit the dialog(s).

6.3 Assigning Specific Yield

Next, we need to assign the storage coefficient to the aquifer. Since this is a 1 layer unconfined aquifer, we need 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. Select the polygons labeled 1 and 2 in the figure below.

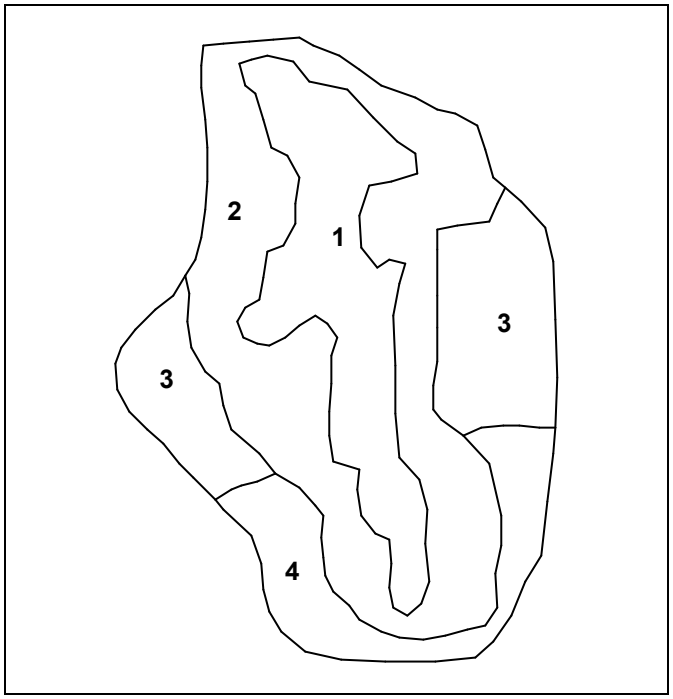

Figure 2. Hydraulic Conductivity Zones

6. Select *Properties* button .

7. Assign a *Specific yield* value of **0.20** to both polygons and select the *OK* button to exit the dialog.

8. Repeat the same procedure with the polygons labeled 3 and 4 only this time assign a value of **0.15** for the specific yield.

7 Initializing MODFLOW Stress Periods

Before converting our conceptual model we need to set up the stress periods.

7.1 Changing the MODFLOW Simulation to Transient

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

1. In the *Project Explorer* expand the *MODFLOW* item located below the 3D Grid Data.

2. In the *Project Explorer* right-click on the *Global* package and select the *Properties…* command.

3. In the *Model type* section, select the *Transient* option.

7.2 Setting up the Stress Periods

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

1. Select the *Stress Periods* button.

2. 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**.

We want the stress periods to match the times where our input data in the map module changes. For example, the value for recharge changes at three different dates 1/1/1986, 3/1/1986, and 7/1/1986. Therefore, we need to make sure that we have stress periods that 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.

	Start	*Num time steps*
1	**10/1/1985 12:00:00 AM**	**2**
2	**1/1/1986 12:00:00 AM**	**1**
3	**3/1/1986 12:00:00 AM**	**8**
4	**5/1/1986 12:00:00 AM**	**4**
5	**6/1/1986 12:00:00 AM**	**4**
6	**7/1/1986 12:00:00 AM**	**8**
7	**9/1/1986 12:00:00 AM**	**8**
End	**12/1/1986 12:00:00 AM**	

5. Select the *OK* button to exit the *Stress Periods* dialog.

6. Select the *OK* button to exit the *Global Package* dialog.

8 Converting the Conceptual Model

Now we will convert our conceptual model data to MODFLOW input data.

1. Right-click on the *BigVal* conceptual model in the *Project Explorer* and select the *Map to* | *MODFLOW/MODPATH* command.

2. Select *OK* at the prompt to use *All applicable coverages*.

3. Select *OK* at the prompt to acknowledge that the xy series will be extrapolated to our numerical model.

9 Setting Starting Heads

For transient models, you should either 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.). Another option is to set the first stress period of the transient model to be steady state. We'll take the first approach.

1. In the *Project Explorer* expand the *Global* package and double-click on the *Starting Heads* data set.

2. Click the *3D Data Set* → *Grid* button.

3. In the *Project Explorer*, expand the **grid** item.

4. Expand the *start (MODFLOW)* solution and select the **Head** data set.

5. Click *OK* twice to exit all dialogs.

10 Saving and Running MODFLOW

We are now ready to save the model and launch MODFLOW.

1. Select the *File* | *Save As* command.

2. Save the project with the name **trans1.gpr**.

3. Select the *MODFLOW* | *Run MODFLOW* command.

4. Once MODFLOW has finished, select the *Close* button to close the window and return to GMS.

The contours should change.

5. Expand the *trans1 (MODFLOW)* item in the Project Explorer and select the *Head* data set.

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.

11 Transient Observation Data

Next, we will input transient observation data for this simulation. Transient observation well data are also entered using the date/time format. The data can be entered either manually or by importing a text file containing the transient measurements. We will use the text file option. We will import the observation point locations from a map file and then import the transient observations from a text file.

11.1 Importing Transient Observation Data

First we need to read in the Map file containing the observation wells.

1. Select the *Open* button .
2. Change the *Files of type* selection to **Project Files (*.gpr)**.
3. In the *Open* dialog, select the *Import into current project* toggle
4. Open the file named **obswells.gpr**.

You should see several observation points appear.

11.2 Transient Observation Data File

Now we will import the transient observation data associated with the observation wells. The transient observation data file format is almost identical to the pumping rate and has the following format:

```
name        date        time        head
"OBS_Q5"    12/3/1999   18:00:00    238.5
"OBS_Q5"    1/30/2000   7:38:25     834.7
"OBS_Q6"    3/27/2000   18:00:00    878.3
"OBS_Q6"    12/3/1999   18:00:00    733.2
"OBS_Q6"    12/5/1999   14:48:32    838.2
…
```

The name column must be included. This tells GMS how to link the transient observation data to the points in the observation coverage.

The first column in the header line defines the name of the measurement. This measurement should be turned on in the *Coverage Setup* dialog before the first file is imported.

As each line is imported, the matching observation point is found and the observed head is added to the time series for the point.

This file should have the extension *.txt. The file is imported through the *Open* command in the *File* menu dialog.

To import the file:

1. Expand the **Observation Wells (2)** conceptual model and double-click on the **Observation Wells** coverage in the *Project Explorer*.
2. In the column of *Observation Points* attributes, turn on the *Trans. Head* attribute and click *OK*.
3. Select the *Open* button.
4. In the *Open* dialog, change the *Files of type* selection to **Text Files (*.txt)**.
5. Open the file named **trans_obs.txt**.
6. In the *File Import Wizard*, turn on the *Heading row* option and click the *Next* button.
7. Set the *GMS data type* to **Transient observation data**.
8. In the *trans_head* column, set the *Type* to **Obs. Trans. Head**, and click *Finish*.

Now we have to re-run MODFLOW.

9. Select the *Save* button.
10. Select the *MODFLOW | Run MODFLOW* command.
11. When MODFLOW finishes running, select *Close*.

The observation targets should now appear. Notice that if you change the time step in the *Project Explorer*, the observation targets are updated accordingly. Also, notice that for the last time step of the solution the observation targets appear "washed out." This is because the MODFLOW solution is outside the time range of observed head at the wells.

11.3 Viewing the Error Associated with the model

Now, we will view the error associated with the MODFLOW model that we just ran.

1. Right-click on the *trans 1 (MODFLOW)* solution in the Project Explorer.
2. Select the *Properties* command.

This brings up a dialog with a listing of the error norms associated with the model. The dialog lists the errors associated with the observed heads and any observed flows. In this particular model we have only specified observed heads; thus, the error associate with observed flows is zero. The dialog also lists the weighted errors (combination of both

head and flow errors). The last error listed is the Sum of Squared Weighted Residual. This is the error that MODFLOW reports at the end of a model run.

3. Select *Done* to exit the dialog.

11.4 Creating Transient Observation Plots

Finally, we will create two types of plots to view our transient observation data. The first plot is the *Error vs time step* plot. This plot displays the mean error (me), mean absolute error (mae), and the root mean squared error (rms) as a function of time.

1. Select the *Plot Wizard* button .
2. Change the plot type to *Error vs. Time Step*.
3. Select the *Next* button.
4. Select the *Finish* button to exit the dialog.

The plot shows that the error between the observed and computed values decreases slightly with time. NOTE: The error displayed in this plot is reported at each output time step. GMS interpolates from the user defined observation data to compute these errors. These errors are different from the error reported by MODFLOW that directly corresponds to the user defined observation data. The error reported by MODFLOW takes into account all observation data entered by the user.

The second type of plot that is useful for transient observation data is the time series plot.

5. Select the *Plot Wizard* button .
6. Change the plot type to *Time Series*.
7. Select the *Next* button.
8. Toggle on points **Point #8** and **Point #10**.
9. Turn on the *Calibration Target* toggle and the *Observed Values* toggle.
10. Select the *Finish* button to exit the dialog.

Notice the dashed lines next to each curve. These dashed lines match the interval defined for each observation point. This makes it so you can easily see where the computed values fall within the observation target. NOTE: the computed values shown on this plot correspond to the MODFLOW output time steps. Most likely the output time steps do not match the user defined observation times.

12 Conclusion

This concludes this tutorial. Here are the things that you should have learned in this tutorial:

- When you bring up the properties dialog for objects in the Map module, you can enter transient data by using the button.
- You can import transient pumping data for wells and transient observation data. The wells or observation points must already exist.
- GMS can show dates and times as scalar values (0.0, 2.5 etc.) or in date/time format (12/03/2003).
- You must define your MODFLOW stress periods before you use the *Feature Objects | Map → MODFLOW / MODPATH* command.