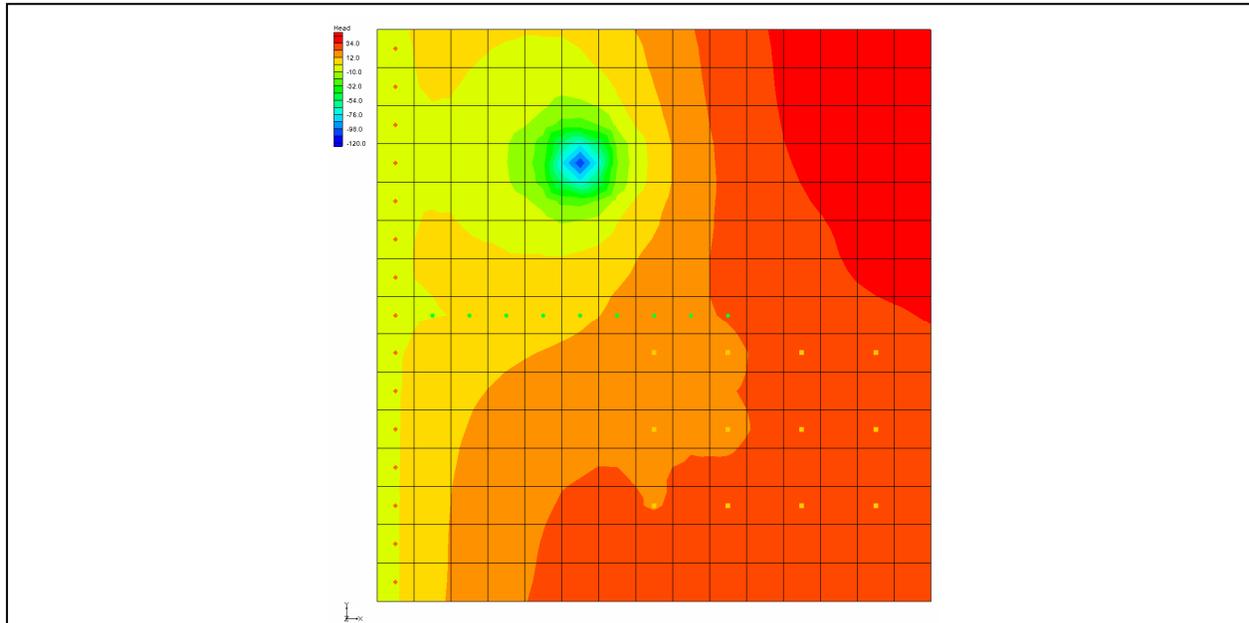*GMS 8.2 Tutorial*

MODFLOW – NWT

Use MODFLOW-NWT With a Simple Model

Objectives

Compare the enhanced ability to handle cell drying and rewetting of MODFLOW-NWT to MODFLOW 2000.

Prerequisite Tutorials

- MODFLOW - Grid Approach

Required Components

- Grid
- MODFLOW

Time

- 30-60 minutes

1   Contents

2   Introduction

MODFLOW-NWT uses a Newton method which can handle cell drying and rewetting situations better than previous versions of MODFLOW. For some model scenarios, using MODFLOW-NWT can help to achieve convergence. GMS includes an interface to MODFLOW-NWT and the UPW and NWT packages included with it.

This tutorial builds on the *MODFLOW - Grid Approach* tutorial. You should complete that tutorial before this one. The purpose of this tutorial is not to teach you all about MODFLOW-NWT, but simply to demonstrate the MODFLOW-NWT interface in GMS.

2.1   Outline

This is what you will do:

1. Read an existing MODFLOW 2000 model.

2. Switch to MODFLOW-NWT but keep using the LPF and PCG packages and compare the results.

3. Switch to the UPW and NWT packages and compare the results.

4. Switch back to MODFLOW 2000 and increase the pumping rate causing a well to go dry.

5. Switch back to MODFLOW-NWT and compare how it handles dry cells.

6. Examine how IPHDRY affects the head solution.

3   Description of Problem

The problem we will be solving in this tutorial is the same as the one in the *MODFLOW - Grid Approach* tutorial and is shown in Figure 1. This problem is a modified version of the sample problem described near the end of the MODFLOW *Reference Manual*. Three aquifers will be simulated using three layers in the computational grid. The grid covers a square region measuring 75000 ft by 75000 ft. The grid consists of 15 rows and 15 columns, each cell measuring 5000 ft by 5000 ft in plan view. For simplicity, the elevation of the top and bottom of each layer is flat. The hydraulic conductivity values shown are for the horizontal direction. For the vertical direction, vertical anisotropy (KH/KV) factors of 10, 5 and 5 are used for layers 1, 2 and 3 respectively.

Flow into the system is due to infiltration from precipitation and will be defined as recharge in the input. Flow out of the system is due to buried drain tubes, discharging wells (not shown on the diagram), and a lake which is represented by a constant head boundary on the left. Starting heads are set equal to zero, and a steady state solution is computed.
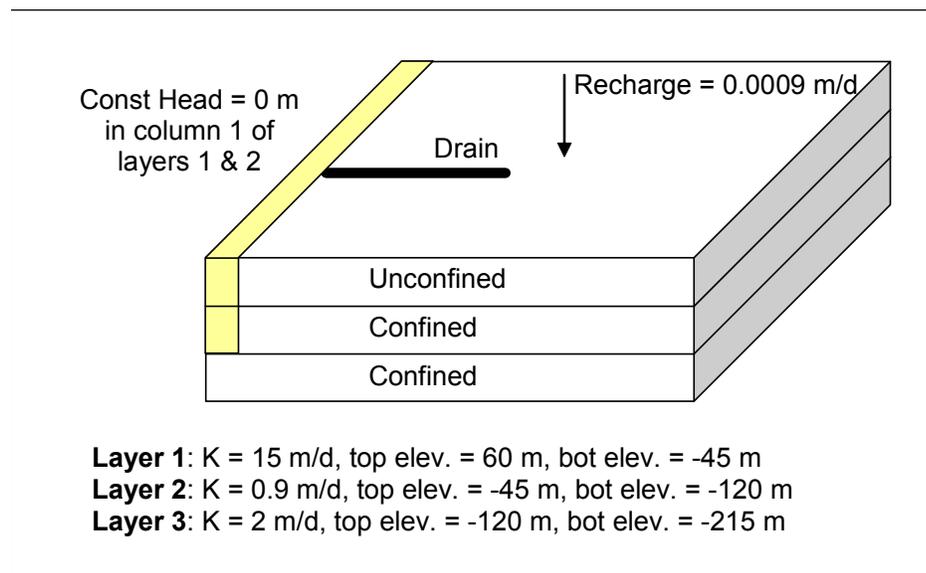

Layer 1: K = 15 m/d, top elev. = 60 m, bot elev. = -45 m
Layer 2: K = 0.9 m/d, top elev. = -45 m, bot elev. = -120 m
Layer 3: K = 2 m/d, top elev. = -120 m, bot elev. = -215 m

Figure 1.   Sample problem to be solved.

4   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.

5   Read in the MODFLOW 2000 Model

First, we will read in an existing model:

1. Select the *Open* button 📂.

2. Locate and open the **tutfiles\MODFLOW\nwt** directory.

3. Open the file entitled **modfgrid.gpr**.

You should see a MODFLOW model with color contours of the head solution.

6   Switch to MODFLOW-NWT

We'll switch the model to use MODFLOW-NWT.

1. Select the *MODFLOW | Global Options* menu command.

Under *MODFLOW version*, notice the model is currently set to use MODFLOW 2000.

2. Change the *MODFLOW version* to **MODFLOW-NWT**.

3. Click on the *Packages* button.

Notice the flow package is set to LPF and the solver is set to SIP1. We will leave these unchanged for now.

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

7   Save the MODFLOW-NWT LPF Project

Before we continue, let's save the project with a new name.

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

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

It's a good idea to save your work periodically as you proceed.

8   Run the Model

We can now run the model.

1.   Select the *Run MODFLOW* ![button] button.

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

GMS reads the solution and contours the head data set. Notice the head contours are exactly the same as they were before. Because we're still using the LPF and SIP1 packages, switching to MODFLOW-NWT hasn't changed anything.

9   Switch to the UPW and NWT Packages

Now we'll switch to the UPW and NWT packages.

1.   Select the *MODFLOW | Global Options* menu command.

2.   Click on the *Packages* button.

3.   Change the *Flow package* to **Upstream Weighting (UPW)**.

Notice the Solver automatically switches to **Newton (NWT)**. These two packages go together and if one is used the other must be used also.

4.   Click *OK* twice to exit both dialogs.

10   Save the MODFLOW-NWT UPW Project

We'll save the project with a new name.

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

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

11   Run the Model and Compare Solutions

We can now run the model.

1.   Select the *Run MODFLOW* ![button] button.

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

GMS reads the solution and contours the head data set. Notice the head contours are slightly different. The UPW and NWT packages give almost the same answer as the LPF and SIP1 packages when there are no cell wetting and drying conditions.

3. Compare the solution generated with the LPF package and the one generated with the UPW package by clicking back and forth on the two solutions in the *Project Explorer*.
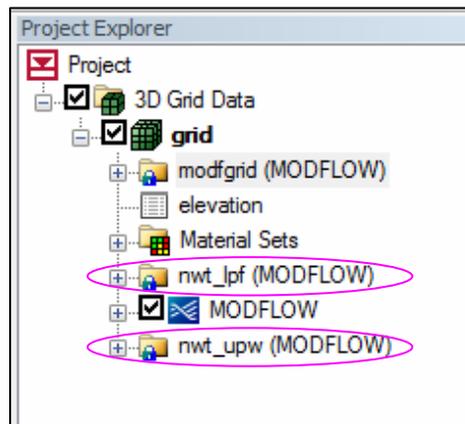

Figure 2.   Switch between the LPF and UPW solutions in the Project Explorer to compare the results.

12   Switch Back to MODFLOW-NWT LPF Model

Let's go back and load the MODFLOW-NWT model that used the LPF package.

1. Select the *New* button to clear the current project.

2. If prompted to save your changes, select *No*.

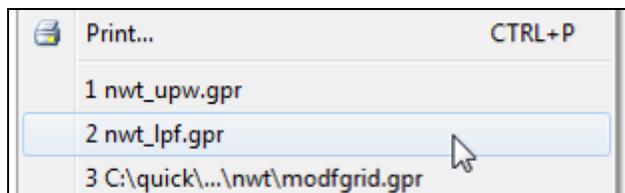3. On the recent file list at the bottom of the *File* menu, click on **nwt_lpf.gpr**.

Figure 3. Reopen the nwt_lpf.gpr model.

13   Increase Pumping to Create a Dry Well

Now let's increase the pumping rate of one of the wells in order to cause the cells to go dry.

1. In the *Mini Grid* toolbar, click on the up arrow to change the view to layer 2.

Figure 4. Changing the ortho level to 2.

2. With the *Select Cell* tool , right-click on the well cell in the upper left and select the *Sources/Sinks* command from the drop down menu. This is the cell pictured in the figure below with IJK coordinates of (4,6,2).
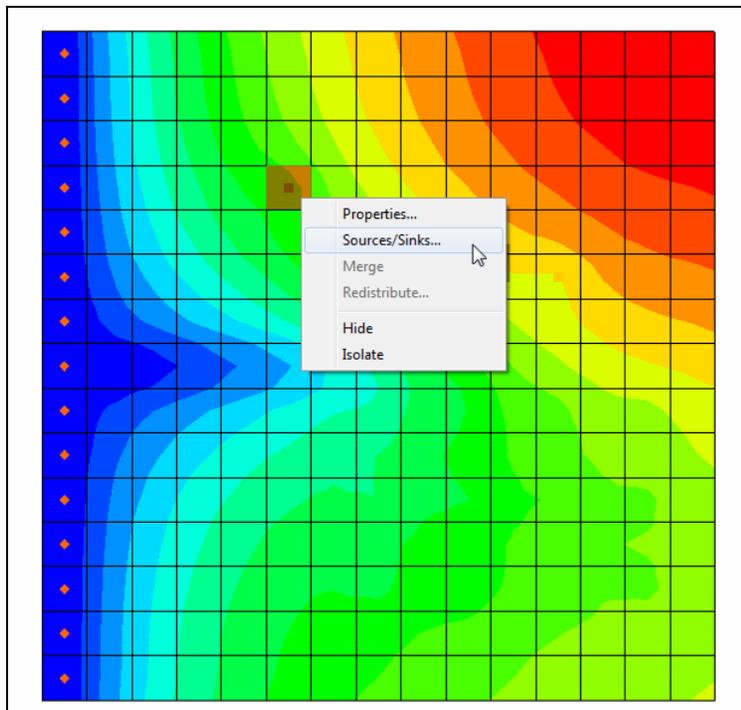

Figure 5.   Selecting the left well in layer 2.

3. Increase the pumping rate making it **-190,000**.

4. Click *OK*.

14   Run the Model

We'll save our changes and run the model.

1. Select the *Run MODFLOW* button.

2. When prompted to save your changes, select *Yes*.

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

GMS reads the solution and contours the head data set. Notice the cell with the well has gone dry. A triangle symbol appears in the cell to indicate the cell is dry.
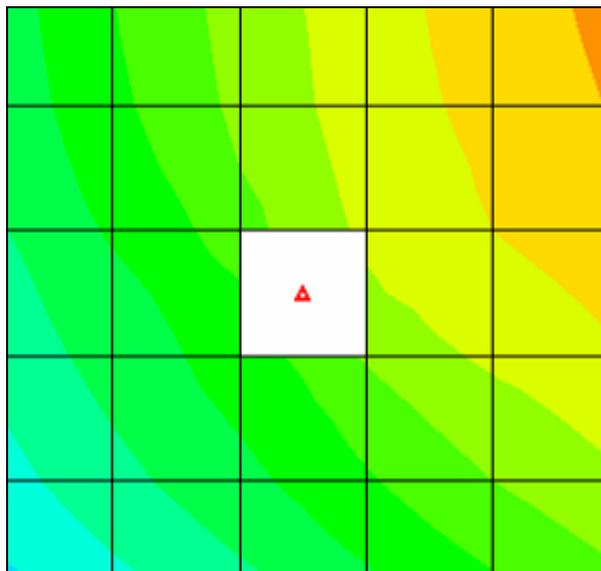

Figure 6.   Dry cell symbol indicating the well went dry.

15   HDRY

The LPF package will assign a key value, the HDRY value, to any cells which go dry. Let's look at the HDRY value.

1.   Select the *MODFLOW | LPF Package* menu command.

2.   Click the *More LPF Options* button in the upper right of the dialog.

Notice the HDRY value is -888.0.

3.   Click *OK* twice to exit both dialogs.

Now let's look at the head solution.

4.   Right-click on the *Heads* data set in the *Project Explorer* under the *nwt_lpf (MODFLOW)* solution and select the *View Values* command from the drop-down menu.
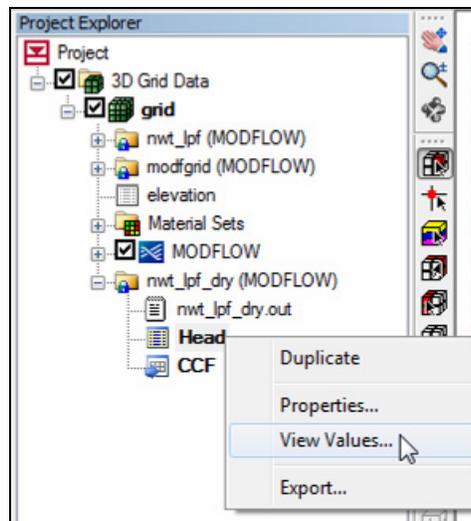
Figure 7.   Viewing the head values.

> 5. Scroll down to row 51 and notice the -888 value for that cell. Also notice the 0 in the *Active* column.

The 0 in the Active column indicates that the cell is inactive and GMS doesn't display contours for it. It basically means there is no data for that cell.

Figure 8.   HDRY value in head solution.

> 6. Click *OK* the exit the dialog.

16   Switch Back to UPW Package

Now let's see how MODFLOW-NWT and the UPW package handle the dry cell.

1. Select the *MODFLOW | Global Options* menu command.

2. Click on the *Packages* button.

3. Change the *Flow package* to **Upstream Weighting (UPW)**.

4. Click *OK* twice to exit both dialogs.

17   Specify PHIRAMP

MODFLOW-NWT has a unique feature that will reduce the pumping rate in cells as the head drops below a user-specified percentage of cell thickness. "Negative pumping rates specified in the Well Package are reduced to zero when the groundwater head drops to the cell bottom using a cubic formula and its derivative. This option is only available for unconfined (convertible) layers." (MODFLOW-NWT p. 14). The user-specified percentage of cell thickness is the variable PHIRAMP in the WEL package.

1. Select the *MODFLOW | Source/Sink Packages | Well (WEL) Package* command.

2. Near the bottom of the dialog turn on the *Specify PHIRAMP* check box.

We will leave the value at the default of 0.25. When the head in the cell drops below 25% of the cell thickness the pumping rate will be reduced by MODFLOW-NWT.

3. Select *OK* to exit the dialog.

18   Save the MODFLOW-NWT UPW Dry Cell Project

We'll save the project with a new name.

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

2. Save the project with the name **nwt_upw.gpr**. Select *Yes* when prompted to replace the existing file.

19   Run the Model

Now we'll run the model.

1. Select the *Run MODFLOW* button.

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

GMS reads the solution and contours the head data set. Notice the solution varies greatly from the one generated using the LPF package. The heads in the UPW solution are much lower because, with the LPF package, as soon as the cell went dry the pumping stopped but in the UPW package the pumping continued but at a reduced rate (as we'll see).

20   Examine the Well

Notice the cell with the well no longer appears dry but it is clear that there is considerable drawdown around the well.

1.   With the *Select Cell* tool , click on the well cell (the cell with all the drawdown at IJK (4,6,2)).

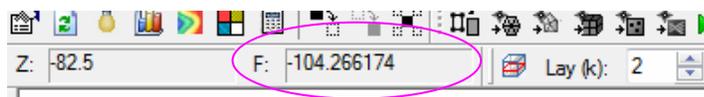Notice the *F* value in the *GMS Edit Window* is about -117.

Figure 9.   Head in cell (4,6,2) is about -104.

2.   Right-click on the well cell and select *Properties* from the drop-down menu.

Notice the *Top elevation* of this cell is -45 and the *Bottom elevation* of this cell is -120, so the head is just above the bottom elevation.

3.   Click *OK*.

4.   In the *Mini Grid* toolbar, click on the down arrow to change the view to layer 1.

Figure 10. Changing the ortho level to 1.

5.   Click on the cell in layer 1 directly above the well in layer 2 (the cell with IJK (4,6,1)).

Notice the head in the cell is about -93 according to the *GMS Edit Window*. Although the head in the cell above the well is below the bottom of the first layer, the cell is still contoured and is showing the dry cell symbol. Why?

6.   Select the *MODFLOW | UPW Package* menu command.

7.   Click on the *More UPW Options* button.

By default the UPW package does not assign the HDRY value to cells that go dry. If we want it to, we must turn on the IPHDRY variable.

8.   Turn **on** the *Set head to HDRY (IPHDRY)* option.

9. Click *OK* twice.

21   Save and Run the Model

Now we'll save the model with the same file name and run.

1. Select the *Run MODFLOW* button.

2. When prompted to save your changes select *Yes*.

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

GMS reads the solution and contours the head data set. Notice that the dry cell symbol now appears in the cell above the well.

22   Reduced Pumping Rates

MODFLOW-NWT reduced the pumping rate of the well as the water table got close to the bottom of the cell. Let's examine that now.

1. In the *Project Explorer*, double-click on the *nwt_upw.out* item.

2. If prompted to pick your viewer, click OK to accept the default or pick another one of your choice.

3. In Notepad (or your alternative viewer), search for the word "reduced".

You should find the following text:

```
TO AVOID PUMPING WATER FROM A DRY CELL
THE PUMPING RATE WAS REDUCED FOR CELL(IC,IR,IL)     6    4    2
THE SPECIFIED RATE IS   -190000.     AND THE REDUCED RATE IS    -176832.
 THE HEAD IS  -1.042662E+02 AND THE CELL BOTTOM IS   -1.200000E+02
```

Figure 11.   Reduced pumping rate as shown in the .out file.

23   Conclusion

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

* GMS includes an interface to MODFLOW-NWT and the UPW and NWT packages.

* MODFLOW-NWT can be used with either the LPF or UPW flow packages. The UPW package typically produces very similar results to the LPF package if there is no cell drying or rewetting taking place.

- The UPW package does not assign the HDRY value to dry cells unless you turn on the IPHDRY option.

- MODFLOW-NWT will reduce the pumping rate in a well as the water table approaches the bottom of the cell.