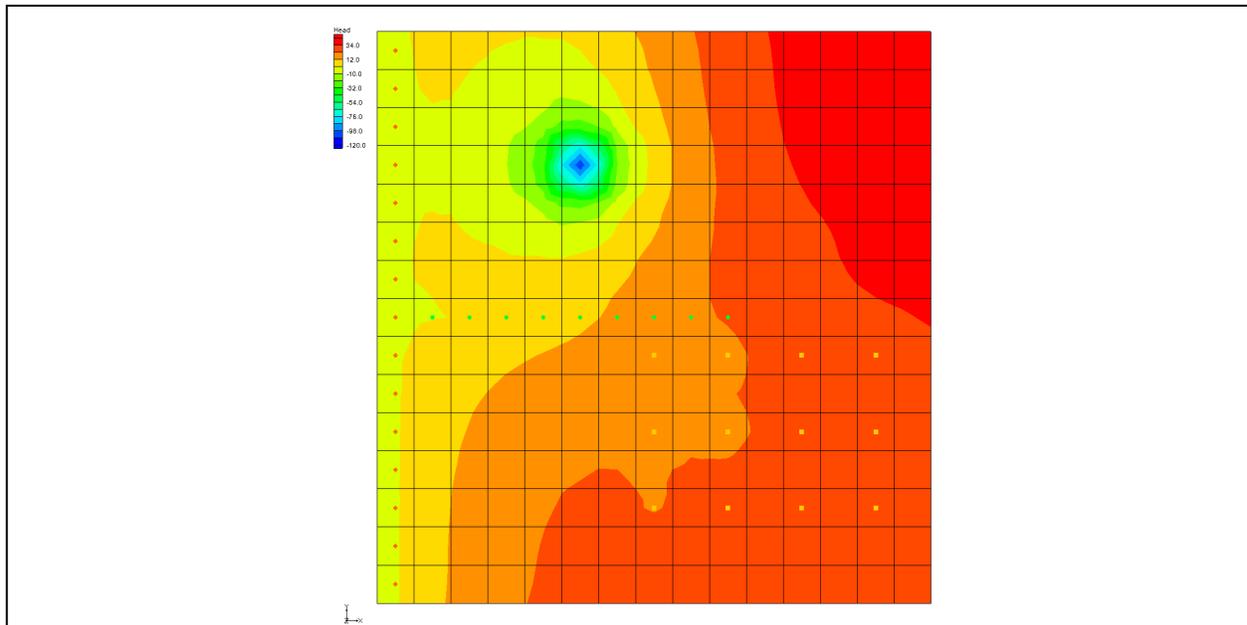


# GMS 10.0 Tutorial

## 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 Module
- MODFLOW

### Time

- 25-40 minutes



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# 1 Introduction

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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. The user should complete that tutorial before this one. The purpose of this tutorial is not to teach the user all about MODFLOW –NWT, but simply to demonstrate the MODFLOW–NWT interface in GMS.

## 1.1 Outline

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Here are the steps for this tutorial:

1. Read in 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.

## 2 Description of Problem

The problem to be solved 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 feet by 75000 feet. The grid consists of 15 rows and 15 columns, each cell measuring 5000 feet by 5000 feet 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.

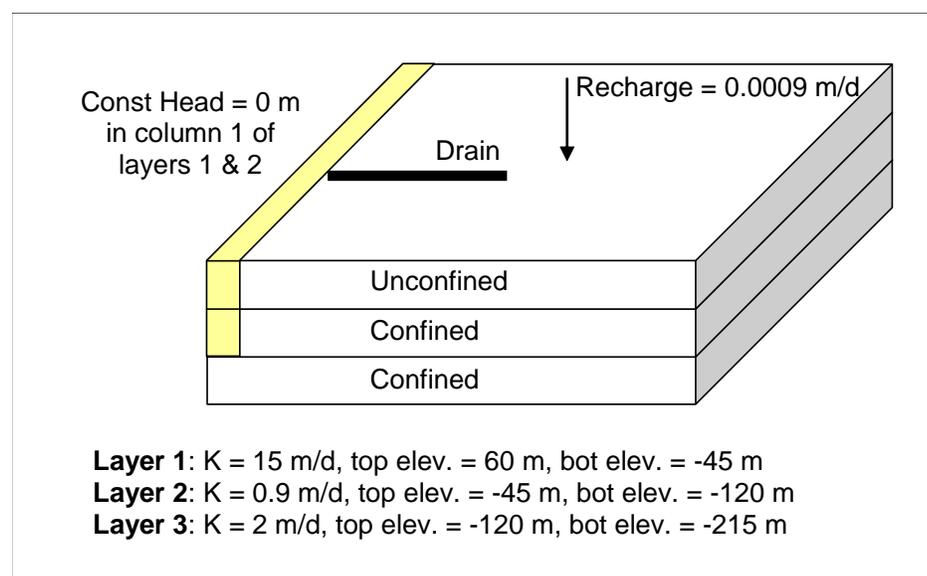


Figure 1 Sample problem to be solved

## 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.

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## 4 Read in the MODFLOW 2000 Model

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First, it is necessary to read in an existing model:

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

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

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## 5 Switch to MODFLOW-NWT

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The next step is to 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. In the *MODFLOW Global/Basic Package* dialog, change the *MODFLOW version* to *NWT*.
3. Click on the **Packages** button.

The *MODFLOW Packages* dialog will appear. Notice the flow package is set to LPF and the solver is set to SIP1. These will be left unchanged for now.

4. Select the **OK** button to exit the *MODFLOW Packages* dialog.
5. Select the **OK** button to exit the *MODFLOW Global/Basic Package* dialog.
6. If necessary, click **No** to the pop-up asking if the user would like to switch to the NWT Solver. That will be explored later.

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## 6 Save the MODFLOW-NWT LPF Project

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Before continuing, it is important to 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 the work periodically.

## 7 Run the Model

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It is now possible to 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 dataset. Notice the head contours are exactly the same as they were before. Because this tutorial is still using the LPF and SIP1 packages, switching to MODFLOW-NWT hasn't changed anything.

## 8 Switch to the UPW and NWT Packages

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Now it is possible to switch to the UPW and NWT packages.

1. Select the *MODFLOW* / **Global Options** menu command.
2. In the *MODFLOW Global/Basic Package* dialog, click on the **Packages** button.
3. In the *MODFLOW Packages* dialog, change the *Flow package* to *UPW – Upstream Weighting*.

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

4. Click **OK** to exit the *MODFLOW Packages* dialog.
5. Click **OK** to exit the *MODFLOW Global/Basic Package* dialog.

## 9 Save the MODFLOW-NWT UPW Project

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The next step is to save the project with a new name.

1. Select the *File* | **Save As** command.
2. Using the **Save** button, save the project with the name “nwt\_upw.gpr.”

## 10 Run the Model and Compare Solutions

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It is now possible to run the model.

1. Select the **Run MODFLOW**  button.

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

GMS reads the solution and contours the head dataset. 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.

- 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 (nwt\_lpf and nwt\_upw) in the Project Explorer. It may be necessary to expand the “3D Grid Data” folder and “grid” item.

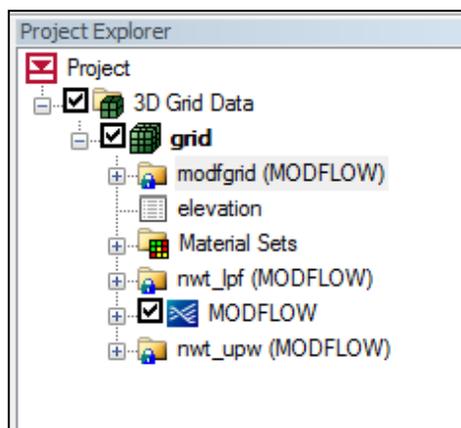


Figure 2 Switch between the LPF and UPW solutions in the Project Explorer to compare the results

## 11 Switch Back to MODFLOW–NWT LPF Model

The next step is to go back and load the MODFLOW–NWT model that used the LPF package.

- Select the **New**  button to clear the current project.
- If prompted to save these changes, select **No**.
- On the recent file list at the bottom of the *File* menu, click on “nwt\_lpf.gpr.”

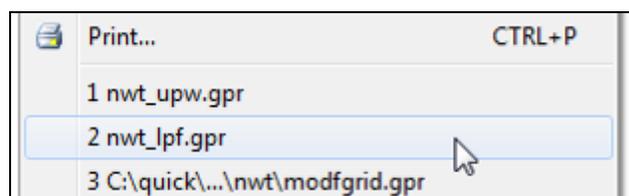


Figure 3 Reopen the nwt\_lpf.gpr model

## 12 Increase Pumping to Create a Dry Well

Now this tutorial will 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.

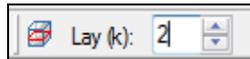


Figure 4 Changing the ortho level to 2

2. With the **Select Cell**  tool, right-click on the well cell in the upper left
3. 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).

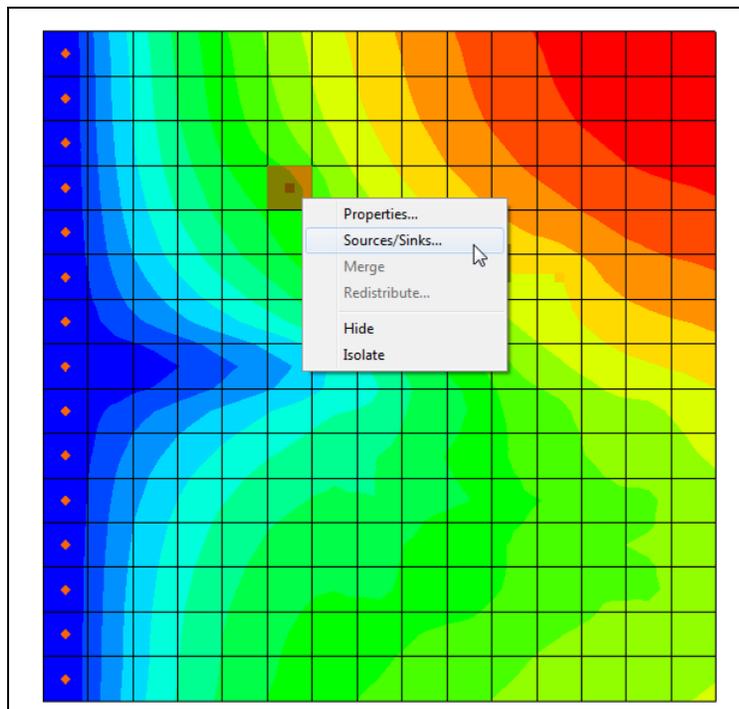


Figure 5 Selecting the left well in layer 2

4. In the *MODFLOW Sources/Sinks* dialog, increase the pumping rate or Q (flow) to “-190000.”
5. Click **OK**.

## 13 Run the Model

Now it is time to save these changes and run the model.

1. Select the **Run MODFLOW**  button.
2. When prompted to save these 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 dataset. Notice the cell with the well has gone dry. A triangle symbol appears in the cell to indicate the cell is dry.

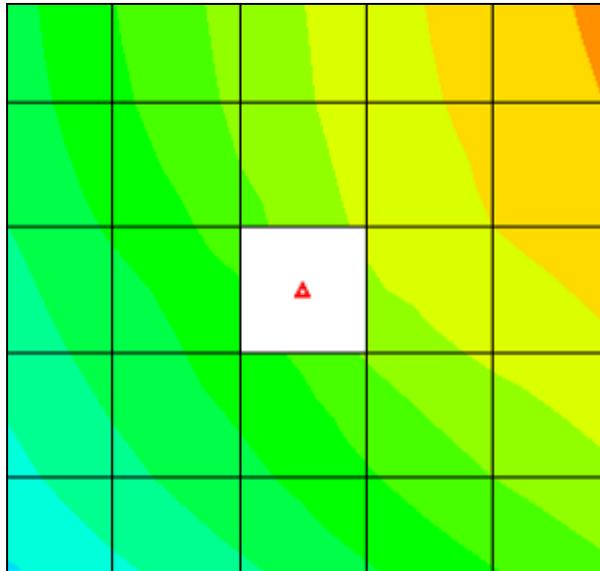


Figure 6 Dry cell symbol indicating the well went dry

## 14 HDRY

The LPF package will assign a key value, the HDRY value, to any cells which go dry. The next step is to look at the HDRY value.

1. Select the *MODFLOW / LPF – Layer Property Flow* menu command.
2. In the *LPF Package* dialog, click the **More LPF Options** button in the upper right of the dialog.

In the *LPF Package Options* dialog, notice the HDRY value is -888.0.

3. Click **OK** to exit the *LPF Package Options* dialog.
4. Click **OK** to exit the *LPF Package* dialog.

The next step is to look at the head solution.

5. Right-click on the *Head* dataset in the Project Explorer under the “nwt\_lpf (MODFLOW)” solution.

6. Select the **View Values** command from the drop-down menu.

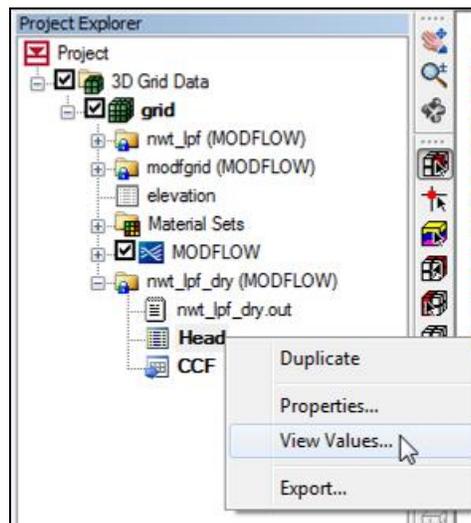


Figure 7 Viewing the head values

7. In the *Edit Dataset Values* dialog, 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.

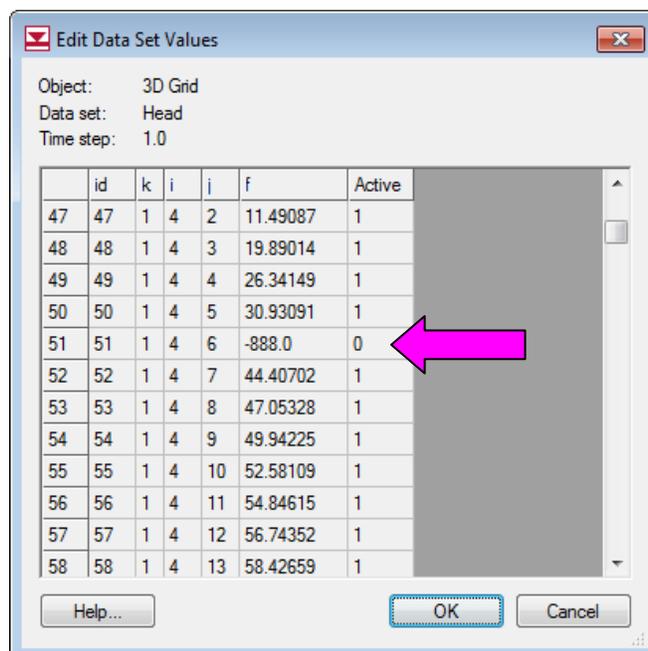


Figure 8 HDRY value in head solution

8. Click **OK** to exit the *Edit Dataset Values* dialog.

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## 15 Switch Back to UPW Package

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Now it is possible to see how MODFLOW–NWT and the UPW package handle the dry cell.

1. Select the *MODFLOW* / **Global Options** menu command.
2. In the *MODFLOW Global/Basic Package* dialog, click on the **Packages** button.
3. In the *MODFLOW Packages* dialog, change the *Flow package* to *UPW – Upstream Weighting*.
4. Click **OK** to exit the *MODFLOW Packages* dialog.
5. Click **OK** to exit the *MODFLOW Global/Basic Package* dialog.

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## 16 Specify PHIRAMP

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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* / *Optional Package* / **WEL – Well** command.
2. Near the bottom of the *MODFLOW Well Package* dialog, turn on the *Specify PHIRAMP* check box.

The value will be left 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.

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## 17 Save the MODFLOW–NWT UPW Dry Cell Project

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The next step is to save the project with a new name.

1. Select the *File* | **Save As** command.
2. Using the **Save** button, save the project with the name “nwt\_upw.gpr.”
3. Select **Yes** when prompted to replace the existing file.

## 18 Run the Model

Now it is possible to 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 dataset. 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 the tutorial will show).

## 19 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 -104.

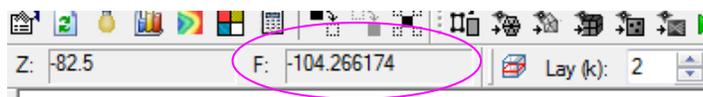


Figure 9 Head in cell (4,6,2) is about -104

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** to exit the *3D Grid Cell Properties* dialog.
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 – Upstream Weighting* menu command.
7. In the *UPW Package* dialog, click on the **More UPW Options** button.

By default, the UPW package does not assign the HDRY value to cells that go dry. If the user wants it to, he or she must turn on the IPHDRY variable.

8. In the *UPW Package Options* dialog, turn on the *Set head to HDRY (IPHDRY)* option.
9. Click **OK** to exit the *UPW Package Options* dialog.
10. Click **OK** to exit the *UPW Package* dialog.

## 20 Save and Run the Model

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The next step is to save the model with the same file name and run MODFLOW.

1. Select the **Run MODFLOW**  button.
2. When prompted to save these 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 dataset. Notice that the dry cell symbol now appears in the cell above the well.

## 21 Reduced Pumping Rates

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MODFLOW–NWT reduced the pumping rate of the well as the water table got close to the bottom of the cell. Now is the time to examine that.

1. In the Project Explorer, double-click on the “nwt\_upw.out” item.
2. If prompted to pick the viewer, click **OK** to accept the default or pick another one.
3. In Notepad (or an alternative viewer), use *Ctrl + F* to search for the word “reduced.”

The user should find the following text:

WELLS WITH REDUCED PUMPING FOR STRESS PERIOD						1	TIME STEP	1
LAY	ROW	COL	APPL.Q	ACT.Q	GW-HEAD	CELL-BOT		
2	4	6	-0.190000E+06	-0.176832E+06	-0.104266E+03	-0.120000E+03		

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

## 22 Conclusion

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This concludes the tutorial. Here are the key concepts 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 the user turns on the IPHDRY option.
- MODFLOW-NWT will reduce the pumping rate in a well as the water table approaches the bottom of the cell.