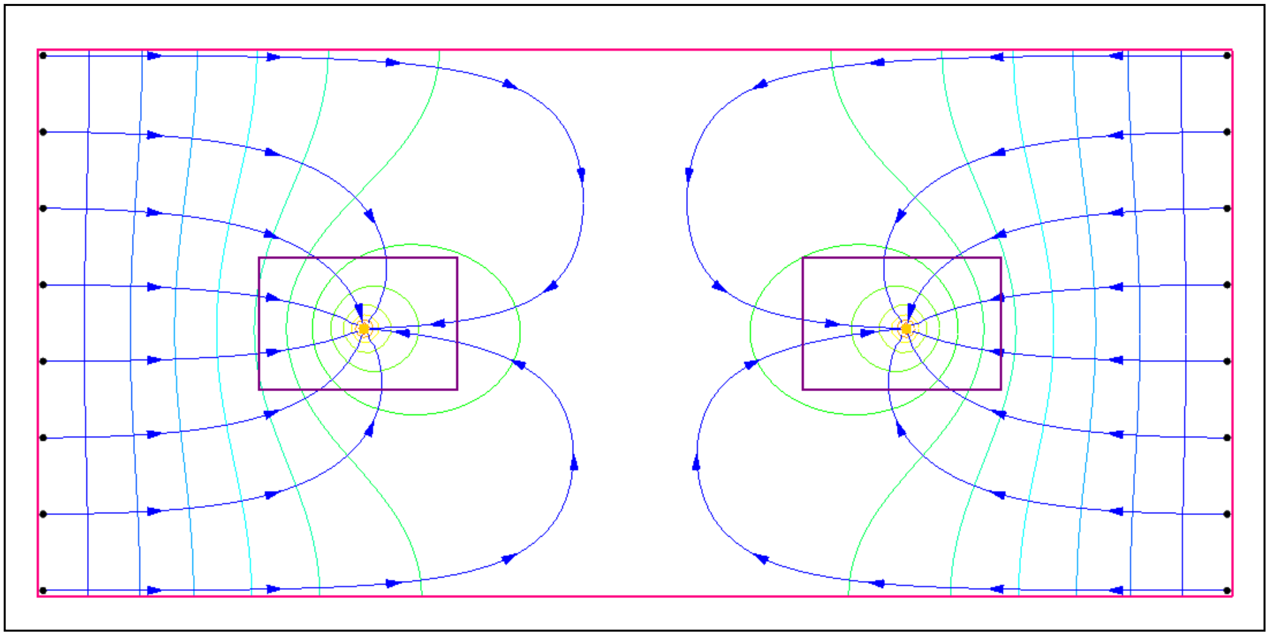
v. 10.0

GMS 10.0 Tutorial

MODFLOW–LGR Dual Refinement

Create a MODFLOW-LGR model with two locally refined grids using GMS



Objectives

This tutorial builds on the MODFLOW-LGR tutorial and shows how to create more than one child grid. This tutorial covers parameters, MODPATH, and using the BFH package to check the accuracy of the coupled boundary heads and flows.

Prerequisite Tutorials

- MODFLOW – LGR

Required Components

- Grid Module
- MODFLOW-LGR

Time

- 20-35 minutes

1 Introduction

MODFLOW-LGR can be used to create MODFLOW models that contain locally refined regions in areas where smaller cell sizes are desired. These refined regions are considered child grids of a parent grid. MODFLOW-LGR solves for the heads and flows of the child and parent grids using an iterative technique while maintaining consistency in the boundary conditions along the borders of the child and parent grids.

MODFLOW-LGR can use multiple child grids. This tutorial builds on the "MODFLOW-LGR" tutorial and demonstrates how to create multiple child grids. This tutorial covers parameters, MODPATH, and using the BFH package to check the accuracy of the coupled boundary heads and flows.

1.1 Outline

Here are the steps of this tutorial:

1. Read in an existing MODFLOW-LGR model.
2. Examine the MODPATH model
3. Examine the parameters on the model
4. Add a second child grid.
5. Save and run MODFLOW-LGR.

2 Description of Problem

The problem in this tutorial is one of the example problems included with MODFLOW-LGR. It is a simple, one layer, confined, steady state model containing two extraction wells as shown in Figure 1. No-flow boundaries occur on the north and south and specified head boundaries are defined on the east and west. Flow is generally to the wells. For this tutorial, a child grid has been created around the area of the well on the left. The user will create another child grid around the well on the right.

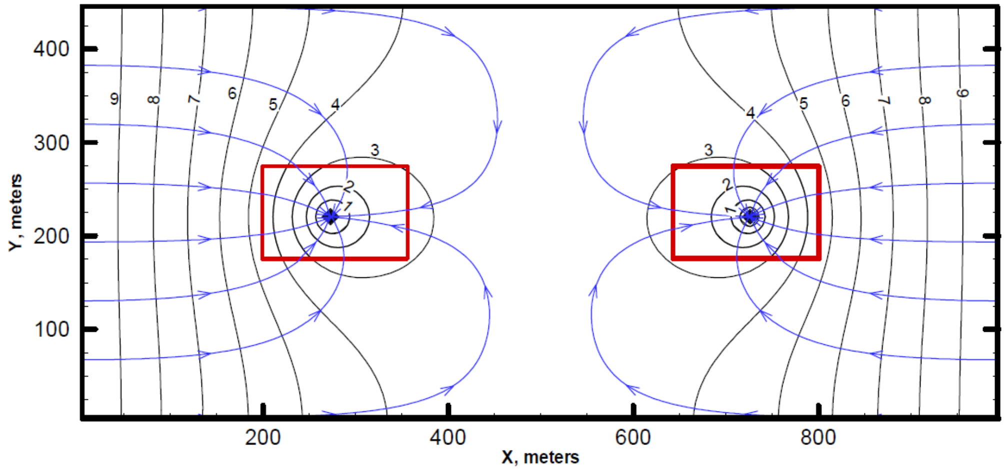


Figure 1 Sample problem to be solved[1]

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 Open the starting model

Start by opening the existing model.

1. Select the **Open** button.

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1 Mehl, S.W. and Hill, M.C. (2007). MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model -- Documentation of the Multiple-Refined-Areas Capability of Local Grid Refinement (LGR) and the Boundary Flow and Head (BFH) Package: Techniques and Methods 6-A21, p. 6.

2. Locate and open the directory entitled *Tutorials\MODFLOW\mflgr-dual*.
3. Select the file entitled "start.gpr."
4. Click **Open**.

The user should see something like the image below.

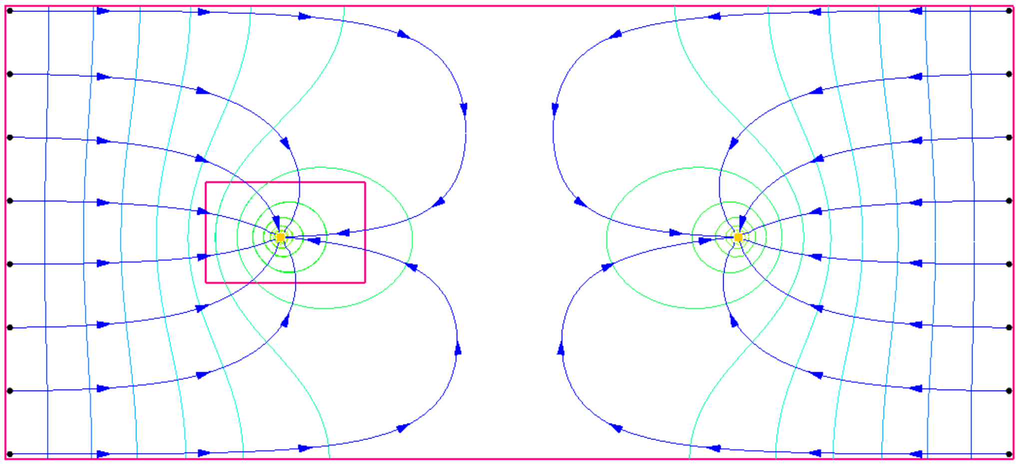

Figure 2 Starting model

4.1 MODPATH

This model includes a child grid around the well on the left side (grid cell edges are turned off but the grid shell is visible). It also includes pathlines generated by MODPATH. The pathlines are on the parent grid and are generated from a solution that was created by running MODFLOW-LGR independently on the parent model. MODPATH does not handle pathlines crossing grid boundaries. Also, in GMS, the user can only create MODPATH particles and generate a MODPATH solution on the parent model.

4.2 Parameters

Both the parent and child models use parameters and clusters to define hydraulic conductivity.

1. Select the *MODFLOW* | **Parameters** command to open the *Parameters* dialog.

Notice that there are 5 parameters defined.

2. Click **Cancel**.
3. Select the *MODFLOW* | **LPF – Layer Property Flow** command.

This opens the *LPF Package – Parent* dialog. Notice the warning about LPF parameters. Also notice the layer type is confined.

4. Click **Cancel**.

It is perfectly acceptable to use parameters to define MODFLOW inputs with MODFLOW-LGR. The user may wish to view the parameters for the CHILD1 model, or look at the zone array used with the parameter clusters.

5 Save with a different name

Before making any changes, save the project under a new name.

1. Select the *File* | **Save As** command.
2. Change the project name to "lgr-dual.gpr."
3. Click the **Save** option.

Now the user can hit the **Save** button periodically as the model is developed.

6 Create a second child grid

The user will create another child grid around the well on the right.

1. Turn on the "Annotation Data" folder in the Project Explorer. A purple rectangle should appear around the well on the right.
2. Using the **Select Cells** tool, drag a box to select the cells in the purple rectangle.
3. Right-click in the selected area.
4. Select the *Create Child Grid* command.
5. In the *Create Child Grid* dialog, change the *Grid name* to "CHILD2."
6. Change the *Horizontal refinement* to "9."

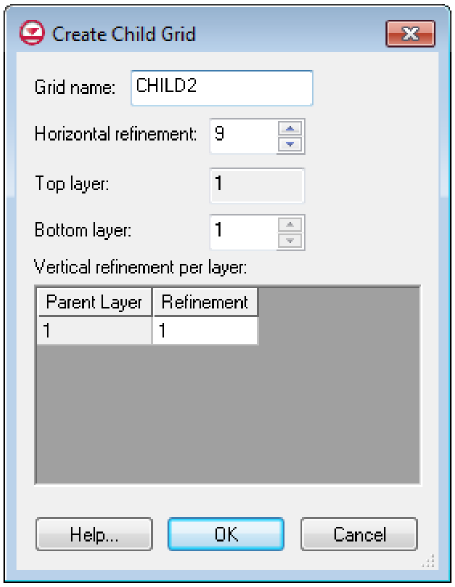

Figure 3 Create Child Grid dialog

7. Click **OK**.

8. Turn off "Annotation Data" in the Project Explorer.

7 LPF package

The user needs to change some things in the LPF package. Although the parent and CHILD1 models use parameters to define hydraulic conductivity, in the interest of time, the user won't do that for CHILD2.

1. Select the *MODFLOW* | **LPF – Layer Property Flow** menu command to open the *LPF Package – CHILD2* dialog.

2. Change the *Layer type* to *Confined*.

3. Click on the **Horizontal Hydraulic Conductivity** button.

4. In the *Horizontal Hydraulic Conductivity* dialog, click the **Constant → Grid** button.

5. In the *Grid Value* dialog, enter "0.0005" and click **OK**.

6. Click **OK** to exit the *Horizontal Hydraulic Conductivity* dialog.

7. Click **OK** to exit the *LPF Package – CHILD2* dialog.

8 Save and Run MODFLOW

Now it is possible to save and run MODFLOW.

1. Click the **Save** button.
2. Click the **Run MODFLOW** button.
3. When the model finishes, click **Close**.

GMS reads the solution and updates the contours and pathlines. Note that the pathlines have changed and they no longer go all the way to the wells. This is because the parent model ends where the child models start and MODPATH does not track pathlines across parent/child model boundaries. To see the original pathlines, simply change the solution back to the "start (MODFLOW)" solution.

9 Examining Accuracy Using BFH Package

The BFH – Boundary Head and Flow package can be used to run parent or child models independently using coupling head and flow data generated from a previous coupled run of MODFLOW-LGR. This was demonstrated in the "MODFLOW-LGR" tutorial. The BFH package can also be used to examine the accuracy of the parent/child model coupling. The tutorial will demonstrate that now.

9.1 Turn on IUPBFSV and IUCBHSV

1. Make the parent model active in the Project Explorer by clicking on its MODFLOW or its grid .
2. Select the *MODFLOW* | **Global Options** menu command.
3. In the *MODFLOW Global/Basic Package – Parent* dialog, click the **LGR Options** button.

This opens the *LGR Options* dialog. Notice the IUPBFSV option in the top right is on and the IUCBHSV option is on for CHILD1 in the spreadsheet. Therefore the coupling flow and head files were created when the user last ran MODFLOW-LGR coupled on the parent and child models. If these options were not on, the user would need to turn them on and run MODFLOW-LGR again in coupled mode to create these files.

4. Click **Cancel** to exit the *LGR Options* dialog.
5. Click **Cancel** to exit the *MODFLOW Global/Basic Package – Parent* dialog.

9.2 Turn on BFH Package

Now it is necessary to activate the BFH package.

1. Make the CHILD1 model active in the Project Explorer by clicking on its MODFLOW or its grid.

2. Select the *MODFLOW* | **Global Options** menu command to open the *MODFLOW Global/Basic Package – CHILD1* dialog.

3. Click the **Packages** button to open the *MODFLOW PACKAGES – CHILD1* dialog.

4. Under *Optional packages* on the right, turn on the *BFH – Boundary Flow and Head* package.

5. Click **OK** to exit the *MODFLOW PACKAGES – CHILD1* dialog.

6. Click **OK** to exit the *MODFLOW Global/Basic Package – CHILD1* dialog.

At this point, the user could look at the file names specified in the BFH package, but they are defaulted to the names of the files so it is not necessary.

9.3 Save and Run CHILD1

Now save and run MODFLOW on just the CHILD1 model.

1. Click the **Save** button.

2. Right-click on the "CHILD1" MODFLOW model (the user may need to expand things to see it).

3. Select the **Run MODFLOW Uncoupled On Just This Model** command.

4. When the model finishes, click **Close**.

9.4 Examine the Accuracy

Now look at the accuracy of the parent/child coupling.

1. If necessary, expand the "lgr-dual_CHILD1 (MODFLOW)" solution in the Project Explorer.

2. Double-click on the "lgr-dual_CHILD1.out" item. If prompted to pick a text editor, pick one.

3. Scroll to the bottom of the file and find the following section:

```
BFH: BOUNDARY FLUX COMPARISON
-----------------------------
NEW TOTAL BOUNDARY FLUX =  0.550000137E-02
OLD TOTAL BOUNDARY FLUX =  0.549999950E-02
AVERAGE ABSOLUTE FLUX DIFFERENCE =  0.401606887E-09
MAXIMUM ABSOLUTE FLUX DIFFERENCE OF  0.164436642E-08
OCCURS AT PARENT LAYER 1 ROW 31 COLUMN 30
NEW FLUX AT THIS NODE =  0.173791253E-03
OLD FLUX AT THIS NODE =  0.173789609E-03
```

Figure 4 BFH Comparison data

The information shows the difference in flux across the boundary between running the models coupled and running them uncoupled. Notice there is a difference but it is very small. This information can help the user determine if the boundary heads and flows are still valid when running and modifying a child model independently.

10 Add Well To Child

Now add another well to CHILD1 and see how it impacts the boundary flows.

1. Using the **Select Cells** tool, right-click somewhere in the upper right area of CHILD1 (the exact location is not important).
2. Select the **Sources/Sinks** command to open the *MODFLOW Sources/Sinks – CHILD1* dialog.

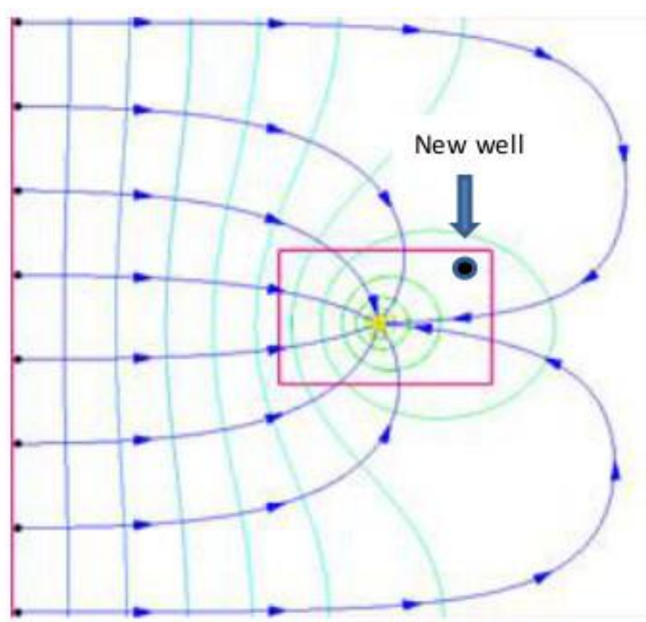

Figure 5 Creating a second well in CHILD1

3. Make sure *Wells* is selected from the list on the left.
4. Click the *Add BC* button.

5. Change the *Q (flow)* rate to "-0.0055" m^3/s. This is the same rate as the first well.

6. Click **OK**.

10.1 Save and Run CHILD1

Now save and run MODFLOW on just the CHILD1 model.

1. Click the **Save** button.

2. Right-click on the CHILD1 "MODFLOW" model.

3. Select the **Run MODFLOW Uncoupled On Just This Model** command.

4. When the model finishes, click **Close**.

10.2 Examine the Accuracy

Again, look at the accuracy of the parent/child coupling.

1. If necessary, expand the "lgr-dual_CHILD1 (MODFLOW)" solution in the Project Explorer.

2. Double-click on the "lgr-dual_CHILD1.out" item.

3. Scroll to the bottom of the file and find the BFH: BOUNDARY FLUX COMPARISON section.

How different is it from the previous results (see Figure 4)? Is the difference acceptable?

11 Add Well To Parent

Now add a well to the parent and see how it affects the boundary heads.

1. Make the parent model active in the Project Explorer by clicking on its MODFLOW or its grid .

2. Using the **Select Cells** tool, right-click somewhere between the two child grids (the exact location is not important).

3. Select the **Sources/Sinks** command to open the *MODFLOW Sources/Sinks – Parent* dialog.

4. Make sure *Wells* is selected from the list on the left.

5. Click the *Add BC* button.

6. Change the *Q (flow)* rate to "-0.0055" m^3/s. This is the same rate as the other wells.

7. Click **OK**.

11.1 Save and Run the Parent

Now save and run MODFLOW on just the parent model.

1. Click the **Save** button.

2. Right-click on the parent MODFLOW model.

3. Select the **Run MODFLOW Uncoupled On Just This Model** command.

4. When the model finishes, click **Close**.

11.2 Examine the Accuracy

Again, look at the accuracy of the parent/child coupling.

1. If necessary, expand the "lgr-dual (MODFLOW)" solution in the Project Explorer.

2. Double-click on the "lgr-dual.out" item.

3. Scroll to the bottom of the file and find the BFH: BOUNDARY HEAD COMPARISON section.

Notice that now this section shows boundary heads, not fluxes. Notice how big the head difference is from the coupled model. Is the difference acceptable?

12 Conclusion

This concludes the tutorial. Here are the key concepts in this tutorial:

- GMS supports MODFLOW-LGR and models with multiple children.
- MODPATH can be used with MODFLOW-LGR, but pathlines do not cross parent/child borders.
- In GMS, MODPATH can only be used on the parent model.
- Parameters can be used with MODFLOW-LGR.
- The BFH package can be used to examine the accuracy of the parent/child coupling and the impact that modifications in uncoupled models have on the boundary heads and flows.