GMS 7.0 TUTORIALS

MODFLOW – Advanced Parameter Options

1 Introduction

This tutorial illustrates how to use some of the advanced features associated with MODFLOW parameters. Since this tutorial assumes you understand how to use the parameter estimation tools available in GMS you should complete the *MODFLOW-Automated Parameter Estimation* tutorial before starting this tutorial. You should also understand how to define array based parameters using clusters and the concept of parameter instances. You can learn more about these concepts by reading the MODFLOW documentation.

1.1 Contents

1.2 Outline

This is what you will do:

1. Open a parameterized MODFLOW model and solution.
2. Define RCH parameters using clusters.
3. Run MODFLOW.
4. Change the model to be transient.
5. Change the parameters to use instances.
6. Run MODFLOW.
7. Define LPF parameters using clusters.
8. Run MODFLOW.
9. Adjust parameter factors.
10. Run MODFLOW.

1.3 Required Modules/Interfaces

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

- Grid
- Map
- MODFLOW
- Inverse Modeling

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

2 Description of Problem

The model we will be using in this tutorial is the same model featured in the *MODFLOW-Automated Parameter Estimation* tutorial. For most cases array-based parameters can be defined using the key value approach used in the *MODFLOW-Automated Parameter Estimation* tutorial. However, this approach is not completely compatible with the native MODFLOW parameter formats. MODFLOW array based parameters are defined using clusters. A cluster is a multiplier array, a zone array, and an IZ value (key values associated with the zone array). The key value approach used in GMS would be like creating an array-based parameter that is defined by a single cluster. MODFLOW supports parameters that are defined by multiple clusters. This feature has been added to GMS. In the *Parameters* dialog, if you toggle on the *Show all columns* option, you can turn on the option to define a parameter using clusters. This allows the user to select a multiplier array, a zone array, and to specify IZ.

In addition to clusters MODFLOW also supports defining parameter instances for parameters associated with a transient MODFLOW model. This feature allows a user to create a single parameter and then associate multiple sets of clusters with instances of that parameter. Then the user can specify which stress period each instance is used with.

As this can be quite confusing we will do an example where we first define RCH parameters using clusters in a steady state model. Then we will change the model to be transient and create more than one instance for one of our recharge parameters.

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 modeling project:

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

You should see a MODFLOW model with a solution and a set of map coverages. In the project explorer you should see seven data sets below the 3D Grid named: **HKZone1**, **HKZone2**, **Mult1**, **Mult2**, **RchZone1**, **RchZone2**, and **RchZone3**. These data sets will be used to define the RCH and LPF parameters.

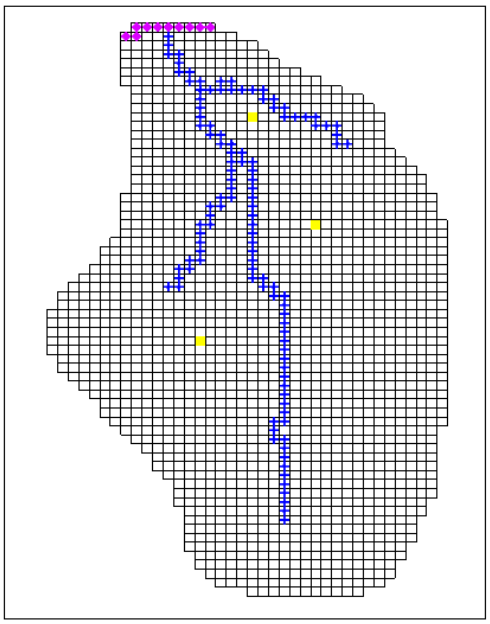

Figure 1. The Model.

5 Creating a Recharge Parameter with a Cluster

First we will create a recharge parameter that is defined by a single cluster. Then we will run MODFLOW.

1. Select the *MODFLOW* | *Parameters* command.
2. Select the *Show all columns* toggle at the top of the dialog.
3. Select the *New* button near the bottom left of the dialog. This will create a new parameter.
4. Change the newly created parameter to have a *Name* of **RCH_1**, a *Type* of **RCH**, and a *Value* of **0.00005**.
5. Turn on the *Use clusters* toggle for the parameter and enter **1** for the *Num. Clusters* and **1** for *Num. Instances*.
6. Select the *Define Clusters* button.

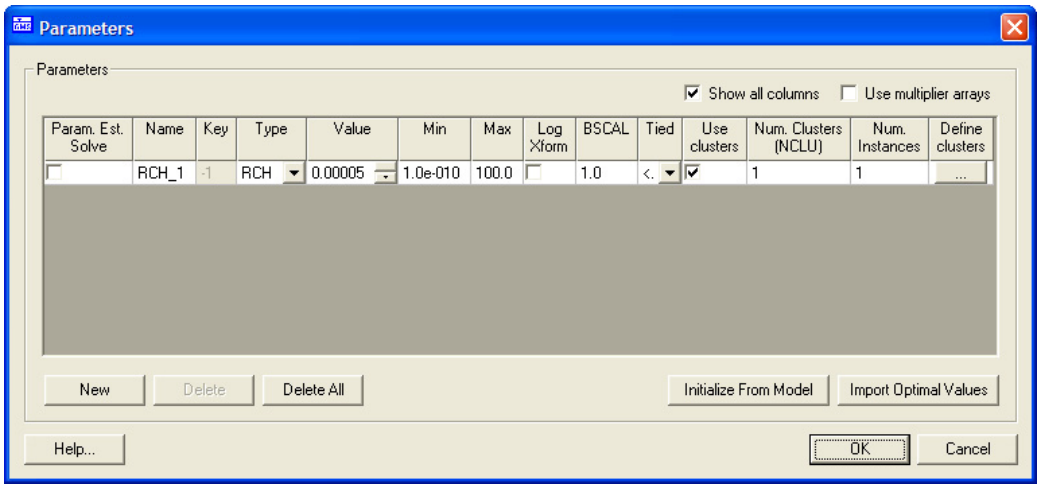

Figure 2. Parameter Instances Dialog.

5.1 The Define Clusters Dialog

Clusters are defined in the *Define Clusters* dialog. Since this is a steady state model we only have one instance. In this dialog you can define parameter instances and clusters. Currently, we only have 1 instance and 1 cluster so there is only one row available in the dialog.

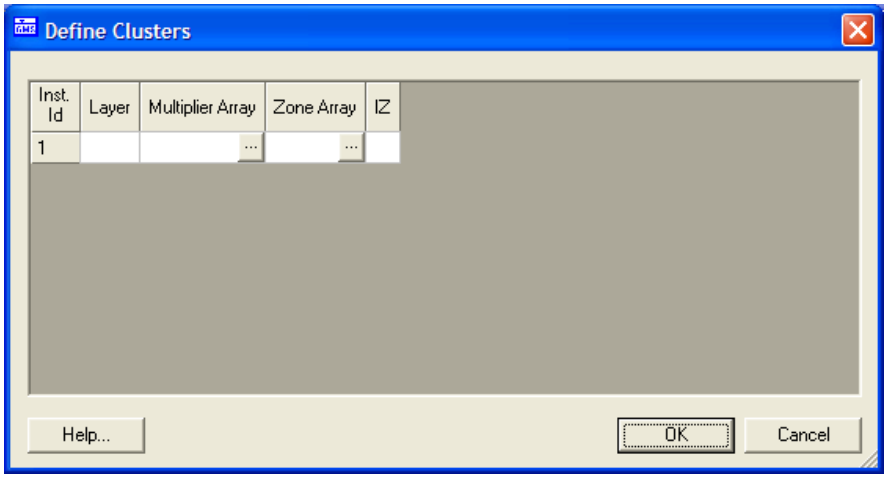

Figure 3. Define Clusters Dialog.

1. Select the *Cancel* button.

2. Change the *Num. Clusters* to **2** and select the *Define Clusters* button.

Notice that now you have two rows in the spreadsheet. You would have to define two multiplier arrays and two zone arrays as well as IZ values to successfully define the clusters.

3. Select the *Cancel* button.

4. Change the *Num. Instances* to be **2** and select the *Define Clusters* button.

Notice that now you have four rows in the spreadsheet. You would have to define two clusters for each instance. Notice also that you must specify an instance name as well as define the stress periods where the instance is used. So for a transient model with 3 stress periods one of the instances could be used for stress periods 1 and 2 and the other instance could be used with stress period 3. If you define a RCH or EVT parameter using clusters and instances you must make sure that at least one parameter instance is assigned to every stress period in the model.

5. Select the *Cancel* button.

6. Change the *Num. Clusters* to be **1** and the *Num. Instances* to be **1**.

7. Select the *Define Clusters* button.

8. Enter **RCH_1_1** for the *Instance Name*. Note: You should limit the length of an instance name to 10 characters; this is a MODFLOW limitation.

9. Select the button in the *Multiplier Array* column. This brings up the *Select Data Set* dialog.

10. Select **Mult1** and then select *OK*.

11. Select the button in the *Zone Array* column.

12. Select **RchZone1** and then select *OK*.

13. Enter **2** in the *IZ* field.

The IZ field is used to specify where the parameter is active in the MODFLOW grid. RchZone1 has values of 0 and 2. We specify 2 as the IZ and then when MODFLOW runs the parameter will only be used where the zone array has a value of 2.

14. Enter **1** in the *Stress Periods* field.

15. Click *OK* to exit the *Define Clusters* dialog.

16. Click *OK* to exit the *Parameters* dialog.

We have now defined a parameter using clusters and we will run MODFLOW.

6 Running MODFLOW

We are now ready to save the project and run MODFLOW.

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

2. Save the project with the name **run1.gpr**.

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

Once MODFLOW is done running you can read in the solution.

4. Make sure that the *Read solution on exit* toggle is checked and select the *Close* button.

You should now see the head contours from the MODFLOW solution.

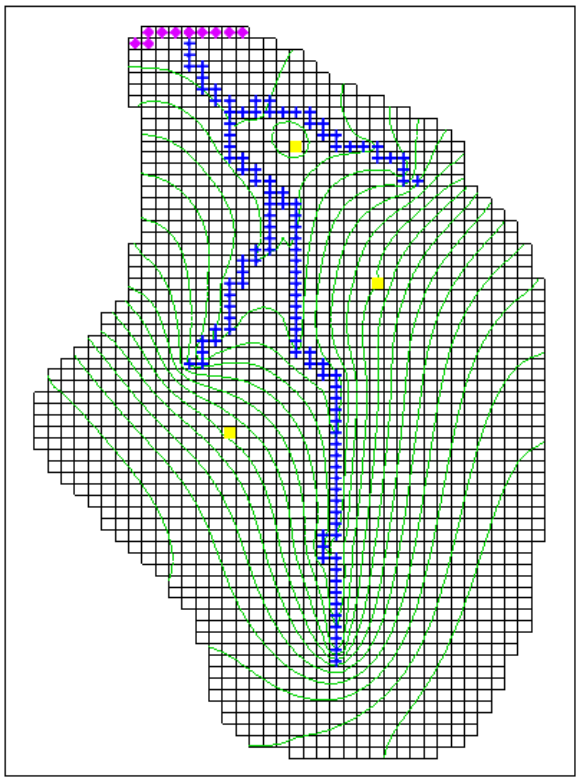

Figure 4. Model with Solution Contours.

7 Creating a Recharge Parameter with Multiple Clusters

Now we will create another recharge parameter that is defined by two clusters before running MODFLOW again.

1. Select the *MODFLOW* | *Parameters* command.

2. Make sure the *Show all columns* toggle at the top of the dialog is checked.

3. Select the *New* button near the bottom left of the dialog

4. Change the newly created parameter to have a *Name* of **RCH_2**, a *Type* of **RCH**, and a *Value* of **0.00004**.

5. Turn on the *Use clusters* toggle for the parameter and enter **2** for the *Num. Clusters* and **1** for *Num. Instances*.

6. Select the *Define Clusters* button.

7. Enter the values for the clusters as shown in the table below. Only the data set names are shown for the Multiplier and Zone arrays below, but you must use the button to select the data sets after which the full path to the data sets will be displayed. The IZ values should be separated by spaces.

Instance Name	Multiplier Array	Zone Array	IZ	Stress Per.
RCH_2_1	Mult2	RchZone2	4 5 3	1
	Mult2	RchZone3	6 7	

8. When you are finished, click *OK* twice to exit both dialogs.

Since we have two RCH parameters that are defined for stress period 1 the final value of the recharge rate will be the sum of the two parameters. MODFLOW computes this internally.

8 Running MODFLOW

We are now ready to save the project and run MODFLOW.

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

2. Save the project with the name **run2.gpr**.

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

Once MODFLOW is done running you can read in the solution.

4. Make sure that the *Read solution on exit* toggle is checked and select the *Close* button.

9 Creating a Transient Model

In addition to defining parameters using clusters, you can also define parameter instances for transient models. Now we will change the model to be transient and use parameter instances.

9.1 Setting up the stress periods

We will change the model to be transient and make 3 stress periods.

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

2. In the *Model type* section of the dialog change the option to *Transient*.

3. Select the *Stress Periods* button.
4. Set the *Number of stress periods* to **3**.
5. Set the *Num Time Steps* for each stress period to be **1**.
6. Select *OK* twice to exit both dialogs.

9.2 Editing the Specific Yield

Since this is an unconfined model we need to edit the specific yield value in the LPF package.

1. Choose the *Select Cells* tool  .
2. Select the *Edit* | *Select All* command.
3. Select the *Edit* | *Properties* command.
4. Enter **0.01** for *Specific yield* and select *OK* to exit the dialog.

9.3 Editing the RCH Parameters

Now we need to update the parameters to be compatible with the stress periods.

1. Select the *MODFLOW* | *Parameters* command.
2. Select the *Define Clusters* button for the **RCH_1** parameter.
3. Change the *Stress Periods* field to have **1 2 3** as the value (numbers separated by spaces).

Now this parameter will be used for each of the stress periods.

4. Repeat these steps for the **RCH_2** parameter.

10 Running MODFLOW

We are now ready to save the project and run MODFLOW.

1. Select the *File* | *Save As* command.
2. Save the project with the name **run3.gpr**.
3. Select the *MODFLOW* | *Run MODFLOW* command.

Once MODFLOW is done running you can read in the solution.

4. Make sure that the *Read solution on exit* toggle is checked and select the *Close* button.

11 Using Parameter Instances

Now we will change one of the recharge parameters to use instances.

1. Select the *MODFLOW* | *Parameters* command.
2. Change the *Num. Instances* to be **2** for the **RCH_1** parameter.
3. Select the *Define Clusters* button for the **RCH_1** parameter.
4. For instance 1 ("RCH_1_1" in the first row):
   - Change the *Stress Periods* field to be **1 3**.
5. For instance 2 (the second row):
   - Enter **RCH_1_2** for the *Instance Name.*
   - Set the *Multiplier Array* to be the **Mult2** data set.
   - Set the *Zone array* to be **RchZone1** and the *IZ* value to **2**.
   - Set the *Stress Periods* field to be **2**.
6. Select *OK* twice to exit both dialogs.

12 Running MODFLOW

We are now ready to save the project and run MODFLOW.

1. Select the *File* | *Save As* command.
2. Save the project with the name **run4.gpr**.
3. Select the *MODFLOW* | *Run MODFLOW* command.

Once MODFLOW is done running you can read in the solution.

4. Make sure that the *Read solution on exit* toggle is checked and select the *Close* button.

13 LPF Parameters

GMS supports parameters with the LPF and HUF packages. In this tutorial we are using the LPF package and we will change horizontal conductivity to use parameters. When entering parameters for the LPF package a layer number is used in place of an instance name.

1. Select the *MODFLOW* | *Parameters* command.
2. Make sure the *Show all columns* toggle at the top of the dialog is checked.
3. Select the *New* button near the bottom left of the dialog.
4. Change the newly created parameter to have a *Name* of **HK_1**, a *Type* of **HK**, and a *Value* of **0.67**.
5. Turn on the *Use clusters* toggle for the parameter and enter **2** for the *Num. Clusters*.
6. Select the *Define Clusters* button.
7. Enter the values for the cluster shown in the table below.

Layer	Multiplier Array	Zone Array	IZ
1	Mult1	HKZone1	1 2
2	Mult1	HKZone1	1 2

8. Repeat the process creating a new parameter with a *Name* of **HK_2**, a *Type* of **HK**, and a *Value* of **0.15**.

Layer	Multiplier Array	Zone Array	IZ
1	Mult1	HKZone2	3 4
2	Mult1	HKZone2	3 4

9. When you're finished, click *OK* twice to exit both dialogs.

14 Running MODFLOW

We are now ready to save the project and run MODFLOW.

1. Select the *File* | *Save As* command.
2. Save the project with the name **run5.gpr**.
3. Select the *MODFLOW* | *Run MODFLOW* command.

Once MODFLOW is done running you can read in the solution.

4. Make sure that the *Read solution on exit* toggle is checked and select the *Close* button.

15 Parameter Factors

The last item that this tutorial will cover is parameter factors. The MODFLOW list based packages (WEL, DRN, GHB, RIV, CHD, STR) allow parameter factors to be defined along with the parameters. For example, in GMS when you create a river boundary condition using the map module GMS will store the length of the arc in the grid cell that is associated with each river boundary condition. Then if the user wishes to parameterize river conductance the parameter can be conductance per unit length and the parameter factor will be the length of the arc. The final conductance for a particular river boundary condition will be the product of the parameter value and the parameter factor.

In MODFLOW this parameter factor can actually vary per stress period. This feature has been added to GMS in order to fully support MODFLOW parameters. We will now create a parameter in the WEL package and we will change the parameter factor on one of the stress periods.

1. Select the *MODFLOW* | *Parameters* command.
2. Select the *New* button near the bottom left of the dialog. This will create a new parameter.
3. Change the newly created parameter to have a *Key* of **-15**, *Type* of **WELL**, and a *Value* of **-15.0**.
4. Select *OK* to exit the dialog.

15.1 Editing Parameter Factors

By default the parameter factors are 1.0 (which will have no effect on the final value that the parameter represents). We will change the parameter factor for the second stress period for the parameter that we just created.

1. Select the *MODFLOW* | *Source/Sink Packages* | *Well Package* command.
2. Change the *Stress period* to **2**.

In the spreadsheet notice the *Q factor* column. This is the parameter factor.

3. For the well in cell ID 1613, change the Q factor to **10.0**.

This means that in the second stress period the pumping rate for this well will be 10.0 times greater or -150.0 instead of -15.0. Note the Q factor is only used by parameters.

4. Select *OK* to exit the dialog.

16 Running MODFLOW

We are now ready to save the project and run MODFLOW.

1. Select the *File* | *Save As* command.
2. Save the project with the name **run6.gpr**.
3. Select the *MODFLOW* | *Run MODFLOW* command.

Once MODFLOW is done running you can read in the solution.

4. Make sure that the *Read solution on exit* toggle is checked and select the *Close* button.

Notice the changes in the contours around the well on the left side of the model when you switch to the second time step on the MODFLOW solution.

17 Conclusion

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

- Array based parameters can be defined using clusters.
- Parameter instances can be defined for array based parameters for transient models.
- Parameter factors can be defined for list based packages in GMS.