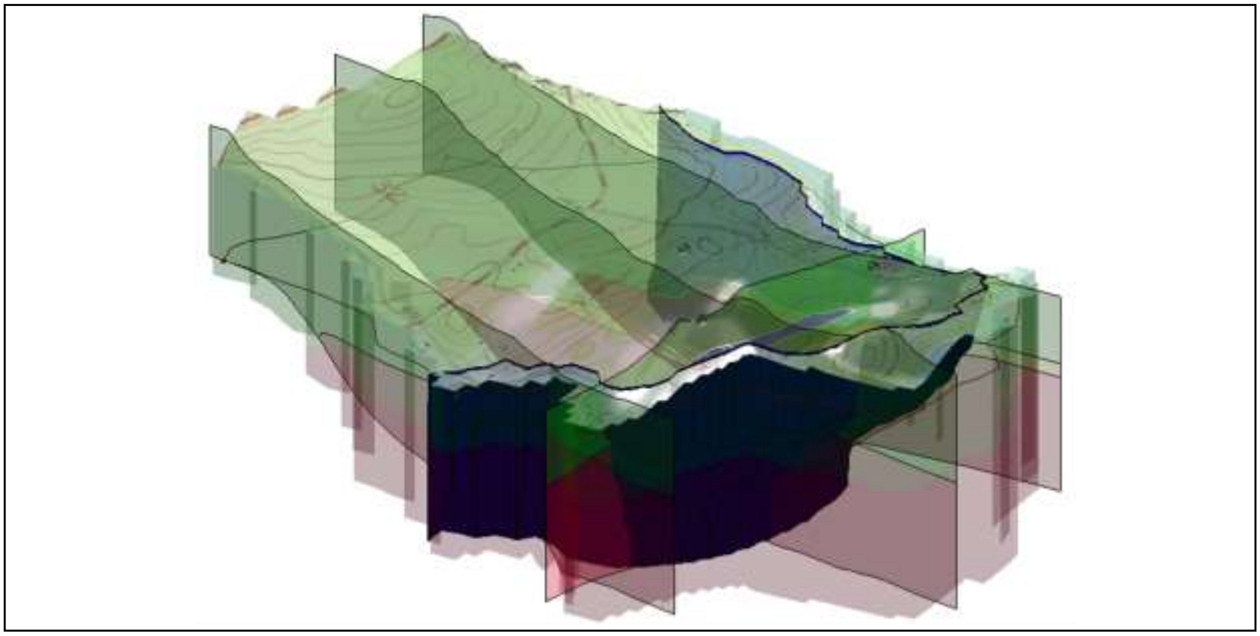
v. 10.0

GMS 10.0 Tutorial

SEAWAT – Conceptual Model Approach

Create a SEAWAT model in GMS using the conceptual model approach



Objectives

Create a SEAWAT model in GMS using the conceptual model approach, which involves using the GIS tools in the Map module to develop a conceptual model of the site being modeled. The location of sources/sinks, layer parameters (such as hydraulic conductivity), model boundaries, and all other data necessary for the simulation can be defined at the conceptual model level. Once this model is complete, the grid is generated.

Prerequisite Tutorials

- MODFLOW – Conceptual Model Approach
- MT3DMS – Conceptual Model Approach

Required Components

- Grid Module
- Map Module
- MODFLOW
- MT3DMS
- SEAWAT

Time

- 25-40 minutes

1 Introduction

"SEAWAT is a generic MODFLOW/MT3DMS-based computer program designed to simulate three-dimensional variable-density groundwater flow coupled with multi-species solute and heat transport. The program has been used for a wide variety of groundwater studies including those focused on brine migration in continental aquifers as well as those focused on saltwater intrusion in coastal aquifers. SEAWAT uses the familiar structure of MODFLOW and MT3DMS."[1]

This tutorial explains how to perform a SEAWAT simulation within GMS using the conceptual model approach. If the user has not done so already, it is recommended that user first complete the "MODFLOW – Conceptual Model Approach" and the "MT3DMS – Conceptual Model Approach" tutorials prior to completing this tutorial.

1.1 Outline

Here are the steps to the tutorial:

1. Import an existing MODFLOW simulation and conceptual model.
2. Create a SEAWAT model to simulate the effects of pumping on salt water intrusion.

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1. http://water.usgs.gov/ogw/seawat/

3. Run the simulation and view the results in 3D.

2 Description of the Problem

The site in this model is a small coastal aquifer with three production wells with variable pumping rates. The no-flow boundary on the upper left corresponds to a parallel flow boundary, and the no-flow boundary on the left corresponds to a thinning of the aquifer due to a high bedrock elevation. A stream provides a specified head boundary on the lower left, and the remaining boundary is a coastal boundary simulated with a specified head boundary condition.

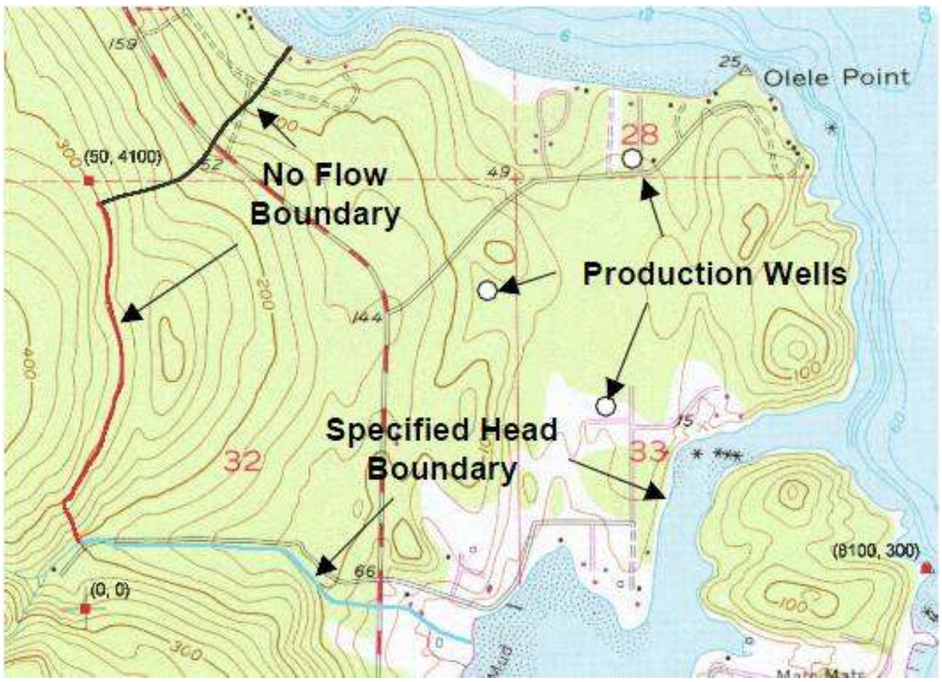

Figure 1 Site map of SEAWAT model

The stratigraphy of the site consists mainly of an upper and lower aquifer. The upper aquifer has a hydraulic conductivity of 1.5 m/day, and the lower aquifer has a hydraulic conductivity of 5.0 m/day. The model also has some areas with confining units. The production wells extend to the lower aquifer.

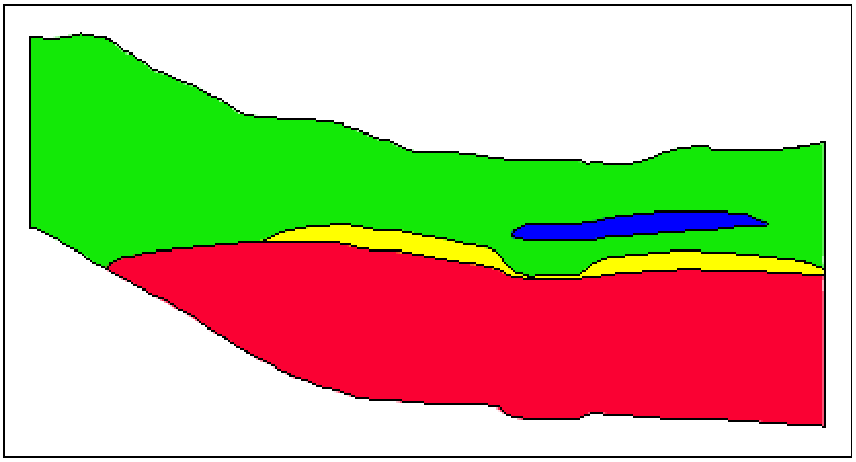

Figure 2 Cross-section through model domain

The user will use this model to simulate the effect of the pumping wells on salt water intrusion. The initial heads and concentrations were created by running a SEAWAT model for a very long time with steady state flow model.

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 Importing an existing MODFLOW Model

The user will start with an existing MODFLOW model and make the necessary modifications to run SEAWAT.

1. Select the **Open** button.
2. Locate and open the directory entitled *Tutorials\SEAWAT\coastal*.
3. Select the file entitled “coastal.gpr.”
4. Select the **Open** button.

The imported model shows a MODFLOW grid on top of a background topo map. The contours on the grid are the heads computed by the “long” SEAWAT run with a steady state flow model.

4.1 Viewing the Initial Concentration

Now the user will view the initial concentration that will be assigned to the SEAWAT model.

1. Expand the "3D Grid Data" folder and the "grid" item in the Project Explorer.
2. Select the "Salt Initial Concentration" dataset.
3. Expand the "Display Themes" folder in the Project Explorer.
4. Select the "Fresh-water Isosurface" display theme.

The user should see an image similar to the figure shown below. Use the Rotate tool to move around the view to see how the fresh water interface looks. The user should also see cross sections through the stratigraphy at the site. The user can also select the "Isosurface Animation" display theme; this theme only shows the isosurface and the 3D grid faces.

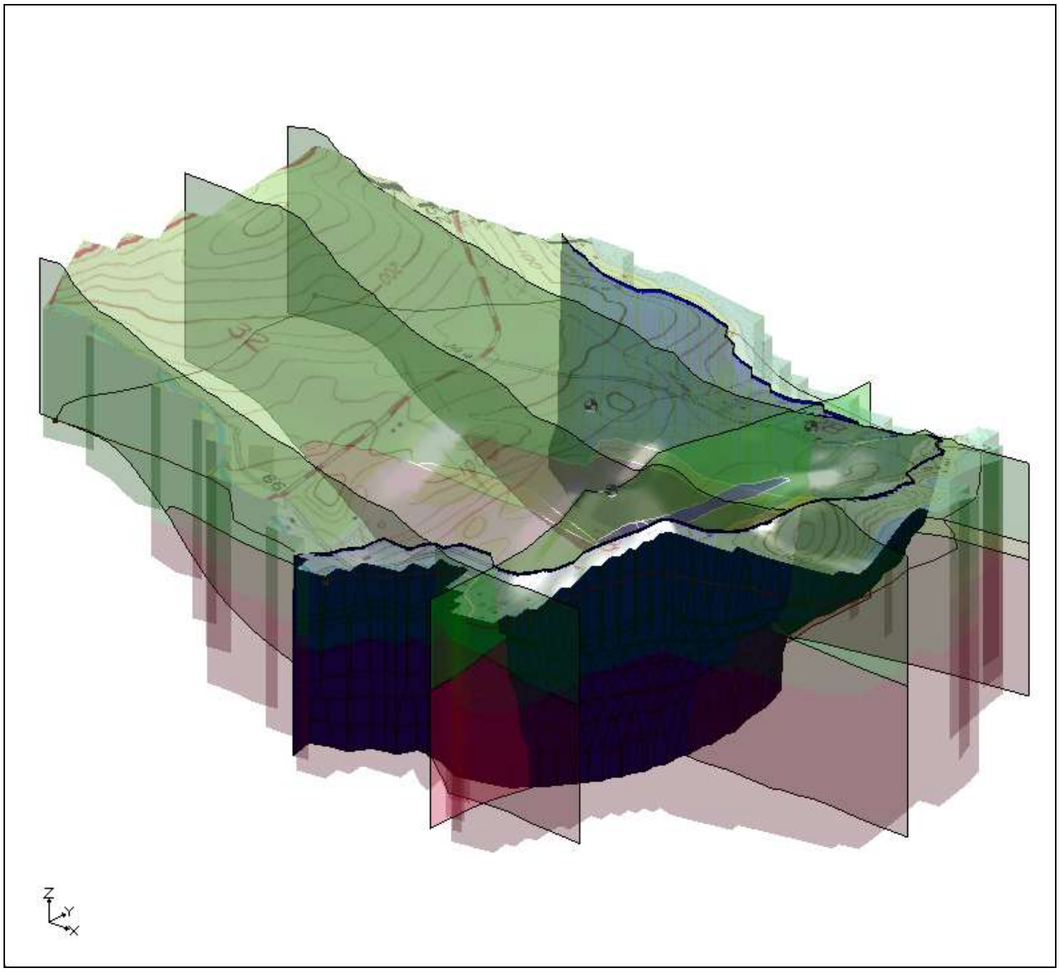

Figure 3 Display of the fresh-water isosurface

5. Select the “Head Contours” display theme.

5 Saving the project

It is a good idea to save often. Save the project under a new name so that it can be saved periodically.

1. Select the *File* | **Save As** command.
2. Enter “seawat.”
3. Select the **Save** button.

Now the user will create a SEAWAT model by modifying the existing MODFLOW model. The user will do this by editing the conceptual model as well as setting up some options in the MODFLOW, MT3D, and SEAWAT interfaces.

6 Editing the MODFLOW simulation

The heads computed by SEAWAT simulation are different than the heads computed by a MODFLOW simulation (for more details see the SEAWAT documentation, p. 13).[2] The SEAWAT simulation will be transient so the user will set the starting heads to be those computed by the prior long-term SEAWAT run. Also, it is necessary to change the MODFLOW model to be transient and to set up the stress periods. The model will run for 730 days, and each stress period will be 10 days long.

1. Select the *MODFLOW* | **Global Options** command to open the *MODFLOW Global/Basic Package* dialog.
2. Make sure the *Starting heads equal grid top elevation* toggle is turned off.
3. Select the **Starting Heads** button to open the *Starting Heads* dialog.
4. Select the **3D Dataset → Grid** button to open the *Select Dataset* dialog.
5. Select the “Starting Heads” dataset.
6. Select **OK**.

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2. Langevin, C.D., Thorne, D.T., Jr., Dausman, A.M., Sukop, M.C., and Guo, W. (2007). SEAWAT Version 4: A Computer Program for Simulation of Multi-Species Solute and Heat Transport: U.S. Geological Survey Techniques and Methods Book 6, Chapter A22, 39 p., pp. 13.

7. Select **OK** to exit the *Starting Heads* dialog.
8. In the *Model type* section of the dialog, select *Transient*.
9. Select the **Stress Periods** button to open the *Stress Periods* dialog.
10. Select the **Initialize** button near the bottom of the dialog.
11. Select **Yes** at the prompt.
12. Enter the values as shown in the following figure.

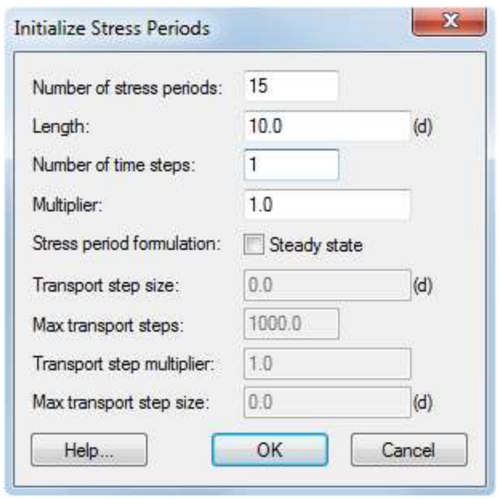

Figure 4 Initialize Stress Periods dialog

13. Select **OK.**
14. Select **OK** to exit the *Stress Periods* dialog.
15. Select **OK** to exit the *MODFLOW Global/Basic Package* dialog.

7 Initializing MT3DMS

As stated earlier, SEAWAT uses the combination of MODFLOW and MT3DMS. The user needs to turn on the MT3DMS and SEAWAT menus. Now, the user will initialize MT3DMS.

1. In the Project Explorer, right-click on the “grid” item. (The user may need to expand the “3D Grid Data” folder.)
2. Select the **New MT3D** command.
3. Select the **Output Control** button to open the *Output Control* dialog.
4. Enter “40” for the *Print or save at specified interval*.

5. Select **OK** to exit the dialog.
6. Select the **Packages** button to open the *MT3D/RT3D Packages* dialog.
7. Turn on *Advection package* and *Source/sink mixing package*.
8. Select **OK** to exit the dialog.
9. Select the **Define Species** button to open the *Define Species* dialog.
10. Select the **New** button.
11. Change the name of the species to “Salt.”
12. Select **OK** to exit the dialog.
13. In the *Layer Data* section of the dialog, turn on *Use materials for porosity and long. dispersivity*.
14. On the right side of the dialog, select the “Salt” species in the spreadsheet.
15. Check the **Edit Per Cell** button.
16. Click the **“…”** button to open the *Starting Concentrations – Salt* dialog.
17. Select the **3D Dataset → Grid** button to open the *Select Dataset* dialog.
18. Select the “Salt Initial Concentration” dataset.
19. Select **OK**.
20. Select **OK** to exit the *Starting Concentrations – Salt* dialog.
21. Select **OK** to exit the Basic Transport Package.

8 Initializing SEAWAT Simulation

With the MODFLOW and MT3DMS models ready, it is possible initialize the SEAWAT simulation

1. In the Project Explorer, right-click on the “grid” item.
2. Select the **New SEAWAT**... command to open the *Global Options* dialog. (The user may need to expand the “3D Grid Data” folder.)
3. Turn on *Include transport in simulation* and *Variable-Density Flow (VDF)*.
4. Select the **OK** button to exit the dialog.

8.1 Modifying the VDF Package

The user can now enter the data necessary for the VDF package. The inputs to the VDF package control the density calculations performed by SEAWAT. In the example problem, the concentration of seawater was defined as 19 g/l. Based on the units of the MODFLOW model, the reference density will be 1000 kg/m^3. If the density of seawater is 1025 kg/m^3, then the linear relationship between concentration and density is defined with a factor of 1.315. The user may wish to refer to SEAWAT manual on pages 20–21 for more information on these parameters.[3]

1. Select the *SEAWAT* | **VDF Package** command to open the *SEWAT VDF Package* dialog.
2. Enter all the values as given in the following figure:

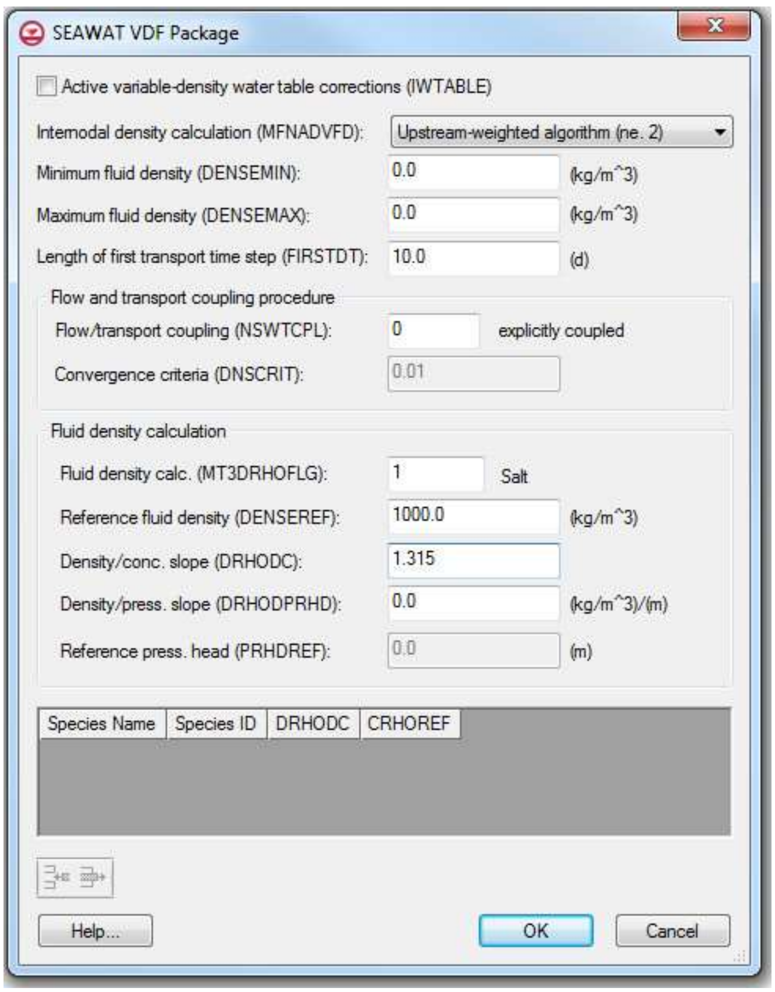

Figure 5 VDF Package inputs

3. Ibid., pp. 20–21.

3. Select the **OK** button to exit the dialog.

9 Editing the Conceptual Model

Now the user will adjust the conceptual model by assigning a concentration to the arc defining the coastline. In order to assign concentrations in the conceptual model, the user will turn on transport and define a species.

1. Expand the "Map Data" folder in the Project Explorer.
2. Right-click on the "MODFLOW_SEAWAT" conceptual model.
3. Select the **Properties** command from the menu to open the *Conceptual Model Properties* dialog.
4. Turn on *Transport*.
5. Make sure the transport model is *MT3DMS*.
6. Click the **Define Species** button to open the *Define Species* dialog.
7. Select **New** and change the species name to "Salt."
8. Select **OK**.
9. Select **OK** to exit the *Conceptual Model Properties* dialog.

9.1 Assign salt concentration at the coastline

Now that the user has defined a species, the user can assign a concentration to the coast line arc.

1. Expand the "MODFLOW_SEAWAT" conceptual model.
2. Select the "Sources & Sinks" coverage in the Project Explorer.
3. Choose the **Select Arcs** tool.
4. Select the arc on the coastline.
5. Select the **Properties** button to open the *Attribute Table* dialog.
6. Enter "19.0" for the *Salt conc*.
7. Select **OK** to exit the dialog.

9.2 Map to MT3DMS

Now the user can convert the conceptual model to the numerical model.

1. Select the *Feature Objects* | **Map → MT3DMS** command.
2. Select **OK** at the prompt.
3. Select the *Display* | **Display Options** command to open the *Display Options* dialog.
4. Select 3D Grid Data in the list in the left-hand column.
5. Select the Modflow tab.
6. Make sure that the *Transient head* toggle is on.

Note that all the cells at the coastline are now assigned with new symbols representing the boundary condition in the MT3DMS source/sink mixing package.

9.3 Map to MODFLOW

At this point, it is also necessary to map over the wells and their pumping schedules.

1. Select the "Wells" coverage.
2. Right-click on the "Wells" coverage.
3. Select the **Map To → MODFLOW/MODPATH** command.

10 Saving and running SEAWAT

Now save the changes and run SEAWAT.

1. Select the **Save** button to save the project
2. Select the *SEAWAT* | **Run SEAWAT** command.
3. When SEAWAT finishes, select the **Close** button.

11 Viewing the Solution

The user will now view the results of the SEAWAT model run. The user will examine how the fresh-water contour line changes with time.

1. Expand the "Display Themes" folder.
2. Select the "MCL contour" display theme.

This display theme is set up to show one contour at a value of .25 g/l.

3. Select the "Salt" dataset below the "seawat (MT3DMS)" solution in the Project Explorer.

4. In the time window, select time 120.0.

Notice that the MCL contour now encloses the northernmost and the southernmost well.

11.1 Creating an animation

Now the user will create an animation of the change in concentration over time. This will help the user see when this well begins pumping lower quality water.

1. Select the *Display* | **Animate** command.

The defaults will work fine for this animation.

2. Select **Next** on the first page.

3. Select **Finish** on the second page.

After a few minutes an animation should begin playing. Notice how the MCL contour line eventually surrounds the northernmost pumping well. The user can also see how the MCL contour line is moving near the southernmost well.

4. Close the *Play AVI Application* to return to GMS.

11.2 Creating a Time Series Plot of Concentration

Now the user will make a plot of concentration verses time at the northern most well.

1. Select the **Zoom** tool and zoom in around the northernmost well.

2. Select the "grid" item in the Project Explorer.

3. Select the **Select Cell** tool.

4. Select the cell containing the well by clicking on the well.

5. Select the **Plot Wizard** button.

6. Select the *Active Dataset Time Series* plot.

7. Then select the **Finish** button.

The user should see a plot similar to the figure below. The user can see how the concentration increases when the well is pumping and then drops off when the well is turned off.

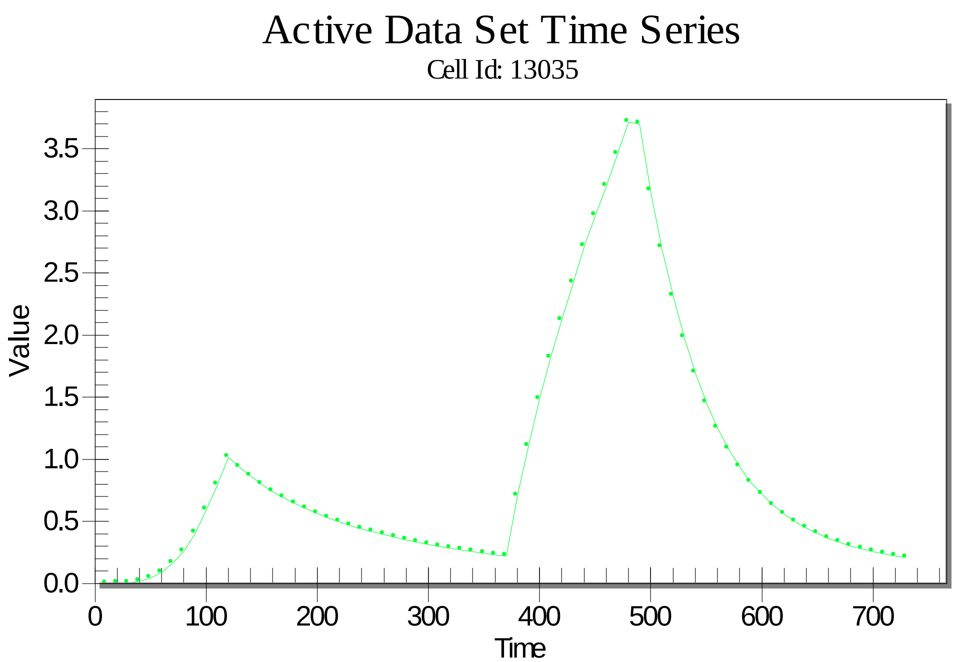

Figure 6 Time series plot of concentration

Close the Plot window and maximize the Graphics Window before continuing.

11.3 Animating the Fresh-Water Surface

Now the user will animate the fresh-water isosurface over time.

1. Select the "Isosurface Animation" display theme.
2. Select the **Select Material Zones** tool.
3. Select the *Edit* | **Select From List** command.
4. Toggle on the *lower_aquifer*.
5. Select **OK**.

The user should now see the lower aquifer and the fresh-water isosurface. There will also be some circles that are visible. Those can be used to select material zones. To avoid having the circles in the animation, the user will change the tool.

6. Select the **Select Cell** tool.
7. Select the Display | **Animate** command.

The defaults will work fine for this animation.

8. Select **Next** on the first page.

9. Select **Finish** on the second page.

After a few minutes an animation should begin playing. Notice how the fresh-water surface is affected by the pumping wells. The user can see how the fresh-water surface passes the northernmost well.

10. Close the *Play AVI Application* to return to GMS.

12 Conclusion

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

- SEAWAT combines MODFLOW and MT3DMS to solve variable density groundwater flow and solute transport problems.
- The user can use the conceptual model approach with SEAWAT models.
- SEAWAT results can be visualized three dimensionally in GMS.

13 Further Reading

1. Langevin, C.D., Shoemaker, W.B., and Guo, W. (2003). MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model–Documentation of the SEAWAT-2000 Version with the Variable-Density Flow Process (VDF) and the Integrated MT3DMS Transport Process (IMT): U.S. Geological Survey Open-File Report 03-426, 43 p.

