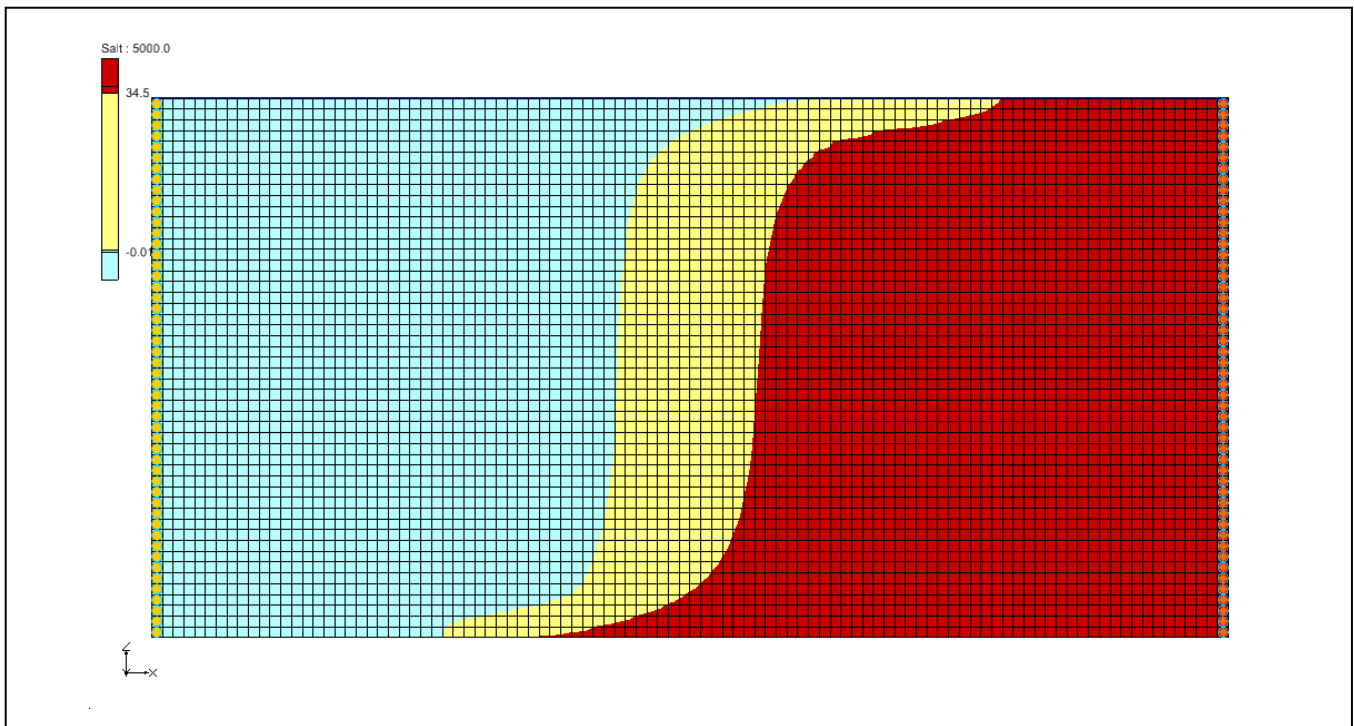


*GMS 10.1 Tutorial*

**SEAWAT – Concentration and Temperature Effects**

Examine Concentration and Temperature Impacts on Fluid Density with SEAWAT



**Objectives**

Learn how to simulate the effects of concentration and temperature on fluid density with SEAWAT.

**Prerequisite Tutorials**

- MODFLOW – Grid Approach
- MT3DMS – Grid Approach

**Required Components**

- Grid Module
- MODFLOW
- MT3D
- SEAWAT

**Time**

- 15–25 minutes



|          |   |          |
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## 1 Introduction

This tutorial describes how to simulate the effects of concentration and temperature on fluid density using SEAWAT. This problem is shown in Figure 1. This problem has a confined aquifer with an initial temperature of 5°C. Warm freshwater is injected from the west side of the model at a 1 m<sup>3</sup>/day. The initial concentration of salt in the model is 35 kg/m<sup>3</sup>. This example problem is very similar to the problem described in the SEAWAT documentation.<sup>1</sup>

This tutorial demonstrates and discusses importing an existing MODFLOW/MT3D simulation, setting up a SEAWAT simulation, running SEAWAT with different scenarios, and comparing SEAWAT results for density effects caused by concentration and temperature.

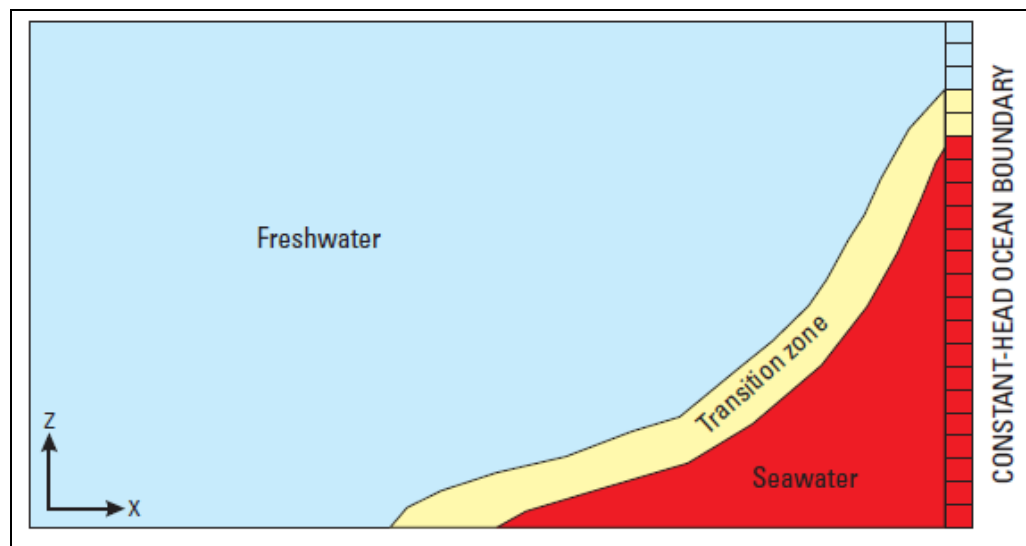


Figure 1 Site to be modeled with SEAWAT

<sup>1</sup> Langevin, Christian. D.; Thorne, Daniel T., Jr.; Dausman, Alyssa M.; Sukop, Michael C.; and Guo, Weixing. (2007). "SEAWAT Version 4: A Computer Program for Simulation of Multi-Species Solute and Heat Transport" in U.S. Geological Survey *Techniques and Methods Book 6*, Chapter A22, 39 p. <https://pubs.usgs.gov/tm/tm6a22/pdf/tm6A22.pdf>.

## 2 Getting Started

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Do the following to get started:

1. If GMS is not running, launch GMS.
2. If GMS is already running, select *File* | **New** to ensure the program settings are restored to the default state.

### 2.1 Importing the Existing Model

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Start with a model that has already been created.

1. Click **Open**  to bring up the *Open* dialog.
2. Select “Project Files (\*.gpr)” from the *Files of type* drop-down.
3. Browse to the `\Tutorials\SEAWAT\Case_Studies` folder and select “start.gpr”.
4. Click **Open** to import the project and exit the *Open* dialog.

A grid similar to Figure 2 should appear. Notice the symbols representing well and specified head boundary conditions on the left and right sides of the model.

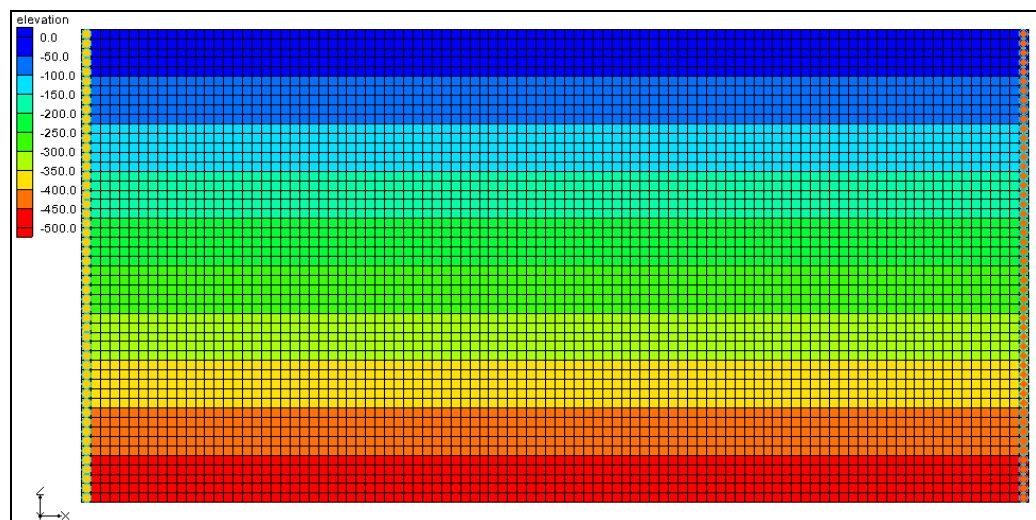


Figure 2 Initial model



## 3 First SEAWAT Scenario

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### 3.1 Initializing the SEAWAT Simulation

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SEAWAT uses a combination of MODFLOW and MT3DMS. Turn on the SEAWAT menu.

1. Fully expand the “ 3D Grid Data” folder in the Project Explorer.
2. Right-click on “ grid” and select **New SEAWAT...** to bring up the *Global Options* dialog.

3. Turn on *Include transport in simulation*.
4. In the *Packages* section, turn on *Variable-Density Flow (VDF)*.
5. Click **OK** to exit the *Global Options* dialog.

### Modifying the VDF Package

For the first scenario, simulate the effect of salinity on the fluid density.

1. Select *SEAWAT / VDF Package...* to open the *SEAWAT VDF Package* dialog.
2. In the *Fluid density calculation* section, enter “1” in the *Fluid density calc (MT3DRHOFLG)* field.

This indicates that the fluid density calculation will be done using the salt species.

3. Enter “1000.0” in the *Reference fluid density (DENSEREF)* field.

This indicates that the reference fluid density (freshwater, in this case) at 25°C is 1000 kg/m<sup>3</sup>.

4. Enter “0.7” in the *Density/conc. Slope (DRHODC)* field.

This *DRHODC* value indicates that the density will vary linearly between 1000 kg/m<sup>3</sup> for freshwater and 1024.5 kg/m<sup>3</sup> for saltwater. *DRHODC* can be estimated by dividing the density difference by the concentration difference. In this case, the result is the following:


$$\frac{1024.5(\text{kg/m}^3) - 1000(\text{kg/m}^3)}{35(\text{kg/m}^3) - 0(\text{kg/m}^3)} = 0.7$$

This means that 35 kg/m<sup>3</sup> is the concentration of salt in saltwater and 0 kg/m<sup>3</sup> is the concentration of salt in freshwater.

5. Click **OK** to close the *SEAWAT VDF Package* dialog.



## 3.2 Saving the Model with a New Name and Running SEAWAT

Now save the changes and run SEAWAT.

1. Select *File / Save As...* to bring up the *Save As* dialog.
2. Select “Project Files (\*.gpr)” from the *Save as type* drop-down.
3. Enter “case1.gpr” as the *File name*.
4. Click **Save** to save the project under the new name and close the *Save As* dialog.
5. Click **Run SEAWAT**  to bring up the *SEAWAT* model wrapper dialog.
6. When SEAWAT finishes, turn on *Read solution on exit* and *Turn on contours (if not on already)*.
7. Click **Close** to import the solution and close the *SEAWAT* model wrapper dialog.

## 3.3 Viewing the Solution

Now view the results of the SEAWAT model run.

1. Select the “ Salt” dataset below the “ case1 (MT3DMS)” solution in the Project Explorer.

The contour options will change because a display theme has been associated with the salt species. To learn more about display themes, see the “Display Themes” tutorial.

2. Compare different time steps in the time step window by selecting various time steps.

Notice the movement of the freshwater (the light blue section). Select time step “10” (it has a value of “5000.0”). The model should appear similar to the one in Figure 3.

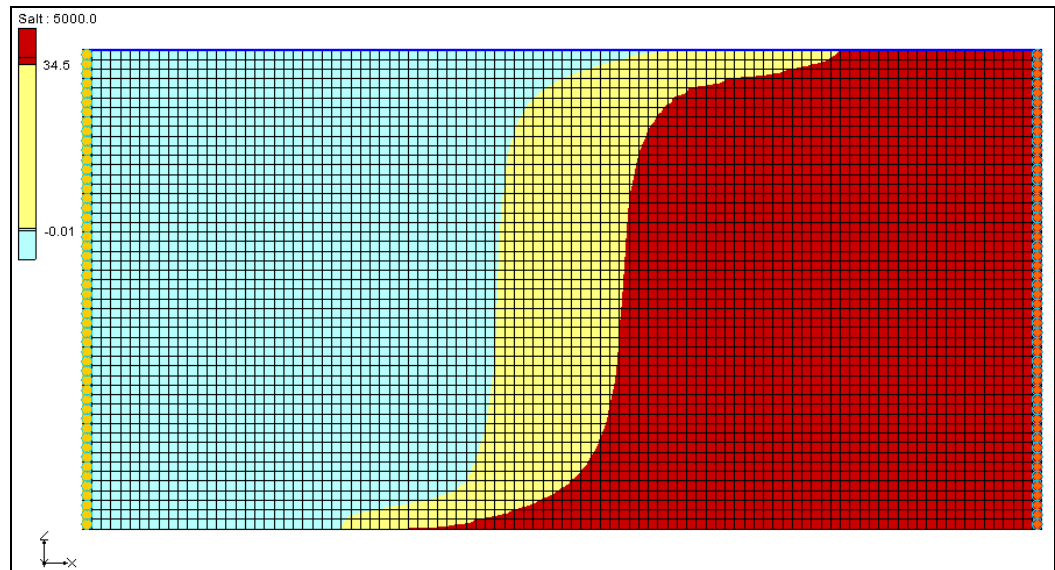



Figure 3 Concentration of salt species at 5000 days

This simulation also includes a temperature species. The “ Temperature” dataset has no effect on the salinity in this scenario. The effect of temperature on the model is examined in the next scenario.

## 4 Second SEAWAT Scenario

### 4.1 Saving the model with a new name

First, save the model with a new name.

1. Select *File / Save As...* to bring up the *Save As* dialog.
2. Select “Project Files (\*.gpr)” from the *Save as type* drop-down.
3. Enter “case2.gpr” as the *File name*.
4. Click **Save** to save the project under the new name and close the *Save As* dialog.

### 4.2 Adding Temperature Effects on Fluid Density


Look at the effect of temperature on the density in this case.

## Modifying the VDF Package

The temperature effects can be activated in the VDF Package.

1. Select *SEAWAT / VDF Package...* to open the *SEAWAT VDF Package* dialog (Figure 4).
2. In the *Fluid density calculation* section, enter “-1” for *Fluid density calc.* (*MT3DRHOFLG*).

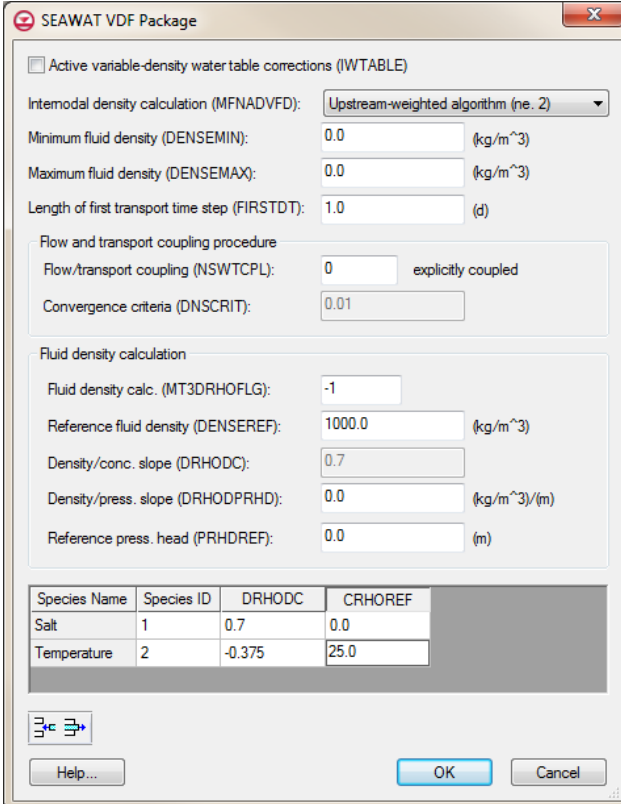
This value means that the fluid density will be calculated using one or more MT3DMS species. In this case, they are *Salt* and *Temperature*.

3. Below the spreadsheet at the bottom, click **Insert Row**  twice to generate two species in the spreadsheet.
4. In the *Species ID* column, enter “1” in the top row and “2” in the bottom row.

Notice that the species names have changed to “Salt” and “Temperature”, respectively.

5. On the *Salt* row, enter “0.7” in the *DRHODC* column and “0.0” in the *CRHOREF* column.
6. On the *Temperature*, enter “-0.375” in the *DRHODC* column and “25.0” for *CRHOREF* column.

The negative value for *DRHODC* means that the fluid density decreases as the temperature increases. *CRHOREF* is the reference (freshwater) concentration/temperature for the species. The reference concentration of *Salt* in freshwater is “0.0” and the reference *Temperature* of freshwater is “25.0”.



SEAWAT VDF Package

Active variable-density water table corrections (IWTABLE)

Intermodal density calculation (MFNADVFD): Upstream-weighted algorithm (re. 2)

Minimum fluid density (DENSEMIN): 0.0 (kg/m<sup>3</sup>)

Maximum fluid density (DENSEMAX): 0.0 (kg/m<sup>3</sup>)

Length of first transport time step (FIRSTD1): 1.0 (d)

Flow and transport coupling procedure

Flow/transport coupling (NSWTCPL): 0 explicitly coupled

Convergence criteria (DNSCRIT): 0.01

Fluid density calculation

Fluid density calc. (MT3DRHOFLG): -1

Reference fluid density (DENSEREF): 1000.0 (kg/m<sup>3</sup>)

Density/conc. slope (DRHODC): 0.7

Density/press. slope (DRHODPRHD): 0.0 (kg/m<sup>3</sup>)/(m)

Reference press. head (PRHDREF): 0.0 (m)

| Species Name | Species ID | DRHODC | CRHOREF |
|--------------|------------|--------|---------|
| Salt         | 1          | 0.7    | 0.0     |
| Temperature  | 2          | -0.375 | 25.0    |

Help... OK Cancel


Figure 4 VDF inputs for second scenario.

7. Leave all other settings at their defaults. The values in the dialog should appear as in Figure 4.
8. Click **OK** to exit the *SEAWAT VDF Package* dialog.

### 4.3 Saving and running SEAWAT

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Now save the changes and run SEAWAT.


1. **Save**  the project
2. Select *SEAWAT / Run SEAWAT...* to bring up the *SEAWAT* model wrapper dialog.
3. When SEAWAT finishes, turn on *Read solution on exit* and *Turn on contours* (if not on already).
4. Click **Close** to import the solution and close the *SEAWAT* dialog.

### 4.4 Viewing the Solution

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Compare the differences between two scenarios.

1. View time step 16 (value of “8000”) in the “ Salt” dataset in “ case1 (MT3DMS)” (Figure 5).
2. View the same dataset and time step in “ case2 (MT3DMS)” (Figure 6).

The light blue portion in the figures represents fresh water and the dark red represents salt water. In “ case2 (MT3DMS)”, notice that the salt water is slightly lower from the top along the left boundary (by about one grid row) and slightly closer to the right boundary along the bottom of the model (by about 10 grid columns). More of the fresh water is “floating” on top of the salt water in “case2” because the fresh water is less dense. This is because SEAWAT is considering temperature in the density calculations.

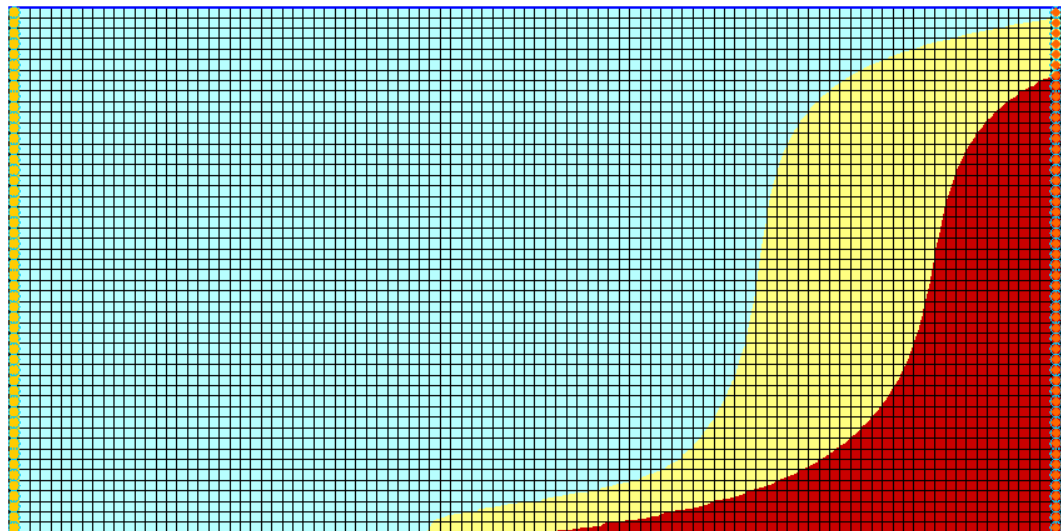


Figure 5 Salt concentration at time step 16 in case1

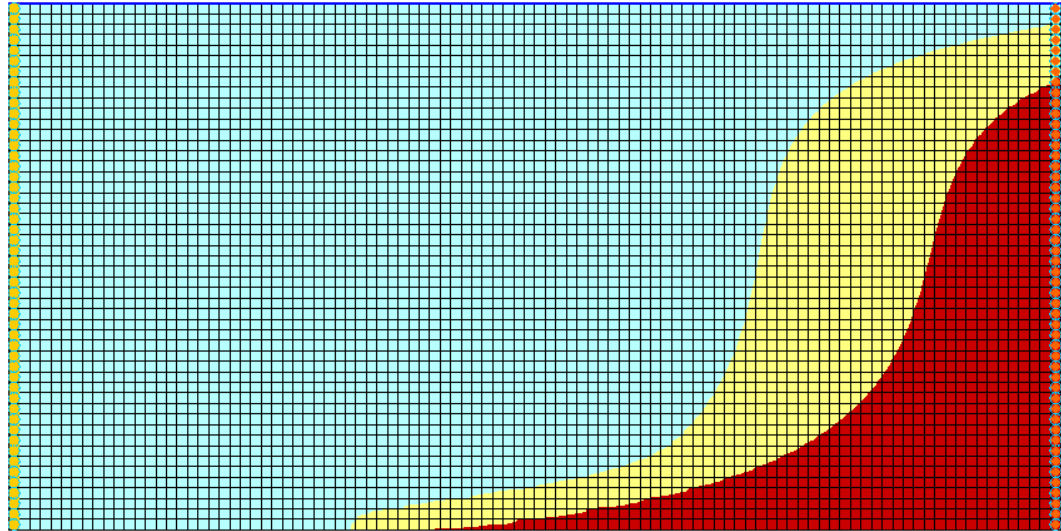


Figure 6 Salt concentration at time step 16 in case2

## 5 Conclusion

This concludes the “SEAWAT – Concentration and Temperature Effects” tutorial. The following key concepts were discussed and demonstrated in this tutorial:

- SEAWAT combines MODFLOW and MT3DMS to solve variable density groundwater flow and solute transport problems.
- SEAWAT simulates the effect of concentration and temperature on fluid density.