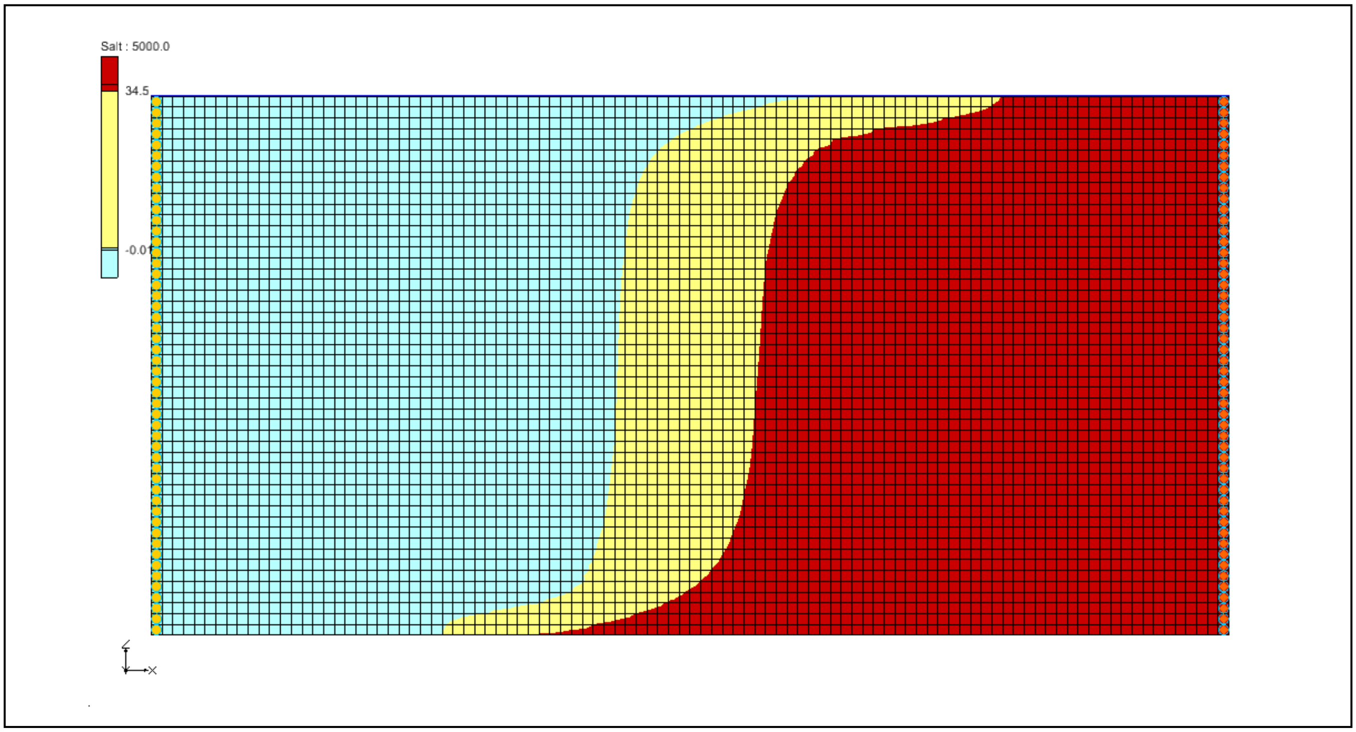
v. 9.2

GMS 9.2 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
- MODFLOW
- MT3D
- SEAWAT

Time

- 30-60 minutes

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1 Contents

2 Introduction

This tutorial describes how to simulate the affects of concentration and/or temperature on fluid density using SEAWAT.

2.1 Outline

This is what you will do:

1. Import an existing MODFLOW/MT3D simulation.
2. Set up a SEAWAT simulation.
3. Run SEAWAT with different scenarios.
4. Compare SEAWAT results for density effects caused by concentration and temperature.

3 Description of Problem

Our problem is shown in Figure 1; this is a confined aquifer with an initial temperature of 5^{o}C. Warm freshwater is injected from the west side of the model at a 1 m^3/day. The initial concentration of salt in the model is 35 kg/m^3.

We will examine the effects of salinity and temperature on density in this example. This example problem is very similar to the problem described in the SEAWAT documentation[1].

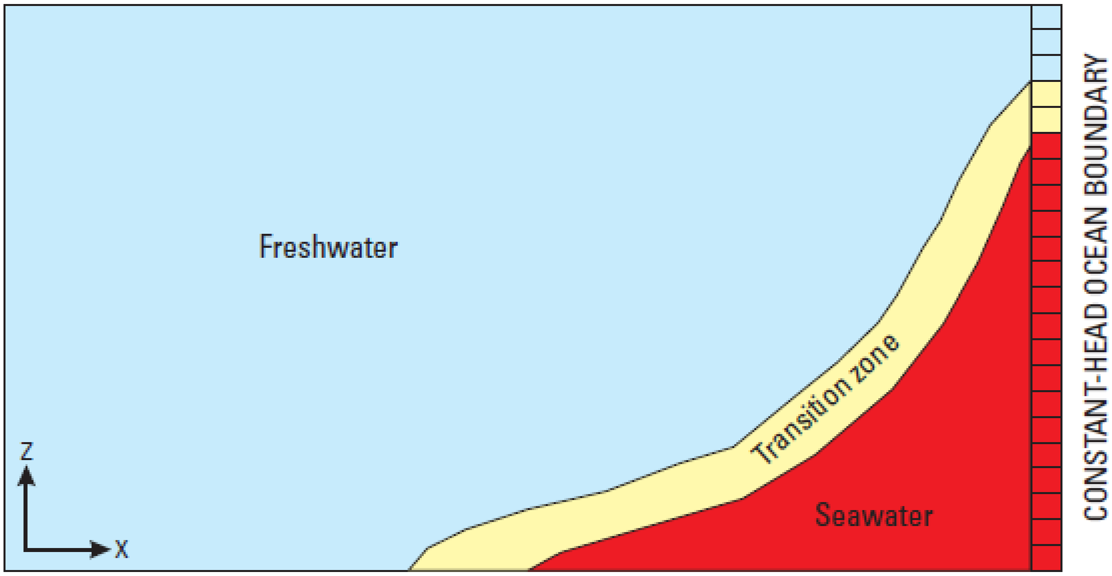

Figure 1. Site to be modeled with SEAWAT.

4 Getting Started

If you have not yet done so, launch GMS. If you have already been using GMS, you may wish to select the *File* | *New* command to ensure the program settings are restored to the default state.

5 Importing the Existing Model

We will start with a model that has already been created.

1. Select the *Open* button (or the *File* | *Open* menu command).
2. Browse to the **\Tutorials\SEAWAT\Case_Studies** folder.
3. Select the **start.gpr** file and click *Open*.

This imports the model. You should see a grid with symbols representing well and specified head boundary conditions similar to the figure below.

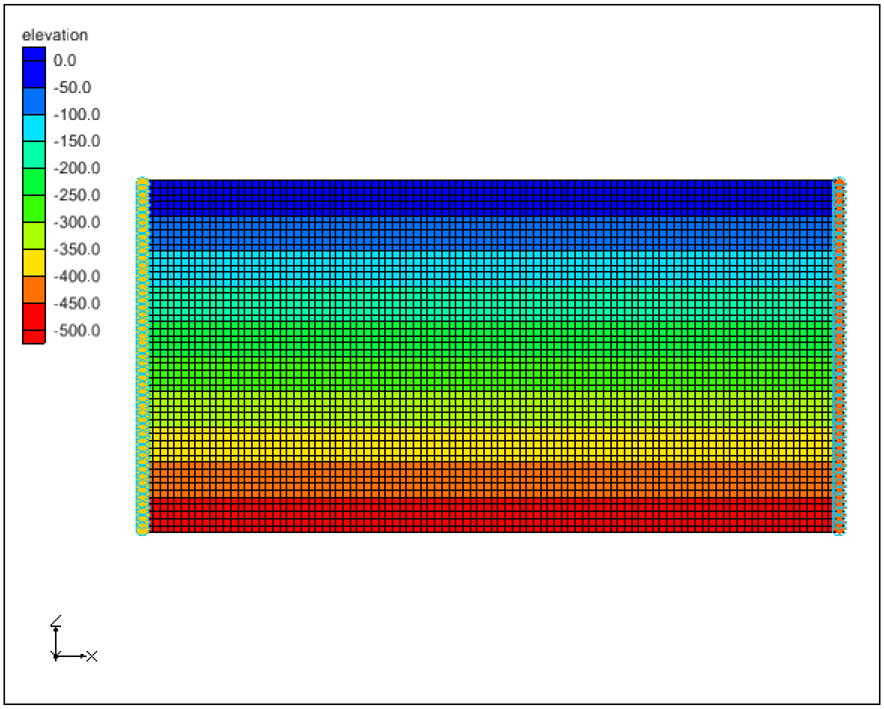

Figure 2. Initial model

6 Initializing the SEAWAT Simulation

SEAWAT uses the combination of MODFLOW and MT3DMS. We need to turn on the SEAWAT menu.

1. Expand the **3D Grid Data** folder.
2. Right click on the **grid** item in the *Project Explorer* and select the *New SEAWAT* menu command.
3. Turn on *Include transport in simulation* and *Variable-Density Flow (VDF).*
4. Select the *OK* button to exit the dialog.

6.1 Modifying the VDF Package

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

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

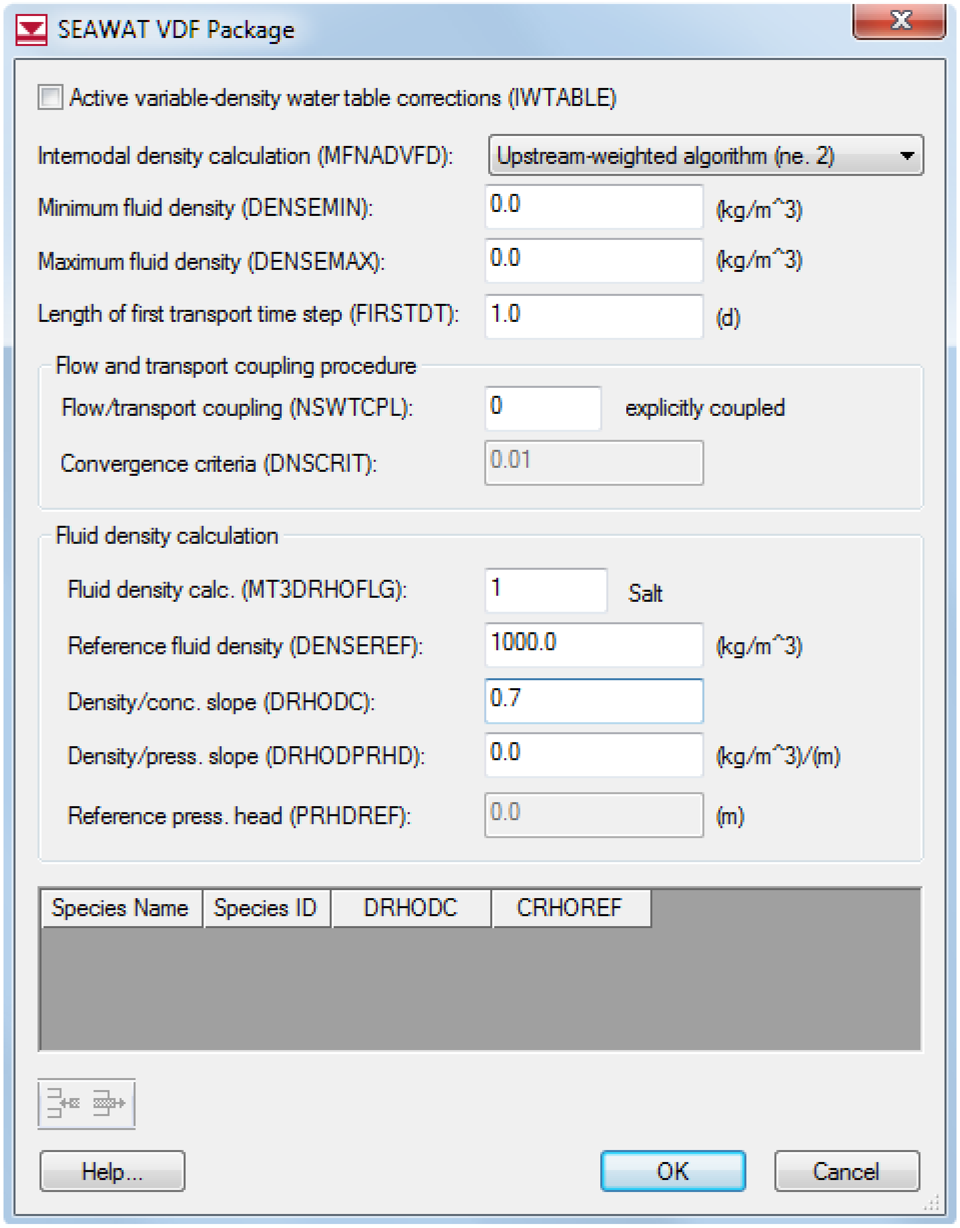

Figure 3. *VDF Inputs for 1st scenario.*

MT3DRHOFLG, DENSEREF and DRHODC are three important inputs for this scenario. A value of 1 for MT3DRHOFLG indicates that fluid density calculation will be calculated using the **Salt** species. A DENSEREF value of 1000 indicates that the reference fluid density (freshwater in this case) at 25°C is 1000 kg/m^3. A DRHODC value of 0.7 indicates that the density will vary linearly between 1000 kg/m^3 for freshwater and 1024.5 kg/m^3 for saltwater.

DRHODC can be estimated by dividing the density difference by the concentration difference. In this case, we have:

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

35 kg/m^3 is the concentration of salt in saltwater; and 0 kg/m^3 is the concentration of salt in freshwater.

3. Select the *OK* button.

7 Saving the Model with a New Name and Running SEAWAT

We are ready to save our changes and run SEAWAT.

1. Select the *File* | *Save As* menu command.
2. Change the project name to **case1**.
3. Save the project by clicking the *Save* button.
4. Select the *SEAWAT* | *Run SEAWAT* command.
5. When SEAWAT finishes select the *Close* button.

8 Viewing the Solution

We will now view the results of the SEAWAT model run.

1. Select the **Salt** data set 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. Select different time steps in the time step window.

Notice the movement of the freshwater. If you select time step 5000.0 you should see something similar to the figure below.

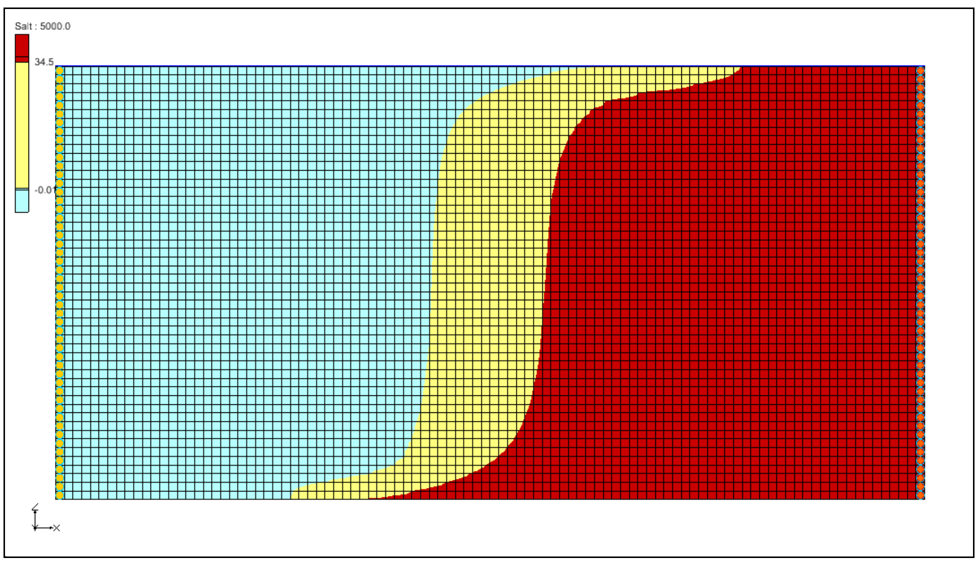

Figure 4. Concentration of Salt Species at 5000 Days

9 Saving the model with a new name

This simulation also included a "temperature" species. The **Temperature** data set has no effect on the salinity in this scenario. The effect of temperature on the model is examined in the next scenario.

We're ready to start the next scenario. Let's save the model with a new name.

1. Select the *File* | *Save As* menu command.
2. Change the project name to **Case2**.
3. Save the project by clicking the *Save* button.

10 Adding Temperature Effects on Fluid Density

We'll look at the effect of temperature on the density in this case.

10.1 Modifying the VDF Package

The temperature effects can be activated in the *VDF Package.*

1. Select the *SEAWAT* | *VDF Package* command
2. Enter a value of -1 for MT3DRHOFLG.

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

3. Click on twice to generate two species.
4. In *Species ID* column, enter **1** and **2** for each corresponding row.

Notice that the species names have changed to *Salt* and *Temperature* respectively.

5. For *Salt*, enter **0.7** for *DRHODC* and **0** for *CRHOREF*.
6. For *Temperature*, enter **-0.375** for *DRHODC* and **25** for *CRHOREF*.

Notice the *DRHODC* value for **Temperature** is negative. The negative value 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 and the reference **Temperature** of freshwater is 25.

7. Your VDF inputs should be the same as the following figure:

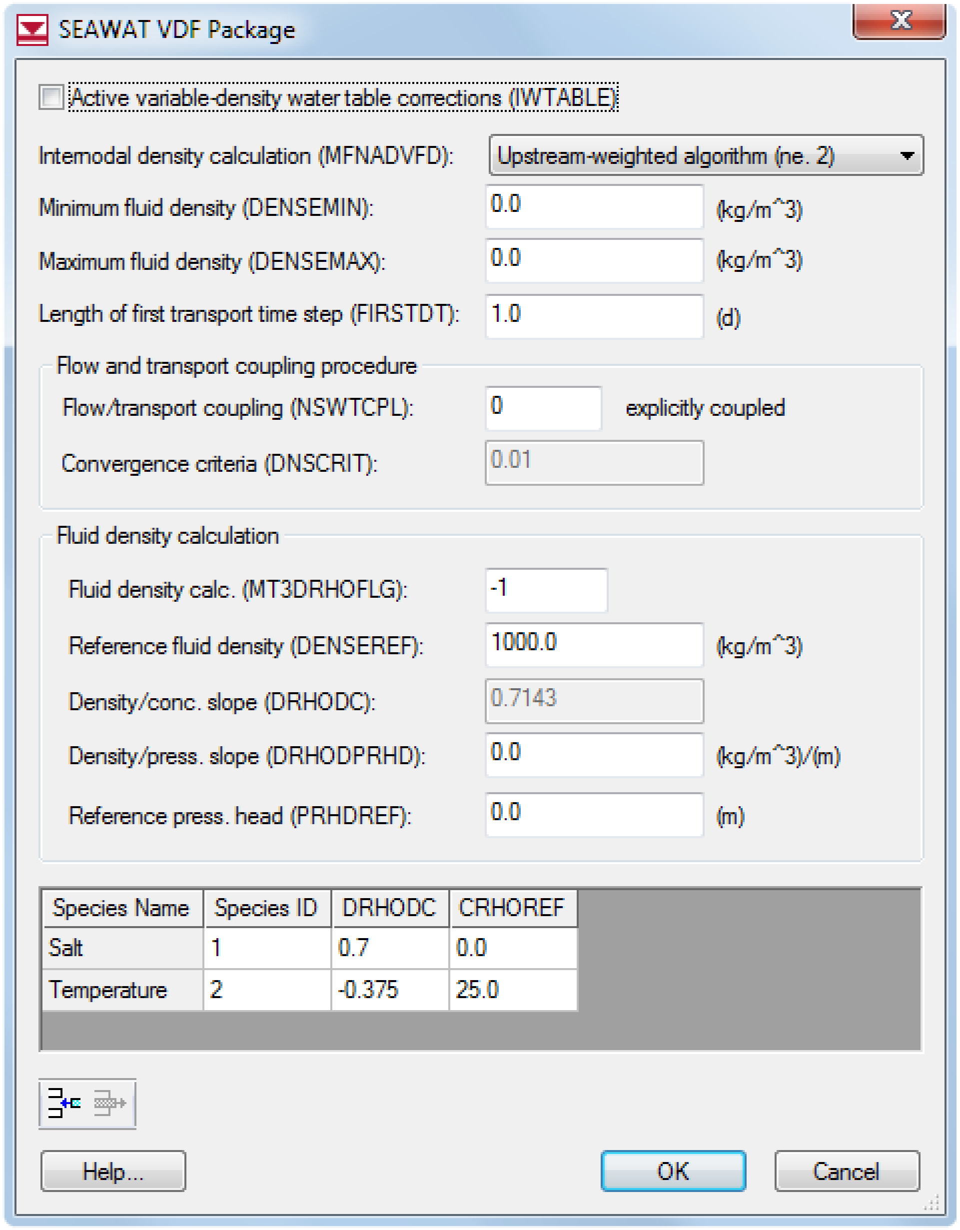

Figure 5. VDF Inputs for 2nd scenario.

8. Select *OK* to exit the dialog.

11 Saving and running SEAWAT

We are ready to save our 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.

12 Viewing the Solution

We will compare the differences between two scenarios.

1. Switch between the **Salt** data set in **case1 (MT3DMS)** and **case2 (MT3DMS)**. Change the time step to **8000.0** for both data sets and view the differences. You should see something similar to the figure below.

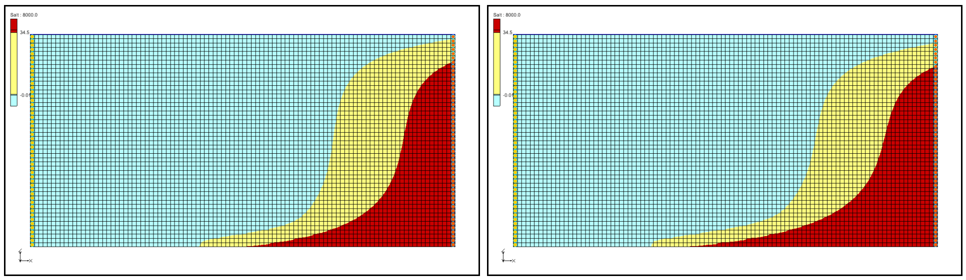

Figure 6 Comparison of Salt concentration at time step 8000.0

case1 is shown on the left and **case2** is shown on the right. The light blue portion in the figure represents fresh water and the dark red represents salt water. Notice that in **case2** the salt water is slightly lower from the top along the left boundary and slightly closer to the right boundary along the bottom of the model. More of the fresh water is "floating" on top of the salt water in **case2** where the fresh water is less dense because SEAWAT is considering temperature in the density calculations.

13 Conclusion

This concludes the SEAWAT - Concentration and Temperature Effects tutorial. Here are the things that you should have learned 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.

14 Notes

1. Langevin, C.D., Thorne, D.T., Jr., Dausman, A.M., Sukop, M.C., and Guo, Weixing, 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.