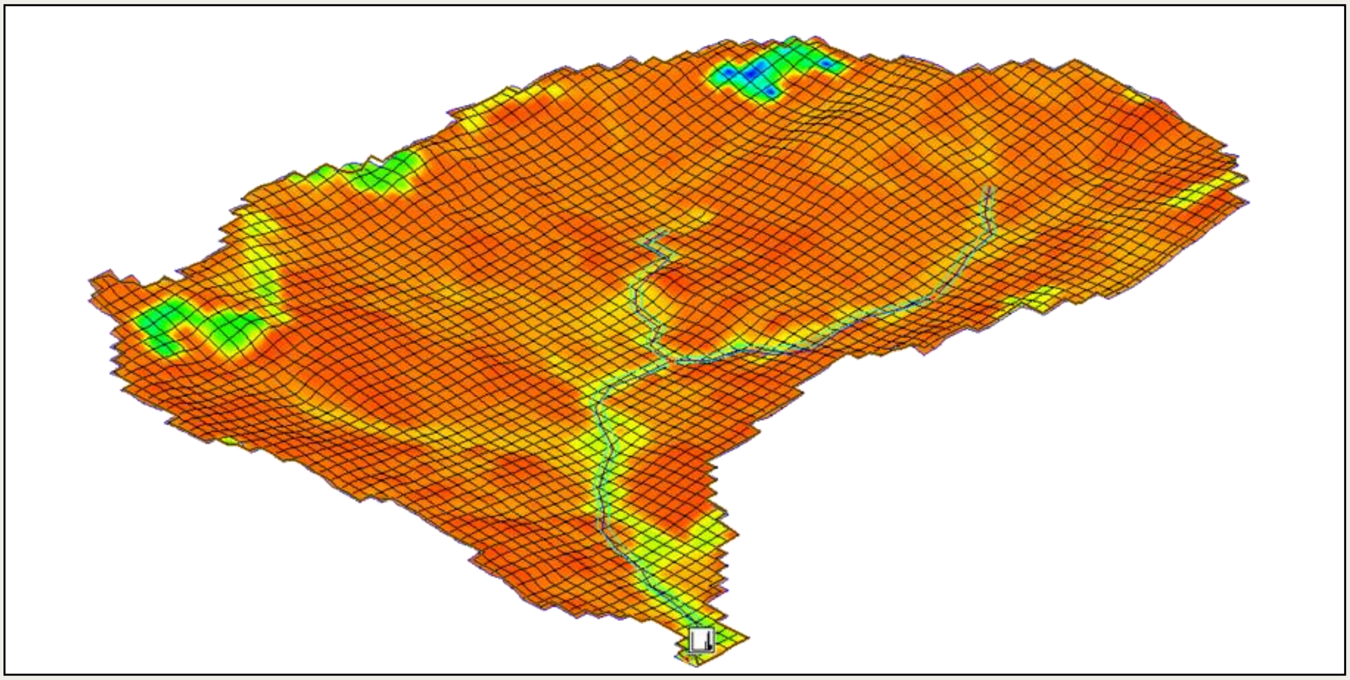
WMS 11.4 Tutorial

Groundwater Modeling in GSSHA

Setup a basic groundwater model using GSSHA



Objectives

Learn how to set up a groundwater model from a basic GSSHA long term model.

Prerequisite Tutorials

- Long Term Simulations in GSSHA

Required Components

- WMS Core
- GSSHA Model

Time

- 30–60 minutes

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1 Introduction

This tutorial teaches how to set up a groundwater model in GSSHA. It begins with an existing long term simulation project with all the parameters for a basic surface water simulation already defined.

2 Open an Existing GSSHA Project

Open a GSSHA project file for the Eight Mile Creek watershed.

1. Make the **2D Grid Module** active.
2. Select *GSSHA* **| Open Project File…** to bring up the *Open* dialog.
3. Locate the *data files* folder for this tutorial, and select the file "Base.prj" file.
4. Click **Open** to import the project.
5. In the Project Explorer, turn off " Map Data" then turn on the " GSSHA" coverage.

The project should appear similar to Figure 1.

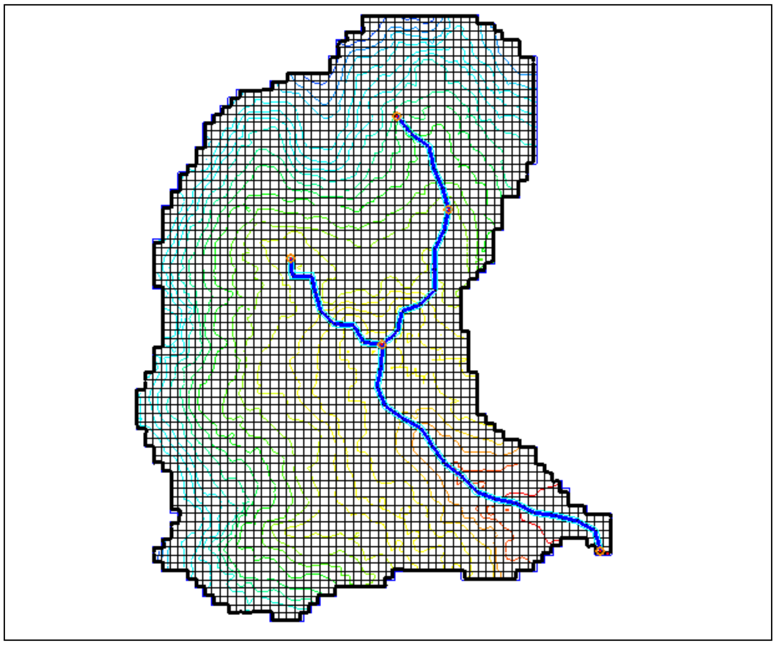

Figure 1 Initial project

Before continuing, save the project under a new name.

6. Select *GSSHA* | **Save Project File** to open the *Save GSSHA Project File* dialog.
7. Enter the *File Name* as "GW.prj" and click **Save** to create the project and close the *Save GSSHA Project File* dialog.

3 Creating Groundwater Datasets

To simulate groundwater in a GSSHA model, the following index maps and tables need to be defined:

- Aquifer bottom map,
- Initial water table elevation map
- Boundary condition map
- Subsurface hydraulic conductivity map
- Subsurface porosity map

The aquifer bottom and water table elevation maps are created from x, y, z points stored in a CSV file. These points were derived from borehole logs. The hydraulic conductivity and porosity inputs will be developed using a geology shape file.

3.1 Aquifer Bottom

The aquifer bottom map is created from XYZ data of the aquifer bottom. These data can be derived from borehole data that contain information about depth to different layers in the subsurface.

1. Select *File* | **Open** to bring up the *Open* dialog.

2. Select the file “aquifer_bot_elevs.csv” and click **Open** to bring up the *File Import Wizard* dialog.
3. Turn on *Space* and *Comma* under *Set the column delimiters*.
4. Change *Start import at row* value to “2”.
5. Ensure *Heading Row* is turned off.

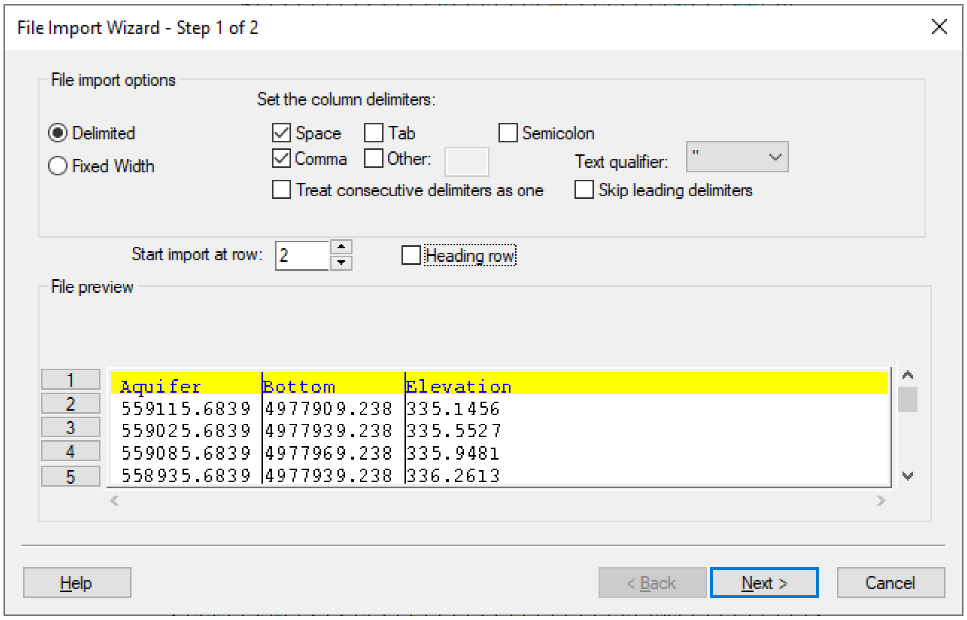

Figure 2 File Import Wizard – Step 1 of 2

6. Click **Next>** to go to *Step 2 of 2* of the *File Import Wizard* dialog.
7. Set *WMS data type* to “2D Scatter Points” from the drop-down menu.
8. In the *Type row,* under *File Preview,* use the drop-down arrows to set the first column to “X”, the second column to “Y", and the third column to “Dataset.

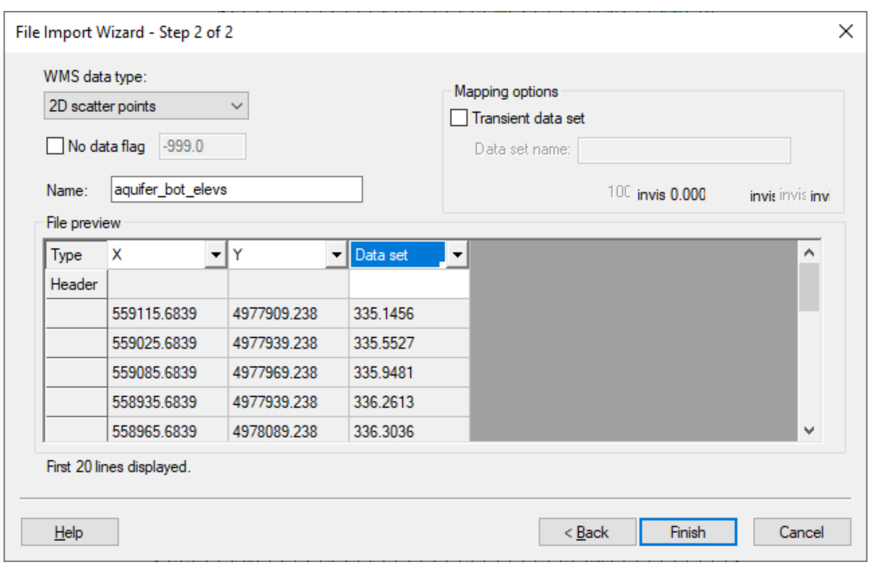

Figure 3 File Import Wizard – Step 2 of 2

9. Click **Finish** to import the dataset as a 2D scatter point dataset.

A new scatter point dataset named "aquifer_bot_elevs" should appear in the Project Explorer and the points are plotted in the Graphics Window.

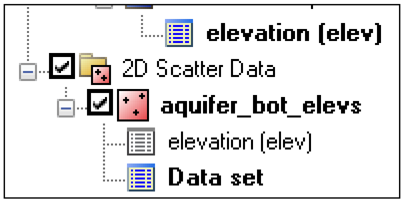

Figure 4 2D Scatter set in the Project Explorer

10. Make sure "Data set" is selected as the active dataset.
11. Right-click on the "aquifer_bot_elevs" scatter set and select *Interpolate* | **...To Grid**.to open the *Interpolate to 2D Grid* dialog.
12. Change the *New interpolated dataset name* to "Aquifer Bottom".
13. Check that *Map elevations* is off and turn off if necessary.
14. Click **OK** to close the *Interpolate to 2D Grid* dialog and to create a new grid dataset from the aquifer bottom scatter points.

A new continuous map named "Aquifer Bottom" should be visible among the other continuous datasets for the grid.

15. Under "GW" folder in the Project Explorer, right-click on the "Continuous Maps" folder and select *Assign* | **Aquifer Bottom**.

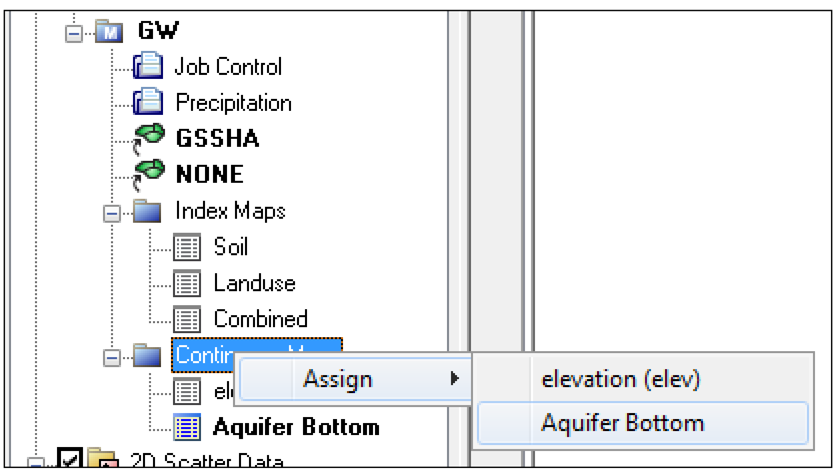

Figure 5 Assigning dataset to the continuous maps

3.2 Initial Water Table Elevations

Ideally, there will be observation well data from which to derive an initial representation of the water table. This XYZ data can be interpolated to the grid to develop the required continuous map in the same way the aquifer bottom map was created. In lieu of measured values, develop an initial water table by assuming an initial water table and running GSSHA to derive a water table map. In this example, use XYZ data that represent well water surface elevations scattered throughout the domain.

1. Select *File* | **Open** to bring up the *Open* dialog.

2. Select the file "water_table_elevs.csv" and click **Open** to bring up the *File Import Wizard* dialog.
3. Turn on *Space* and *Comma* under *Set the column delimiters:* section.
4. Change *Start import at row* value to "2".
5. Turn off the *Heading Row* option if turned on.
6. Click **Next>** to go to *Step 2 of 2* of the *File Import Wizard* dialog.
7. Make sure the *WMS data type* is set to "2D Scatter Points".
8. On the *Type* row, under *File Preview,* use the drop-down arrows to set the first column to "X", the second column to "Y", and the third column to "Dataset.
9. Click **Finish** to import the dataset as a 2D scatter point dataset.

A new scatter point dataset named " water_table_elevs" should appear in the Project Explorer and the points are plotted.

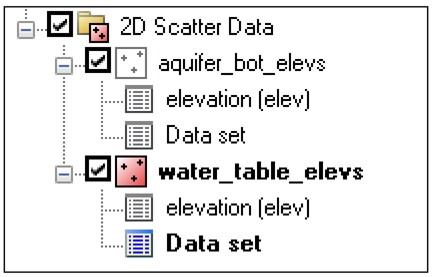

Figure 6 Scatter sets in the Project Explorer

10. Under " water_table_elevs", select " Data set" to make it active.
11. Right-click on the " water_table_elevs" scatter set and select *Interpolate* | **...To Grid** to open the *Interpolate to 2D Grid* dialog.
12. Change the *New interpolated dataset name* to "Initial Water Table".
13. Check *Map elevations* to make sure it is off. Turn off if necessary.
14. Click **OK** to close the *Interpolate to 2D Grid* dialog and to create a new grid dataset.
15. In the Project Explorer, under the " GW" folder, right-click on " Continuous Maps" and select *Assign* | **Initial Water Table**.

Notice the new continuous map named " Initial Water Table" among the other continuous datasets of the grid.

3.3 Checking Water Table Elevation Data

After interpolating the water table XYZ data to define the water table elevation map, the water table elevation at some locations could be higher than the ground elevation or lower than the aquifer bottom which is not desirable. Be sure to check this and fix any anomalies before using the water table elevation map with the model.

One of the easiest ways to check this is to use the data calculator to subtract the water table map from the elevations map or subtract the aquifer bottom from the water table elevations.

1. With the **2D Grid Module** active, select *Data* | **Data Calculator** to open the *Data Calculator* dialog.
2. Double-click "elevation (elev)" data which will insert a dataset symbol such as "d1" in the *Expression* field.

Note that the dataset symbol might be different in this case.

3. Click the "-"(minus) button or type it from the keyboard.
4. Double-click the "Initial Water Table" dataset.
5. Enter "Elev-Water table" in *Result* field.

The data calculator will look similar to Figure 7:

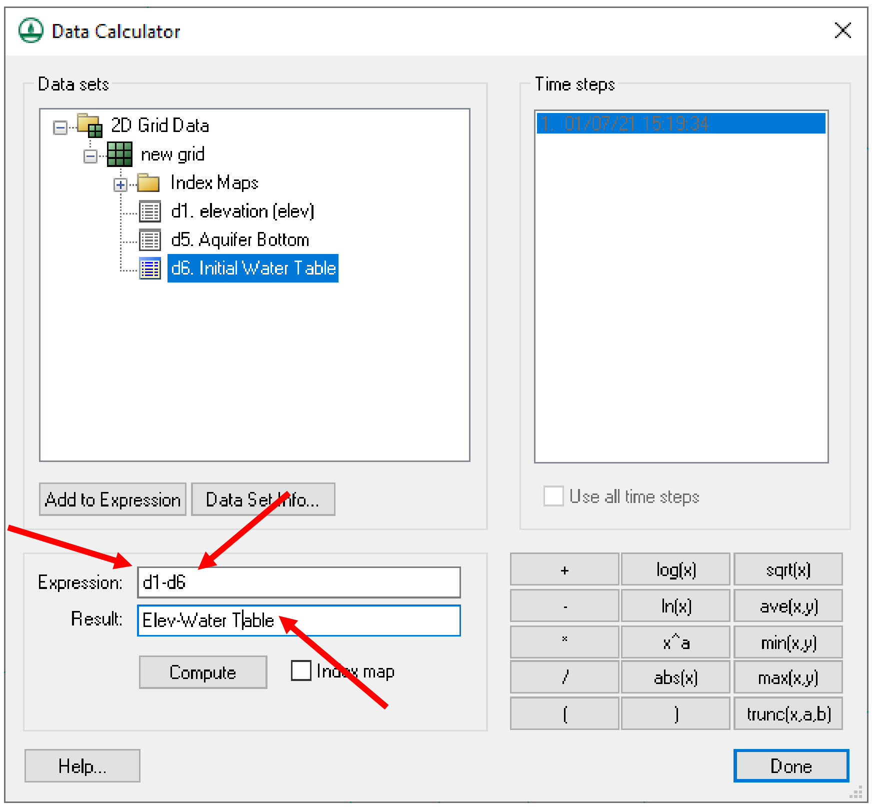

Figure 7 The Data Calculator

6. Click **Compute** to create the new dataset.
7. Click **Done** to close the *Data Calculator* dialog.
8. In the Project Explorer, under " new grid", right-click on the " Elev-Water table" map and select **Properties** to open the *Data Set Info* dialog.

In the *Data Set Info* dialog, notice the *Histogram* of the values in the data selected.

9. Double-click on the plot area to open the *Histogram Customization…* dialog.
10. Select the **Maximize** button.

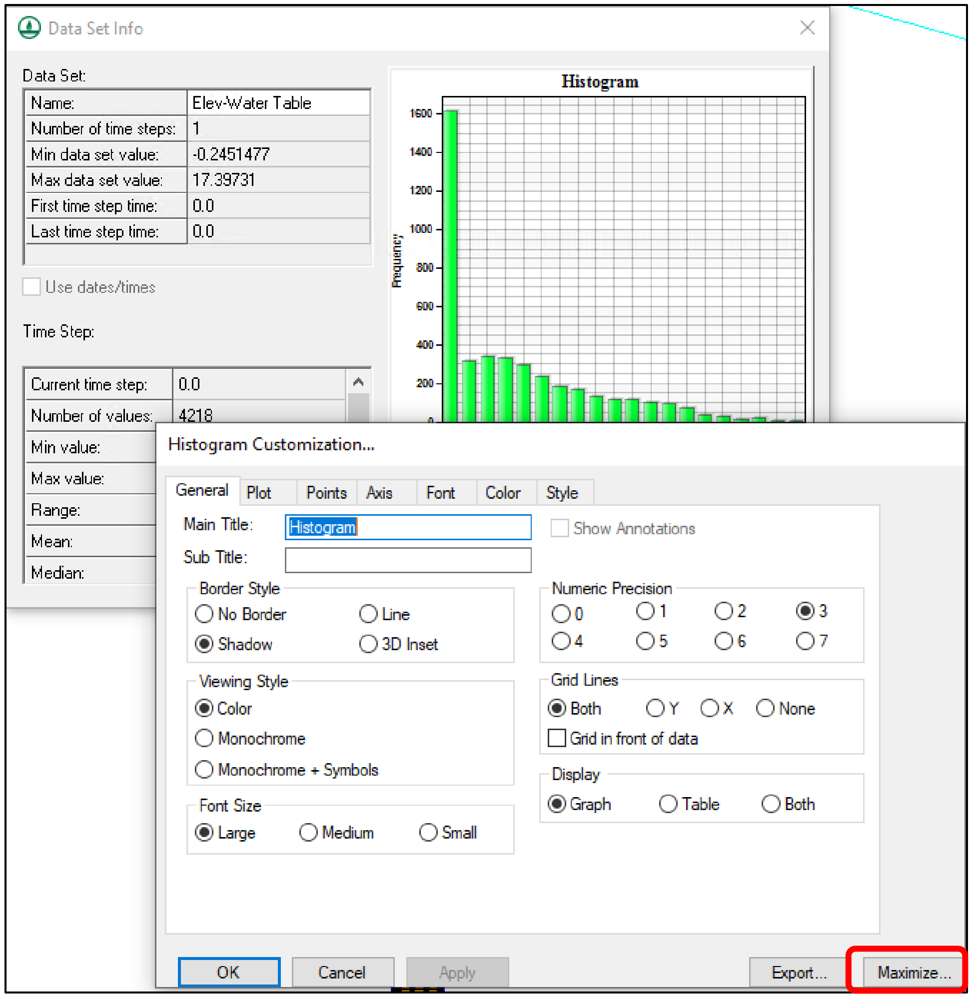

Figure 8 Maximize button location

In the maximized histogram plot, check to see if there are any negative values.

This example has a negative value. This means that the water table elevation is greater than the ground elevation at these cells. If desired, change the contour options to display the locations where the negative values occur.

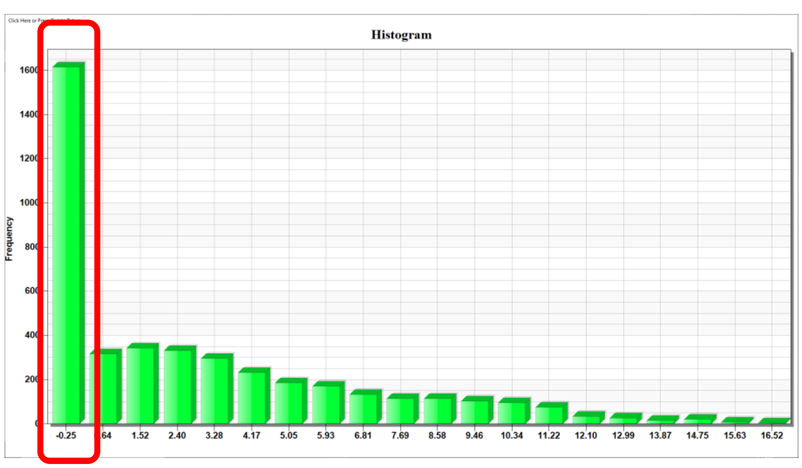

Figure 9 Histogram with showing where negative values occur

Similarly, if desired, use the expression *InitialWaterTable – Aquifer Bottom* in the data calculator to see if any cells have a water table elevation that is below the aquifer bottom. Then view the properties of the new dataset to see if there are any negative values. There are negative values in this case which means that, for some cells, the water table elevation is lower than the aquifer bottom.

11. When done, close the histogram plot by clicking on the window bar.
12. Click **Cancel** to close the *Data Set Info* dialog.

3.4 Adjusting the Water Table Elevation Data

There are different ways to get around having a water table elevation that is lower than the aquifer bottom. This exercise will explore using the **max(x, y)** and **min(x, y)** functions available in the *Data Calculator*. These functions pick the maximum and minimum value from two datasets and assign them to the new dataset.

The water table dataset should be adjusted so it is:

- At least 0.25m below the ground surface
- At least 0.5m above the aquifer bottom

This can be done by using the **min(x, y)** function to select the lesser of the water table and the ground surface elevation values. Then, subtract 0.25m from this so that the water table is at least 0.25m below the ground surface. Finally use the **max(x, y)** function between the result from the previous step and the aquifer bottom and add 0.5m to it. This ensures that the water table is at least 0.5m higher than the aquifer bottom.

The user may create a new water table dataset for each step or use the following formula directly:

Max(*(****min****(InitialWaterTable, ground elevation)-0.25), (aquifer bottom +0.5))*

Use the formula to create a new water table dataset.

1. With the **2D Grid Module** active, select *Data* | **Data Calculator…** to open the *Data Calculator* dialog.
2. In the *Expression* field, enter the modified water table equation as seen below, ensuring that values match the index map names:

   max((min(d6,d1)-0.25),(d5+0.5))

3. Enter "New Water Table" in the *Result* field.
4. Click **Compute** to create the new dataset.
5. Click **Done** to close the *Data Calculator* dialog.

Once the updated water table map is computed, it should automatically get associated with the current GSSHA model.

If " New Water Table" is listed under the " Continuous Maps" folder under the GSSHA model " GW", then it is already assigned. If it is not listed, use the following step:

6. In the Project Explorer, under " GW", right-click on the " Continuous Maps" folder and select *Assign* | **New Water Table**.

3.5 Hydraulic Conductivity and Porosity

To define the hydraulic conductivity and porosity, use a geology shapefile which has information about the underground soil type distribution. In GSSHA, hydraulic conductivity and porosity are used to derive the values of transmissivity and storage.

1. In the Project Explorer, right-click on " Coverages" and select **New Coverage** to bring up a *Properties* dialog.
2. Select "Soil Type" from the drop-down menu for *Coverage type.*
3. Change the *Coverage name* to "Geology".
4. Select **OK** to close the *Properties* dialog*.*

This will add a coverage named " Geology" under the " Coverages" folder.

5. Select *File* | **Open** to bring up the *Open* dialog.
6. Select the file "Geology.shp" and click **Open** to import the shapefile in the GIS module.
7. Make sure that the " Geology" coverage is selected and " Geology.shp" is active.
8. In the **GIS module** , select *Mapping* | **Shapes** → **Feature objects** to bring up the *GIS to Feature Objects Wizard*.
9. Make certain *Select a coverage for mapping* is set to "Geology" and that *Select shapefile to map* has "Geology.shp" checked.
10. Click **Next>** to go to *Step 2 of 3*.
11. Accept the default mapping options and click **Next>** to go to *Step 3 of 3 (Finished)*.
12. Click **Finish** to close the *GIS to Feature Objects Wizard*.

The geology shapefile has now been mapped to the map coverage. Feel free to delete the shapefile from the Project Explorer and turn off the display of " Geology" coverage.

13. Select the " GSSHA" coverage to make this coverage active.
14. In **2D Grid Module** , select *GSSHA* | **Maps…** to open the *GSSHA Maps* dialog.
15. Under the *Index–Grid* tab, select "Geology" as the *Input coverage* and "Texture" as the *Coverage attribute*.
16. Enter "Geology" for the *Index map name*.
17. Click **Coverages→Index Map**.
18. When the index map is finished, click **Done** to close the *GSSHA Maps* dialog.

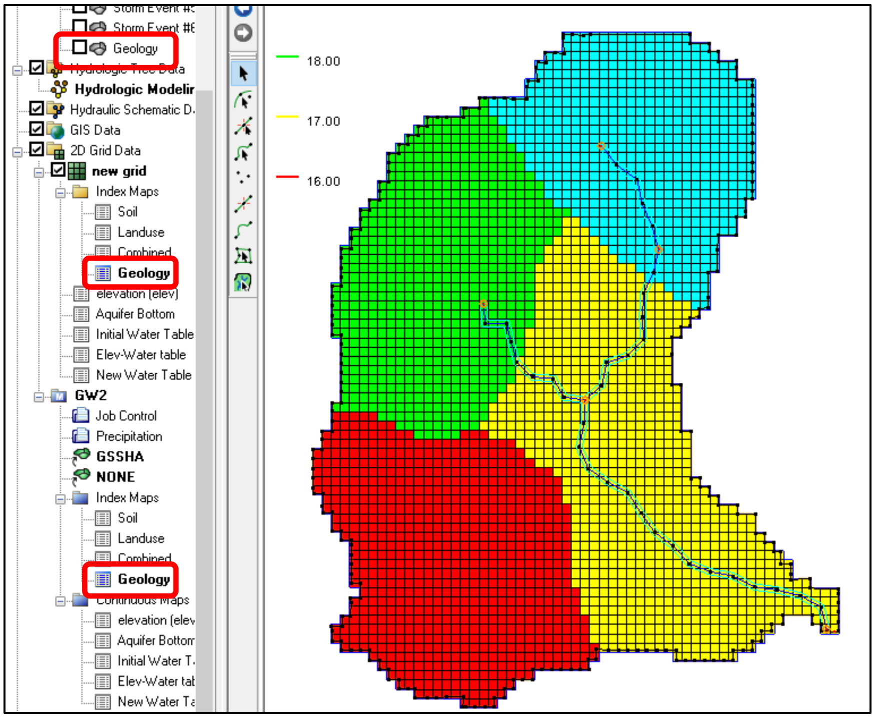

Figure 10 Geology shapefile mapped to GSSHA

4 Groundwater Job Control

Now to assign the job control parameters to use groundwater by doing the following:

1. Select *GSSHA* | **Job Control** to open the *GSSHA Job Control Parameters* dialog.
2. In the right-most column, turn on the *Groundwater* option
3. Click the **Edit parameter** button next to *Groundwater* to open the *GSSHA Groundwater* dialog.

Note: When turning on the groundwater option, a groundwater boundary condition index map named “ Gw boundary” is created automatically in the Project Explorer. Also, GSSHA assumes a no-flow groundwater boundary condition around the perimeter of the watershed.

4. In the *Dataset* column, set *Aquifer bottom* to “AquiferBottom”.
5. Set *WaterTable* to “New WaterTable”.

The *Hydraulic Conductivity* and the *Porosity* will be set for the groundwater mapping table in the next section.

6. In the *Groundwater* section, set the following values:
   - Set *Time Step* to be “600”.
   - Set the *LSOR direction* to “Horizontal”.
   - Set the *LSOR convergence* to “0.00001”.
   - Set the *Relaxation coefficient* to “1.2”.

- Set the *Leakage rate* to "0.0".

7. Click **OK** to close *GSSHA Groundwater* dialog.
8. Click **OK** to close the *GSSHA Job Control Parameters* dialog.

5 Groundwater Map Table

The hydraulic conductivity and porosity maps have not been defined for groundwater model yet. Use the geology index map to define these values in a groundwater mapping table.

1. Select *GSSHA* | **Map Tables…** to open the *GSSHA Map Table Editor* dialog.
2. Select the *Groundwater* tab.
3. For *Using index map,* select "Geology" from the drop-down menu.
4. Click **Generate IDs**.

Notice the four different IDs.

5. Enter the values as shown in the following table, ensuring the correct values match the parameter name:

Parameter	Loamy Sand	Sandy Loam	Loam	Silt Loam
Hydraulic Conductivity	5.98	2.18	1.32	0.68
Porosity	0.437	0.453	0.463	0.501

6. Click **Done** to close the *GSSHA Map Table Editor* dialog.

6 Verifying Long Term Simulation Data

Before running the groundwater model, make sure that the long term simulation is set up correctly.

1. Select *GSSHA* | **Job Control** to open the *GSSHA Job Control Parameters* dialog.
2. On the far right, next to the *Long term simulation* option, click **Edit parameters** to open the *Long Term Simulation* dialog.
3. Enter the following values if not already set to them:
   - *Latitude* to "44.81"
   - *Longitude* to "267.83"
   - *GMT* to "-6" hours
   - *Minimum Event Discharge* to "0.1" cms
   - *Soil Moisture depth* to "0.25" m.
4. Under *HMET* (right side), next to the *HMET data file* option, click on the browse button to bring up an *Open* dialog.
5. Select the file "HMETData.txt" and click **Open**.
6. Set *Format* is to *WES*.
7. Click **OK** to close the *Long Term Simulation* dialog.

7 Setting Output Control

1. In *GSSHA Job Control Parameters* dialog, click **Output Control** to open the *GSSHA Output Control* dialog.
2. In the *Gridded datasets* section, turn off *Surface Depth.*
3. Turn on *Groundwater elevations.*
4. Turn on *Cumulative groundwater recharge*.
5. Change the *Write frequency* to “180” minutes.
6. Leave the *Hydrograph Write frequency* as it is.
7. Click **OK** to close the *GSSHA Output Control* dialog.
8. Click **OK** to close the *GSSHA Job Control Parameters* dialog*.*

8 Saving and Running the GSSHA Model

The project is now ready to be saved, and the GSSHA model can be run.

1. Select *GSSHA* **| Save Project File** to open the *Save GSSHA Project File* dialog.
2. Enter the *File Name* as “GW.prj” and click **Save** to create the project and close the *Save GSSHA Project File* dialog.
3. Select *GSSHA* **| Run GSSHA** to bring up the *GSSHA Run Options* dialog.
4. Click **OK** to close the *GSSHA Run Options* dialog and bring up the *Model Wrapper* dialog.

The model should take about 10–15 minutes to run, depending on the capacity of the computer.

5. When the model run is complete, turn on *Read solution* on exit and click **Close** to exit the *Model Wrapper* and load in the solution.

9 Viewing Groundwater Model Results

With the model run completed and the solution set imported into WMS, the results can be visualized.

1. Using the **Select Hydrographs**  tool, double-click on the hydrograph icon at the outlet location to bring up a hydrograph plot.

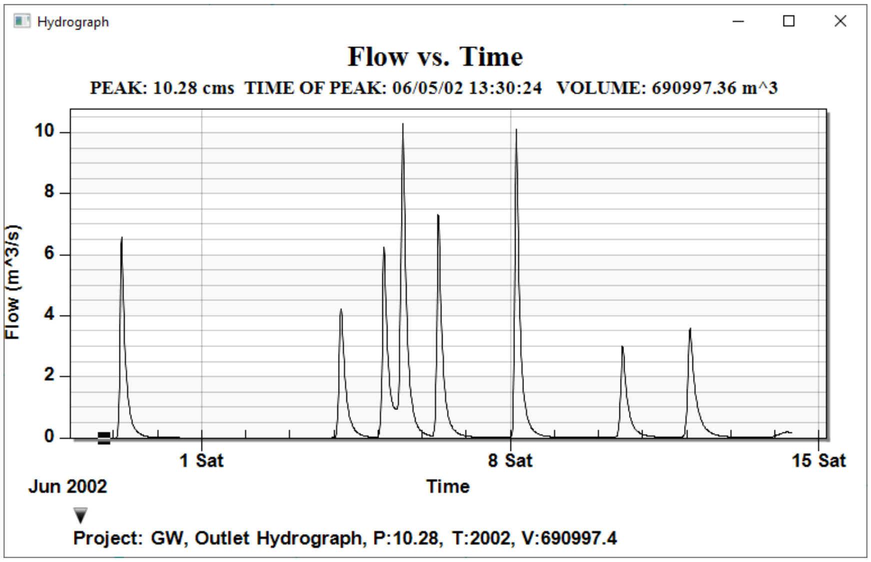

Figure 11 Hydrographs plot

2. When done reviewing the hydrograph, close the window.
3. In the Project Explorer, select the " groundwater_head" dataset and toggle through the time steps to see how the groundwater head varied with time.
4. In the Project Explorer, select " gw_recharge_cum" (Cumulative groundwater recharge) dataset and toggle through the time steps to see the amount of recharge in various parts of the watershed as the simulation progresses.

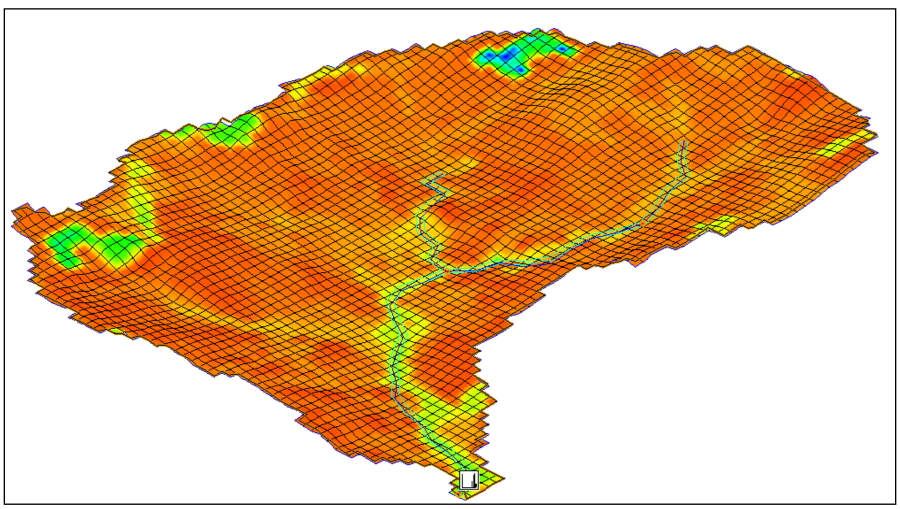

Figure 12 Groundwater recharge

10 Conclusion

This concludes the "Groundwater Modeling in GSSHA" tutorial. Additional options and functionalities of groundwater modeling with GSSHA are explored in other tutorial.

If desired, continue exploring the model or exit the program.

