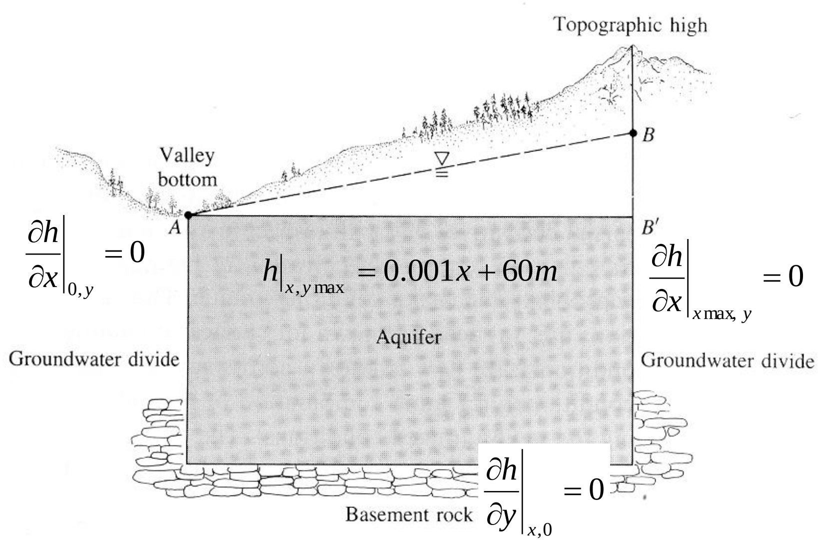
GLY-4822, Assignment 6

1. Solve problems 3, 4, and 5 from Assignment 5 using a 1-D spreadsheet finite difference model. This is the model that requires iterative calculation and 'ghost' nodes in some cases. Provide the equation being iteratively solved and provide enough of the spreadsheets you use that the ghost nodes are visible.

   Plot the results from both the analytical and finite difference approaches on the same graph; use open symbols for the numerical solution and a solid line for the analytical solution.

2. The 2-D Laplace equation (Poisson equation without recharge) is $\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0$. It can be solved on a spreadsheet by iteration with a remarkably simple numerical stencil [for example, in cell c3, *h = (b3 + c2 + d3 + c4)/4*]. Use this model to solve for the heads in a domain 100 meters in the x direction and 60 m in the y direction. The head gradient along the top boundary (a constant head boundary) is 0.001 (head increasing with x) and the head at x = 0 is 60 m. The boundary conditions are those represented on the following figure (Wang and Anderson, 1982):



Plot and contour the heads, and draw the flowlines.

3. Change the upper BC in Problem 2 to include a sine function: $h = h_o + x\, dh/dx + 0.1 \sin(4\pi x/x_{max})$, with $h_0 = 10$, $dh/dx = 0.005$, and $x_{max} = 100$. Plot and contour the heads, and draw the flowlines.

4. The Thiem equation for steady state flow towards a well in a particular confined aquifer is

$$h = 10m + \frac{Q}{2\pi T} \ln \frac{r}{2000m} \qquad (1)$$

The head is a function of the radial distance from the well r, which for a well centered at (0,0), is

$$r = \sqrt{x^2 + y^2} \qquad (2)$$

Take your Thiem equation out to at least 2000 m from the well; the 2000 m in the equation is known as the 'radius of influence' and extends out to where the drawdown due to the pumping well is negligible. This is how the Modflow problem below is set up. Use Q = 2000 m^3d^{-1} and T = 300 m^2d^{-1}. Plot the head field using Excel.

5. Compute the solution to the same problem using a spreadsheet numerical solution. The numerical stencil including recharge (which will be used for the well flow) is now, for example, in cell c3, $h = (b3 + c2 + d3 + c4)/4 - R(\Delta x)^2/(4T)$. Because it is a well, we distribute the flow over the whole area of the node to get R (i.e., $R = Q/A = Q/(\Delta x)^2$). But we just multiply it by $(\Delta x)^2$ again anyway, so we might have just as well written that $h = (b3 + c2 + d3 + c4)/4 - Q/(4T)$.

6. Get the ModelMuse software at
https://water.usgs.gov/nrp/gwsoftware/ModelMuse/ModelMuse.html

Use MODFLOW (via the ModelMuse GUI) to solve the pumping well problem. Compare with the results obtained in Problems 4 and 5.

If you use the default x and y spacing of 100 m but set a 41 x 41 grid, your domain will be about 4000 x 4000 m with its center roughly at 2000, 2000 (at cell 21,21). That's a good place for the well.

Reducing the number of layers to 1 will work for this problem. To get T = 300 m^2d^{-1}, the product $K\,b$ of course needs to be 300 m^2d^{-1}. So, if the aquifer thickness b is set to 10 m, K must be 30 m d^{-1}. For this homogeneous, isotropic aquifer $K_x = K_y = K_z$.. K_x can be set under Data/Edit Data Sets/Required/Hydrology/Kx, and the others will be set automatically.

Set constant head boundaries of 10 m on all edges of the domain. First, under Model/MODFLOW Packages and Programs/Boundary Conditions/Specified Head, you want to check CHD for constant head. You can set CHD_Par1 to 10 meters, which is the constant head value at the boundaries. Then use the Create Rectangle Object tool to create an object that encompasses the centers of the cells on one of the boundaries. Select MODFLOW Features, and check CHD and CHD_Par1. Use -1 and 0 for the start and end times, and 1 for any multipliers. Repeat this process for the other boundaries, but take care that the windows that you draw do not overlap; ModelMuse adds values from overlapping boundaries.

Note that this is only an approximation to the Thiem equation, which has constant head at 2000 m RADIUS from the pumping well. If you are ambitious, you can set constant heads at the proper locations inside the model domain too.

Include the pumping well. First, under Model/MODFLOW Packages and Programs/Boundary Conditions/Specified Flux, you want to check WEL for the well package. Increase the number of parameters to 1. Use the well pumping rate Q = 2000 m^3d^{-1} for the Q_Par1 entered as -2000 for the value. Then use the Create Point Object tool to create a point object in the center of the domain. Select MODFLOW Features, and check WEL, check Q_Par1. Use -1 and 0 for the start and end times, and 1 for any multipliers.

Layer 1 should be a confined aquifer. This corresponds to the assumption in the Thiem equation. If you don't have this and the head falls below the bottom of the aquifer, your aquifer will dry up.

To run the model, you will very likely have to download and install MODFLOW on your computer. ModelMuse provides a link to the required web page and an internal file locator to find the right file after it is on the computer (usually mf something.exe under the downloaded bin directory).

Use the Import and Display Model Results button to open the .fhd file, which contains the model output heads. Color plot and contour the results.

Compare the results you obtain with the results of the Theim solutions in Problems 4 and 5. Plot profiles of the heads from the MODFLOW and numerical spreadsheet models as open symbols and the same profile through the Theim results as a solid line. To obtain the profile information from ModelMuse Under Data, Data Set Values, use the Data Set drop down menu to expand Optional/Model Results/3D Data/Head_P1_S1and then Save or select results with mouse, copy, and paste into Excell to make the comparison plot.