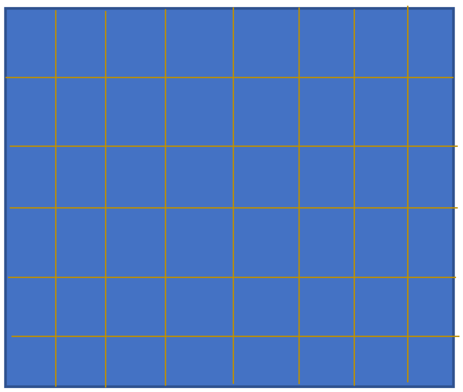
Box Model– Hand-Built MODFLOW <!-- omit in toc -->

The Challenge

1. Create a conceptual model of the homogenous MODFLOW model: This should be an illustration that shows the locations and values of constant head boundaries, the number of grid cells and their spacing as well as any other model properties. You should also include in here a cross section with your predicted head gradient and direction of flow. You can draw this by hand if you would like.

The box is 25 (x) and 25 (y) square. The box is 2500 m by 2500m with a 10 m depth. Each box is 100 m by 100 m by 10 m

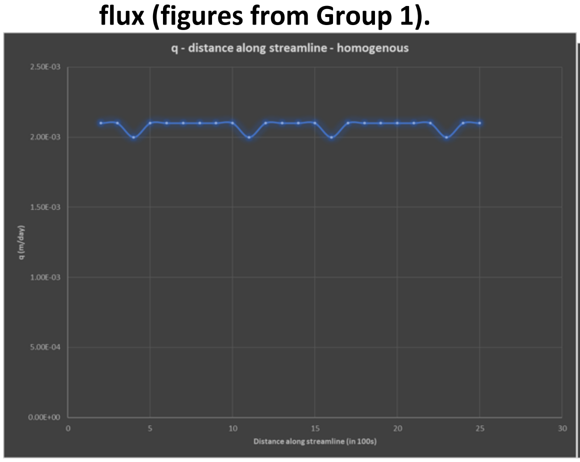


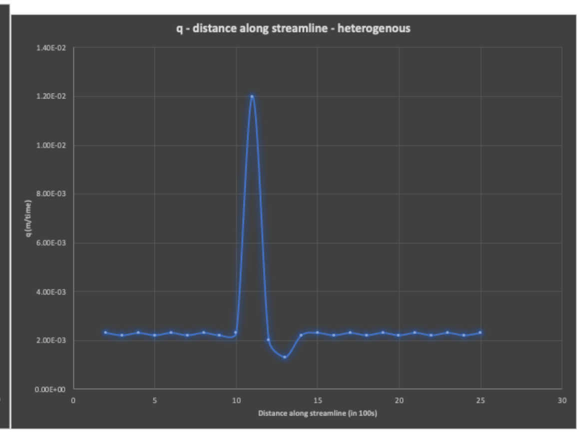
Constant head boundaries on both the left and right side of the model domain.

Flow goes from left to right

2. Show, based on the flux with horizontal distance from a constant head boundary, that the model is steady state. Repeat this for a homogenous and a heterogenous cases where you place different K values in series in the direction of flow (Note: to modify the K values you should change the `.bcf` file, just be careful because spacing matters! Note 2: see the excel sheet for an example calculating flux. Keep in mind that that heads are calculated at the center of a cell and the K values are defined across the entirety of a cell)

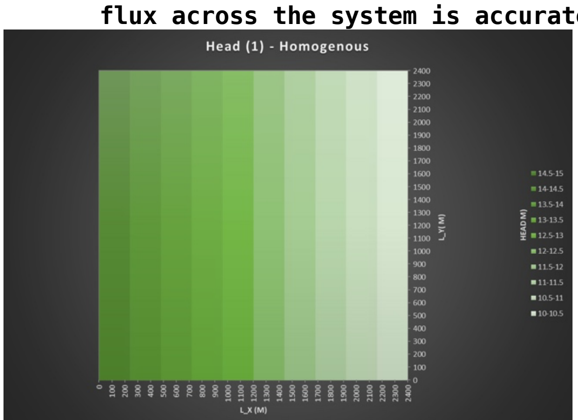
Since steady state means that there is no change in storage across the entire system and the flux out is equal to the flux in at every step, we should see that the same flux entering and leaving the model. In looking at both the homogeneous and the heterogeneous cases we see that the flux in is equal to the flux out across the full system. The big blip in the heterogeneous case is due to the change in K which changes Keffective for this cell and the flux (figures from Group 1).

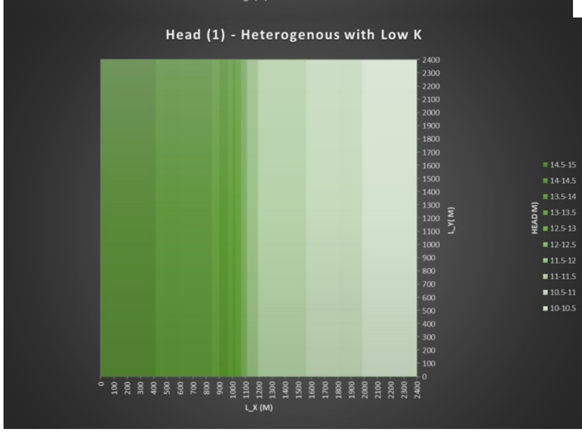


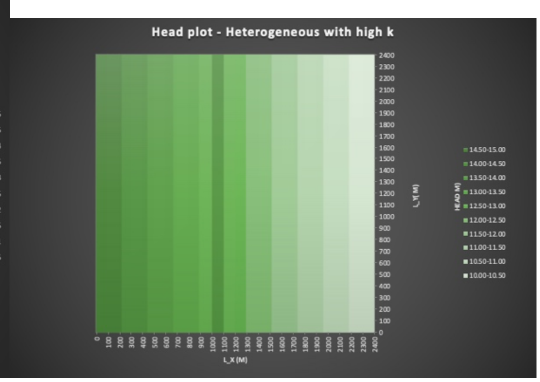


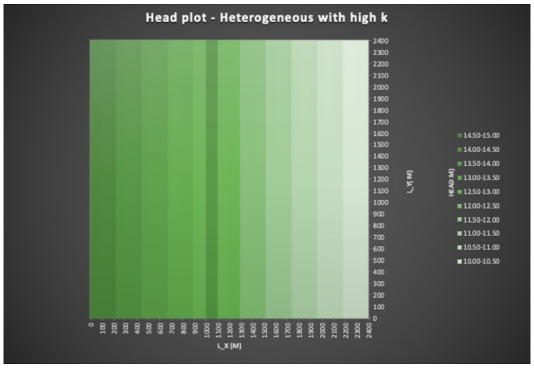
3. Show the steady state head contour in plan view for the homogenenous and heterogeneous (zones in series) condition. Use this plot to defend a contention that flow is 1D. Then, drawing on your first assignment, use the results to explain WHY the equivalent hydraulic conductivity, Keq, is closer to the lower of the two K values.

   We can tell that flow is 1D because the head is going from one constant on the left and approaching the other constant head on the right. If we had another direction of flow, then our head values would not be sequential by column and would also be sequentially changing in that direction as well. In the high K plot, we see that the heads change in the high K column, but continue to follow the same pattern we saw in the homogeneous plot (figures from group 1). Based on last week, we discussed that Keff is always closest to the lower K value. For me, it makes more sense to think about it as a rate limiting reaction (due to my biochemistry background). Since the lower K value causes water to move more slowly and ultimately more head is loss in that region. Therefore, the Keff will have to be closer to the lower K value in order to ensure that the flux across the system is accurate.



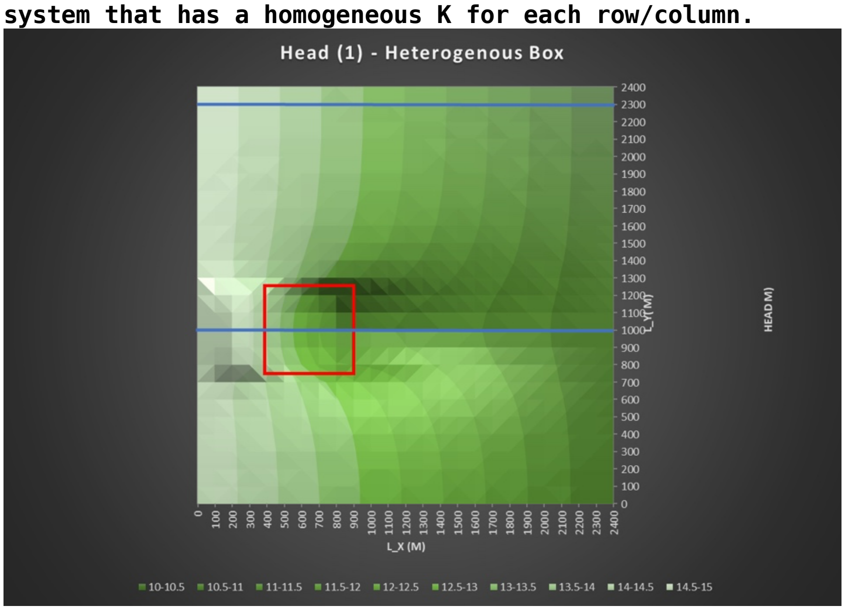






4.

5. Build a model based on a homogeneous domain with a square region of lower K in the middle of the domain. What can you learn based on your explanation of what controls the effective K for a 1D flow system now that you are applying it to a 2D system? What do you think the Keq of this entire system would be compared to the high and low K values? Explain why it is much more difficult to develop a direct solution for this 2D system than it was for a 1D system (including the zones placed in series).
   In this setting we would have to use a harmonic and arthimetic mean because we would have low K in series (along a column) and in parallel (along a row). This makes the Keff calculation more complex because flow is moving. The K effective should be closer to the low K value since we're added more low K values into the system. It's harder to develop a direct answer because now a head value within that box is dependent on four heads around them and we do not have a system that has a homogeneous K for each row/column.



6.

7. For steady state conditions, there are equivalent Type I and Type II boundary conditions. What would the Type II boundary condition be that would result in the same equipotentials for the first model? What is the value of the constant flux? What about the second model? What are the values of the constant flux on the left and right boundaries? What is fundamentally different about the equivalent Type II boundary for the third model compared to the first two?

   Model 1:
   The type II boundary condition would be constant flux which would be 2.0 *10^-3

   Model 2: Type II = constant flux with a value equal to 1.0*10^-3 and 1.0 *10^-3

   Model 3: The type II boundary conditions would have to shift depending on the side of the model. We would have to have two different constant fluxes because we would be slowing water down in the box center.

Glossary Questions:

1. What is MODFLOW? What is a MODFLOW package (provide at least 2 examples)? What are the inputs to a MODFLOW model?

   Modflow is a groundwater model and mudflow packages are different add ons to the base model like wells, evapotranspiration, or lakes for example. The inputs to a mudflow model are K values for the whole model, total model dimensions, grid cell dimensions, and boundary conditions.

2. What is the relationship between head gradients and hydraulic conductivity in steady state systems?

   In steady state systems, the relationship between head gradients and hydraulic conductivity is a inverse relationship as Darcy's equation is $Q = -AK(dH/dL)$. Meaning if K goes up then H goes down and visa versa.

3. What is a model node? A model cell? Use a simple diagram to show the relationship between heads defined at nodes and properties defined in cells.

   A model node is where the calculation of equations takes place. For our excel model the node was the center of each cell. A model cell is the predescribed area that sees changes to grided inputs.

4. What is the difference between TypeI and Type II boundary conditions and under what conditions might you use each? Provide at least 2 examples for locations where we might use Type I or Type II boundaries to represent a feature in the real world.

Type I boundary conditions are constant head conditions and these are most useful in lakes sitting above groundwater tables or at aquifers. Type II are constant flux conditions where water is continually moving. These are useful for recharge (we have a constant flux of water moving downward) or to model wells (constant flux leaving the system).