Q1: *Show, based on the flux with horizontal distance from a constant head boundary, that the model is steady state. Repeat this for a homogeneous and for a heterogeneous column for which zones of different K are placed in series with the direction of flow.*

A1 - Figures:

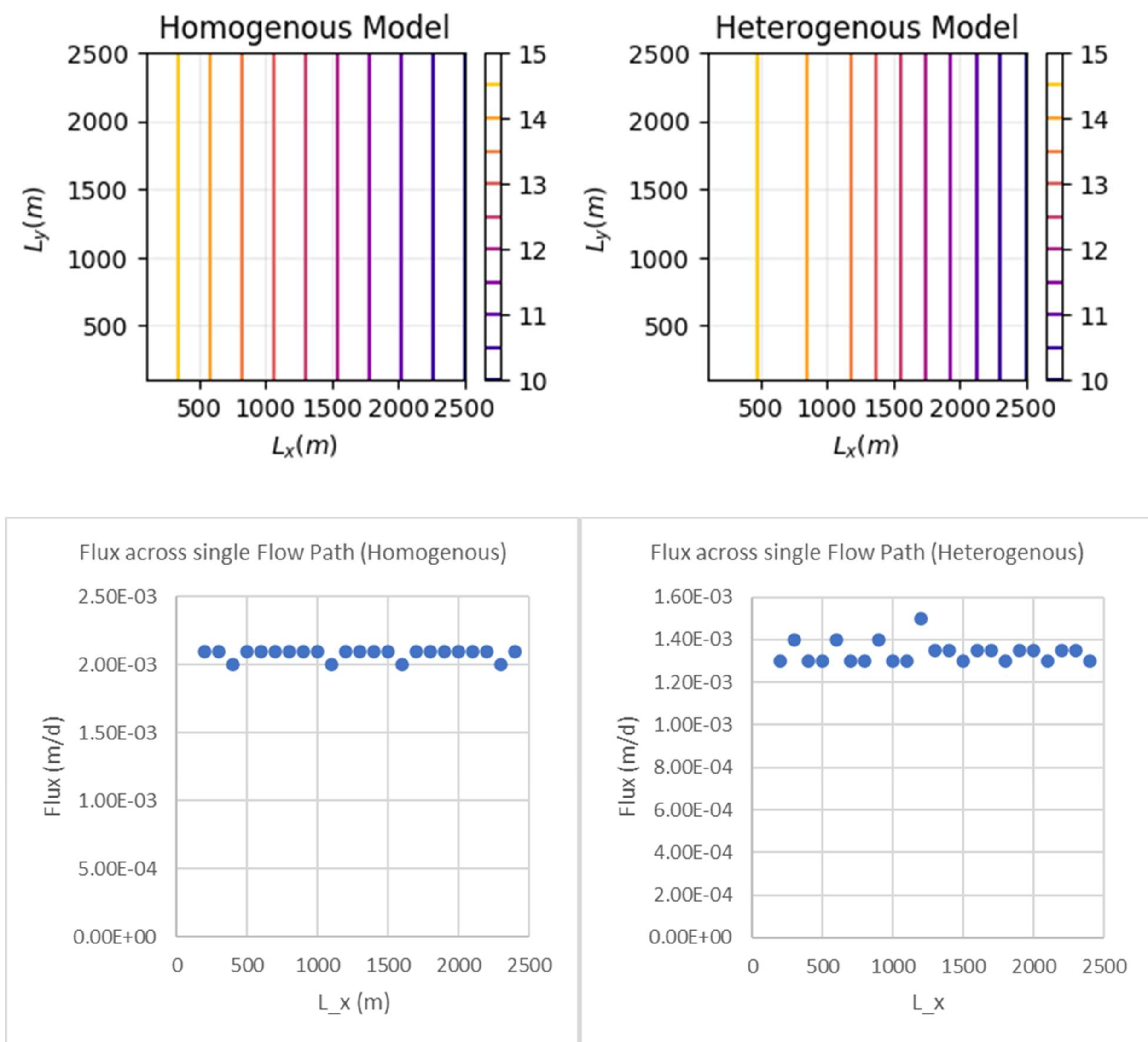


Figure 1: Top figures show the head distribution for both models and the bottom figures show the flux as calculated across one flow line for each of those models.

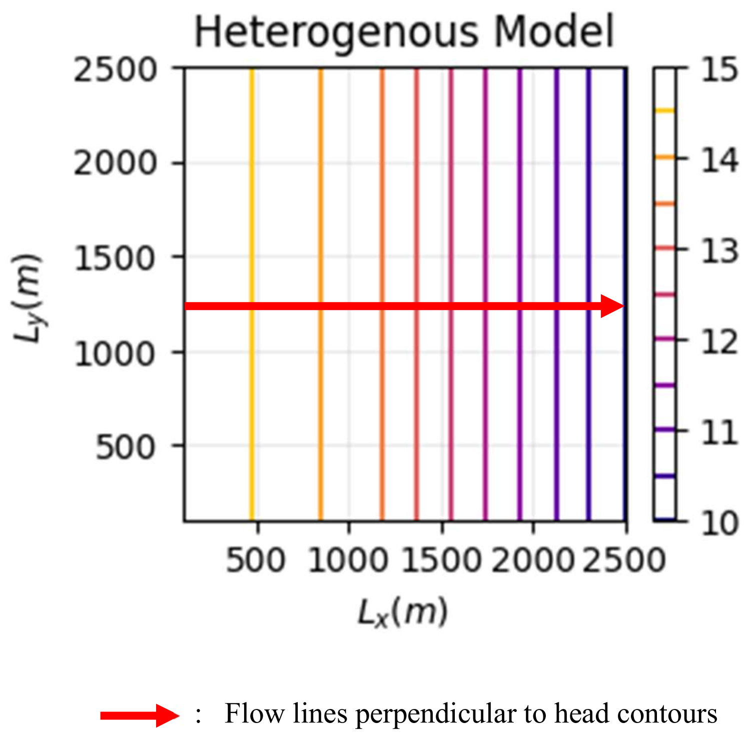
<u>A1 – Response:</u>

To account for the fact that the head values were calculated at nodes located within the center of cells of a constant K, the K_{eq} between each cell was calculated as a harmonic mean of the two cells and multiplied by dh/dL between the two cells to calculate the flux (which only allows for 24 flux calculations over the 25 measured head values in the direction of flow).

Each flux calculation between cells was similar enough that they could be considered steady; some minor variations/oscillations were seen within the flux calculations, which can be attributed to the iterative method utilized by MODFLOW to reach an answer for the head conditions within each cell (it gets the values within an acceptable tolerance level of the theoretical value, which can be greater/less than the real value within the cell within the tolerance condition).

Q2: *Show the steady state head contour in plan view for the hetero-condition. Explain WHY the equivalent hydraulic conductivity, Keq, is closer to the lower of the two K values.*

A2 – Figure:



A2 - Response:

- The plot shows the flow is 1D as flowlines can be drawn perpendicular to the head contours; doing so results in straight lines that move from the left side of the graph to the right side with no interruption in the pattern no matter how you move along L_y.
- Using the average of the calculated fluxes along the flow line (from question 1), which were equal into and out of each cell (within a certain tolerance), K_{eq} was then calculated using Darcy's equation:

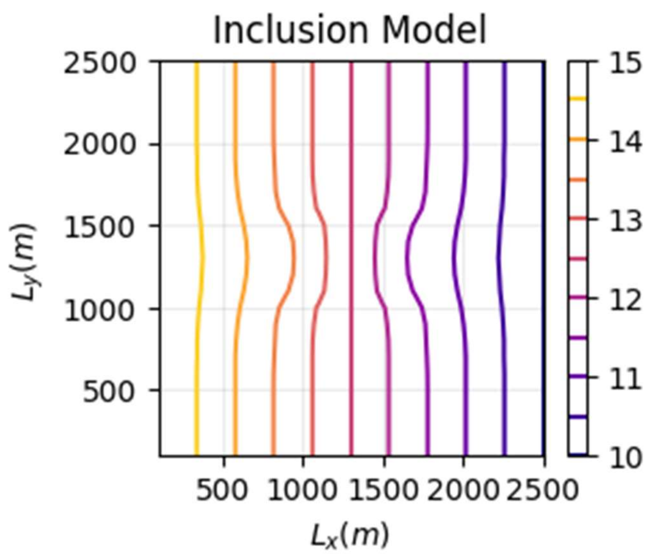
$$K_{eq} = -q_{avg} * \frac{dL}{dh}, \qquad q_{avg} = 1.34E-03, dL = 2400\ m, dh = -5\ m$$

$$\therefore K_{eq} = 0.643\ m/d$$

- This makes sense in regards to the first homework assignment, whereby we determined that the K_{eq} is closer to the lower value due to the conservation of energy equation; if it takes a greater amount of energy to move through the lower K medium, there is less energy to drive flow through the higher K medium, resulting in a larger gradient of head change within the low-K medium (seen in the plan view as the lines with closer spacing on the right hand side of the graph).

Q3: *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).*

A3 - Figure:



A3 – Response:

- What I learned is that the 1D explanation cannot be used in a 2D system directly. In order to determine an K_{eq} for the entire system would require using a vector approach to calculate the flux, and subsequently the K_{eq}, in both the x and y directions based upon the resulting head contours seen above.
- I think the K_{eq} for the entire system would be closer to a midpoint between the higher and lower K mediums. (Partially due to fewer cells within the inclusion model with the lower-K medium, as well as the possibility for the flow to be mostly directed around the low-K region as water prefers to move along the path of least resistance/expend less energy by diverting around the low-K inclusion.)
- It is not possible to directly apply the method of calculating K_{eq} from the 1D flow example to a 2D model because flow in & out of cells varies in two directions within the model. This would require (as previously stated) using a vector analysis of the gradients between the cells in both directions to calculate a flux and K_{eq} in both the x and y directions.