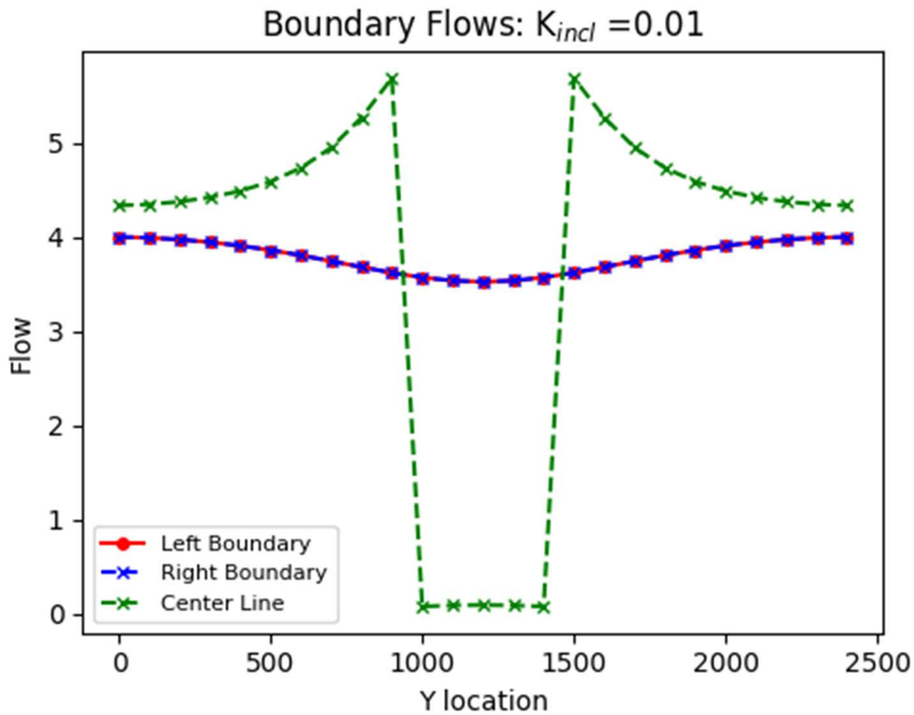
Challenge Answers:

Challenge 1:



Question:

For the initial values of background and inclusion K, plot the flow into the left and out of the right boundary. (The code, as provided, makes this plot for you.) Explain why the values are not constant along the boundary (relate to the definition of a Type I boundary). Explain why the flow distributions are the same for the left and right boundaries.

Answer:

The values along the left and right boundaries are not constant due to the low K inclusion in the center of the domain. As water flows through the system, it will redirect around the low K inclusion and find the easiest path to change along. Due to the constant head boundaries imposed at the left and right of the domain, the system reaches equilibrium by changing the flow along the middle (y-axis) of the system.

The flow along both constant head boundaries are the same due to the symmetric nature of the system. This symmetry would potentially allow for only half of the system (either top or bottom) to be modelled to decrease the model load/increase efficiency when modelling.

Challenge 2:

****See plot from Challenge 1****

<u>Question:</u>

Add a plot of the left-to-right flow along a line that passes through the center of the inclusion. What can you learn from comparing this distribution to that seen on the boundaries?

<u>Answer:</u>

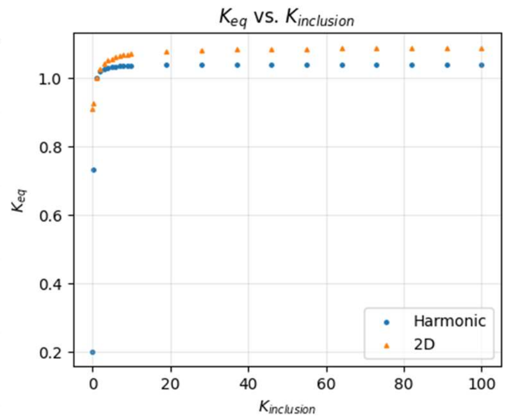
By examining the flow along the center column of the system (approximately column 13) you can see that flow increases in the regions immediately surrounding the low K inclusion as water is diverted away from the region.

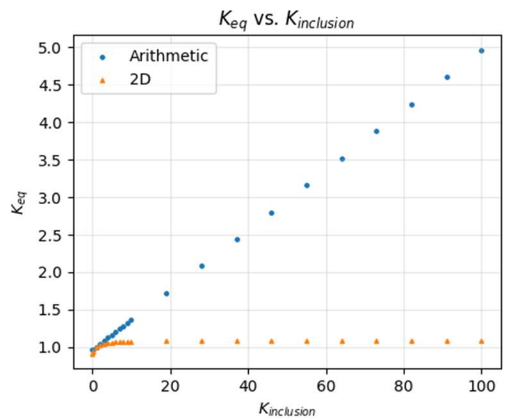
The reason these peaks of flow are so high immediately adjacent to the inclusion is due to the no-flow boundaries on the top and bottom of the system; if the water was to attempt to divert farther away, you would experience a build-up of energy/pressure as water backs-up against the boundary. Since the water would like to “expend” the least amount of energy/reach the lowest energy equilibrium, it will instead move more linearly (left to right) immediately adjacent (top/bottom) to the inclusion once it has diverted around the inclusion.

The hump at the center of the low flow region within the inclusion is due to the linear nature of the flow; at the exact center of the system, while flow is lower, it can still be considered a relatively 1D system. Just up and down of the exact center, flow begins to have 2 components of motion (it wants to tend towards the higher K background medium) which lead to the lower values.

Challenge 3:

K_incl	Harmonic	Arithmetic	2D
0.01	0.202000	0.960000	0.910757
0.1	0.735000	0.964000	0.927795
1.0	1.000000	1.000000	1.000000
2.0	1.020000	1.040000	1.028087
3.0	1.027000	1.080000	1.042630
4.0	1.031000	1.120000	1.051619
5.0	1.033000	1.160000	1.057748
6.0	1.034000	1.200000	1.062201
7.0	1.036000	1.240000	1.065584
8.0	1.036000	1.280000	1.068244
9.0	1.037000	1.320000	1.070391
10.0	1.037000	1.360000	1.072159
19.0	1.039000	1.720000	1.080267
28.0	1.040000	2.080000	1.083409
37.0	1.040000	2.440000	1.085080
46.0	1.041000	2.800000	1.086116
55.0	1.041000	3.160000	1.086821
64.0	1.041000	3.520000	1.087333
73.0	1.041000	3.880000	1.087721
82.0	1.041000	4.240000	1.088025
91.0	1.041000	4.600000	1.088270
100.0	1.041000	4.960000	1.088471





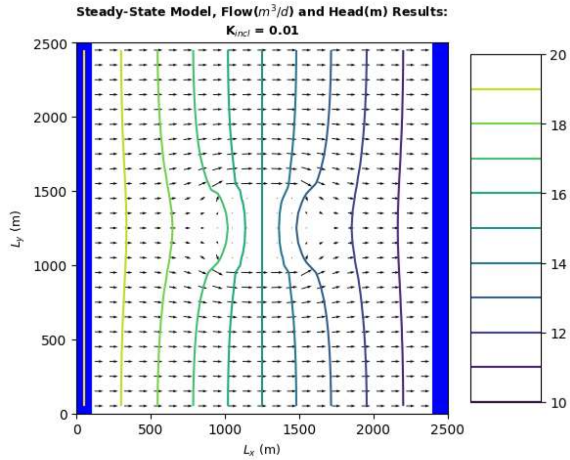
<u>Question:</u>

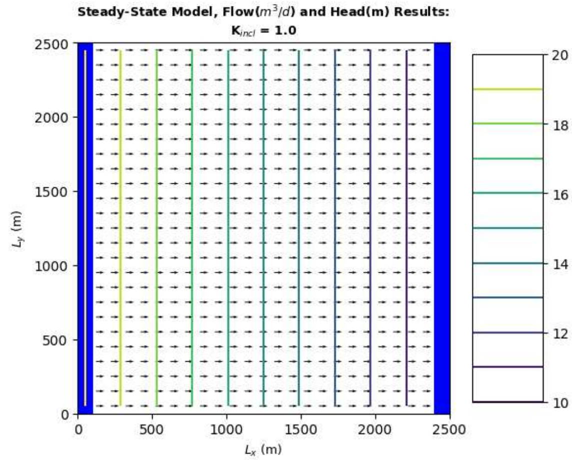
Calculate the total flow into (and out of) the domain. Use this to calculate the Keq of the heterogeneous system with the K values as given in the starter code. Repeat this calculation for the following K values for the inclusion (keeping the background K as it is given): 0.01, 0.1, 1, 10, 100. Compare the Keq to the harmonic and arithmetic mean K values based on the area occupied by each medium (rather than the length for a 1D system). Can you draw any general conclusions about the impact of high or low K heterogeneities on the equivalent K for the flow system examined?

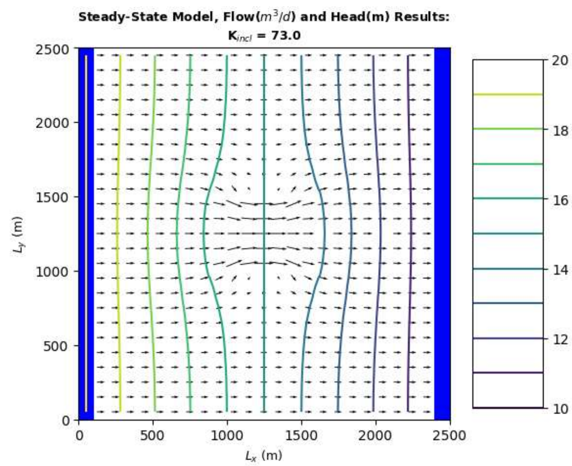
<u>Answer:</u>

The K_{eq} calculated via the Harmonic Mean closely resembles the 2D calculated K_{eq} for values between 1-2 m/d (at 1 m/d for $K_{inclusion}$, the system would be homogenous), but underestimates it as $K_{inclusion}$ increases as well as below 1 m/d (vastly underestimates it under 1). The Arithmetic Mean K_{eq} is closest to the 2D calculated K_{eq} for values under 1 m/d. Both mean methods are poor estimators of the real K_{eq} as neither account for the physics of water flow in such a system (whereby the low K inclusion would be bypassed, for the most part, as water seeks the path of least resistance), though the Arithmetic is likely closer to the average K_{eq} of the system (to what degree, I'm not sure).

Challenge 4:







Question:

Does the equipotential distribution depend on the absolute or relative K values for the background and the inclusion? How would you use the model to test your answer?

Answer:

The equipotential distribution (head contours) depends more on the relative K of the background and inclusion. As the direction of flow is related to the gradient of the equipotential in the different regions, the flow can be inferred by drawing lines that leave/arrive at the each equipotential contour pair perpendicular to the contour. The change in head/gradient of the head is related to the K of the cell being measured in comparison to the neighboring cells (true for all grid layouts, whether using square/rectangular cells or triangular cells).

A good visual representation of this is shown via 3 models (in the above graphs); the top left shows the initial system setup with a low K inclusion, the top right a homogenous system with no inclusion, and the bottom with a high K inclusion.

I would test this in my model by using slightly higher or lower K inclusion values than currently used, or reversing the situation; the inclusion is a higher K medium surround by extremely low K background medium.