HWRS 582 – Groundwater modeling

HM3 - Challenge

Luis De la Fuente

Submitted on 02/03/2021.

1. 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.

The left and right flow distribution at the boundary is the same because the inclusion is exactly in the middle of the domain. In other words, if the inclusion would be close to one boundary, the flow distribution will be more affected in the closer boundary and more homogeneous in the further boundary. However, the total flow will be always the same in both boundaries because this is the definition of the steady-state that we are using to solve the system.

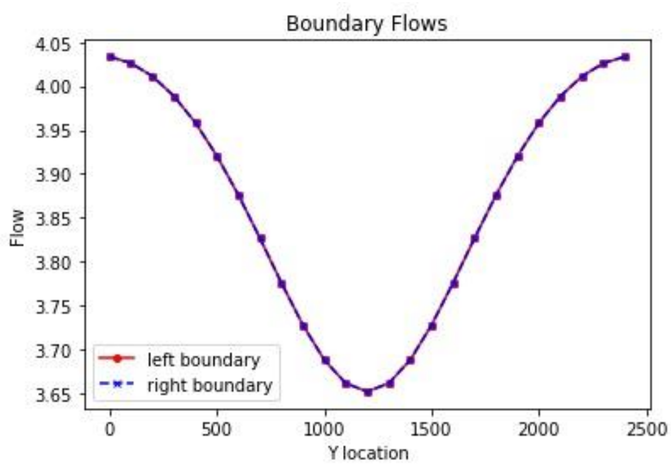

Figure 1. Flow distribution in both boundary conditions.

2. 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?

Firstly, we can watch a big difference in the magnitude of the flow between the center and boundary. The range in the boundaries is low, showing a smoother effect of the inclusion. Secondly, in the centerline, the flow near the inclusion increases the speed because some flow is trying to avoid the inclusion moving up or down of that. However, not all the flow takes that option because, despite the low K of the inclusion, the energy loss close of the inclusion is high (higher speed) which is comparable with the loss given the low K, therefore some flow lines go through the inclusion anyway. Finally, in the center of the inclusion the flow is higher than the border of the inclusion, that happens because in the center the system is in perfect symmetry. Therefore, the flow moves in a straight line from left to right. However, the flow that is immediately upper or lower feels a small gradient up or down, which is expressed in less flow in these cells.

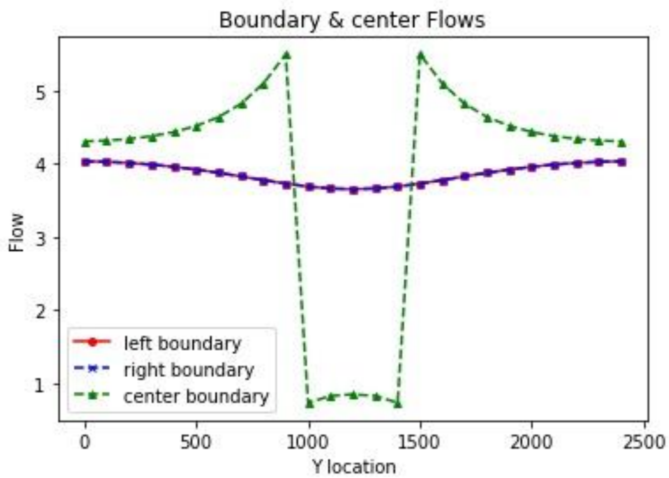

Figure 2. Flow distribution in boundaries and center.

3. 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?

Two thoughts emerge from this exercise. The first is that inclusions with low K have a behavior more similar to the arithmetic mean and a high K inclusion has a Keq more similar to the Harmonic mean. However, the arithmetic mean is representative of an in parallel flow and the Harmonic mean represents an in-series flow. That means that for low K the water mainly follows two paths, which means that the higher K controls the Keq. In the other case, when we have a higher K the flow mainly goes through one path (the center) which means that the low K controls the Keq. That analysis is consistent with the flow line generated in each iteration.

The second thought is an extrapolation to the real world. Given that we never will know completely the spatial distribution of K, we can assume that the existence of inclusions in the soil does not affect drastically the total flow. Therefore, we must be worry mainly about collecting enough samples to know the K that has more presence in the soil, because that will control the total flow in the system.

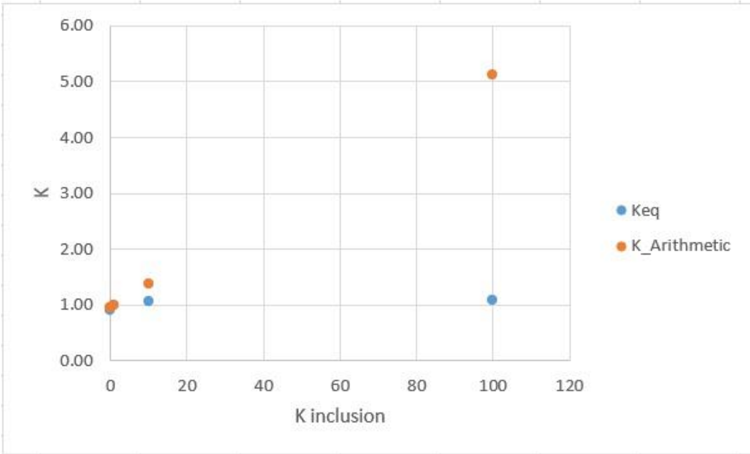

Figure 3. Comparison between Keq and K with arithmetic mean.

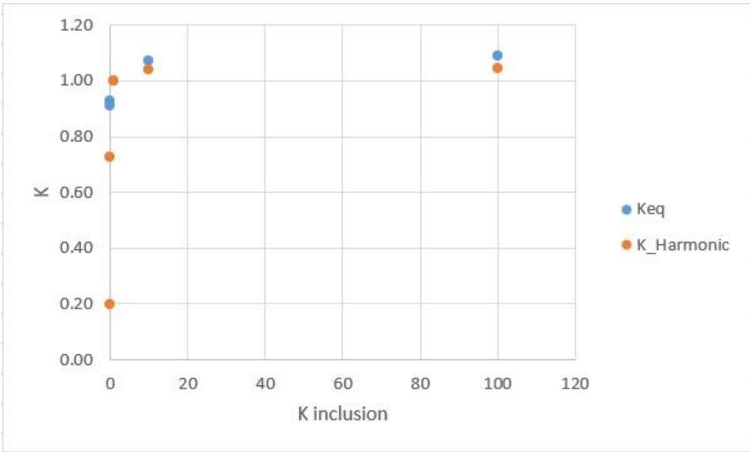

Figure 4. Comparison between Keq and K with harmonic mean.

4. 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?

The equipotential or flow distribution depends on the spatial distribution of K. For that reason, the amplification of the same K distribution for a factor does not affect the equipotential. The value that is amplified is the total flow. To test that hypothesis, I ran the model amplifying the background and inclusion K for the same factor. The results were the same equipotential distribution in all the cases (factors higher than 1 and lower).

Discussion questions

5. What are the implications for your results for representing K in a model cell, given that the distribution of K is always heterogeneous at the small scale?

We must understand that K is just an idealization of reality. Even with a field sample, this value just represents a local K that nothing can tell you about the value 1 meter from it. Therefore, the fact that we are using a distributed value of K does not mean that we can be sure that K represents the overall value of one specific cell. Consequently, you can only infer a general understanding and estimation about what is happening.

6. Discuss what it means to say that, for steady state flow, there are equivalent Type I and Type II boundary conditions. How might this be useful in practice?

In a specific boundary, the relationship of Type I and II is unique. That means that defining the water head imposes a flux in the boundary, and if we define the flux, this imposes a specific water head. Therefore, they are interchangeable for steady-state.

7. How could you (or did you) use looping to answer The Challenge more efficiently?

In the case that we should evaluate many combinations of K values, the optimum implementation would be to create a loop in the definition of K and to put all the other steps inside. I did not do it because sometimes coding easy lines takes more time than just do it.

8. What are some advantages (easy) and disadvantages (harder) of using flopy rather than building MODFLOW models manually?

I agree with Chloe about how useful and powerful is to plot the input and output. That helps you a lot in debugging your model. However, we can easily forget the meaning of each file or any other functionality that is not supported by flopy. However, the final budget is highly positive.

9. What would you find if you altered your model to consider unconfined conditions??

Probably, you would find low vertical flux in the boundary. In that case, this would mean that the boundary is affecting the flux inside of the domain. Therefore, you should expand it until the flux is completely horizontal (1D), which means that your model is completely independent of this boundary condition.