HWRS 582 – Groundwater modeling

HM4 - Challenge

Luis De la Fuente

Submitted on 02/08/2021.

1. For the initial well location, plot the flow into the left (constant head = 20) and out of the right (contant head = 10) boundaries. (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 the shapes of the flow distributions and why they are not the same for the left (inflow) and right (outflow) boundaries.

The flow in the boundaries is different because we are applying a local extraction which has a non-uniform effect in the boundaries. Each cell of the transect has a different distance from the well and the closest cells transport (left side) or is stolen (right side) more water to supply the requirement of the well. Given the steady-state condition, the difference between the 2 transects is exactly the flow extracted from the well, any change in storage is allowed in this condition.

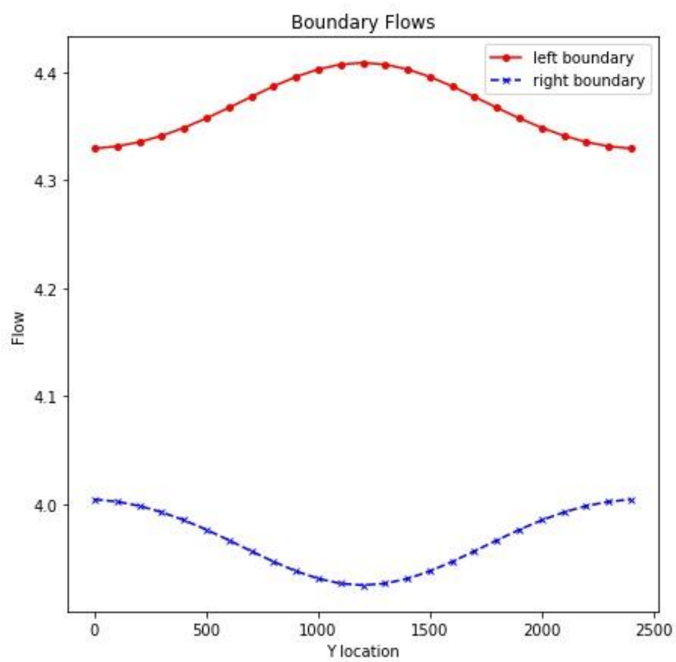

Figure 1. Transect in the boundary conditions.

2. Add a series of the left-to-right flow along a line that passes through the center of the well [:,12]. How do you interpret the flow along this transect? Hint, also look at the flow along a transect just upgradient from the well [:,11].

The shape of the center and before the center transect are associated with the local extraction of the well. Immediately before the well, the flow paths tend to concentrate close to the well. Given that between flow paths we transport equal flow, when we have more flow paths, we have more total flow. That is the reason for the peak before the well. On the other hand, the transect in the center already discounted the flow extracted from the well, therefore less concentration of flow path exists after the well which is represented as lower flow in the center than the borders.

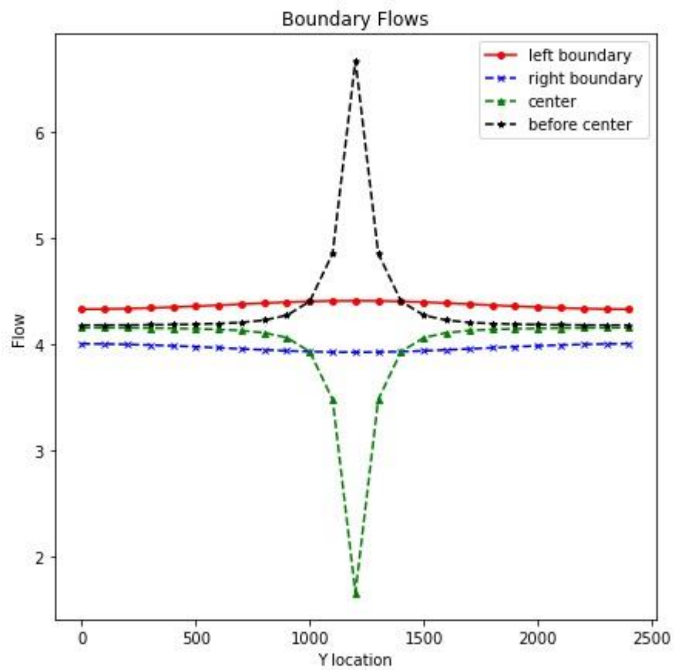

Figure 2. Transect in the boundary conditions and close to the well.

3. Then, look at the plot of equipotentials and flow vectors. Describe how water flows through the domain. To aid in your description, draw a line through all of the flow vectors that terminate in the well. This approximates the capture zone of the well. Use this to refine your description of the flow system, being as specific as possible about where water that ends up being extracted by the well originates on the inflow boundary.

Given that the extraction is not so high, the flow vectors are affected just very close to the well. For that reason, I drew horizontal lines that change the direction only in the cell before the well. Outside of the capture zone, the flow vector changes the direction to fill the vacuum created for the lack of the flow extracted from the well, for that reason we can see a big change in the direction above and under the well.

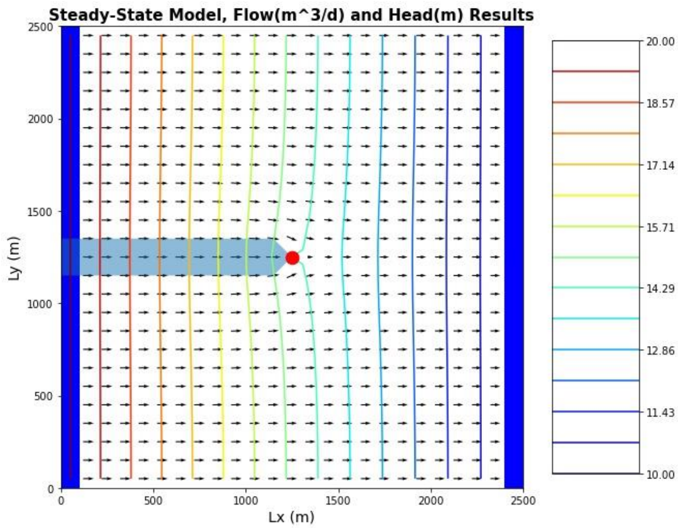

Figure 3. Approximation of the capture zone of the well.

4. Then, look at the plan view drawdown plot. Why aren't the drawdown contours circles? Either explain why this is correct or fix the plot.

The lines in the drawdown are not circles, because the influence of the well is not the same in all the direction. Only in the case that the boundaries are very far away from the well we could see circles. That happens because the upper and lower boundaries are feeling the gradient produced by the well but, they cannot allow flux through the boundary. In response to that, the cells close to the boundary have more influence from the well than in a normal situation which distorts the drawdown lines.

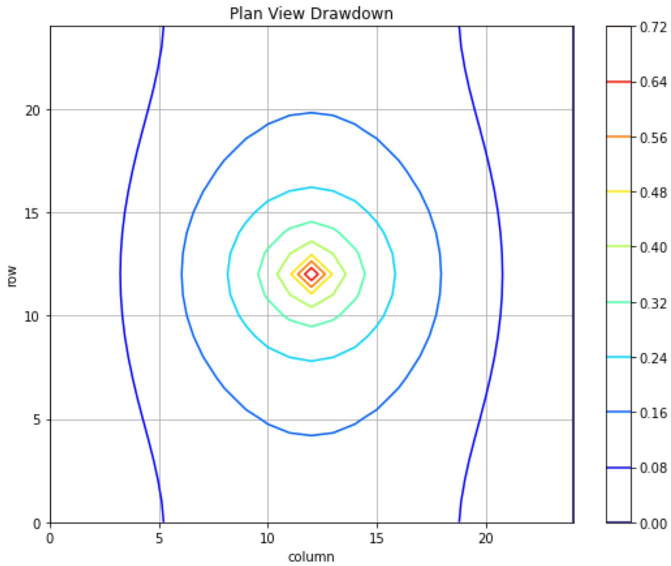

Figure 4. Drawdown for the well.

5. Move the well to [0,5,5]. Use all plots necessary to describe fully how water is flowing through the domain with the well in this location. Be sure to include the drawdown plot in your discussion - compare this plot to the equipotentials and flow vectors. Something is not right about how the well location is shown. Fix it and explain what was wrong!!

Similar to figure 3, the capture zone is mainly the two rows on the left of the well, and only near the extraction, the vectors change the direction toward the well. In the case of the transects in the boundaries (Figure 6), the flow is concentrated in the cells above and immediately under the well showing us that the top boundary concentrates the effect of the well in the top left region. The drawdown lines are not circles because each of the 4 boundaries (Top, bottom, left, and right) are at a different distance of the well. Moreover, each kind of boundary (Type I and II) has a different effect in the drawdown as shown in the top left of figure 7.

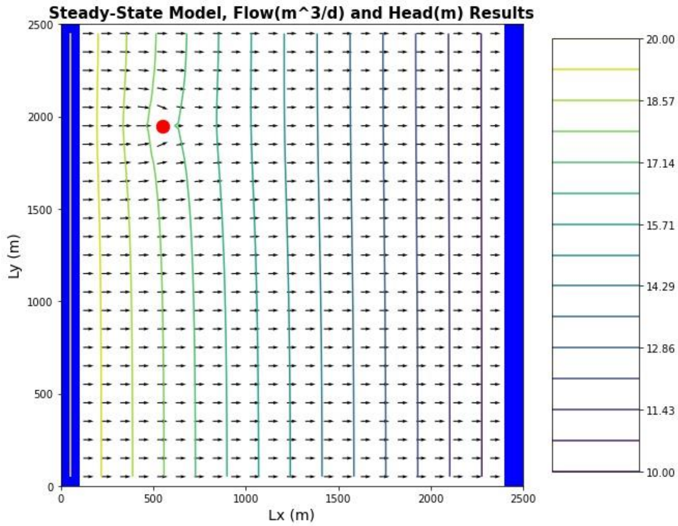

Figure 5. Equipotential and flow vectors for well in the new location.

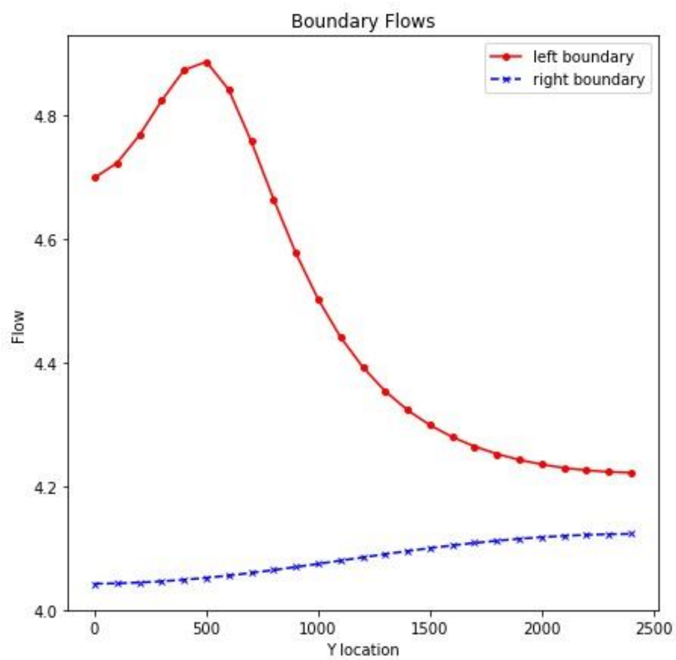

Figure 6. Transect in the boundary conditions for the new well.

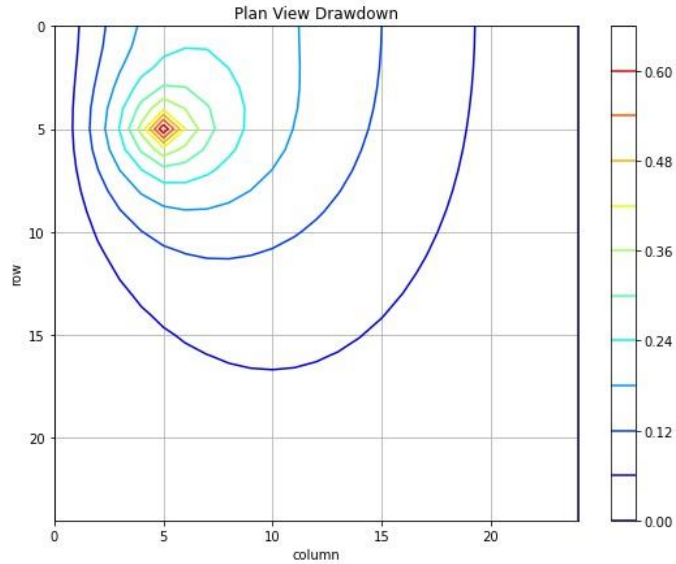

Figure 7. Drawdown for the new well.

Discussion Points

6. You are still modeling steady state conditions? So, what is supplying water to the well? Why are the drawdown contours not equally spaced?

Given that we are modeling steady-state condition, the water must come from the boundary condition. There is no flow coming from the storage. Moreover, not all the boundaries are supplying water, therefore the drawdown will tend to follow the shape of the boundary that is supplying the water.

7. If the right boundary represented a stream, what would the impact of the well be on the stream? This is referred to as 'capture' - can you describe this concept in a sentence that a non-expert might understand?

We can think of the flow that goes directly to the well as a “direct capture zone”. However, that water is not free, that water was taken from someplace. In that case, we can think of that as the “influence zone or the indirect capture zone” because this water is taken from the flow that is coming from the left side and from the flow that the river was receiving previously. That situation can be visualized if we compare the flow in the river in the situation with and without well. The next figure shows that the flow with the well decreased the flow coming to the river.

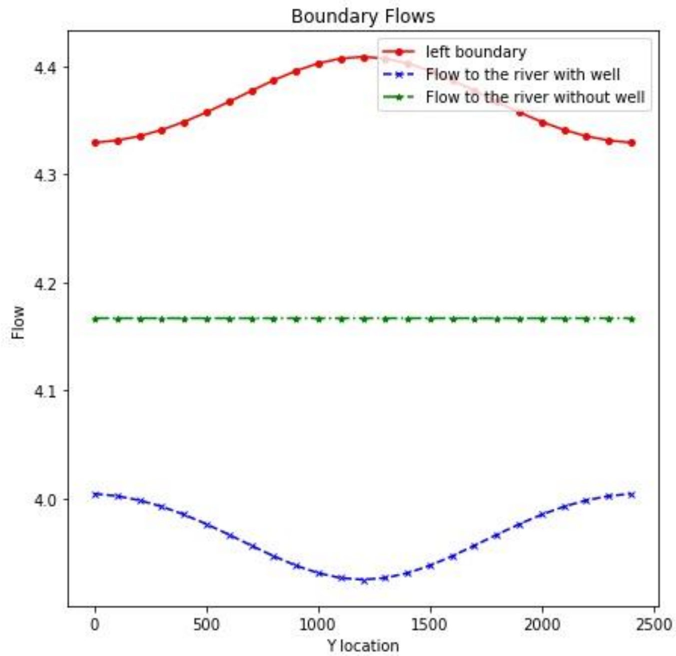

Figure 8. Flow in the boundaries and the flow without well.

8. Before running the model, predict what you would happen to the inflow/outflow boundary fluxes if you reduced the pumping rate to -5 with the well located at [0,12,12]. Were you correct? If not, how were you wrong? Now predict what would happen if you increased the pumping rate to -20. Still correct? Now try -25. Uh oh, what happened??

I guess that the blue and red line from Figure 8 will move closer to the green line. Additionally, the shape will decrease the bump in both lines. After running the model, I confirmed my guess. Firstly, it watched as not changes in the figure however given that the scale of the figure changed all my guesses were correct.

In the case of increasing the pumping rate, my guess is exactly the opposite of the first case. The lines will move farther from the green line and the shape will be more like a normal distribution. Again, my guess was correct as shown in figure 9.

In the case of the pumping rate of $25m^3/d$, the model does not converge. That situation is controlled by the cell size which suggests that we are imposing a gradient so high that for a grid of 100m, the change in water head is outside of the boundary condition [10,20]. I experimented with a grid size of 1m and the model worked properly.

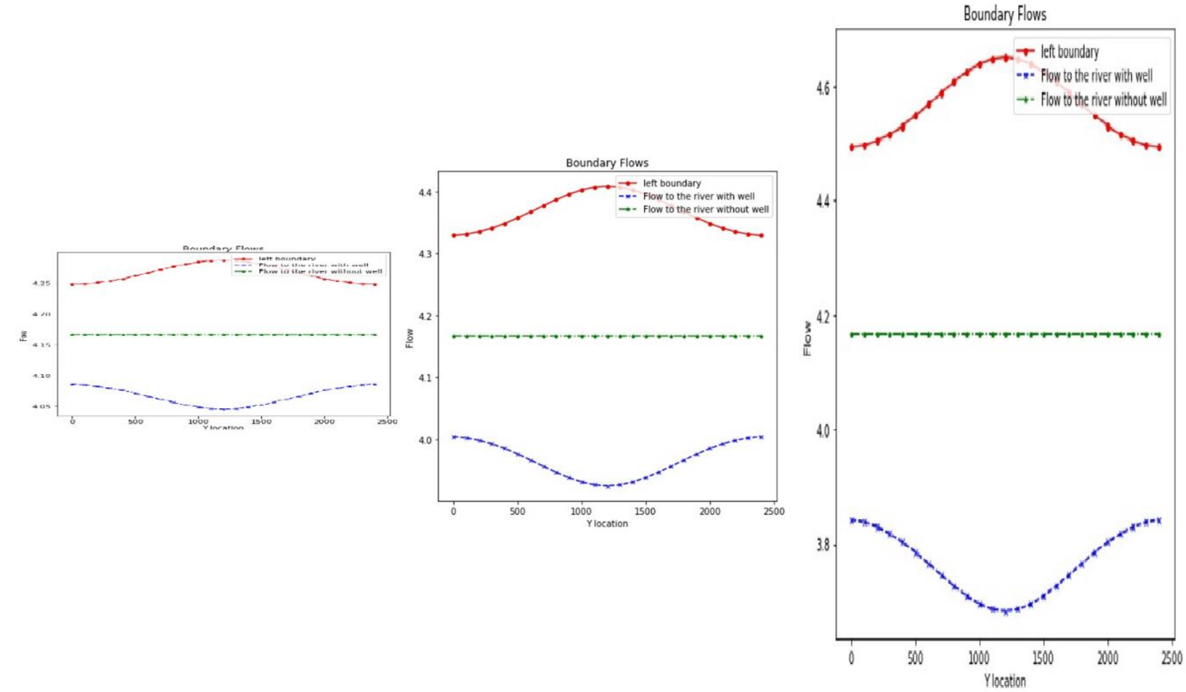

Figure 9. Flow in the boundaries for different pumping rate (Left: 5m^3/d, Middle: 10m^3/d, Right:20m^3/d).