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HWRS 582

16 March 2022

Homework 7 Report

Model Description, Assumptions, and Parameters

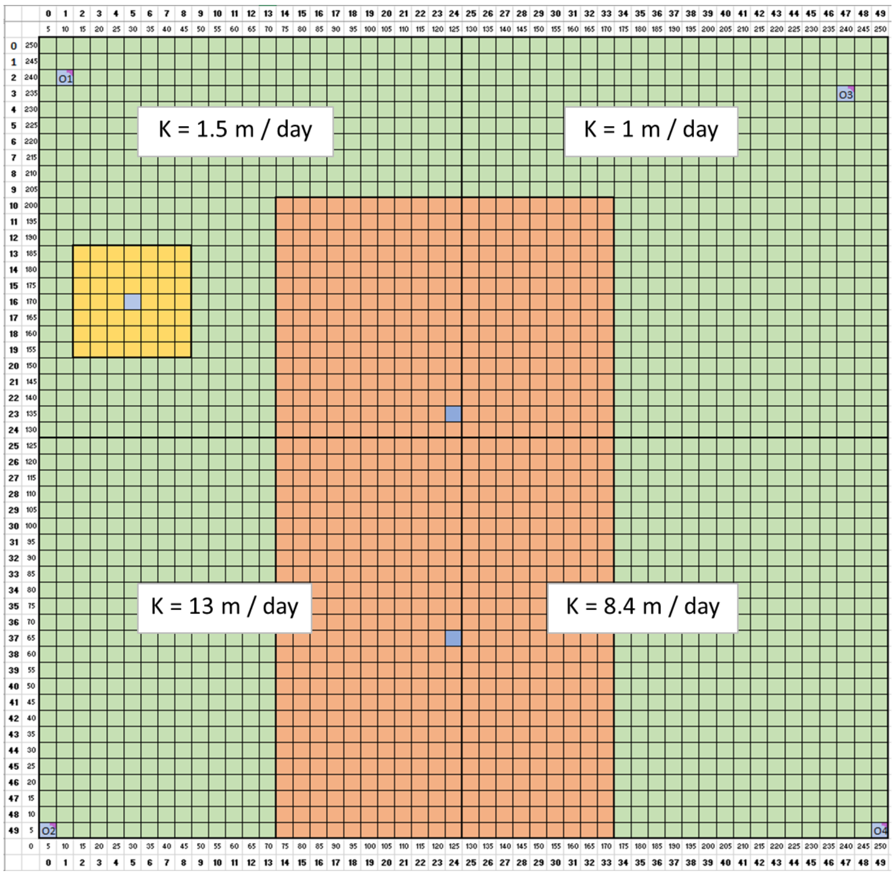

Figure 1: Conceptual Model, with K divided into 4 quadrants (Scenario #1)

My model has a 2500m x 2500m domain. It is a 50x50 cell grid, with each cell having x and y dimensions of 50m x 50m. I chose to create a finer-resolution model than the ones used previously in this class, because it would allow the farms and observation wells to be more accurately represented spatially. The representation still does not match the given position coordinates exactly, but I believe the difference is now negligible for our purposes.

Wildcat Farm is represented by the yellow square, and ACME Farm is represented by the orange rectangle.

There is one vertical layer with a thickness of 800m. This thickness was chosen because it was greater than 200m, which is the deepest the ACME well screen can go, but it was also chosen somewhat arbitrarily by simply adjusting the thickness until I could get MODFLOW to converge to a solution. Even after telling MODFLOW to iterate a maximum of 1000 times, it could still not converge to a solution in some cases.

There are left and right constant head boundary conditions. The values were calculated by averaging the heads of the north and south observation wells for their respective left (west) and right (east) boundaries. Water table depth was subtracted from layer thickness to arrive at the head value. Because the head is less than the layer thickness, the aquifer is unconfined.

A recharge rate of $1*10^{-4}$ m/day was applied to the entire domain, per the instructions, and then further recharge was applied within the farm boundaries. Consumptive water demand for plants was given in inches / year, and then I converted those values to meters per day. 120% of this value would need to be pumped from the aquifer, per unit area, with 100% being consumed by the plant, and the additional 20% returning to the aquifer as recharge (which is a parameter that is encoded manually). Well pumping rates for the farms were calculated by taking the required irrigation depth [m] and multiplying by the area of the farm [m^2], to arrive at a volume of water per day [m^3 / day]. The pumping rate of ACME farm was reduced by 50%, per the instructor's recommendation. This reduction also affected the recharge rate over ACME farm.

Table 1: Wildcat Farm Calculations

Wildcat Farm			
30	Area (acres)		
121,406	Area (m^2)	122,500	Rounded Area (m^2)
350	Width (m)	350	Length (m)
41.2	in / year	Cotton Consumptive Water Use	
1.04648	m / year		
0.00287	m / day	100% Required Irrigation	
0.00344	m / day	120% (Excess) Irrigation	
0.00057	m / day	Recharge (Excess - Required)	
421	m^3 / day	Required Pumping Rate of Well	

Table 2: ACME Farm Calculations

ACME Farm			
500	Area (acres)		
2,023,430	Area (m^2)	2,000,000	Rounded Area (m^2)
1,000	Width (m)	2,000	Length (m)
37.15	in / year	Alfalfa Consumptive Water Use	
0.94361	m / year		
0.00259	m / day	100% Required Irrigation	
0.00310	m / day	120% (Excess) Irrigation	
0.00052	m / day	Recharge (Excess - Required)	
6,205	m^3 / day	Required Pumping Rate (Total)	

An ET rate of $5*10^{-5}$ m/day was applied across the domain, with an extinction depth of 3m. Because the water table everywhere in the domain is below 3 meters depth, there was actually no ET in the simulation.

Scenario #1

In my first scenario, there are four different quadrants, each with their own hydraulic conductivity (K). The K values chosen for each quadrant were based on the K measured at the quadrants' respective observation wells, which were all in the far corners of each quadrant (and thus, the far corners of the entire domain). In this scenario, the well at Wildcat Farm does not run dry. The WTD at the well is approximately 12 meters. This is the best-case scenario.

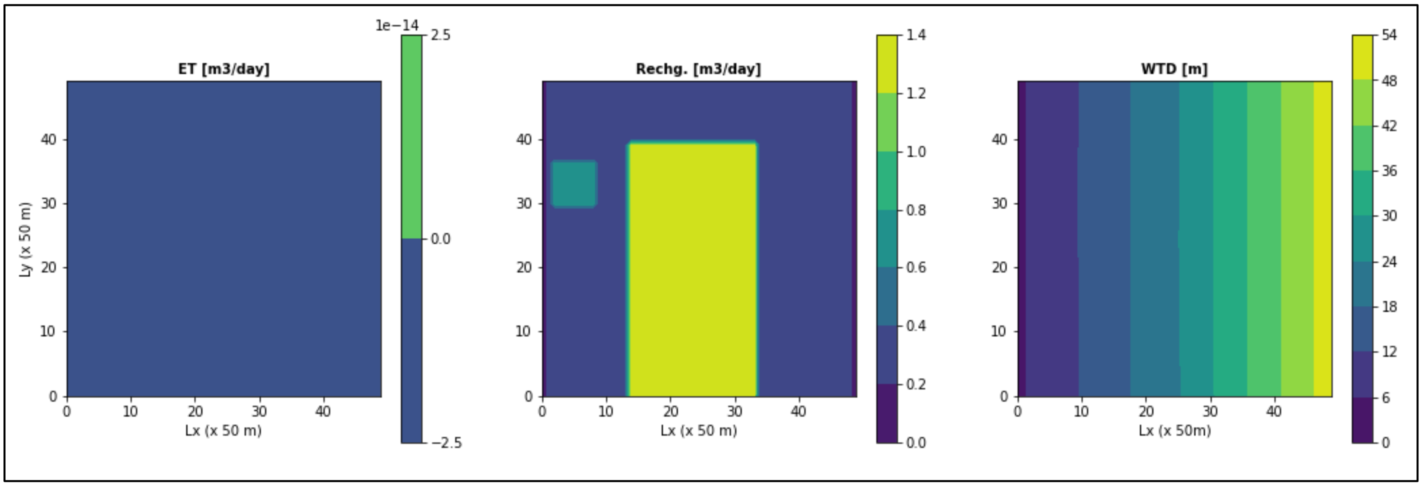

Figure 2: Scenario #1 ET, Recharge, and WTD

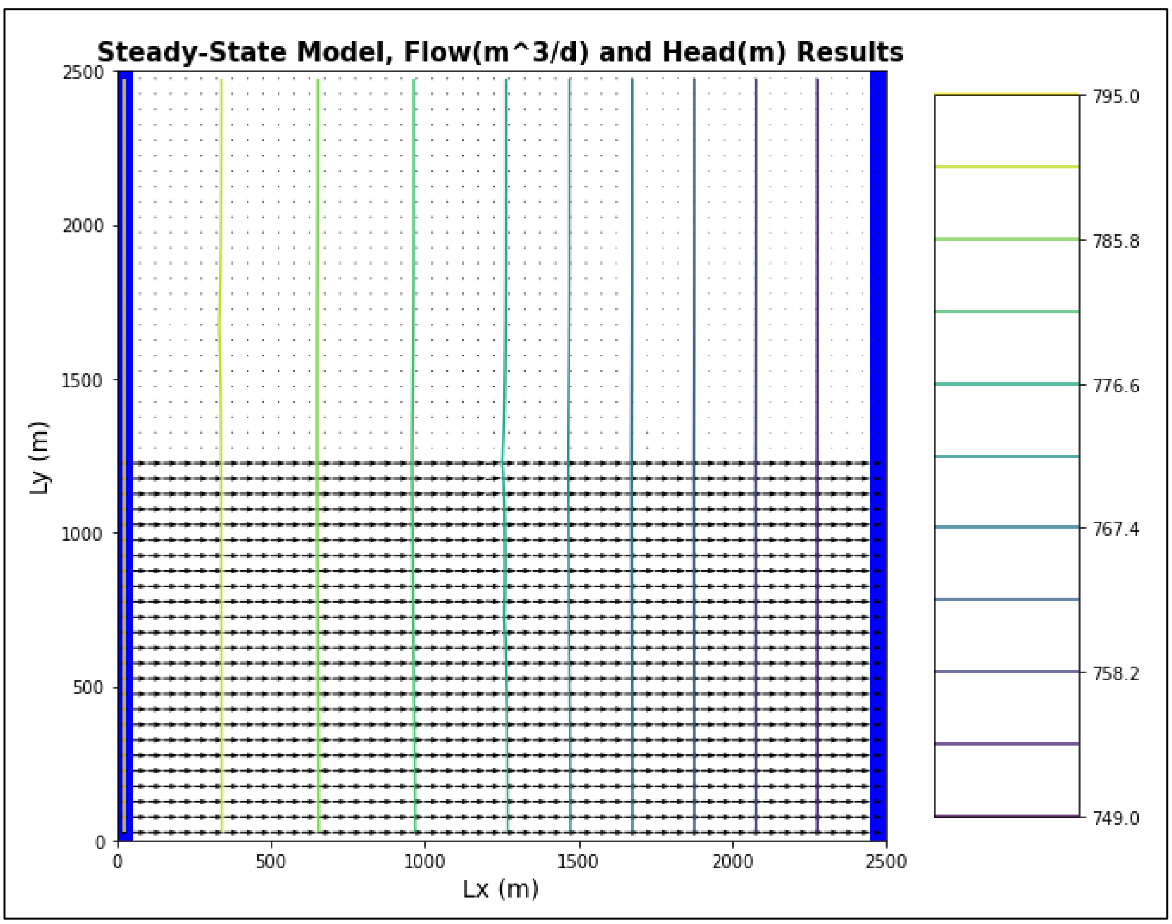

Figure 3: Scenario #1 Flow Lines and Head Contours

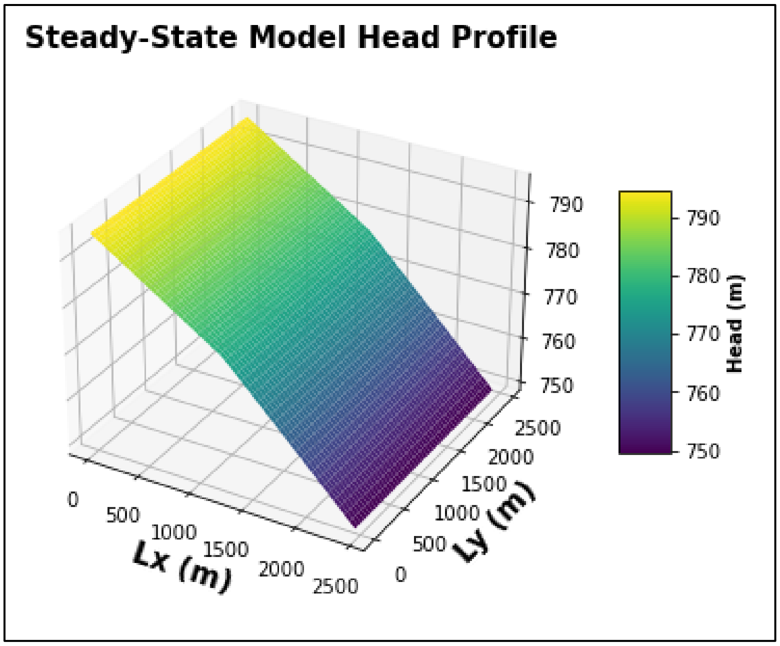

Figure 4: Scenario #1 Head Profile

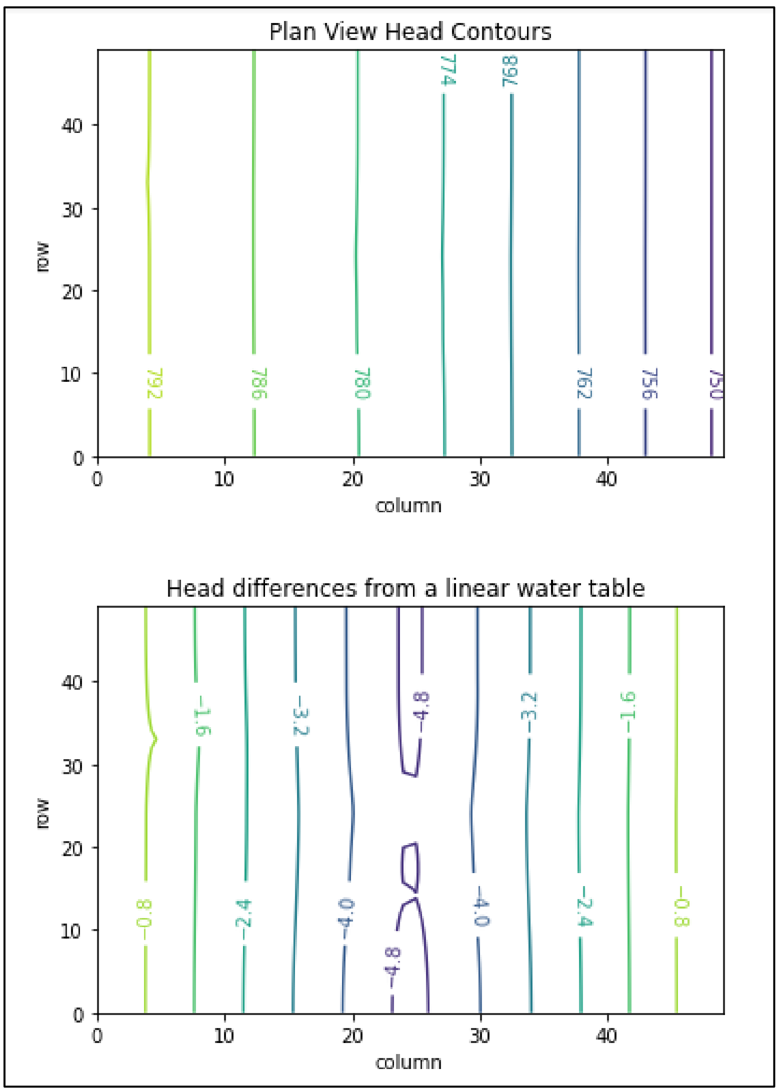

Figure 5: Scenario #1 Head Contours

Scenario #2

In the second scenario, the wells at ACME farm are in the same locations, but there is one K for the north half of the domain and one K for the south half of the domain. A harmonic average of the west and east K (as measured by the observation well) was used for each domain half. This also does not cause the Wildcat well to run dry, but the WTD is slightly greater than in Scenario 1 (~14 m vs. ~12 m).

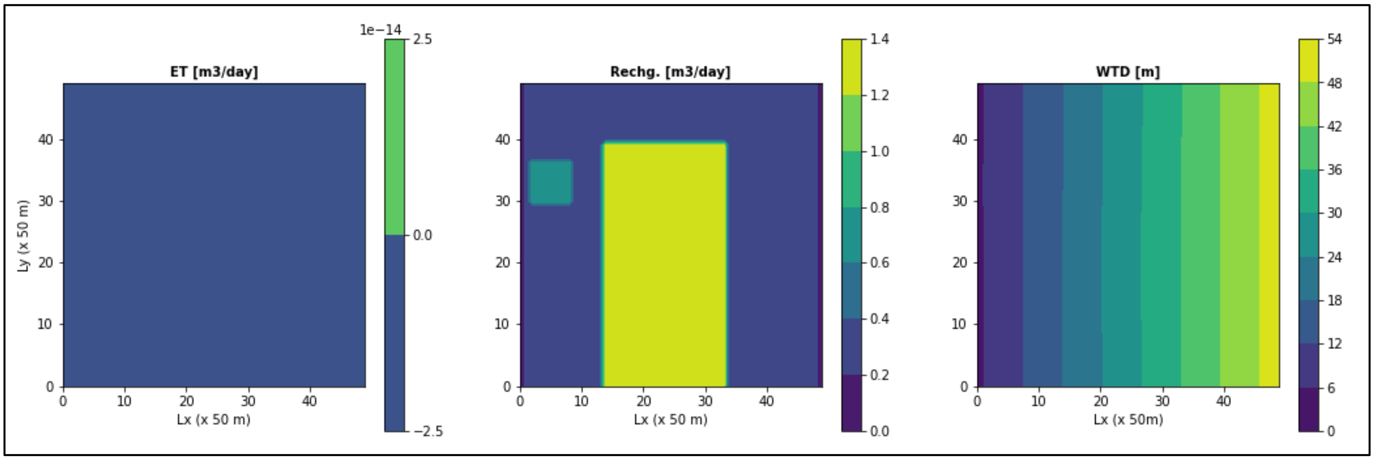

Figure 6: Scenario #2 ET, Recharge, and WTD

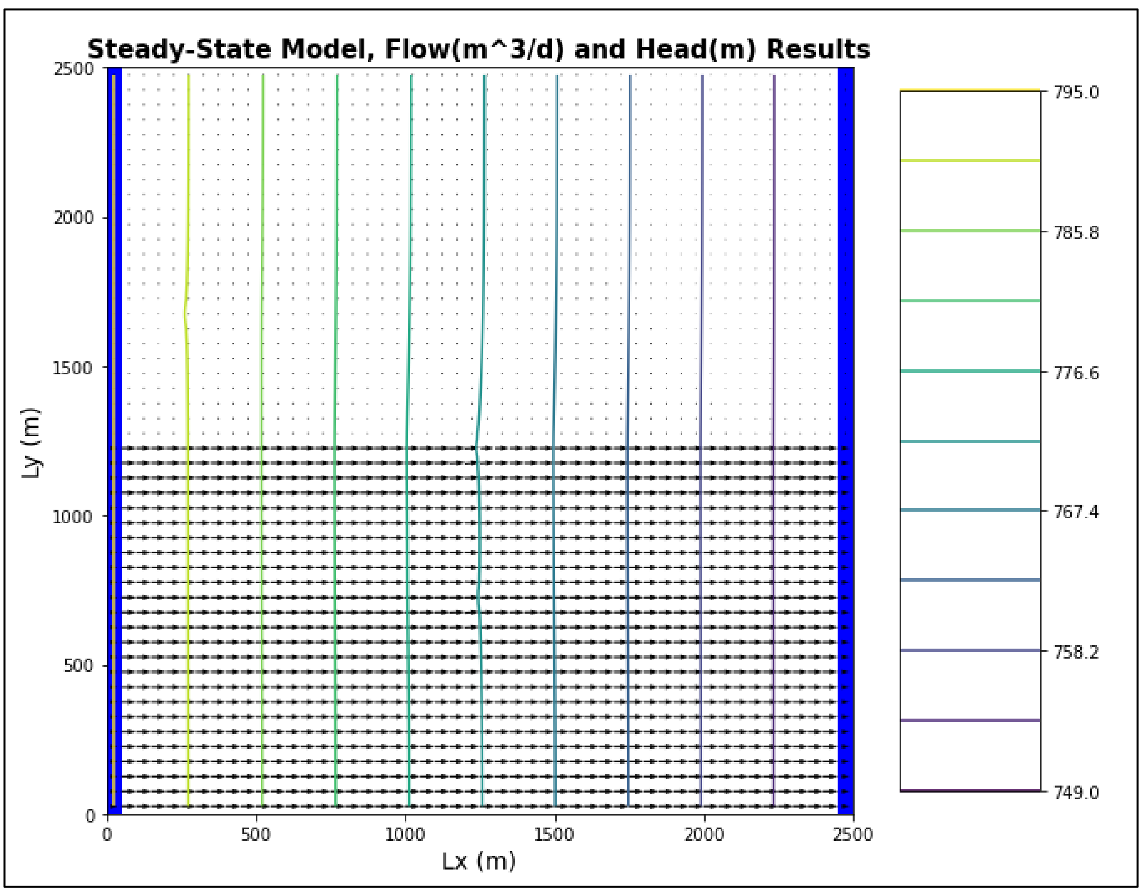

Figure 7: Scenario #2 Flow Lines and Head Contours

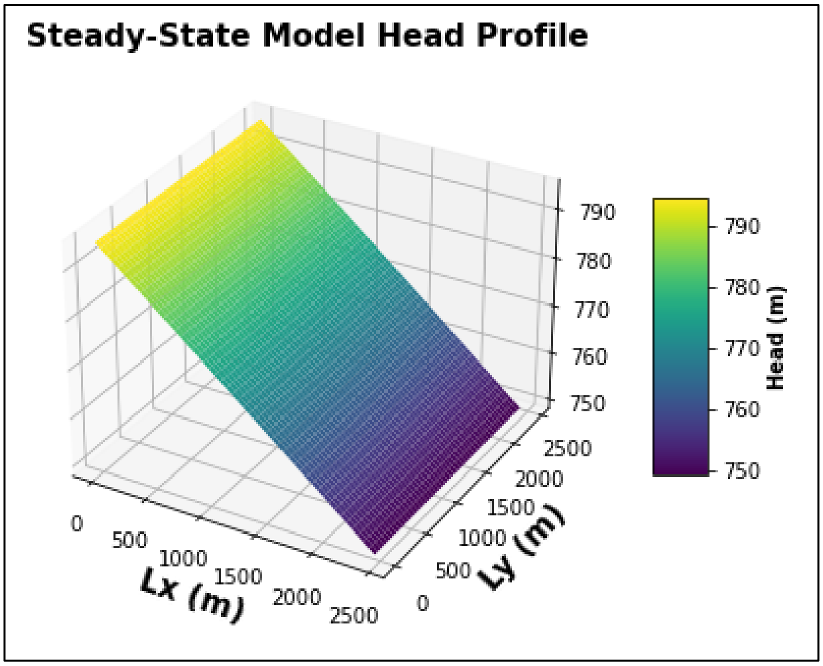

Figure 8: Scenario #2 Head Profile

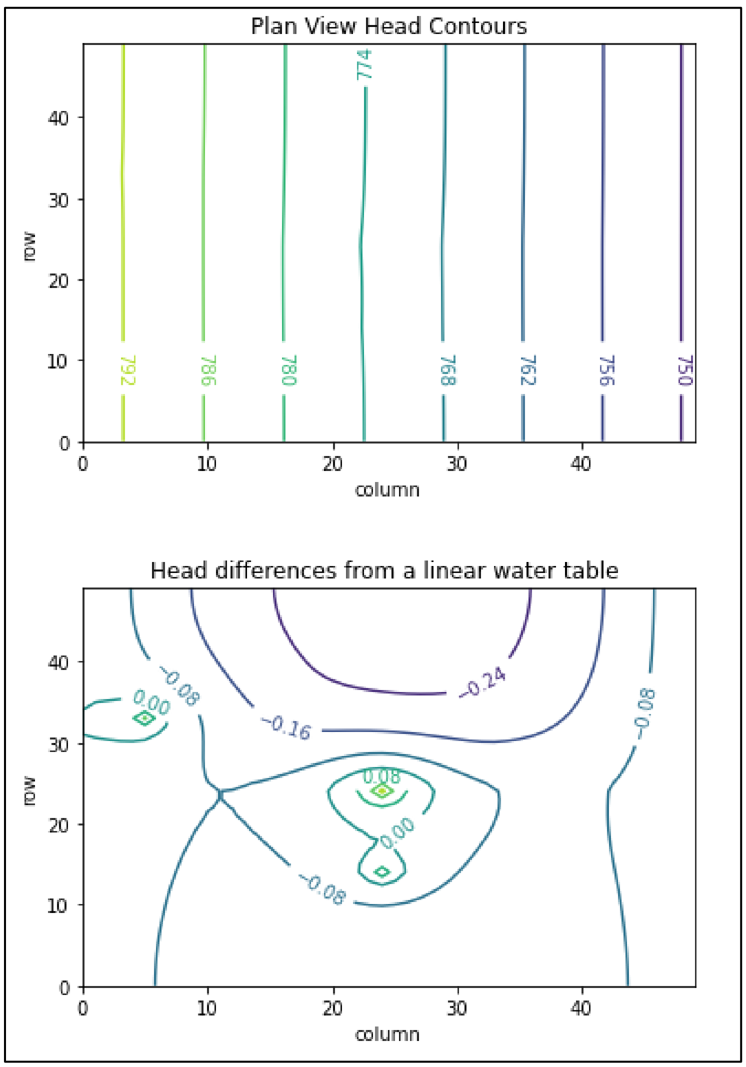

Figure 9: Scenario #2 Head Contours

Scenario #3

In the third scenario, the domain's K is the same as in the second scenario, but the ACME Farm wells are moved to be on the same row as the Wildcat Farm well. This puts both wells into the low-K half of the domain. In this scenario, the cells around the ACME Farm wells run dry (MODFLOW defaults to showing a head of $-1*10^{30}$ when this happens). MODFLOW "breaks" in this scenario, which can be interpreted to mean that the entire domain will run dry. This is the worst-case scenario.

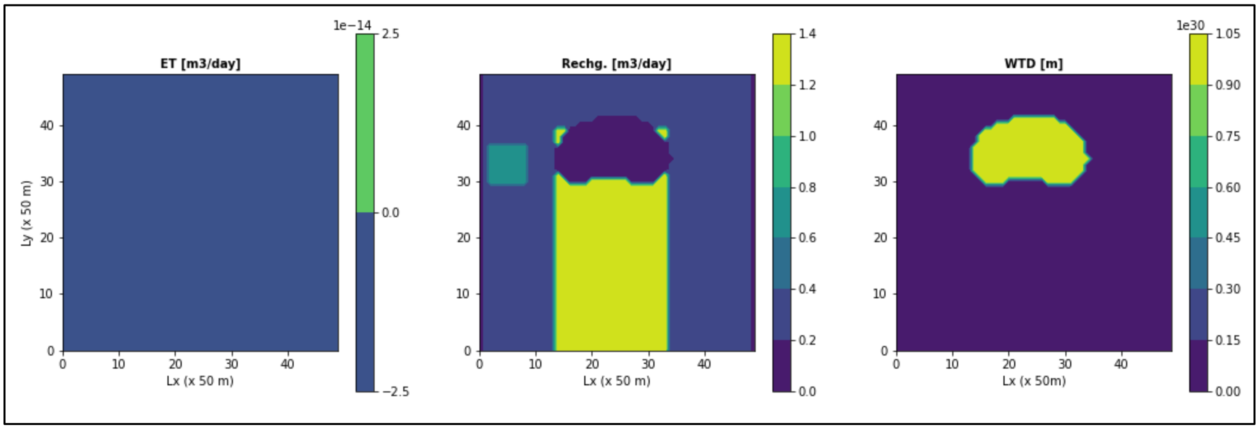

Figure 10: Scenario #3 ET, Recharge, and WTD

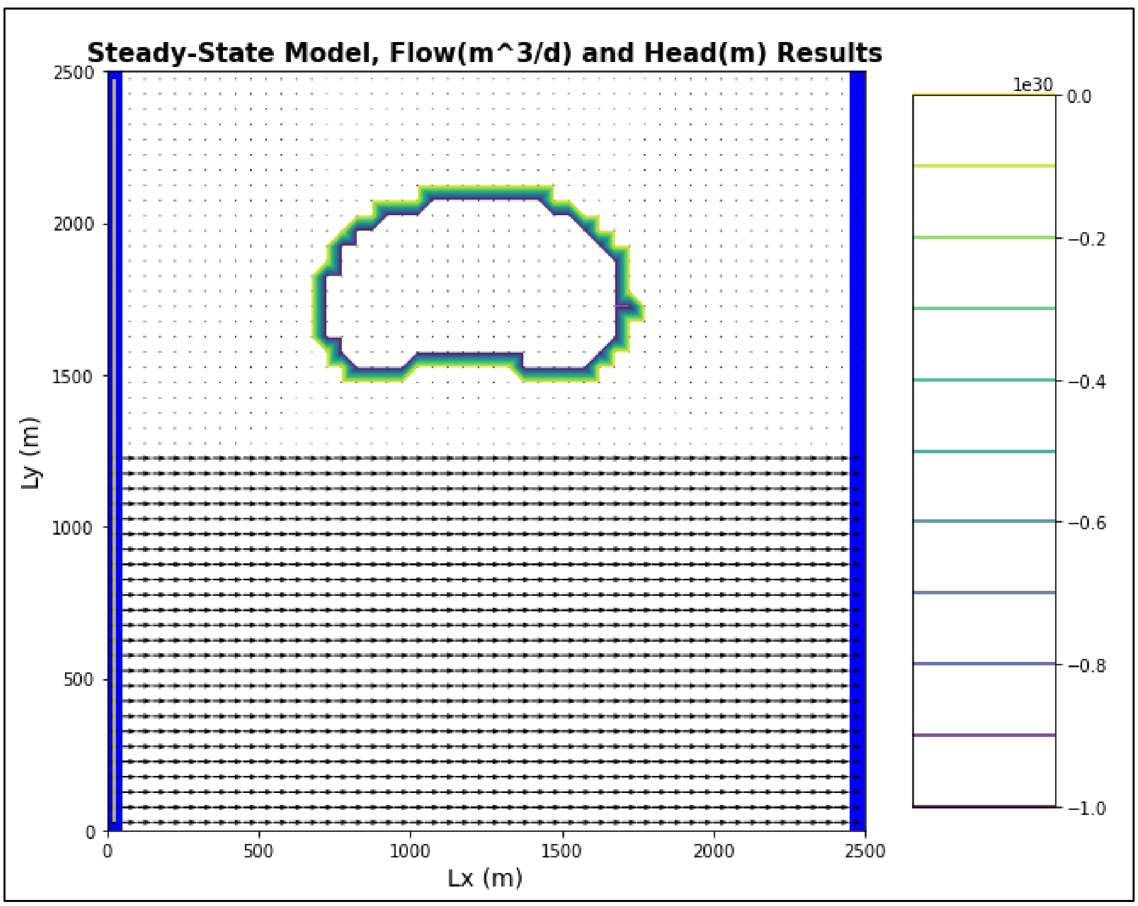

Figure 11: Scenario #3 Flow Lines and Head Contours

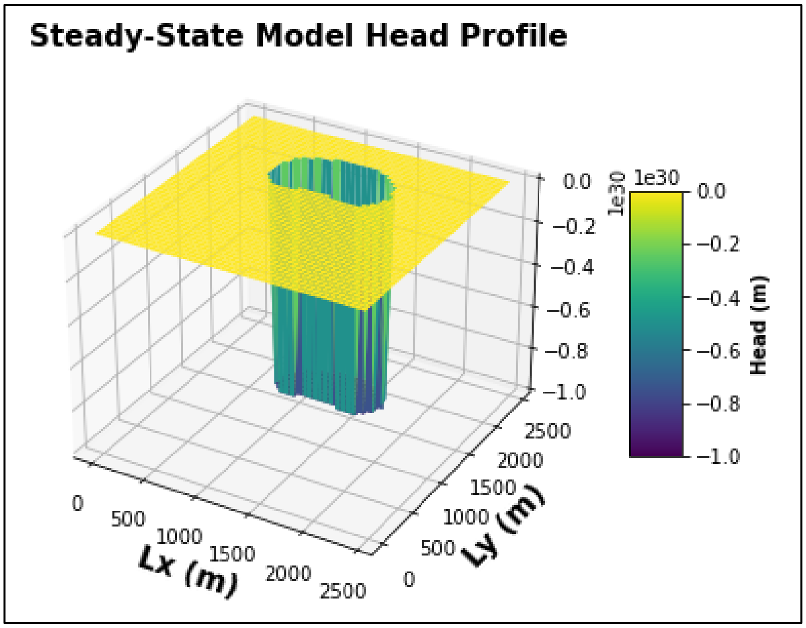

Figure 12: Scenario #3 Head Profile

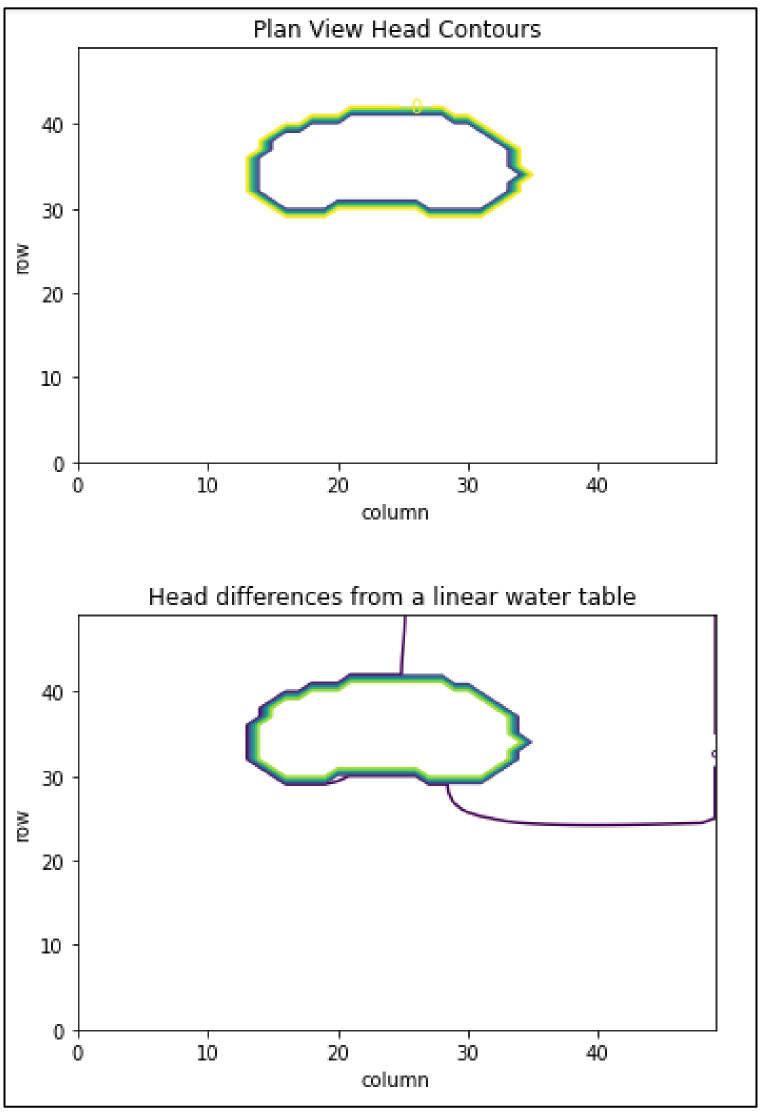

Figure 13: Scenario #3 Head Contours

Glossary questions

1. What does it mean to be simulating saturated flow vs variably saturated flow? What are the advantages and disadvantages of each? Why is it much harder to solve for unsaturated flow? Integrate the concept of a linear versus a nonlinear model into your answer.

    Saturated flow is simulated using a simple linear equation: Darcy's Law. Variably saturated flow uses a much more complex non-linear equation such as the Richards equation or Van Genuchten equation. In these equations, the hydraulic conductivity changes as a function of the water content/saturation of the medium. A non-linear equation is much harder to solve, for both human and computer. Many, if not most non-linear equations do not have analytical solutions, and a lot of computing power is needed to iteratively solve for a numerical solution.

2. What is meant by an internal source/sink for ground water flow and how is it different than a boundary condition? Give an example.

    An internal source/sink adds (source) or removes (sink) water from the domain without the water having to enter or exit through a boundary. In MODFLOW, these sources or sinks will add or remove a specific amount of water to/from a cell, regardless of other conditions (e.g., head gradient at/around the cell).

3. What is meant by 'forecast uncertainty' in the context of a groundwater model? What are the sources of this uncertainty? What is required for a prediction to be as robust as possible?

    All forecasts are wrong, but some are less wrong than others. Because so many assumptions have to be made, a model cannot ever be perfectly accurate. We will always be uncertain about the exact physical properties of the subsurface, since we can only directly observe very small portions of the subsurface. Assumptions must be made, but to be robust, they should be carefully considered, and remain consistent with what can be observed and what can be inferred through physical laws.