Starlivia Kaska

HWRS 482

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The Challenge

**Graphical user interface, chart, table, Excel

Description automatically generatedSummary and Design of Model:**

We chose a grid resolution of 25 X 25 with cells measuring 100m X 100 m. This resolution was chosen as the size represented the two farms well within this grid. A larger cell size would reduce the resolution of our model and we would make larger assumptions about each area in our model. With a cell size of 100m x 100m we would have to estimate some locations and orientations of both farms, however these estimations do not deviate from their actual values as much as they would if the cell sizes were larger. With our cell length and width at 100m it provides a small enough resolution to where our grid is easy enough to read and areas is the domain can be manipulated without too much tedious work on our end. 12 cells are roughly equivalent to 30 acres for your farm and 200 cells are 500 acres on ACME farm. The determined area for irrigation on ACME farm for our model was 40 acres which is equal to 16 cells.

We chose head boundaries and hydraulic conductivity based on the information given from the four observation wells in the area and the land use. This area is being used for farming and from a little research on farming soil, we determined that farming soil tends to have hydraulic conductivity values of less than 1m/day. Therefore, we set the background hydraulic conductivity at this value, this meant that the entire grid and the represented have a hydraulic conductivity of 1m/day. For this model we chose to disregard Evapotranspiration as the area that is being irrigated on both farms aren’t extremely large. The thickness of our model is set at 400m as due to the deepest well in our grid being 200m (ACME Farm). To account for this well depth the thickness of our model had to be set at a value higher than 200m, and we decided to double that value for our thickness. The head boundaries were set according to observation well 1 (left of domain) which had a water table depth of 4.8, and observation well 4 (right of the domain) which had a water table depth of 51.6m. The head at these wells are equal to the thickness of our layer minus the water table depth, giving us a rounded value of 395m for well 1 and 348 for well 4. Therefore, our left head boundary is 395m and our right head boundary is 348m.

To determine pumping rates for each of the wells in our model we first started with the consumptive water use for each crop in Arizona. The consumptive use for cotton is 41.2 inches/yr and it is 74.3 for alfalfa. We assumed that the area each crop was planted on would take up 100 percent of the consumptive use. Therefore we would have to determine the are each crop would be planted on and distribute the consumptive use in these areas. We determined the entire acreage on the Wildcat farm would be used for crops and the pumping rate for Wildcat farm by the following process.

30 acres = 121406 m^2

Cotton uses 41.2 inches per year

41.3 in/yr = 1.046 m/yr = 0.00286 m/day

0.00286 m/day x 121406 m^2 = 348 m^3/day

30 acres of cotton needs 348 m^3/day

1 well pumping 348 m^3/day

We determined that only 40 acres of the 500 on ACME farm would be used for crops, and the pumping rate was determined by the following process.

40 acres = 156,677 m^2

Alfalfa 74.3 inches per year

74.3 in/yr = 1.887 m/yr = 0.00516 m/day

0.00516 m/day x 156,677 m^2 = 808 m^3/day

40 acres of alfalfa needs 808 m^3/day

2 wells pumping a total of 808 m^3/day

The assumptions our model made were that the area the crops were planted, used up all of the water irrigated on it and there was no recharge happening on these areas. We also assumed that the recharge on non-irrigated areas was 1e-4 m. We also assumed there was no evaporation happening in our domain. We also made the large assumption that the hydraulic conductivity was the same throughout our domain.

**Scenarios:**

The first scenario is that ACME farm does not used the entire 500 acres for the alfalfa crop. A reduced alfalfa spread would result in lower demand for water. The second scenario is that ACME farm decides to import most of the water necessary to run the farm on the said acreage and will only use the water pumped from the well for use in the buildings on the farm. The third scenario is that ACME farm will pump out enough water to supply half of what the alfalfa needs and import the other half from outside sources.

A screenshot of a computer

Description automatically generated

For scenario one, the likely outcome is that ACME farm can produce alfalfa and irrigate it properly given that the area they choose is no larger than twice the size of the Wildcat farm. We determined that the irrigated area in ACME farm should not be more than twice the area of Wildcat farm by running simulations through our model. If ACME farm pumps more than 804 m^3/day, a large portion of the domain will dry out. The current pumping rate for this scenario was determined to be the max without causing our systems to crash. With well one set at a pumping rate of 348 m^3/day, well 2 set at 508 m^3/day, and well three set at 300 m^3/day it produces the above plot. As we can see, all three wells are stable and the head gradient shows the capturing of water by the wells, however flow is present, and the head gradients are decreasing from left to right. This means that the wells did not skew the head gradient enough to impact your well.

A screenshot of a computer

Description automatically generated

For the second scenario, the likely outcome is that ACME farm will import the majority of their water needs and your well is guaranteed to not be affected. ACME farm would only be pumping a total of 60m^3/day, with well two pumping 10 m^3/day, and well three pumping 50m^3/day. We can see from the diagram above that your well is the only one making a difference to the head gradient, we can also see a capture zone for your well, however it is missing for the wells on ACME farm. This is a great outcome for your farm as you would not need to worry about ACME farm at all. With the current assumption made to the area, ACME farm should consider importing the water they need as they would not be able to get the water required to plant on the entire 500 acres in this location (with the conditions set for K, recharge, and the extreme pumping rates required).

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For the third scenario, the likely outcome is that ACME farm will use the wells on their farm to provide a total of 404 m^3/day to their farm which is half of the water needed to irrigate the 40 acres of alfalfa. This will not affect you well. Here wells two and three (on the ACME farm) are pumping at the same rate, 202 m^3/day. This is half of the water need to farm 40 acres of alfalfa. Again, we see that the only well impacting the domain is the one located on your farm, and the wells on ACME farm do not affect the water flowing to it. If ACME farm wanted to pump only half of what they need for their alfalfa field, then it would be feasible without any impact to you or your business.

All three of the scenarios presented will not dry your well. These aren’t the only options that are available to you, however these are the ones we could provide on such short notice. Please keep in mind that the assumptions we made in our model aren’t an accurate representation of the area. In order to better accommodate your situation, it would be best if we could conduct an extensive survey of the area in our model in order to present a more effective forecast on whether your well will go dry if ACME farm does decide to operate their proposed wells for an entire 500-acre alfalfa field.

**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.**

Simulating saturated flow means that each column is entirely saturated and for a variably saturate flow the columns have areas that are saturated and some that are not. An advantage for simulating saturated flow is that the equations for fluxes are a lot simpler and a disadvantage is that the model will assume the subsurface is always saturated (which is not the case). An advantage for a variable saturation flow is that it can show a relative simulation of the subsurface and models can be represented in three dimensions. A disadvantage of variable saturated flow is that the equations for fluxes get more complicated. It is much harder to solve for a variable saturated flow compared to the saturated flow as the cross-sectional area changes over time (in our equation for Darcy’s law) rather than being constant. This results in math involving integrals and we will end up with an equation which produces a curve rather than a linear relationship.

Answers:

Saturated flow = all pore spaces filled with water, Darcy’s Law

Variably Saturated flow = Richard’s equation, hydraulic conductivity varies with saturation

Easier to compute saturated flow as the hydraulic conductivity is constant, can linearize much easier. For variably saturated flow it is harder to compute as the K changes over time, more complex integral.

We do not model process of Recharge or ET, can’t solve all these parameters using our models. Hydraulic conductivity varies with moisture content. You need to know how K varies as a function of the moisture, these have parameters, now you need all of this in your model.

**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 for ground water flow is a drainage area I the subsurface. This is different from a boundary condition as the boundary condition has one direction of flow where the sink has no defined flow pattern. An example of this could be saltwater intrusion near the ocean.

Answers:

Internal Sink: anything we pull in and out from any cell except those at the edge.

Surface water body = sink, source

Source sink vs boundary condition, boundary condition (can be a source and a sink). A boundary conditions are on the edge of the domain, fluxes across the edge of our model (ET and Recharge can be considered).

W**hat 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?**

Forecast uncertainty means that models can simulate conditions and make predictions, but it is not for certain. Conditions change overtime and some models may fail to predict what will happen in the future accurately due to this nature, that is one source of uncertainty, also using past data. You would need enough historical data to make a good prediction and conditions should stay as constant as possible.

Answers:

How we choose to measure, where we measure, how many data points.

When fitting a model, we always leave some observations, and then validate it later (better)

Sources of Uncertainty: K values, accuracy of the reported data, locations of items: configurations of domain (structural uncertainty), parameter uncertainty, processes to consider,

You can use sensitivity to combat uncertainty.