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Homework 4

Discussion

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Figure Base case boundary flows for initial condition

**2. a)** Type 1 boundaries have a specified constant head, which does not mean the flow has to be constant across that boundary.

**b)** The base case pumping well is located in the center of the domain. The direction of flow is with the head gradient, from left to right. Flow across the center of the left boundary could be greater than the right side center because pumping is causing drawdown in the direction of flow. At the right center boundary pumping is against the flow; reflected in the lower flow values in that area (Fig. 1).

**c)** If the pumping continues at a constant rate over a long enough period of time, the system can achieve equilibrium and be considered steady state because the drawdown at the point of pumping does not change. This assumes uniform thickness and infinite water supply. Figure 2 shows a loss of 10 m^3/day which indicates we are not modeling steady state.

Chart

Description automatically generated**3.** The flow profile through the center well shows near-zero flow at the center, while the center of the left well has the greatest flow (Fig. 2). If my interpretation in part b is correct, I think this is a reflection of the same concept. But it is hard to reconcile different center flow trends. In this confined model, the cone of depression manifests as a pressure gradient. If each of the locations are pumped at the same rate, there could be a larger head gradient between the left well and inflow boundary (highest head) than between the center well and the outflow boundary (lower head).

Figure Base case flux through the midline of the domain

**Chart, table

Description automatically generated4** Flow vectors increase with proximity toward the well from left to right (Fig. 3). The capture zone is fed from the center of the inflow boundary. Increasing the pumping rate would extend this zone to capture more of the flow originating along the inflow boundary.

Figure Equipotential lines with flow vectors through the midline of the domain

**5** The contours should be circular (as shown in Fig. 4) for a steady state system.

Chart

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Figure Plan view drawdown for base case

**6** Chart, line chart

Description automatically generatedThe behavior of flow profiles is the same for both cases; only the y location has changed (Fig. 5). With the well located in the upper left of the domain, this is where the greatest rate of flow occurs (Fig 6). The drawdown plot is no longer circular, and I think this has to do with the well’s proximity to a no-flow boundary (Fig. 7).

Figure Base case boundary flows for the moved well

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Figure Equipotential lines with flow vectors for the moved well

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Figure Plan view drawdown at the moved well

**Glossary**

**1 What are equipotentials? How do we create them from MODFLOW Models?**

Equipotentials are lines or contours of constant values. In our model, we are interested in equipotential head distributions. In MODFLOW, we define constant head boundaries and starting values to create an array of starting heads to create a BAS object. Running the model with this package returns a binary head file with metadata for timesteps. We use this to create an array of head values with shape (1,25,25), which we can index for 2D or 3D plotting.

**2 What are flowlines? (BONUS thought experiment: How can you impose a no flow boundary based on symmetry? Give it a shot to explain WHY this works in a couple of sentences.)**

Flowlines indicate the direction of groundwater movement. In our model we have been plotting flowlines as vectors, showing both the direction and velocity of flow. Our inflow and outflow boundaries are reciprocal and proportional: higher flow on the left corresponds to lower flow on the right. If we increased the pumping rate enough, I think this would cause the right boundary to approach zero flow.

**3 What are flownets? And how does a flownet vary from a map of equipotentials with flow lines drawn on it?**

Flownets show the direction of flow in steady state conditions and are useful to supplement when analytical solutions are difficult to apply. They are created by drawing perpendicular lines through drawdown contours, as opposed to head equipotentials.

**4 Define the concept of 'capture' in a way that a non-expert might understand?**

Capture describes the extent of a well’s impact both in distance and volume. Similar to the diminishing ripples created by throwing a rock into a lake, a pumping well will have a large impact on the area immediately around it. The farther from the well, the less drawdown will occur. The region of “ripples” around the well defines its capture zone. If a stream is within a well’s capture zone, pumping will pull from the stream and reduce its flow.