Abigail Kahler
HWRS 582, HW 11

The Challenge

1. Read the paper that summarizes the stream flow packages in Modflow and look at the flopy documentation for the str package to understand how we have implemented this in our code. Write a short explanation for how the str package works and what assumptions it is making.

The STR package can simulate surface flow, unlike the RIV package. The flow is determined by the initial stream flux into the model. The discharge into each cell is calculated by the discharge of the previous cell plus or minus any seepage through the stream bed. An important assumption is that the previous discharge is instantaneously available at each progressive cell along the stream. This is a reasonable premise, giving the slow rate of groundwater flow. Overall, the STR package is best used for simulating simple systems because it is limited by simplified input parameters.

The surface water level is calculated by

$Q = \frac{1}{n}\left(AR^{2/3}S^{1/2}\right)$, where Q = discharge [$m^3$/s]; *n* = Manning's roughness coefficient [ ]; A = cross-sectional area of the stream [m^2]; R = hydraulic radius [m]; S = hydraulic gradient slope [m/m]

Some of the stream object inputs describe the number of stream reaches, segments, tributaries, and diversions. Each of these default to zero. Other stream object arguments specify when to calculate stream stage, various flags for activating and saving specific calculations, and options to create dictionaries for stream segment and period data. For our model, we specify 75 reaches, 1 segment, and a flag for calculating stage.

2. The code is provided to produce the first set of 'correct' figures. Use these figures to describe the nature (direction/magnitude) of stream/aquifer exchange along the stream. In particular, explain why the leakage changes magnitude or direction where these values change.

Streamflow progressively increases downstream until peaking at the center reach (Fig. 1A). We know that there is zero flow coming into the domain (set by the variable Flow_into_the_1st_reach). The flow in each cell is calculated by the flow from the previous cell and the constant stream stage, which leads to increased flow into cells the further along the upstream portion. Recharge of 5e-5 m/day in the first 26 cells contributes to the increased flow. Hydraulic conductivity also affects the flow. The slight decrease in acceleration of flowrate at row 20 may reflect the greater seepage loss caused by changing K from .01 m/d to .1 m/d for rows 20-25. Increasing hydraulic conductivity to 1 m/d while removing recharge causes a sharp decline in flow for the lower portion of the stream.

All of the streambed properties are constant except for K. The overall decreasing head in Figure 1B is attributable to the constant head boundaries on each side of the domain driving the flow from left to right. The streambed top and stage head remain constant along the whole stream. For a constant Q, increasing K must decrease the head gradient. However, the Q in this case is not constant. The head gradient begins to plateau at row 25, where the K is increased to 1 m/d and recharge is discontinued. This leveling off could suggest that the streambed has reached saturation and there is effectively no head loss. The sharp decline at the end of the stream could be attributed to the restriction of a constant head boundary at that location.

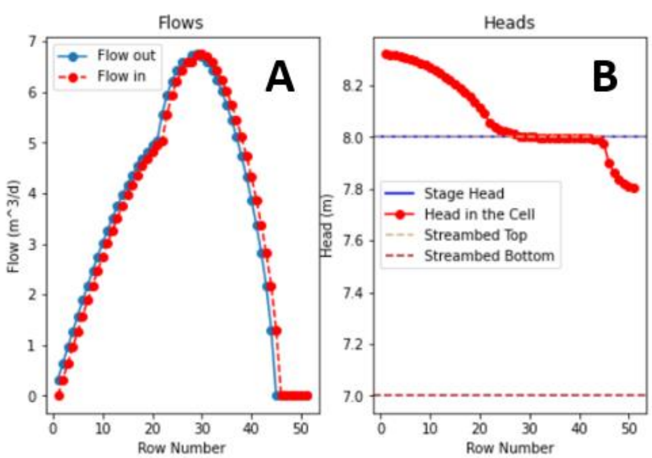

Figure 1 Stream flow and head profiles along the length of the stream

3. Use the head distribution to describe the movement of water across the boundaries and into/out of the stream.

We see a major disruption in the head gradients between the stream and the right boundary, especially along the lower half of the stream (Figure 2). Figure 3 is included to provide a corresponding spatial map. Possible reasons for this decrease are introduced above, including the discontinuation of recharge and increased seepage loss along that reach. The head gradient this causes is driving flow out the bottom right of the domain.

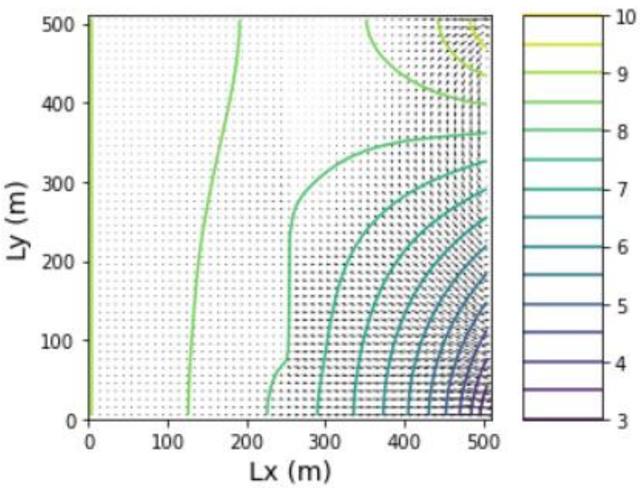

Figure 2 Head distribution for single layer model with stream

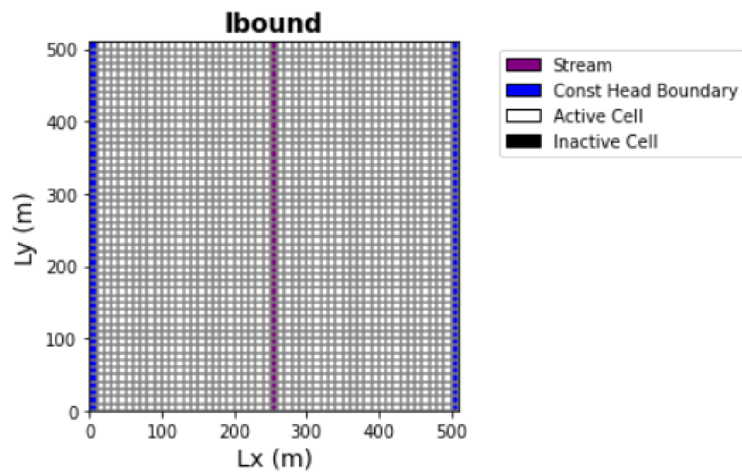

Figure 3 Stream orientation within single layer domain

4. Choose two things to explore (e.g. impact of streambed K or inflow into the river or recharge rate). Produce a plot for each to compare to the base plots and use the plots to explain the impact of the hydrologic change.

I first explored the overall effects of changing one variable at a time for inflow, and then stage level. These effected little-to-no significant change. Before altering K or exploring covariant properties, I decided to investigate the depth of the river. The findings are summarized in the figures below.

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Figures 4 and 5 are the result of running the model with a streamflow of 2 m^3/d into the model. This simply increased the maximum rate of flow and made no significant change.

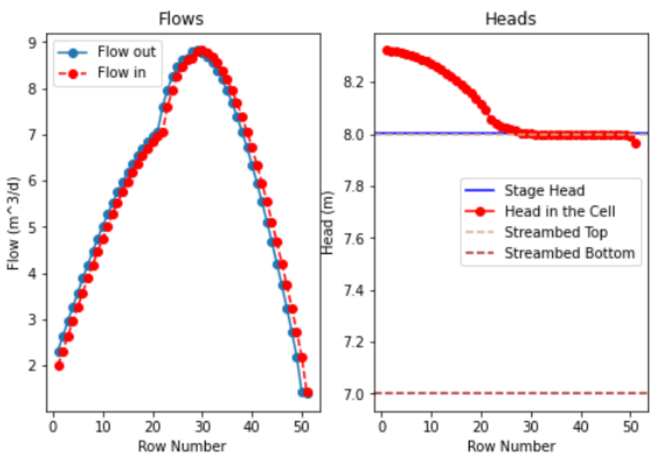

Figure 4 Flow and head profiles for inflow of 2m^3/day

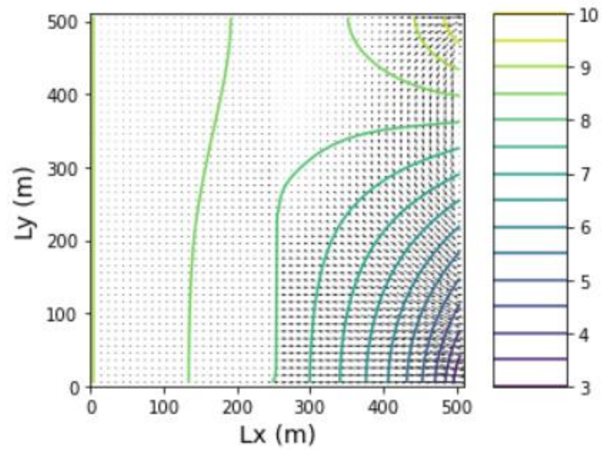

Figure 5 Head distribution for inflow of 2m^3/day

Figures 6 and 7 show no differences between a stage of 3, 8, or 12 meters (only one example shown). This is unexpected considering that state is part of the streamflow calculation.

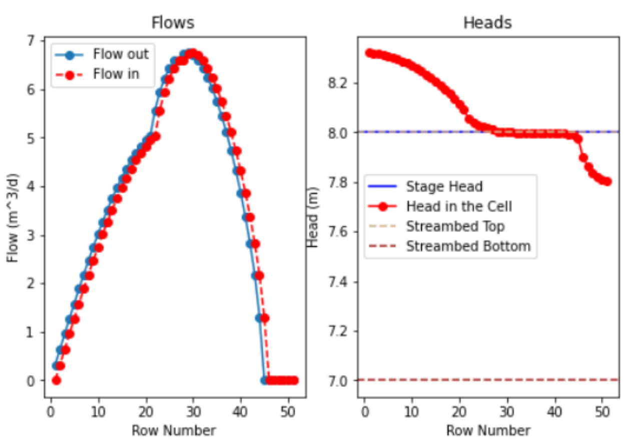

Figure 6 Flow and head profiles for stage of 3, 8, 12m

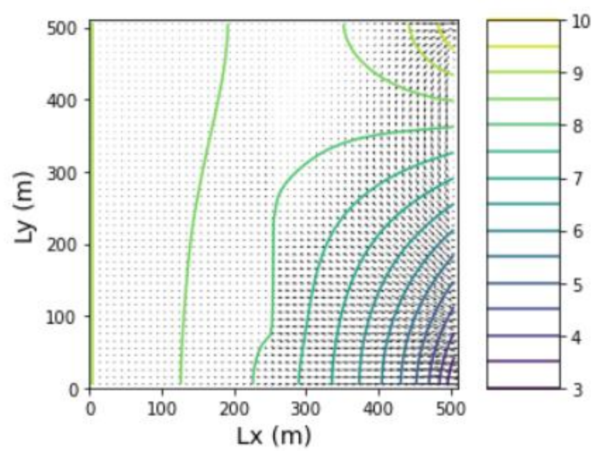

Figure 7 Head distribution for stage of 3, 8, 12m

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Decreasing the stream bed depth (derived from the variable strbott) from 7 meters to 4 meters while leaving the other variables unchanged clearly affects the stream behavior (Figure 8), though I am uncertain of the interpretation. Changing this value reduces the stage at inflow to 5 meters, which we have already identified as having little effect on the results. strbott does effect riverbed conductance but that is something explicitly calculated in the RIV package, not STR.

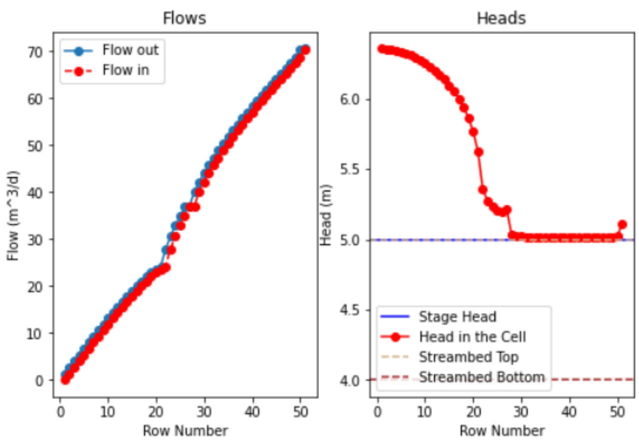

Figure 8 Flow and head profiles for bottom of stream 4m

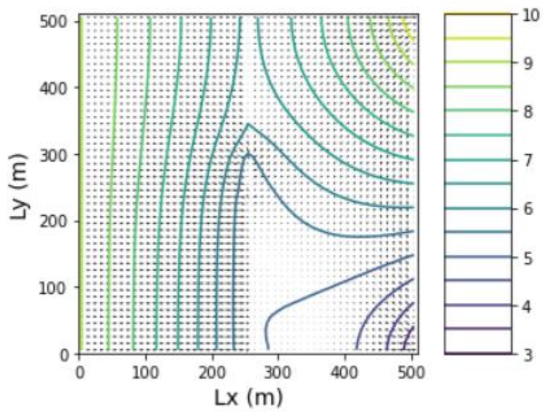

Figure 9 Head distribution for bottom of stream 4m