

HW11 Discussion – River Package

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Question 1:

MODFLOW does not model the surface movement of water in the river. Instead, it focuses on the seepage between the river and the aquifer as determined by their difference in head. In order to quantify this seepage as a flow, MODFLOW decomposes Darcy's Law into two parts, $CRIV_n$ and $(HRIV_n - h_{i,j,k})$.

$CRIV_n$ is the conductance of the streambed material and is calculated with the following equation:

$$CRIV_n = \frac{K_n L_n W_n}{M_n}$$

Where:

K_n = hydraulic conductivity of the streambed material

L_n = length of riverbed sediment that intersects grid cell

W_n = width of the river

M_n = thickness of riverbed sediment

$(HRIV_n - h_{i,j,k})$ is the difference in head between the river stage and the head of the grid cell underneath the river. When recombined to find $QRIV_n$, it can be readily seen that MODFLOW is still solving using Darcy's Law.

The RIV package parameters are defined and used as follows (**bold** denotes use and *italics* denotes lack of use in our model):

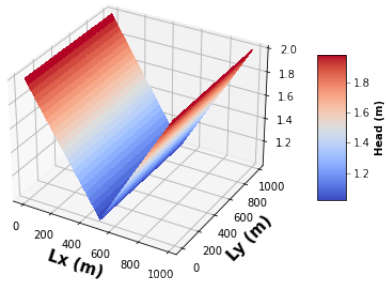
```
stress_period_data =  
{0: [  
    lay, row, col, seg, reach, flow, stage, cond, sbot, stop, width, slope, rough]
```

Using a for loop, the model specifies the row for each head value associated with the river for each stress period.

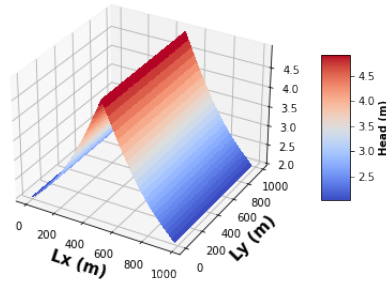
Question 2:

For the first stress period where the boundary conditions of the domain are set to 2m and the head value along the stream stage is set to 1m, the model constructs a gaining stream along the entire reach from the top of the domain to the bottom. In the second stress period, where a transient system is created, the stream stage is set to 5m, and this creates a loss of water to the subsurface.

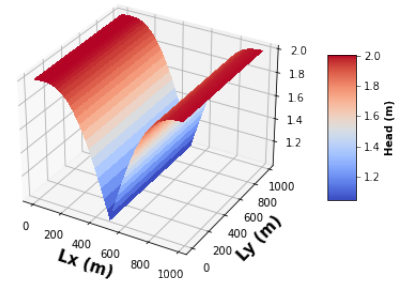
Head Surface: Stress-Period 1



Head Surface: Stress-Period 2



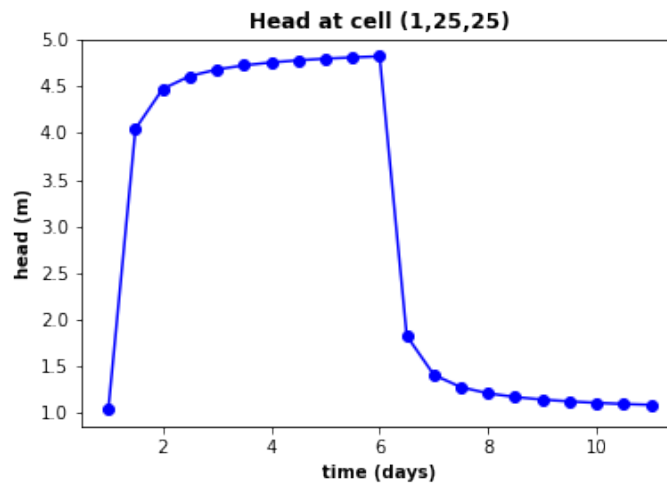
Head Surface: Stress-Period 3



In these 3D head surface plots, we can see that the leakage changes depending on the value of the river head because the boundary conditions are kept constant. In the last plot, for stress period 3, the surface does not look exactly like the first plot even though they represent the same model parameter values. This is due to the first plot reflecting a steady-state model scenario and the third plot reflecting a transient time—had the last scenario been given enough time in its stress period, it would have eventually reflected steady state.

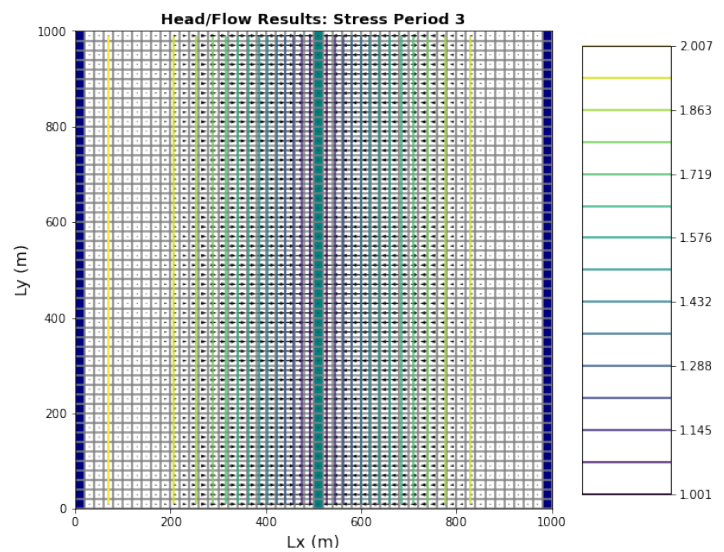
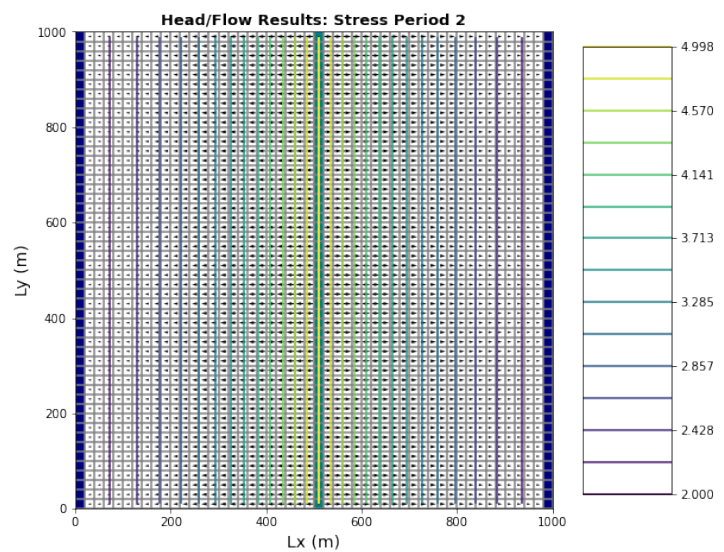
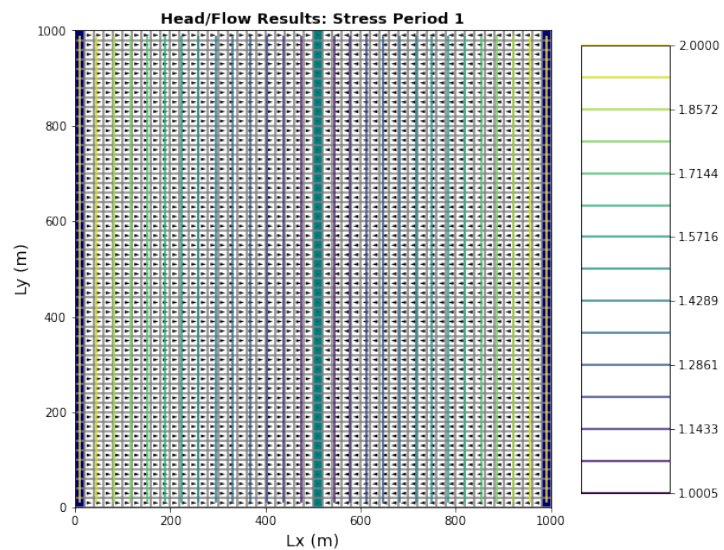
Question 3:

In this image below, the time series shows the head value of a cell just to the left of the river at location (1, 25, 25) for the two periods during the transient scenario. The starting head value of the cells outside of the river was 1m, but once the first stress period began and the stream stage was set at 5m for the first five days, the cell's head value can be seen rapidly increasing and then gradually leveling off until finally reaching ~4.82m (not quite getting to 5m). This suggests the river is losing water to the subsurface until day 6 when the stream stage is immediately dropped to 1m. At this point, the subsurface has stored a significant amount of water and it begins flowing in the opposite direction back into the river.



The below three images on the next page further demonstrate this movement of water in through the domain according to the following descriptions:

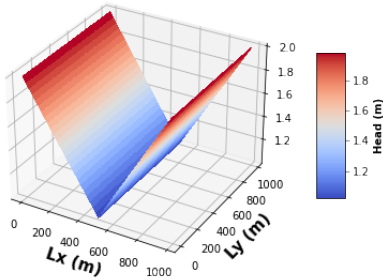
1. **Stress Period 1:** water flows from the L/R boundaries in to the stream
2. **Stress Period 2:** water flows from the stream into the subsurface and across the boundaries
3. **Stress Period 3:** water flows back from the aquifer and into the stream



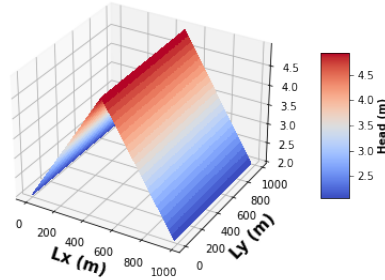
Question 4:

Specific storage decreased from $1e-4$ to $1e-5$

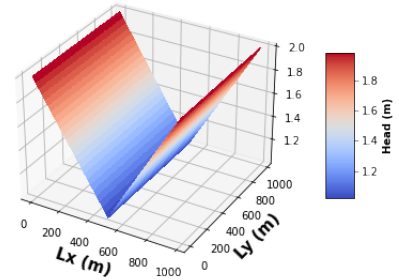
Head Surface: Stress-Period 1



Head Surface: Stress-Period 2

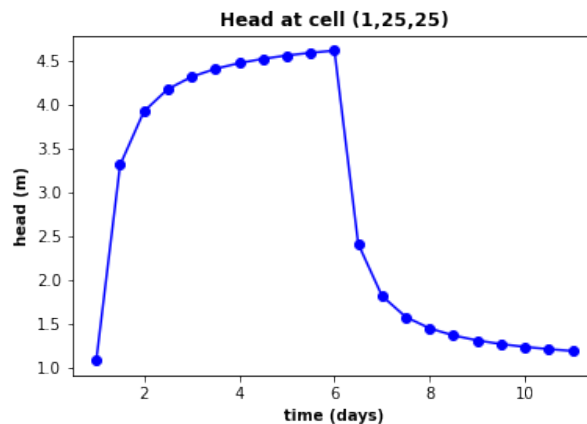


Head Surface: Stress-Period 3



After decreasing the specific storage of the subsurface, the effects of the various stream stages create a system in steady state within the same number of days as the default scenario. Specific storage relates the unit volume of water released or stored for a unit increase in head. With a lowered value, the system does not have as much storage as previously which allows the propagation of pressure gradients to increase in speed.

Streambed sediment hydraulic conductivity decreased from 10 m/d to 0.1 m/d



Returning the specific storage to its original value, the streambed sediment hydraulic conductivity was then decreased by two orders of magnitude to 0.1 m/d. When comparing the head surface plots between this scenario and the original, it was difficult to see much difference. Instead, the most illustrative plot that showed the effects of the reduced conductance was in the head value time series seen above. The lower hydraulic conductivity reduced the speed of propagation as can be seen in the less steep increases and decreases in head for the higher and lower stages, respectively.