Follow up Waquoit Bay and Lab Questions:

1. 15/15 The field trip data showed that the hydraulic conductivities were high and within a factor of three or four of one another between the three test locations. All three stations had a hydraulic head drop of around 1 mm (bay minus sediment) implying a water flux into the sediment. The salinities of the bay and sediment water were reported to be around 25-28 ppt. However, the near shore and far shore station had a flux of water coming out of the sediment in the opposite direction of the gradient! Could Darcy's Law be wrong? Please give your best guess as to what happened with the field trip experiments (Hints. See previous solution set for one idea? Is the system at steady state? Do you think interesting things might occur where fresh and saltwater interface? Should this system be further researched?)

   Darcy's Law is not wrong or we would not teach it to you. The Waquoit Bay system is ideal for class field trips but is in fact a very complicated hydraulic system with transient boundary conditions, density dependent flow, and heterogeneous conductivities. All of your ideas were very good and could be relevant to study hydrology in Waquoit Bay. The two biggest ideas we were looking for was: 1) the possibility that density differences caused us to measure the hydraulic gradient incorrectly, implying that density measurements would be needed in the future and; 2) the system was transient. While it would not be possible for transience to produce a flux in the opposite direction of the gradient, it might cause our measurements to be erroneous. For example, the seepage meter records the average flux over the period of an hour and it is possible for the flux to switch directions due to tidal affects. If the flux was upwelling most of the time, switched to downwelling at the end when we measured our gradient, then it would appear that the flux is in the opposite direction of the gradient. To account for this, the gradient should be monitored during the entire time the flux is being measured. Future research will help us understand these and other flow mechanism, such as heterogeneous hydraulic conductivity, density instabilities and density dependent flow.

2. 10/10 Since the field trip experiment suggests Darcy's Law is invalid, or at least we didn't take all the proper measurements, we will ask you to analyze some older data collected by Emily Slaby, which was taken at Waquoit Bay using the same measurement techniques that you applied. Please see attached excel sheet. First compare the tidal height and the fluxes (a graph with two different Y axis (flux and tidal height) vs. time might be helpful). What does this plot tell you about the boundary conditions controlling this flux?
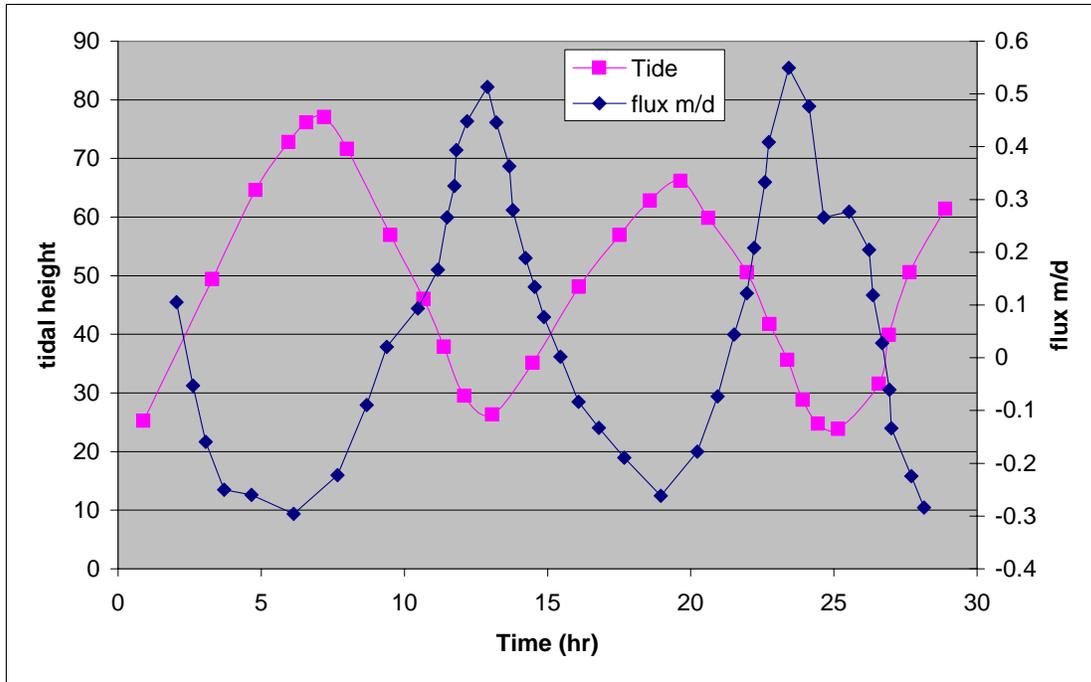
3. 10/10 Next make another plot of the gradient and flux over time (another plot with two Y axis). Does Darcy's law appear to be valid? If Darcy's law is valid why would there be any discrepancy at all?
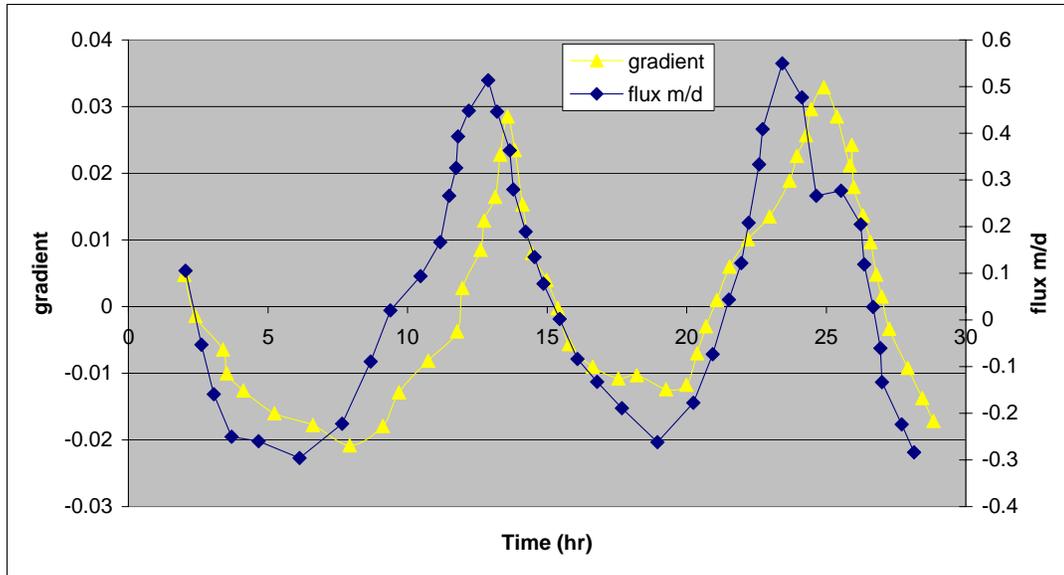
Yes, Darcy law does appear to be valid since the flux is generally proportionally to the gradient. Discrepancies could come from several reasons that were addressed in problem 1 such as the instantaneous gradient not representing the average flux, or density issues.

4. 15/15 Next take the data and determine the hydraulic conductivity. You should be able to do this two ways 1) one graphically and 2) a straight calculation that will also provide you with an uncertainty of your estimate. (Hint. Matlab's interp1 function might be useful). How does your value(s) compare to the four values that we measured in the lab: 5.6×10^{-5} m/s, 5.6×10^{-5} m/s, 6.8×10^{-3}, 5.7×10^{-7} m/s. All of these values were measured on a nice sandy beach. What do these values tell you about measuring hydraulic conductivity? What do these values suggest about hydraulic conductivity in nature?

Applying matlabs interpolation function yields gradient and flux values at the same time. This means that we can plot gradient vs. flux to fit a straight line with the slope corresponding to hydraulic conductivity:

flux vs gradient

$y = 14.033x$
$R^2 = 0.6438$
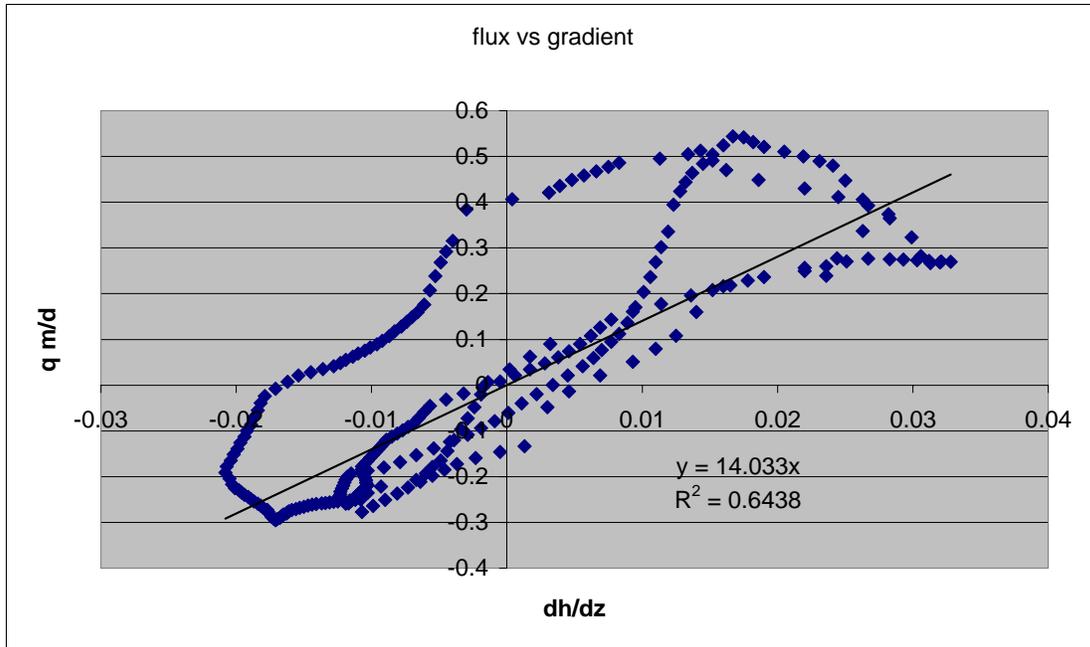
Giving a hydraulic conductivity of 14 m/d. Another way of calculating hydraulic conductivity is to take the entire gradient and flux pairs to calculate values of hydraulic conductivity. This yields a mean K of 18 m/d with a standard deviation of around 80. These values change slightly if you remove extreme values, such as the negative conductivities. These values are reasonable for fine sand and are consistent with the values measured in the lab. The spread of the values in the lab and the high variance of K shows how difficult it is to measure hydraulic conductivity and how nature is heterogeneous.