Using Excel Spreadsheet to Interpret Darcy’s Law and Groundwater Flow

Yongli Gao, East Tennessee State University

Introduction

This lab introduces the fundamental principle of groundwater flow using Excel spreadsheet. Step-by-step problem solving processes and interactive tools will be used to process groundwater aquifer data and to understand groundwater flow in porous media. Students will start with a problem solving question to calculate groundwater flow velocity based on observed porosity, hydraulic gradient, and hydraulic conductivity. The next step involves more calculations for different porous materials. The final step is to create graphs and interactive tools to understand how changes of hydraulic conductivity and hydraulic heads affect groundwater flow.

Darcy's Law – Empirical observations as well as theory indicates that the fluid flux and hydraulic gradient are linearly related through the constant of proportionality called hydraulic conductivity:

\[ q = -K \frac{\Delta h}{\Delta x} \]

where:

- \( K \) – hydraulic conductivity
- \( \Delta h \) – head drop between manometers
- \( \Delta x \) - distance along sand column
- \( q \) – Darcy flux \( (Q/A, \ v \times n, \ Q \ - \ discharge, \ A \ - \ cross \ section \ area, \ v \ - \ velocity, \ n \ - \ porosity) \)

Lab Activities:

1) Estimate darcy flux “q” and flow velocity “v” in m/s and m/day using measured or observed porosity, hydraulic gradient for a gravel aquifer if the hydraulic conductivity \( K \) is 0.01 m/s.

2) Repeat step 1 in Excel to calculate darcy flux and flow velocity.

3) Calculate darcy flux and flow velocity for different sediments in Excel and plot a \( K \) vs. \( v \) graph to show the relationship between hydraulic conductivity and fluid velocity.

4) Create interactive to observe how changes of hydraulic conductivity and hydraulic head affect groundwater flow.
Creating a Scroll Bar in an Excel Worksheet

The key to create an interactive environment is the ability to change an aquifer parameter (for example, hydraulic conductivity) and to view the effect of this change on the type curve(s). A “scroll bar” can be used to vary parameter values in Excel. A scroll bar is created using the “Control Toolbox”. This toolbox is shown in Figure 1. (Note: The Control Toolbox in your Excel program might have a different arrangement. Also, it might be “docked” to the edge of the worksheet, or “floating” on the worksheet.) If this toolbox is not visible, it can be displayed by clicking the “View” menu, then selecting “Toolbars”, and then selecting “Control Toolbox”.

To create a scroll bar on a worksheet, click the Scroll Bar button on the Control Toolbox, then draw (press left mouse button and drag) a long skinny rectangle on the worksheet to outline the scrollbar. When you are done, your worksheet should look like Figure 1. Note that (1) the small white squares around the scrollbar allows you to reshape the scrollbar, and (2) the Design Mode button in the Control Toolbox is now pressed, indicating that you can change the properties of the scroll bar. (Note that the scroll bar need not be aligned with the worksheet cells.) Next, right click on the scroll bar. A pop-up menu appears. Select “Properties”. This displays the Properties window for the scroll bar (Figure 1). In the Properties window, enter a cell to be linked to the scroll bar. In our example, we will use cell F11 as the linked cell. Also, change the “Max” value to 10,000.

To return the worksheet to its normal operating mode, click the Design Mode button so it is no longer pressed. Test the scroll bar by dragging the slider. You should see the value in cell F11 change as you drag the slider. When the slider is at the left end of the scrollbar, the value in cell F11 should be 0. When the slider is at the right end of the scrollbar, the value in cell F113 should be 10000. Note: If you want to modify the toolbar at a later time, just click the Design Mode button and then click on the toolbar. Next, convert the value in cell F11 into a hydraulic conductivity value, which we will put in cell C11. If you want the hydraulic conductivity value to vary from $10^{-10}$ to $10^0$, The formula for cell C11 is $10^{-((F11/1000)-10)}$. Now if you drag the slider, the value in cell C11 should change from $10^{-10}$ to $10^0$ (Figure 2). The final step is to repeat the above procedure to create two more scroll bars to change the hydraulic heads. The recharge and discharge hydraulic head values will be put in cell C15 and F15. Figure 3 shows the interactive tools created to observe how changes of hydraulic conductivity and hydraulic head affect groundwater flow.
Figure 1. Control Toolbox in Excel (Notice that the “Scroll Bar” button is used to create a scroll bar. “Design Mode” button is pressed to edit the properties of the scroll bar. Here we entered “F11” as linked cell and “10000” as Max value).

Figure 2. Using a scroll bar to change hydraulic conductivity value in cell C11.
Figure 3. Excel worksheet showing interactive tools.