

# SimuLink Tutorial

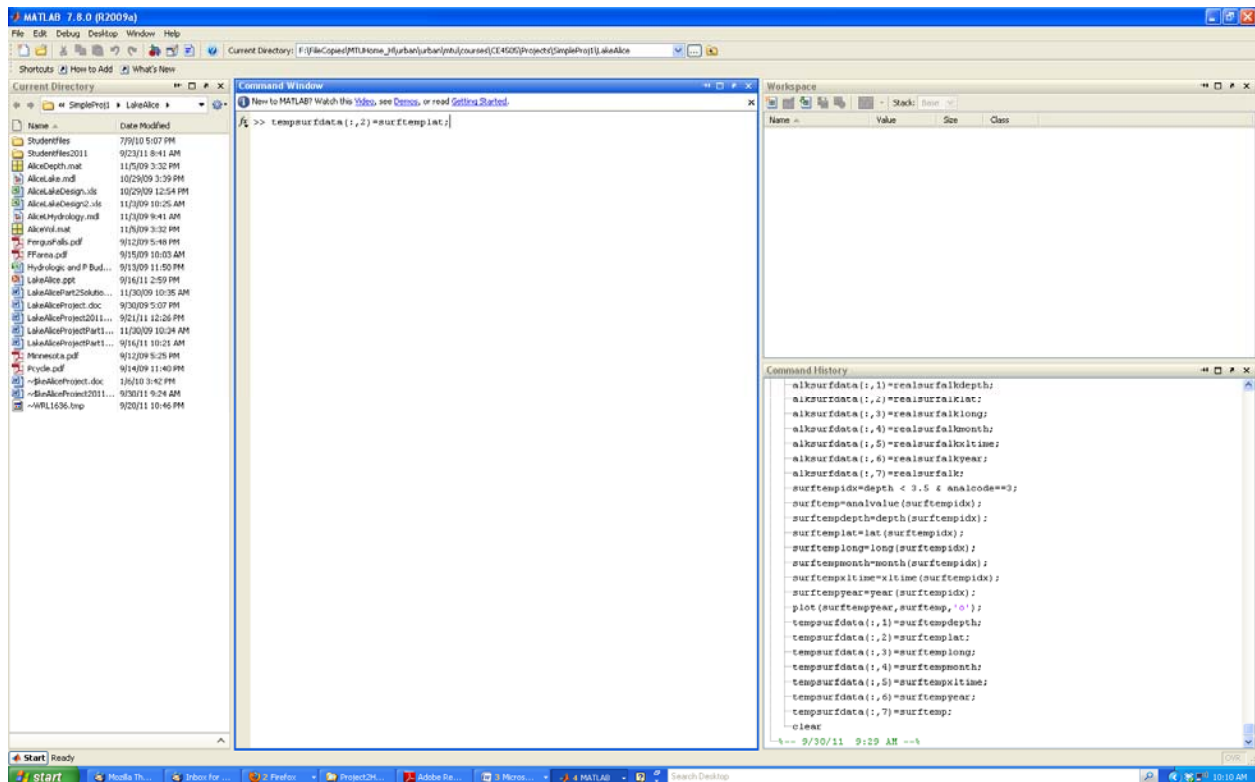
## I. Before starting the program:

Before beginning to work with MatLab/SimuLink you should do three things:

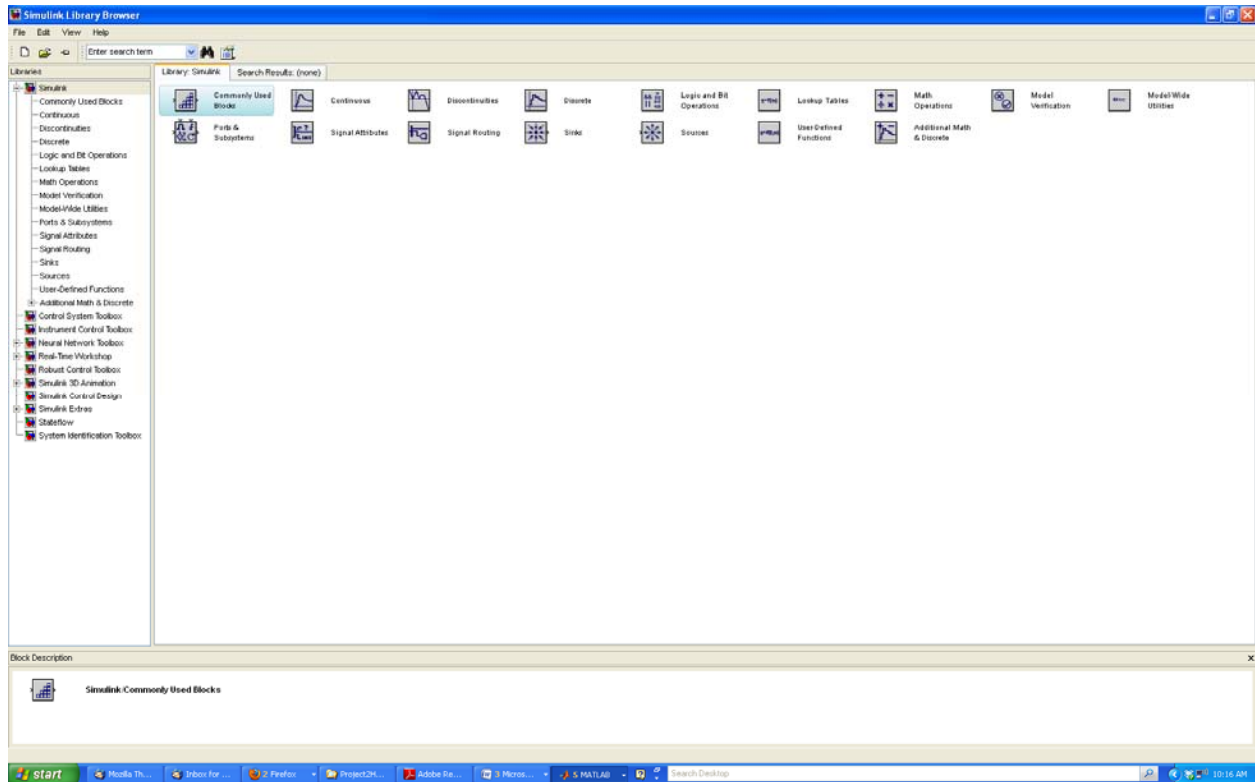
1. Draw a box-and-arrow flow diagram of the substance to be modeled;
2. Write the mass balance equation (ordinary differential equation) and rearrange it so  $dC/dt$  is the only term on the left-hand side of the equation;
3. For each term in the equation, list the constants or the algebraic expressions used;

## II. Start the program:

1. **If you have a model file already:** double click on the *mdl* file in Windows Explorer and this will cause Windows to start MatLab and to open the SimuLink file. You should then have a minimum of two windows open on your computer: one will be the MatLab window and one will be the SimuLink diagram of the model.
2. **If you do not have a model file (.mdl) but will be making one:** a) Start MatLab by going to the Start button; select All Programs then select MatLab. This should open one window on your screen that has 5 components: Current Directory, Command Window, Workspace, and Command History. This screen is shown below.



II.2b. To start SimuLink click on the *Start* icon in the lower left corner of the MatLab screen. This will bring up a pull-up menu on which you should select *Simulink – Library Browser*. This will open the library browser window (shown below). From the drop-down menu at the top select *File – New – Model*. This will open a blank model window in which you will create your model diagram.



Constructing the model cycle diagram: This applies if you do not have a model file already given to you or one you created previously. You should have the Simulink Library Browser window and a Blank model file window open (steps II.2.a-b).

**Overview:** To create a model, you select elements from the Library Browser, paste them into your open Model file, specify values or constraints, link the elements with arrows, and select the type of output (i.e., where you want the model output to go) that you want (visual, workspace, file).

**Demo:** We will walk through the steps needed to create a Phosphorus mass balance model for a small lake. We will assume constant inputs and complete mixing in the lake. The mass balance equation (rearranged as suggested above) is:

$$\frac{dC}{dt} = \frac{Q_{in}}{V} C_{in} + P \cdot \frac{A}{V} \cdot C_p - C \left( \frac{Q}{V} + v_s \frac{A}{V} \right)$$

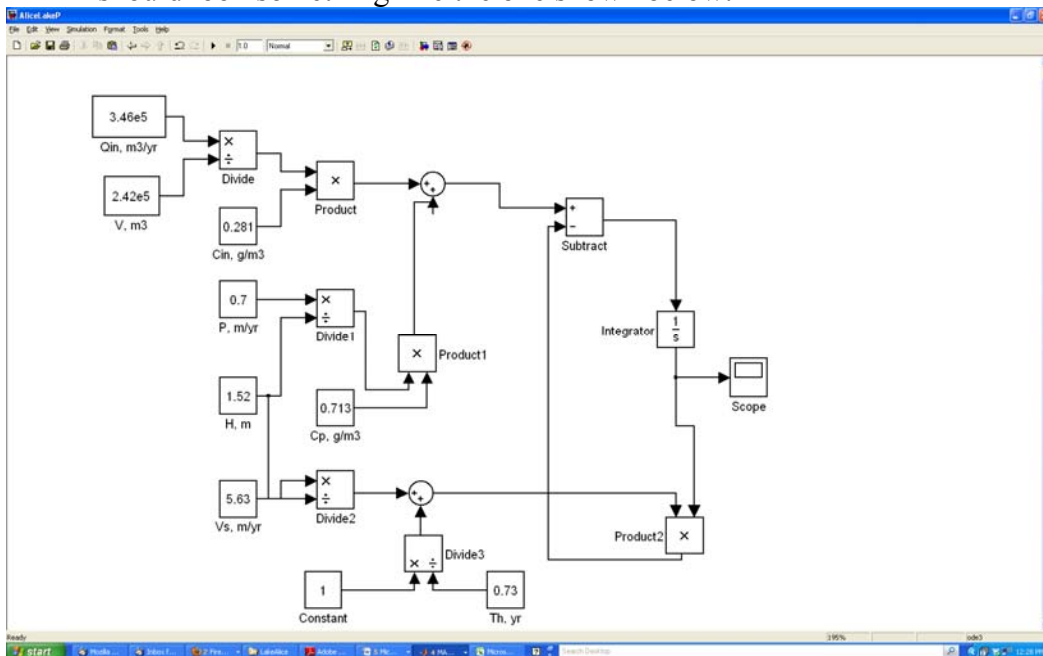
where C is phosphorus concentration in the lake, t is time,  $Q_{in}$  is the stormwater or river flow in,  $C_{in}$  is the P concentration in stormwater or river input, V is lake volume, P is precipitation (cm/yr), A is lake area,  $C_p$  is phosphorus concentration in precipitation, Q is the flow out of the lake,  $v_s$  is the phosphorus settling velocity. This can be simplified slightly to:

$$\frac{dC}{dt} = \frac{Q_{in}}{V} C_{in} + \frac{P}{H} \cdot C_p - C \left( \frac{1}{\tau_H} + \frac{v_s}{H} \right)$$

where H is the mean depth (V/A) and  $\tau_H$  is the hydraulic residence time.

1. In the Library Browser window, double click on the *Commonly Used Blocks* library.

- Find the *Integrator* element, left-click on it, hold the left mouse key down and drag it into your open model window; release the left mouse key. The integrator symbol should be pasted into your model. The output of the integrator will be  $C$  as a function of time.
- On the right hand side of the equation are 5 algebraic operations (division, addition, multiplication, and subtraction). Find each of these operations in the Library and drag them into your model file window. Note that you will have to go to the *Math Operations* library to find division and subtraction.
- On the right-hand side of the equation are 8 constants ( $Q_{in}$ ,  $V$ ,  $C_{in}$ ,  $P$ ,  $H$ ,  $C_p$ ,  $\tau_H$ ,  $v_s$ ); find the symbol labeled *Constant* in the Library window and drag this into your model 8 times.
- In your model file window, double click on the first *constant* symbol. This opens a dialog box. In the square labeled *Constant value*, enter a value of  $3.46 \times 10^5$ . Close this dialog box.
- Click on the word *Constant* below the box whose value you just specified. This will open an edit box; replace the word *Constant* with “ $Q_{in}$ ,  $m^3/yr$ ”. Hit enter. This should place a label below this box that identifies that the value in this box is the stormwater or river inflow in units of  $m^3/yr$ .
- Repeat steps 5 and 6 for the remaining 7 Constants, putting in the correct values and labels for each.
- Arrange the icons in your model such that the correct *Constants* may be attached to the correct algebraic operators. To connect elements in the model, select one of the constants and, while holding down the *Control* key click on the mathematical operator box; an arrow should appear joining the two boxes.
- You will want to end up with a closed loop that includes the Integrator. Remember that the output of the Integrator is  $C$ , the phosphorus concentration. Hence the output of the Integrator must be multiplied by the quantity  $(1/\tau_H + v_s/H)$ . The input to the Integrator is the difference between  $(Q_{in}C_{in}/V + PC_p/H)$  and  $C(1/\tau_H + v_s/H)$ . Your completed diagram should look something like the one shown below:



10. You are almost ready to run the model (instructions below). First you must specify the properties of the *Integrator*. Double click on the *Integrator* icon. In the dialog box, fill in a value for the *initial condition*; you can choose any reasonable value of phosphorus concentration for the lake. E.g., you could choose 0.5 (units are g/m<sup>3</sup>).
11. Now we will add an output option that allows us to see a graph of phosphorus concentration vs. time. From the *Commonly Used Block* library select the *Scope* icon; left-click and drag it into your model. Connect the *Scope* to the output from the *Integrator* by clicking on the arrow coming out of the *Integrator* and, while holding down the *Control* key, drag a line to the *Scope* icon.
12. Save your model file using the drop-down *File* menu.

#### Running the (a) program:

The instructions below refer specifically to the model file created above. After doing this once, you should be able to apply it to other files such as the water budget model that you are asked to create.

1. To run the program you must set the Integration conditions. There are many possible conditions that could be used. Click on the *Simulation* pull down menu and select *Configuration Parameters*.
2. Because we entered values for our constants in units of m<sup>3</sup>/yr, we are operating in time units of 1 year. To run the model for one year, under *Start time* enter 0.0 and under *Stop time* enter 1.0.
3. We will run this at a fixed time step of 1 day (0.002738 yr). In the Solver Options box, click on the *Type* menu box and select *Fixed time step*. Now in the *Fixed-step size* box enter a value of 0.002738. Click on the *Apply* button in the lower right and then on the *OK* button.
4. To run the simulation, you can either select *Start* in the *Simulation* pull-down menu or click on the right facing black triangle in the second row of pictorial commands.
5. When the model runs, a window should open showing a graph of concentration vs. time. To obtain a better scaling, click on one of the axes and select *Autoscale* in the dialog box. If the graph does not automatically appear, double click on the *Scope* icon in your model diagram, and the graph window should appear.

**Modeling Project I Part 3**  
**MatLab/Simulink Exercise**  
**Due Friday, Oct. 7 by 3 p.m.**

To introduce you to the MatLab/Simulink modeling environment, you are going to walk through the tutorial above, create a phosphorus model for Lake Alice, and then couple that to a water balance model.

A) Construct a continuous-state Simulink model for phosphorus, and verify it is working properly by using the same input conditions as in Part I and running to steady-state. What concentration of phosphorus do you predict at steady state? Hint: Solve the mass balances you specified for phosphorus for  $dC/dt$  first. Paste your scope output into the word document.

B) Now create a new model file for the water balance to predict the lake depth (stage) and outflow as a function of time. Use the mass balance equation for water. Again assume that all rates are constant. Assume the surface area remains constant, and use the rating curve to calculate outflow. Run your model to steady state and check if the volume you obtain is the same as that specified in Part I of the project. If it is not, explain why it is not. Again paste the scope output into your word document.

Hint: Use the polynomial (“polyval”) block to describe the rating curve.

C) Link your hydrologic and phosphorus models by pasting all of one model into the other, and then connecting in the appropriate location. Run to steady state using starting lake heights of 2.0 and 0.5 m and initial concentration of  $0.5 \text{ g/m}^3$ . Paste the Scope output into your word file that you turn in.

General Matlab/Simulink tips:

Output Simulink signals to the Matlab workspace, where they can be easily manipulated and plotted. To avoid clutter in your model diagram (and resulting confusion), route signals using the “From” and “Goto” blocks. Label model components. You may also wish to experiment with subsystems. *Remember “integrator” blocks contain the initial values of state variables... these need to be specified!*