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April 8, 2015

Channel Flow Calculator Write-Up

Executive Summary

Business Description

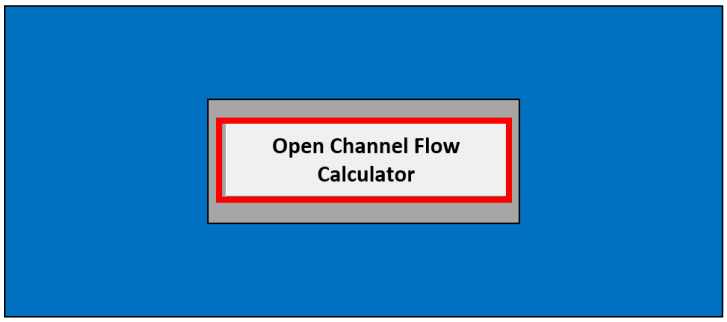
After receiving her bachelors in Civil Engineering, my wife now works for HDR, which is a worldwide architecture and engineering firm with 9,200 employees, working in more than 225 locations around the world. She currently works at the HDR Salt Lake Office in the Water business group as a Water Resources EIT. As a team, they analyze and design projects in the water field ranging from dams and watersheds to roadway drainage and stream restoration. Recently, they have acquired a number of river, stream, and canal projects requiring them to analyze and size new and existing channels. These channels come in a variety of shapes and sizes and require them to design for different aspects of each individually. process is tedious and monotonous if done by hand. Several spreadsheets have been created to solve any one set of conditions but ideally, a universal spreadsheet that covers all conditions would reduce time and effort in the initial design phases.

Solution

I created a user form in Excel that solves for flow velocity and flow discharge, channel slope from flow velocity, channel slope from flow discharge, manning coefficient from flow velocity, manning coefficient from flow discharge, depth from flow discharge, and bottom width from flow discharge for channel types that are trapezoids, triangles, rectangles, or circles. After making calculations, the user form allows the user to export the results to a spreadsheet.

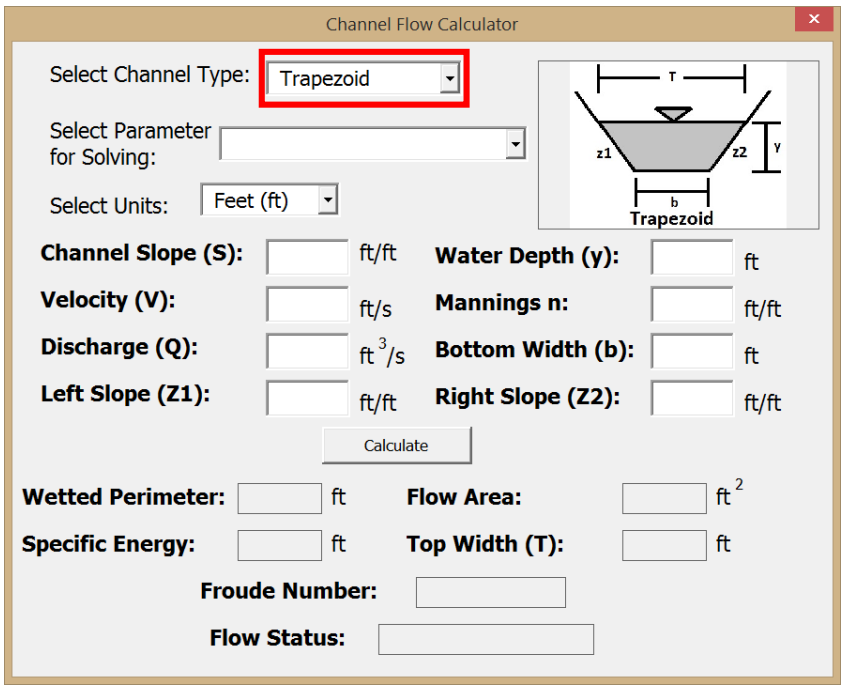
Implementation Documentation

1. Channel Flow Calculator Form
    a. The form is opened by using the button on the spreadsheet ‘Calculator’ or by using the ribbon ‘Flow Calc’ button ‘Calculator.’ I included these so that the user could easily open the form.

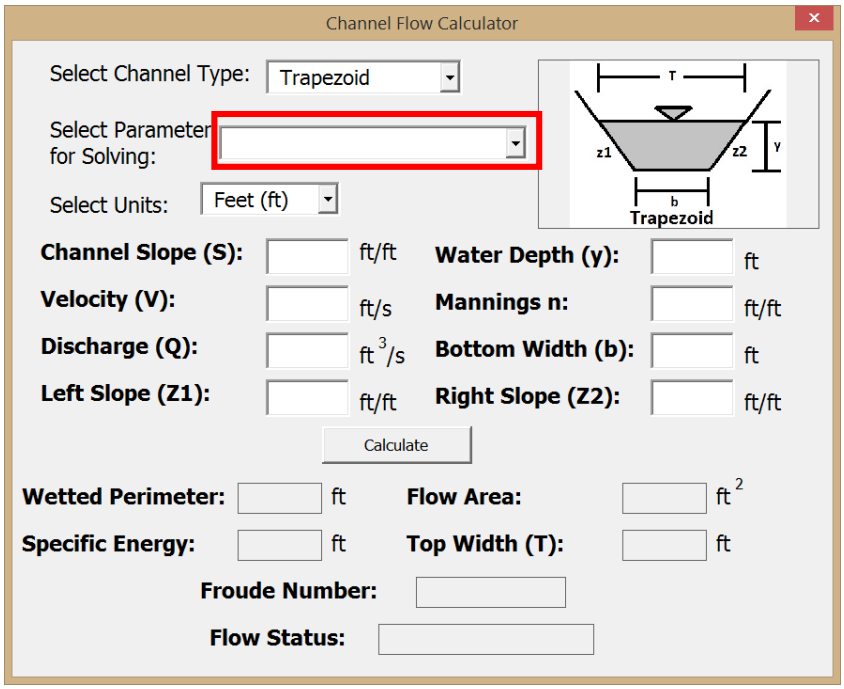


    b. The form solves for different channel types
        i. Channel Types:
            1. Trapezoid
            2. Rectangle
            3. Triangle
            4. Circle
        ii. Importance for solving for the channel types
            1. There are many different shapes that a channel can be for a bridge.
            2. Different channel types use different equations for solving for parameters.

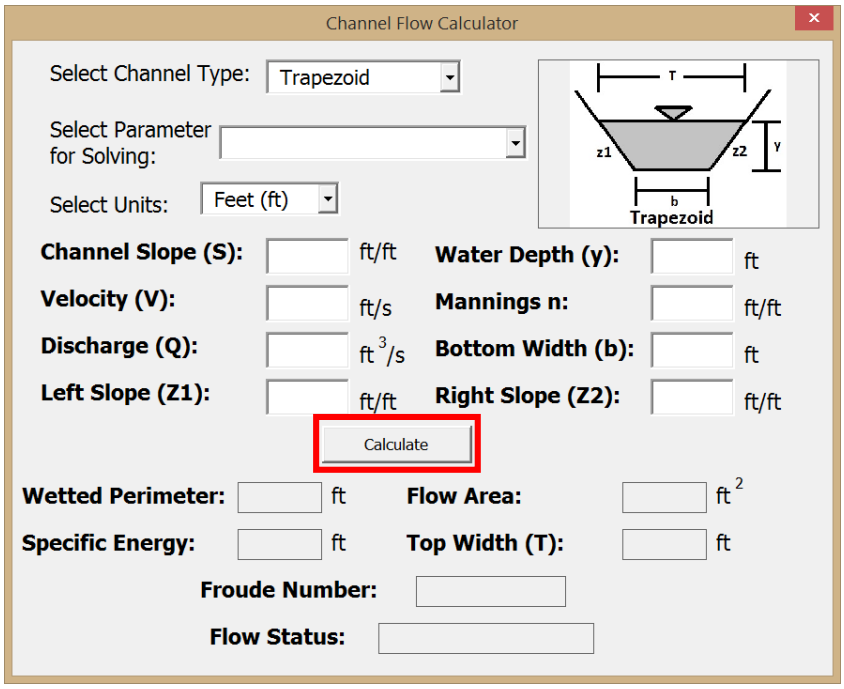
iii. I used a combo box that reads values from a sheet named 'Types,' which is hidden to the user, in order to populate the combo box with the appropriate channel type values.
iv. Rather than having a blank channel type and picture appear on the form, I made the default channel type to be 'Trapezoid' when the form is opened.



c. The form solves for certain parameters of the channel types
   i. Parameters:
      1. Flow Velocity and Flow Discharge
      2. Channel Slope from Flow Velocity
      3. Channel Slope from Flow Discharge
      4. Manning Coefficient from Flow Velocity
      5. Manning Coefficient from Flow Discharge
      6. Depth from Flow Discharge
      7. Bottom Width from Flow Discharge
   ii. Importance of solving for these parameters
      1. Civil engineers solve for these parameters to help them construct bridges.
      2. By calculating these equations, they can double check their work that they do manually on their own.
   iii. I used a combo box that reads values from a sheet named 'Parameters,' which is hidden to the user, in order to populate the combo box with the appropriate parameter values. The default value for the combo box is blank, so that the user has to pick which parameter to solve for before continuing.



d. By solving the main parameters, other informative parameters can be derived from those parameters that are beneficial to know for civil engineers. I made them labels rather than text boxes because their values should not be edited by the user
    i. These other parameters include the following:
        1. Wetted Perimeter
        2. Flow Area
        3. Specific Energy
        4. Top Width
        5. Froude Number
        6. Flow Status
e. The Calculate Button functionalities
    i. The calculate button triggers calculations that are performed in the 'Calculator' module



1. The 'Calculator' Module includes calculations to solve for the parameters using the following procedures below. I did this to be able to keep track of the different equations and for a reference to fix any errors in the future.
    a. solveVelocityDischarge
        i. Solve for flow velocity and flow discharge by using the other parameter inputs.
    b. solveSlopeFromV
        i. Solve for flow discharge and channel slope by using the other parameter inputs.
    c. solveSlopeFromQ
        i. Solve for flow velocity and channel slope by using the other parameter inputs.
    d. solveManNFromV
        i. Solve for flow discharge and manning's n coefficient by using the other parameter inputs.
    e. solveManNFromQ
        i. Solve for flow velocity and manning's n coefficient by using the other parameter inputs.
    f. solveDepthFromQ
        i. Solve for flow velocity and depth by using the other parameter inputs and 'SolveDepthCalc' procedure that is found in the 'modSolver' module.
        ii. The 'SolveDepthCalc' uses Excel's solver on a hidden sheet called 'shtSolver' to solve for depth using the flow discharge formula.
            1. In solving for circle channel type, this formula is complicated for engineers to solve or Excel solver, so circle should be solved using other software.
    g. SolveDepthCalc

i. Uses Excel's solver on a hidden sheet called 'shtSolver' to solve for depth using the flow discharge formula.
ii. Each channel type uses a different formula in solver to solve for depth. For each formula there is a procedure:
1. SolverDepthFromQTrapezoid
2. SolverDepthFromQRectangle
3. SolverDepthFromQTriangle

h. solveBottomFromQ
i. Solve for flow velocity and bottom width by using the other parameter inputs and 'SolveBottomCalc' procedure that is found in the 'modSolver' module.
ii. The 'SolveBottomCalc' uses Excel's solver on a hidden sheet called 'shtSolver' to solve for bottom width using the flow discharge formula.
1. In solving for circle channel type, this formula is complicated for engineers to solve or Excel solver, so circle should be solved using other software.

i. SolveBottomCalc
i. Uses Excel's solver on a hidden sheet called 'shtSolver' to solve for bottom width using the flow discharge formula.
ii. Each channel type uses a different formula in solver to solve for bottom width. For each formula there is a procedure:
1. SolverBottomFromQTrapezoid
2. SolverBottomFromQRectangle
3. SolverBottomFromQTriangle

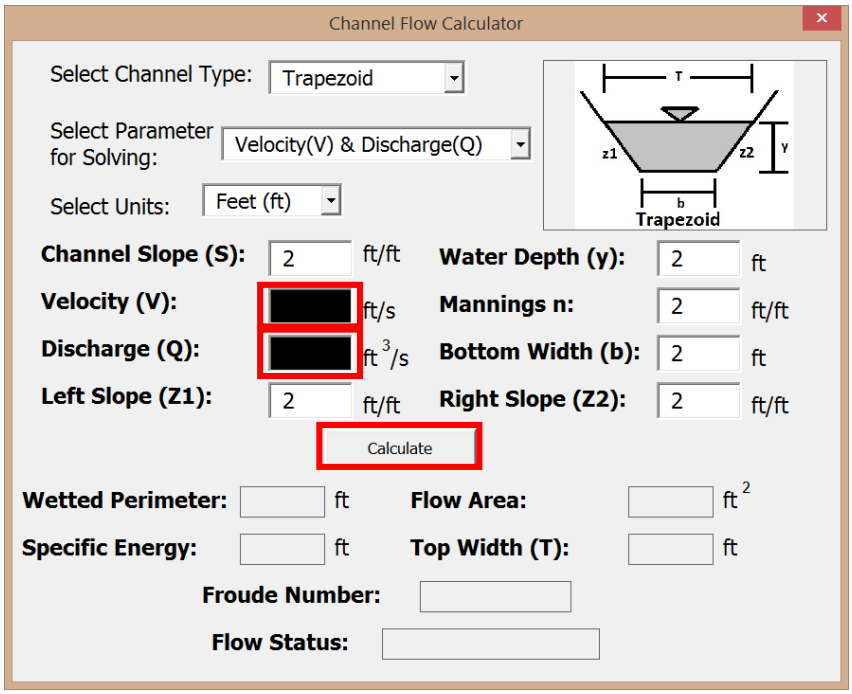
j. getUnits
i. Gravity is measured in either SI Units (Meters) or English US Units (feet)
ii. This is important to know what units the calculator is using and this procedure is linked to the combo box 'cboUnits' on the form.

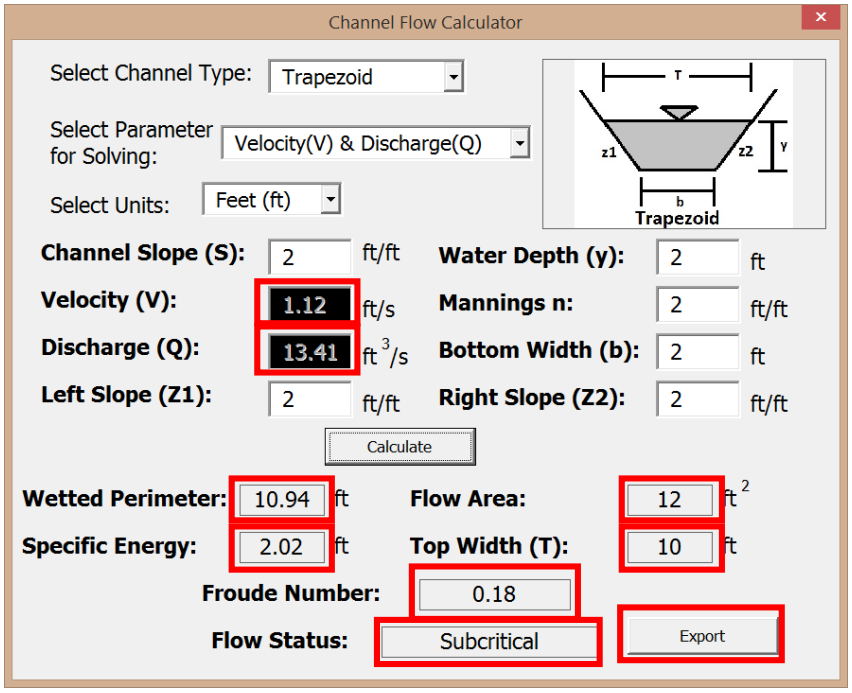
k. PATCalc
i. This procedure calculates wetted perimeter, flow area, and top width.
ii. This procedure was created to make these parameters be solved in one procedure rather than throughout the code several times.

l. EFSCalc
i. This procedure calculates specific energy, Froude's number, and the follow status of the channel.
ii. This procedure was created to make these parameters be solved in one procedure rather than throughout the code several times.

m. openChannelFlowCalcForm
i. This procedure was created to have the channel flow form be callable easily to the user and to make the form a modal to allow the user to work on the worksheet as they are using the channel flow form.

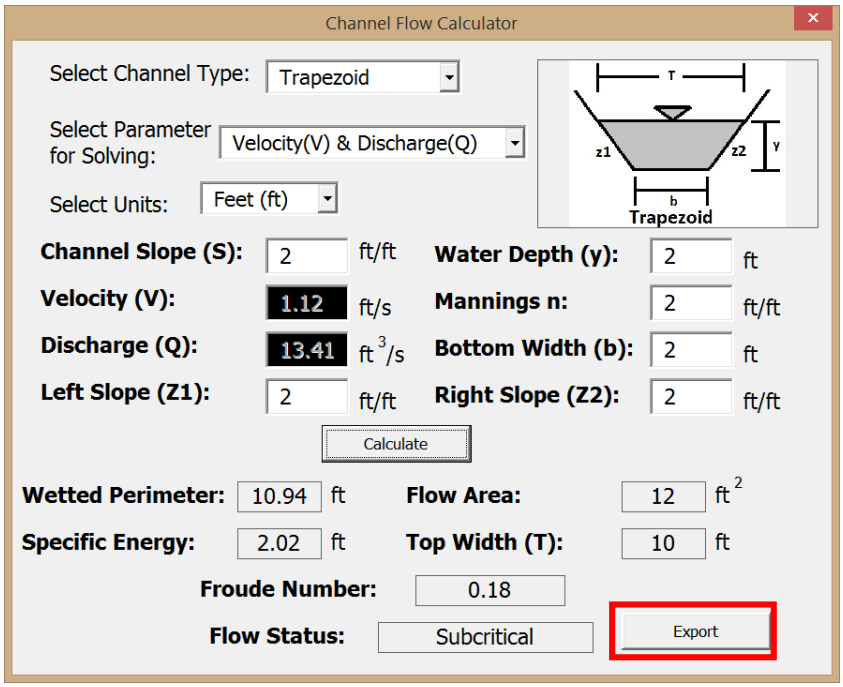
ii. Once the appropriate form text boxes are filled, the user clicks calculate and the form labels below show the calculated solutions and in the appropriate form text boxes that were being solved. Also the export button appears on the form to allow the user to export the results to a spreadsheet in the workbook. I only allowed the export button to appear after calculations are performed so that the user isn't confused with a button that doesn't work.

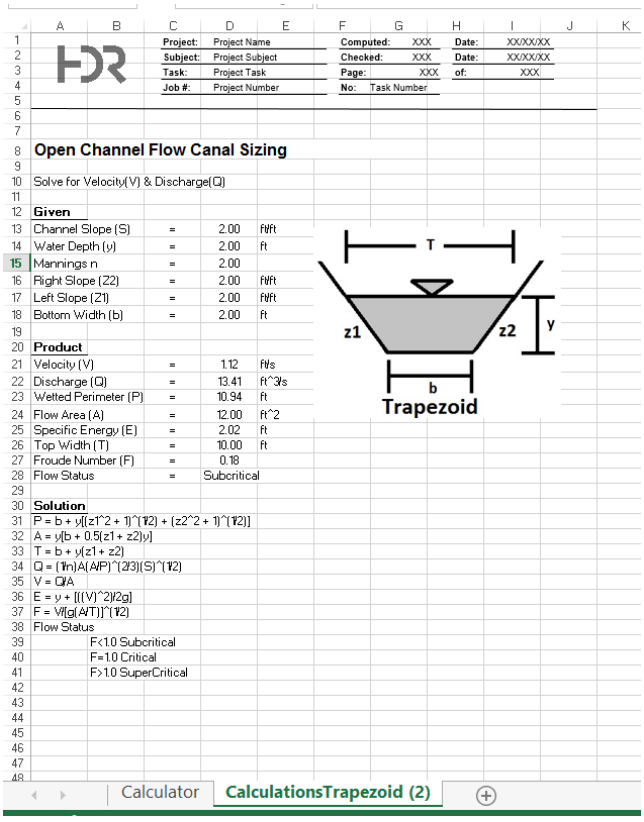




f. The Export Button functionality

   i. This button uses the 'btnExportClick' procedure to export the results of the channel flow calculator form to a new spreadsheet that could be printed to show the calculation process of the form. I created templates for each of the channel types, making it easier to bring in values from the form to certain cells into a spreadsheet that was copied from a template.

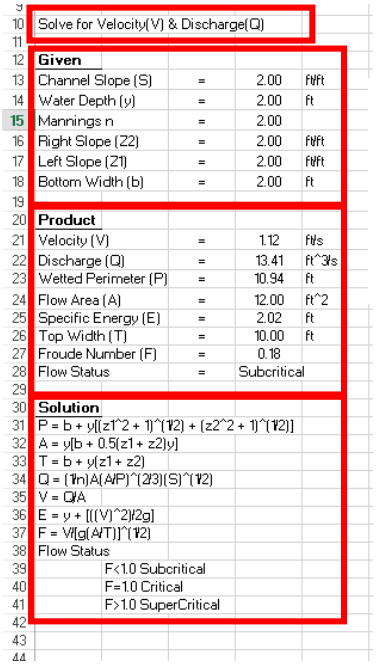




ii. The ‘btnExportClick’ procedure uses the ‘modExport’ module to enter in all of the cells for the spreadsheet.

1. modExport
    a. ExportToSheet
        i. The main procedure that takes values and calculations from the form to the spreadsheet

ii. Other sub procedures such as ‘products,’ ‘getPolynomials,’ ‘solutions,’ ‘solverSolutions,’ and ‘clearCells’ are all for formatting the design of the new spreadsheet to be beneficial to the user. I used different sub procedures in order to clearly define where different sections are to be edited on the spreadsheet.



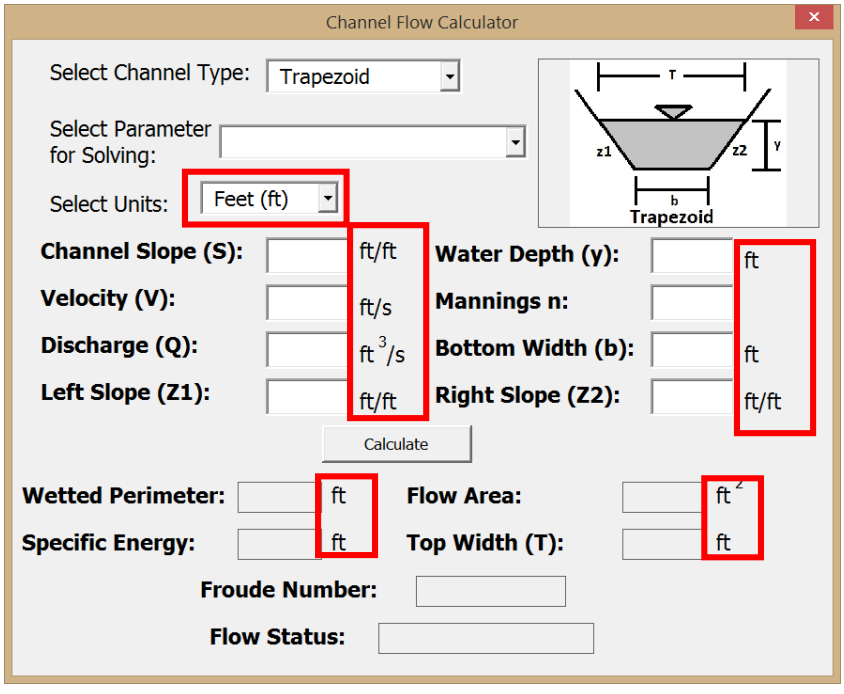
10	Solve for Velocity(V) & Discharge(Q)			
11				
12	**Given**			
13	Channel Slope (S)	=	2.00	ft/ft
14	Water Depth (y)	=	2.00	ft
15	Mannings n	=	2.00	
16	Right Slope (Z2)	=	2.00	ft/ft
17	Left Slope (Z1)	=	2.00	ft/ft
18	Bottom Width (b)	=	2.00	ft
19				
20	**Product**			
21	Velocity (V)	=	1.12	ft/s
22	Discharge (Q)	=	13.41	ft^3/s
23	Wetted Perimeter (P)	=	10.94	ft
24	Flow Area (A)	=	12.00	ft^2
25	Specific Energy (E)	=	2.02	ft
26	Top Width (T)	=	10.00	ft
27	Froude Number (F)	=	0.18	
28	Flow Status	=	Subcritical	
29				
30	**Solution**			
31	P = b + y[(z1^2 + 1)^(1/2) + (z2^2 + 1)^(1/2)]			
32	A = y[b + 0.5(z1 + z2)y]			
33	T = b + y(z1 + z2)			
34	Q = (1/n)A(A/P)^(2/3)(S)^(1/2)			
35	V = Q/A			
36	E = y + [(V)^2)/2g]			
37	F = V/[g(A/T)]^(1/2)			
38	Flow Status			
39	F<1.0 Subcritical			
40	F=1.0 Critical			
41	F>1.0 SuperCritical			
42				
43				
44				

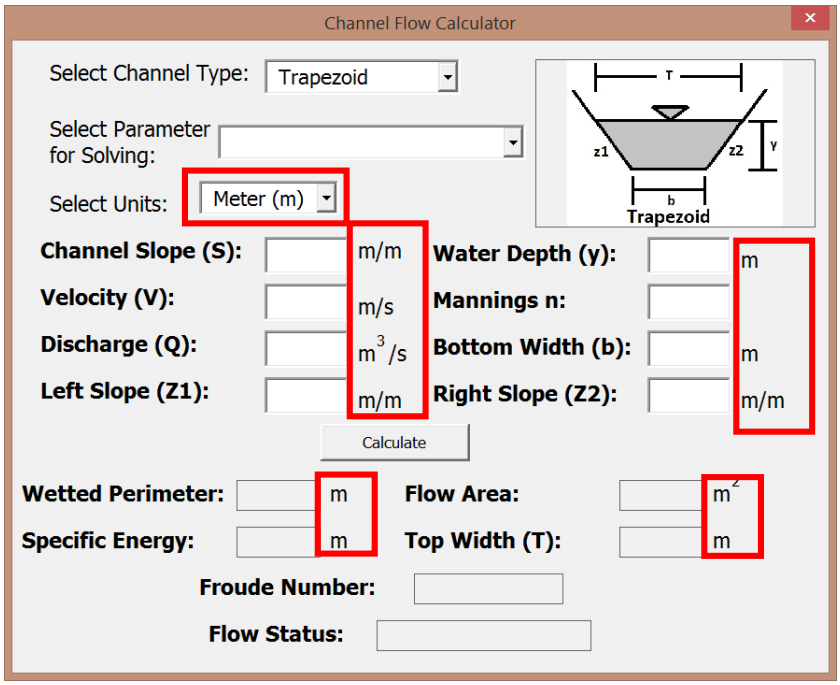
g. The Units Combo Box

i. I used a combo box that reads values from a sheet named ‘Units,’ which is hidden to the user, in order to populate the combo box with the appropriate measuring values (being feet or meters).

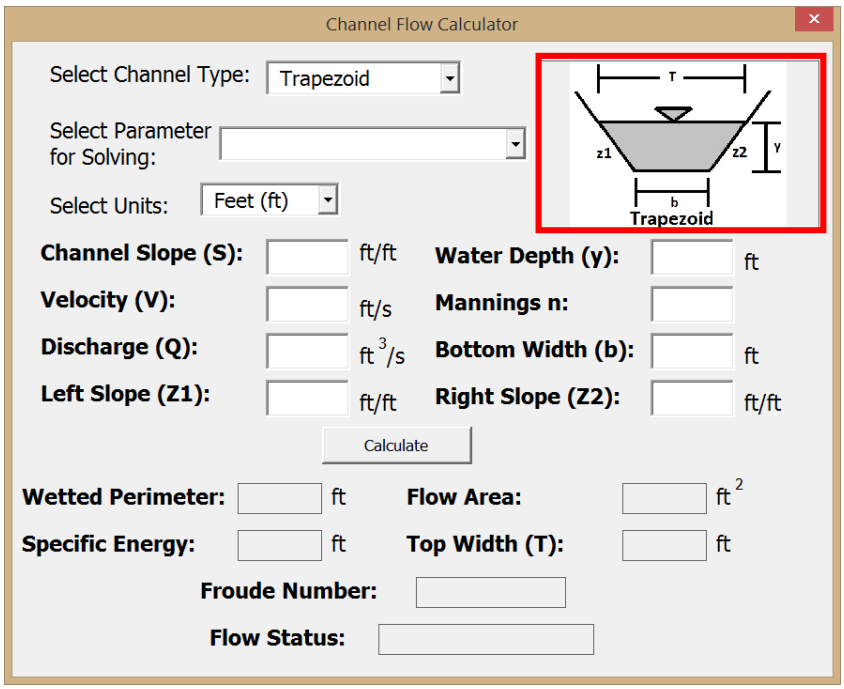
ii. By changing the different values of this combo box, labels next to the text boxes and labels for parameters change appropriately for the measurement of feet or meters.

iii. Because the majority of the calculations that HDR perform are using feet, I determined that feet should be the default value for this combo box when the form is initially opened.



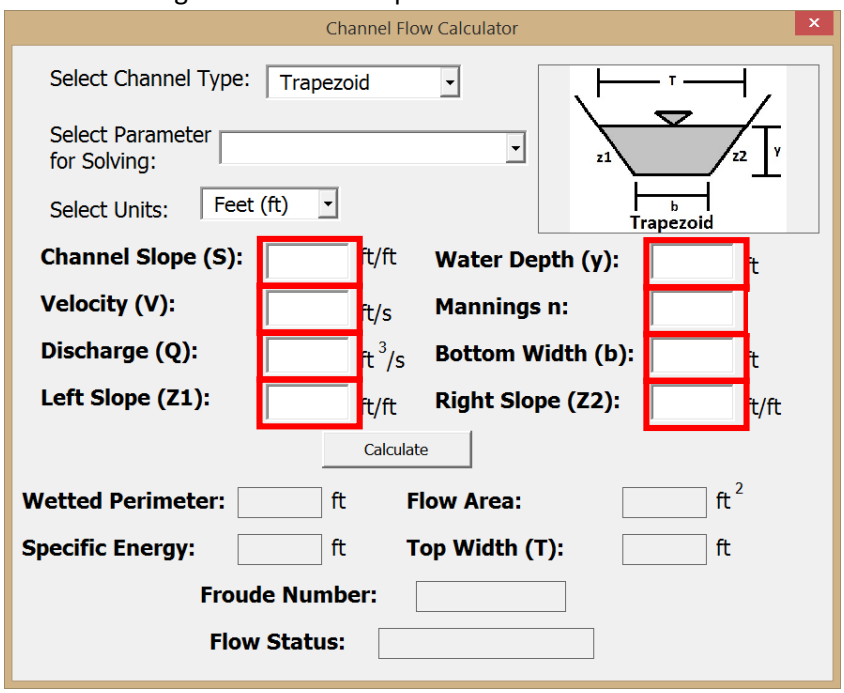


h. The Image Place Holder for Channel Type Pictures
    i. I used an individual image place holder to be shown for each channel type and changes depending on which channel type is selected in the channel type combo box.
    ii. I created each images using paint. There are images for each channel type (trapezoid, rectangle, triangle, and circle).



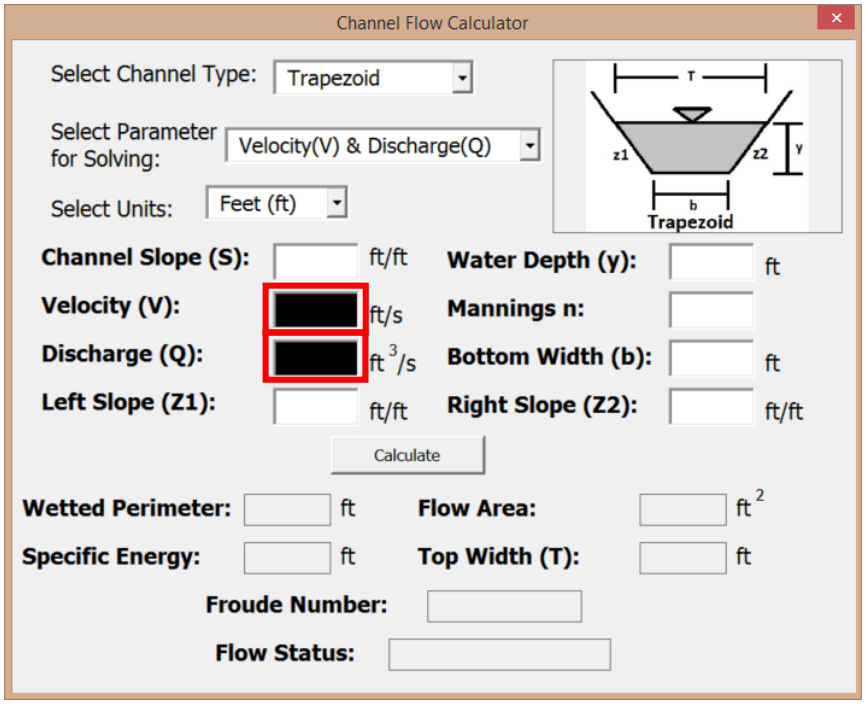
i. The Parameter Text Boxes
    i. The parameter text boxes are locked from allowing the user to input data into them until the parameter for solving is selected. I did this to prevent the user from solving for no particular parameter.

ii. When the text boxes are unlocked, when data is entered into them, the input goes through a sub procedure, 'onlyNumbers', which only allows numeric input into the text boxes. If non numeric data is entered then there is a message box that alerts the user and doesn't let the user move on until the text box has only numeric input. I did this to have the user only input numeric data for solving for the different parameters.

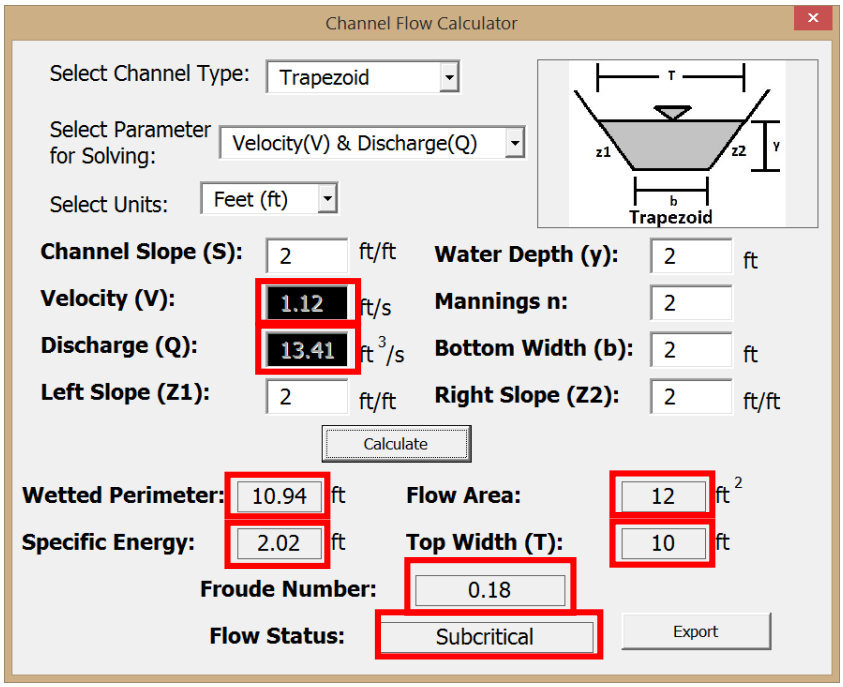


iii. Also, I found that most people when entering a decimal value such as '0.8,' they don't include the proceeding zero. So when the user enters a decimal point as the first value, I have the form automatically include a zero in front of the decimal point.

iv. Depending on the parameter being solved, those text boxes needed to be shown in a different color (I chose 'vbBlack') and to be locked, so that the user couldn't input any values.



v. Once the parameters are solved for, they are then shown in the appropriate text boxes. Also, the other parameters' labels have their given values shown.



Learning Outcomes and Conceptual Difficulties

1. I didn't know how these parameters were calculated, so I learned from my wife about all of the equations that need to be included in calculating the different variables for each of the different channel types. My wife walked through the formulas (see Figure 1) which were programmed into the channel flow calculator form.

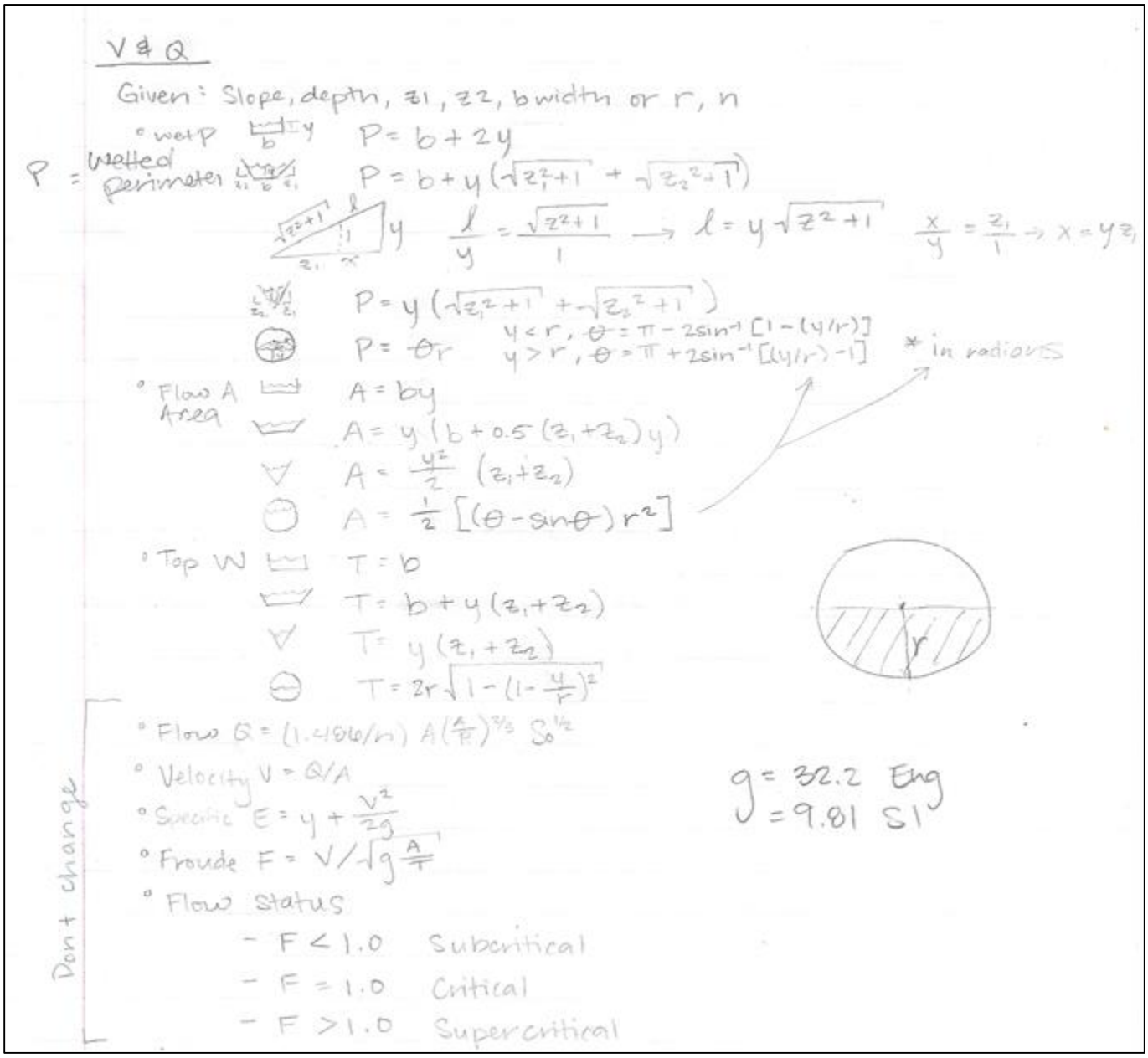


Figure 1. Formula Equations for Parameters

2. Some of the parameters to be solved required that I used Excel's solver add-in. I was able to apply what we learned in class about automating solver tasks.
3. Originally, I had one image place holder on the channel flow calculator form and used images that were on a sheet in my workbook. I found a module online (http://www.oaltd.co.uk/Excel/SBXLPage.asp) that is called 'modPastePicture' that would use the clipboard to copy and paste the image from the workbook sheet and paste it into the form. During the course of the semester, Dr. Allen said in class that the clipboard is owned by the user and should not be used. So I had to find another approach and it was difficult to find one. I met with Dr. Allen and he suggested having each of the images be their own image place holder. Once the picture is browsed

by Excel in the image placeholder, it is copied into the excel workbook file and doesn't need to have the actual picture file attached with the workbook. I didn't need to use the 'modPastePicture' module anymore, and implemented Dr. Allen's advice.

4. I wanted to find a way to make a superscript in a label for the measurements found on the form, such as ft^3/s. In researching online how to accomplish this online, I found that form labels don't have the functionality to allow superscripts. I met with Dr. Allen and he suggested to create other labels that had a font smaller to insert the different values that I wanted to have superscripted.
5. I wanted to find a procedure that would only allow numeric input to be put in the form's input boxes. I found that it is possible by using the 'IsNumeric' function. I found a great explanation on how to accomplish this task at http://www.ozgrid.com/VBA/validate-numbers.htm.
6. I wanted to find a way to appropriately hide the cells that the form's combo boxes use. Dr. Allen showed us in class how to make certain sheets very hidden, which makes it not viewable to the user. I found this very helpful and I implemented it in my project for the combo boxes and for other parts of my project.
7. For the last two parameters (depth and bottom width) that are solved from flow discharge, I had to figure out how to implement Excel's solver add-in in my project. If I didn't use Excel's solver, I would have to figure out an ugly equation that most engineers don't know how to manipulate to solve for a particular variable. Dr. Allen showed us in class how to automate solver and I implemented the general ideas to automate those calculations in my project. In solving for these two parameters for circles, it presented another problem. Theta is solved based on depth and radius being given. Theta is used in the formula in solver to solve for depth or radius, which made it difficult to do with solver. The equation appropriate to solve for these two parameters is complicated and most engineers use online software to calculate it for them. Dr. Allen's solution to this is to use the site's java script (http://www.eng.auburn.edu/~xzf0001/Handbook/Channels.html) that does this calculation already and read that value into the workbook, but this requires that the html and java script file of this site to be attached with this workbook. My wife told me that most engineers wouldn't use this project if there were multiple files attached to the workbook, so she told me not to worry about those two calculations. In order to implement solver in my project, I had to add the reference 'SOLVER.XLAM' to my project.
8. I needed to add the ribbon 'Flow Calc' to access the form calculator. I forgot how to properly do this with the Custom UI Editor, so I met with Dr. Allen and he helped me implement it into my project. It was great to apply what I learned in class into my project.

Assistance

The majority of the help I received for this project were from the lectures of Dr. Allen. When I had challenges that I could not find resources online, I met with Dr. Allen to receive help with those challenges, as stated in *Learning Outcomes and Conceptual Difficulties* section of this report. In designing the form, I used the general layout found on http://www.eng.auburn.edu/~xzf0001/Handbook/Channels.html. A site that I used to have only numeric input in text boxes was found at http://www.ozgrid.com/VBA/validate-numbers.htm, which the code used from this site is appropriately commented in my project.