CE 3372 WATER SYSTEMS DESIGN

LESSON 13: OPEN CHANNEL FLOW (NORMAL FLOW) FALL 2020

OPEN CONDUITS

- Open conduits: upper boundary of flow is the liquid surface.
  - Canals, streams, bayous, rivers are common examples of open channels.
  - Storm sewers and sanitary sewers are special cases of open channels; in some parts of a sewer system these channels may be operated as pressurized pipes, either intentionally or accidentally.
- The relevant hydraulic principles are the balance of friction, gravitational, and pressure forces.

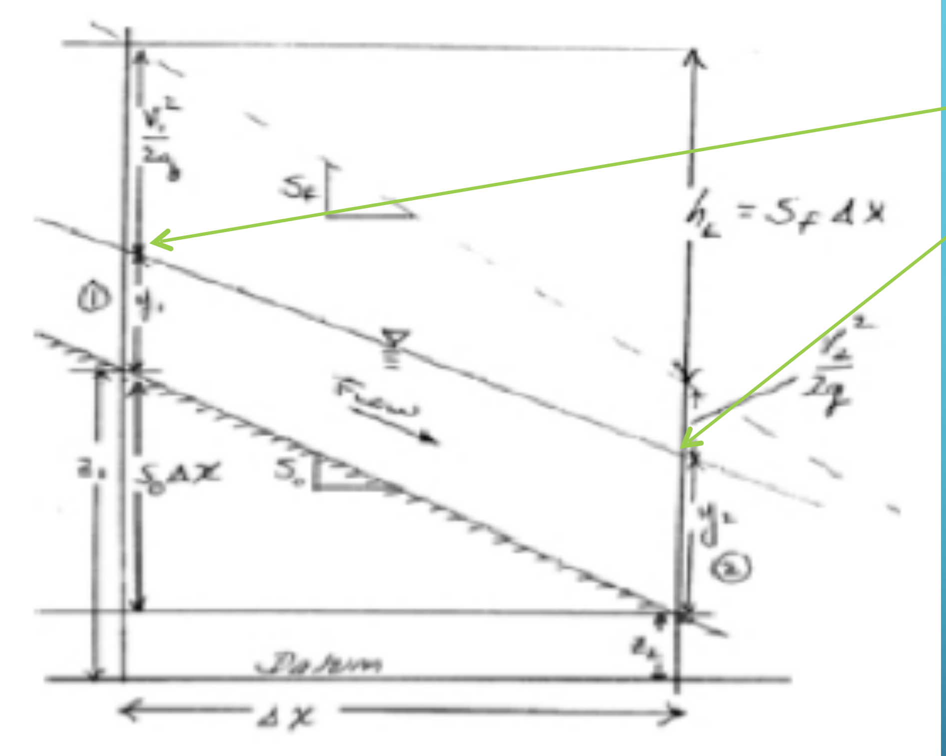
STEADY UNIFORM FLOW

- For a given discharge, Q, the flow at any section can be described by the flow depth, cross section area, elevation, and mean section velocity.
- The flow-depth, depth-area, depth-perimeter, and depth-topwidth relationships are non-unique.
  - Knowledge of the flow type (subcritical, critical, or supercritical is relevant).

STEADY UNIFORM FLOW

- Uniform flow (normal flow) is flow in a channel where the flow depth does not vary along the channel.
  - In uniform flow the slope of the water surface would be the same as the slope of the bottom of the channel.

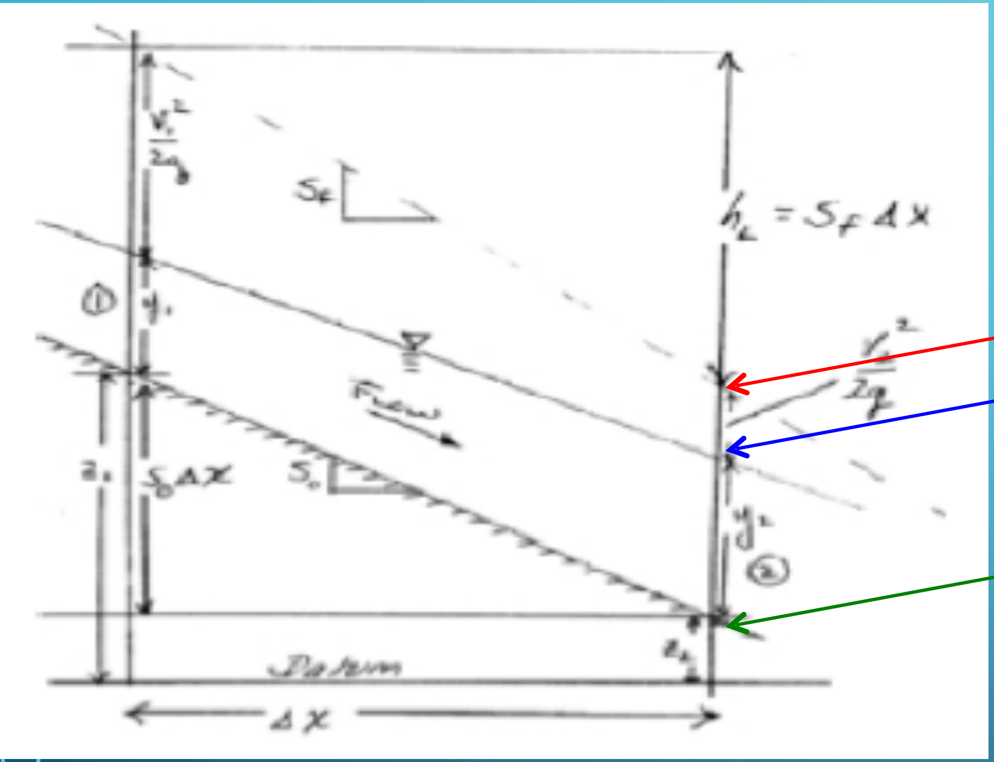
STEADY FLOW



Section 1 is upstream
Section 2 is downstream

- Sketch of steady flow in a channel

STEADY FLOW



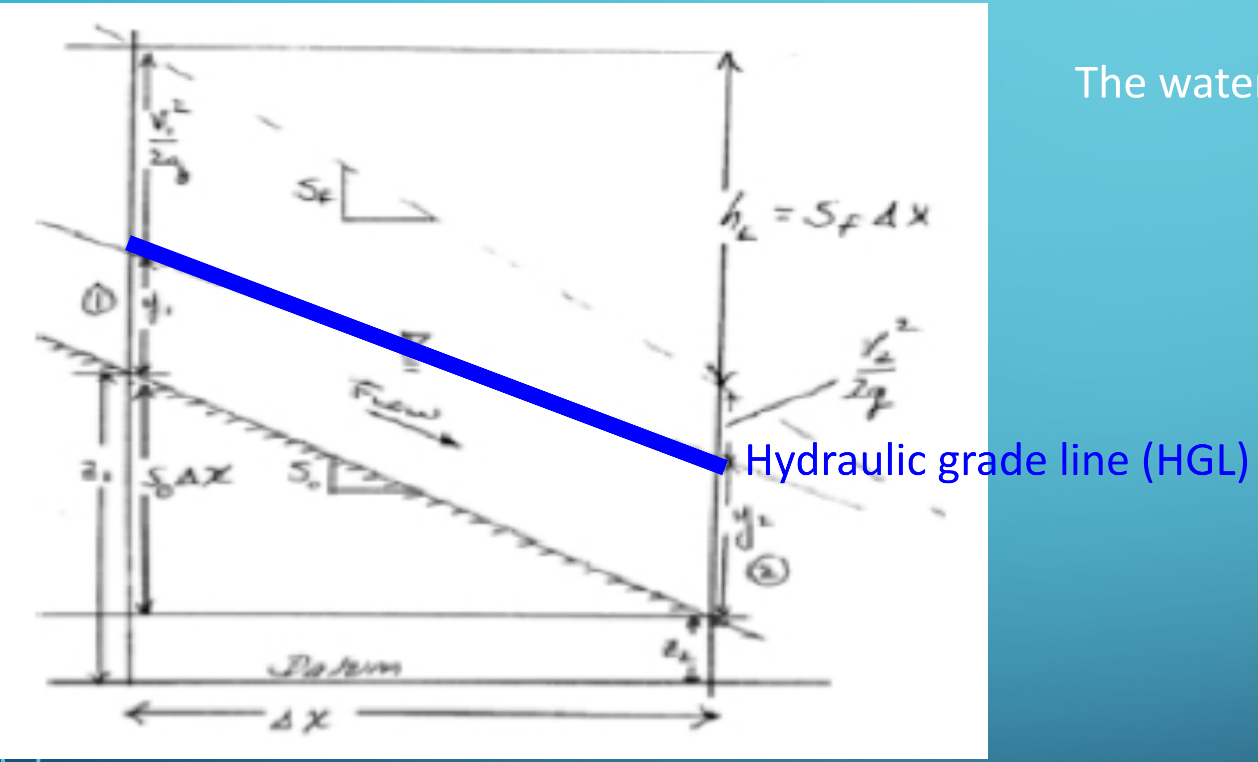
The hydraulic energy at a section is the sum of

elevation head z,
pressure head y,
and velocity head

velocity
pressure (depth)
elevation

- Sketch of steady flow in a channel

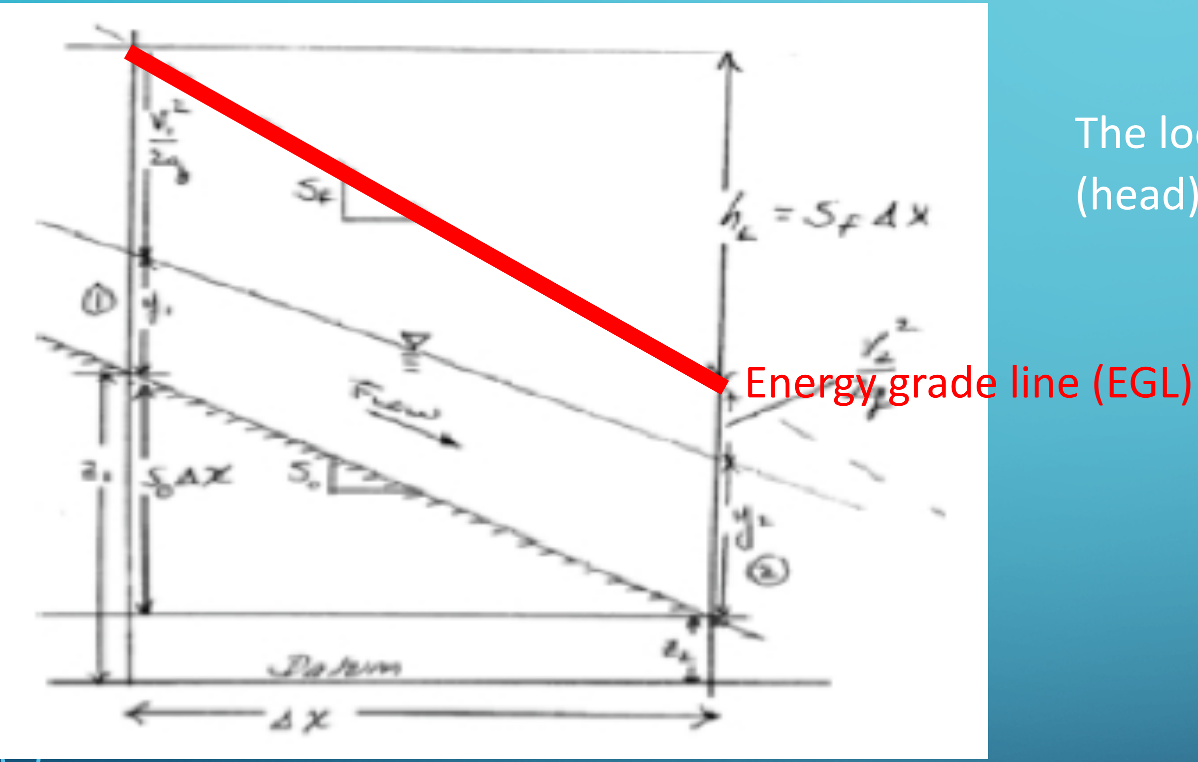
STEADY FLOW



The water surface is the hydraulic grade line (HGL).

- Sketch of steady flow in a channel

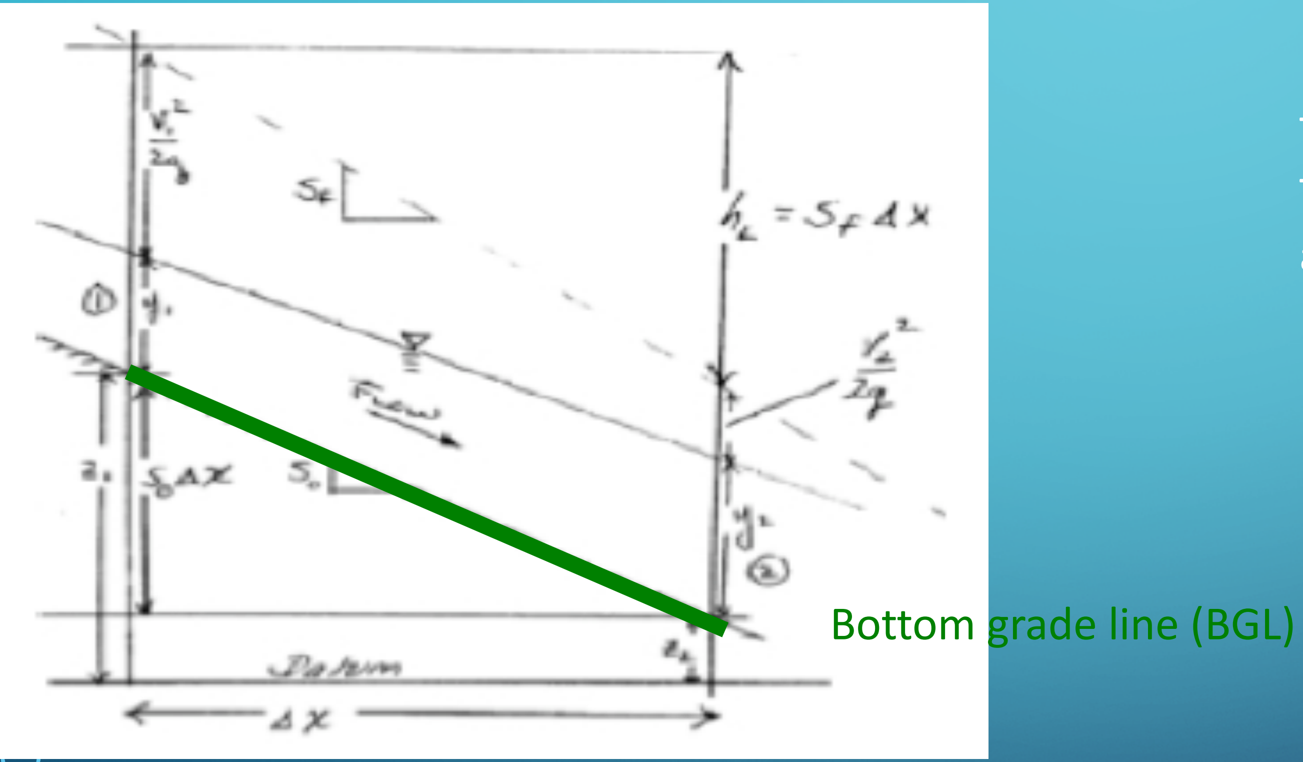
STEADY FLOW



The locus of points of total hydraulic energy (head) is the energy grade line (EGL).

- Sketch of steady flow in a channel

STEADY FLOW

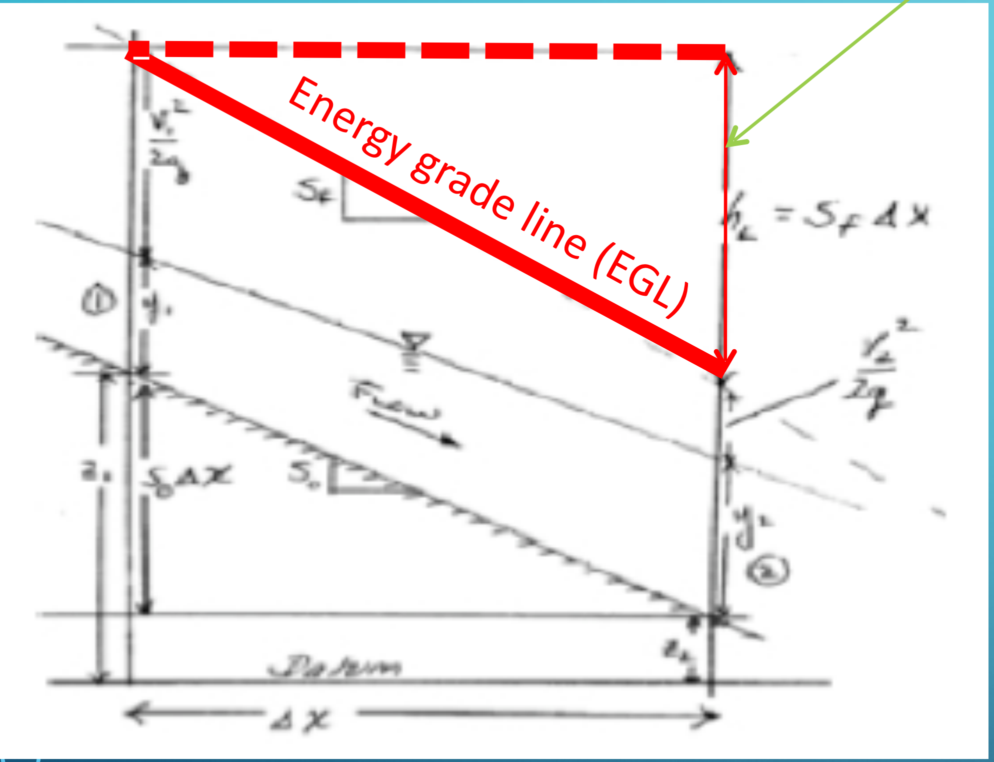


- Sketch of steady flow in a channel

The topographic “path” is
The bottom grade line (BGL) or
also called the flow line.

STEADY FLOW

Head Loss



The head loss is depicted as the difference between a horizontal zero-loss energy grade line and the energy grade line

Head loss is also a consequence of bad governance

UNIFORM FLOW

- Uniform flow occurs when the two flow depths y1 and y2 are equal.
- In that situation the the friction slope S_f would be the same as the bottom slope S_0.

$$S_f = S_0$$

- In fact this equality is the definition of uniform flow (also called normal flow)

GRADUALLY VARIED FLOW

- Gradually varied flow means that the change in flow depth moving upstream or downstream is gradual (i.e. NOT A WATERFALL!).

- In gradually varied flow the two flow depths y_1 and y_2 are not necessarily equal.
  - Rapidly varied flow means the change in flow depth occurs over a very short distance.

- Flow out of sluice gates, or in hydraulic jumps or through energy dissipaters is usually rapidly varied.

OPEN CHANNEL DESIGN CONCEPTS

1. Estimate the required system capacity Q.
   - This estimate will usually involve some hydrology or in the case of sanitary sewers the number of anticipated service connections.
2. Use a uniform flow assumption to size conduits with adequate freeboard, select slopes, and achieve design velocities.
3. Evaluate the design using a hydraulic model, esp. where backwater effects are anticipated or likely.
   - If the hydraulic model is satisfactory, then the design is likely to be hydraulically adequate; if not, adjust the design.
4. Check that the other non-negotiable constraints are satisfied (alignments, right-of-way, set-back distances from other systems).
5. Iterate between 3 and 4 until have some workable alternatives, estimate cost, present to client

CONDUIT HYDRAULICS

- Conduit sizing requires knowledge of the:
  - depth-area,
  - depth-perimeter,
  - and depth-topwidth relationship at a cross section.

STAGE (DEPTH) - GEOMETRY

- Regardless of the section type, depth-geometry functional relationships are based on the same common theme.
- important relationships are:
  - depth-area
  - depth-perimeter
  - depth-topwidth

DEPTH (STAGE)

- Depth (stage) – geometry diagram

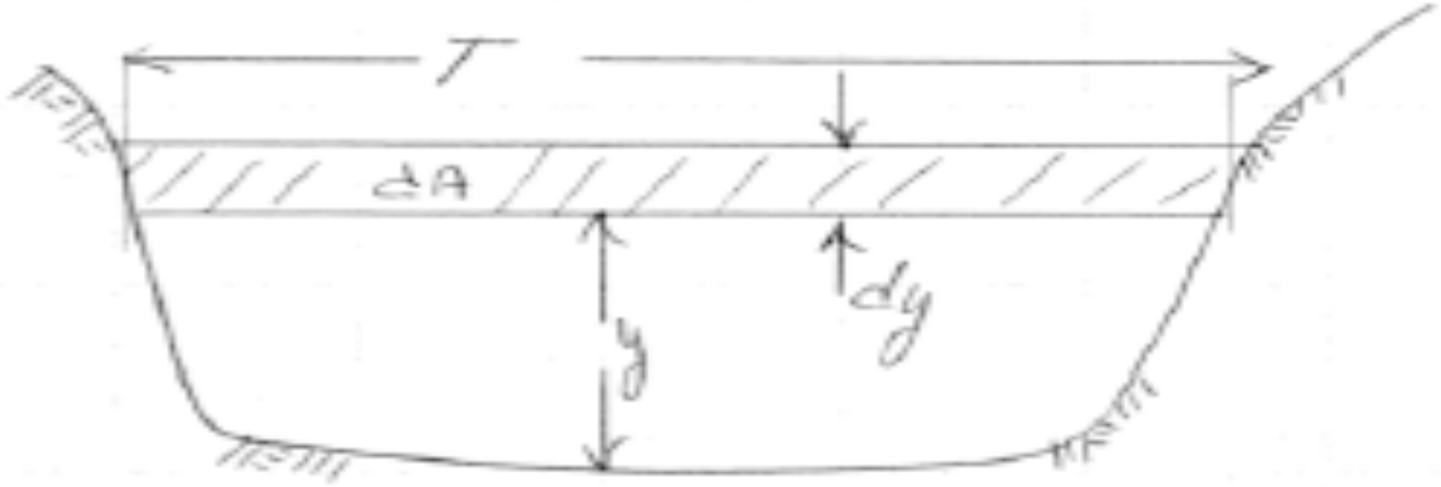
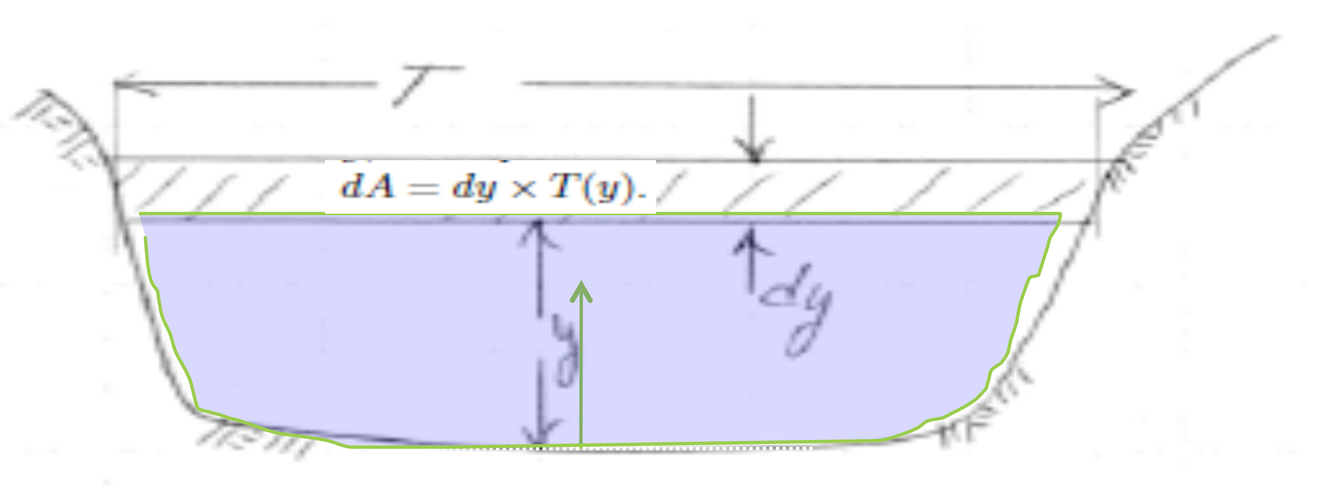


Figure 2: Topwidth, depth and dA relationship in an arbitrary cross section

CROSS SECTIONAL FLOW AREA

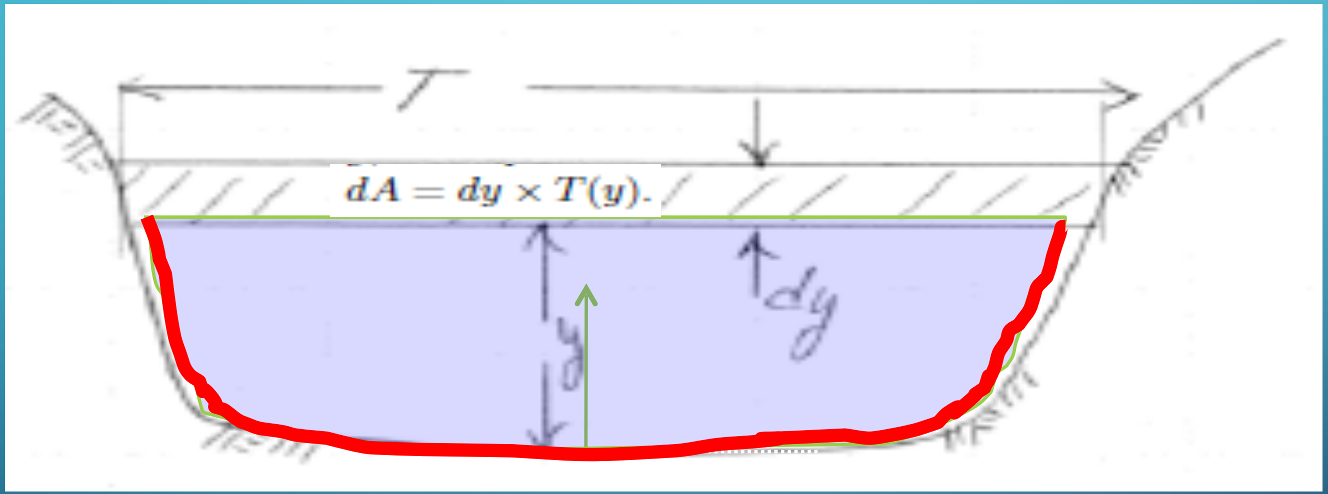
- Depth-Area relationship



$$A(y) = \int_{\tau=0}^{\tau=y} T(\tau)\, d\tau$$

WETTED PERIMETER

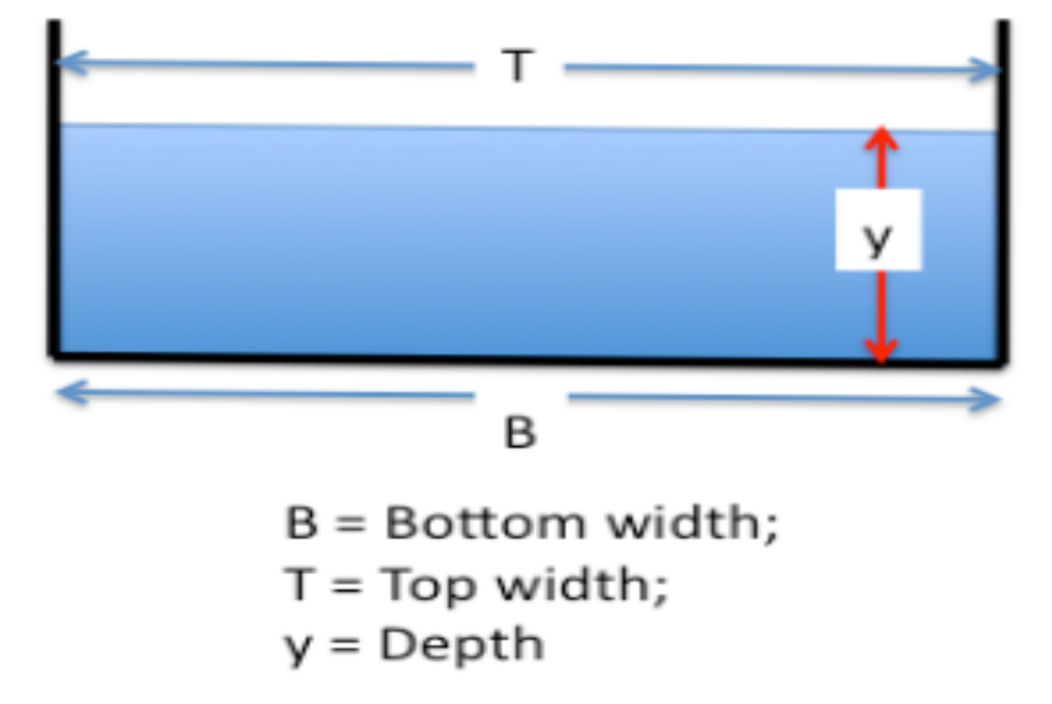
- Depth-Wetted Perimeter relationship



RECTANGULAR CONDUIT

- The simplest geometry to consider is the rectangular conduit.
  - Box culverts flowing with a free surface are an example of such a geometry.
  - Rectangular channels are common in many urban drainage systems -- such channels will be concrete lined; maintenance of a soil lined rectangular channel would be nearly impossible.

RECTANGULAR CONDUIT



$$A_{\text{rect.}}(y) = B \times y$$

$$T_{\text{rect.}}(y) = B$$

$$P_{w\ \text{rect.}}(y) = B + 2y$$

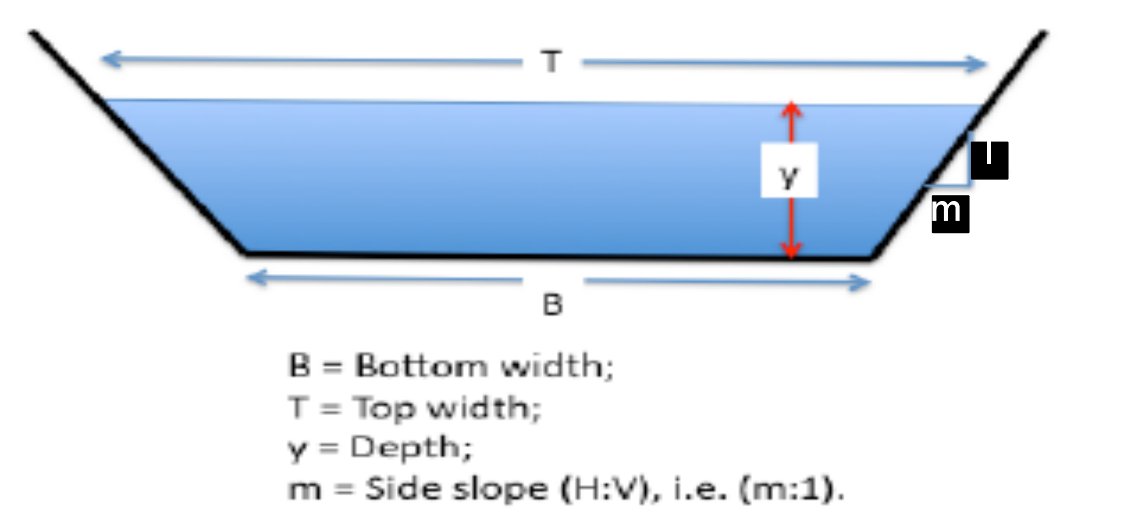
HYDRAULIC RADIUS

- Ratio of area and wetted perimeter
  - Concept used so that hydraulic equations apply regardless of geometry
  - For rectangular geometry
    - Expressed as closed-form in terms of depth.

$$R_{h\ \text{rect.}}(y) = \frac{B \times y}{B + 2y}$$

TRAPEZOIDAL CHANNEL

- The trapezoidal conduit is a reasonably common geometry
  - triangular channel and rectangular channel are special cases of the trapezoidal conduit.
- Engineered (improved) natural channels are reasonably well approximated by trapezoidal equations
  - the geometry is important in drainage engineering



$$A_{\text{trap.}}(y) = y(B + my)$$

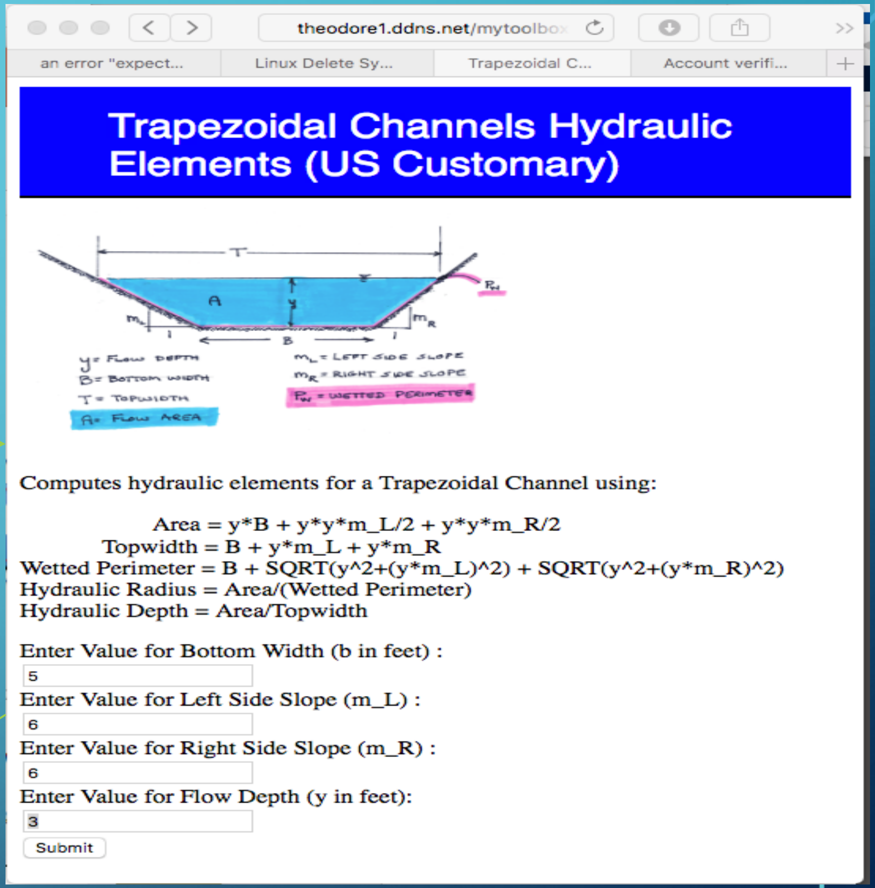
$$T_{\text{trap.}}(y) = B + 2my$$

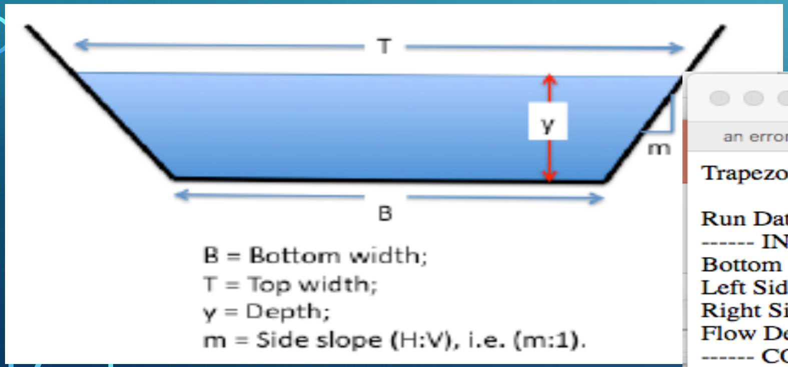
$$P_{w\ \text{trap.}}(y) = B + 2y\sqrt{1 + m^2}$$

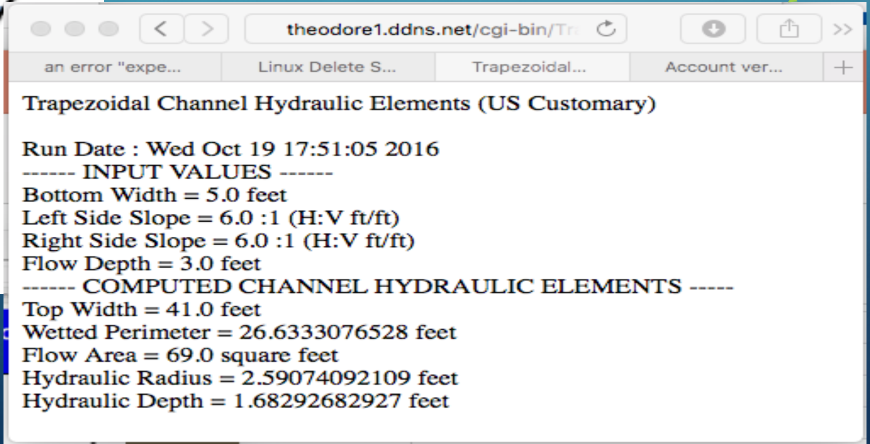
$$R_{h\ \text{trap.}}(y) = \frac{y(B + my)}{B + 2y\sqrt{1 + m^2}}$$

TRAPEZOIDAL CHANNEL

- Online Tool → Considers different side slopes.
- Example:
  INPUT: B=5ft., m=6:1, y=3 ft.
  OUTPUT: Area = 69 sq. ft.
  Perimeter = 26.63 ft.
  Hyd. Radius = 2.59 ft.



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Trapezoidal Channel Hydraulic Elements (US Customary)

Run Date : Wed Oct 19 17:51:05 2016
------ INPUT VALUES ------
Bottom Width = 5.0 feet
Left Side Slope = 6.0 :1 (H:V ft/ft)
Right Side Slope = 6.0 :1 (H:V ft/ft)
Flow Depth = 3.0 feet
------ COMPUTED CHANNEL HYDRAULIC ELEMENTS -----
Top Width = 41.0 feet
Wetted Perimeter = 26.6333076528 feet
Flow Area = 69.0 square feet
Hydraulic Radius = 2.59074092109 feet
Hydraulic Depth = 1.68292682927 feet

RECTANGULAR CONDUIT

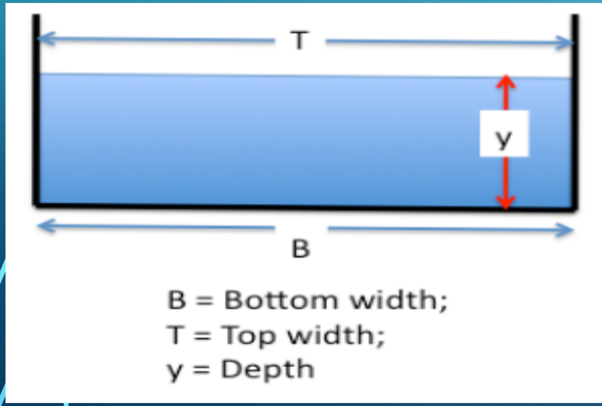
- On-line Tool → Use Trapezoidal Channel, set side slopes to 0
  - Example

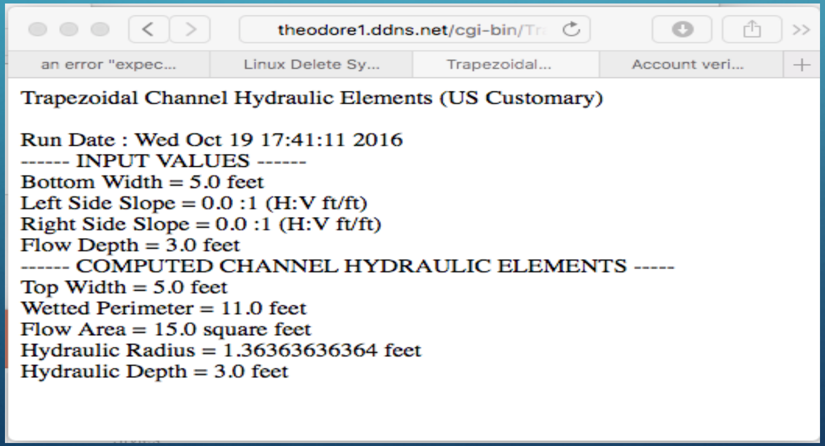
    INPUT: B = 5 ft., y= 3ft.

    RETURN: Area = 15 sq.ft.

    Perimeter = 11 ft.

    Hyd. Radius = 1.36ft.





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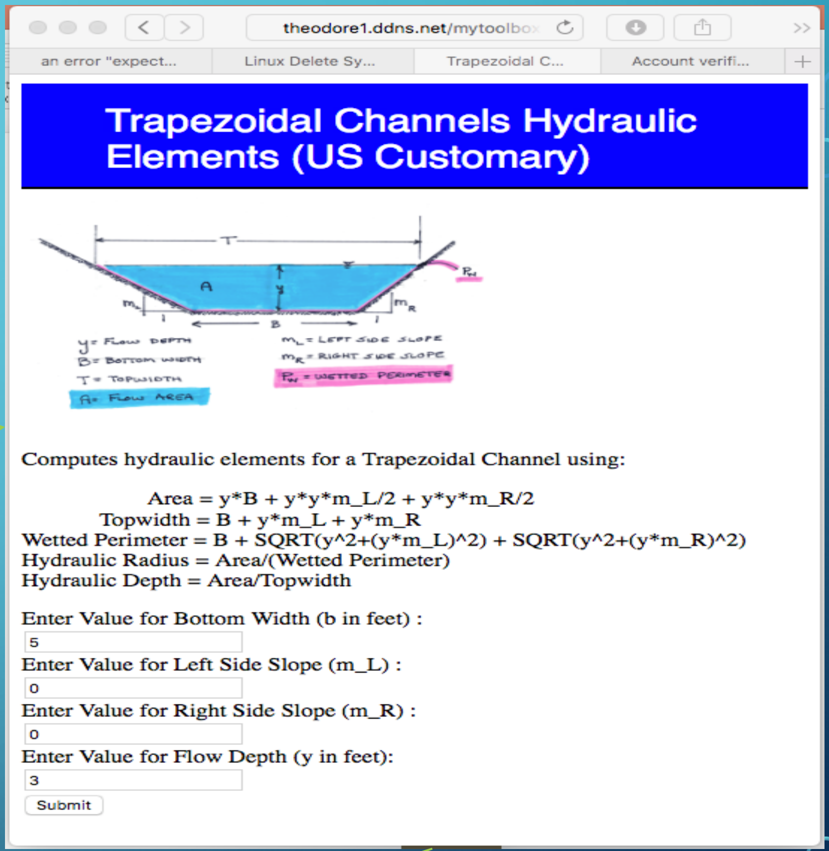
Trapezoidal Channel Hydraulic Elements (US Customary)

Run Date : Wed Oct 19 17:41:11 2016
------ INPUT VALUES ------
Bottom Width = 5.0 feet
Left Side Slope = 0.0 :1 (H:V ft/ft)
Right Side Slope = 0.0 :1 (H:V ft/ft)
Flow Depth = 3.0 feet
------ COMPUTED CHANNEL HYDRAULIC ELEMENTS -----
Top Width = 5.0 feet
Wetted Perimeter = 11.0 feet
Flow Area = 15.0 square feet
Hydraulic Radius = 1.36363636364 feet
Hydraulic Depth = 3.0 feet



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Trapezoidal Channels Hydraulic Elements (US Customary)

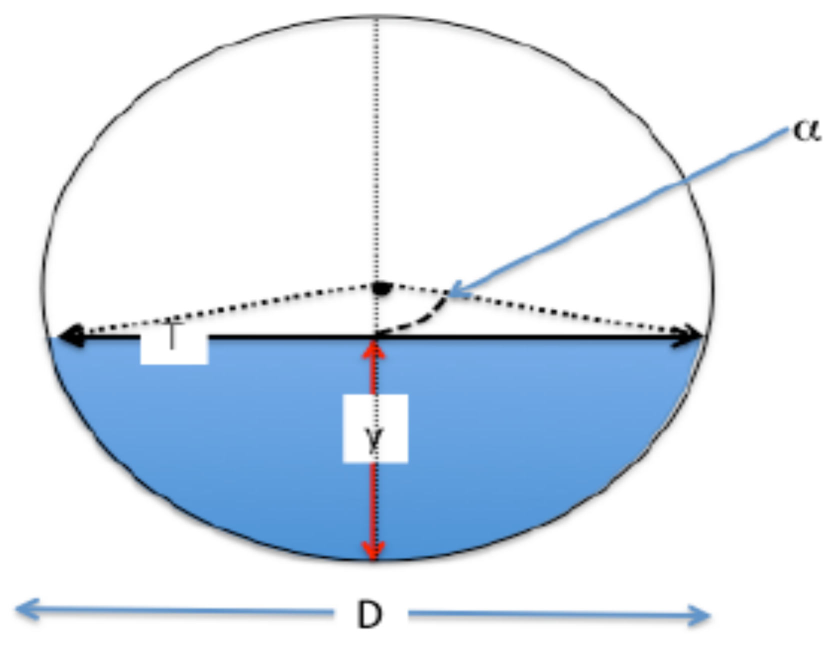
Computes hydraulic elements for a Trapezoidal Channel using:

Area = y*B + y*y*m_L/2 + y*y*m_R/2
Topwidth = B + y*m_L + y*m_R
Wetted Perimeter = B + SQRT(y^2+(y*m_L)^2) + SQRT(y^2+(y*m_R)^2)
Hydraulic Radius = Area/(Wetted Perimeter)
Hydraulic Depth = Area/Topwidth

Enter Value for Bottom Width (b in feet) : 5
Enter Value for Left Side Slope (m_L) : 0
Enter Value for Right Side Slope (m_R) : 0
Enter Value for Flow Depth (y in feet): 3
Submit

CIRCULAR CONDUIT

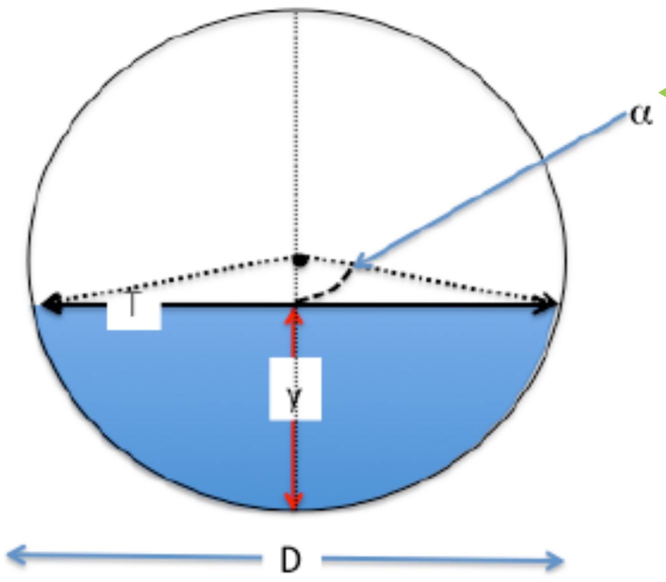
- Obviously common in sewer systems!
  - Pipes flowing with a free surface are circular cross section open channels!



D = Diameter;
T = Top width;
y = Depth;
α = angle between vertical bisector and top width contact.

CIRCULAR CONDUIT

- Sweep angle definition matters, SOME Authors use 2α.



D = Diameter;
T = Top width;
y = Depth;
α = angle between vertical bisector and top width contact.

$$\alpha_{circ.}(y) = cos^{-1}(1 - \frac{2y}{D})$$

$$A_{circ.}(y) = \frac{D^2}{4}(\alpha - sin\alpha\ cos\alpha)$$

$$T_{circ.}(y) = D\ sin\alpha$$

$$P_{w\ circ.}(y) = D\ \alpha$$

$$R_{h\ trap.}(y) = \frac{\frac{D^2}{4}(\alpha - sin\alpha\ cos\alpha)}{D\ \alpha}$$

CIRCULAR CONDUIT

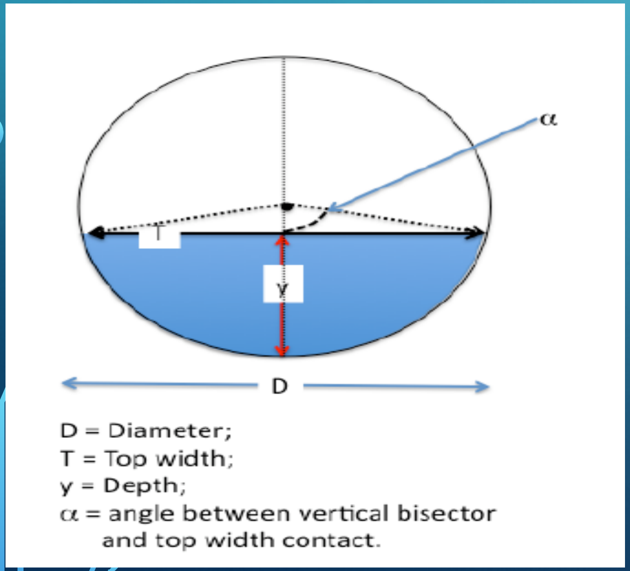
- Online Tool → Use circular and supply depth and diameter.
  - Example:

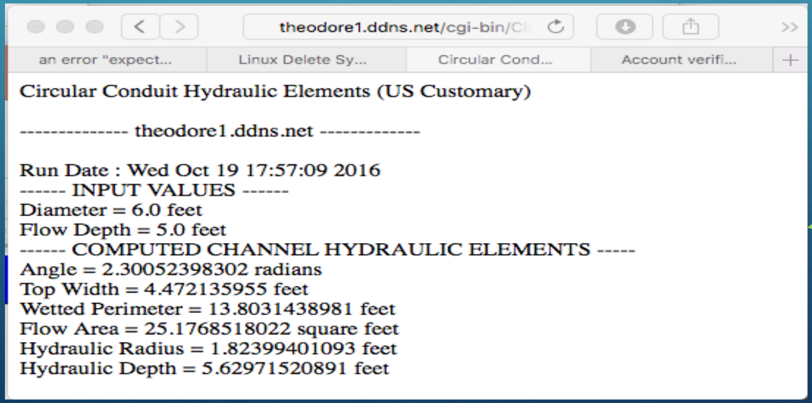
    INPUT: D = 6 ft., y=5 ft.

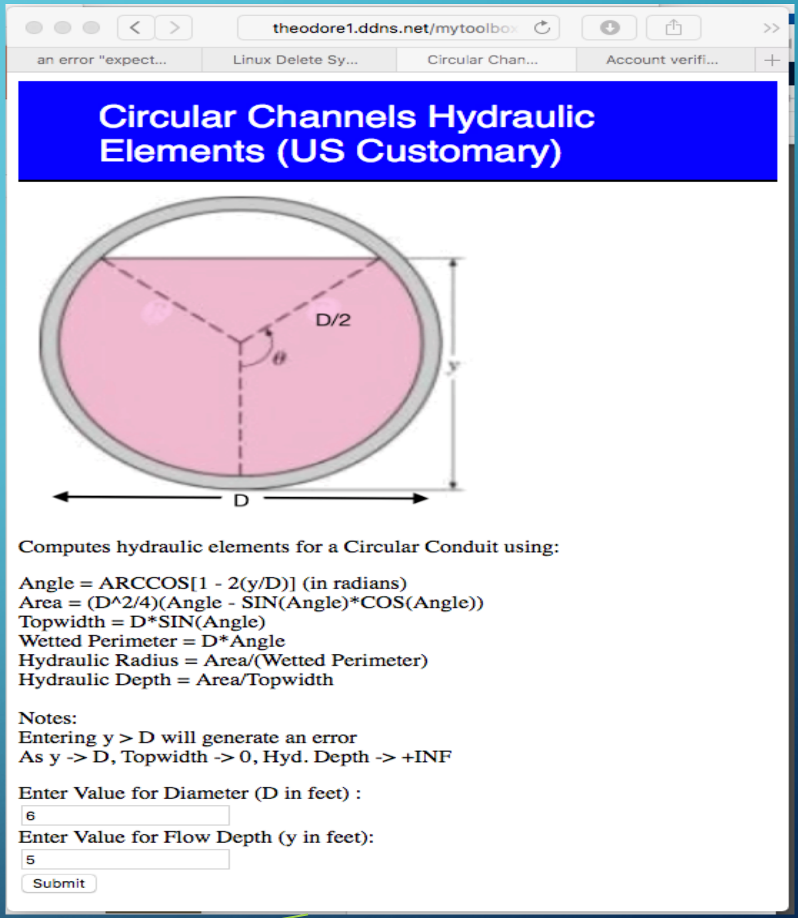
    OUTPUT: Area = 25.17 sq. ft.

    Perimeter = 13.8 ft.

    Hyd. Radius = 1.82 ft.







DEPTH-AREA DISGRAMS

- Designer should sketch their own definition sketches before using the equations to validate that the equations produce the desired results.
- Other geometries are common, and these depth-area tables are usually constructed on as-needed basis.

BUILDING CALCULATORS

- The circular conduit is sometimes a nuisance to relate the hydraulic elements because of the semi-implicit nature of the expressions, especially when the diameter is unknown.
- Two reasonable approaches are to
  - build a calculator (The on-line tool is one such calculator)
  - Use an id-10-t computation sheet and hand-calculator
  - use a dimensionless chart that relates full pipe behavior, where the relationships are simple to compute to partial full behavior.

BUILDING CALCULATORS

- Depth-Discharge Calculator for a Circular Conduit implements Manning's equation in a circular conduit.

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

  - The equation is the U.S. customary version of Manning's equation and is identical to Manning's equation on pg 161 of the NCEES supplied reference.
  - The equation is an adaptation of Equations 3.42 and 3.288 in Chin (adapted for U.S. customary units).
    - A drainage engineer in the US should memorize this equation!

BUILDING CALCULATORS

- What such a calculator might look like

	A	B	C	D	E
1	Circular Pipe Flow Computations				
2	US Customary Units Version				
3					
4	**INPUT DATA**				
5	Manning's n	0.015	<=Table Lookup		
6	Depth	0.500	<=Feet		
7	Diameter	1.000	<=Feet		
8	Slope	0.001	<=Dimensionless		
9	**INTERMEDIATE COMPUTATIONS**				
10	Angle	1.571	<=Radians		
11	Area	0.393	<=Feet Squared		
12	Perimeter	1.571	<=Feet		
13	Radius	0.250	<=Feet		
14	**DISCHARGE AND VELOCITY**				
15	Discharge	0.490	<=Cubic Feet per Second		
16	Velocity	1.247	<=Feet per Second		

The designer supplies values of flow depth, diameter, topographic slope, and Manning's n. These values are then used to determine the sweep angle α as a function of depth and diameter. From this angle, the flow area and wetted perimeter are computed. Finally the hydraulic radius is computed and the resulting discharge is returned.

BUILDING CALCULATORS

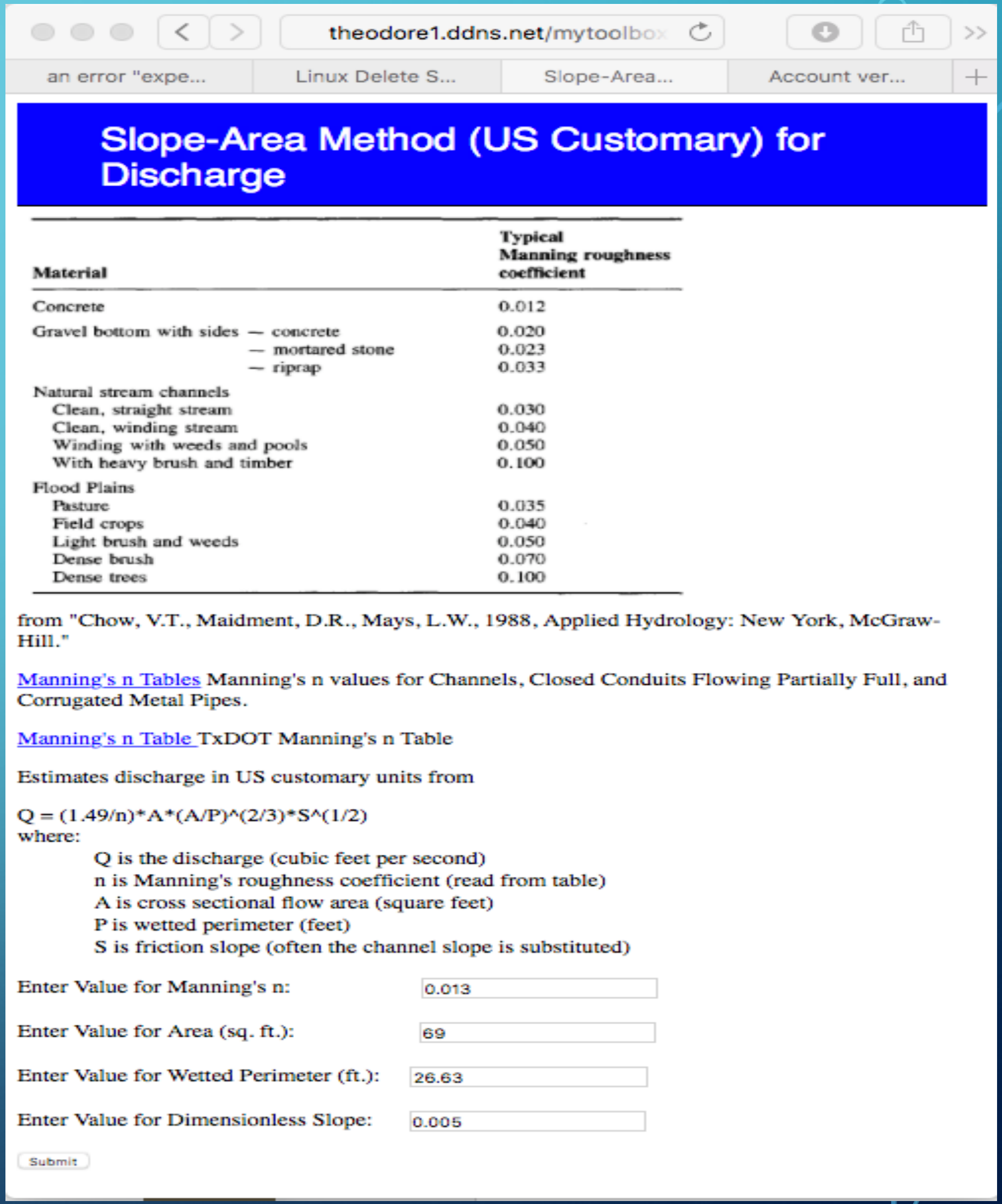
- What such a calculator might look like (displayed as formulas)

	A	B	C	D
1	Circular Pipe Fl			
2	US Customary			
3				
4	**INPUT DATA**			
5	Manning's n	0.015	<=Tab	
6	Depth	0.5	<=Fee	
7	Diameter	1	<=Fee	
8	Slope	0.001	<=Dim	
9	**INTERMEDIAT**			
10	Angle	=ACOS(1-2*B6/B7)	<=Rac	
11	Area	=B7^2*(B10-SIN(B10)*COS(B10))/4	<=Fee	
12	Perimeter	=B10*B7	<=Fee	
13	Radius	=B11/B12	<=Fee	
14	**DISCHARGE A**			
15	Discharge	=(1.49/B5)*B11*B13^(2/3)*B8^(1/2)	<=Cut	
16	Velocity	=B15/B11	<=Fee	

The designer supplies values of flow depth, diameter, topographic slope, and Manning's n. These values are then used to determine the sweep angle α as a function of depth and diameter. From this angle, the flow area and wetted perimeter are computed. Finally the hydraulic radius is computed and the resulting discharge is returned.

ON-LINE CALCULATOR

- Slope-Area (A version of Manning's equation) Model
  - Supply: Manning's n, Flow Area, Perimeter, and Slope
  - Returns: Flow Rate



Slope-Area Method (US Customary) for Discharge

Material	Typical Manning roughness coefficient
Concrete	0.012
Gravel bottom with sides — concrete	0.020
— mortared stone	0.023
— riprap	0.033
Natural stream channels	
Clean, straight stream	0.030
Clean, winding stream	0.040
Winding with weeds and pools	0.050
With heavy brush and timber	0.100
Flood Plains	
Pasture	0.035
Field crops	0.040
Light brush and weeds	0.050
Dense brush	0.070
Dense trees	0.100

from "Chow, V.T., Maidment, D.R., Mays, L.W., 1988, Applied Hydrology: New York, McGraw-Hill."

Manning's n Tables Manning's n values for Channels, Closed Conduits Flowing Partially Full, and Corrugated Metal Pipes.

Manning's n Table TxDOT Manning's n Table

Estimates discharge in US customary units from

Q = (1.49/n)*A*(A/P)^(2/3)*S^(1/2)
where:
Q is the discharge (cubic feet per second)
n is Manning's roughness coefficient (read from table)
A is cross sectional flow area (square feet)
P is wetted perimeter (feet)
S is friction slope (often the channel slope is substituted)

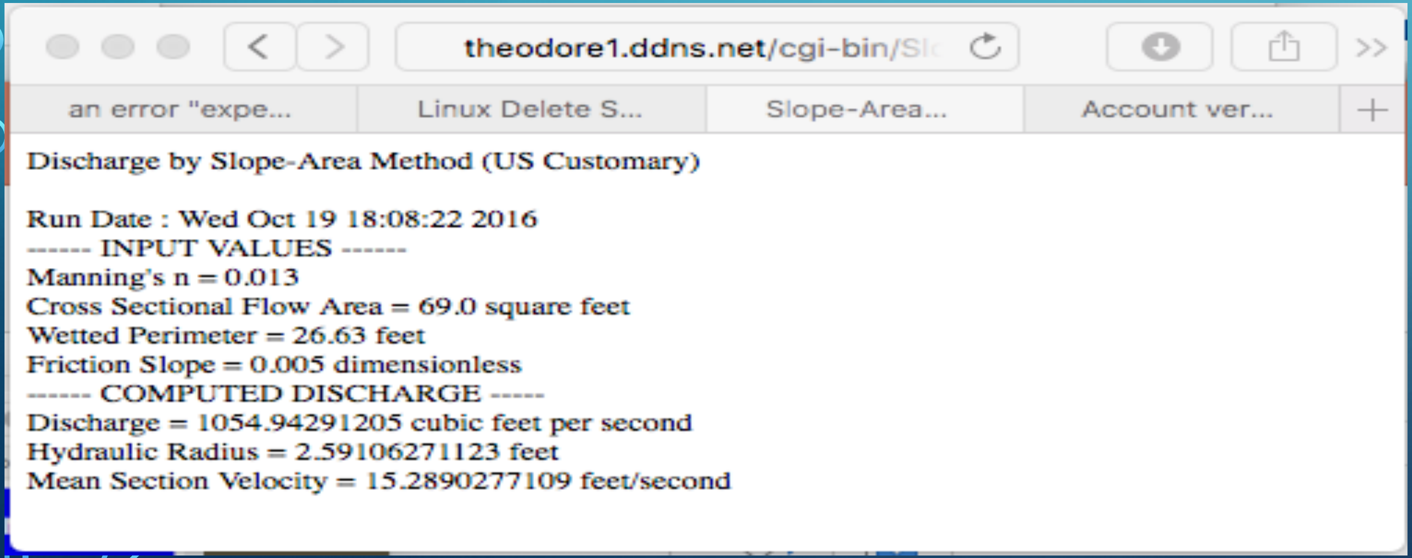
Enter Value for Manning's n: 0.013

Enter Value for Area (sq. ft.): 69

Enter Value for Wetted Perimeter (ft.): 26.63

Enter Value for Dimensionless Slope: 0.005

Submit



Discharge by Slope-Area Method (US Customary)

Run Date : Wed Oct 19 18:08:22 2016
------ INPUT VALUES ------
Manning's n = 0.013
Cross Sectional Flow Area = 69.0 square feet
Wetted Perimeter = 26.63 feet
Friction Slope = 0.005 dimensionless
------ COMPUTED DISCHARGE -----
Discharge = 1054.94291205 cubic feet per second
Hydraulic Radius = 2.59106271123 feet
Mean Section Velocity = 15.2890277109 feet/second

ID-10-T CALCULATION SHEET

- The ID-10-T Sheets are like an IRS tax return form.
- The analyst enters known values and follows the calculation instructions.
- The sheets are intended when the analyst has only a hand-calculator (although if one had a table of logarithms and trig. Tables, you could use the sheet without any electronics!)

ID-10-T-US-CIRCULAR

CE 3372 – Water Systems Design
ID-10-T-US Circular

Purpose:	Compute discharge in a circular section using Manning's equation assuming normal (uniform) flow
Required Tools:	Calculator/Slide-Rule, or Logarithmic and Trigonometric Tables
Input Data:	Manning's n; Conduit Slope, S_0, (dimensionless); Flow Depth, d, (in feet); and Conduit Diameter, D, (in feet)
Output Values:	Discharge, Q, (in cubic feet per second)
Use:	When on-line tools or spreadsheet tools are unavailable.

1. Manning's $n =$ ________
2. Flow Depth $d =$ ________ feet.
3. Conduit Diameter $D =$ ________ feet.
4. Conduit Slope $S_0 =$ ________
5. Ratio of flow depth to diameter; $\frac{d}{D} =$ ________
6. Compute $cos(\alpha) = 1 - 2 \times \frac{d}{D} =$ ________
7. Compute the inverse cosine of the result in line [6] in **radians**. Enter the result below.

   $cos^{-1}(1 - 2 \times \frac{d}{D}) = \alpha =$ ________
8. Compute the flow area using

   $A = \frac{D^2}{4} \times (\alpha - sin(\alpha)cos(\alpha)) =$ ________ feet^2.
9. Compute the wetted perimeter

   $P_w = \alpha \times D =$ ________ feet.
10. Compute the hydraulic radius, $R_h = \frac{A}{P_w} =$ ________ feet.

11. Copy the value from Line [1], $n =$ ________
12. Copy the result from Line [8], $A =$ ________ feet^2.
13. Copy the result from Line [10], $R_h =$ ________ feet.
14. Copy the result from Line [4], $S_0 =$ ________
15. Compute square root of Line [14],

    $\sqrt{S_0} =$ ________
16. Compute Line[13] raised to the 2/3-rds power;

    $R_h^{2/3} =$ ________
17. Multiply Line [16],Line [15], and Line [12];

    $R_h^{2/3} \times \sqrt{S_0} \times A =$ ________
18. Multiply Line [17] by 1.49;

    $1.49 \times R_h^{2/3} \times \sqrt{S_0} \times A =$ ________
19. Divide Line [18] by Line [11], result is discharge,Q.

    $Q = \frac{1.49}{n} \times R_h^{2/3} \times \sqrt{S_0} \times A =$ ________ cubic feet per second.

ID-10-T-SI-CIRCULAR

CE 3372 – Water Systems Design
ID-10-T-SI Circular

Purpose:	Compute discharge in a circular section using Manning's equation assuming normal (uniform) flow
Required Tools:	Calculator/Slide-Rule, or Logarithmic and Trigonometric Tables
Input Data:	Manning's n; Conduit Slope, S_0, (dimensionless); Flow Depth, d, (in meters); and Conduit Diameter, D, (in meters)
Output Values:	Discharge, Q, (in cubic meters per second)
Use:	When on-line tools or spreadsheet tools are unavailable.

1. Manning's $n =$ ________________
2. Flow Depth $d =$ ________________ meters.
3. Conduit Diameter $D =$ ________________ meters.
4. Conduit Slope $S_0 =$ ________________
5. Compute ratio of flow depth to diameter; $\frac{d}{D} =$ ________________
6. Compute $cos(\alpha) = 1 - 2 \times \frac{d}{D} =$ ________________
7. Compute the inverse cosine of the result in line [6] in **radians**. Enter the result below.

   $cos^{-1}(1 - 2 \times \frac{d}{D}) = \alpha =$ ________________
8. Compute the flow area using

   $A = \frac{D^2}{4} \times (\alpha - sin(\alpha)cos(\alpha)) =$ ______________________________ meters^2.
9. Compute the wetted perimeter

   $P_w = \alpha \times D =$ ________________ meters.
10. Compute the hydraulic radius, $R_h = \frac{A}{P_w} =$ ________________ meters.

11. Copy the value from Line [1], $n =$ ________________
12. Copy the result from Line [8], $A =$ ________________ meters^2.
13. Copy the result from Line [10], $R_h =$ ________________ meters.
14. Copy the result from Line [4], $S_0 =$ ________________
15. Compute square root of Line [14],

    $\sqrt{S_0} =$ ________________
16. Compute Line[13] raised to the 2/3-rds power;

    $R_h^{2/3} =$ ________________
17. Multiply Line [16],Line [15], and Line [12];

    $R_h^{2/3} \times \sqrt{S_0} \times A =$ ________________
18. Multiply Line [17] by 1.0;

    $1.0 \times R_h^{2/3} \times \sqrt{S_0} \times A =$ ________________
19. Divide Line [18] by Line [11], result is discharge,Q.

    $Q = \frac{1.0}{n} \times R_h^{2/3} \times \sqrt{S_0} \times A =$ ________________ cubic meters per second.

DIMENSIONLESS DIAGRAMS

- Using the same principles as the circular flow calculator, a dimensionless depth-discharge diagram table can be constructed.
  - Essentially the same input information is supplied; diameter, material properties, and slope.
- The table then divides the depth into specific ratios of the diameter, then computes the discharge for each ratio.
  - In this forward computational step, there is no advantage, but if one has the tabulation (or the dimensionless chart) the reverse look-up greatly simplifies the design process.

DIMENSIONLESS DIAGRAMS

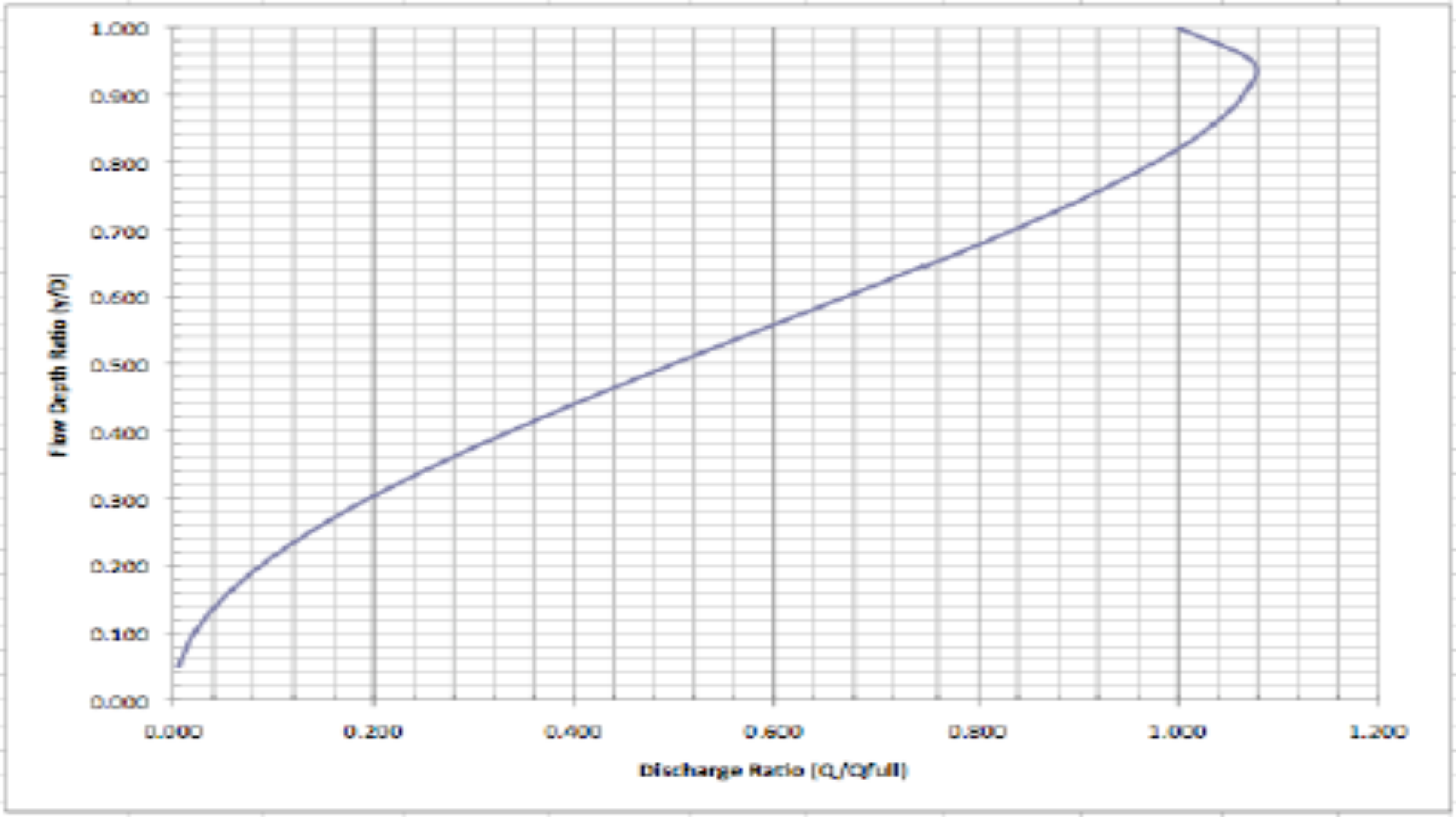
Circular Pipe Flow Computations
US Customary Units

Pipe Diameter	**1**
Manning's n	**0.015**
Slope	**0.001**

Input Values					Intermediate Computations				Results	
Manning's n	Diameter (feet)	Dimensionless Slope	Flow Depth (feet)	Flow Depth Ratio (y/D)	Angle (Radians)	Flow Area (sq.ft.)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Discharge (cfs)	Discharge Ratio (Q/Qfull)
0.015	1	0.001	0.050	0.050	0.451	0.015	0.451	0.033	0.005	0.005
0.015	1	0.001	0.100	0.100	0.644	0.041	0.644	0.064	0.020	0.021
0.015	1	0.001	0.150	0.150	0.795	0.074	0.795	0.093	0.048	0.049
0.015	1	0.001	0.200	0.200	0.927	0.112	0.927	0.121	0.086	0.088
0.015	1	0.001	0.250	0.250	1.047	0.154	1.047	0.147	0.134	0.137
0.015	1	0.001	0.300	0.300	1.159	0.198	1.159	0.171	0.192	0.196
0.015	1	0.001	0.350	0.350	1.266	0.245	1.266	0.193	0.257	0.263
0.015	1	0.001	0.400	0.400	1.369	0.293	1.369	0.214	0.330	0.337
0.015	1	0.001	0.450	0.450	1.471	0.343	1.471	0.233	0.408	0.416
0.015	1	0.001	0.500	0.500	1.571	0.393	1.571	0.250	0.490	0.500
0.015	1	0.001	0.550	0.550	1.671	0.443	1.671	0.265	0.573	0.585
0.015	1	0.001	0.600	0.600	1.772	0.492	1.772	0.278	0.658	0.672
0.015	1	0.001	0.650	0.650	1.875	0.540	1.875	0.288	0.741	0.756
0.015	1	0.001	0.700	0.700	1.982	0.587	1.982	0.296	0.820	0.837
0.015	1	0.001	0.750	0.750	2.094	0.632	2.094	0.302	0.893	0.911
0.015	1	0.001	0.800	0.800	2.214	0.674	2.214	0.304	0.957	0.977
0.015	1	0.001	0.850	0.850	2.346	0.712	2.346	0.303	1.009	1.030
0.015	1	0.001	0.900	0.900	2.498	0.745	2.498	0.298	1.043	1.065
0.015	1	0.001	0.950	0.950	2.691	0.771	2.691	0.286	1.052	1.074
0.015	1	0.001	1.000	1.000	3.140	0.785	3.140	0.250	0.979	1.000

DIMENSIONLESS DIAGRAMS

	A	B	C	D	E	F	G	H	I	J	K
28	0.015	3	0.002	2.700	0.900	2.498	6.701	7.494	0.894	27.626	1.065
29	0.015	3	0.002	2.850	0.950	2.691	6.936	8.072	0.859	27.852	1.074
30	0.015	3	0.002	3.000	1.000	3.140	7.069	9.419	0.750	25.932	1.000



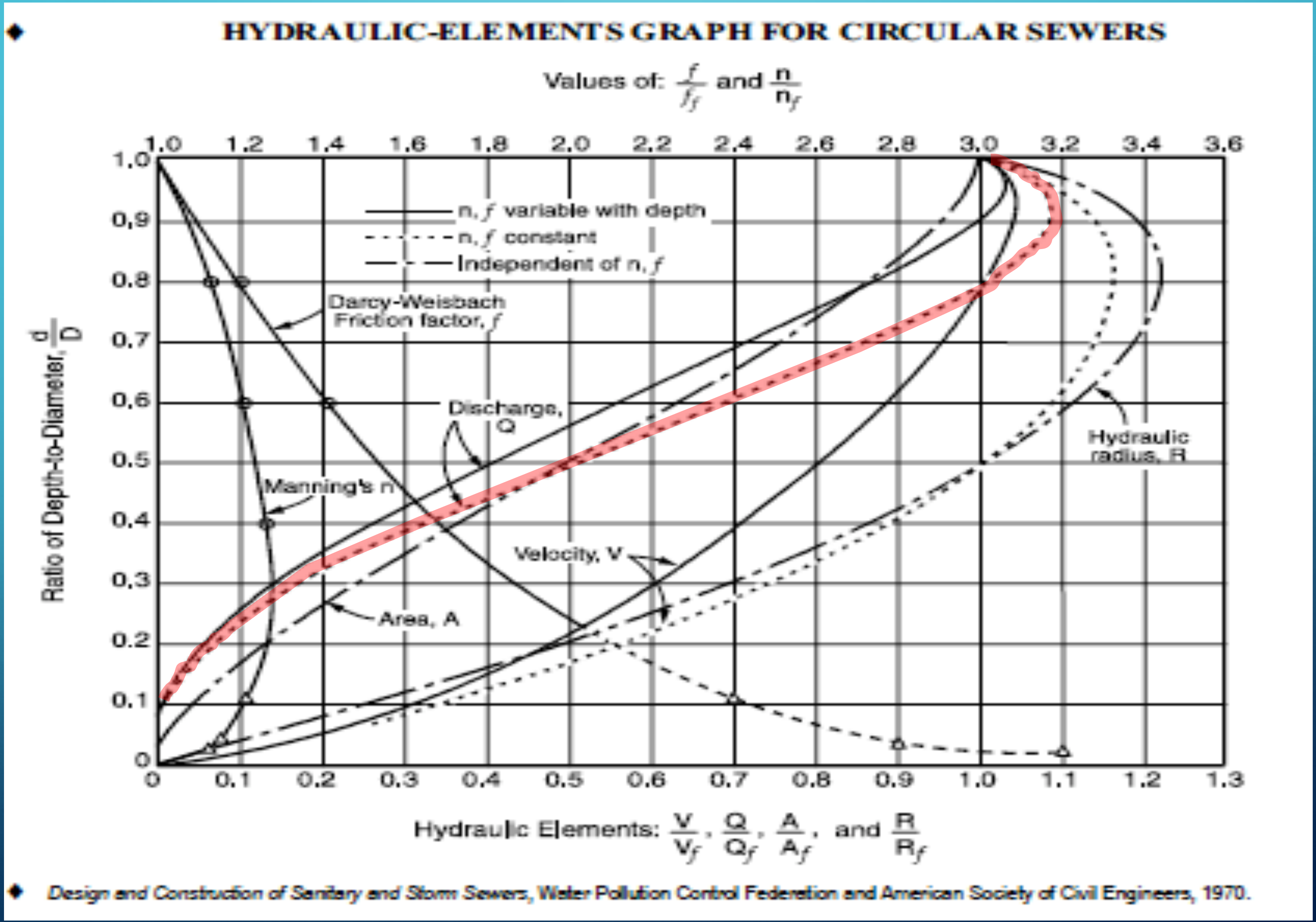
HOW TO USE DIMENSIONLESS CHART

- Determine full pipe discharge

$$Q_{full} = (\frac{1.49}{n})(\frac{\pi D^2}{4})(\frac{D}{4})^{\frac{2}{3}}(S)^{\frac{1}{2}}$$

- Determine flow depth ratio of interest, suppose ¾ full is value of interest – the ratio is 0.75
- Locate discharge fraction for the depth fraction on the chart. For 0.75 full, $Q/Q_{full} = 0.911$
- Multiply the discharge fraction by the full pipe discharge fraction to recover the discharge for the particular depth of flow. $Q_{75\%} = 0.911 Q_{full}$

DIMENSIONLESS CHART (NCEES)



DIMENSIONLESS CHARTS

- Value comes when using backwards (reverse-lookup) to determine a design diameter for a required fill depth and supplied discharge

OTHER DIMENSIONLESS CHARTS

- Trapezoidal channel
  - FHWA HEC-22

1.1.4 HEC-22 Trapezoidal Channel Depth-Discharge Chart

Trapezoidal channels also occur frequently enough in practice that their design is often facilitated using charts — these charts are not dimensionless in the usual sense.

Figure 11 is a tool to estimate the flow depth given a discharge and Manning's n.

The following procedure outlines how to use this chart[4]

1. The analyst/designer must specify the channel width, B, the side slope, Z, the longitudinal slope, S_0, the material properties, n, and the discharge, Q.
2. Locate the value of S_0 on the first vertical scale from the left of the chart.
3. Compute $Q \times n$. Locate this value on the second vertical scale from the left of the chart.
4. Draw a line connecting these two values that also intersects the third vertical line in the chart (called the "turning line").
5. Locate the value of B on the fourth vertical scale from the left of the chart.
6. Draw a line connecting the intersection of the first analyst drawn line with the turning line and the value of B just plotted, be sure the extent the line to the side-slope scale on the right of the figure.
7. At the intersection of the side-slope scale and this line, draw a horizontal line across the side slope scale.
8. Read the depth to width ratio for the appropriate value from the side-slope scale.
9. Multiply the depth by this ratio to recover the flow depth for the channel.

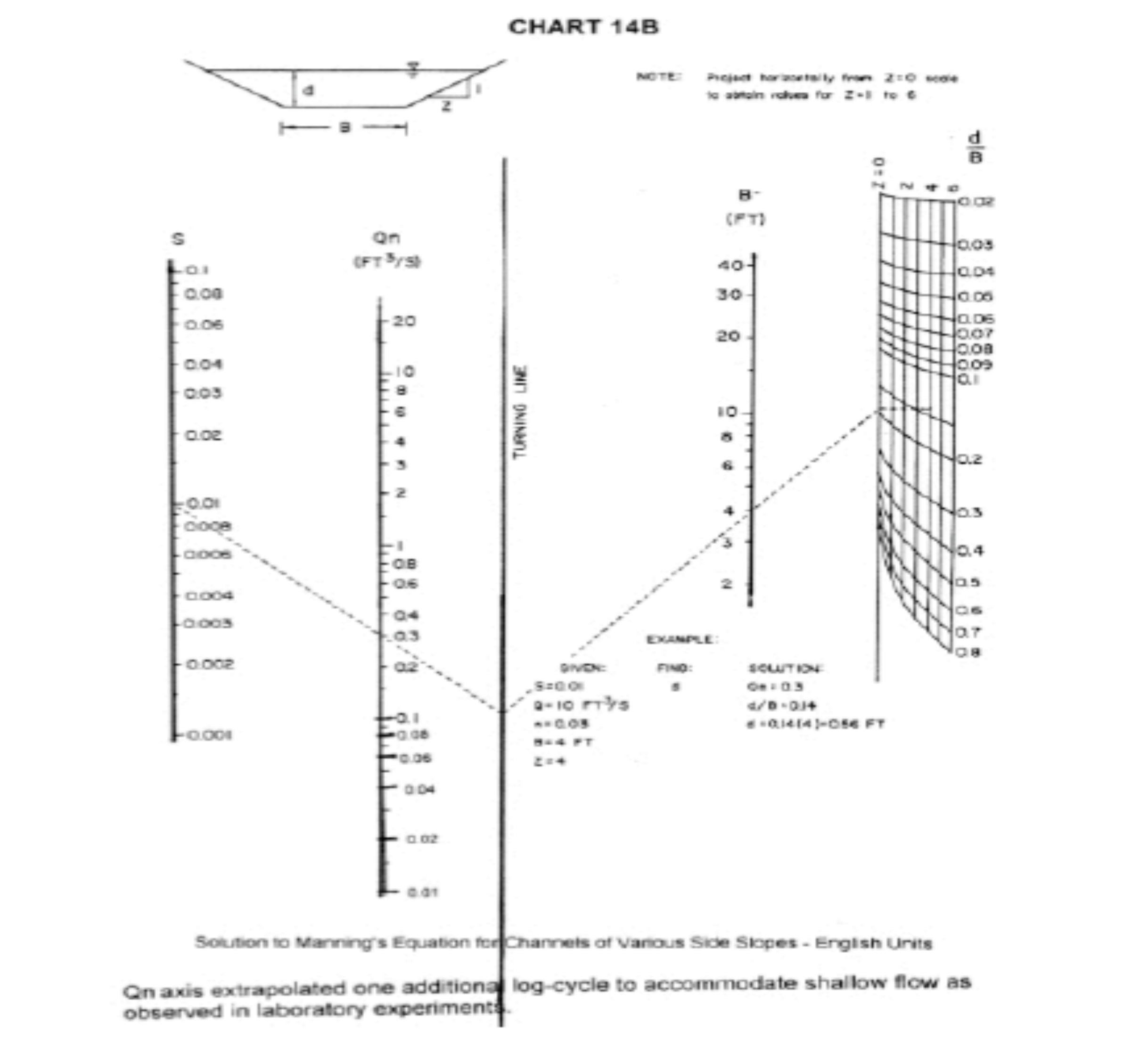


Figure 11: Trapezoidal Channel Discharge-Depth Chart (from FWHA HEC-22)

NEXT TIME

- Gradually Varied Flow
  - Demonstrate that NORMAL flow is a special case of GVF