ASSIGNMENT 2

# WMD651 – Water Management Systems Design

Winter 2021

Due Date: Monday February 08, 2021

Instructions:

Below are five questions based on lessons 1 through 6. Solutions may be hand-written or typed. All questions are exercises in communication, so answers should be clear and well-structured. Any unclear answers will not be graded. List any assumptions in addition to those given by a problem. Show all work. The assignment is out of 20 marks.

QUESTION 1   [5 MARKS]

Below is a trapezoidal section for an open channel. The channel base width is b = 5 m, the bed slope is S_0 = 0.005 m/m, the Manning roughness is n = 0.015, and the side slope is characterized by z = 3 m/m. If the channel has a flow of Q = 20 m³/s, determine the channel's normal depth y_n. Perform up to three iterations, and comment on whether and why additional iterations are needed. Note that for a trapezoidal channel section, $A = y(b + zy)$ and $R = \frac{A}{b + 2y\sqrt{1+z^2}}$. **Hint:** *see the normal depth example in the lesson 4 slides.*
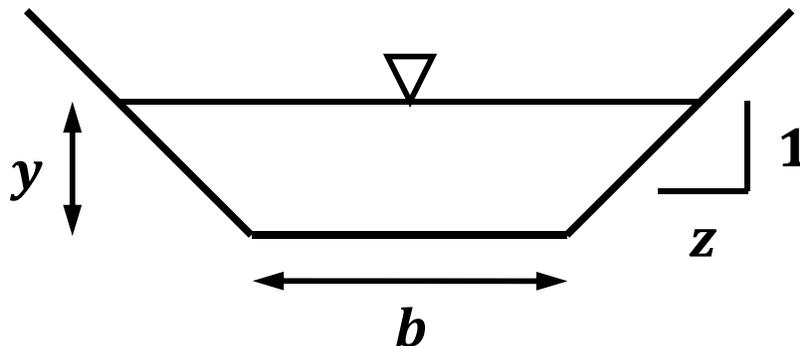
QUESTION 2 [5 MARKS]

Below is a reservoir-pipe-reservoir system with pressurized flow. Determine the system's flow, and perform up to three iterations. Note that you will need to use the Moody chart to determine the friction factor f.

$$H_1 = 200 \text{ m}$$

$$L = 1200 \text{ m}$$
$$D = 300 \text{ mm}$$
$$e = 0.5 \text{ mm}$$
$$Q = ?$$

$$H_2 = 175 \text{ m}$$
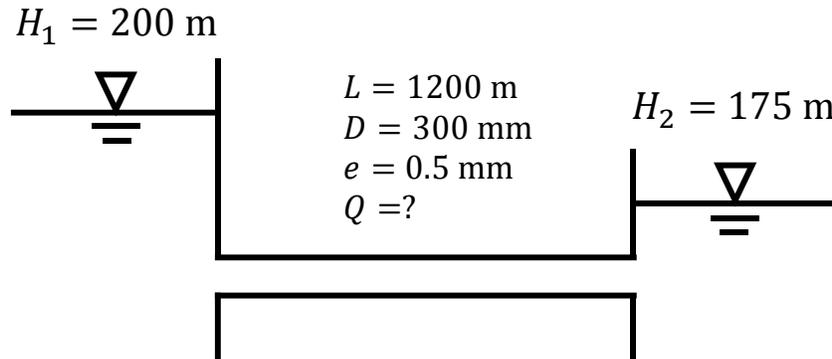
Hint: To solve this problem, begin by developing a system equation, estimating the friction factor f (e.g., start with f = 0.03), calculate the system flow, then determine f from the Moody chart and compare it against your estimate. Perform up to three iterations, and comment on whether further iterations are needed. Your estimated f and calculated f (from the Moody diagram) should gradually get closer and closer with each iteration. See also (i) the supplemental notes at the end of this assignment and (ii) the example in the lesson 3 slides.

QUESTION 3 [5 MARKS]

Below is a pumping pipeline system. The reservoirs have H_1 = 230 m and H_2 = 280 m, and two pump options are being considered.

$$EGL$$

$$H_2$$

$$H_{Pump}$$

$$k_{local}$$

$$H_1$$

$$K_{friction}$$

$$H_{Pump} = a - bQ^2$$
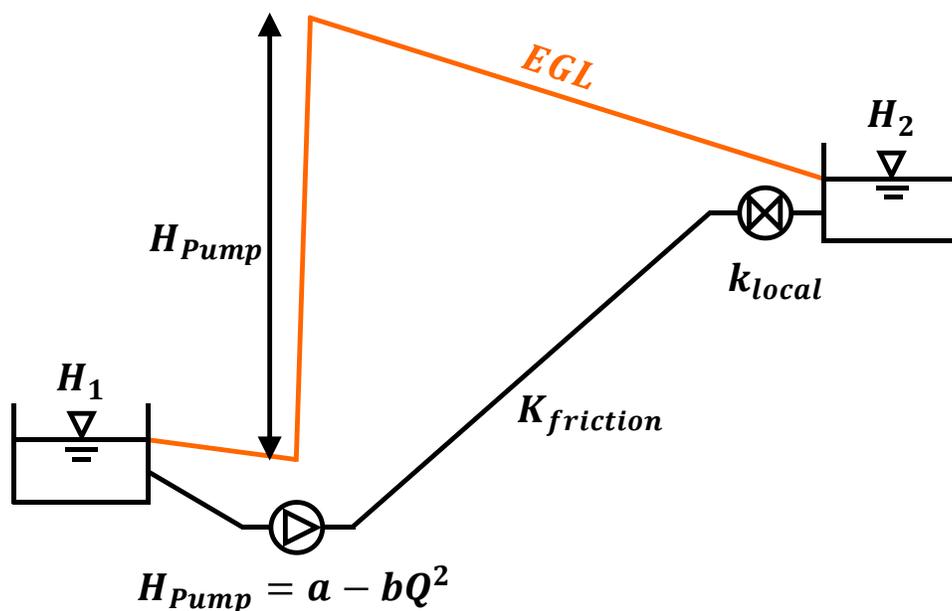
The TDH curve for pump option #1 has coefficients a = 75 m and b = 180 s²/m⁵. The coefficients for pump option #2 are a = 100 m and b = 270 s²/m⁵. The pipeline has resistance $K_{friction}$ = 90 s²/m⁵ for use with $H_{friction} = K_{friction}Q^2$. Assume local losses are negligible (i.e., K_{local} = 0 s²/m⁵). Complete the following:

a) Determine the system flow if Pump #1 is installed.

b) Determine the system flow if Pump #2 is installed.

c) If the system must provide a minimum flow of 350 L/s, which pump is better? (i.e., which pump can provide the minimum flow?)

QUESTION 4   [5 MARKS]

An urban subcatchment has area A = 0.45 ha and time of concentration t_c = 15 min (0.25 h). Complete the following questions:

a) Estimate the runoff for a 100-year storm (T = 100 years) using the IDF equation $i = \frac{a}{(t_c+b)^c}$, where i = average rainfall intensity (mm/h), a = 59.7 mm/h, b = 0.33 h, and c = 0.8. Note: Be sure to enter t_c into the equation in units of hours!

b) Use the Rational Method to estimate the peak runoff rate for the subcatchment under the 100-year storm.

c) What is the likelihood that at least one 100 year storm will occur during an n = 100 year period? (I.e., what is the failure probability?)

d) What are the 5 key assumptions of the rational method?

SUPPLEMENTAL NOTES – USING THE MOODY DIAGRAM

- **<u>Step 1:</u>** Calculate the Reynolds number: $Re = VD/\nu$, where $\nu = 1 \times 10^{-6}\ m^2/s$. Note that Re is dimensionless (no units), so enter V in [m/s], D in [m], and ν in [m²/s].

- **<u>Step 2:</u>** Calculate the relative roughness e/D. It is dimensionless (no units), so enter e in [m] and D in [m]. Locate e/D on the right vertical axis.

- **<u>Step 3:</u>** Trace out the corresponding curve for e/D and move leftward along the curve. Continue tracing left along the curve until you reach the vertical line for Re.

- **<u>Step 4:</u>** Trace a horizontal line left from the point on the curve towards the friction factor axis. The corresponding value on the friction factor axis is f.

Example: D = 0.3 m, A = 0.0707 m², Q = 0.01 m³/s, $V = Q/A$ = 0.141 m/s, and e = 0.0003 m
- Step 1: $Re = \dfrac{VD}{\nu} = \dfrac{(0.141\ m/s)(0.3\ m)}{(1\times10^{-6}m^2/s)} = 4.2 \times 10^4$
- Step 2: $e/D = (0.0003\ m)/(0.3\ m)$ = 0.001
- Step 3: Locate Re along curve for e/D
- Step 4: Trace horizontal line to f = 0.026