National Exams December 2018

16-Civ-A5, Hydraulic Engineering

<u>3 hours duration</u>

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED BOOK examination. The following are permitted:

   - **one** 8.5 x 11 inch aid sheet (both sides may be used); and
   - approved Casio or Sharp calculator.

3. This examination has a total of **six** questions. You are required to complete any **five** of the six exam questions. Indicate clearly on your examination answer booklet which questions you have attempted. The first five questions as they appear in the answer book will be marked. All questions are of equal value. If any question has more than one part, each is of equal value.

4. Note that 'cms' means cubic metres per second; 1 inch=2.54 cm.

5. The following equations may be useful:

   - Hazen-Williams: $Q = 0.278CD^{2.63}S^{0.54}$, $S=\Delta h/L$
   - Mannings: $Q = \frac{A}{n}R^{2/3}S^{0.5}$, $S=\Delta h/L$
   - Darcy-Weisbach: $\Delta h = \frac{fL}{D}\frac{V^2}{2g} = 0.0826\frac{fL}{D^5}Q^2$
   - Loop Corrections: $q_l = -\frac{\sum_{loop} k_i Q_i |Q_i|^{n-1}}{n\sum_{loop} k_i |Q_i|^{n-1}}$, $n = 1.852$ (Hazen-Williams)
   - Total Dynamic Head: $TDH = H_s + H_f$, H_s=static head; H_f=friction losses

6. Unless otherwise stated, (i) assume that local losses and velocity head are negligible, (ii) that the given values for pipe diameters are nominal pipe diameters and (iii) that the flow involves water with a density ρ = 1,000 kg/m^3 and kinematic viscosity υ = 1.31 x 10^{-6} m^2/s.

/20 1. A branched pipe network conveys water from reservoir R1 with constant water level of 110 m to 5 nodes, all at elevation of 40 m (Figure 1). All pipes are made of ductile iron and have a Hazen-Williams 'C' factor of 110, an internal diameter of 405 mm, and a length of 340 m. Nodes 1 through 5 have a maximum day demand of 1.0 L/s. Node 5 also carries a fire flow of 25 L/s.

a) Determine the steady-state pressure head at Node 4 during maximum day demand + fire flow at Node 5.

b) Determine the steady-state pressure head at Node 5 during maximum day demand (no fire flow at Node 5).

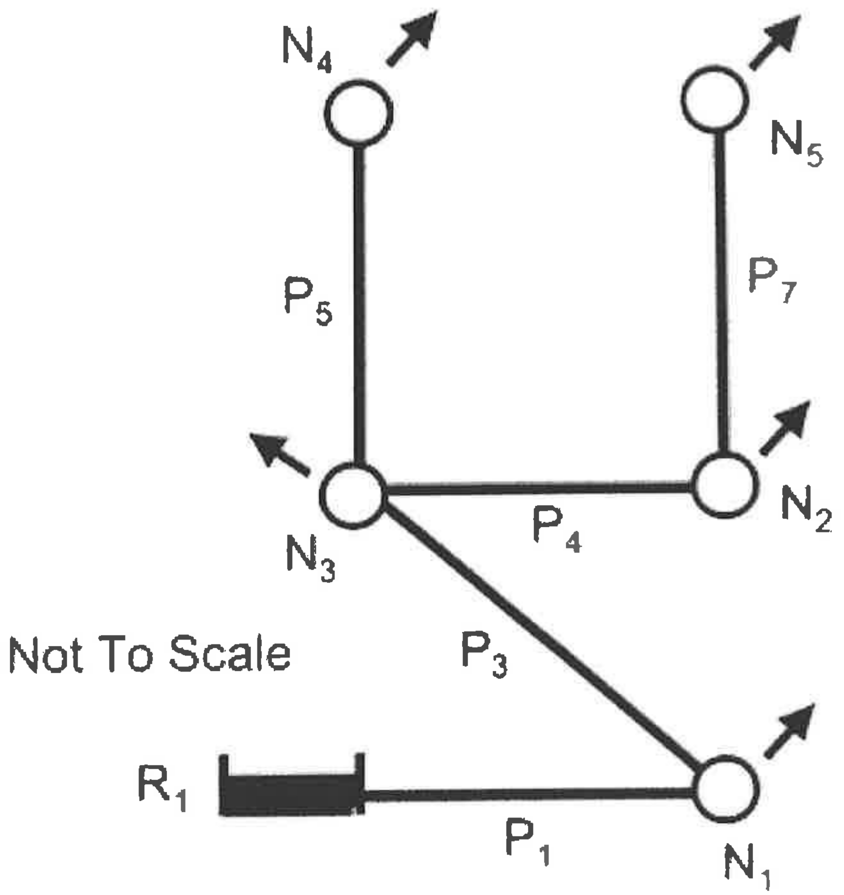


Figure 1. Water supply system.

/20 2. A number of identical pipes connect an upstream reservoir A (Res. A with a water level of 120 m) to a downstream reservoir B (Res. B with a water level of 70 m). All the pipes are at 17 m elevation. Each pipe has a 400 mm diameter, is 350 m long and has a 'C' value of 145.

a) Determine the total flow through this pipe system.

b) Determine the maximum and minimum pressure head in the system.

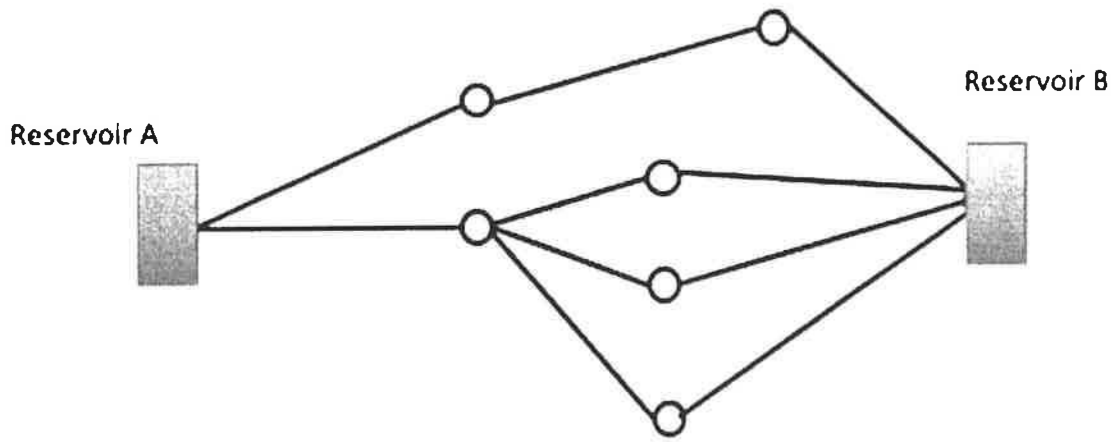


Figure 2. Pipes that connect Reservoirs A and B.

/20 3. A transmission pipeline that conveys water from an upstream reservoir to a downstream reservoir is indicated below. The transmission main has a valve along its length that controls the discharge in the system. The discharge through the valve is computed with the valve equation below. The pipeline has a length of 5,000 m, a Hazen-Williams 'C' factor of 140, and an inner diameter of 1,167 mm. The upstream reservoir has a water level of 105 m. The valve discharge constant is Es = 0.45 $m^{5/2}/s$.

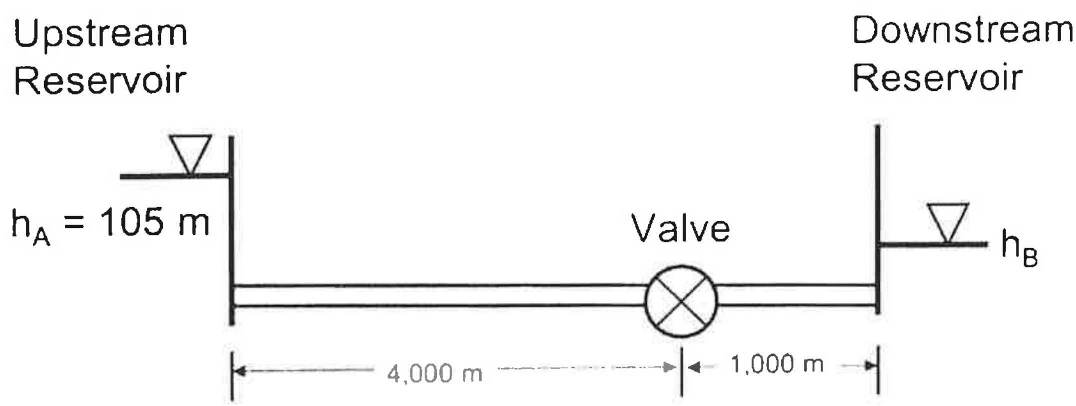
$$Q = \tau E_s [H_{u/s} - H_{d/s}]^{1/2}$$

where Q = discharge (m^3/s), Es = valve discharge constant ($m^{5/2}/s$), Hu/s = upstream head, Hd/s = downstream head.

a) When the valve is partially closed, a steady state discharge of 0.92 m^3/s generates a headloss of 6 m across the valve. Given this data, compute the τ-value of the partially-closed valve.

b) For the steady state discharge and τ-value computed in a), compute the water level in the downstream reservoir.

c) When the valve is closed further, the τ value is lowered to τ = 0.3. If the water level in the downstream reservoir remains fixed at the level computed in b), compute the discharge in the transmission pipeline.



/20 4. Using a force balance across a pipe, derive a closed-form equation that relates wall shear stress to average velocity in a pipe under steady-state conditions. The equation can be applicable to laminar or turbulent flow. For a pressure difference of 15 kPa across a length of 2 m in a pipe with a diameter of 150 mm, calculate the shear stress at the pipe wall.

/20 5. A rectangular channel with a width of 11 m carries a flow of 1.2 m^3/s. The water depth in the channel upstream of the hydraulic jump is 0.3 m.

a) Write an equation that describes the momentum conditions across the hydraulic jump.

b) Using the momentum expression from a), calculate the fluid velocity on the downstream side of the hydraulic jump.

/20 6. A road cross-section is 8 m wide (from edge to edge of pavement), with a 2% crossfall slope from the centreline and is bounded by curbs. The Manning's 'n' for asphalt is 0.013 and the longitudinal slope of the roadway is 0.02.

a) Calculate the water depth in the road cross-section when the flow is 1.3 m^3/s.

b) The flood flow is expected to increase by 15% with a change in climate. Under these new conditions, calculate the water depth in the road cross-section. Can the road "contain" the new climate-adjusted flow within the roadway section?

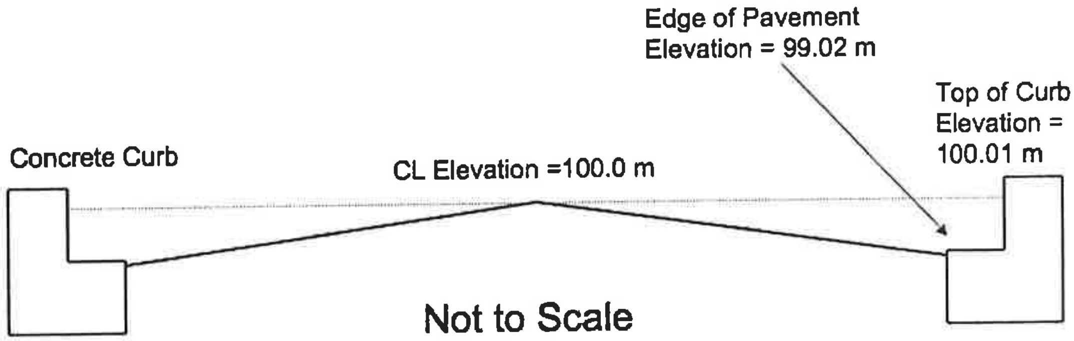


Figure 3. Roadway cross-section.