National Exams December 2016

98-Civ-A5, Hydraulic Engineering

3 hours duration

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
   - any non-communicating 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: $\Delta h = \frac{fL}{D}\cdot\frac{V^2}{2g} = 0.0826\frac{fL}{D^5}\cdot Q^2$
   - Loop Corrections: $q_l = -\frac{\sum_{\text{loop}} k_i Q_i |Q_i|^{n-1}}{n\sum_{\text{loop}} k_i |Q_i|^{n-1}}$, 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/m³ and kinematic viscosity υ = 1.31 x 10^{-6} m²/s.

/20 1. A PVC pipe carries water from an upstream reservoir with constant water level of 70 m to an elevated tank located downstream. The water level in the elevated tank is 49 m. The PVC pipe has a Hazen-Williams 'C' factor of 132, an internal diameter of 1057 mm, and a length of 1,200 m.

a) Determine the fluid velocity in the PVC pipe.

b) Design guidelines require the fluid velocity in the pipe to be below 3 m/s to prevent pipe wall erosion. Is the fluid velocity in a) below 3 m/s? If not, determine the internal pipe diameter needed to produce a fluid velocity equal to or lower than 3 m/s?

/20 2. A pipe-pump system has a 3 km long pipe that draws water from an upstream reservoir and discharges it to a downstream reservoir. The upstream reservoir has a water level of 13 m, and the downstream reservoir has a water level of 68 m. The pipe has a high point at location A (1,000 m from the upstream reservoir) where the ground elevation is 55 m. The pipe has an internal diameter of 450 mm and a Hazen-Williams 'C' factor of 115. Two pumps are connected in parallel at the upstream reservoir. Each pump has a characteristic curve described by TDH = 80 - 10 Q^2, in which TDH is the total dynamic head of the pump (in metres) and Q is the pump discharge in cubic metres per second.

a) Estimate the total flow supplied by the two pumps in parallel.

b) Estimate the pressure head at location A. Is the pressure head at location A above or below the minimum pressure head of 28 m required at this location?

c) If the pressure head in b) is below the minimum of 28m, suggest 2 ways to increase the pressure head at location A so that it is above the minimum required.

/20 3. An elevated tank with a fixed water level of 67m supplies water to the distribution network shown in Figure 1. The network has 5 pipes with the following parameters: Length = 450 m, Hazen-Williams 'C' factor = 110, and Diameter = 305 mm. The 2 demand nodes in the network are at an elevation of 9 m. The demand at the 2 demand nodes are: Q_2 = 200 L/s and Q_3 = 50 L/s. A valve along pipe 3 (P3) is initially closed.

a) Determine the hydraulic grade line (HGL) value at nodes N2 and N3.

b) The valve along pipe 3 (P3) is opened gradually such that no transient pressures are produced. Will the pressure head at node N3 be higher or lower than in part a)? Describe the hydraulic changes in the network that account for the change in pressure head at N3. Be as specific as possible.

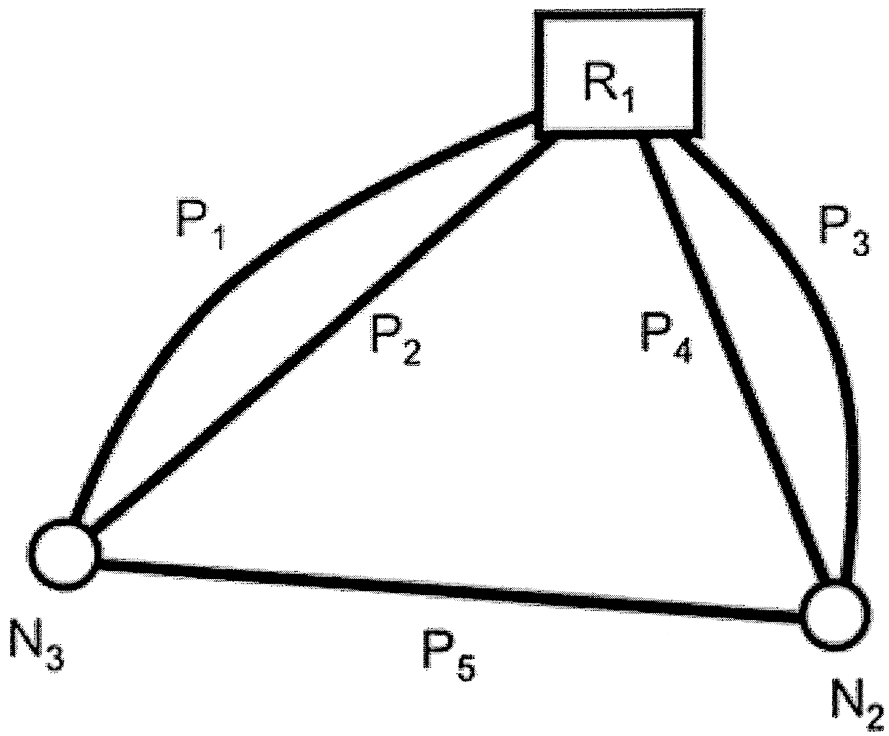

Figure 1. Network layout.

/20 4. 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 0.01.

a) Calculate the water depth in the road cross-section when the flow is 1 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?

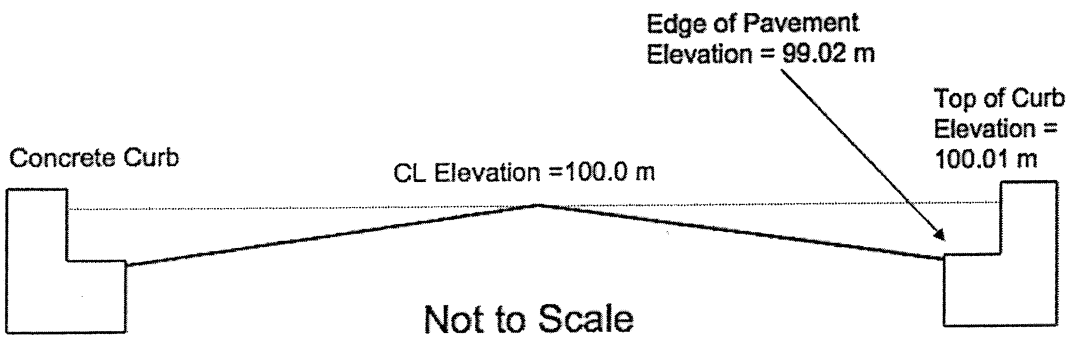

Figure 2. Roadway cross-section.

/20 5. A sluice gate is closed suddenly downstream of a rectangular channel. During a brief period of time after the closure of the gate, the upstream water surface profile at times t = 0, t = Δt, and t = Δt (indicated in Figure 3) are observed. Based on the appearance of the water surface profiles in Figure 3, discuss whether the kinematic wave model or the dynamic wave model would be more appropriate to describe the hydraulic conditions in the channel. Structure your answer in terms of the mathematical terms in one of these models as well as key concepts such as steady flow, unsteady flow, uniform flow, non-uniform flow, momentum, inertia, compressibility and any other relevant concepts.

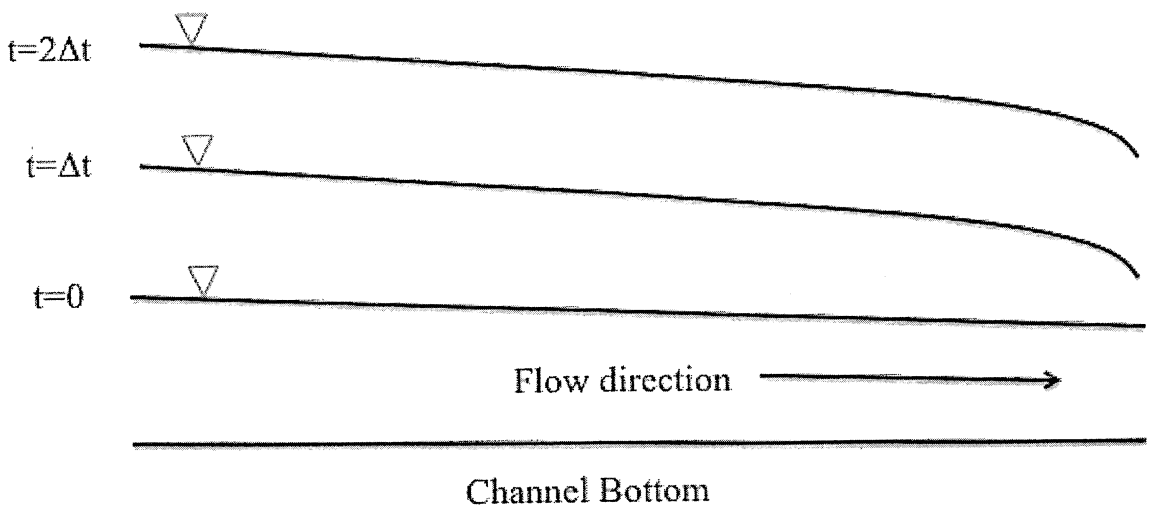

Figure 3. Water surface profile at times t = 0, t = Δt, and t = 2Δt in rectangular channel after sudden closure of sluice gate.

/20 6. A rectangular channel carries a flow of 3.0 m^3/s. The rectangular channel has a width of 11 m and sides of height 2.5 m. The Manning's 'n' for the channel is 0.015 and its longitudinal slope is 0.002.

a) Calculate the normal depth in the channel.

b) The channel leads to a broad-crested weir where flow measurements are taken and critical depth occurs. Calculate critical depth just upstream of the broad-crested weir.

c) Given your calculations in a) and b), are flow conditions well upstream of the broad-crested weir sub-critical or super-critical?

d) If you can, draw a diagram of specific energy and on this diagram show the progression from sub- or super-critical conditions to critical conditions between the upstream section and the broad-crested weir.