National Exams December 2015

07-Str-B11, 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: $\text{TDH} = H_s + H_f$, 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 $\rho = 1{,}000$ kg/m^3 and kinematic viscosity $\upsilon = 1.31 \times 10^{-6}$ m^2/s.

/20 1. Ten identical pipes connect an upstream reservoir A (water elevation 95 m) to a downstream reservoir B (water elevation 70 m). The elevations of the pipe nodes are given by dashed contour lines with the contour elevations indicated (in metres). Each pipe has a 250 mm diameter, is 200 m long and has a 'C' value of 130.

a) Determine the total flow through this pipe system.

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

c) Which branch conveys the highest flow: Branch P1-P2-P4-P5-P8 or Branch P3-P6-P7-P9? Why?

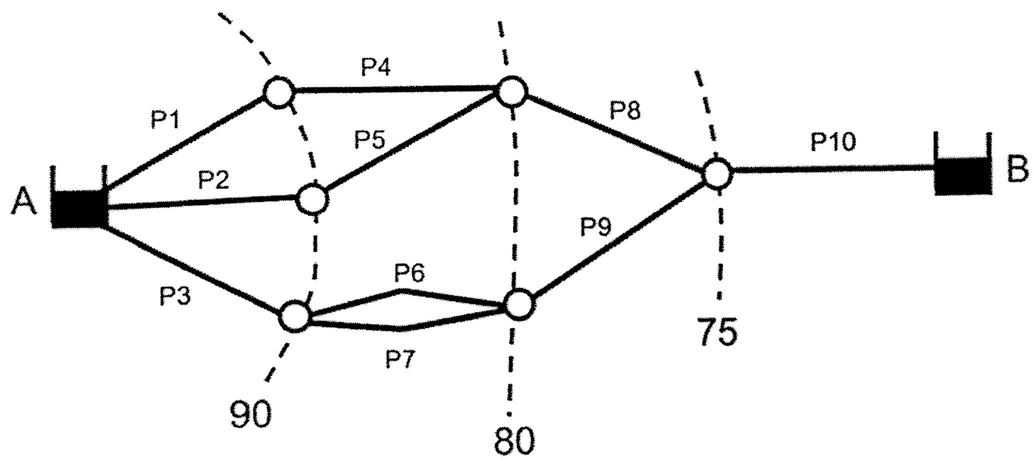


Figure 1. Network of pipes that carries flow from upstream reservoir A to downstream reservoir B.

/20 2. A transmission pipeline that conveys water from an upstream reservoir to a downstream reservoir is indicated below in Figure 2. 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 120, and an inner diameter of 450 mm. The upstream reservoir has a water level of 105 m. The valve discharge constant is Es = 0.45 $m^{5/2}/s$.

$$Q = \tau E_s \sqrt{H_{u/s} - H_{d/s}}$$

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

a) If the downstream head hB = 95 m and the valve is partially closed (τ-value is equal to 0.7), calculate the flow through the system.

b) The downstream head decreases to hB = 85 m. To maintain this constant flow calculated in part a), discuss whether the valve should be opened or closed further. Calculate the new τ-value to hold the flow constant at the value calculated in part a).

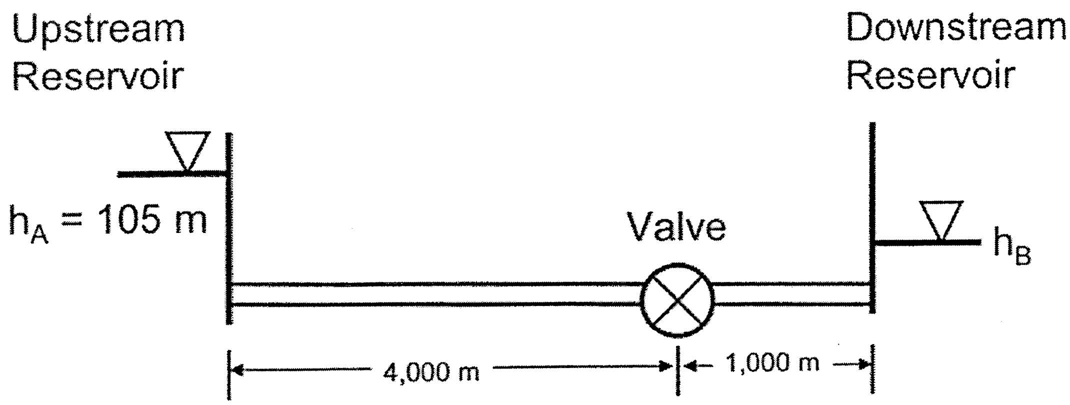


Figure 2. Schematic of water transmission system.

/20 3. A three-pipe network is indicated in the figure below. The pipes in the network have a diameter of 250 mm, a 'C' factor of 110, and a length of 500 m. The nodal demands are all 5 L/s. The source reservoir has a water level of 90 m. Calculate the flows in the pipes and the pressure heads at the nodes.

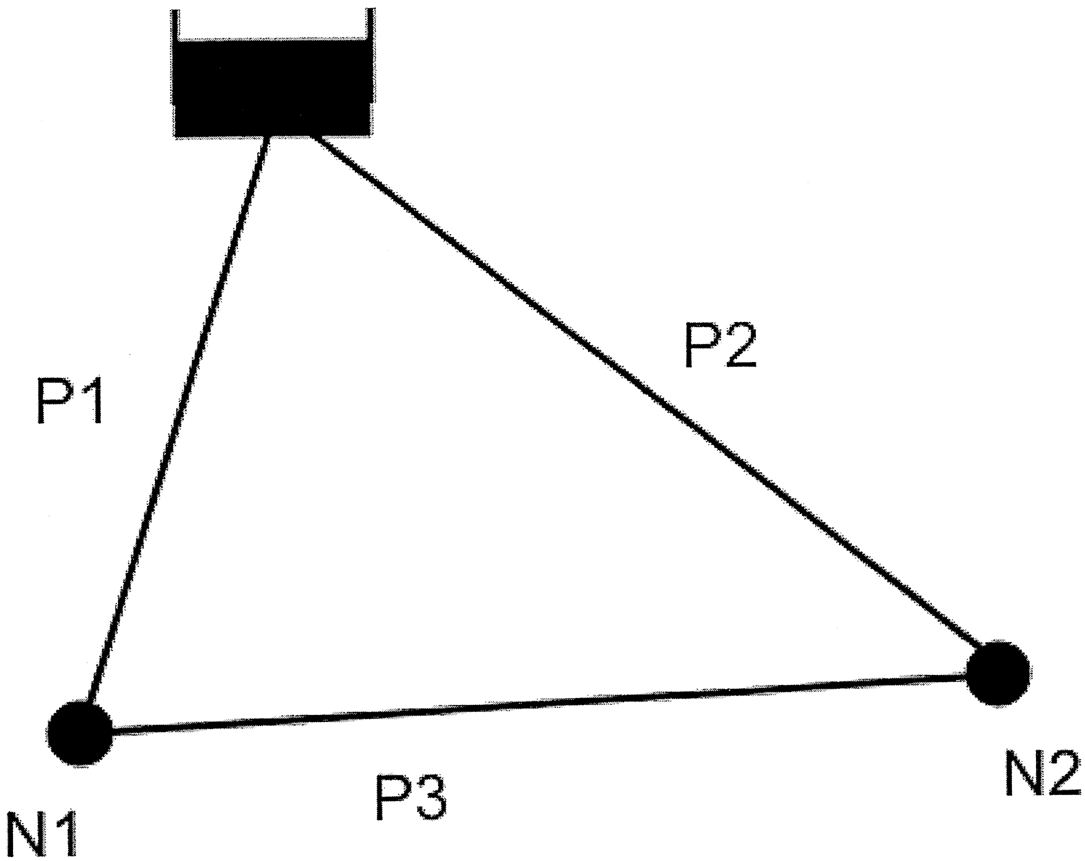


Figure 3. Schematic of water distribution system.

/20 4. Two elevated tanks supply water to a demand node with a valve at its outlet (Figure 4). The elevated tanks are cylindrical and have diameters of 5 m. The initial water level in Tank 1 is 96 m and the initial water level in Tank 2 is 89 m. The valve is half open and has a discharge coefficient of 0.10 $m^{5/2}/s$. The initial steady-state flow through the valve is 300 L/s. The valve discharges to the atmosphere. Both pipes have a Hazen-Williams 'C' factor of 110, an internal diameter of 250 mm, and a length of 300 m. Assuming quasi-steady conditions in the system, determine the pressure head at the demand node and the flow in the pipes in the first three time steps of the simulation. Use a time step of 10 seconds to carry out the quasi-steady state simulation.

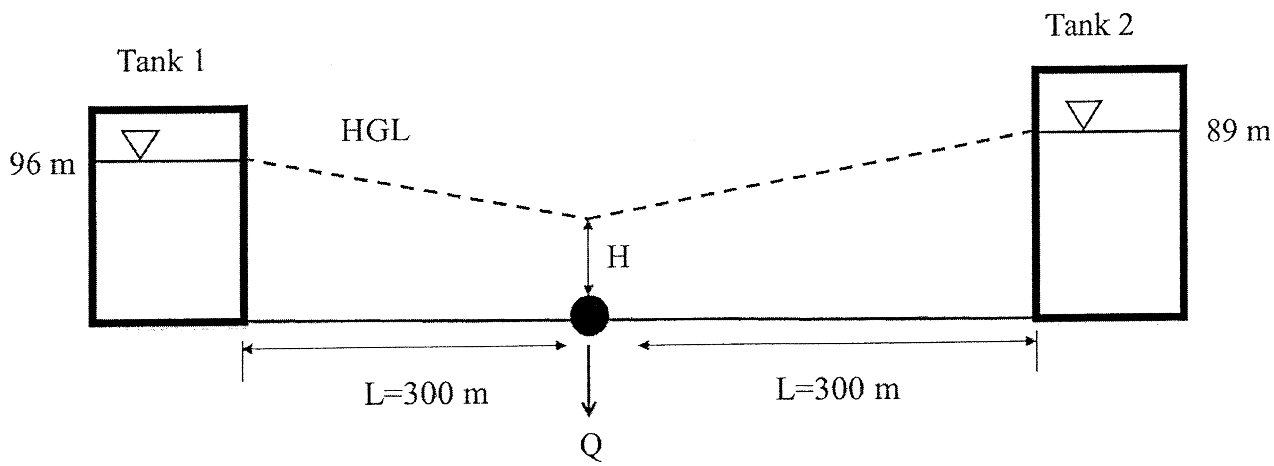


Figure 4. Water supply system.

/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 5) are observed. Based on the appearance of the water surface profiles in Figure 5, 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.

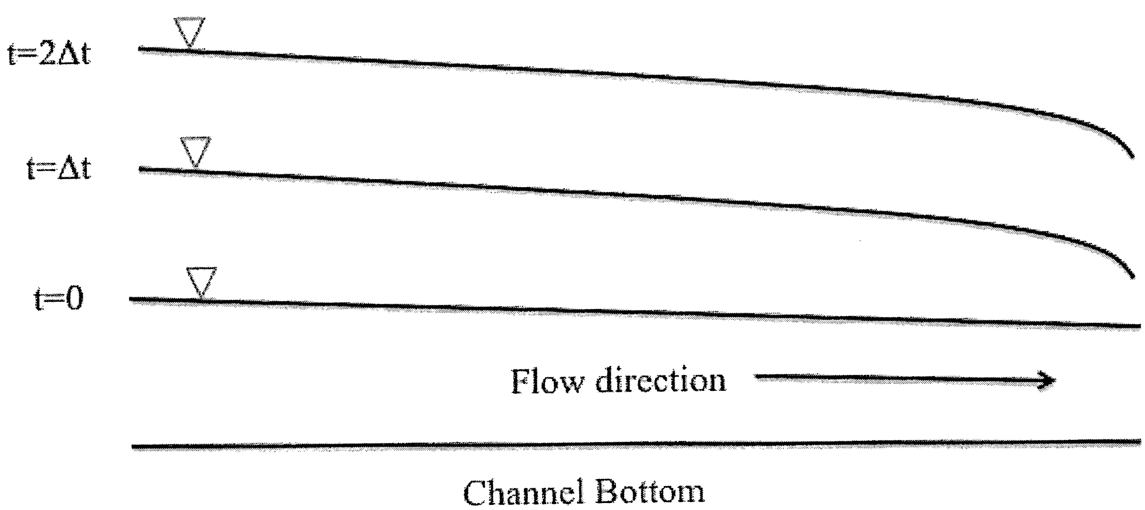
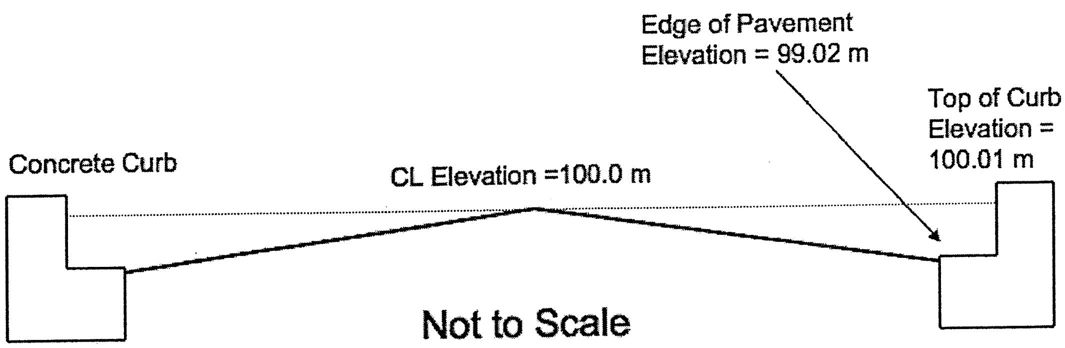


Figure 5. Water surface profile at times t = 0, t = Δt, and t = 2Δt in rectangular channel after sudden closure of sluice gate.

/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 0.01.

a) Calculate the water depth in the road cross-section when the flow is 0.8 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?



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Marking Scheme

1. 20 marks total (3 parts times 6 marks each - approximately)
2. 20 marks total (2 parts times 10 marks each)
3. 20 marks total (1 part - 20 marks)
4. 20 marks total (1 part – 20 marks)
5. 20 marks total (1 part – 20 marks)
6. 20 marks total (2 parts times 10 marks each)