The answers to all questions must be given on these question sheets, using the reverse side if you need to. No additional papers handed in by the candidate will be accepted or considered in the grading.

Name: _____ ____ _____ ___ Date: _____ __ _ ___

National Exams May 2016

98-Civ-A3, Municipal Engineering

3 hours duration

Notes:

1. **Candidates MUST answer Question 1, then any 3 out of the 4 remaining questions.**
   Only the first four questions answered will be graded.

2. **Answers to all questions must be given on this question sheet, using the facing (blank) side if necessary. No additional papers handed in by the candidate will be accepted or considered in the grading.**

3. Each question carries a maximum of 25 marks, for a total of 100. Try to arrange your time in accordance with the value of the question (hence slightly less than 2 minutes per mark).

4. Part marks will be given for incomplete responses or incorrect answers, provided that the method is correct, therefore show each step in the calculations clearly.

5. If doubt exists as to the interpretation of any question, the candidate is urged to include with their answer a clear statement of any assumptions made.

6. This is an open book exam.

7. Candidates may use one of two calculators, the Casio or Sharp approved models.

8. Please take care to give your answers clearly and logically. State any assumptions which you need to make, as well as any sources of information used which are not in the examination paper (for example, a table or page number in a textbook).

Question 1. YOU MUST ATTEMPT TO ANSWER THESE SHORT QUESTIONS
Take note of the number of marks assigned for each question, and answer accordingly.
(25 marks total)

a) A 250 m length of 50-year old water main of asbestos-cement (a-c) is to be replaced by a plastic pipe. This is because of a 30% drop in pressure from the original, and concern over asbestos in the water. In order not to disturb the original pipe, it is proposed that the new pipe will be placed inside the old one using trenchless technology techniques. At the same time, two open check-valves which were installed in the original pipe will be covered over by the new pipe material. The specification for the new pipe is that the headloss should be equal to or less than the original headloss. Would the new pipe be able to meet this specification? Important information is given in the table below. **(4 marks)**

	Old a-c pipe	**New plastic pipe**
Diameter (mm)	500	470
Effective Hazen-Williams coefficient	140	150
Check valve K value for $Kv^2/2g$	10	-
Flow (m^3/s)	0.2	0.2

b) Some old circular sanitary sewer pipes in a certain subdivision of a city were backing up because of an increase in the flow by 20% due to conversion of single dwellings into duplexes with a consequent increase in the population. The 400 mm diameter pipes were made of smooth concrete, steel trowelled, and the pipes that backed up were at the shallowest allowable slope of 0.002. A consultant recommended that the city replace those pipes with pipes of the same NOMINAL diameter, same material, and same Manning coefficient, but with a horseshoe cross-section. This way, the same trench could be used. Would this pipe really be able to solve the problem? **(5 marks)**

Horseshoe-shaped pipes have the following characteristics:
area = $0.913D^2$; wetted perimeter = 3.466D; hydraulic radius = 0.263D
where: D is the diameter.

Question 1, contd.

c) i. A 300 mm diameter smooth concrete sanitary sewer (Manning's "n" = 0.014) was designed to flow ⅔ full (in terms of depth). The intended slope was 0.002. Calculate the flow in the pipe (m^3/s). **(2 marks)**

ii. In fact, the pipe was actually laid at a slope of 0.0015 because during construction some hard rock was encountered. For the same flow as in the original design, what is the new depth of flow? **(2 marks)**

d) The correct spacing of stormwater inlets is crucial if flooding of the road is to be avoided. Describe in general terms how the spacing of the inlets would be different for two extreme cases: **(2 marks)**

- Case 1, the road is almost horizontal for several km

- Case 2, the road has a steep slope of 6 % for 1 km

Question 1, contd.

e) The rainfall intensity-duration-frequency relationship for a certain watershed may be obtained from the following equations:

frequency (years)	equation
2	$i = 1{,}780/(t + 13)$
5	$i = 2{,}460/(t + 16)$
10	$i = 2{,}820/(t + 20)$
25	$i = 4{,}320/(t + 27)$

where i is the rainfall intensity in mm/h, and t is the duration of the storm in minutes. If the time of concentration for the watershed is 20 minutes, the area is 80 acres (32.4 ha), and the watershed itself can be described as mainly single-family dwellings, which type of storm below would yield the higher flow to the storm sewer: **(4 marks)**

- 10 year, 15 minutes
- 5 year, 30 minutes

f) Centrifugal pumps:

i) Multiple pumps may be used in series or in parallel. Under what conditions would a designer choose pumps in series, and when in parallel? **(2 marks)**

ii) If two identical pumps are used, why would the head or the flow not be double that of one pump? Use a graph to help with your explanation. **(2 marks)**

iii) How should operators (or automatic controllers) take into account the efficiency curves of pumps when there are multiple pumps in a single system? **(2 marks)**

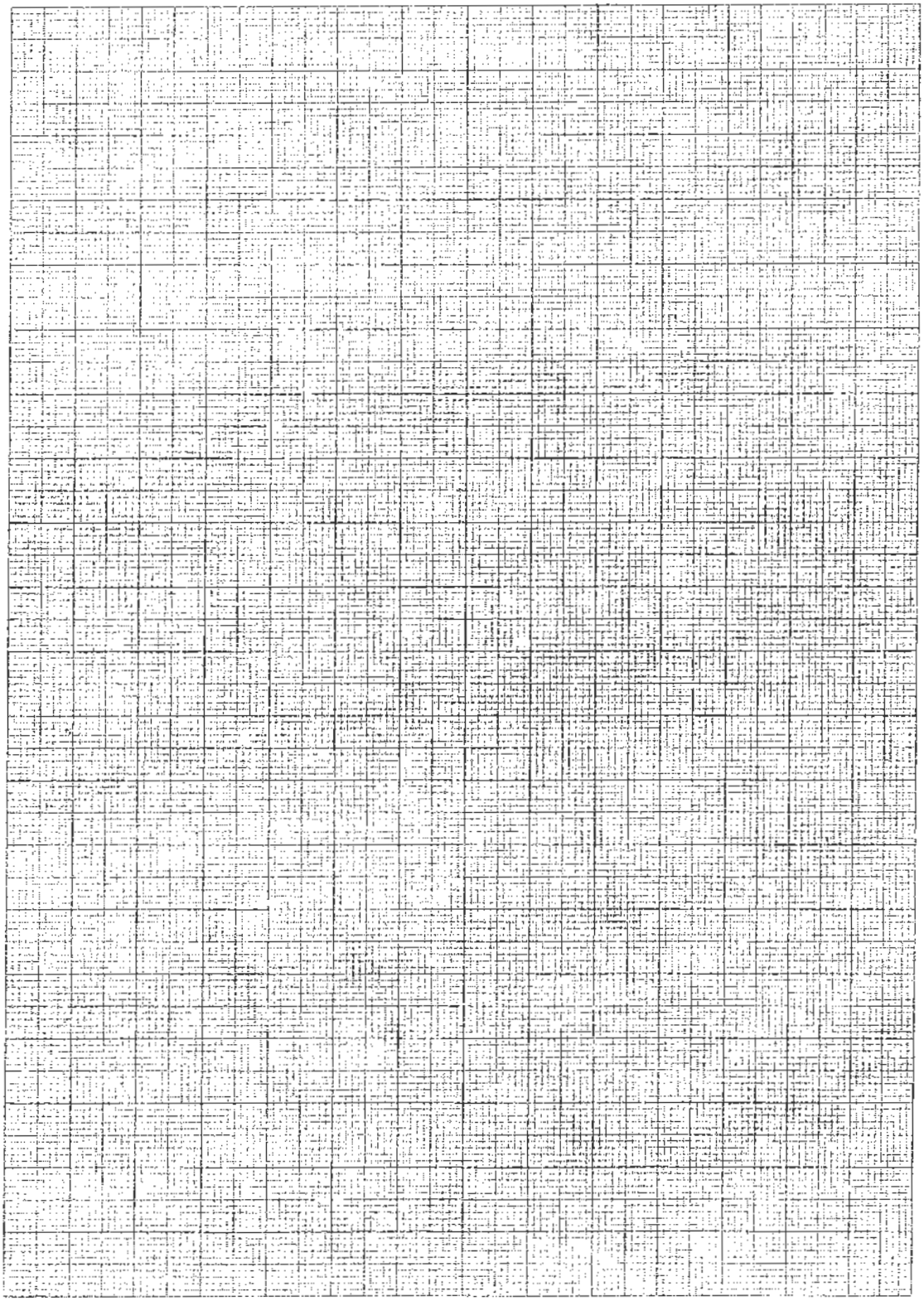
Question 2. Elevated storage. (25 marks)

You are required to design an elevated cylindrical storage tank to accommodate fluctuating flows ("service storage"), fire flows and emergency storage, for the water supply system for a small town in Ontario.

a) Service storage should be determined from the flows recorded over a 24-hour period. These are given in the table below for the maximum daily flow. Note that extra blank columns are provided if you need them for calculations. You may use the graph paper on the following page, or any other method which should be fully described, to determine the storage volume.

Time (h)	Flow (m^3/h)		
0 - 2	145		
2 - 4	205		
4 - 6	250		
6 - 8	315		
8 - 10	405		
10 - 12	490		
12 - 14	590		
14 - 16	400		
16 - 18	285		
18 - 20	195		
20 - 22	155		
22 - 24	165		

Volume required for service storage _____ m^3 **(15 marks)**



Question 2, contd.

b) For fire storage, the tank should hold enough water for an appropriate fire. You can use the following equation to calculate the fire flow, assuming that the per-capita water consumption is 500 L/d. **(3 marks)**

$$G = 3.86\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

where: G = flow (m^3/min)
P = population in thousands

For populations below 5,000, the fire is expected to last no more than 2 hours
Then up to 13,000 people, the time increases to 3 hours
Up to 17,000 people, the time increases to 4 hours
Above that, use 5 hours.

Volume for fire storage: ____ ____ m^3

c) For emergency storage use 0.25•(service storage + fire storage). **(2 marks)**

Volume for emergency storage: _____ m^3

d) Three standard sizes from a large manufacturer of storage tanks are available. Choose an appropriate one:

No	Capacity (m^3)	Head range (m)	Diameter (m)
1	1,900	11.3	15.2
2	2,300	11.0	17.0
3	2,800	11.8	18.3

Tank chosen: _____ **(1 mark)**

e) i. In addition to the storage function, elevated storage tanks serve an important purpose in a water distribution system. Explain briefly what it is. **(2 marks)**

ii. In what way can elevated storage tanks compromise the water quality? How can it be avoided? **(2 marks)**

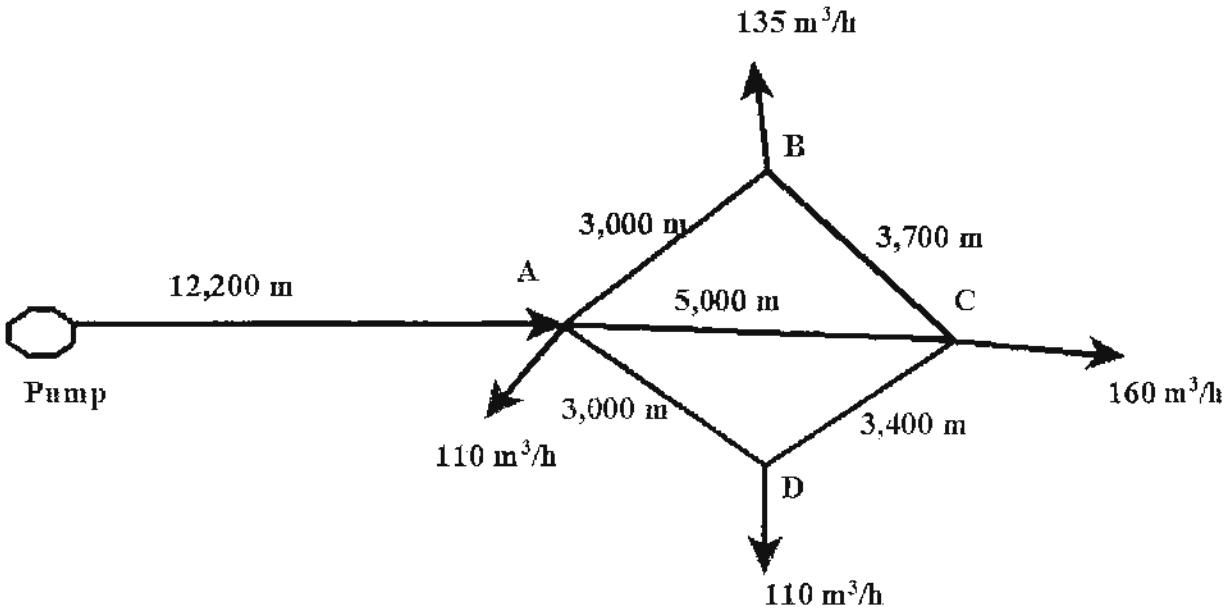
Question 3. Water distribution system analysis. (25 marks)

Four towns are supplied by a single water treatment plant. The water entry points are shown in the diagram below. The pumps chosen for the water treatment plant are capable of delivering the required flow at a pressure (head) at the plant of 650 kPa (66 m). You have been asked to verify whether the pressure at town C is sufficient, given that the critical fire at the town is at the entry point (node C), that the minimum pressure during a fire should be at least 140 kPa (12.3 m), and that the town is situated 30 m higher than the water treatment plant.

All pipes are the same material and have a Hazen-Williams coefficient of 130.
Pipe diameters:

Water treatment plant (pump) to A: 650 mm
AB, AC, AD: 450 mm
BC, CD: 300 mm

You may use the Hardy-Cross method, or any other method; if using Hardy-Cross, determine flows and any required headlosses after 2 iterations.



Calculation page for Question 3.

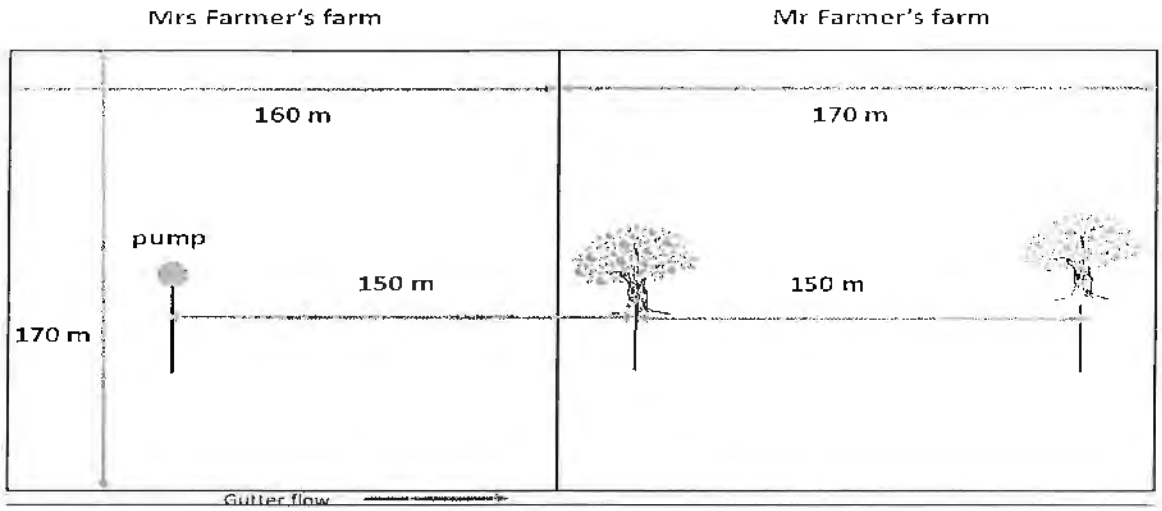
Iteration 1.

Iteration 2

Pressure at node C: ____ ____ kPa

Question 4. Groundwater and stormwater runoff. (25 marks)

Mr Farmer and Mrs Farmer own two adjacent farms. Mr Farmer has an orange orchard. His trees rely on groundwater for much of their moisture. The roots prefer a water depth of 3 m or less, but the trees can survive if the depth is 5 m; this is the limit. The current water table is 1 m below the surface, and the aquifer consists of silty sand, with a hydraulic conductivity of 10^{-5} m/s. It is 12 m thick. Mrs Farmer will be pumping water from the same aquifer (see Part b). A plan of the two farms is given below (not to scale).



a) Sketch a section through the aquifer showing the key elements (**2 marks**)

b) Mrs Farmer wants to irrigate her land by drip irrigation (the best sustainable method), and she also wants to maintain her friendship with Mr Farmer. What steady-state pumping can she maintain? (**8 marks**)

Question 4, contd.

c) The next concern of Mr Farmer is whether his aquifer will be replenished by rainfall, and will not have to rely on groundwater flow from a great distance. **(15 marks)**

It may not be realistic, but assume the following:

- The aquifer is replenished only by rain falling over the two farms.
- Mrs Farmer irrigates once a week for 12 hours
- Most of the rainfall is absorbed by the soil and enters the aquifer; the runoff coefficient is 0.1.
- The total annual rainfall is 3 x rainfall of the single critical storm.
- The critical duration of the storm is the time it takes the runoff to flow from the boundary of the farms to a storm gutter which drains water away from the aquifer.
- The slope of the land is 1% in the 170 m direction towards the gutter.
- The intensity-duration equation is:

$$i = \frac{5{,}230}{t + 30}$$

where i = intensity (mm/h)
t = time (minutes)

Question 5. Storm sewer design. (25 marks)

a) A storm sewer system was designed for a town in Southern Ontario. The original design was based on a storm frequency of once in 10 years. The rainfall intensity equation for this case is:

$i = 2{,}820/(t + 16)$, where i is in mm/h and t is in min.

The watershed had an average slope of 2%, and the distance of the farthest point of the watershed to the storm sewer inlet was 183 m. When the system was built, roof drains from the houses were fed into the storm sewer, as did the runoff from the highways, so the watershed could be considered as partly bare soil, partly paved. As a result of climate change, storms which were expected to occur once in 10 years are now forecast to be the equivalent of once every 25 years. For this case,

$i = 4{,}320/(t + 27)$

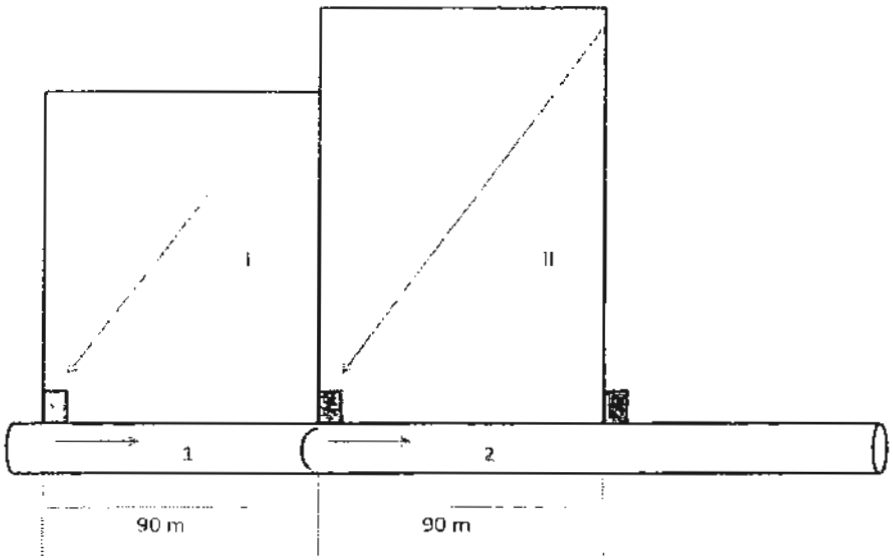
The city responded by requiring houses to redirect their roof drains to gardens, and the highway runoff to swales, thus changing the nature of the watershed to the equivalent of a poor grass surface. Would these measures be sufficient so that the existing storm sewer system would not be overloaded every 10 years? Justify your answer with calculations. **(10 marks)**

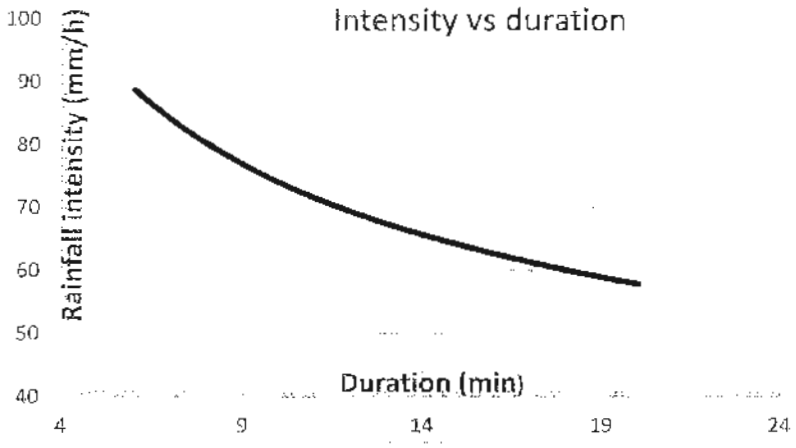
NOTE: You will need to use additional information from one or more appropriate sources. Give details here:

Description:	
Source:	

Question 5. (contd.)

b) The diagram below shows two small watersheds (I and II) feeding into a reinforced concrete storm sewer. Details of each watershed are given in the table on the next page. Water from each watershed flows into a catch-basin at the upstream end of the sewer, as shown. Rainfall intensity vs duration is given in the graph. First, calculate the flow in each pipe for the critical storm(s). Then determine the diameters of the two sewers and the flow velocities, given that the slope of each sewer is 0.0017, the length is 100 m, and Manning's "n" is 0.013. Furthermore, the pipes should flow at approximately ⅔ full (d/D) or less at the calculated flows (constant "n"). Use only commercially-available pipe sizes (mm): 375, 450, 525, 600, 675, 750. **(15 marks)**





Question 5. (contd.)

Parameter	Watershed I	Watershed II
Overland flow time (min)	8	14
Runoff coefficient	0.6	0.4
Area (m^2)	9,500	12,200

Sewer pipe	Manning's "n"	Slope	Length (m)	Flow (m^3/min)	Diameter (mm)	Depth of flow (mm)	Velocity (m/s)
1	0.013	0.0017	100				
2	0.013	0.0017	100				