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 December 2014

98-Civ-A3, Municipal Engineering

3 hours duration

Notes:

1. **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.**
2. 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).
3. Candidates should answer any 4 out of 5 questions. **DO NOT ANSWER FIVE QUESTIONS. ONLY THE FIRST FOUR QUESTIONS ANSWERED WILL BE GRADED.**
4. 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.
5. This is an open book exam.
6. Candidates may use one of two calculators, the Casio or Sharp approved models.
7. 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. **Short questions. Take note of the number of marks assigned for each question, and answer accordingly.** (25 marks total)

a) The population statistics for Vaughan, Ontario, are given in the table below.

Year	Population
1971	15,873
1981	29,674
1991	111,359
1996	132,549
2001	182,022
2006	238,866
2011	288,301

i. Plot a graph of the raw data on the graph sheet below. (2 marks)

ii) Fit any two mathematical models to the data, and suggest which one is the best. Give reasons for your choice. If necessary, you may assume that the maximum population will be capped by zoning regulations at 375,000. (3 marks)

Question 1, continued.

iii) If total water consumption for Vaughan in 2011, including all sectors of the population, is the Ontario average of 490 L/capita-day, but if over the next 20 years this per capita consumption figure will be cut by 15% due to the use of water-saving devices and leakage prevention, estimate the TOTAL daily water consumption (m^3/d) for Vaughan in 2026, using the best model developed in Part (ii) above. (3 marks)

b) A municipal campsite has two potential sources from which to pump groundwater for the community. The total steady-state flow required is 4.5 m^3/day. The aquifer at site 1 is unconfined, whereas the aquifer at site 2 is confined, with a thickness of 13 m. The depth of the lowest impervious stratum is 17 m.

Additional information:

Permeability	0.04 $m^3/d\text{-}m^2$
Allowable drawdown at observation well 1 at 150 m (m)	1.5 m
Allowable drawdown at observation well 2 at 500 m (m)	0.15 m

Which site would be preferable to meet the water demand? (4 marks)

Question 1, continued.

c) When municipalities experience rapid and major population expansion, they have the choice of linking to an existing centralized wastewater treatment plant, or using a decentralized (i.e. new) plant for that new sector alone. In the table below, give 4 advantages and 4 disadvantages of using the decentralized system (4 marks).

Advantages	Disadvantages

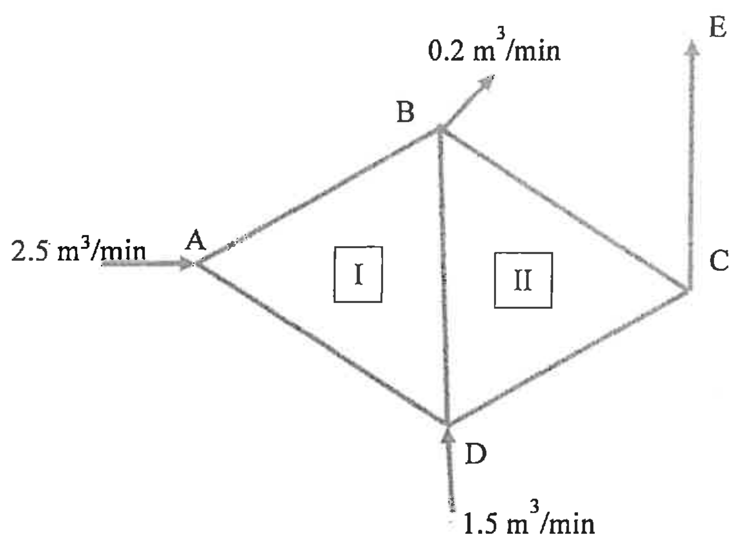
d) A trenchless technology is proposed to replace an old sewer pipe which is not only leaking, but is surcharging under peak conditions (0.30 m^3/s). The slope is 0.15 m/m. The effective Manning coefficient (n) of the old pipe is 0.017; for the new pipe it will be 0.011. The original diameter of the old pipe was 300 mm; inserting the new pipe will reduce it to 270 mm. Will the surcharging be avoided? (4 marks)

Question 1, continued.

e) A pump is to be installed at a water treatment plant (at sea level) which is 6.2 m above the top water level of the water source. The intake pipe is 200 mm in diameter, 30 m long, and has a Hazen-Williams coefficient of 100. Minor headlosses (including velocity head) through the system are 0.1 m. The temperature of the water is 10°C, resulting in a vapour pressure of 1.2 KPa (or 0.12 m). The NPSH required for the pump is 3 m. Will this pump operate in a satisfactory manner if the flow required is 0.06 m^3/s? If not, what problem(s) would be expected? (5 marks).

Question 2. Water distribution systems. (25 marks)

A water distribution system is shown below. All pipes are the same length (300 m), have the same diameter (305 mm) and have a Hazen-Williams coefficient of 110. The looped system (triangles) are all at the same ground level, but node E is 10 m higher than node C. Determine the flow (in m^3/min) and pressure at point E (in KPa), if the pressure at point A is 45 m of water (441 KPa). Use the Hardy-Cross method (2 iterations) for the loop calculations; a table to assist you is provided below. You may neglect minor losses.



Iteration 1.

Loop	Line	Flow (m^3/min)				
I	AB					
	BD					
	DA					
II	BC					
	CD					
	DB					

Question 2, contd.

Iteration 2.

Loop	Line	Flow (m^3/min)				
I	AB					
	BD					
	DA					
II	BC					
	CD					
	DB					

Flow at point E (m^3/min) ______________

Pressure at point E (KPa) ______________

Question 3. Storage. (25 marks)

(a) Water storage tanks are common components for water supply systems. Give 3 benefits of having storage tanks in addition to their role in minimizing the need for pumps to operate at various flows during the day. (3 marks)

(b) The hourly consumption rates on the peak demand day for a water supply system are given in the table below. Draw a graph (on the next page) showing hourly variation in water consumption. Also plot the cumulative consumption vs. time of day. (5 marks)

Time	Water consumption (ML/d)		Time	Water consumption (ML/d)	
12 am	0		1 pm	12.75	
1	4.54		2	10.30	
2	4.09		3	10.30	
3	4.09		4	9.08	
4	4.54		5	9.99	
5	5.90		6	10.90	
6	7.36		7	13.17	
7	9.81		8	11.81	
8	13.24		9	11.36	
9	15.70		10	8.16	
10	14.72		11	6.81	
11	13.24		12 am	4.54	
12 pm	10.30				

(c) Find the effective (or service) storage (in ML (10^6L)) and the pumping rate (in ML/d) that is required to equalize the fluctuations in demand, if the water is pumped

(i) at a constant rate for 24 hours (5 marks)

(ii) at a constant rate between 4 a.m. and 8 p.m. (6 marks)

(d) What are the advantages as well as the disadvantages of operating in mode (ii) above (i.e. from 4 a.m. and 8 p.m.)? (4 marks)

Advantages	Disadvantages

(d) If storage tanks are not operated properly, several problems may arise. Describe two such problems. (2 marks)

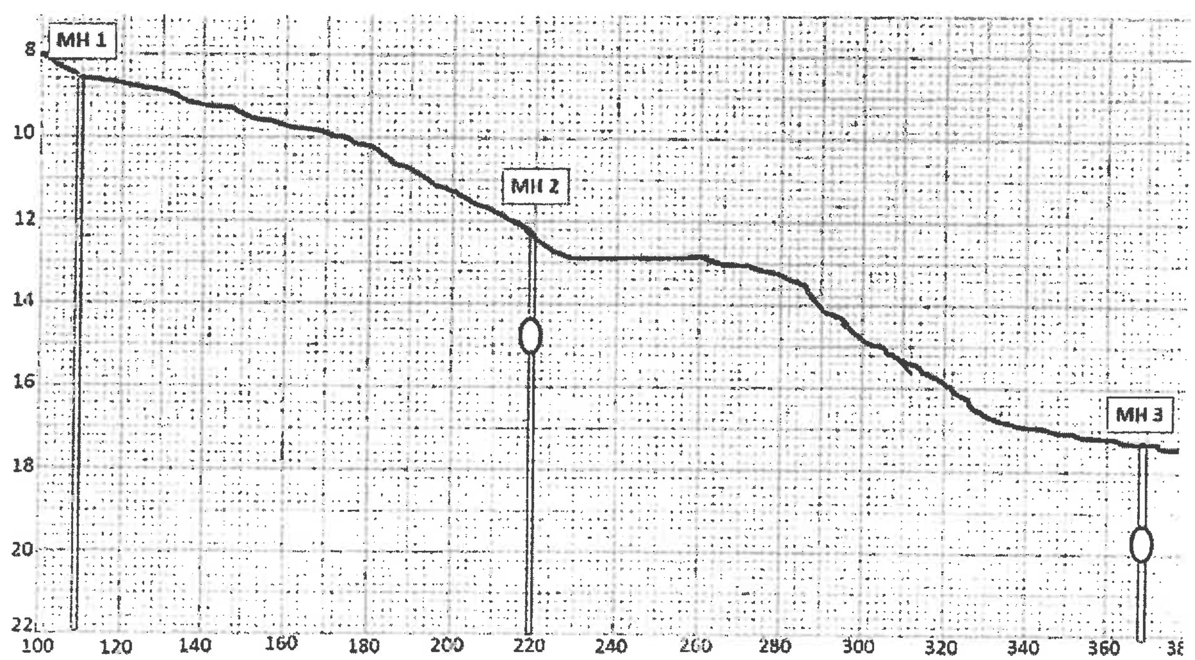
Question 4. Sanitary sewer design. (25 marks)

You are required to design, and to show their position on the diagram below, three collector sanitary sewer pipes, and complete the design information on the table on the following page. The pipes have the following common characteristics:

- Infiltration 100 m^3/d-km of sewer. Design for the total infiltration entering the UPPER manhole of each pipe.
- Manning "n" = 0.013
- Available commercial pipe diameters (m): 0.15, 0.20, 0.25, 0.31, 0.38, 0.46, 0.51
- Pipes should flow ⅔ full (i.e. depth/Diameter, d/D = 0.667) or less, including infiltration (assume variable Manning "n" coefficient)
- Maximum velocity = 4 m/s; minimum velocity = 0.6 m/s (both for pipe flowing full)
- Minimum depth of cover over the crown of the pipe = 2 m (you can neglect pipe thickness)

The average daily sanitary sewage flow of 550 m^3/h (or 0.153 m^3/s) enters pipe A, which is located between MH 1 and MH 2.
Pipe B joins MH 2 and MH 3, and carries the flow from pipe A, plus infiltration, plus 300 m^3/h from the sewer pipe shown connecting to MH 2.
Pipe C joins MH 3 to MH 4 (not shown), is 130 m long, and carries the total flow from pipe B, plus infiltration, plus 350 m^3/h from the sewer pipe shown connecting to MH 3. The ground is essentially horizontal for the entire length of pipe C.

Your design need not be optimized, however the grading will take into account efforts to minimize excavation and pipe diameter. The table also allows for comments on the type of manhole used, or any other special features of the design.



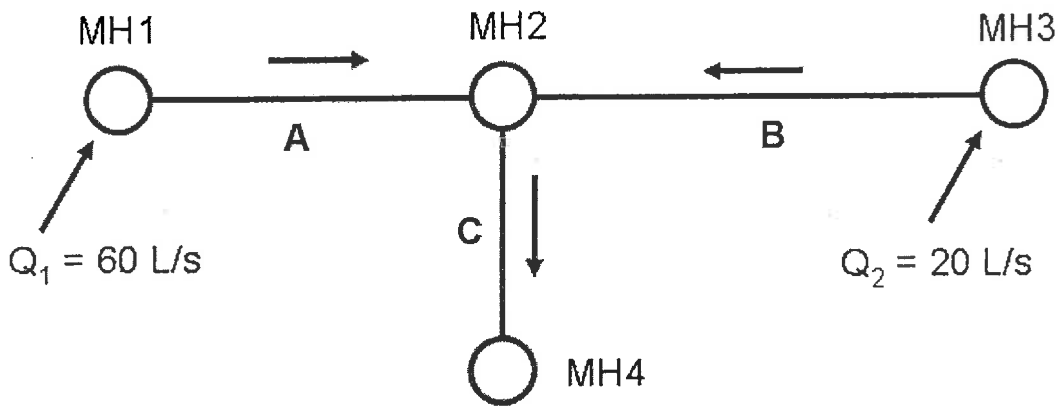
All dimensions in m.

Design information

Pipe	A	B	C
Design flow, including infiltration (m^3/s)			
Diameter (m)			
Length (m)			130
Elevation of upstream crown (m)			
Elevation of downstream crown (m)			
Slope (decimal fraction)			
Flow full (m^3/s)			
Velocity at design flow (m/s)			
depth/Diameter ratio (d/D)			
Comments			

Question 5. **Storm sewer design.** (25 marks).

A preliminary design of the storm sewer system below is to be conducted. The pipes should flow full or slightly below at the design flow, if possible. All pipes must be self-cleansing at the design flow, and the selected slopes must not be less than the minimum acceptable for construction.



Important information:

- All pipes are made of concrete with a Manning coefficient of 0.015 under full flow conditions.
- Assume a minimum invert drop of 0.05 m across manhole 2 (MH2)
- Assume a minimum cover requirement of 2.5 m throughout the entire system.
- Commercial pipe sizes (internal diameters) that are available include the following: 0.200, 0.225, 0.250, 0.310, 0.380, 0.460, 0.530 m.

Local pipe details and ground elevations are provided in the summary table (next page). Summarize your design in this table.

NOTE: In conducting your design, attempt to minimize excavation. Do not fully optimize your design, even though you may see opportunities to do so. Provide comments to indicate where you think improvements can be made and how you think you could attempt to improve your design.

There are 29 open cells, numbered 1 to 29, in the table; a correct answer in each cell is worth 1 mark (maximum 25 marks), so you don't need to complete the table to obtain full marks. Some of the answers will be easier to give than others. Optimize your chances for high marks! When doing your calculations, please refer to each cell to assist in grading.

SUMMARY OF SEWER DESIGN

	Pipe A	Pipe B	Pipe C
Upper manhole	MH1	MH3	MH2
Lower manhole	MH2	MH2	MH4
Upper manhole ground elevation (m)	10.70	10.85	10.25
Lower manhole ground elevation (m)	10.25	10.25	9.35
Length (m)	80	95	110
Slope (m/m)	1	2	3
Diameter (mm)	4	5	6
Q_{full} (m^3/s)	7	8	9
V_{full} (m/s)	10	11	12
Design flow (m^3/s)	0.06	0.02	13
V at design flow (m/s)	14	15	16
depth/Diameter ratio (d/D) at design flow	17	18	19
Invert at upper manhole (m)	20	21	22
Invert at lower manhole (m)	23	24	25
Cover at upper manhole (m)	2.5	2.5	26
Cover at lower manhole (m)	27	28	29