Name:_______________________________ Date:____________________

National Exams May 2013

98-Civ-A3, Municipal Engineering

3 hours duration

Notes:

1. **The 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. Four questions should be answered. Candidates **MUST** answer Question 1. Then they may answer any 3 out of the remaining 4 questions.
DO NOT ANSWER FIVE QUESTIONS.

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).

Marks

Question 1. Short questions. Take note of the number of marks assigned for each question, and answer accordingly. (25 marks total)

3 a) Source water protection is part of the overall strategy to deliver safe drinking water to municipalities over an extended period. Give 3 such measures which can be taken for source protection, and explain very briefly, for each one, how these measures would work (½ mark each measure or explanation).

Measures taken	**How would they work**

2 b) Pumping tests for wells can be performed under steady-state conditions, or under non-steady-state conditions. Give two reasons why non-steady-state conditions might be preferred (½ mark each). Could there be a way to minimize the negative impact of any of these disadvantages of steady-state testing (1 mark)?

Reasons why non-steady-state conditions are preferred:
How to minimize the negative impact of steady-state testing:

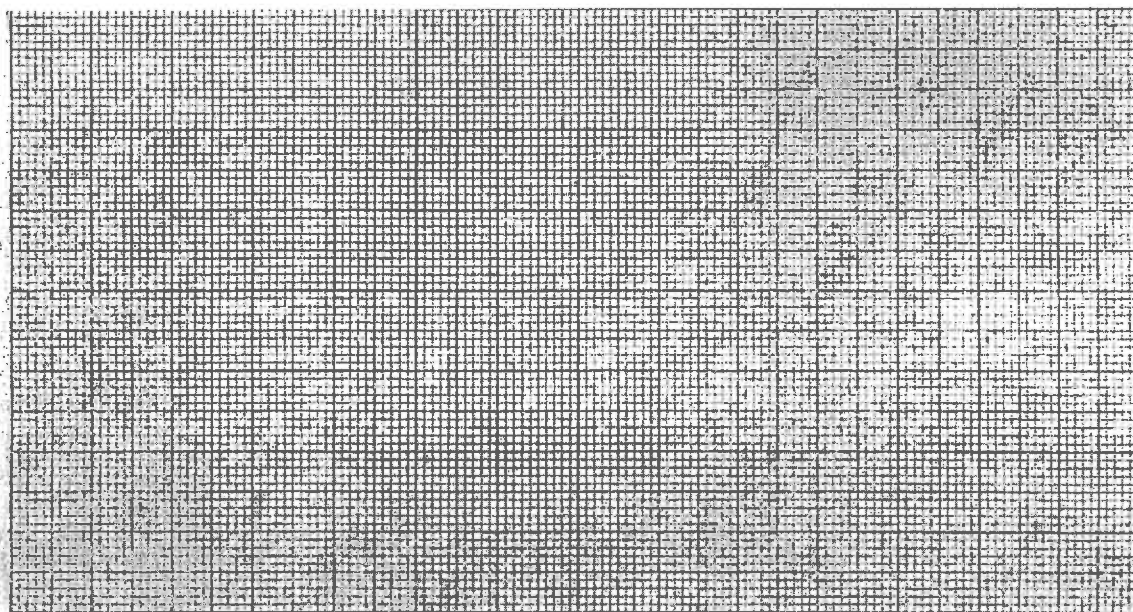
2 c) What is the reason for specifying the maximum allowable velocity in sewers? Why is this velocity lower in storm sewers?

Reason:	
Why lower in storm sewers?	

Marks

4 d) Population statistics are given in the table below for a town which for various reasons has been limited to a saturation population of approximately 135,000. Using graphical approximation as well as a method based on calculations, estimate the population in the year 2030.

Year	1910	1930	1950	1970	1990	2010
Pop. in thousands	60	82	100	115	124	128



Marks

e) Insurance companies, not town planners or politicians, are often the organisations which determine the fire flow requirements for buildings, however some municipalities or local authorities have also developed their own codes. Using any of the abovementioned codes, determine the fire flow, in m^3/min, needed to protect a 2-storey wood-frame home, each storey having a floor area of 250 m^2, situated near the middle of a large property. Give the source of your equation and other factors involved in the calculation, and list your assumptions.

Marks		
1	Source or name of the code	
2	Assumptions (½ mark for each)	
3	Calculations	

Marks

f) It is planned to discharge wastewater effluent from a primary municipal wastewater treatment plant in a temperate climate area into a slow-flowing river (~ 0.1 m/s). Considering only average conditions for wastewater flow and quality, as well as river flow, the following information is available:

- Flow of wastewater = 0.04 X flow of the river upstream of the plant
- <u>For the wastewater effluent</u>:
  BOD_5 = 50 mg/L;
  Dissolved oxygen (DO) = 0 mg/L
- <u>For the river, upstream of the discharge</u>:
  BOD_5 = 2 mg/L
  DO = 8.2 mg/L

Based on requirements of the river fauna, regulations for that area state that the minimum dissolved oxygen in the river should not drop below 6 mg/L.

3 i. Is it likely that this discharge would violate the regulations?

1 ii. What other factors should be considered when assessing whether this wastewater effluent could reduce the DO in the river below acceptable levels?

Marks

4 g) Calculations have shown that the load on a 350 mm nominal diameter buried reinforced concrete pipe will not exceed 60 kN/m. With a factor of safety of at least 1.5 for the bearing capacity, give two potential combinations of bedding class and pipe type (ASTM specification) that would be suitable.

Marks

Question 2. Water pipes: Hydraulics of flow (under pressure or just full); and operational problems and solutions. (25 marks total)

2 a) The Hazen-Williams formula is widely used to calculate the headlosses in pipes carrying water under pressure. Why is it used in preference to Darcy-Weisbach?

2 b) What is the effect of water temperature on the headloss in water distribution systems and supply pipes?

4 c) A section of a town which was constructed very rapidly, such that all the water distribution pipes are considered to be the same age, used coated cast iron pipes. The Hazen-Williams C value was expected to decrease by 1 unit each year of operation. Since the pumping system and reservoirs delivered a constant pressure, the flow available to residents also decreased each year. If a 20% decrease in flow was tolerable, after how many years would the town have to replace or reline its pipes?

Marks

d) The city referred to in Part (c) above has reached the point where flows are no longer adequate. Briefly describe the solutions which are available, highlighting the advantages and disadvantages of each solution (½ mark per point made).

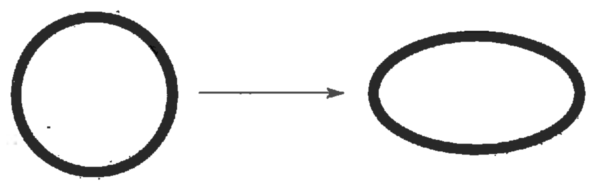
6

Marks

e) A circular PVC pipe (Manning's coefficient 0.011) has been installed to carry runoff from a highway to a creek 300 m away. The entry into the pipe was via a vertical shaft, 1.5 m deep and 1 m in diameter. The peak flow from the highway was determined to be 5.4 m^3/min, and the slope of the ground and the pipe beneath it was 0.0072 m/m.

3 i. Determine the diameter of the pipe, if it is meant to flow full under these conditions, but not under pressure.

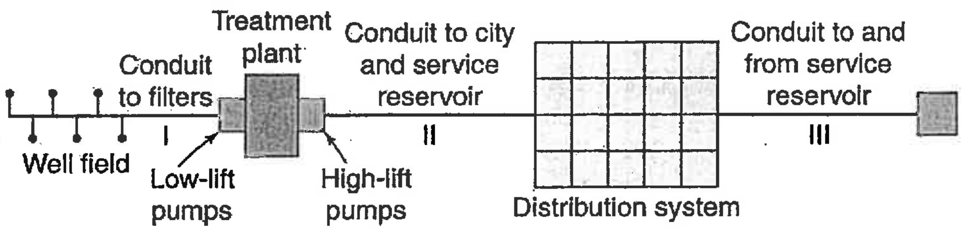
8 ii. The pipe which was selected was buried under 2 m of heavy, clayey soil, to avoid freezing, but the unexpected consequence was that the pipe assumed an oblong cross-section, as shown below, and the effective area for flow decreased by 20%. For the same flow (5.4 m^3/min), is it possible that the stormwater would backup through the shaft and flood the highway? Justify your answer with appropriate calculations.



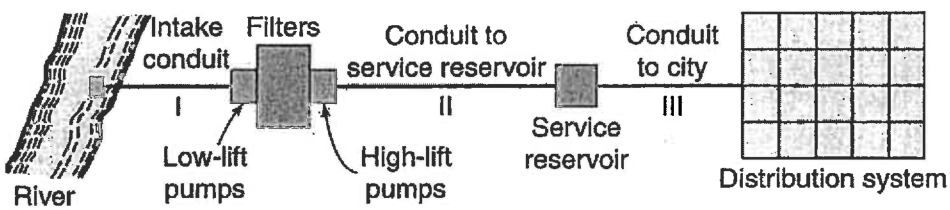
Question 3. Analysis of component systems. (25 marks total)

Two scenarios for water supply to a city, shown in the figure below and described in the table, are considered:

A



B



Structure	Purpose
Conduit I	Conveys raw water from source to water treatment plant (WTP)
Conduit II	Conveys treated water from HLP to the load centre
Conduit III	Conveys treated water from reservoir to load centre
Low-lift pumps (LLP)	Pumps raw water from source to WTP
High-lift pumps (HLP)	Pumps treated water from WTP to load centre and to reservoir

The client has supplied the following information:

- Future population = 170,000
- Average water consumption = 300 L/cap-d
- Maximum daily flow = 1.7 x average daily flow
- Maximum hourly flow = 3 x average daily flow
- Fire flow = 700 L/s
- Emergency/maintenance flow = 0.25 x fire flow
- The pumping stations for both LLP and HLP will each contain four pumps, of which one will be a reserve pump, which operates only if one pump fails or is being maintained. In addition, each pumping station will have a standby (diesel-operated) pump capable of supplying the maximum day flow in the event of a power failure.
- The reservoir balances ALL peaks due to low or high flows, in excess of maximum day flow, including fire and emergency/maintenance

If you need to make any other assumptions, list them here:

Calculate the capacities of the component structures for two scenarios:

Scenario A: Well field → conduit I → LLP → WTP → HLP → conduit II → load centre → conduit III ↔ reservoir

Scenario B: River → conduit I → LLP → WTP → HLP → conduit II → reservoir → conduit III → load centre

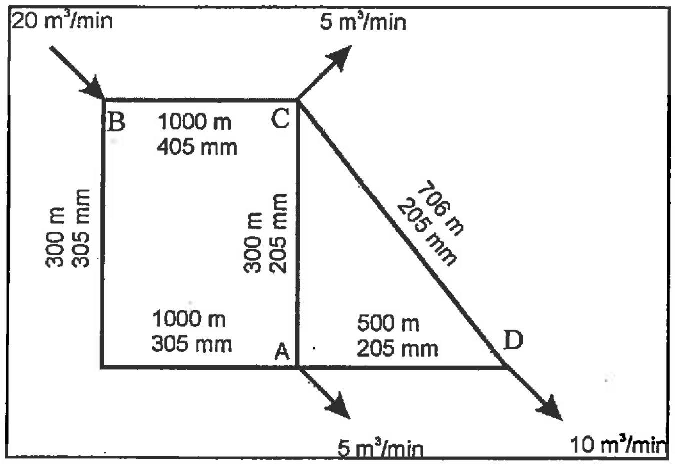
Complete the following table. All flows/capacities should be in m^3/s:

Component	Required capacity (description)	Scenario (a) (m^3/s)	Scenario (b) (m^3/s)
Lake			
Conduit I			
Conduit II			
Conduit III			
LLP (total)			
HLP (total)			
Standby pump			
WTP			

Source of figure: Shammas, N.K. and Wang, L.K. Water Supply and Wastewater Removal. 3rd ed. Wiley, 2011.

Question 4. Analysis of water distribution systems. (25 marks total)

In the pipe system shown below, assuming that all pipes have a Hazen-Williams coefficient of 100 and the pressure at B is 45 m of water, find the flow-rates in all pipes (in m^3/min) and the pressure at point A (in m), using the Hardy-Cross method. Neglect minor losses, perform only 2 iterations, use the initial estimates as given, show your final flows on the diagram below, and be sure to complete the two iteration tables below.
[Note: You may use a different method of analysis. In this case show your calculations on the reverse sides (blank) of the pages]



Iteration 1.

Loop	Line	Flow (m^3/min)	D (m)	L (m)		
I	BC	13	0.405			
	CA	3	0.205			
	AB		0.305			
II	CD		0.205			
	DA		0.205			
	AC		0.205			

Iteration 2.

Loop	Line	Flow (m^3/min)	D (m)	L (m)		
I	BC		0.405			
	CA		0.205			
	AB		0.305			
II	CD		0.205			
	DA		0.205			
	AC		0.205			

Pressure at A: ___________ m

Marks

Question 5. Storm water systems. (25 marks total)

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

$i = 1{,}520/(t + 13)$, 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,

$i = 1{,}700/(t + 10)$

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.

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

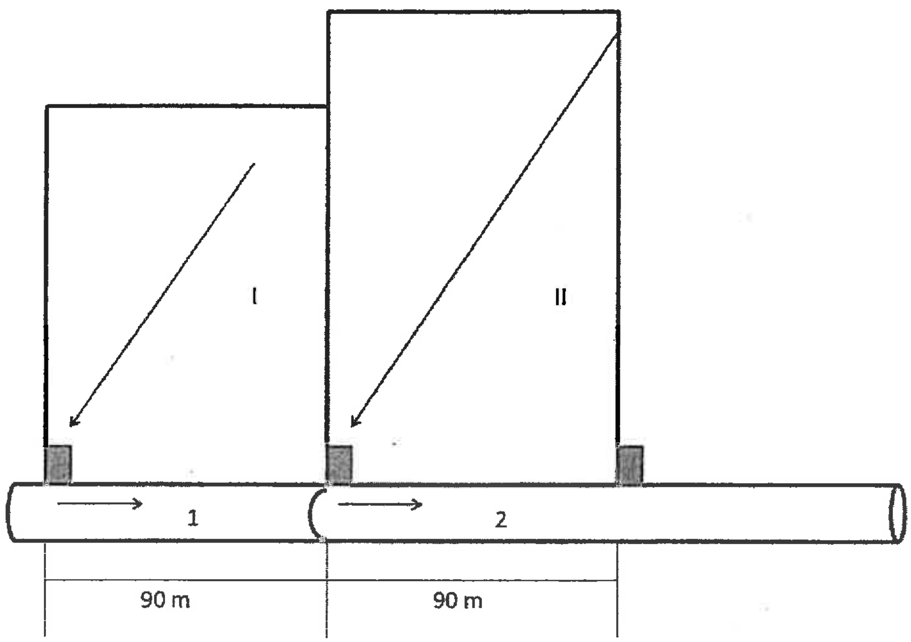
Description:	
Source:	

Marks

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. Water from each watershed flows into a catchbasin at the upstream end of the sewer, as shown. The critical rainfall intensity can be taken as 80 mm/h over 8 minutes, 60 mm/h over 18 minutes, and linear in between.

First, calculate the flow in each pipe for the critical storm(s). Then determine the diameter of the two sewers, given that the slope of each one is 0.0015, the length of each is 90 m, and Manning's "n" is 0.013. Furthermore, the pipes should flow at approximately ⅔ full (d/D) at the calculated flows (constant "n").

15 Use only commercially-available pipe sizes (mm): 375, 450, 525, 600, 675, 750



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	0.0015	90				
2	0.013	0.0015	90				

Working page for Question 5b.