# NATIONAL EXAMS MAY 2016

# 04-ENV-A2 HYDROLOGY AND MUNICIPAL HYDRAULICS 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 Exam with a candidate prepared $8\frac{1}{2}''$ x $11''$ double sided Aid-Sheet allowed.

3. Candidates may use one of two calculators, the Casio or Sharp approved models. Write the name and model designation of the calculator on the first inside left hand sheet of the exam work book.

4. Any five (5) questions constitute a complete paper. Only the first five (5) answers as they appear in your work book(s), will be marked.

5. Each question is worth a total of 20 marks with the section marks indicated in brackets ( ) at the left margin of the question. The complete Marking Scheme is also provided on the final page. A completed exam consists of five (5) answered questions with a possible maximum score of 100 marks.

## Problem 1

Provide answers to the following questions related to *conceptual models of runoff*, *hydraulics of closed pipe systems* and *water distribution systems*.

(8) (i) Briefly describe two (2) main differences between a process-based model and a stochastic conceptual model. For each type of model, describe runoff modelling where one model approach is preferred over the other.

(ii) Consider water flowing though a PVC pipe having length $L$ of 800 $m$ , diameter $d$ of 300 $mm$ and a full flow rate of 500 $L/s$. Calculate the following:

(2) (a) The average fluid velocity $V$ in $m/s$.

(2) (b) Reynolds number $Re$ and type of flow (i.e., laminar or turbulent).

(2) (c) Pipe friction loss $H_f$ in $m$.

(6) (iii) Within distribution systems there may exist points called cross-connections where non-potable water can be connected to potable sources. Explain two (2) possible scenarios that can lead to cross-connections and how they can be prevented.

## Problem 2

Provide answers to the following questions related to *components* and *processes* of the *natural hydrologic cycle* and *stormwater collection system design.*

(7) (i) Provide a simple labelled schematic showing the natural hydrologic cycle identifying three (3) key processes and briefly explain how each process depends on a different process(es) within the hydrologic cycle.

(7) (ii) Briefly explain what a stormwater culvert is, two (2) of its important design considerations and its primary function in a stormwater collection system.

(6) (iii) Storm sewer pipe sizing is commonly based on flows determined using the Rational Formula (below). Briefly explain and give consistent dimensions of each term of the Rational Formula.

$$Q = C \cdot I \cdot A$$

# Problem 3

Provide answers to the following questions related to *precipitation and snow melt*, *wastewater collection system* and *intensity-duration-frequency (IDF) analysis*.

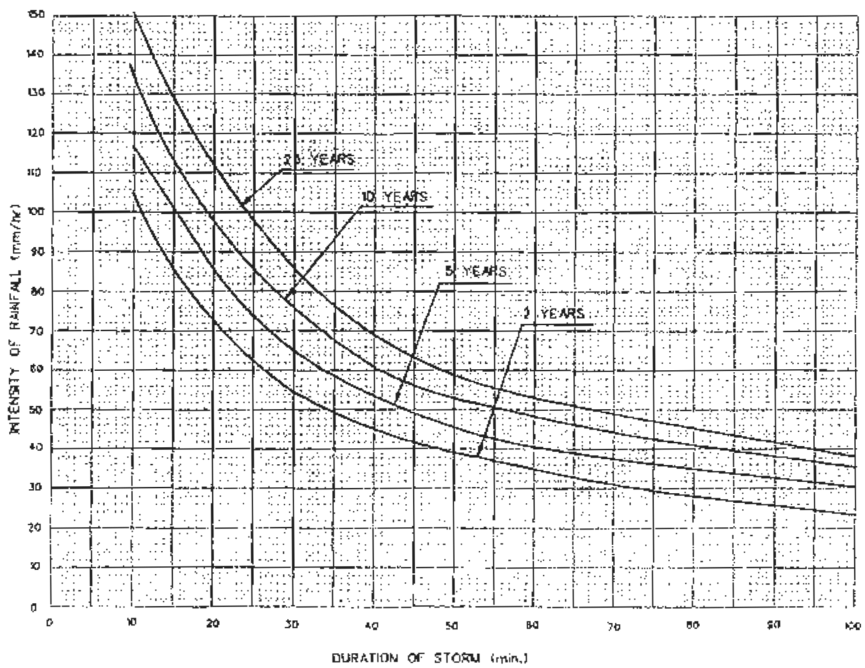
(6) (i) Briefly explain two (2) engineering methods that may be used to incorporate snow melt in the design of a stormwater detention pond to prevent downstream flooding during Spring melt in a northern climatic region.

(6) (ii) Briefly explain the function or importance of the following components of a wastewater collection system:

(a) Sanitary forcemain; and

(b) Sanitary trunk sewer;

(8) (iii) Briefly explain how the infiltration-distribution-frequency (IDF) curve is generated and three (3) main steps in using the IDF curve to design a storm sewer system.



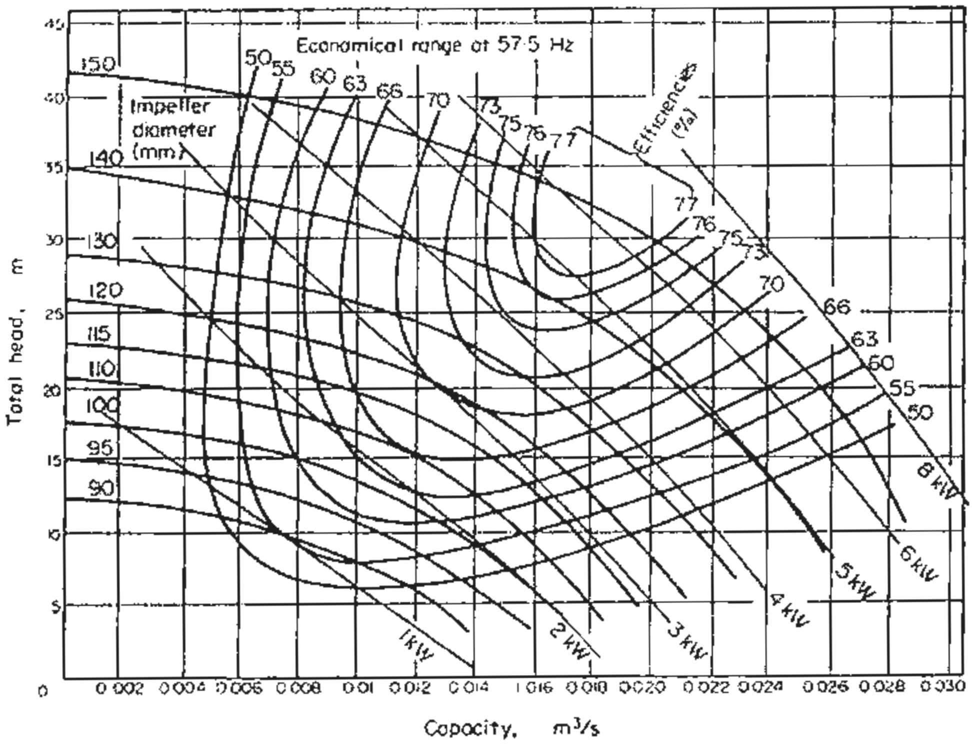
## Problem 4

Provide answers to the following questions related to *stream flow and hydrograph analysis* and *basic pumps or prime movers*.

(6) (i) Explain three (3) important abstractions in a watershed that ultimately determine the runoff hydrograph.

(6) (ii) Briefly explain two (2) main watershed factors that influence the shape of the runoff hydrograph and explain the effect this has on the peak flow and time to peak. Use a table to organize your answer.

(8) (iii) Assume an impeller diameter change from 100 mm to 140 mm. With reference to the pump characteristic curve (below), determine the new optimum capacity ($m^3/s$), the head (m), the brake horse power (kW), pump efficiency expected and the percent pump capacity improvement (%).

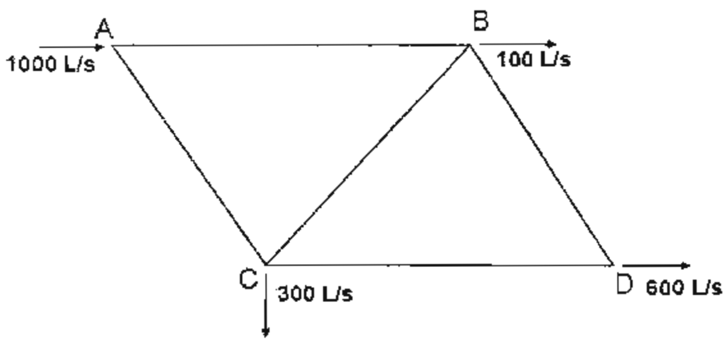


## Problem 5

Provide answers to the following questions related to *pipe networks*, *network design* and *sanitary sewers design*.

(10) (i) Solve for the flows in each pipe of the pipe network below (not to scale) using the Hardy-Cross or similar method, given the following pipe lengths (L) and corresponding diameters (d):

| Pipe | Length (m) | Diameter (mm) |
|---|---|---|
| AB | 600 | 300 |
| BC | 700 | 350 |
| CD | 600 | 400 |
| AC | 400 | 350 |
| BD | 400 | 450 |




(4) (ii) Briefly provide one (1) condition and an advantage of using gravity, pressure and vacuum sanitary sewers. A total of three (3) conditions and corresponding advantages should be provided.

(6) (iii) Explain the meaning of the Manning formula (below) and provide consistent dimensions of the parameters $Q$, $A$, $n$, $R$ and $S$.

$$Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

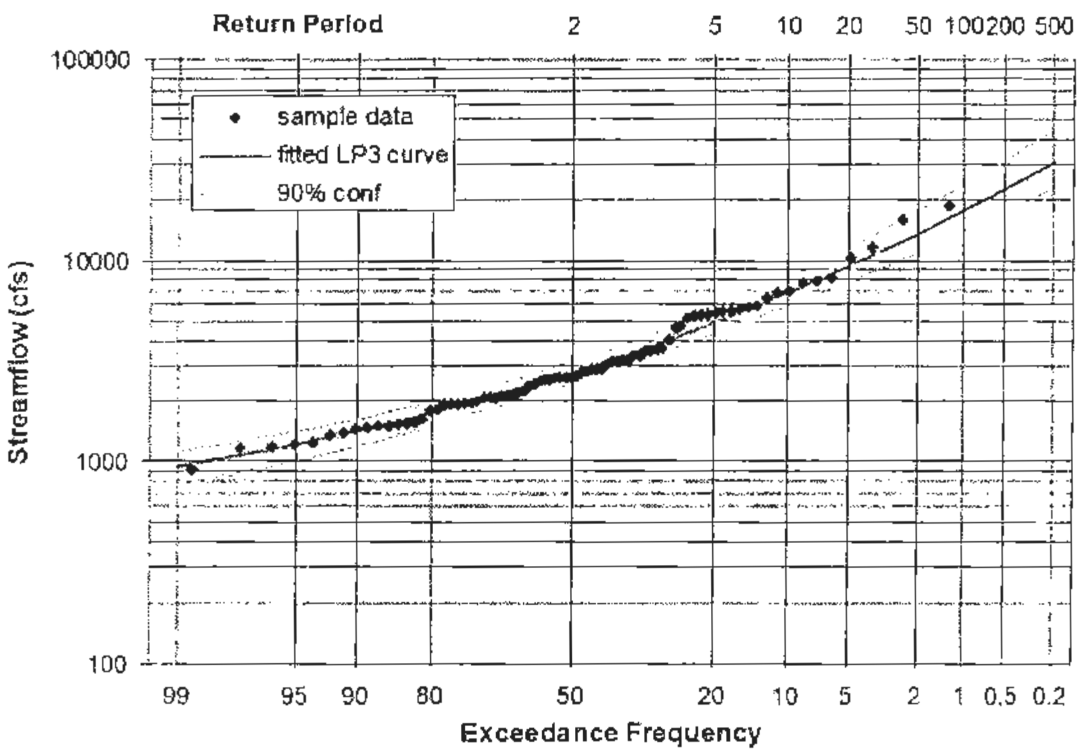
## Problem 6

Provide answers to the following questions related to *urban drainage with runoff control system design, frequency and probability analysis related to precipitation, floods and droughts.*

(6) (i) Describe one (1) on-site and one (1) off-site runoff control system and briefly compare each in terms of groundwater and surface water recharge effects.

(6) (ii) Briefly explain the primary purpose of dry and wet stormwater management ponds and give two (2) design or performance differences between them.

(8) (iii) Flooding occurs when streams overtop their banks and downstream areas are flooded. These events are recorded and flood frequency historical curves (similar the one below) are generated for engineering designs. Briefly explain how the 90 % confidence band is used to design a flood gate to protect against the average 100-year streamflow event.



# Problem 7

Provide answers to the following questions related to *open channel flows* under *uniform* and *gradually varied flow* conditions and *sediment transport*.

(i) An excavated earth lined trapezoidal channel experiences uniform flow at a normal depth of 4 *m*. The base width is 15 *m* and the side slopes are equal at a V:H of 1:4. Using an appropriate Manning's *n* and a bed slope $S_o$ of 5 % calculate the following:

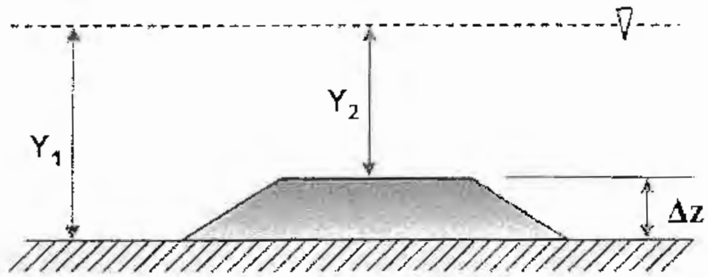
(3) (a) The discharge flow rate $Q$ in $m^3/s$; and

(3) (b) Reynolds number $Re$ and type of flow (i.e., laminar or turbulent).

(ii) Assume flow in a wide channel approaches a bump with a height $\Delta Z$ of 0.12 m at a velocity of 2.0 m/s and a flow depth $Y_1$ of 1.2 *m*.

(4) (a) Estimate the water depth $Y_2$ over the bump; and

(4) (b) the bump height ($\Delta Z$) which will cause the crest flow to be critical.




(6) (iii) The point at which water flow begins to transport sediment is called the critical Shields stress ($\tau^*$) given below. This equation creates an empirical curve that can be used to approximate at what flow rate a sediment particle will move based on particle size. Briefly explain the meaning of each parameter and provide consistent dimensions for each term.

$$\tau^* = \frac{\tau}{g(\rho_p - \rho_f)D_p}$$

# Marking Scheme

1. (i) 8, (ii) (a) 2, (b) 2, (c) 2, (iii) 6 marks, 20 marks total
2. (i) 7, (ii) 7, (iii) 6 marks, 20 marks total
3. (i) 6, (ii) 6, (iii) 8 marks, 20 marks total
4. (i) 6, ii) 6, (iii) 8 marks, 20 marks total
5. (i) 10, (ii) 4, (iii) 6 marks, 20 marks total
6. (i) 6, (ii) 6, (iii) 8 marks, 20 marks total
7. (i) (a) 3, (b) 3, (ii) (a) 4, (b) 4, (iii) 6 marks, 20 marks total