ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2021

*** YOU MUST HAND IN THE QUESTION BOOKLET WITH YOUR ANSWER SHEET ***

Open-book examination
Calculator : only authorized models
Duration : 3 hours

16-CI-B3 ENGINEERING HYDROLOGY

Question 1 (30 points)

A client has come to you with an ambitious plan to reuse water from his warehouse roof and to reduce water flows to the city utilities. In reality, the city is asking the client to reduce his current peak discharge by 20%, for the same rainfall as initially designed for and this is just a plan he's devised on his own and wants you to validate.

According to your client, the previous engineering analysis calculated a peak discharge of 69.5 litres/second using the rational method, but he can't seem to remember for what rain intensity.

Using the little information he's brought with him, you must quickly help him identify if this project is even feasible. To do this, you decide to employ the rational method as well (see annex for runoff coefficients) and base yourself off of the two plans he's brought along (see figures 1 and 2).

This client wishes to disconnect the roof drains from the current water collection system and reroute the water to an elevated distribution basin. This will act as a central hub and redistribute the rainwater uniformly over the large grassy area on his property, adjacent the warehouse. This will use a sprinkler system that is fed solely by the basin.

1) What is the initial rainfall intensity used for this project in mm/hr? (6 points)
2) You must tell the client if his idea would feasibly meet the demands of the city according to the rational method. (20 points)
3) If his idea does not seem feasible, you must suggest a different way of achieving this goal. If his idea seems feasible, could you suggest a better model for the water management scheme presently used? (4 points)

**you can assume that concentration times won't vary enough to have an impact and that the grass will not saturate*

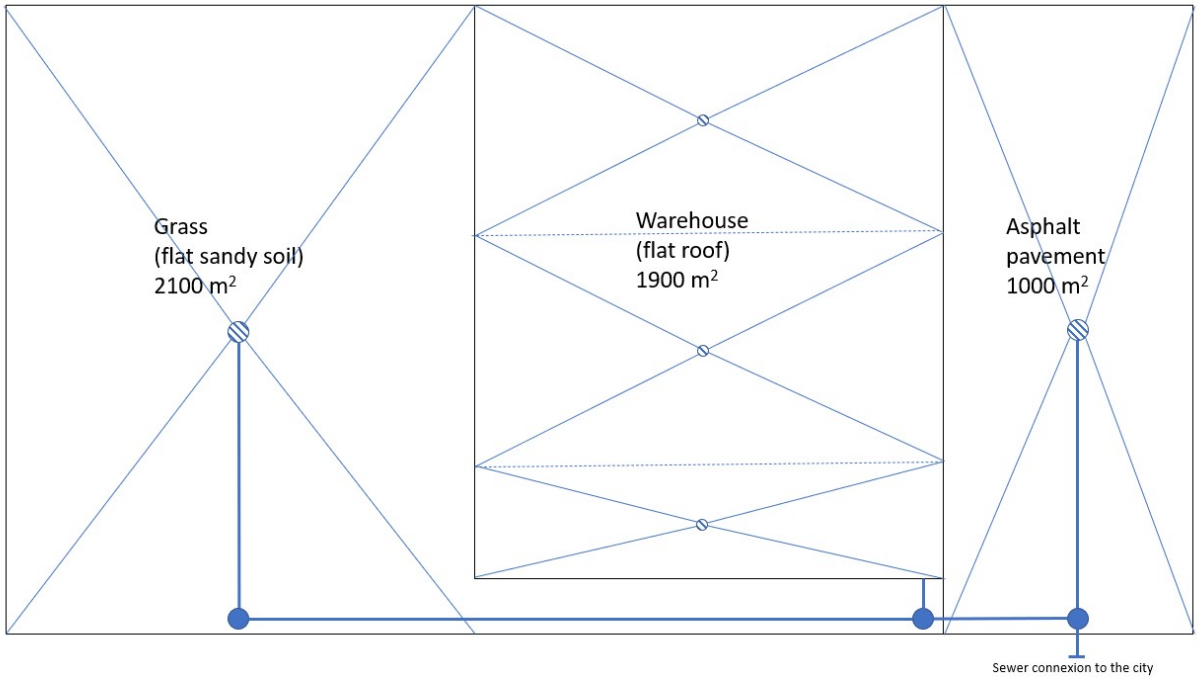

Figure 1 – Initial plan of stormwater drainage (flat roof drains directly to sewer)

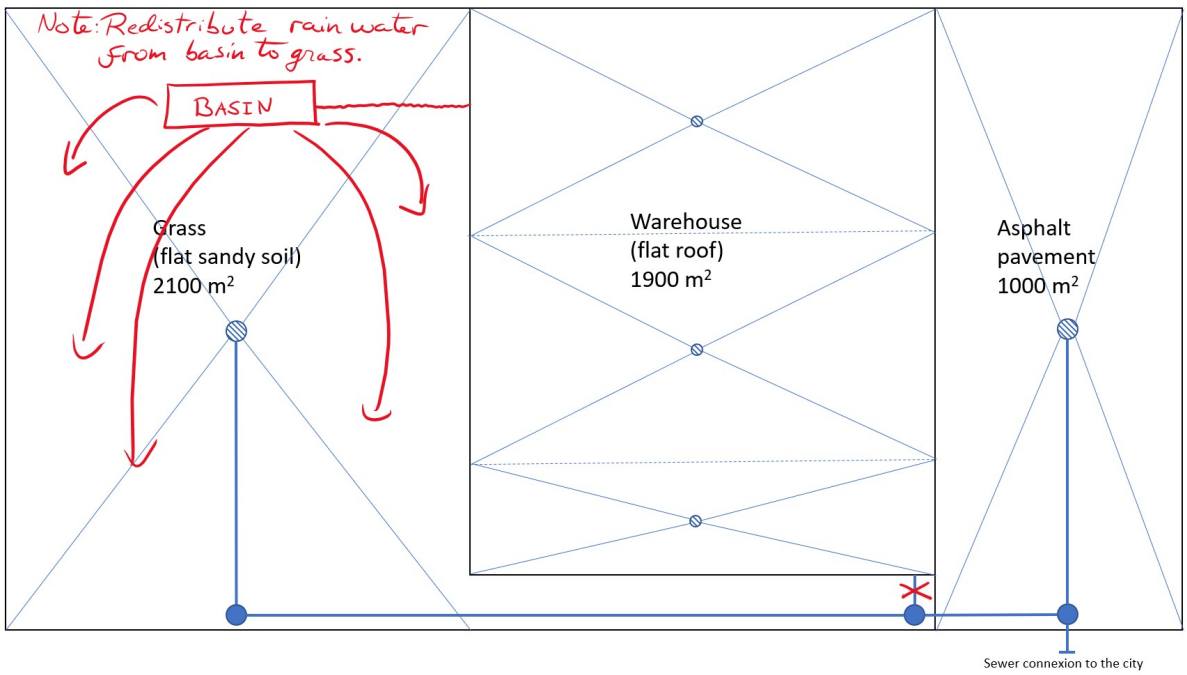

Figure 2 –Plan of stormwater drainage annotated by client (flat roof drains basin which then uniformly redistributes water over the grassy area)

Question 2 (25 points)

A local farmer has developed a passion over time for hydrological data and decided to record rainfall and runoff from his farmland (4 hectares). This passion stems from a fear that his cattle will be carried away if the runoff gets too strong.

Though he records this data, he doesn't quite know how to interpret it, or what he could learn from it. For this, he comes to you. Seeing this information, you offer him to produce a unit hydrograph for his farmland. This way, he could better predict the hydrological response and thus know when to bring in his cattle to avoid the strong runoffs.

The information from the last rainfall is presented in table 1

Table 1 – Most recent rainfall event information

Time (hr)	I (mm/hr)	Runoff (m^3/s)
0	2	0
1	5	4
2	0	18
3	0	22
4	0	5
5	0	0

You must:

1) Produce a 1h unit hydrograph (13 points)
2) Transform this into a 2h unit hydrograph (12 points)

Question 3 (30 points)

The following hydrograph (table 2) was recorded roughly 10km upstream from a quaint town on the riverfront. The average velocity of the river is 0.8 m/s and the full flow depth is 2.5m. Over the full length of this channel set between the data collection point and the town, the bottom of the channel itself drops 3m in elevation.

Using the Muskingum routing method, you must:

1) Estimate the K and *x* coefficients for the Muskingum method (6 points) ;
2) Assume K=2h and *x*=0.25 and calculate the Muskingum coefficients (C_0, C_1, C_2). You must validate your answer (5 points);
3) determine the downstream hydrograph up to (and including) t=4h (15 points).
4) Do you expect peak flow downstream to be higher or lower than upstream? Explain (4 points).

Table 2 – Upstream hydrograph

t (hours)	I (m^3/s)
0	100
1	105
2	125
3	135
4	150
5	120
6	105
7	100
8	100
9	100
10	100

Question 4 (15 points)

Using Daltons law of diffusivity, you must estimate surface evaporation for a lake. For this application, you must consider $f(V)=1+0.062V_{10}$ to account for wind speeds at 10m elevation [km/h], that the empirical coefficient b_1=3.66 and that vapor pressures are to be used in kPa in order to calculate daily evaporation [mm/day].

You know that ambient surface air temperature is 20 ºC and water temperature is 15 ºC. Relative humidity around the lake surface is 43%. And wind speed at 10m elevation is 10 km/h.

1- Calculate daily evaporation for the lake surface [mm/day] (10 points);
2- For what relative humidity would the evaporation stop assuming air and water temperatures are constant, as well as wind speed (5 points)?

Annex

Table I – Typical runoff coefficient values

Character of Surface	Range of Runoff Coefficients	Recommended Value*
Pavement		
Asphaltic and Concrete	0.70–0.95	0.85
Brick	0.75–0.85	0.80
Roofs	0.75–0.95	0.85
Lawns, sandy soil		
Flat, 2%	0.05–0.10	0.08
Average, 2 to 7%	0.10–0.15	0.13
Steep, 7%	0.15–0.20	0.18
Lawns, heavy soil		
Flat, 2%	0.13–0.17	0.15
Average, 2 to 7%	0.18–0.22	0.20
Steep, 7%	0.25–0.35	0.30

Source: Hydrologic analysis and design (2nd edition), R. McCuen

Table II – Saturation vapor pressure by temperature

Température (degrés C)	Saturation vapor pressure (kPa)	Température (degrés C)	Saturation vapor pressure (kPa)
-35	0,030	0	0,611
-30	0,050	5	0,873
-25	0,080	10	1,228
-20	0,125	15	1,704
-15	0,184	20	2,339
-10	0,288	25	3,169
-5	0,425	30	4,244

Source: Hydraulique et hydrologie (3e édition), S. Bennis