



POSTAL BOOK PACKAGE 2024

CIVIL ENGINEERING

CONVENTIONAL Practice Sets

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ENGINEERING HYDROLOGY

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Introduction

- Q1** The average surface area of a reservoir in the month of June is 20 km². In the same month, the average rate of inflow is 10 m³/s, outflow rate is 15 m³/s, monthly rainfall is 10 cm, monthly seepage loss is 1.8 cm and the storage change is 16 million m³. What is the evaporation (in cm) in that month?

Solution:

Let 'x' cm evaporation takes place in month of June.

$$\text{Total inflow} = I + P$$

$$= \left(\frac{10 \times 30 \times 24 \times 60 \times 60}{20 \times 10^6} \times 100 \right) + 10 = 139.6 \text{ cm}$$

$$\text{Total outflow} = Q + S + E$$

$$= \left(\frac{15 \times 30 \times 24 \times 60 \times 60}{20 \times 10^6} \times 100 \right) + 1.8 + x = 196.2 + x \text{ cm}$$

As total outflow is more than total inflow, therefore depression in storage takes place.

Depression in storage

$$= -\frac{16 \times 10^6}{20 \times 10^6} \times 100 = -80 \text{ cm}$$

$$\Rightarrow 139.6 - (196.2 + x) = -80$$

$$-x = -80 + 56.6$$

$$\therefore x = 23.4 \text{ cm}$$

- Q2** A catchment area of 140 km² received 120 cm of rainfall in a year. At the outlet of the catchment the flow in the stream draining the catchment was found to have an average rate of 2.0 m³/s for 3 months, 3.0 m³/s for 6 months and 5.0 m³/s for 3 months. (i) What is the runoff coefficient of the catchment? (ii) If the afforestation of the catchment reduces the runoff coefficient to 0.50, what is the increase in the abstraction from precipitation due to infiltration, evaporation and transpiration, for the same annual rainfall of 120 cm?

Solution:

$$(i) \quad P = \frac{120}{100} \times 140 \times 10^6 = 168 \text{ Mm}^3$$

$$R = [2 \times 3 + 3 \times 6 + 5 \times 3] \times 30 \times 24 \times 3600$$

$$= 101.088 \text{ Mm}^3$$

$$\therefore \text{Runoff coefficient, } k = \frac{R}{P} = \frac{101.088}{168} = 0.6017$$

$$(ii) \quad \text{Increase in abstraction} = (0.6017 - 0.5) \times 168 = 17.09 \text{ Mm}^3$$

- Q3** What is hydrological cycle? How does it keeps balance between water of earth and moisture in the atmosphere? What is the importance of hydrological cycle?

Solution:

Hydrological cycle is the cyclic movement of water from oceans to atmosphere, from atmosphere to land and from land back to the oceans.

It contains basic continuous processes listed below:

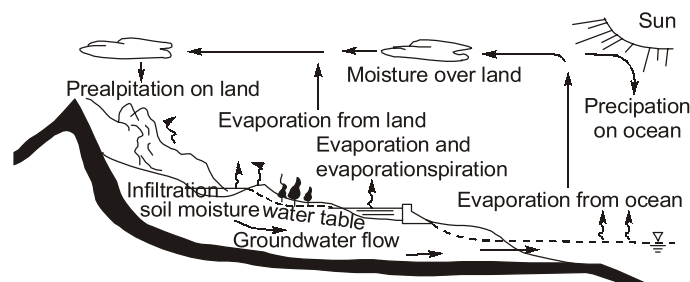
- (i) Evaporation
- (ii) Precipitation
- (iii) Runoff

Process of hydrological cycle starts with oceans. Water in oceans, gets evaporated due to heat energy provided by solar radiation and forms water vapour. This water vapour moves upwards to higher altitudes forming clouds. Most of the clouds condense and precipitate in any form like rain, hail, snow, sleet. And a part of clouds is driven to land by winds.

Precipitation, while falling to the ground, some part of it evaporates back to atmosphere. Portion of water that reaches the ground, enters the earth's surface infiltrating various strata of soil and enhancing the moisture content as well as water table. Vegetation sends a portion of water from earth's surface back to atmosphere through the process of transpiration. Once water percolates and infiltrates the earth's surface, runoff is formed over the land, flowing through the contours of land heading towards river and lakes and finally joins into oceans after many years. Some amount of water is retained as depression storage.

Further again the process of this hydrological cycle continues by blowing of cool air over ocean, carrying water molecules, forming into water vapour then clouds getting condensed and precipitates as rainfall. Similarly, then water gets percolated into soil, increasing water table then formation of runoff waters heading towards water bodies. Thus the cyclic process continues.

Thus hydrological cycle helps in providing freshwater in terms of rainfall, recharge groundwater, maintain appropriate moisture in the atmosphere keeping the balance between water of ocean, atmosphere and land and maintaining circulation of water in biosphere.



Q4 A river reach had a flood wave passing through it. At a given instant, the storage of water in the reach was estimated as 15.5 ha.m. What would be the storage in the reach after an interval of 3 hours if the average inflow and outflow during the time period are 14.2 m³/s and 10.6 m³/s respectively.

Solution:

Given data:

$$\Delta S = 15.5 \times 10^4 \text{ m}^3$$

$$\text{Inflow} = 14.2 \times 60 \times 60 \times 3 = 153360 \text{ m}^3$$

$$\text{Outflow} = 10.6 \times 3600 \times 3 = 114480 \text{ m}^3$$

$$\Delta S' = 155000 + (153360 - 114480) = 193880 \text{ m}^3 = 19.388 \text{ ha.m}$$

Q5 A catchment has four sub-areas. The annual precipitation and evaporation from each of the sub-areas are given in table below:

Assume that there is no change in the groundwater storage on an annual basis. Calculate for the whole catchment the values of annual average (i) precipitation, and (ii) evaporation. What are the annual runoff coefficients for the sub-areas and for the total catchment taken as a whole?

Sub-area	Area (Mm ²)	Annual precipitation (mm)	Annual evaporation (mm)
A	10.7	1030	530
B	3.0	830	438
C	8.2	900	430
D	17.0	1300	600

Solution:

$$(i) \quad \text{Average annual precipitation} = \frac{(10.7 \times 1030 + 3 \times 830 + 8.2 \times 900 + 17 \times 1300)}{(10.7 + 3 + 8.2 + 17)} = 1105.167 \text{ mm}$$

$$(ii) \quad \text{Average annual evaporation} = \frac{(10.7 \times 530 + 3 \times 438 + 8.2 \times 430 + 17 \times 600)}{(10.7 + 3 + 8.2 + 17)} = 532.416 \text{ mm}$$

$$\text{Runoff coefficient} \quad k_A = \frac{1030 - 530}{1030} = 0.485$$

$$k_B = \frac{830 - 438}{830} = 0.472$$

$$k_C = \frac{900 - 430}{900} = 0.52$$

$$k_D = \frac{1300 - 600}{1300} = 0.538$$

For whole catchment average runoff coefficient

$$= \frac{1105.167 - 532.416}{1105.167} = 0.518$$

Q6 A lake had a water surface elevation of 103.200 m above datum at the beginning of a certain month. In that month the lake received an average inflow of 6.0 m³/s from surface runoff sources. In the same period, the outflow from the lake had an average value of 6.5 m³/s. Further, in that month, the lake received a rainfall of 145 mm and the evaporation from the lake surface was estimated as 6.10 cm. Write the water budget equation for the lake and calculate the water surface elevation of the lake at the end of the month. The average lake surface area can be taken as 5000 ha. Assume that there is no contribution to or from the groundwater storage.

Solution:

In a time interval Δt the water budget equation for the lake can be written as:

Inflow volume – Outflow volume = Change in water storage of the lake

$$(\bar{I}\Delta t + PA) - (\bar{Q}\Delta t + EA) = \Delta S$$

Where, \bar{I} = average rate of inflow of water into the lake

\bar{Q} = average rate of outflow from the lake

P = precipitation

E = evaporation

A = average surface area of the lake and

ΔS = change in storage volume of the lake

Here,

$$\begin{aligned} \Delta t &= 1 \text{ month} = 30 \times 24 \times 60 \times 60 \text{ sec} \\ &= 2.592 \times 10^6 \text{ sec} = 2.592 \text{ M sec} \end{aligned}$$

} Given data

In one month:

$$\text{Inflow volume} \quad \bar{I}\Delta t = 6.0 \times 2.592 = 15.552 \text{ M m}^3$$

$$\text{Outflow volume} \quad \bar{Q}\Delta t = 6.5 \times 2.592 = 16.848 \text{ M m}^3$$

$$\text{Inflow due to precipitation} \quad PA = \frac{145 \times 5000 \times 10^4}{1000 \times 10^6} \text{ M m}^3 = 7.25 \text{ M m}^3 \quad (\because 1 \text{ ha} = 10^4 \text{ m}^2)$$

$$\text{Outflow due to evaporation} \quad EA = \frac{6.10}{100} \times \frac{5000 \times 10^4}{10^6} = 3.05 \text{ M m}^3$$

$$\text{Hence,} \quad \Delta S = 15.552 + 7.25 - 16.848 - 3.05 = 2.904 \text{ M m}^3$$

$$\text{Change in elevation,} \quad \Delta z = \frac{\Delta S}{A} = \frac{2.904 \times 10^6}{5000 \times 10^4} = 0.058 \text{ m}$$

$$\begin{aligned} \text{New water surface elevation at the end of the month} &= 103.200 + 0.058 \\ &= 103.258 \text{ m above the datum.} \end{aligned}$$

Q.7 A catchment area of 140 km² received 120 cm of rainfall in a year. At the outlet of the catchment, the flow in the stream draining the catchment was found to have an average rate of (i) 1.5 m³/s for the first 3 month, (ii) 2.0 m³/s for 6 months and (iii) 3.5 m³/s for the remaining 3 months. (a) What is the runoff coefficient of the catchment? (ii) If the afforestation of the catchment reduces the runoff coefficient to 0.35, what is the increase in the abstraction from precipitation due to infiltration, evaporation and transpiration for the same annual rainfall of 120 cm?

Solution:

(i) Before afforestation

Given data: Consider a period = $\Delta t = 1$ year

Input volume to the catchment through precipitation,

$$V_i = 140 \times 10^6 \times \left(\frac{120}{100} \right) = 168 \text{ Mm}^3$$

$$\begin{aligned} \text{Runoff} = \text{Output volume} = V_o &= (1.5 \times 3) + (2 \times 6) + (3.5 \times 3) \\ &= 27 \text{ Mm}^3 \text{ month} \end{aligned}$$

$$= 27 \left(\frac{365}{12} \right) \times 24 \times 60 \times 60 = 70.956 \times 10^6 \text{ m}^3 = 70.956 \text{ Mm}^3$$

$$\text{Runoff coefficient} = \frac{70.956}{168.0} = 0.4224$$

$$\text{Abstraction volume} = 168.0 - 70.956 = 97.044 \text{ Mm}^3$$

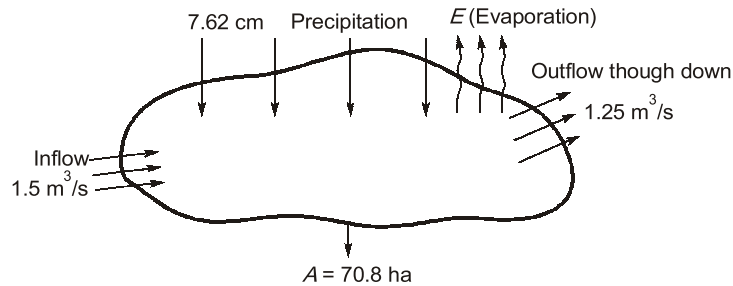
(ii) After Afforestation

$$\text{Runoff} = 0.35 \times 168 = 58.8 \text{ Mm}^3$$

$$\text{New abstraction volume} = 168.0 - 58.8 = 109.2 \text{ Mm}^3$$

$$\text{Increase in abstraction} = 109.20 - 97.044 = 12.156 \text{ Mm}^3$$

Q.8 For a lake of 70.8 ha surface area, the inflow was 1.5 m³/s in certain 30 day month. The dam on lake regulates the outflow (discharge) from the lake to 1.25 m³/s in that month. If the recorded precipitation in that month was 7.62 cm and storage volume increased by an estimated 6,50,000 m³. What is the estimated evaporation in m³ and cm.? Assume no water infiltrates out of bottom (and sides) of that lake.

Solution:

$$\Delta S = +6,50,000 \text{ m}^3$$

the problem finds its solution in water budget equation,

$$\Sigma I \Delta t - \Sigma Q \Delta t = \Delta S$$

Here

$$\Delta t = 1 \text{ month or } 30 \text{ days}$$

Input (+) $\left\{ \begin{array}{l} \rightarrow \text{Inflow (I)} \\ \rightarrow \text{Precipitation (P)} \end{array} \right.$

Out (-) $\left\{ \begin{array}{l} \rightarrow \text{Outflow/discharge (Q)} \\ \rightarrow \text{evaporation (E)} \end{array} \right.$

$$P + I - Q - E = \Delta S$$

$$P = (+) \frac{7.62}{100} \times 70.8 \times 10^4 = 5.394 \times 10^4 \text{ m}^3$$

$$I = (+) 1.5 \times 86400 \times 30 = 38,88,000 \text{ m}^3$$

$$Q = (-) 1.25 \times 86400 \times 30 = 32,40,000 \text{ m}^3$$

$$\Delta S = (+) 6,50,000 \text{ m}^3$$

$$E = (-)?$$

Putting all in equation of water budget,

$$5.394 \times 10^4 + 388.8 \times 10^4 - 324 \times 10^4 - E = 65 \times 10^4$$

$$\therefore E = 5.194 \times 10^4 \text{ m}^3$$

In terms of depth,

$$E = \frac{5.194 \times 10^4}{70.8 \times 10^4} \times 100 \text{ (in cm)} = 7.336 \text{ cm}$$

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