Engineering Hydrology
Discussion Ch. #1

Prepared by:
Eng. Wael Salem
Eng. Doaa Safi
Question #1

A lake had a water surface elevation of 103.2 m above datum at the beginning of a certain month. In that month the lake received an average inflow of 6 m$^3$/sec from surface runoff sources. In the same period the outflow from the lake had an average value of 6.5 m$^3$/sec. Further, in that month, the lake received a rainfall of 145 mm and the evaporation from the lake surface was estimated as 6.1 cm.

1) Write the water budget equation for the lake, and
2) Calculate the water surface elevation of the lake at end of the month. The average lake surface area can be taken as 5,000 ha. (1 ha = 10,000 m$^2$)
**Solution:** In a time interval $\Delta t$ the water budget for the lake can be written as

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

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 $\Delta S$ = change in storage volume of the lake.

Here $\Delta t = 1$ month = $30 \times 24 \times 60 \times 60 = 2.592 \times 10^6$ s = 2.592 Ms

In one month:

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

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

Input due to precipitation = $PA = \frac{14.5 \times 5000 \times 100 \times 100}{100 \times 10^6}$ M m$^3$ = 7.25 M m$^3$

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

Hence

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

Change in elevation

$$ \Delta z = \frac{\Delta S}{A} = \frac{2.904 \times 10^6}{5000 \times 100 \times 100} = 0.058 \text{ m} $$

New water surface elevation at the end of the month = $103.200 + 0.058$

= 103.258 m above the datum.
Question #2

A small catchment of area 150 ha received a rainfall of 10.5 cm in 90 minutes due to a storm. At the outlet of the catchment, the stream draining the catchment was dry before the storm and experienced a runoff lasting for 10 hours with an average discharge of 1.5 m³/s. The stream was again dry after the runoff event.

1) What is the amount of water which was not available to runoff due to combined effect of infiltration, evaporation and transpiration? What is the ratio of runoff to precipitation?
Solution: The water budget equation for the catchment in a time $\Delta t$ is

$$ R = P - L $$

(1.2-b)

where $L =$ Losses = water not available to runoff due to infiltration (causing addition to soil moisture and groundwater storage), evaporation, transpiration and surface storage.

In the present case $\Delta t =$ duration of the runoff = 10 hours.

Note that the rainfall occurred in the first 90 minutes and the rest 8.5 hours the precipitation was zero.

(a) $P =$ Input due to precipitation in 10 hours

$$ = 150 \times 100 \times 100 \times (10.5/100) = 157,500 \text{ m}^3 $$

$R =$ runoff volume = outflow volume at the catchment outlet in 10 hours

$$ = 1.5 \times 10 \times 60 \times 60 = 54,000 \text{ m}^3 $$

Hence losses $L = 157,500 - 54,000 = 103,500 \text{ m}^3$

(b) Runoff/rainfall = $54,000/157,500 = 0.343$

(This ratio is known as runoff coefficient and is discussed in Chapter 5)
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?
Question #4

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

Assume that there is no change in the groundwater storage on an annual basis and 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?

<table>
<thead>
<tr>
<th>Sub-area</th>
<th>Area $\text{Mm}^2$</th>
<th>Annual precipitation $\text{mm}$</th>
<th>Annual evaporation $\text{mm}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10.7</td>
<td>1030</td>
<td>530</td>
</tr>
<tr>
<td>B</td>
<td>3.0</td>
<td>830</td>
<td>438</td>
</tr>
<tr>
<td>C</td>
<td>8.2</td>
<td>900</td>
<td>430</td>
</tr>
<tr>
<td>D</td>
<td>17.0</td>
<td>1300</td>
<td>600</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
<td>-------------</td>
<td>----------------</td>
</tr>
<tr>
<td>A</td>
<td>10.7</td>
<td>1030</td>
<td>11.021</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>830</td>
<td>2.49</td>
</tr>
<tr>
<td>C</td>
<td>8.2</td>
<td>900</td>
<td>7.38</td>
</tr>
<tr>
<td>D</td>
<td>17</td>
<td>1300</td>
<td>22.1</td>
</tr>
<tr>
<td></td>
<td>38.9</td>
<td>m²</td>
<td>42.991</td>
</tr>
</tbody>
</table>
Runoff coefficients = rain flow

<table>
<thead>
<tr>
<th>Sub-area</th>
<th>Run off</th>
<th>Rain flow</th>
<th>Run off coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.35</td>
<td>11.021</td>
<td>0.485</td>
</tr>
<tr>
<td>B</td>
<td>1.176</td>
<td>2.49</td>
<td>0.472</td>
</tr>
<tr>
<td>C</td>
<td>3.936</td>
<td>7.38</td>
<td>0.53</td>
</tr>
<tr>
<td>D</td>
<td>11.9</td>
<td>22.1</td>
<td>0.538</td>
</tr>
<tr>
<td>Whole</td>
<td>22.362</td>
<td>43</td>
<td>0.52</td>
</tr>
</tbody>
</table>
Homework #1

- Problems #1.3 and 1.4
- Submission Due in One Week