1. 20-min unit hydrograph of a basin of size 72 km\(^2\) is triangular with the peak discharge 2 cm/hr, lag time 10 minutes. The rainfall intensity of a storm in this basin is 18 mm/hr in the first 20 minutes, 12 mm/hr in the second 20 minutes, and 6 mm/hr in the third 20 minutes. Infiltration index of the basin is 6 mm/hr. Determine the hydrograph. Base flow is constant at 10 m\(^3\)/s.

Solution: The peak discharge occurs at \((20/2)+10=20\) minutes, according to the definition of the lag time. The base width of the unit hydrograph can be found as follows, considering that its direct runoff depth is 1 cm:

\[
\frac{1}{2} \times 2 \times t_b = 1 \rightarrow t_b = 1 \text{ hr}
\]

It is thus determined that the 20-min. unit hydrograph is a triangle of the base with 60 minutes, with the peak discharge of 2 cm/hr occurring at 20 minutes.

Rainfall excess depths:
\[
R_1 = \frac{20}{60} (18 - 6) = 4 \text{ mm} = 0.4 \text{ cm} \quad \text{in the first 20 minutes}
\]
\[
R_2 = \frac{20}{60} (12 - 6) = 2 \text{ mm} = 0.2 \text{ cm} \quad \text{in the second 20 minutes}
\]
\[
R_3 = \frac{20}{60} (6 - 6) = 0 \quad \text{in the third 20 minutes}
\]

In order to obtain the direct runoff hydrograph, the ordinates of the unit hydrograph are multiplied by \(R_1=0.4\). Then the ordinates of the unit hydrograph translated to the right by 20 minutes are multiplied by \(R_2=0.2\). These two hydrographs are combined to obtain the direct runoff hydrograph.

<table>
<thead>
<tr>
<th>t (min)</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>R₁U (cm/hr)</td>
<td>0</td>
<td>0.8</td>
<td>0.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R₂U (cm/hr)</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Direct runoff (cm/hr)</td>
<td>0</td>
<td>0.8</td>
<td>0.8</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Direct runoff (m³/s)</td>
<td>0</td>
<td>160</td>
<td>160</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Total runoff (m³/s)</td>
<td>10</td>
<td>170</td>
<td>170</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

The direct runoff discharges in cm/hr can be converted to m³/s by considering that in this basin:

\[
11 \frac{\text{cm}}{\text{hr}} = \frac{0.01 \text{m}}{3600 \text{s}} \times 72 \times 10^6 \text{m}^2 = 200 \frac{\text{m}^3}{\text{s}}
\]

Total flows are found by adding the base flow of 10 m³/s to the direct runoff discharges.