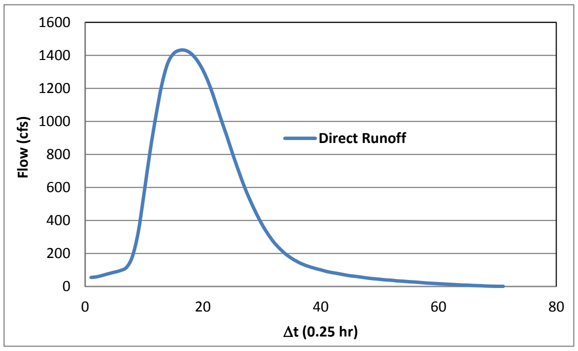
Computing Phi-index using Direct Runoff Hydrograph and Rainfall Hyetograph

For an observed storm event, direct-runoff hydrograph at 15 mins interval is shown below.



The total depth of direct run-off (calculations not shown), as computed by Equation 1, is equal to 0.72 inch.

$$r_d = \frac{\sum Q_i * \Delta t}{A} \qquad (1)$$

Where R_d is the run-off depth, Q_i is the direct runoff ordinate at ith time step, Δt is the time step for each Q_i, and A is the watershed area. The data used here is for Hall Creek in Indiana with a watershed area of 21.8 square miles. The unit for direct runoff for the Hall Cree data is cfs and time interval is 15 mins. The area is converted to square feet and Δt is 15*60 seconds. The answer that we get from Eq. 1 is then in ft, which is multiplied by 12 to get the answer in inch. As mentioned above, the direct runoff depth for the hydrograph shown above is 0.72 inch. This also means that the rainfall contributing to this direct runoff must produce a total excess rainfall depth of 0.72 inch. The rainfall hyetograph corresponding to this event is given below.

Time (mins)	15	30	45	60	75	90	105	120	135	150	165	180	195
P (inch)	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.1

The total rainfall depth from this event is 1.6 inch, which means 0.88 inch (1.6 – observed total runoff depth of 0.72) was lost in the form of infiltration or abstractions. The equation for computing phi-index is given below

$$r_d = \sum_{m=1}^{M} (R_m - \emptyset \Delta t)$$

Where M is the total number of ordinates in the excess rainfall hyetograph, Rm is the mth ordinate in the total rainfall hyetograph and ϕ is the phi index. Because there are two unknowns in the above equation (M and ϕ), this equation is solved by trial and error by assuming values for M and computing ϕ.

To begin, assume M = 13, which means the total number ordinates in excess rainfall hyetograph is equal to that in the total rainfall hyetograph. A value of M = 13 gives,

$0.72 = (0.1+0.1+0.1+0.1+0.1+0.1+0.4+0.1+0.1+0.1+0.1+0.1+0.1 – 13*\phi*\Delta t$

$\phi\Delta t = (1.6-0.72)/13 = 0.068$ inch or $\phi = 0.068 * (60/15) = 0.272$ inch/hr. Plotting of a line corresponding to 0.068 on the rainfall hyetograph shows that the assumption of M = 13 is correct because we end up with 13 ordinates in the excess rainfall hyetograph.