Appendix C - Mean Velocity in a Triangular Channel

Flow time in curbed gutters is one component of the time of concentration for the contributing drainage area to the inlet. Velocity in a triangular gutter varies with the flow rate, and the flow rate varies with distance along the gutter, i.e., both the velocity and flow rate in the gutter are spatially varied. Figure C.1 illustrates the concept used to develop average velocity in a reach of channel.

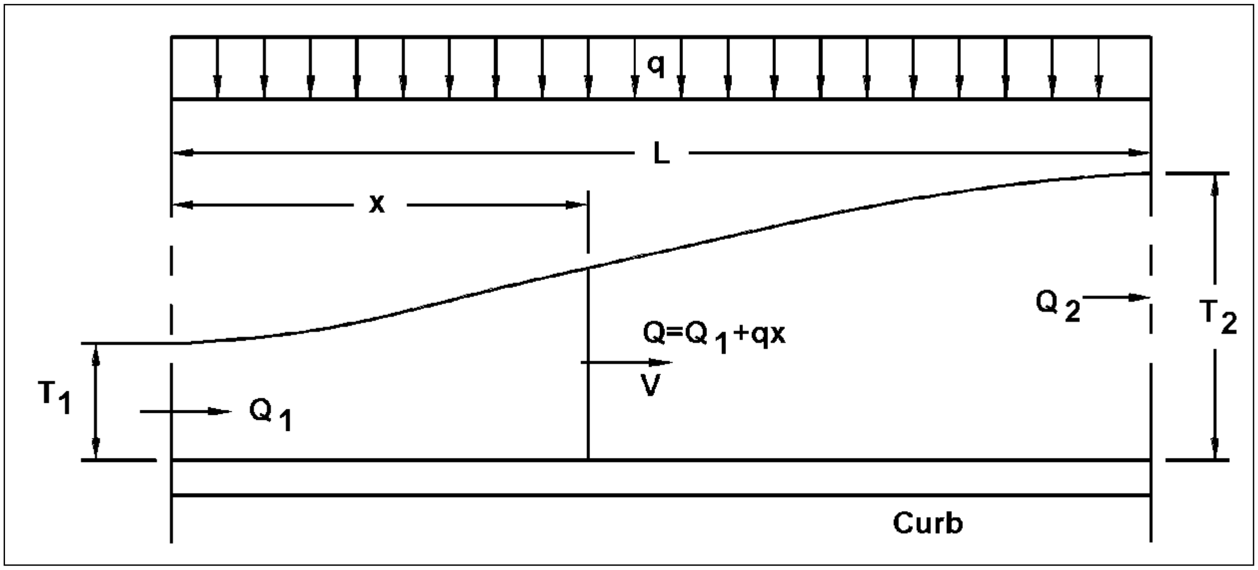

Figure C.1. Conceptual sketch of spatially varied gutter flow.

Time of flow can be estimated by use of an average velocity obtained by integration of the Manning's equation for a triangular channel with respect to time. The assumption of this solution is that the flow rate in the gutter varies uniformly from Q_1 at the beginning of the section to Q_2 at the inlet. Using the gutter equation (equation 5.2), Q is:

$$Q = \left(\frac{K_u}{n}\right) S_L^{0.5} S_x^{1.67} T^{2.67} = K_1 T^{2.67} \tag{C.1}$$

With $K_1 = \left(\frac{K_u}{n}\right) S_L^{0.5} S_x^{1.67}$

where:

Q	=	Gutter flow, ft^3/s (m^3/s)
n	=	Manning's roughness coefficient
S_L	=	Gutter longitudinal slope, ft/ft (m/m)
S_x	=	Gutter transverse scope, ft/ft (m/m)
T	=	Spread, ft (m)
K_u	=	Unit conversion constant, 0.56 in CU (0.376 in SI)

Dividing the gutter flow by the gutter cross-section area, V becomes:

$$V = \frac{Q}{\left(\left(T^2 S_x\right)/2\right)} = \left(\frac{2K_u}{n}\right) S_L^{0.5} S_x^{0.67} T^{0.67} = K_2 T^{0.67} \tag{C.2}$$

With $K_2 = \left(\frac{2K_u}{n}\right) S_L^{0.5} S_x^{0.67}$

where:

V	=	Gutter velocity, ft/s (m/s)
n	=	Manning's roughness coefficient
S_L	=	Gutter longitudinal slope, ft/ft (m/m)
S_x	=	Gutter transverse scope, ft/ft (m/m)
T	=	Spread, ft (m)
K_u	=	Unit conversion constant, 0.56 in CU (0.376 SI)

From equation C.1:

$$T^{0.67} = \left(\frac{Q}{K_1}\right)^{0.25} \tag{C.3}$$

Substituting equation C.3 into equation C.2 with V = dx/dt results in:

$$\frac{dx}{Q^{0.25}} = \left(\frac{K_2}{K_1^{0.25}}\right) dt \tag{C.4}$$

where:

dx	=	Change in longitudinal distance, ft (m)
dt	=	Change in time, s

Here, $Q = Q_1 + qx$ and therefore $dQ = qdx$. Combining these with equation C.4 and performing the integration results in:

$$t = \frac{4}{3}\left(Q_2^{0.75} - Q_1^{0.75}\right)\left(\frac{K_1^{0.25}}{qK_2}\right) \tag{C.5}$$

The average velocity, V_a is:

$$V_a = \frac{L}{t} = \frac{3}{4}\left(\frac{qK_2}{K_1^{0.25}}\right)\left(\frac{L}{Q_2^{0.75} - Q_1^{0.75}}\right) \tag{C.6}$$

Substituting $L = (Q_2 - Q_1)/q$ and $Q = K_1 T^{2.67}$, V_a becomes:

$$V_a = \left(\frac{3}{4}\right) K_2 \left(\frac{T_2^{2.67} - T_1^{2.67}}{T_2^2 - T_1^2}\right) \tag{C.7}$$

Defining a gutter geometry parameter as:

$$K_G = (S_L^{0.5} S_X^{0.67}) / n \tag{C.8}$$

Then substituting results in:

$$V_a = K_u K_G \left(\frac{T_2^{2.67} - T_1^{2.67}}{T_2^2 - T_1^2} \right) \tag{C.9}$$

where:

V_a	=	Average velocity in the gutter section between T_1 and T_2 locations, ft/s (m/s)
T_1	=	Upstream spread, ft (m)
T_2	=	Downstream spread, ft (m)
K_G	=	Gutter geometry parameter
K_u	=	Unit conversion constant, 0.840 in CU (0.564 in SI)