Theoretical basis

Analysis of an open-channel section.

Uniform flow

The discharge of an uniform flow through a channel section can be expressed by the following relation:

$$Q\ (mc/s) = A \times v_m;$$

where:

A (mq) = water area of the channel cross section;
v_m (m/s) = average velocity of the flow.

Imposing a uniform-flow condition, meaning that the energy line of the water flow has the same slope of the bottom of the channel along the stream direction, the average velocity of water can be given by the Manning-Strickler's formula:

$$v_m\ (m/s) = K_s \times R_h^{2/3} \times (i/100)^{1/2};$$

where:

K_s ($m^{1/3}s^{-1}$) = Strickler coefficient;
R_h(m) = hydraulic radius = Water area / wetted perimeter;
i (%) = slope of the channel bottom.

Using as an alternative the Chézy-Tadini's relation, the expression of the average velocity is the following:

$$v_m\ (m/s) = \chi \times (R_h \times i/100)^{1/2};$$

where the parameter χ is given by the relation:

$$\chi = \frac{100}{1 + \frac{m}{\sqrt{R_h}}}$$

m = Kutter's coefficient.

Estimated the stream velocity, known the value of the water area, it's possible to calculate the maximum discharge capacity and then compare it to the peak discharge of the hydrological basin.

The following are values of K_s (Strickler) and of m(Kutter) gotten by the literature:

Channel type	m (m1/2)	K_s ($m^{1/3}s^{-1}$)
OPEN CHANNEL (Rh ≈1)		
Covered by:		
bituminous concrete	0,33-0,76	57-75
bricks	0,39-0,76	57-72
concrete	0,29-0,76	57-77
rock fills	1,00-4,00	20-50
stones	2,33-5,67	15-30
Digged or dredged:		
linear and uniform earth channels	0,67-2,33	30-60
curved and uniform earth channels	1,00-4,00	20-50
Earth channels in rough condition; rock channel	1,00-4,00	20-50
SMALL CHANNEL (Rh ≈ 2) (width <30 m)		
regular section	1,39-4,89	20-45
irregular section	3,62-6,99	15-25
Creeks with a few rock blocks	2,19-4,89	20-35
Creeks with big rock blocks	3,63-6,99	15-25
LARGE CHANNEL (Rh ≈ 4) (width ≥ 30 m)		
regular section	1,53-3,29	30-45
irregular section	3,29-5,94	20-30
FLOOD PLAIN		
pasture	1,50-4,00	20-40

plantation	1,00-4,00	20-50
natural vegetation	2,33-4,00	20-30

The parameter K_s may be directly evaluated through the following relation, useful in case of coarse sediment on the bottom of the channel:

$$K_s\ (m^{1/3}s^{-1}) = 26 / d_{90}^{1/6};$$

d_{90} (m) = 90% pass-through of the granulometric curve.

Solid discharge in open channel.

The variable q_s, is expressed as mq/s, being referred to an unitary width of the cross section. To obtain the total solid discharge, q_s, has to be integrated throughout the width of the section. The effective solid discharge is eventually given dividing q_s for the factor (1-n), where n is the porosity of the sediment at the bottom of the channel.

1)Schocklitsch (1962).

$$q_s\,(mq/s) = \frac{2.5}{\frac{\rho_s}{\rho}}\, i^{1.5}\left(q - q_c\right)$$

where:

i	= mean slope of the channel bottom;
q(mq/s)	= water discharge for a unitary width of the cross section;
q_c	$= 0.15 i^{-1.12}\sqrt{gd^3}$;
ρ_s	= volumetric mass of the soil grain on the channel bottom= γ/9.81, where γ=specific gravity;
ρ	= volumetric mass of water;
g	= 9.81;
d(m)	= grain diameter of the sediment on the channel bottom.

The solid transport on the channel bottom begins when the following condition is verified:

$$q_c > q$$

2) Bathurst (1987)

$$q_s(mq/s) = 8\sqrt{d^3 g\Delta}\left(\phi * -\phi_c{}^0\right)^{1.5}$$

where:

Δ	$= \dfrac{\rho_s - \rho}{\rho}$;
$\phi_c{}^0$	= 0.047;
ϕ*	$= \dfrac{\rho u^2}{\gamma\Delta d \cos\theta(\tan\beta - \tan\theta)}$
u	$= \dfrac{v\sqrt{g}}{K_s R^{1/6}}$
v(m/s)	= mean velocity of the stream;
K_s	= Strickler's coefficient;
R	= hydraulic radius;
θ°	= mean slope of the channel bottom;
β°	= rest angle of shearing resistance of the sediment on the channel bottom;

The solid transport on the channel bottom begins when the following condition is verified:

$$\phi * > \phi_c{}^0$$

3)Suszka (1991)

$$q_s(mq/s) = 10.4\sqrt{d^3 g\Delta}\phi^{3/2}\left(1 - \frac{\phi_c{}^0}{\phi}\right)^{5/2}$$

where:

ϕ	= Shields's index = $\frac{u^2}{g\Delta d}$;
$\phi_c{}^0$	$= 0.0851\left(\frac{h}{d}\right)^{-0.266}$;
h(m)	= hydrometric level in respect to the bottom.

The solid transport on the channel bottom begins when the following condition is verified:

$$\phi > \phi_c{}^0$$

4)Meyer-Peter e Müller (1948)

$$q_s(mq/s) = 13.3\sqrt{d^3 g\Delta}(\phi - \phi_c)^{1.5}$$

where:

$\phi_c{}^0$	$= 0.06\left(1 + 0.67\sqrt{\frac{d}{h}}\right)$;
ϕ_c	$= \phi_c{}^0 \cos\theta\left(1 - \frac{\tan\theta}{\tan\beta}\right)$;

The solid transport on the channel bottom begins when the following condition is verified:

$$\phi > \phi_c$$

5)Pezzoli (1979)

$$q_s(mq/s) = \frac{2}{3} d \sqrt{\frac{\tau}{\rho}} \left(\frac{\tau}{\rho}\right)^{1/6} \left(\sqrt{\frac{\tau}{\tau_c}} - 1\right)^{5/3}$$

where:

ϕ_c^0	$= 0.06\left(1 + 0.67\sqrt{\frac{d}{h}}\right)$;
ϕ_c	$= \phi_c^0 \cos\theta \left(1 - \frac{\tan\theta}{\tan\beta}\right)$;
τ	$= (\rho_s - \rho) g d \phi$
τ_c	$= (\rho_s - \rho) g d \phi_c$

The solid transport on the channel bottom begins when the following condition is verified:

$$\phi > \phi_c$$