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Assessment of manning's resistance coefficient in compound channels

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ABSTRACT

In this paper twelve different empirical resistance coefficients expressed in terms of Manning's roughness are used apiece in seventeen known compositing methods. The data obtained from ten different cross-sections of the Sefidrood River, Iran, are used for the evaluation of the empirical formulas. The present case-study is selected from a reach with gravel bed topology. Then no remarkable bed form exists. Comparison of the calculated discharges and resistance coefficients with measurements shows that the Keulegan formula used simultaneously with the Brownlie formula in different compositing methods results in highly over estimated discharges, while the Meyer-Peter & Muller, Marion, Chien-Mai formulas in conjunction with the total force approach match best with the measurements. Also comparison of the calculated discharges from empirical formulas in individual sections reveals that Chien-Mai and Subramanya formulas have the least discrepancies from measurements.

Keywords

Roughness, manning's resistance coefficient, compound channel, discharge, alluvial channels

1. Introduction

Resistance to flow in alluvial streams depends on many interrelated factors. The complex effects of these factors on river morphology and flow regimes have challenged interested scientists to carry out experimental and numerical simulations in this field.

The most important factors governing flow resistance are; the fluid, flow, bed material and channel geometry. Rouse (1965) classified flow resistance into four separate types: (1) surface or skin drag (2) form drag (3) wave resistance due to free surface irregulaties (4) resistance induced by local acceleration or flow unsteadiness. Rouse expressed the flow resistance in terms of the Darcy Weisbach resistance coefficient in the following dimensionless function:

$$f=F(R, K, \eta, N, F, U) \quad (1)$$

In which R=Reynolds; number; K=relative roughness, usually expressed as Ks/R, where K_s is the equivalent wall roughness and R is hydraulic radius of the flow; η=cross-sectional geometric shape; N=channel non-uniformity both in plan and profile; F=Froude number; U=degree of flow unstea

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diness. Obviously, the six independent parameters in Eq (1), as well as the four resistance components (surface, form, wave, and unsteadiness), interact in a nonlinear manner such that any linear separation is artificial (Ben Chie Yen 2002).

Consequently, Leopold, Bagnold, Wolman and Brush (1960) stated that flow resistance is comprised of three components of skin resistance, form resistance and spill resistance.

Skin resistance, a resistance produced by the boundary surface, depends on depth of flow relative to size of roughness element along the boundary surface. Form resistance is produced by discrete boundary elements developed as a result of sediment transport and deposition in different locations. Spill resistance accounts that part of flow resistance generated due to local flow disturbances and is not considered in this paper.

When a channel bed contains stone or gravel it is difficult to distinguish between grain and form drag because elements considered as grain resistance at high flows can present form resistance at low flows.

In other words, in case of gravel bed, no distinct bed form can be developed. So the flow resistance formulas developed for gravel bed rivers are similar to those for fixed bed grain roughness.

The flow resistance formulas are stage-discharge relationships derived under the assumption of uniform flow. The most frequently used formulas relating Flow velocity, V, to resistance coefficient are:

$$V = \frac{K_n}{n} R^{2/3} S^{1/2} \quad (2)$$

$$V = \sqrt{\frac{8g}{f}} \sqrt{RS} \quad (3)$$

$$V = C\sqrt{RS} \quad (4)$$

In which n, f, and C are the manning, Darcy Wiesbach and Chezy resistance coefficients respectively; R=hydraulic radius, S=slope; g=gravitational acceleration; and K=1 $m^{1/2}/s$ in SI units, 1.487 $ft^{1/3}$-$m^{1/6}/s$ for English units.

The resistance coefficients can be related as:

$$\sqrt{\frac{f}{8}} = \frac{n}{R^{1/6}} \frac{\sqrt{g}}{K_n} = \frac{\sqrt{g}}{C} = \frac{\sqrt{gRS}}{V} \quad (5)$$

During last decades numerous researchers have made contributions to open channel flow resistance in terms of manning's coefficient. It can be referred to the contributions of Lane and Carlson (1953), Limerson (1970), Hey (1979) and Bray (1979). In most of these empirical works, the manning's n is used as a power function of the particle size. Simons and Richardson in 1996 suggested that washed-out dunes and ripples in the transition regime are responsible for the generation of bed forms and different values of flow resistance. Researches on alluvial resistance have prevailed that, in general, there are two different relationships describing lower and upper regimes (Shiqiang Wang, William Rodner White 1993)

The well-known Strickler's (1923) formula for rigid bed as a function of the particle size is:

$$n = c.k_s^{\frac{1}{6}} \quad (6)$$

Where;

C=0.034 for riprap size calculations where K_s=D_{90}

=0.038 for discharge capacity of ripaped channels where K_s =D_{90}

=0.034 for natural sediment where K_s =D_{50} (Chow 1959)

Strickler's formula is based on data from gravel-bed rivers and fixed bed channels. Substituting Strickler's formula for n into Manning's formula yields the famous Manning-Strickler formula:

$$\frac{U}{U_*} = 6 + \left(\frac{R}{d_{50}}\right)^{\frac{1}{6}} \tag{7}$$

Where $U_* = \sqrt{gRS}$ is the shear velocity. As stated, many other formulas fall in the same form as the Strickler's. For example, Meyer-Peter and Muller (1948) proposed the following relationship for sand mixture:

$$n = 0.038 d_{90}^{1/6} \tag{8}$$

Where d90 is the size (in meters) for which 90% of the material is finer. Lane and Carlson (1953) suggested the following formula for the San Luis canals in Colorado:

$$n = 0.026 d_{75}^{1/6} \tag{9}$$

Where d75 is the size (in inches) for which 75% of the material is finer. The Federal Highway Administration formula was developed for rock riprap which is shown in the form of Manning-Strickler equation as (Thomas, Copeland and McComas 2002):

$$\frac{ng^{1/2}}{D^{1/6}} = 0.0225\left(\frac{d_{50}}{D}\right)^{1/6}, \text{ or} \quad n = 0.0395 d_{50}^{1/6} \tag{10}$$

Where D is the Depth and d50 is expressed in feet. Kellerhalls in 1967, proposed the following relationship for gravel bed streams (Kellerhalls 1967) :

$$\frac{U}{U_*} = 6.5\left(\frac{R_v}{d_{90}}\right)^{\frac{1}{4}} \tag{11}$$

Where R_v is the volume of overlying water per unit plan area of bed which is referred to as the volumetric hydraulic radius.

(Simons, Senturk 1976), (Henderson 1966), (Raudkivi 1976), (Grade, Raju 1978), (Subramanya 1982) and many other investigators obtained relationships for Manning's coefficient as power-function of grain roughness size. These relationships are presented in Table 1.

There are many other stage-discharge relationships suggested by different researchers which, for brevity, are not included in Table 1. Most of these approaches do not yield satisfactorily reliable and universally acceptable results. The discrepancy of the results is due to the following reasons:

1. They are basically derived from rigid boundary flow concept and are not adapted to erodible channels.
2. The roughness coefficient both in fixed and moveable surfaces is not easily predicable.
3. Characterizing skin roughness by a single grain representative size without considering sediment size distribution (uniformity vs. non-uniformity and skewness of the particle size variations) is not valid.
4. Many of the proposed methods /formulas are confined to specific grain sizes or definite hydraulic regimes.

where
d50 = the particle size for which 50% of the sediment mixture is finer.
R = hydraulic radius of the bed portion of the cross section.
S = bed slope; probably the energy slope would be more representative if flow is non-uniform.
σ = the geometric standard deviation of the sediment mixture, where

$$\sigma = 0.5\left(\frac{d_{84}}{d_{50}} + \frac{d_{50}}{d_{16}}\right) \tag{12}$$

Table 1. Empirical equations of Manning's Coefficient

Researcher(s)	Equ.
Simons and Senturk(1976)	$n = 0.047d^{1/6}$
Henderson(1966)	$n = 0.034d^{1/6}$
Raudkivi(1976)	$n = 0.042d^{1/6}$
Grade and Raju(1978)	$n = 0.039d_{50}^{1/6}$
Subramanya(1982)	$n = 0.047d_{50}^{1/6}$
Chien & Mai	$n = \frac{d_{65}^{1/6}}{19} = 0.052d_{65}^{1/6}$
Lane & Carlson (1953)	$n = 0.026d_{75}^{1/6}$
Meyer-Peter and Muller (1948)	$n = 0.038d_{90}^{1/6}$
Marion et al.(1998)	$n = \frac{d_{90}^{1/6}}{26}$
Keulegan(1938)	$\begin{cases} C = 32.6\log\left[\frac{12.2R}{k}\right] \\ C = 32.6\log\left[\frac{5.2R_n}{C}\right], R_n = \frac{4RV}{\nu} \end{cases}$
The Iwagaki relationship	$\begin{cases} C = 32.6\log\left[\left(\frac{R}{k_s}\right)10^{A_r^{0.5}/32.6}\right] \\ A_r = -27.058\log(F+9) + 34.289 \end{cases}$ $\begin{cases} C = 32.6\log\left[\left(\frac{R_n g^{0.5}}{4C}\right)10^{A_s g^{0.5}/32.6}\right] \\ A_s = -24.739\log(F+10) + 29.349 \\ 0.2 \le F \le 8 \end{cases}$ $\begin{cases} \frac{(R_n/C)}{(R/k_s)} \rangle 50 \\ C = -32.6\log\left[\frac{4C}{R_n g^{0.5} 10^{A_s g^{0.5}/32.6}} + \frac{k_s}{\left(R \times 10^{A_r g^{0.5}/32.6}\right)}\right] \end{cases}$
Brownlie (1983)	LOWER REGIME FLOW $n = \left[1.6940\left(\frac{R}{d_{50}}\right)^{0.1374} S^{0.1112}\sigma^{0.1605}\right]0.034(d_{50})^{0.167}$ UPPER REGIME FLOW $n = \left[1.0213\left(\frac{R}{d_{50}}\right)^{0.0662} S^{0.0395}\sigma^{0.1282}\right]0.034(d_{50})^{0.167}$

2. Transition Function:

If the slope is greater than 0.006, flow is always Upper Regime. Otherwise, the transition is correlated with the grain Froude number as follows:

$$F_g = \frac{V}{\sqrt{(S_g - 1)gd_{50}}} \quad , \quad F'_g = \frac{1.74}{S^{1/3}}$$

If $F_g < F_g'$ Lower Regime Flow

If $0.8\,F_g' < F_g < 1.25\,F_g'$ Transition Flow

If $F_g > F_g'$ Upper Regime Flow

Where

F_g = grain Froude number.
S_g = specific gravity of sediment particles.
V = velocity of flow.
S = bed slope.

In the case of irregular cross-sections the problem is more intricate. The boundary turbulent characteristics are a function of local point wall shear and relative roughness. When channel bed and banks have different roughness elements, the cumulative effects of them are calculated through various compositing methods. Many different methods for determination of resistance factor in compound channel sections have been suggested by different investigators that each of them is based on some assumptions regarding flow conditions and applied and resisting forces.

The most important question frequently asked by the designing engineer is which of the proposed common formulas in combination with compositing methods is preferably recommended in applied projects?

It should be noted that each river has unique behavior and its responses to the variables is quite different from others. In other words, any change in climate, geological or hydrological conditions and deposition and scouring is accompanied by a series of river responses with nonlinear interactions which are quite dependent on the properties and characteristics of that specific river. On the other hand, the rivers are dynamic systems which mean continual change in river conditions and flow patterns.

Flow resistance equation is a relationship indicating dynamic equilibrium state of the river which is the result of river responses to different natural or artificial effects. So, it is justified to expect that each river has a unique flow resistance relationship at each reach for a definite time span. This relationship might be changed in long or short-term spans as a result of river responses to variations.

Since it is difficult to find a specific flow resistance formula, universally accepted for each river site, it is logical to compare the results obtained from different approaches and categorize the formulas on account of their validity and applicability limits for each river type into different groups.

In this paper 12 different empirical resistance coefficients expressed in terms of Manning's roughness are applied apiece in 17 known compositing methods. The data gathered from 10 different cross sections of Sefidrood River, north of Iran, are selected for comparisons. The cross-sections are chosen from a reach downstream of the Manjil dam. The Sefidrood river basin is located in Guilan province and its branches stem from Alborz-mountains and continues downstream where it reaches the Caspian Sea. Morphological investigation of the selected reach clears that the river bed is covered by particles in the range of gravel and no obvious bed form is observed.

3. Selected Formulas and Methods:

The resistant formulas used in this paper are tabulated in Table 1.

The Cowan's proposed relationship to ac

count for channel non-uniformity and flow disturbances is also used in the following form (Arcement, Schneider 1989):

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m \quad (13)$$

Where

n_b=basic n value

n_1=addition for surface irregularities

n_2=addition for variation in channel cross section

n_3=addition for obstructions

n_4=addition for vegetation

m=ratio for meandering

Also 17 compositing formulas as in Table 2 are used to account for irregularities of channel cross-sections.

Table 2. Equations for Compound or Composite Channel Resistance Coefficient

	Assumptions		
Eqs. n_c	Concept	Equation	Reference
$A = \frac{\sum n_i A_i}{A}$	Sum of component n weighted by area ratio; or Total shear velocity is weighted sum of subarea shear velocity	$\sqrt{gRS} = \sum\left(\frac{P_i}{P}\sqrt{gR_iS_i}\right)$ $(V_i / V) = (R_i / R)^{7/6}$	U.S.Army Corps of Engineers Los Angeles District Method See Cox (1973)
$B = \sqrt{\sum n_i^2 \frac{A_i}{A}}$	Total resistance force is equal to sum of subarea resistance forces; or , n_i weighted by $\sqrt{A_i}$	$P\gamma RS = \sum P_i \gamma R_i S_i$ $(V_i / V) = (R_i / R)^{4/3}$	Cox (1973)
$C = \frac{A}{\sum (A_i / n_i)}$	Total discharge is sum of subarea discharges	$Q=VA=\sum(V_iA_i)=\sum Q_i$ $(S_i / S)=(R/R_i)^{4/3}$	Cox (1973)
$D = \left[\frac{\sum (n_i^{3/2} A_i)}{A}\right]^{2/3}$	Same as Horton and Einstein 's Eq. E but derived erroneously	$V = V_i$ $A = \sum A_i, S = S_i$	Colebatch (1941)
$E = \left[\frac{1}{P}\sum (n_i^{3/2} P_i)\right]^{2/3}$	Total cross sectional mean velocity equal to subarea mean velocity		Horton (1933) Einstein (1934)
$F = \frac{P}{\sum (P_i / n_i)}$	Total discharge is sum of subarea discharge	$Q = \sum Q_i$ $(S_i / S) = (R / R_i)^{10/3}$	Felkel (1960)
$G = \left[\frac{1}{P}\sum (n_i^2 P_i)\right]^{1/2}$	Total resistance force, F, is sum of subarea resistance forces, $\sum F_i$	$P\gamma RS = \sum P_i \gamma R_i S_i$ $(V_i / V) = (R_i / R)^{1/6}$	Pavlovskii (1931)
$H = \frac{\sum (n_i P_i)}{P}$	Total shear velocity is weighted sum of subarea shear velocity; or, contributing component roughness is linearly proportional to wetted perimeter	$\sqrt{gRS} = \sum\left(\frac{P_i}{P}\sqrt{gR_iS_i}\right)$ $(V_i / V) = (R_i / R)^{1/6}$ $nP = \sum (n_i P_i)$	Yen (1991)

Table 2. Equations for Compound Continues

$I=\left[\frac{R^{1/3}}{P}\sum\frac{n_i^2 P}{R_i^{1/3}}\right]^{1/2}$	Total resistance force, F, is sum of subarea resistance forces	$P\gamma RS=\sum P_i\gamma R_i S_i$ $(V_i/V)=1$	
$J=\left[\frac{\sum n_i^2 P_i R_i^{2/3}}{PR^{2/3}}\right]^{1/2}$	Total resistance force, F, is sum of subarea resistance forces	$P\gamma RS=\sum P_i\gamma R_i S_i$ $(V_i/V)=(R_i/R)^{1/2}$	
$K=\frac{PR^{7/6}}{\sum\frac{P_i}{n_i}R_i^{7/6}}$	Total discharge is sum of subarea discharge	$Q=VA=\sum(V_i A_i)$ $(S_i/S)=(R/R_i)$	
$L=\frac{PR^{5/3}}{\sum\frac{P_i R_i^{5/3}}{n_i}}$	Total discharge is sum of subarea discharge	$Q=VA=\sum(V_i A_i)$ $(S_i/S)=1$	Lotter (1933)
$M=\frac{\sum P_i R_i^{5/3}}{\sum\frac{P_i R_i^{5/3}}{n_i}}$	Same as Eq.I with modified of R	$Q=VA=\sum(V_i A_i)$ $(S_i/S)=1$	Ida (1960) Engelund (1964)
$N=\frac{\sum(n_i P_i/R_i^{1/6})}{P/R^{1/6}}$	Total shear velocity, $\sqrt{gRS}$ is weighted sum of subarea shear velocity	$\sqrt{gRS}=\sum\left(\frac{P_i}{P}\sqrt{gR_iS_i}\right)$ $(V_i/V)=1$	Yen (1991)
$O=\frac{\sum(n_i P_i R_i^{1/2})}{PR^{1/2}}$	Total shear velocity is weighted sum of subarea shear velocity	$\sqrt{gRS}=\sum\left(\frac{P_i}{P}\sqrt{gR_iS_i}\right)$ $(V_i/V)=(R_i/R)^{2/3}$	
$P=\frac{\sum(n_i P_i R_i^{1/3})}{PR^{1/3}}$	Total shear velocity is weighted sum of subarea shear velocity	$\sqrt{gRS}=\sum\left(\frac{P_i}{P}\sqrt{gR_iS_i}\right)$ $(V_i/V)=(R_i/R)^{1/2}$	Yen (1991)
$Q=\frac{AR^{2/3}}{\sum\left(\frac{A_i R_i^{2/3}}{n_i}\right)}$			W.A.Thomas, R.R. Copeland & D.N. McComas (2002)

4. Measured Data

To evaluate the empirical relations 10 different cross-sections of the Sefidrood River from a reach having a slope from 0.0016 to 0.01681 were chosen. Site investigations and morphological studies revealed that each cross section consists of a mobile bed and two lateral fixed banks. Table 3 shows the properties of the cross-sections.

5. Method of Analysis

Each cross section is divided to three subsections, consisting of the main channel and two side channels. The roughness coefficient of each sub section is calculated separately using empirical formulas, and the compound resultant roughness is evaluated by one of the mentioned compositing approaches. The measured discharge from each section is used for the assessment of the analytical method.

6. Comparison of the Results

The difference between calculated discharge from empirical formulas and field measurement is shown in (Fig.1).

The averaged measured discharge of the selected reach is 122.89(m3/s) and is shown by a horizontal line as a basis for comparison. As it is seen, each of the 12 common is applied in 17 compounding formulas. To compare the results more exactly, some of the compounding methods the results of which are comparably different from the measurements are omitted in (Fig.2).

According to this figure it seems that the total force approach in conjunction with all empirical formulas gives the most accurate result except for the Keulegan formula.

Comparison of the results obtained by the Keulegan formula in conjunction with other compounding approaches reveals that Keulegan formula is not appropriate for the selected river. The average Manning's coefficient calculated by different formulas of Table 1 applied in different compositing methods of Table 2 is illustrated in (Fig.3).

The discrepancy of the results obtained by "B-Compositing Method" from empirical formulas is remarkable.

The over-estimated result of "B Method" is shown in (Fig.1), in terms of the difference between calculated discharges and the measured ones. Comparing the difference between Manning's coefficient computed from Keulegan formula with the values obtained from other formulas (Fig.3) and discharges obtained from the same formulas (Fig.2) reveals that the discharges are more sensitive to the variations of Manning's n.

Tables 4, 5 and 6 show the number of calculated discharges by compositing methods In conjunction with empirical formulas for the main channel and Brownlie method (1983) for side channels that fall respectively below 5, 10, 20% variations versus the measured discharge.

Table 3. Properties of the cross-sections

Section	A(m^2)	P(m)	Radius(m)	Slope	Froude	Q(m^3/s)	V(m/s)
1	87.09	75.06	1.16	0.0016	0.43	122.98	1.59
2	98.85	69.03	1.431	0.0044	0.36	122.24	1.27
3	88.83	73.52	1.208	0.0048	0.42	122.98	1.22
4	82.70	95.67	0.864	0.0021	0.49	122.97	1.59
5	84.10	89.12	0.943	0.0033	0.47	122.95	1.39
6	87.96	77.71	1.131	0.0031	0.44	122.98	1.54
7	99.21	76.08	1.304	0.0023	0.35	122.93	1.27
8	97.71	66.54	1.468	0.0033	0.33	122.97	1.20
9	93.13	65.11	1.429	0.0063	0.37	122.98	1.32
10	68.92	92.93	0.741	0.0168	0.63	122.95	1.53

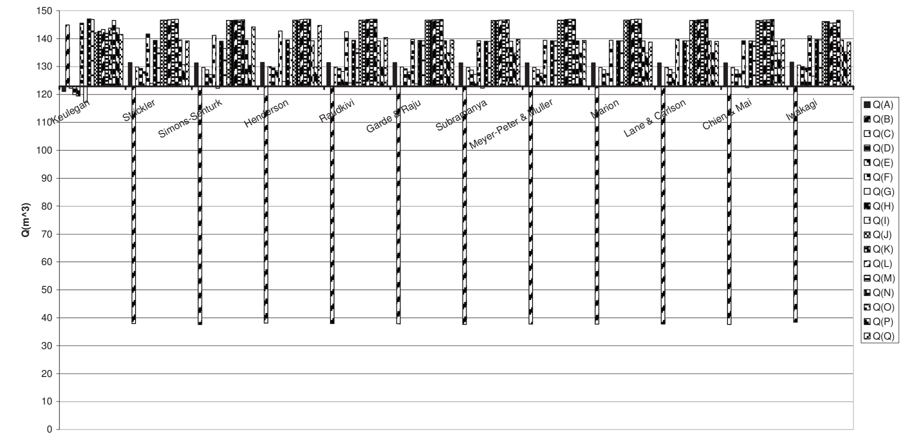

Fig.1: The difference between calculated discharge from empirical formulas and field measurement

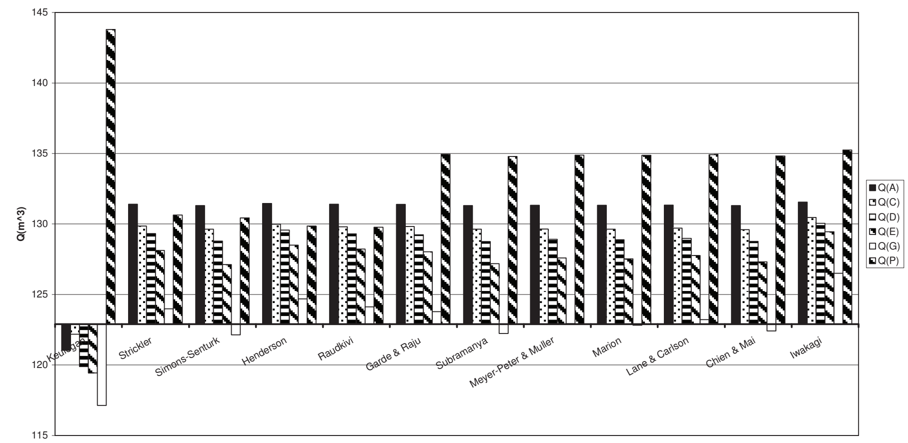

Fig. 2: The difference between calculated discharge from empirical formulas and field measurement

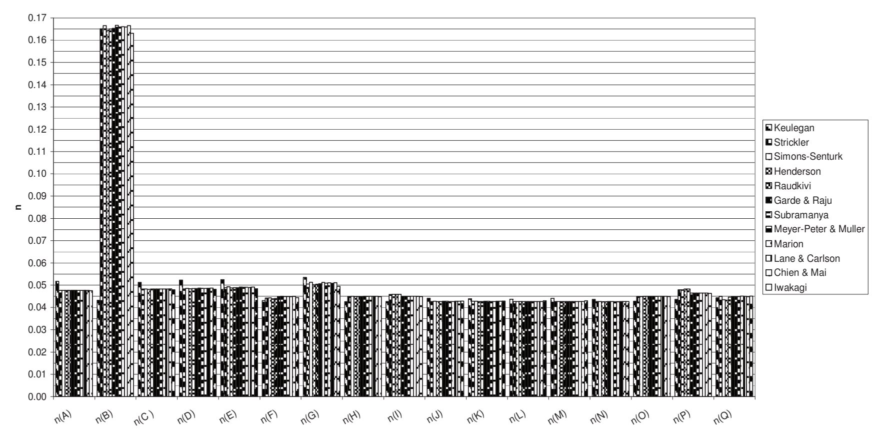

Fig. 3: The average Manning's coefficient calculated by different formulas

Table 4. The number of calculated discharges by compositing methods and Brownlie method for side channels that respectively have less than 5% variations with the measured discharge

Method	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Total
Keulegan	-	1	-	-	-	1	1	-	1	-	-	-	-	-	1	2	-	7
Strickler	1	-	1	2	2	-	3	1	1	-	-	-	-	-	1	2	-	14
Simons-Senturk	1	-	1	2	1	1	4	1	1	-	-	-	-	-	1	2	-	15
Henderson	1	-	1	1	2	-	1	1	1	-	-	-	-	-	1	2	-	11
Raudkivi	1	-	1	2	2	-	3	1	1	-	-	-	-	-	1	2	-	14
Garde-Raju	1	-	1	2	2	-	2	1	1	-	-	-	-	-	1	3	-	14
Subramanya	1	-	1	2	1	1	4	1	1	-	-	-	-	-	1	3	-	16
Meyer-Peter-Muller	1	-	1	1	1	1	3	1	1	-	-	-	-	-	1	3	-	14
Marion	1	-	1	1	1	1	3	1	1	-	-	-	-	-	1	3	-	14
Lane-Carlson	1	-	1	1	2	-	4	1	-	-	-	-	-	-	1	3	-	14
Chien-Mai	1	-	1	2	2	1	4	1	1	-	-	-	-	-	1	3	-	17
Iwakagi	1	-	1	1	2	-	1	1	1	-	-	-	-	-	1	3	-	12
Total	11	1	11	17	18	6	33	11	11	0	0	0	0	0	12	31	0	162

Table 5. The number of calculated discharges by compositing methods and Brownlie method for side channels that respectively have less than 10% variations with the measured discharge

Method	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Total
Keulegan	1	1	-	1	2	2	2	1	1	-	-	-	-	-	1	5	0	17
Strickler	2	-	1	4	5	2	9	1	1	-	-	-	-	-	1	3	0	29
Simons-Senturk	2	-	1	3	5	2	9	1	1	-	-	-	-	-	1	3	0	28
Henderson	2	-	1	3	4	2	9	1	1	-	-	-	-	-	1	4	0	28
Raudkivi	2	-	1	3	4	2	9	1	1	-	-	-	-	-	1	4	0	28
Garde-Raju	2	-	1	4	5	1	9	1	1	-	-	-	-	-	1	5	0	30
Subramanya	2	-	1	4	6	1	9	1	1	-	-	-	-	-	1	5	0	31
Meyer-Peter-Muller	2	-	1	4	6	1	9	1	1	-	-	-	-	-	1	5	0	31
Marion	2	-	1	3	4	1	8	1	1	-	-	-	-	-	1	5	0	27
Lane-Carlson	2	-	1	4	4	1	8	1	1	-	-	-	-	-	1	5	0	28
Chien-Mai	2	-	1	4	5	1	9	1	1	-	-	-	-	-	1	5	0	30
Iwakagi	2	-	1	3	4	2	8	1	1	-	-	-	-	-	1	5	0	28
Total	23	1	11	40	54	18	98	12	12	0	0	0	0	0	12	54	0	335

Table 6. The number of calculated discharges by compositing methods and
Brownlie method for side channels that respectively have less than 20% variations with the measured discharge

Method	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	To-tal
Keulegan	3	7	2	3	3	9	3	5	6	8	8	8	8	8	6	8	3	98
Strickler	10	-	9	10	10	8	10	8	6	8	8	8	8	8	6	7	10	134
Simons-Senturk	10	-	9	10	10	8	10	8	6	8	8	8	8	8	6	7	10	134
Henderson	10	-	9	10	10	6	9	8	-	8	8	8	8	8	7	7	10	126
Raudkivi	10	-	9	10	10	6	9	8	8	8	8	8	8	8	7	7	10	134
Garde-Raju	10	-	9	10	10	8	9	8	8	8	8	8	8	8	8	8	10	138
Subramanya	10	-	9	10	10	8	9	8	8	8	8	8	8	8	8	8	10	138
Meyer-Peter-Muller	10	-	9	10	10	6	9	8	8	8	8	8	8	8	8	8	10	136
Marion	10	-	9	10	9	6	9	8	8	8	8	8	8	8	8	8	10	135
Lane-Carlson	10	-	9	9	9	8	9	8	8	8	8	8	8	8	8	8	10	136
Chien-Mai	10	-	9	10	10	8	9	8	8	8	8	8	8	8	8	8	10	138
Iwakagi	10	-	9	10	10	4	10	6	6	9	9	10	10	8	8	8	10	137
Total	113	7	101	112	111	85	105	91	80	97	97	98	98	96	88	92	113	1584

7. Conclusion:

From the foregoing study the following conclusions are made:

1- The Keulegan formula used simultaneously with the Brownlie formula in different compositing methods results in highly over-estimated discharges, so it is not recommended in Sefidrood River.

2- The composing formulas represented by letters of “D”, “E”, and “G” illustrate the closest results respectively. Also, the results of methods shown by letters “J”, “K”, “L”, “M” and “N” have the maximum difference from field measurement.

3- In the comparison of empirical formulas identically, it is concluded that the Chien-Mai and Subramanya formulas in conjunction with the Brownlie approach have the best results respectively.

4- In addition to the above conclusions, authors propose the Meyer-Peter-Muller, Marion and Chien-Mai formulas as the best empirical formula and the “Total Force Approach” as the best compounding method for the present case study.

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