Shape parameters of the transverse cross-section of river beds

N Maalem¹ and O Kadirov¹

¹Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

yuvipper29@gmail.com

Abstract. The construction of hydrotechnical structures on rivers will require the establishment of the planned dimensions of sustainable supply and discharge rivers. The main goal of this work is to determine the parameters of a stable cross-sectional shape of the river channels of Algeria. The problem was solved using hydromorphological and probabilistic-static methods for determining the parameters of stable channels. Hydromorphological dependencies were established for tens of Algerian rivers between the relative width and water discharge and mainly feedback. Using the probabilistic-static method, the static parameters of the alignment curves were calculated (Sidi Bel Atar of the Shelef River $\beta_0 = 58.7$, $CV = 0.184$, $\xi = 5$, $CS = 0.92$, and also for $\beta_0 = 30.44$, $CV = 0.295$, $\xi = 4$, $CS = 1.18$. A comparison is made of the theoretical binomial security curve with the actually measured data and which are well approximated. An example of calculation by the proposed method for a specific alignment of the Algerian Shelef river is performed.

1. Introduction

When studying the process and hydromorphology of rivers and channels the assessment of the stability of their rivers is very important [1, 2].

The first assessment of the stability of riverbeds belongs to V. M. Lokhtin. As a criterion for the assessment of the stability of the riverbed, he recommended the ratio of the drop in water level per kilometer of the longitudinal slope to the weighted average size of bottom sediments i.e. $i/d$. He calculated the numerical values of this parameter for a number of river sections in Russia. [3]

Subsequently, Shoklich I. Y. Orlov and others. V. M. Lokhtin's criterion was given more General Form $H_i/d$, $H_i/p$, $d$, etc. The physical meaning of these relations means the ratio of the shear forces to the holding forces of bottom particles. Currently, the numerical values of these criteria for laboratory beds are proposed. For natural conditions, the numerical values of these criteria are variable. Therefore, at present, there are proposals to the assessment the stability of the channel by the value of the ratio of the channel width along the water edge to the average depth i.e. $B/H_{sr}$ [4]

This hydromorphological parameter is widely used to assess the stability of riverbeds and channels [5 – 8]. Several specific hydromorphological dependencies have been proposed for determining the values of the channel shape parameter $B/H_{sr}$ depending on the characteristics of the flow and soil of the channel. These studies relate to specific conditions, and new developments are required for the Algerian rivers.

Recently, when studying the channel shape parameter, they began to use the probabilistic-statistical method. A.F. Demyanenko. This technique was used to study the shape parameter of the Amu Darya riverbed [9].

Following this work, we tried to establish the laws of the probability of the distribution of the channel shape parameter for the Shelef and Bussalakh rivers.
2. Method

Field studies have been carried out for the conditions of Algerian rivers. Sections of the rivers on which long-term monitoring of morphological \( B/H \) and hydraulic parameters of rivers \( Q, V \) are conducted. Based on field data for each river section, graphs of the dependence of the channel shape parameter on the flow characteristics are constructed.

Using statistical data processing methods of mathematical statistics obtained values of the coefficients. Calculate the static parameters of the \( B_0, C_r, \) and \( C_s \) security curves as well and prove the applicability of the theoretical binomial security curve for the two sections of the Shelef and Busallah rivers. The security curve for field values of the channel shape parameter is approximated by a theoretical binomial law.

3. Results

Currently, the calculation of the cross-section shape parameter is mainly made by hydromorphological dependencies. Our studies of the hydromorphological characteristics of the channel, i.e. the width of the channel along the water edge and the average depth of the flow allow us to establish the following hydromorphological dependencies for calculating the shape parameter of the channel cross-section- \( \beta = B/H \):

Sli river, Ben Abdel Kadir section

\[
\beta = 47.66Q^{-0.08}
\]  (1)

Haddad river, Sidi Abdel Kader section

\[
\beta = 16.24Q^{0.078}
\]  (2)

Shelef river, Sidi Bel Atar section

\[
\beta = 71.05Q^{-0.18}
\]  (3)

Kebir West river, Ayn Sharpar section

\[
\beta = 46.97Q^{0.44} / (0.094 + 0.022Q + 0.037Q^2)
\]  (4)

Busallah river, Kudyat Tendart section

\[
\beta = 425.04Q^{-0.076}
\]  (5)

Ryumel river, Alatmaniya section

\[
\beta = 18.85Q^{-0.145}
\]  (6)

Ryumel river, Ayn Samara section

\[
\beta = 26.71Q^{0.05}
\]  (7)

Ryumel river, Grarem section

\[
\beta = 24.07Q^{0.023}
\]  (8)

Smandu river, Bushdira section

\[
\beta = 29Q^{0.03}
\]  (9)

Arrimal river, Alxang section

\[
\beta = 457.4Q^{-3.281}
\]  (10)

Resul river, Ayn Berda section

\[
\beta = (2.1 + 2.37Q + 0.16Q^2) / (0.08 + 0.27Q)
\]  (11)

Tafna river, Pir-Shata section

\[
\beta = 74.57Q^{0.249}
\]  (12)

The installation of these calculated hydromorphological dependencies allows calculating the values of the cross-section shape parameter for a given flow rate of the corresponding security.

By analyzing the values and the degree of these dependencies, it can be revealed that for the rivers of Algeria, there is a weak direct link \([10 – 13]\) and mainly an inverse relationship between the channel shape parameter and the water flow rate.
The feedback between the channel shape parameter and the water flow rate is explained by the trough-like shape of the cross-section with steep slopes. In such sections, the degree of change in the width of the water edge is less than the degree of change in the average depth. This feature of the cross-section shape is typical for Mountain Rivers [14 – 22].

The processing method is similar to the method of studying the flow characteristics of rivers. The channel shape parameters are shown in fig. 1 and fig. 2. graphs of the probability distribution. Studies were conducted for the Sidi Bel Otar section of the Shelif river (Fig. 1) and Kudyat Tendart section of the Busallakh river (Fig. 2).

![Figure 1. Graph comparing the theoretical curve of the security of the channel shape parameter with the observational data at the Sidi Bel Atar section of the Shelef River.](image)

We calculated the statistical parameters of the security curves $\beta_0$, $C_v$, and $C_r$. Then we investigated the applicability of the binomial distribution law.

$$\beta_p = (1 + F_r + C_r) \cdot \beta_0$$

(13)

Where: $\beta_p = B/H$ is the theoretically calculated value of the channel shape parameter;
$\beta_0$ is the norm of the channel shape parameter;
$F_r$ is the parameter of the theoretical curve determined depending on the accepted security- $P \%$.

The numerical values of the parameters of the theoretical curve were determined by statistical processing:

- for Sidi Bel Atar section of the river Shelef

$$\beta_0 = 58.7; \; C_v = 0.184; \; \zeta = 5; \; C_r = 0.92$$

- for Kudyat Tendart section of the river Busallakh

$$\beta_0 = 30.44; \; C_v = 0.295; \; \zeta = 4; \; C_r = 1.18$$

In figure 1 and 2 graphs of comparison of the theoretical binomial security curve with actually measured data are shown. From these graphs, it can be seen that the security curve of the actual values of the channel shape parameter is quite well estimated by the theoretical binomial law (13).
4. Discussion

Suppose that we know the type of hydraulic structure. According to the existing building norms and rules, we determine the capital class and, consequently, the percentage of water consumption security- $P\%$.

Setting the percentage of security $P\%$, using the theoretical curves of security costs, allows you to calculate the maximum and average annual water consumption.

Having determined the estimated water consumption by hydromorphological parameters the values (1-12) can be used to calculate the parameters of riverbeds. By setting the numerical values of the flow rate $Q$, the width of the water channel $B$, and the average depth, you can easily calculate the average flow Rate $V = Q/H$, $H$.

The established values of hydrological and hydromorphological characteristics of rivers are the basis for performing design work and construction or reconstruction of structures on rivers.

For example, a third-class barrier structure is planned to be built on the Shelef river near Sidi Bell Atar. According to SNiP P-17-65 this structure must be designed for a flow rate of 0.5 percent security.

Using the theoretical security curves of the maximum (Fig. 3) and the average annual (Fig. 4) expenses or use the formula to set the estimated expenses of the river. The values of these costs are equal – $Q_{\text{max}} = 3950 \text{ m}^3/\text{s}$ and $Q_{\text{av}} = 112 \text{ m}^3/\text{s}$

Figure 2. Graph of comparison of the theoretical security curve of the channel shape parameter with the observation data at Kudyat Tendart section of the Busallakh river.

Figure 3. Graph of comparison of the theoretical curve of security of maximum expenses with those observed in Sidi Bell Atar section r. Shelef.
According to the calculated formulas for the width of the water cut and the average depth flow the corresponding values of these parameters of the channel are calculated:

\[ B_{\text{max}} = 164.7 \text{ m}, \quad B_{\text{av}} = 60.72 \text{ m}, \quad H_{\text{max}} = 10.38 \text{ m}, \quad H_{\text{av}} = 2.02 \text{ m} \]

Then the values of the parameters of the channel shape and the average flow rate are calculated:

\[ \beta_{\text{max}} = 15.87, \quad \beta_{\text{av}} = 30.06, \quad V_{\text{max}} = 2.31 \text{ m/s}, \quad V_{\text{av}} = 0.91 \text{ m/s} \]

In this way, the main averaged characteristics of the flow and the channel that are necessary for calculating the main parameters of the projected channel are calculated.

The results obtained and the proposed recommendations allow us to set the necessary flow and channel parameters for other rivers as well.

![Graph of comparison of the theoretical curve of security of annual expenses with those observed in Sidi Bell Atar section r. Shelef.](image)

Note that our research is the first step in studying the hydromorphology of riverbeds and the continuation of the studies of the hydrological regime.

There is no doubt that research needs to be continued for other rivers in Algeria, and the results should always be adjusted for specific objects based on direct measurements.

Despite all this, the results we have obtained and the recommendations we have proposed are great scientific and practical interest when designing a project.

5. Conclusions

1. The hydrological regime of rivers in Algeria are investigated. The regularities of distribution of maximum and average annual water consumption are studied. It is found that the measured data are dealt in a good way with the binomial theoretical distribution law.

2. The applicability of the probability-statistical method for studying the parameter of the cross-section shape of the riverbed is considered. Based on the conducted research, it was found that the regularities of changes in the \( B/H \) are well approximated by the theoretical binomial law. The numerical values of their statistical parameters are determined.

3. The developed recommendations can serve as one of the scientific bases for designing various water management and transport facilities in Algeria, as well as for continuing similar studies in other basins.

4. The research made it possible to develop recommendations specific to the rivers of Algeria for calculating the maximum and average annual water consumption and the parameter of the cross-section of the riverbed of various resources. The results of studies of hydromorphological
characteristics of riverbeds allow us to calculate with high accuracy the average parameters of the flow and channel $B, H, V$ and other characteristics.

References

[1] Altunin S T 1962 Regulation of channels Moscow 352p
[2] Velikanov M A 1968 Channel processes Moscow 395p
[3] Lokhtin V M 1885 On the mechanism of the riverbed Kazan 76p
[4] Talmaza V F 1963 To the question of the transporting ability of the rivers of the mountain-foothill zone. Moscow A series of natural and technical sciences 3 pp27-51
[5] Annaev S A Aidov H A 1973 To the question of the formation of channel beds in sandy soils In the book. Dynamics and thermics of rivers pp267-275
[6] Velikanov M A 1958 Channel process Moscow 396p
[7] Glushkov V G 1925 Morphology of the river channel Proceedings of the I All-Union Hydrological Congress Leningrad
[8] Ismagilov H A 1978 Some hydromorphological dependencies of Central Asian rivers Reports of VASKHNIL 3 pp39-41
[9] Demyanenko A F 1988 A study of the work of bridge crossings in difficult hydraulic operating conditions Tashkent 24 p
[10] Maalem N 1993 Hydromorphological characteristics of the rivers of Algeria and recommendations for their design. Abstract of dissertation for the degree of candidate of technical sciences TIIAME, Tashkent 33p
[11] Hydrology of Africa 1978 Moscow 35-122
[12] Statistical Yearbook of Algeria 1961 Algeria 18p
[13] Padun N N 1974 Annual stock and water balance of Northern Algeria Abstract of the dissertation of the candidate of geographical sciences Moscow 21p
[14] Klibashev K P Goroshkov I F 1970 Hydrological calculations Leningrad 460p
[15] Kritsky S N Menkel M F 1981 Hydrological basics of river flow management Moscow 255p
[16] Antropovsky V I Denisova I V Izotov A B 2005 Hydrological and morphological direction of research of channel processes Proceedings of the Russian State Pedagogical University named after And. I Herzen: Natural and exact sciences St. Petersburg 5 (13) pp233–241
[17] Kiselev D V Zemtsov V A 2011 Hydromorphological dependences for the rivers of the Tomsk region Earth Sciences pp169-173
[18] Lepikhin A P 2015 On the problem of constructing hydromorphometric dependencies for alluvial channels Geographical Bulletin 3 (34) pp115-125
[19] Antropovsky V I 2006 Hydrological and morphological patterns and background forecasts of the reformation of river channels St. Petersburg 216p
[20] Bazarov D R 2000 Scientific justification of new numerical methods for calculating channel deformations of rivers the channel of which is composed of easily eroded soils Thesis for the degree of Doctor of Technical Sciences
[21] Bazarov D R, Vokhidov O F, Lutsenko L A and Sultanov S 2019 Restrictions Applied When Solving One-Dimensional Hydrodynamic Equations In: Proc. EECE 2019, Lect. Notes Civ. Eng. 70. pp 299–305
[22] Bazarov D R and Mavlyanova D A 2019 Numerical studies of long-wave processes in the reaches of hydrosystems and reservoirs Mag Civ Eng 87 123 doi: 10.18720/MCE.87.10