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# Study of Side Wall Deformation in Irrigation Channels

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**Abstract:** The article analyzes existing methods and approaches to hydraulic calculation of the process of deformation of lateral slopes of irrigation canals with a soil channel. Also, using the example of the Amu-Bukhara and Karshi main canals with a connected soil channel, cases of bank deformation and transverse velocity distribution are presented. Our observations have shown that existing methods do not fully take into account the uneven distribution of test stress values due to the uneven distribution of flow velocities on the surface of the live section.

**Keywords:** open channels, bank deformation, shear stress, flow velocity distribution, permissible velocities

## INTRODUCTION

The main task of designing stable channels with and without lining is to ensure that the maximum shear stress at the bottom and flow boundary observed at the calculated water flow rate does not exceed the permissible critical shear stress for the channel bed material, and to select the type of bed lining accordingly [1].

Currently, there are more than 196,000 kilometers of irrigation canals in our Uzbekistan, and sediment deposition is being observed in the beds of earthen canals, such as the Mirishkor and Karshi main canals, while intensive bank erosion is being observed in some sections of the Amu-Bukhara machine canal, Figure 1.

The existing methods for calculating stable channels around the world can be conditionally divided into two groups. The methods in the first group calculate dynamic stable channels using empirical formulas based on regime theory, while the methods in the second group are based on the concepts of permissible shear stress and velocities, and minimum energy dissipation to determine the static stability of the channel cross-section.

## LITERATURE REVIEW

In our republic, the method of permissible velocities is used according to the construction norms and rules (SNHQ 2.06.03-12), and according to this method, when designing channels, the average velocity in the channel should be between maximum and minimum permissible velocities:

$$\vartheta_{\min.p.} < \vartheta < \vartheta_{\max.p.} \quad (1)$$

According to construction norms and rules, the values of the maximum permissible velocities for different bed materials of open canals are based on the methodology and experiments of S.Ye. Mirskhulava, which provides permissible velocity values for cohesive sediment materials, [2, 10, 11].

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**Figure 1. The condition of the right bank erosion of the Amu-Bukhara Machine Canal at PK 950 station**

If the shear stress $\tau_0$ acting on the sediment particles that make up the alluvial bed material through which water flows is less than a certain critical value $\tau_{cr}$, the flow cannot move these particles. For the washing process to start, the relative tractive force must be greater than one [3, 12].

$$\eta_* = \frac{\tau_0}{\tau_{cr}} > 1.$$

where $\tau_{cr}$ - critical shear stress, $N / m^2$

$\tau_o$ - boundary shear stress, $N / m^2$

Due to the large difference between the properties of cohesive and non-cohesive sediments located on the channel sidewall, their mass erosion due to fluvial erosion occurs differently.

When testing the side walls of a channel with cohesive soil bed for scour resistance, it is necessary to accurately know the distribution of the shear stress value along the wetted perimeter and the critical value of the shear stress for the side wall.

When calculating the resistance of the channel side walls to scour, the distribution of flow velocities along the channel cross-section and, accordingly, the distribution of shear stress at the boundary between the flow and the bed material depends not only on the shape of the channel cross-section, but also on the curvature of the channel in plan. The flow structure changes in the curved sections of the channel, and the greater the curvature, the greater the likelihood of transverse flows. When the flow enters the bend, centrifugal forces direct the faster moving surface flows to the outer convex bank, and the slower moving flow near the bottom to the inner bank [4].

It can also be concluded from the formulas provided by Rozovsky, Engelund, and Kikkawa that as the ratio of channel width to flow depth $B / h$ increases, the transverse flows in the channel bend section decrease significantly.

In order to prevent the influence of these transverse flows on the flow in the channel from increasing, according to the construction planning norms and rules currently in force in our republic "Irrigation systems. Design norms" - SHNQ 2.06.03-12, the size of the radius of canal bends should not be less than five times their width at the water level [2]. Nevertheless, bank deformation is observed even in trapezoidal earthen canals built on the basis of these rules, Figure 1.

In non-cohesive embankments, the resistance to scour increases faster than the shear stress with depth, so critical conditions occur at shallow depths. In cohesive embankments, the shear stress increases faster than the resistance to scour with depth. As a result, critical points of massive failure occur in the deeper parts of such embankments [4, 5].

Also, the critical shear stress $\tau_{cr}$ for the channel sidewall is much smaller than the critical shear stress at the bottom of the channel due to the additional gravitational force of the sediment particle acting down the side slope of the trapezoidal channel. Because the gravitational force component acting on the particle on the bank contributes to the hydrodynamic force of the flow that causes the start of the sediment motion [1, 6].

Therefore, it is appropriate to consider the lower half of the channel side wall in terms of depth or the side wall section closest to the bed where the maximum flow velocity is observed as the part of the channel bed with a cohesive soil bed that is prone to erosion, and we believe that there is no need to perform calculations for other verticals along the channel cross-section.

## RESULTS AND DISCUSSION

Erosion under the influence of current is one of the main causes of massive erosion on the banks due to the displacement of sediment particles on the surface of the side walls. Therefore, hydraulic calculations are performed to prevent the side walls of channels with soil beds from being washed out under the influence of currents. The object of our study is the Amu-Bukhara machine channel, the side walls of which are mainly composed of cohesive soils, Table 1.

**Granular composition of soil particles in the Amu-Bukhara machine canal bed**

**Table 1**

| Sample location | The percentage of all fractions (mm), in % | | | | | | **Total** | $D_{10}$ | $D_{30}$ | $D_{50}$ | $D_{60}$ | Heterogeneity coefficient $Cu = \frac{D_{60}}{D_{10}}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0,5>-0,25 | 0,25-0,10 | 0,10-0,05 | 0,05-0,01 | 0,01-0,002 | <0,002 | | | | | | |
| PK 1202+00 | 0,3 | 6,0 | 16,6 | 32,5 | 39,4 | 5,2 | 100,0 % | 0,00297 | 0,00704 | 0,0166 | 0,0290 | 9,73 |
| PK 1201+00 | 0,6 | 8,2 | 18,6 | 36,2 | 34,1 | 2,3 | 100,0 % | 0.00381 | 0,00850 | 0,02503 | 0,03608 | 9,48 |

Despite the fact that studies have been conducted by Olsen, Florey, Lane, and a number of other scientists to determine the distribution of the shear stress $\tau_0$ at the flow and bed boundary over the cross section in the study of the deformation of the cross section of channels with a soil bed, the results of these studies remain less convincing.

An example of a typical distribution of shear stress across a trapezoidal channel cross-section using the membrane analogy method by Olsen and Florey is shown in Figure 3 below [6].

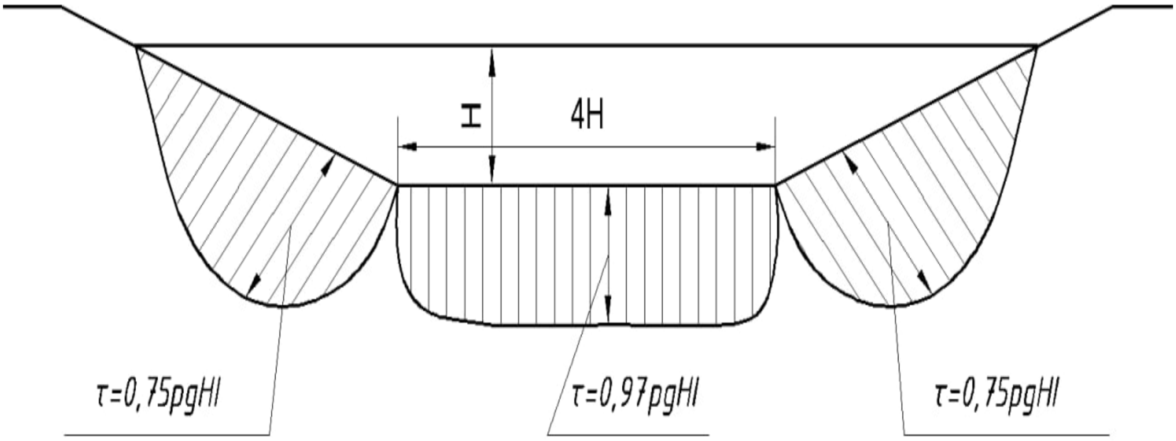


**Figure 3. Typical distribution of shear stress across the cross-section of a trapezoidal channel (adapted from Chow 1959)**

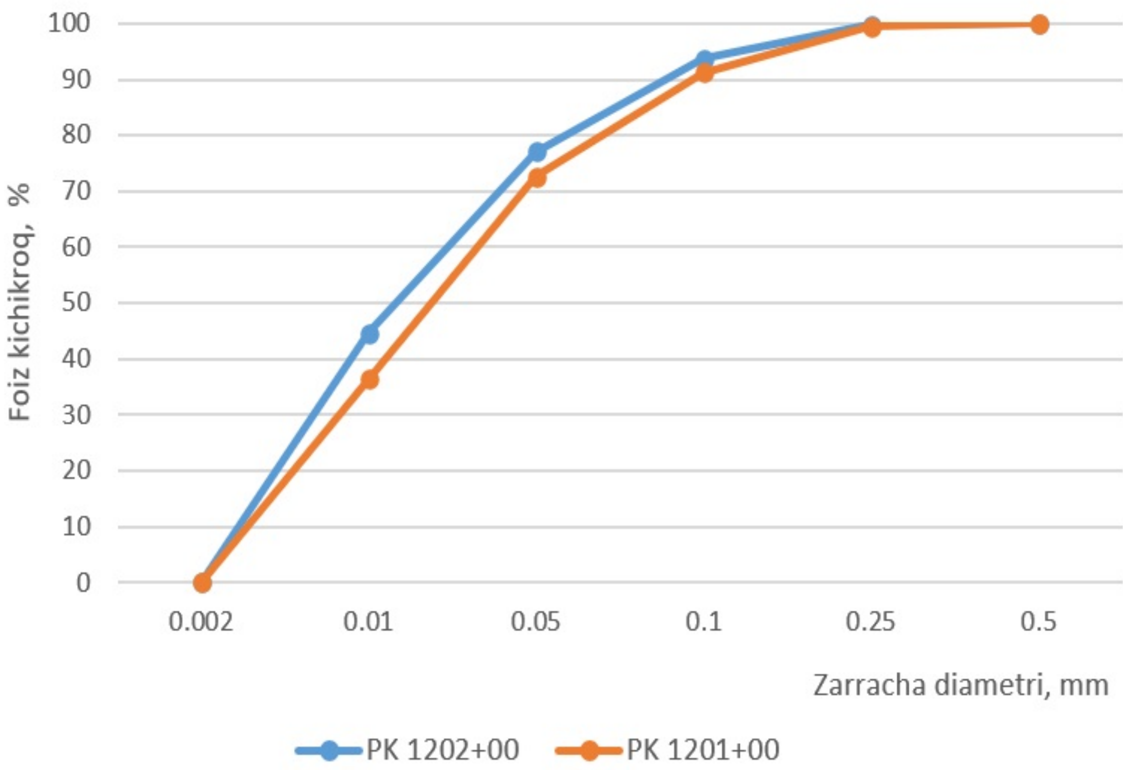


**Figure 2. Graph of cumulative fractional composition of soil particles in the Amu-Bukhara machine canal**

Many researchers (Engelund, Lundgren and Johnson, Knight, Shiono, Abril, etc.) have attempted to predict or measure the time-averaged boundary stress distribution along the wetted perimeter of channels of various shapes. These studies have been conducted mainly in laboratory conditions using rectangular, trapezoidal cross-sections for convenience.

According to Da Silva and Yalin, the logarithmic velocity distribution law gives generally good results over the entire depth, but it gives the most accurate results at a distance $0.15 \div 0.2h$ from the bed vertically [7].

In modeling with the HES-RAS program, when calculating the distribution of shear stress along the wetted perimeter, the cross-section surface area is divided into non-vertical zones - radial prisms. In this case, these radial prisms are bounded by lines perpendicular to the velocity isotachs (contours of velocities of the same value), and the hydraulic radius is calculated separately for each prism [8].

According to Kean (2001), if the channel bed and walls have the same roughness, then the bisector line that bisects the junction of the channel bottom and sidewall (the heel) is normal to the isotachs [8, 9].

Therefore, the first step in determining the radial distribution of shear stress using isotachs is to find the line bisecting the sidewall. Radial prisms are created for each point on the channel sidewall and the hydraulic radius $R_i$ is calculated for each prism [8].

However, the following main disadvantages of determining the flow velocity and shear stress distribution along the channel cross-section by constructing isotaches exist:

1. Isotaches assume a smooth and continuous change between the measured velocities, but in reality the flow velocity may be completely unevenly distributed along the cross-section.
2. In earthen channels with a complex cross-sectional shape and a variable channel bottom slope, isotaches cannot accurately represent the cross-sectional distribution due to the change in the direction of the velocities.
3. In the variant proposed by Kean, the core of the flow, where the maximum velocities are observed, is located near the water surface and in the center of the cross-section. In fact, numerous measurements using acoustic Doppler velocimeters in irrigation channels in the Bukhara and Kashkadarya regions made it possible to observe that the location of maximum flow velocities are in two or more places and is unevenly distributed.
4. Even a very small angle of inclination of the channel in the plan leads to a shift of the location of the maximum flow velocity from the center of the cross-section. In addition, the change in the direction of the flow velocities in the channel, which has not been studied so far, due to the movement of the Earth around its axis, and the location of the channel in different positions and flow directions, such as from south to north or from north to south, leads to an uneven distribution of velocities across the cross-section.

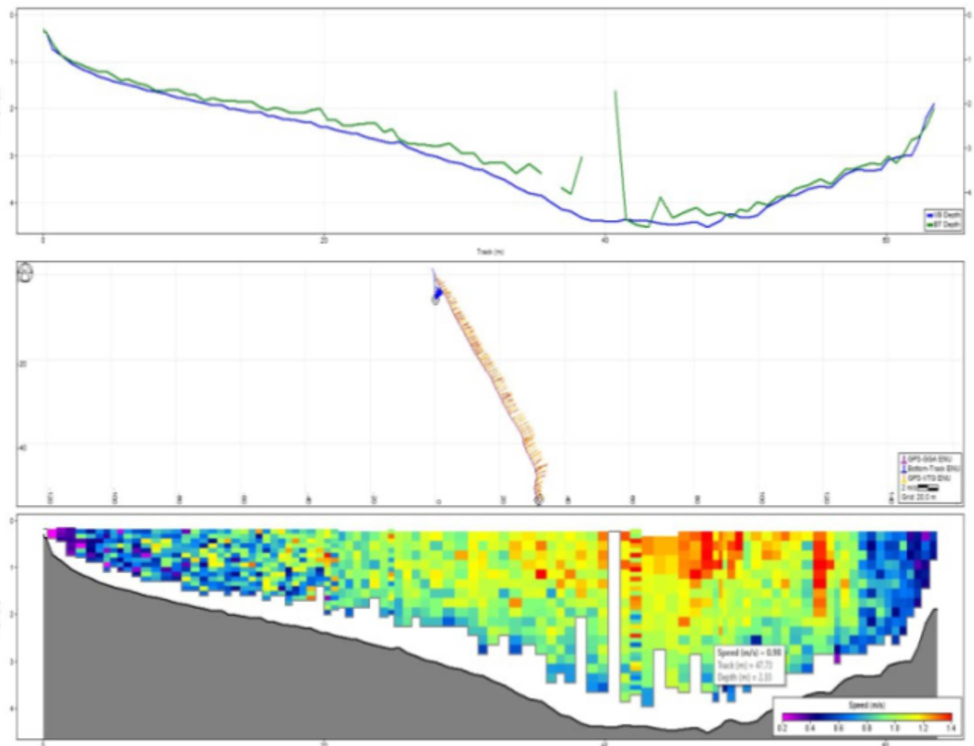

**Fig. 5. Data from the River TB-5M acoustic Doppler profilometer at PK 1201 station of the Amu-Bukhara Machine Canal**

These complexities indicate that not only the idealistic method proposed by Kean, but also other analytical methods for determining the stress distribution of the embankment, do not provide accurate results for earthen channels with complex geometries.

The method of calculating the hydraulic radius values for each section by dividing the cross-sectional area graphically was first proposed by Keulegan in 1938, in which the section was divided into three sections using a bisector drawn from the lower corner of the polygonal channel. However, the reason for choosing the bisectors to draw the line dividing the section into sections was not sufficiently justified.

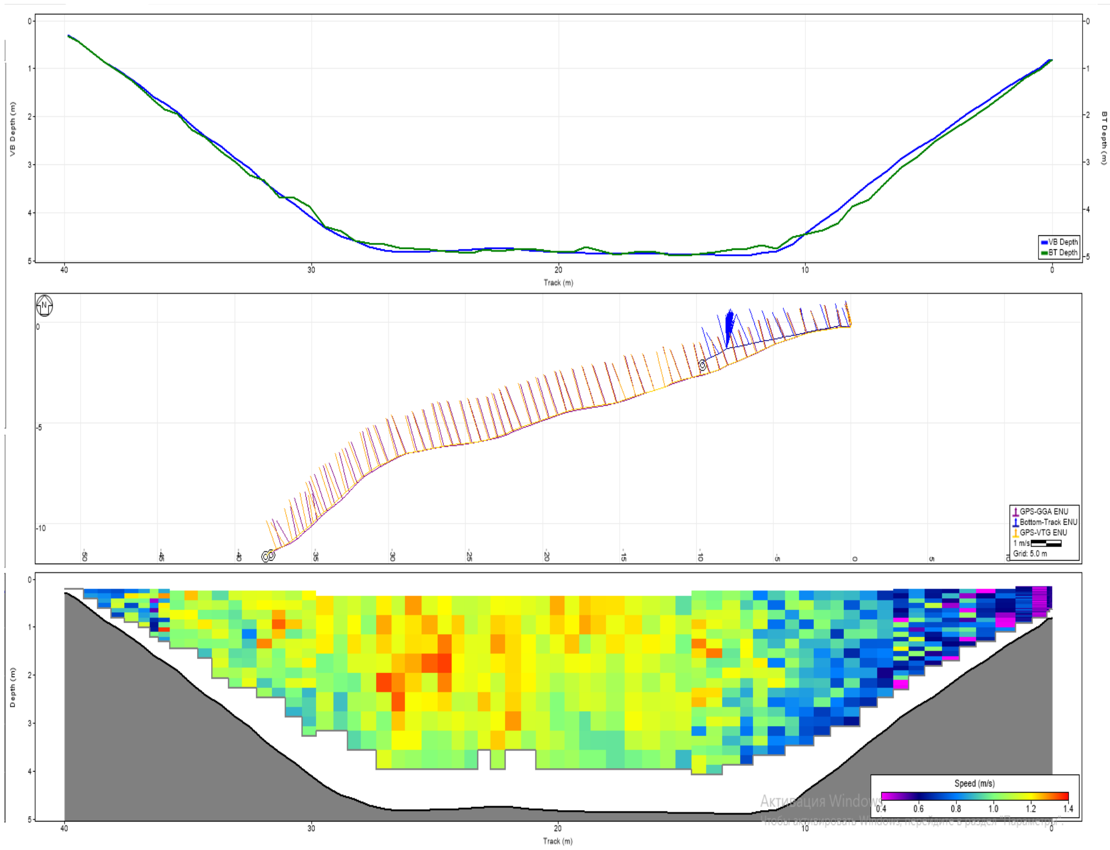


**Figure 6. River TB-5M acoustic Doppler profilometer data at PK 178 station of the Karshi main canal**

In 1942, Einstein proposed a method of dividing the cross-section of a polygonal channel into lines drawn taking into account the channel side walls and flow velocity isotachs, Figure 7. In this case, it was assumed that there were separate average velocities in each section, which made it possible to calculate the stress on the channel side walls using separate hydraulic radius values in each section.

Despite the fact that the Einstein method allows for the separate calculation of the shear stress values for the channel side walls, the results of our field measurements show that the flow velocities are unevenly distributed over the live cross-sectional area, resulting in an uneven distribution of shear stress values (Figures 5-6). This indicates the need to improve the methods proposed by Einstein and Keulegan.

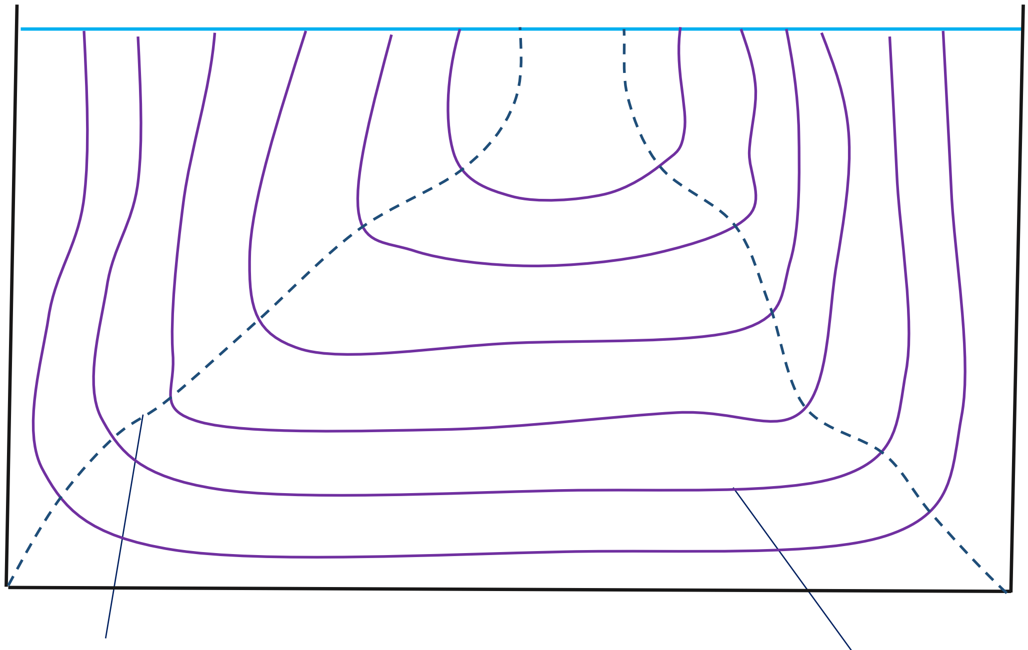


**Figure 7. Einstein's method of dividing the cross-sectional area of a flow**

## CONCLUSION

It should be noted that the current situation in the Amu-Bukhara machine channel shows that it is not enough to take only the average flow velocity in the bed as the main criterion in calculations to ensure that bed deformations do not occur due to scouring in the open bed cross-section. Because, the distribution of flow velocities along the channel cross-section, the shear stress and shear velocity at the boundary between the flow and bed material, as well as the slope of the side walls, the shape of the cross-section (ratio of bed width to depth), etc. also play an important role in the scouring of the channel bed, especially the side walls.

Bundan tashqari kanal yon devor qiyaligi darajasi, oqim tarkibidagi muallaq oqiziqlar xususiyati, o'zan materialining xususiyati, qirg'oqdagi vegetatsiyaning, grunt suvlarining, ekspluatatsiya jarayonining yon devor yuvilishiga ta'siri mavjudligini ham e'tirof qilgan holda kanal yon devorlarida oqim ta'sirida yuvilish hisobiga deformatsiya jarayonini Amu-Buxoro mashina kanali sharoitida qirg'oqlar deformatsiyasining dastlabki va asosiy sababchisi ekanligini ko'rsatdi. Bunda oqim ta'sirida qirg'oqlar yuvilishi hisobiga ularning qiyalik koeffitsiyentlari kamayishi natijasida qiyaliklar yanada tikroq bo'ladi va qirg'oqning massiv o'pirilish hodisasi kuzatiladi.

In addition, recognizing the influence of the slope of the channel side wall, the nature of suspended solids in the stream, the nature of the bed material, the vegetation on the bank, groundwater, and the operation process on the side wall erosion, it was shown that the deformation process of the channel side walls due to erosion under the influence of the stream is the initial and main cause of the deformation of the banks in the Amu-Bukhara Machine Canal. In this case, as a result of the decrease in the slope coefficients of the banks due to erosion under the influence of the stream, the slopes become steeper and a massive erosion of the bank is observed.

Existing methods for studying bank deformation, which is considered a complex hydraulic process, have shown that the uneven distribution of flow velocities over the cross-section area in natural field conditions, and consequently the uneven distribution of shear stress values, are not fully taken into account.

In addition, we believe that it is appropriate to consider the lower half of the channel side wall in terms of depth or the side wall section closest to the bed where the maximum flow velocity is observed as the part of the channel bed with a cohesive soil bed that is prone to erosion and that there is no need to perform calculations for other verticals along the channel cross-section.

**LITERATURE**


1. Sturm, T. W. (2001). Open channel hydraulics (Vol. 1, p. 1). New York: McGraw-Hill.
2. SHNQ 2.06.03-12. "Irrigation systems. Design standards". Davarkhitektqrulish of the Republic of Uzbekistan. Tashkent, 2012. 120 pages
3. Da Silva, A. M. F., & Yalin, M. S. (2017). Fluvial processes. CRC Press
4. Garcia, M. (Ed.). (2008, May). Sedimentation engineering: processes, measurements, modeling, and practice. American Society of Civil Engineers.
5. Terzaghi, K., Peck, R. B., & Mesri, G. (1996). Soil mechanics in engineering practice. John wiley & sons.
6. Te Chow, V. (1959). Open channel hydraulics.
7. Da Silva, A. M. F., & Yalin, M. S. (2017). Fluvial processes. CRC Press.
8. HEC-RAS USDA-ARS Bank Stability & Toe Erosion Model (BSTEM), Technical Reference & User's Manual.
9. Kean, J. W., & Smith, J. D. (2000). Computation of Sediment Erosion from the Base of Cut Banks in River Bends. V. Processes, 31.
10. Eshev, S., Linkevich, N., Rahimov, A., Khazratov, A., Mamatov, N., & Sharipov, E. (2023, March). Calculation of its dynamically stable cross-section in the steady motion of the channel flow. In *American Institute of Physics Conference Series* (Vol. 2612, No. 1, p. 050007).
11. Khazratov, A. N., Bazarov, O. S., Jumayev, A. R., Bobomurodov, F. F., & Mamatov, N. Z. (2023). Influence of cohesion strength in cohesive soils onchannel bed erosion. In *E3S Web of Conferences* (Vol. 410, p. 05018). EDP Sciences.
12. Eshev, S., Rahmatov, M., Khazratov, A., Mamatov, N., Sagdiyev, J., & Berdiev, M. (2021). Critical flow velocities in cohesive saline soils. In *E3S Web of Conferences* (Vol. 264, p. 03071). EDP Sciences.