

Determining the Shezi Coefficient Under Regulated Water Flow Conditions

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DOI:

<https://doi.org/10.47134/scbmej.v3i1.5231>

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Received: 16-11-2025

Accepted: 23-12-2025

Published: 02-01-2026



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Abstract: In the lower reaches of the Amu Darya River, the hydraulic regime has been significantly transformed under regulated flow conditions. The determination of the Chezy coefficient plays a crucial role in analyzing the kinematics and hydraulic resistance of the river flow. Based on field data obtained from Tuyamuyin, Kipchak, Niyetbaytas, Samanbay, and Kiziljar hydroposts, empirical relationships between the Chezy coefficient, discharge, and morphological parameters were developed. The analysis revealed that conventional formulas proposed by Manning, Forchheimer, Pavlovskiy, Agroskin, and Jeleznyakov showed considerable deviations under regulated conditions due to nonuniform depth distribution and increased roughness coefficients. The derived relationship for the lower Amu Darya provides improved accuracy in estimating the Chezy coefficient compared to classical methods. This approach enhances hydraulic computations and offers a practical basis for riverbed regulation and hydraulic design in managed flow conditions.

Keywords: Amu Darya River; Regulated Flow; Chezy Coefficient; Hydraulic Resistance; Empirical Relationship; Morphological Parameters.

Introduction

Regulation of river flow by reservoirs and hydraulic structures significantly alters the hydraulic and hydromorphological characteristics of river channels, especially in downstream reaches. Such regulation affects channel geometry, depth distribution, flow velocity, and hydraulic resistance, thereby influencing the reliability of hydraulic calculations. Under these conditions, the accurate determination of flow resistance parameters becomes critically important for river engineering analysis and design (Altunin, 1965; Jeleznyakov & Danilevich, 1966).

In hydraulic practice, the Chezy coefficient is widely used to characterize flow resistance and velocity distribution in open channels. Classical approaches proposed by Manning, Forchheimer, Pavlovskiy, Agroskin, and Zheleznyakov were primarily developed for natural, unregulated river conditions and assume relatively stable channel roughness. However, in regulated rivers such as the lower reaches of the Amu Darya River, non-uniform depth distribution, channel deformation, and dynamically changing roughness significantly reduce the accuracy of these traditional formulas.

The main objective of this study is to develop an empirical relationship for determining the Chezy coefficient under regulated water flow conditions in the lower reaches of the Amu Darya River. The study focuses on analyzing the dependence of the Chezy coefficient on discharge, average flow depth, and channel slope based on field observations. In addition, the proposed relationship is evaluated through comparison with commonly used classical formulas to assess its reliability and applicability.

The significance of this research lies in improving the accuracy of hydraulic calculations for regulated river systems. A more reliable estimation of the Chezy coefficient enables better prediction of flow velocity and hydraulic resistance, which is essential for the design of river training structures, bank protection measures, and water management projects. The results of this study provide practical benefits for engineers and researchers involved in river regulation and hydraulic infrastructure planning (Mirzaev et al., 2023).

Previous studies emphasized the close relationship between river flow kinematics and channel morphology, highlighting the limitations of classical hydraulic formulas under changing flow regimes (Altunin, 1965; Jeleznyakov & Danilevich, 1966). Recent studies in the lower Amu Darya River basin have confirmed significant hydromorphological changes caused by flow regulation (Ibragimov et al., 2022).

Methodology

This study is based on field hydrometric observations and empirical analysis aimed at obtaining reliable estimates of the Chezy coefficient under regulated flow conditions. Hydrological and hydraulic data were collected from five representative hydroposts in the lower reaches of the Amu Darya River: Tuyamuyin, Kipchak, Niyetbaytas, Samanbay, and Kiziljar, which reflect different morphodynamic conditions of the regulated riverbed.

The collected parameters included water discharge, average flow depth, flow velocity, and channel slope. Discharge and flow velocity were measured using standard hydrometric techniques during different hydrological periods, while average depth was determined from cross-sectional measurements. The channel slope was calculated based on the observed water levels along the studied riverbanks.

The data were analyzed using statistical and regression methods to establish empirical relationships between the Chezy coefficient and key hydraulic parameters, particularly discharge and average flow depth. The reliability of the proposed relationship was assessed by comparing the obtained Chezy coefficient values with those calculated using classical formulas by Manning, Forchheimer, Pavlovsky, Agroskin, and Zheleznyakov. The differences between the results were interpreted in relation to uneven depth distribution and changes in channel roughness caused by regulated flow conditions.

Result and Discussion

The results of field observations in the lower reaches of the Amu Darya River showed that under regulated flow conditions, the Chezy coefficient changes systematically with water discharge and average flow depth. The obtained empirical relationships reflect the change in hydraulic resistance with increasing water discharge, which is associated with

uneven distribution of flow depths and deformation of the channel shape. This situation corresponds to the views of modern hydromorphodynamic theories on the interaction of flow and channel.

Based on the data of field studies, we obtained the following formula for the lower reaches of the Amu Darya:

$$C = \frac{V}{\sqrt{Hi}} \quad (1)$$

here C – Chezy coefficient

V – Average flow rate

H – Average flow depth

i – slope

All the empirical relationships obtained as a result of the analysis of the $V = f(Q)$ graphs in the Tuyamuyun, Kipchak, Nietbaytas, Samanbay, and Kyzylzhar hydroposes were expressed in the form of exponential functions, i.e.:

$$V = K \cdot Q^y \quad (2)$$

here Q – River discharge, m^3/s ;

K – proportionality coefficient;

y – exponent

Generalizing formulas (1) and (2), we obtain the following.

$$C = \frac{KQ^y}{\sqrt{Hi}} \quad (3)$$

When comparing the values of the Chezy coefficient obtained by formula (1) with the values of the existing formulas, a decrease in the results according to the formulas of Manning, F. Forchheimer, N.N. Pavlovsky, I.I. Agroskin, G.V. Zheleznyakov is explained by an increase in the roughness coefficient, taking into account the uneven distribution of depths along the width of the flow. Table 1.

Table 1. Comparison of the calculated Shezi (C) values obtained for the lower reaches of the Amu Darya River with existing formulas developed by scientists.

T/r	Actual water consumption Q_h (m^3/s)	Velocity by Formula 2 v (m/s)	Flow depth H , (m)	River bed width B , (m)	Channel slope i	Chezy coefficient C ($m^{0.5}/s$)	Channel roughness coefficient n	According to Manning		According to F. Forchheimer		According to N.N. Pavlovsky		According to I.I. Agroskin		According to G.V. Zheleznyakov	
								C ($m^{0.5}/s$)	Difference %	C ($m^{0.5}/s$)	Difference %	C ($m^{0.5}/s$)	Difference %	C ($m^{0.5}/s$)	Difference %	C ($m^{0.5}/s$)	Difference %
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
On the Tuyamuyun Hydropost																	
1	505	0,58	2,13	452	0,0002	32,62	0,039	28,86	-11,5	29,59	-9,3	30,92	-5,2	31,26	-4,2	30,30	5,0
2	1040	0,75	2,51	570	0,0002	38,69	0,035	33,05	-14,6	34,08	-11,9	35,20	-9,0	35,43	-8,4	34,54	4,5

3	1470	0,85	2,73	675	0,000 2	41,88	0,033	35,3 0	- 15, 7	36,5 0	- 12, 8	37,4 2	- 10, 6	37,5 9	- 10, 2	36,75	4,1
4	2080	0,96	3,31	709	0,000 2	42,94	0,032	38,4 0	- 10, 6	39,9 6	- 6,9	40,3 9	-5,9	40,6 7	- 5,3	39,88	3,8
5	2530	1,02	3,67	712	0,000 2	43,68	0,031	40,2 3	-7,9	42,0 1	- 3,8	42,0 4	-3,7	42,4 0	- 2,9	41,66	3,6
6	3000	1,09	3,98	734	0,000 2	44,52	0,030	41,8 4	-6,0	43,8 1	- 1,6	43,4 3	-2,4	43,8 6	- 1,5	43,18	3,2
7	3510	1,15	4,24	736	0,000 2	45,57	0,029	43,2 9	-5,0	45,4 2	- 0,3	44,6 6	-2,0	45,1 4	- 0,9	44,52	2,9
8	4110	1,21	4,44	726	0,000 2	47,06	0,029	44,6 7	-5,1	46,9 4	- 0,3	45,8 2	-2,6	46,3 1	- 1,6	45,76	2,4
9	4500	1,25	4,7	743	0,000 2	47,21	0,028	45,7 1	-3,2	48,1 3	1,9	46,6 4	-1,2	47,2 3	0,0	46,72	2,2
On the Kipchak Hydropost																	
1	501	0,67	2,58	295	0,000 1	38,25	0,034	34,6 3	-9,5	35,7 4	- 6,6	36,7 3	-4,0	36,8 6	- 3,6	36,03	4,0
2	1000	0,94	3,81	299	0,000 1	44,17	0,028	43,9 2	-0,6	45,9 3	4,0	45,3 9	2,8	45,4 4	2,9	44,89	2,2
3	1620	1,20	4,28	299	0,000 1	52,78	0,025	50,5 2	-4,3	53,0 3	0,5	51,2 0	-3,0	50,8 4	- 3,7	50,60	0,1
4	1980	1,32	4,79	300	0,000 1	55,05	0,024	54,1 3	-1,7	57,0 3	3,6	54,1 7	-1,6	53,7 5	- 2,4	53,66	- 0,9
5	2570	1,50	5,8	300	0,000 1	56,85	0,022	59,6 5	4,9	63,2 5	11, 3	58,4 0	2,7	58,0 3	2,1	58,21	- 2,4
6	3020	1,62	6,18	300	0,000 1	59,60	0,022	62,7 6	5,3	66,6 9	11, 9	60,8 7	2,1	60,3 5	1,3	60,68	- 3,3
On the Niyetbaytas Hydropost																	
1	507	0,55	2,67	270	0,000 1	32,25	0,029	40,2 8	24, 9	41,6 2	29, 1	42,0 5	30, 4	41,7 6	29, 5	41,18	2,2
2	1050	0,91	2,79	426	0,000 1	51,76	0,022	55,0 9	6,4	57,0 1	10, 1	55,7 6	7,7	54,3 3	5,0	54,30	- 1,4
3	1550	1,18	2,7	455	0,000 1	68,57	0,018	64,5 3	-5,9	66,7 0	- 2,7	64,4 0	-6,1	62,3 3	- 9,1	62,57	- 3,0
5	2010	1,41	2,7	506	0,000 1	81,82	0,016	71,9 7	- 12, 0	74,4 0	- 9,1	71,1 8	- 13, 0	68,6 4	- 16, 1	69,05	- 4,1
6	2510	1,64	3	550	0,000 1	90,28	0,015	80,4 1	- 10, 9	83,4 -	- 7,6	78,6 7	- 12, 9	75,4 1	- 16, 5	76,05	- 5,4
On the Samanbay Hydropost																	
1	586	0,79	1,9	435	0,000 1	57,51	0,023	47,9 9	- 16, 6	49,0 2	- 14, 8	48,9 2	- 14, 9	48,0 6	- 16, 4	47,88	- 0,2
2	1080	1,04	1,95	500	0,000 1	74,29	0,019	58,9 7	- 20, 6	60,3 0	- 18, 8	59,2 9	- 20, 2	57,9 0	- 22, 1	57,96	- 1,7
3	1540	1,21	2,47	513	0,000 1	77,16	0,017	68,9 6	- 10, 6	71,0 7	- 7,9	68,5 1	- 11, 2	66,2 7	- 14, 1	66,58	- 3,4
4	1990	1,36	2,57	527	0,000 1	84,68	0,015	75,5 4	- 10, 8	77,9 6	- 7,9	74,4 9	- 12, 0	71,8 1	- 15, 2	72,27	- 4,3
5	2560	1,52	2,81	570	0,000 1	90,47	0,014	83,3 2	-7,9	86,2 4	- 4,7	81,4 0	- 10, 0	78,0 9	- 13, 7	78,75	- 5,5
On the Kyzylzhar Hydropost																	

1	521	1,10	2,56	170	8E-05	76,79	0,018	63,6 7	- 17, 1	65,6 9	- 14, 5	63,6 4	- 17, 1	61,6 7	- 19, 7	61,87	- 2,8
2	1040	1,45	2,62	267	8E-05	100,0 8	0,015	78,6 4	- 21, 4	81,2 1	- 18, 9	77,2 8	- 22, 8	74,3 9	- 25, 7	74,92	- 4,7
3	1540	1,70	3,15	305	8E-05	106,7 9	0,013	91,2 3	- 14, 6	94,7 8	- 11, 2	88,2 5	- 17, 4	84,1 8	- 21, 2	85,05	- 6,8
4	2010	1,89	3,31	320	8E-05	115,8 9	0,012	99,6 4	- 14, 0	103, 69	- 10, 5	95,6 0	- 17, 5	90,8 3	- 21, 6	91,88	- 7,8
5	2550	2,07	3,6	372	8E-05	122,2 3	0,011	108, 52	- 11, 2	113, 25	- 7,3	103, 19	- 15, 6	97,5 1	- 20, 2	98,77	- 9,0
Minimum indicators						32,25		28,8 6	- 21, 4	29,5 9	- 18, 9	30,9 2	- 22, 8	31,2 6	- 25, 7	30,30	- 9,0
Maximum Indicators						122,2 3		108, 52	24, 9	113, 25	29, 1	103, 19	30, 4	97,5 1	29, 5	98,77	5,0
Arithmetic mean						64,05		58,1 9	-7,6	60,4 8	- 3,9	58,2 0	-6,5	56,9 4	- 7,9	56,88	- 0,9

As can be seen from Table 1, the errors between the formulas differed significantly. Therefore, it is recommended to use formula 1 to determine the Chezy coefficient under regulated water flow conditions of the Amu Darya River.

Conclusion

Using the derived empirical formulas for riverbed roughness and flow discharge, the calculated results were compared with actual flow measurements obtained in the lower reaches of the Amu Darya River. Comparison of Chezy coefficient values determined by the proposed approach with those obtained using classical formulas by Manning, Forchheimer, Pavlovsky, Agroskin, and Zheleznyakov revealed noticeable differences. These differences confirm that traditional methods, developed mainly for natural flow conditions, are less suitable for regulated river systems.

The analysis demonstrated that under regulated flow conditions, the newly developed empirical Equation (1) provides more accurate and reliable estimates of the Chezy coefficient. This finding highlights the importance of considering uneven depth distribution and dynamically changing channel roughness when assessing hydraulic resistance in regulated rivers.

The practical implications of this study are that the proposed empirical formula can significantly improve the accuracy of hydraulic calculations related to flow velocity, resistance, and channel behavior. Therefore, it is recommended for use in hydraulic engineering design, river training, and bank protection planning in the lower reaches of the Amu Darya River and similar regulated river systems.

For further research, it is recommended to apply the proposed approach to other regulated rivers to assess its wider applicability and further investigate the influence of sediment transport and channel deformation on the Chezy coefficient. Such studies would contribute to the development of more comprehensive hydraulic models for managed river environments.

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