ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 10 , October 2022

Calculation of the cross-section profile of a channel in steady flow of water

Sobir Samatovich ESHEV, Ashraf Rasul o'gli RAHIMOV, Alisher Normurodovich KHAZRATOV*, Samandar To'lqin o'gli ERKINOV

Professor, Department of "Hydraulics and hydraulic Structures", Karshi Engineering Economics Institute - Mustaqillik 225, Karshi city, Uzbekistan

Associate professor, Department of "Hydraulics and hydraulic Structures", Karshi Engineering Economics Institute - Mustaqillik 225, Karshi city, Uzbekistan

Associate professor, Department of "Hydraulics and hydraulic Structures", Karshi Engineering Economics Institute - Mustaqillik 225, Karshi city, Uzbekistan

Student, Department of "Hydraulics and hydraulic Structures", Karshi Engineering Economics Institute - Mustaqillik 225, Karshi city, Uzbekistan

ABSTRACT: The article presents the results of research conducted by the authors in laboratory and field conditions on the study of the cross-sectional profile of the Karshi main canal. Based on the results of the research, formulas were obtained for the calculation of dynamic cross-section profiles in the steady flow of water in the earthen channels. A comparison of the values calculated by the obtained formula with the data of laboratory and field conditions showed that they are close to each other.

KEYWORDS*:* dynamic stability of earthen channels, permissible flow velocity, cross-section of channels, deformation, earthen canal

I. INTRODUCTION

The main calculation of the earthen channel is to determine its geometric dimensions, which ensure its stable shape, in which irreversible deformations do not occur in a channel. We know that deformations in the channel have a negative impact on its stability, leading to a decrease in the flow capacity of the cross-section of the channel. There are the following methods to determine the stability of a canal cross-section: 1) the regime method; 2) the permissible velocity method; 3) the rational method. 4) the tractive force method [4,5,7,10,11,13,14].

We know that the shape of the cross-section of a canal affects the hydraulic processes of the flow in it. However, quantifying these effects presents many challenges.

Researchers have studied the shape of the riverbed in their work with research questions to assess its impact on flow capacity [1,2,3,6,8,9,12]. Most of them dealt only with the calculation of static stable channels but paid little attention to the calculation of dynamic stability of earthen channels.

II. METHODOLOGY

To study the process of formation of cross-sections of the river in the steady conditions of the flow in the canal, research was conducted in the laboratory of the Karshi Institute of Engineering and Economics. The first experiments

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 10 , October 2022

were conducted to study the deformation of the side slopes of the channel model in the steady flow regime at known water flows (Table 1).

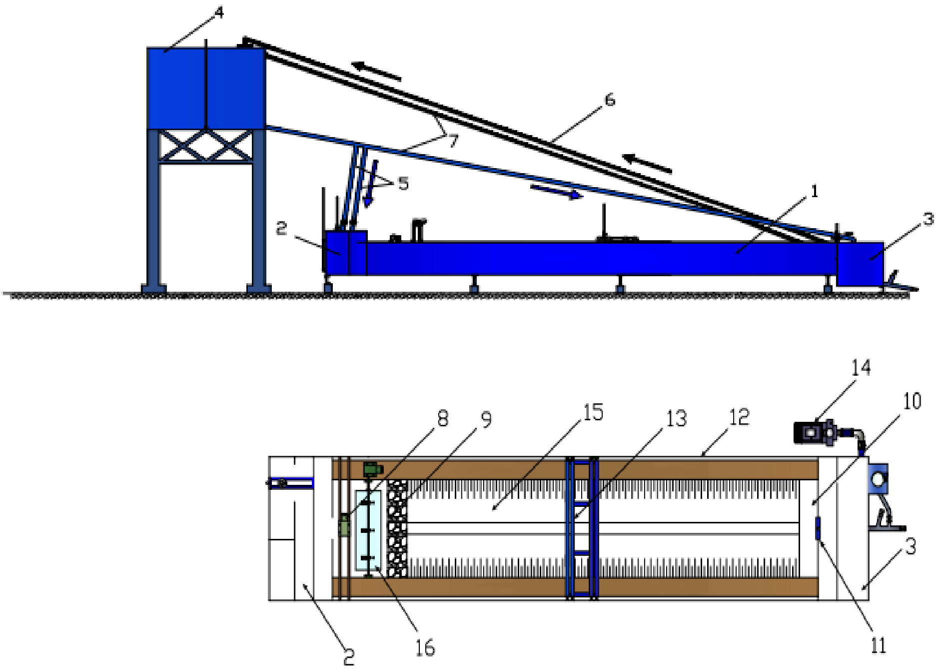

Figure 2. Scheme of the laboratory flume:

1–flume; 2 – transition part to flume; 3 – lower reservoir; 4 – upper reservoir; 5 – water supply pipe; 6 – water-lifting pipes to tank; 7 – drainage pipes; 8 – mixer; 9 – rocks; 10 – sediment trap; 11 – gate; 12 – metal rails; 13 – carriage; 14 – pumps; 15 – sand trapezoidal channel model; 16 – wave generating device.

Laboratory experiments were performed to determine the dynamic strength of the channel cross-section. Sands with an average diameter $d_{aver.}=0{,}47$ *mm* were used in the hydraulic flume, from which channel models with side slope coefficients $m=2{,}5$, $m=3{,}0$, and $m=3{,}5$ were constructed. The experiments were carried out at values of the channel model up to and above the permissible flow velocities. In the first experiments, the deformations of the cross-section of the channel under the influence of the steady flow of the channel were studied. The data of the conducted laboratory research are presented in Table 1.

The flow velocities in the central and lateral parts of the defined cross-sections were measured with a rotating current meter to study the kinematic characteristics of the water flow in the canal model [14].

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 10 , October 2022

Table 1: Calculation of the cross-section of the channel in the steady flow of water

Expt.#	Flow discharge, [l/s]	Side slope, y/H	Flow depth [m]	Average flow velocity [m/s]	Flow surface width [m]	Tangent of the angle of internal friction	Maximum flow depth [m]	Width of channel bed [m]	Flow depth [m]		
									Estimated	Measured	Relative error
1A	13.20	2.5	0.127	0.225	0.82	0.73	0.19	0.082	0.181	0.17	0.065
								0.164	0.154	0.15	0.027
								0.246	0.112	0.1	0.12
								0.328	0.059	0.05	0.18
								0.41	0.015	0.01	0.5
2A	14.05	2.5	0.112	0.26	0.72	0.785	0.18	0.074	0.156	0.14	0.114
								0.148	0.136	0.125	0.088
								0.222	0.099	0.1	0.01
								0.296	0.052	0.03	0.733
								0.37	0.013	0.01	0.3
3A	19.05	2.5	0.123	0.34	0.76	0.762	0.185	0.076	0.175	0,19	0.079
								0.152	0.149	0.13	0.146
								0.228	0.108	0.12	0.1
								0.304	0.057	0.07	0.19
								0.38	0.015	0.01	0.50

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 10 , October 2022

4A	31.50	2.5	0.151	0.40	0.88	0.808	0.227	0.088	0.215	0.195	0.103
								0.176	0.183	0.17	0.076
								0.264	0.133	0.145	0.083
								0.352	0.070	0.08	0.125
								0.44	0.018	0.01	0,8
5A	40.08	2.5	0.157	0.47	0.90	0.822	0.246	0.09	0.224	0.2	0.12
								0.18	0.190	0.205	0.073
								0.27	0.139	0.14	0.007
								0.36	0.073	0.09	0.189
								0.45	0.019	0.01	0.9
6A	51.0	2.5	0.164	0.56	0.94	0.821	0.18	0.094	0.234	0.22	0.064
								0.188	0.199	0.19	0.047
								0.282	0.145	0.15	0.033
								0.376	0.076	0.085	0.106
								0.47	0.020	0.01	1.0
1C	12.52	3.5	0.14	0.18	1.14	0.578	0.210	0.114	0.200	0.185	0.081
								0.228	0.171	0.17	0.006
								0.342	0.123	0.14	0.121
								0.456	0.065	0.07	0.071
								0.57	0.017	0.01	0.7
2C	14.70	3.5	0.127	0.25	1.04	0.575	0.191	0.104	0.181	0.19	0.047
								0.208	0.154	0.16	0.038
								0.312	0.112	0.1	0.12

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 10 , October 2022

								0.416	0.059	0.08	0.263
								0.52	0.015	0.01	0.5
								0.106	0.195	0.21	0.072
								0.212	0.166	0.18	0.078
3C	20.22	3.5	0.137	0.30	1.06	0.609	0.206	0.318	0.121	0.14	0.136
								0.424	0.064	0.09	0.289
								0.53	0.016	0.01	0.6
								0.106	0.195	0.18	0.083
								0.212	0.166	0.17	0.024
4C	28.05	3.5	0.137	0.42	1.06	0.609	0.206	0.318	0.121	0.13	0.070
								0.424	0.064	0.09	0.289
								0.53	0.017	0.01	0.7
								0.086	0.158	0.07	1.257
								0.172	0.135	0.12	0.125
5C	25.0	3.5	0.111	0.53	0.86	0.608	0.167	0.258	0.098	0.08	0.225
								0.344	0.052	0.03	0.733
								0.43	0.013	0.01	0.30
								0.104	0.198	0.17	0.165
								0.208	0.169	0.16	0.06
6C	40.0	3.5	0.139	0.58	1.04	0.630	0.209	0.312	0.123	0.1	0.23
								0.416	0.065	0.09	0.278
								0.52	0.017	0.01	0.70

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 10 , October 2022

To study the profile of the cross-section of the canal in nature, the study has been conducted at stations 539 and 550 of the Karshi main canal in the Kashkadarya region of the Republic of Uzbekistan. The designed flow capacity of the Karshi main canal is 360 m^3/s. The working part of the Karshi main canal starts from the Tallimarjan reservoir and its total length is 105.3 km. The average flow in the working part of the canal is 331 m^3/s and the maximum flow is 350 m^3/s, and the width of the canal bottom varies from 8 to 42 meters. The side slope coefficients of the channel are m = 2.5 ÷ 3.0. The channel bed slope is equal to i = 0.00015. Studies were carried out to determine the flow discharge and velocities in the defined cross-sections of the Karshi main canal between stations 539 and 550. The following instruments were used in the field research: rotating current meter GR-42, acoustic doppler profiler SONTEC S5 (Figure 2), tachometer STONEX R2 PLUS, and others.

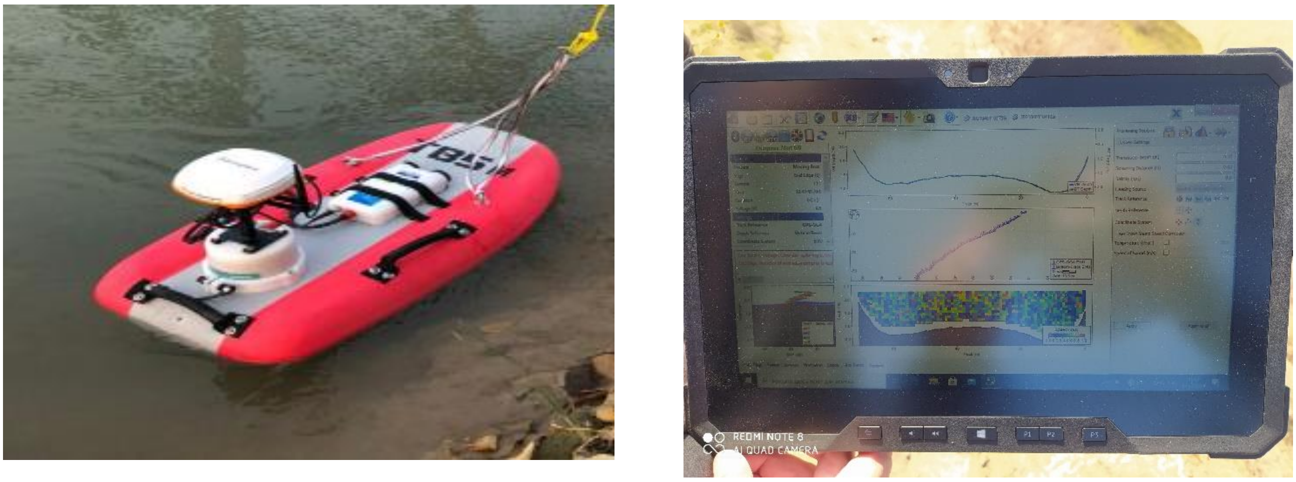

Figure 2. SONTEC S5 hardware and software complex

Table 2: Field survey data, obtained using the SONTEC S5 acoustic doppler profiler in the Karshi main channel

Station	Flow discharge, [m^3/s]	Average flow velocity [m/s]	Maximum flow velocity [m/s]	Maximum flow depth [m]	Channel bed slope	Flow surface width [m]
540	47.532	0.386	1.142	3.257	0.0001	55.052
541	47.049	0.408	1.103	2.029		70.256
542	48.876	0.419	1.121	2.178		70.708
543	48.425	0.430	1.123	2.110		71.066

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 10 , October 2022

544	46.916	0.376	1.094	2.369		73.200
545	42.548	0.380	1.047	2.352		72.811
546	52.425	0.398	1.358	2.303		68.866
547	42.432	0.398	1.213	2.287		69.380
548	43.452	0.413	1.126	2.270		64.760
549	43.045	0.413	1.193	2.254		62.114

III. RESULTS AND CONCLUSIONS

The main task of our research was to improve the calculation methods based on the results of research to determine the dynamic stability of the canal cross-section. We use the equation that was recommended by the U.S. Bureau of Land Reclamation to determine the dynamic stable section of the canal [5, 14].

$$\frac{h}{h_0} = \cos\left(\frac{tg\,\theta}{h_0}x\right) \qquad (1)$$

[4] have shown that connections representing these static strengths can be used to predict the static and dynamic strength of a stream, i.e., the cross-section of a stream transporting streams. To do this, the formulas of static stable channels include its reduced value instead of the internal friction angle:

$$\theta_D = \frac{\theta}{1,65}, \qquad (2)$$

where: θ_D and θ are the internal friction angles in the dynamic and static stability of the soil, respectively.

In evaluating the reliability of equation (2) by comparing laboratory experimental and field survey data, formula (2) is correct only for the finite number of actual measured values and in many cases also shows significant uncertainties. Therefore, using equation (1) we know the maximum depth of the channel and, given that expression (2) and the proposed depth $h_m = 1,5h_0$ by most researchers, we have the following equation that represents the dynamic stability of the cross-section for the channel stable flow:

$$\frac{h}{h_m} = \cos\left(\frac{tg\theta_D}{h_m}x\right) \qquad (3)$$

or

$$h = h_m \cos\left(\frac{tg\theta_D}{h_m}x\right), \qquad (4)$$

where h_m is the average depth of the dynamic stable channel flow in the cross section;

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 10 , October 2022

$$tg\,\theta_D = (4,71h_0)/B.$$

We now proceed to the analysis of the research data obtained on the process of formation of a dynamic stable cross-section in the steady flow of the channel.

Experiments conducted on the steady flow of the channel model (Figure 3) show that when the flow velocity exceeds the permissible flow velocity values, first the bottom of the channel and the side adjacent section are washed, then the top of the side slopes is washed and the bottom of these washed streams with the lower part of the side slopes falling into the adjacent section. Hence, in the deeper part of them, there is a flattening section of the side slopes, which reaches its maximum, and at the same time, there is observed higher shear stress.

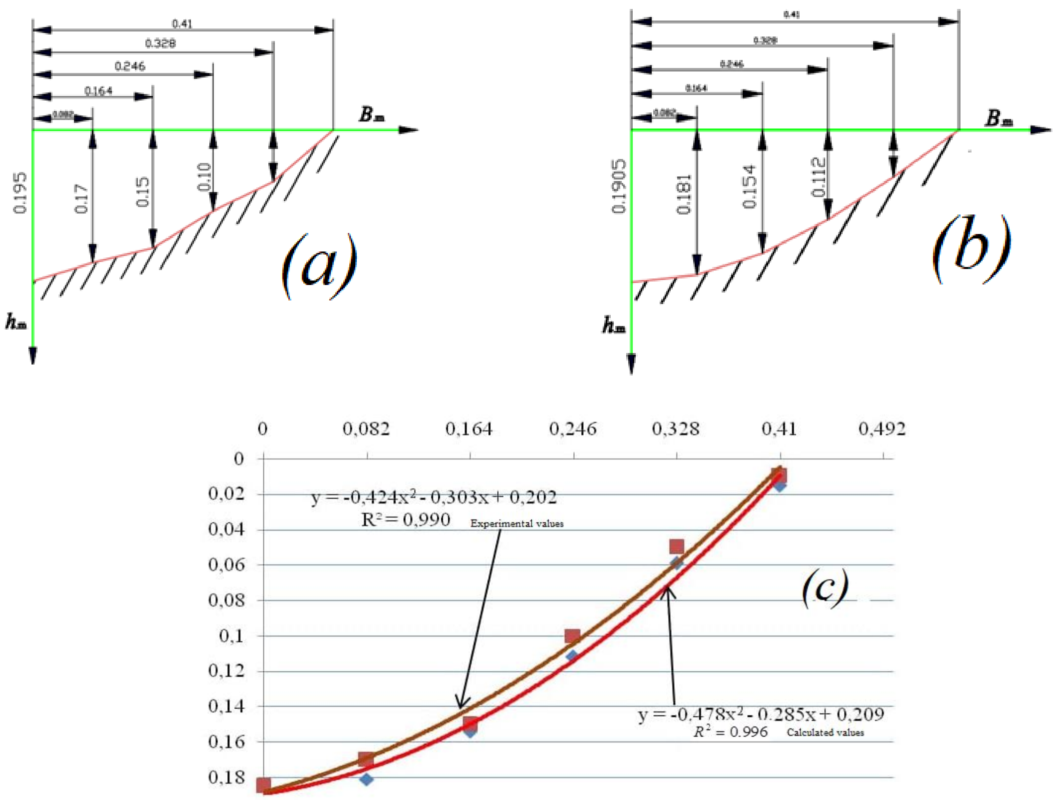

Figure 3. Channel cross-section profiles in experiment 1A:
a - of the lab model; *b* – calculated with equation (3);
c – estimated with regressional analysis.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 10 , October 2022

To consider this issue, we use Table 1, which includes the conducted laboratory data. As mentioned above, the values of the calculated parameters of the cross-section formation on equation (3) are included in Table 1 above. The profiles of the cross-sections of the channel were constructed according to the laboratory experimental data (Fig. 4, *a*) and the generated formula (3) (Fig. 3, *b*). The profiles of the channel cross-sections obtained under laboratory and field conditions were analyzed (Fig. 3, *c*). Based on the regressional analysis, the following equations were obtained:

For cross-sections built on experimental data:

$$y = -0,424x^2 - 0,303x + 0.202$$
$$R^2 = 0,990;$$

for the profile constructed according to the formula (3):

$$y = -0,487x^2 - 0,285x + 0.209$$
$$R^2 = 0,996.$$

It is possible to see their similarity when comparing the obtained profiles.

In addition, when comparing canal cross-sections constructed according to laboratory and field research data obtained from the study of the formation process of the canal cross-section and the calculated values of the equation (3), their closeness can be seen in Table 1 and Figure 4.

Also, the comparison of measured and calculated flow depths shown in Figure 5 shows the closeness of the calculated values determined by the laboratory data (3).

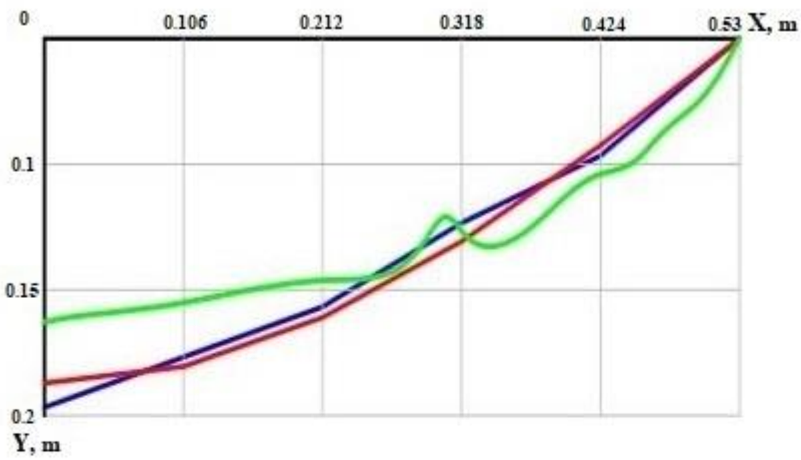

Figure 4. Channel cross-section:

results of the lab model; results of the field experiment at station 544

calculated profile with equation (3);

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 10 , October 2022

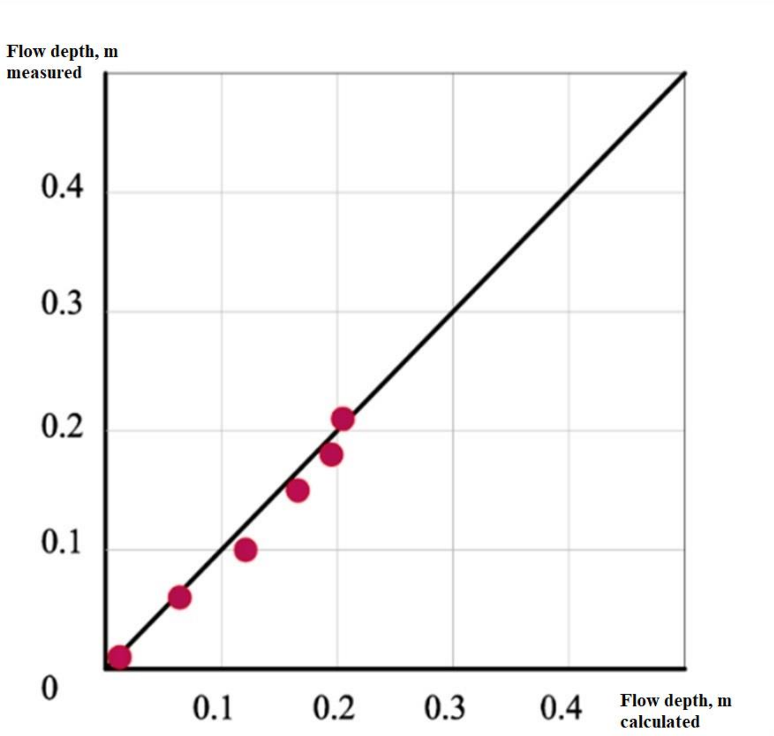

Fig. 5. Comparison of measured and calculated flow depths

Thus, based on the results of the study, an equation (3) was obtained to calculate the cross-sectional profiles in the steady movement of flow in the earthen channels, we can conclude that this formula can be used to predict designing dynamic stable cross-sections of channels.

REFERENCES

[1] Abalyants S. Kh., “The form of the limit equilibrium channel”, Collection of scientific works of SANIIRI, pp. 12-21, 1981.
[2] Ibad-Zade Yu. A., “Transportation of water in open channels”, Moscow: Stroyizdat, 1983.
[3] Kosichenko Yu. M., “Investigation of a hydraulically advantageous profile of a polygonal section of large channels and their hydraulic resistances”, Nature Engineering, Vol 2. pp. 85-89, 2014.
[4] Eshev S.S., “Calculation of deformable large earth channels in conditions of unsteady water flow”, Tashkent: Voris, 2018.
[5] Chow V. T., “Open-channel hydraulics”, New York: McGraw-Hill, 1959.
[6] Joshi S., Xu Y., “Recent changes in channel morphology of a highly engineered alluvial river – the Lower Mississippi River” Physical Geography, Vol. 39, Jun. 2017, DOI: 10.1080/02723646.2017.1340027.
[7] Rijn L., “A simple general expression for longshore transport of sand, gravel and shingle,” Coastal Engineering, Vol. 90, pp. 23–39, Aug. 2014, DOI: 10.1016/j.coastaleng.2014.04.008.
[8] Wang B. and Xu Y. J., “Long-term geomorphic response to flow regulation in a 10-km reach downstream of the Mississippi–Atchafalaya River diversion,” Journal of Hydrology: Regional Studies, Vol. 8, pp. 10–25, Dec. 2016, DOI: 10.1016/j.ejrh.2016.08.002.
[9] Gonzalez-Santamaria R., Zou Q., and Pan S., “Impacts of a Wave Farm on Waves, Currents and Coastal Morphology in South West England,” Estuaries and Coasts, Vol. 38, Jan. 2013, DOI: 10.1007/s12237-013-9634-z.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 10 , October 2022

[10] Roelvink J. A., “Coastal morphodynamic evolution techniques,” Coastal Engineering, Vol. 53, pp. 277–287, Feb. 2006, DOI: 10.1016/j.coastaleng.2005.10.015.

[11] Yangiev A., Eshev S.S., Panjiev S., Rakhimov A.R., “Calculation of sediment flow in channels taking into account passing and counter wind waves” IOP Conf. Ser.: Mater. Sci. Eng., Vol. 883, p. 012036, Jul. 2020, DOI: 10.1088/1757-899X/883/1/012036.

[12] Eshev S.S., Khazratov A.N., Rahimov A.R., Latipov S.A., “INFLUENCE OF WIND WAVES ON THE FLOW IN FLOWING RESERVOIRS,” IIUM Engineering Journal, Vol. 21, pp.125-132, Jul. 2020, DOI: 10.31436/iiumej.v21i2.1329.

[13] Eshev S.S., Latipov S.A., Qurbonov A., Sagdiyev J., Berdiev M., Mamatov N., “Non-eroding speed of water flow of channels running in cohesive soils,” IOP Conference Series: Materials Science and Engineering, Vol. 1030, p. 012131, Jan. 2021, DOI: 10.1088/1757-899X/1030/1/012131.

[14] Eshev S.S., Rahimov A.R., Gayimnazarov I.X., Isakov A.N, Shodiev B., Bobomurodov F., “Dynamically stable sections of large soil canals taking into account wind waves,” IOP Conf. Ser.: Mater. Sci. Eng., Vol. 1030, p. 012134, 2021, DOI: 10.1088/1757-899X/1030/1/012134.