Kinematic characteristics of the flow, in the compression region, with bilateral symmetric restriction by floodplain dams

Masharif Bakiev¹, Uktam Kaxxarov², Azizjon Jakhonov³ and Otanazar Matkarimov⁴

¹Hydrotechnical construction and engineering structure department, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 39 Kary Niyaziy street, Tashkent, Uzbekistan, bakiev1947@rambler.ru
²Hydrotechnical construction and engineering structure department, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 39 Kary Niyaziy street, Tashkent, Uzbekistan, uktam-nig@rambler.ru
³Hydrotechnical construction and engineering structure department, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 39 Kary Niyaziy street, Tashkent, Uzbekistan, azizjon_1990@umail.uz
⁴Hydrotechnical construction and engineering structure department, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 39 Kary Niyaziy street, Tashkent, Uzbekistan, bakiev1947@rambler.ru

Abstract. Of great importance is the solution of the problem of research aimed at improving design methods and calculating the parameters of a bilaterally symmetrically constrained river flow with wide floodplains, for regulating river channels, protecting river banks from erosion and for the efficient use of floodplain fertile lands. The aim of this work is to develop a methodology for calculating the flow velocity field in the compression region, which is bilaterally constrained by floodplain transverse dams. Experimental studies were carried out in a schematized channel with a bilateral floodplain of rectangular cross section with parallel dynamic axes. It was experimentally established that the velocity distribution in the zone of interaction between channel and floodplain flows obeys the universal Schlichting-Abramovich dependence. The relative width of the interaction zone depends on the ratio of the depths of the channel and floodplain flows. The device of transverse floodplain dams to conduct to the appearance of areas of backwater, compression and spreading. In the compression region, the greatest longitudinal and transverse differences in depths are observed, as well as the velocity field with zones characteristic of jet flows: a weakly perturbed core, turbulent mixing, and reverse currents. The problem is realized for the compression domain by a joint solution of the equations of conservation of momentum and conservation of flow in the stream. Design dependencies are proposed to determine the patterns of change in speed in the channel and on floodplains. In contrast to existing solutions, the interaction of channel and floodplain flows, uneven velocity distribution in the zone of a weakly perturbed core, and transverse and longitudinal differences in depth in the compression region are taken into account. The combined use of experimental and theoretical solutions allowed the establishment of kinematic flow parameters in the compression region of the flow constrained by floodplain dams.
1. Introduction

The problems of protecting river banks from erosion [1] the movement of streams in channels and floodplains, the kinematic and dynamic interaction of channel and floodplain flows, taking into account the roughness and complex morphology of the floodplain and channel [2, 3, 4, 5, 6, 7, 8, 9, 10, 11] special attention is paid throughout the world.

The construction of bilateral transverse dams on the floodplain is accompanied by a significant change in the natural flow in the area of structures characterized by the appearance of longitudinal and transverse slopes of the free surface of the water, the redistribution of the kinematic parameters of the flow both on the floodplain and in the channel [12, 13, 14, 15, 16]. Reclamation areas appear above the site of tightness O-O, compression between the target O-O and C-C, and spreading over the compression target 'figure 1'.

Moreover, the compression region is characterized by further compression of the transit flow both in plan and in vertical direction. In the compression section where there is a minimum width of the transit flow and minimal transverse level differences [17].

Significant deformations undergo and velocity field flow. Nevertheless, a qualitative picture of the flow (Figure. 1) allows it to be considered consisting of hydraulically homogeneous zones, as is customary in the theory of turbulent jets [18,19,20,21].

In the stream, zones are clearly traced: a weakly perturbed core in the channel with a uniform velocity distribution, width ; slightly perturbed core with uniform velocity distribution on the left

Figure 1. Scheme of the flow constrained by floodplain transverse dams in the areas of compression and backwater
and right floodplains respectively width; the first zone of intense turbulent mixing width, the second zone of intense turbulent mixing width with speed; zones of interaction of channel and floodplain flows with a width, reverse currents with speeds.

On the diagram: О’-1, О”-5 – boundaries between a weakly perturbed core on floodplains and zones of intense turbulent mixing; О’-2, – external boundaries of zones of intense turbulent mixing; О’-3, – transit flow boundaries; О’-4 – zero speed lines.

2. Materials and methods
The studies were carried out in a schematized channel with a bilateral floodplain of rectangular cross section with parallel dynamic axes. The floodplain and the bed have the same concrete roughness. The channel is 30 cm wide, the right-side floodplain is 85 cm, the left-side is 85 cm, the length of the channel is 11 m, the floodplain roughness is nnn = 0.016, nл = 0.016, the channel nр = 0.016. A series of studies was performed when the left floodplain had an artificial roughness. It was created by gluing sand with an average roughness of 1'2 mm, where the roughness coefficient is nл = 0.023. Over the walls of the tray, guide rails were installed along which a trolley with measuring instruments moved freely. The instruments moved across the cart, so it was possible to carry out the necessary measurements at any point in the flow ‘figure 2’

Figure 2.

The flow rates were determined by the SANIIRI micro-rotator with the TSISPV-6 electronic sensor. To control the water levels at the beginning and end of the working part of the tray, fixed pitch scales were installed (measurement accuracy up to +/- 0.1 mm). Experimental studies were carried out with the following parameters of the tray and structures: degree of restriction of flow by flow rate varied from 0.14 to 0.62, angle of dam installation установки α = 45 °, 60 °, 90 °, 135 °; ratio of flow width to depth B / hб > 6, water flow rate Q = 5 ... 25 l / s, the Froude number in the everyday state Frп = 0.01-0.18, and in the compressed section Frс = 0.40;

The boundaries of the upper and lower whirlpool zones, the longitudinal and transverse differences in depth, velocity and direction of the current were experimentally studied.

The number of measuring verticals was assigned: in the backwater area after 2-2.5 cm.; in the compression area after 1-2 cm.; in the spreading area after 5-10 cm. After the designated position of the sections and measuring verticals, the free surface marks and the flow velocity were measured, and the arithmetic mean values were taken as the final marks. Based on measurements, longitudinal and transverse differences in water levels in the upper and lower pools of the structure were established.
Based on the distribution of average velocities and depths of the flow, vertical diagrams of elementary household water flow rates were constructed, which turned out to be equal to the flow rate supplied to the model with a difference of +/- 5%.

The distance between the verticals in the selected sections were established depending on the issue under study and the nature of the change in the studied flow characteristics. In the alignment of the slightly perturbed O-O flow, the velocities were measured on verticals, the distance between which was 10 cm, in the alignment of the structure - 2-10 cm, in the compressed section - 2-10 cm, at the end of the whirlpool - 5-10 cm, in the speed equalization zone - 10-20 cm. The minimum distances were in places with a sharp change in speeds, including directly at the head of the dam, in the zone of intense turbulent mixing; off the coast occupied by the dam and in the reverse current zone. Water level and bottom marks were recorded over the entire area deformed by the spur of the flow, and the distances between the measurement points were 5-10 cm, in places with a sharp change in the level of the water surface, including directly at the dam, they were minimal.

Theoretical studies were performed using the basic equations of hydromechanics: the law of conservation of momentum in the stream and conservation of flow.

3. Results and discussion
The distribution of velocities in the interaction zone with symmetric constraint also obeys the theoretical Schlichting-Abramovich dependence [12,18,20].

\[
\frac{U - U_{nx}}{U_{px} - U_{nx}} = \left(1 - \eta^{3/2}\right)^2
\]

Where \( \eta = \frac{\delta^* - Y}{\delta^*} \); \( Y \) – ordinate of the point where determined \( U \)

![Figure 3](image)

**Figure 3.** The velocity profile in the zone of interaction between the channel and floodplain flows

The width of the interaction zone is determined from the dependence

\[
\frac{\delta^*}{h_n} = 2.4 \cdot \frac{h_p}{h_n} - 2.4
\]
Figure 4. Dependence of the width of the zone of interaction between the channel and floodplain flows on the ratio of depths $h_p / h_n$.

A distinctive feature of the problem is the formation of two zones of intense turbulent mixing:

1. First between the rays $0' - 5$ width $\theta_{1x}$
2. Second between the rays $0' - 1$ and $0' - 2$ width $\theta_{2x}$

In the first zone, the velocity distribution obeys the Schlichting-Abramovich dependence

$$\frac{U_{1x} - U_{nx}}{U_{mx} - U_{nx}} = \left(1 - \eta^{1.5}\right)^2$$

where $\eta = \frac{Y_1 - Y}{Y_1 - Y_5}$ (3)

In the second zone

$$\frac{U_{mx} - U_{2x}}{U_{mx} - U_{nx}} = \left(1 - \eta^{1.5}\right)^2$$

where $\eta = \frac{Y_2 - Y}{Y_2 - Y_1}$ (4)

We compose the momentum conservation equation for the cross sections $O - O$ and $X - X$ willow compression

$$2 \rho h_{po} U_{po}^2 (B_p - e_{po}) + 2 \rho h_{po} \int_{a_{po}}^{a_{po}} U^2 dy + 2 \rho h_{no} \int_{a_{po}}^{a_{po}} U^2 dy + 2 \rho h_{no} U_{no}^2 e_{1o} +$$

$$+ 2 \rho h_{no} \int_{y_3}^{y_1} U^2 dy + 2 \rho h_{nx} U_{nx}^2 e_{nx} = 2 \rho h_{px} U_{px}^2 (B_p - e_{px}) + 2 \rho h_{px} \int_{a_{px}}^{a_{px}} U^2 dy +$$

$$+ 2 \rho h_{nx} \int_{y_3}^{y_1} U^2 dy + 2 \rho h_{nx} U_{nx}^2 e_{nx} + 2 \rho h_{nx} \int_{y_3}^{y_1} U^2 dy + 2 \rho h_{nx} \int_{y_3}^{y_1} U^2 dy + 2 \rho h_{nx} U_{nx}^2 e_{nx} +$$

$$+ \gamma B_p (h_{po}^2 - h_{px}^2) - \gamma B_n (h_{no}^2 - h_{nx}^2)$$

Conservation equation for the same sections

$5$
\[2h_{po}U_{po}(B_p - \theta_{po}) + 2h_{po} \int Udy + 2h_{no} \int Udx + 2h_{no}U_{no}^2 \theta_{no} + 2h_{po} \int Udy + \int Udx + 2h_{no}U_{no}^2 \theta_{no} + \]

\[+ 2h_{no}U_{no} \theta_{no} = 2h_{px}U_{px}(B_p - \theta_{px}) + 2h_{px} \int Udy + 2h_{nx} \int Udy + 2h_{nx}U_{nx}^2 \theta_{nx} + \]

\[+ 2h_{nx} \int Udy + 2h_{nx} \int Udy + 2h_{nx}U_{nx}^2 \theta_{nx} \]  
(6)

Will accept \( U_{ns} = U_{no} = 0 \) since in the compression region the conditions are satisfied \(-0.6 < U_{ns}/U_{mx} < 0 \) [14,15,19]. In addition, a variable slope of the water surface, in the area from the site of maximum backwater II-II to compressed section C-C, replace the linear law of change

\[h_{px} = h_{po} - I_p x\]

\[h_{nx} = h_{no} - I_n x\]

Water slope

\[I_p = I_n = \frac{Z_n}{l_n + l_c} = \frac{Z_p + i(l_n + l_c)}{l_n + l_c}\]

Where \( i \) - river slope; \( Z_p \) - backwater; \( Z_n \) - the difference between the target maximum backwater II-II and compressed section C-C; \( l_c \) - compression area length; \( l_n \) - distance from range O-O to the target with maximum backwater II-II. Backwater Length \( l_c, l_n \) are determined according to recommendations [5] and the amount of backwater according to [5], taking into [17], account the two-way flow restriction.

Performing integration in (5) and (6) taking into account (1,2,3,4) we write

\[h_{po}U_{po}^2(B_p - \theta_{po}) + h_{po}U_{po}^2 \theta_{po}K_3 + h_{no}U_{po}^2 \theta_{po}K_4 + h_{no}U_{no}^2 \theta_{no} + \]

\[+ h_{no}U_{no}^2 \theta_{no} = (0.316 + 0.268m_n + 0.416m_n^2) = h_{px}U_{px}^2(B_p - \theta_{px}) + \]

\[+ h_{px}U_{px}^2 \theta_{px}K_5 + h_{nx}U_{nx}^2 \theta_{nx}K_6 + h_{nx}U_{nx}^2 \theta_{nx}K_6 + h_{nx}U_{nx}^2 \theta_{nx} + (0.316 + \]

\[+ 0.268m_n + 0.416m_n^2) + 0.416h_{nx}U_{nx}^2 \theta_{nx} + \frac{gB_p}{2}(h_{po}^2 - h_{px}^2) + \frac{gB_n}{2}(h_{no}^2 - h_{nx}^2) \]

Divide both equations by \( h_\theta \)

\[U_{po}^2(B_p - \theta_{po}) + h_{po}U_{po}^2 \theta_{po}K_7 + h_{no}U_{po}^2 \theta_{po}K_8 + h_{no}U_{no}^2 \theta_{no} + \]

\[+ h_{no}U_{no}^2 \theta_{no} = (0.45 + 0.55m_n) = h_{px}U_{px}^2(B_p - \theta_{px}) + h_{px}U_{px}^2 \theta_{px}K_9 + \]

\[+ h_{nx}U_{nx}^2 \theta_{nx}K_{10} + h_{nx}U_{nx}^2 \theta_{nx}K_{11} + h_{nx}U_{nx}^2 \theta_{nx}K_{12} + h_{nx}U_{nx}^2 \theta_{nx}K_{13} + h_{nx}U_{nx}^2 \theta_{nx}F(m_n) + \]

Divide both equations by \( h_\theta \)

\[U_{po}^2(B_p - \theta_{po}) + h_{po}U_{po}^2 \theta_{po}K_{10} + h_{no}U_{po}^2 \theta_{po}K_{11} + h_{no}U_{no}^2 \theta_{no} + h_{no}U_{no}^2 \theta_{no}F(m_n) = \]

\[= h_{px}U_{px}^2(B_p - \theta_{px}) + h_{px}U_{px}^2 \theta_{px}K_{12} + h_{nx}U_{nx}^2 \theta_{nx}K_{13} + h_{nx}U_{nx}^2 \theta_{nx} + h_{nx}U_{nx}^2 \theta_{nx}F(m_n) + \]

\[+ 0.416h_{nx}U_{nx}^2 \theta_{nx} + \frac{gB_p}{2}(h_{po}^2 - h_{px}^2) + \frac{gB_n}{2}(h_{no}^2 - h_{nx}^2) \]
\[
U_{po}(B_p - \bar{a}_{po}) + U_{po}\bar{a}^* K_7 + \bar{h}_{no}U_{po}\bar{a}^* K_8 + \bar{h}_{no}U_{no}\bar{a}_{ano} + \bar{h}_{no}U_{m}\bar{a}_{1o}(0.45 + 0.55m_x) = \\
\bar{h}_{px}U_{px}(B_p - \bar{a}_{px}) + \bar{h}_{px}U_{px}\bar{a}^* K_9 + \bar{h}_{nx}U_{px}\bar{a}^* K_{10} + \bar{h}_{nx}U_{nx}\bar{a}_{anx} + \bar{h}_{nx}U_{m}\bar{a}_{1x}(0.45 + \\
+ 0.55m_x) + 0.55 \bar{h}_{nx}U_{mx}\bar{a}_{2x}.
\]

(11)

In the equations indicated
\[
K_3 = \psi + \psi m_{no} + \psi_{0}^2 m_{no}^2;
K_4 = \psi' + \psi m_{no} + \psi_{0}^2 m_{no}^2;
K_5 = \psi + \psi m_{nx} + \psi_{0}^2 m_{nx}^2;
K_6 = \psi' + \psi m_{nx} + \psi_{0}^2 m_{nx}^2;
\]
\[
\psi' = 1.5 \bar{a}_p^4 - 1.6 \bar{a}_p^{2.5} - 0.72 \bar{a}_p^{5.5} + 0.14 \bar{a}_p^7 + \bar{a}_p; \\
\psi' = 1.6 \bar{a}_p^{2.5} - 2.5 \bar{a}_p^4 + 1.45 \bar{a}_p^{5.5} - 0.28 \bar{a}_p^7; \\
\psi' = 0.143 \bar{a}_p^7 + 0.727(\bar{a}_p)^{5.5} - (\bar{a}_p);
\]
\[
\bar{B}_p = B_p / \bar{a}_0; \\
\bar{\bar{a}} = \bar{a} / \bar{a}_0; \\
\bar{a}_{anx} = a_{anx} / \bar{a}_0; \\
\bar{a}_{px} = a_{px} / \bar{a}_0; \\
\bar{a}_{nx} = a_{nx} / \bar{a}_0; \\
\bar{a}_{2x} = a_{2x} / \bar{a}_0;
\]
\[
m_{no} = U_{no} / U_{no}; \\
m_{nx} = U_{no} / U_{no}; \\
m_{nx} = U_{nx} / U_{nx}; \\
K_5 = \psi + \psi m_{nx}; \\
K_6 = \psi' + \psi m_{nx}; \\
K_9 = \psi + \psi m_{nx}; \\
K_{10} = \psi' + \psi m_{nx}; \\
E_1 = (\bar{a}_p - 1); \\
E_2 = (1 - \bar{a}_p).
\]

\[
F(m_x) = 0.316 + 0.268m_x + 0.416m_x^2; \\
F(m_x) = 0.316 + 0.268m_x + 0.416m_x^2;
\]

Function availability \( F(m_x) \) in equation (10) creates a definition of difficulty in the analytical solution of the problem. To eliminate which we use the following trick.

The graph of the function \( F(m_x) \) is shown in ‘figure 2’, from where it can be seen that the function varies according to a curvilinear law from 0.316 at \( mx=0 \) and \( F(m_x)=1 \) at \( mx=1 \).

Statements \( m_x > 0.3 \) : The graph has the greatest curvature on the plot \( m_x < 0.3 \).

Given the above, to facilitate the solution of the problem, the function \( F(m_x) \) replace by function \( F_1(m_x) = 0.386 + 0.614m_x^2 \).
The values of the functions are given in the table.

Table 1. Comparative calculations for \( F(m_x) \) и \( F_1(m_x) \)

| \( m_x = \frac{U_m}{U_{mx}} \) | 0    | 0,2  | 0,3  | 0,6  | 0,8  | 1,0  |
|------------------------------|------|------|------|------|------|------|
| \( F(m_x) \)                | 0,316| 0,386| 0,49 | 0,627| 0,797| 1,0  |
| \( F_1(m_x) \)              | 0,41 | 0,48 | 0,61 | 0,78 | 1,0  |      |

As can be seen from the graphs on the segment \( m_x = 0,2 \div 1,0 \) function values \( F(m_x) \), \( F_1(m_x) \) are close to each other i.e. in equation \( 10 \) the function \( F(m_x) \) can be replaced \( F_1(m_x) \). In addition to this study [1,5] shows that the maximum velocity vector \( U_m \) on the O-1 line in the compression region practically remain constant \( U_m = U_{mx} = U_{mo} \) while their longitudinal component decreases to the site of constraint due to the presence of flow deviation angles \( \varphi \).

Performing some transformations in \( 10 \), taking into account the above, we obtain

\[
U^2_{po}[(\overline{B}_p - \overline{a}_po) + \overline{a}_s^* K_3 + \overline{h}_n a^* K_4 + \overline{h}_m m^2 \overline{a}_na^* + \overline{h}_m m^2 \overline{a}_mo^* F(m_o) - \\
0.416 \overline{h}_m m^2 \overline{a}_x - 0.386 \overline{h}_m m^2 \overline{a}_1x - \frac{0.5 \overline{B}_p}{Fr_p}(1 - \overline{h}_p^2) - \frac{0.5 \overline{B}_m}{Fr_m}(\overline{h}_n^2 - \overline{h}_p^2)] = (11)
\]

\[
= U^2_{ps}[\overline{h}_p (\overline{B}_p - \overline{a}_ps) + \overline{h}_p a^* K_3 + \overline{h}_n a^* K_4 + \overline{h}_m m^2 \overline{a}_snx + 0.614 \overline{h}_m m^2 \overline{a}_1x]
\]

Where do we get the formula for establishing the laws of change of speeds in the channel...
\[ U_{px} = \frac{(B_p - \bar{\sigma}_{po}) + \bar{\sigma}^* K_3 + \bar{h}_{no} \bar{\sigma}^* K_4 + \bar{h}_{mo} m_{no}^2 \bar{\sigma}_{ano} + \bar{h}_{mo} m_{mo}^2 \bar{\sigma}_{10} F(m_o) - \sqrt{\frac{h_{px} (B_p - \bar{\sigma}_{px}) + \bar{h}_{px} \bar{\sigma}^* K_5 + \bar{h}_{nx} \bar{\sigma}^* K_6 + \bar{h}_{nx} m_{nx}^2 (\bar{\sigma}_{ax} + 0.614 \bar{\sigma}^*_{1x})}{U_{po}}}}{0.416 \bar{h}_{nx} m_{mo}^2 \bar{\sigma}_{2x} - 0.386 \bar{h}_{nx} m_{mo}^2 \bar{\sigma}_{1x} - \frac{0.5 \bar{B}_p}{Fr_{po}} (1 - \frac{h_{px}^2}{Fr_{po}}) - \frac{0.5 \bar{B}_{p_n}}{Fr_{po}} (\bar{h}_{no} - \bar{h}_{px}^2)} \] (12)

\[ Fr_{po} = \frac{U_{px}^2}{g \bar{h}_{po}} ; \quad m_{no} = \frac{U_{m}}{U_{po}} ; \quad \bar{h}_{no} = \bar{h}_{no} / h_{po} ; \]

\[ \bar{h}_{px} = h_{px} / h_{po} ; \quad \bar{h}_{nx} = h_{nx} / h_{no} ; \]

From the flow conservation equation we have

\[ U_{po} [B_p - \bar{\sigma}_{1o} + \bar{\sigma}^* K_7 + \bar{h}_{no} m_{no}^2 \bar{\sigma}_{ano} + \bar{h}_{no} m_{mo} \bar{\sigma}_{1o} (0.45 + 0.55 m_{o}) - 0.45 \bar{h}_{nx} m_{mo} \bar{\sigma}_{1x} - 0.55 \bar{h}_{nx} m_{mo} \bar{\sigma}_{2x} = U_{px} [\bar{h}_{px} (B_p - \bar{\sigma}_{px}) + \bar{h}_{px} \bar{\sigma}^* K_9 + \bar{h}_{nx} \bar{\sigma}^* K_{10} + \bar{h}_{nx} m_{n_o} \bar{\sigma}_{ano} + 0.55 \bar{h}_{nx} \bar{\sigma}_{1x}, m_{nx} ] \]

From which

\[ U_{po} = \frac{\bar{h}_{px} (B_p - \bar{\sigma}_{px}) + \bar{h}_{px} \bar{\sigma}^* K_9 + \bar{h}_{nx} \bar{\sigma}^* K_{10} + \bar{h}_{nx} m_{n_o} \bar{\sigma}_{ano} + 0.55 \bar{h}_{nx} \bar{\sigma}_{1x}, m_{nx} ]}{\bar{h}_{px} (B_p - \bar{\sigma}_{px}) + \bar{h}_{px} \bar{\sigma}^* K_9 + \bar{h}_{nx} \bar{\sigma}^* K_{10} + \bar{h}_{nx} m_{n_o} \bar{\sigma}_{ano} + 0.55 \bar{h}_{nx} \bar{\sigma}_{1x}, m_{nx} ]} \]

(13)

Solving (13) and (12) together we arrive at the quadratic equation

\[ A_1 m_{nx}^2 + A_2 m_{nx} + A_3 = 0 \]

(14)

where

\[ A_1 = D_1 D_4^2 - D_5 D_6^2 ; \quad A_2 = D_1^2 D_2 - 2 D_1 D_5 D_6 ; \]

\[ A_3 = D_1^2 D_1 - D_0 D_5^2 . \]

\[ D_0 = B_p - \bar{\sigma}_{po} + \bar{\sigma}^* K_7 + \bar{h}_{no} \bar{\sigma}^* K_4 + m_{no}^2 (\bar{h}_{mo} \bar{\sigma}_{ano} + \bar{h}_{mo} \bar{\sigma}_{1o} F(m_o) - 0.416 \bar{h}_{nx} \bar{\sigma}_{1x} - 0.386 \bar{h}_{nx} m_{mo} \bar{\sigma}_{2x} - 0.5 \frac{B_p}{Fr_{po}} (1 - \frac{h_{px}^2}{Fr_{po}}) - \frac{B_{p_n}}{Fr_{po}} (\bar{h}_{no} - \bar{h}_{px}^2) ; \]

\[ D_1 = \bar{h}_{px} (B_p - \bar{\sigma}_{px}) + \bar{h}_{px} \bar{\sigma}^* \psi_3 + \bar{h}_{nx} \bar{\sigma}^* \psi_3^* ; \]

\[ D_2 = \bar{h}_{px} \bar{\sigma}^* \psi_5 + \bar{h}_{nx} \bar{\sigma}^* \psi_5^* ; \]

\[ D_3 = \bar{h}_{px} \bar{\sigma}^* \psi_6 + \bar{h}_{nx} \bar{\sigma}^* \psi_6^* + \bar{h}_{nx} \bar{\sigma}^* \psi_7 + 0.614 \bar{h}_{nx} \bar{\sigma}_{1x} ; \]

\[ D_4 = B_p - \bar{\sigma}_{po} + \bar{\sigma}^* K_7 + \bar{h}_{no} m_{no} \bar{\sigma}_{ano} + \bar{h}_{no} m_{mo} \bar{\sigma}_{1o} (0.45 + 0.55 m_{o}) - \bar{h}_{nx} m_{no} (0.45 \bar{\sigma}_{1x} - 0.55 \bar{\sigma}_{2x}) ; \]

\[ D_5 = \bar{h}_{px} (B_p - \bar{\sigma}_{px}) + \bar{h}_{px} \bar{\sigma}^* \psi_7 + \bar{h}_{nx} \bar{\sigma}^* \psi_7^* ; \]

\[ D_6 = \bar{h}_{nx} \bar{\sigma}^* \psi_8 + \bar{h}_{nx} \bar{\sigma}^* \psi_8^* + \bar{h}_{nx} \bar{\sigma}^* \psi_9 + 0.55 \bar{h}_{nx} \bar{\sigma}_{1x} ; \]

The roots of the quadratic equation (14) are positive one greater than unity, which does not correspond to the physics of the phenomenon \(U_{nx} > U_{px}\), another less than one is accepted as calculated because \(U_{nx} < U_{px}\).
4. Discussion
Since ancient times, people have settled along rivers with fertile floodplain lands. At the same time, an increase in the population of the country by 2030 to 35 million people, expansion of large cities can lead to an acute shortage of land resources. The development of floodplain lands is carried out under the protection of longitudinal or transverse dams. Profitability, the possibility of gradual construction and development of the inter-dam space gives an advantage to the construction of bilateral transverse dams on floodplain rivers.
Experimental studies were performed both to reveal the physical picture of the flow around the named dams symmetrically constraining the stream and to obtain the recipe dependencies $\theta_s = Q_{in} / Q$. The studies were carried out with the following flow and structure characteristics: degree of restriction by flow rate $\theta_s$ (here $Q_{in}, Q$ consumption of the overlapped part and the total) installation angles $\alpha = 45^\circ - 135^\circ$; width to depth ratio $B/h > 6$ number of frudes $Fr_n = 0.01 - 0.18$.

The possibility of using the main position of the theory of turbulent jets, a scheme for dividing the flow into homogeneous hydraulic zones has been experimentally established. For the case of symmetrical floodplains, the universality of the velocity distribution in the interaction zones of channel and floodplain flows was confirmed, which is consistent with the previously obtained dependences for the case of the presence of a one-sided floodplain [7,12,15].
A calculated dependence is proposed for determining the boundaries of the zone of interaction between the channel and floodplain flows. Design dependences are proposed for determining the velocities in the channel and on the floodplain, which are obtained by jointly solving the equations of conservation of momentum and flow in the stream.

Unlike the existing groves, the uneven distribution of velocities on the floodplain, the presence of the interaction zone, and the longitudinal and transverse fallows of the lips are taken into account.
An experimental verification of the obtained dependences shows their acceptable purpose.

5. Conclusions
1. The kinematic characteristics of the flow constrained by transverse dams on floodplain rivers have their own peculiarities, consisting in the need to take into account the interaction of floodplain and channel flows, different roughnesses of floodplains and channels, longitudinal and transverse differences in depths, etc.
2. It was found that the velocity distribution in the compression region of the flow constrained by floodplain dams also has a jet character: a weakly perturbed core in the channel and in the floodplain, two zones of intense turbulent mixing, and the zone of interaction between the channel and floodplain flows, where the velocity distribution is affine.
3. The width of the zone of interaction between the channel and floodplain flows varies in proportion to the ratio of the depths of the channel and floodplain flows.
4. Hydraulic dependences have been proposed to determine the patterns of changes in velocities in the channel and in the floodplain, which depend on the parameters of the flow and dams in the tightness range, the relative sizes of the boundaries of hydraulically homogeneous zones, and the relative depths in the channel and in the floodplain.

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