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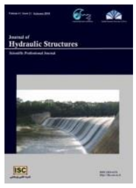

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Influence of T shape baffles arrangement on flow hydraulic characteristics in fishways

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Abstract

Hydraulic structures constructed along the rivers cause disturbances in the natural process of aquatic life and the ecosystem of the region. In order to solve this problem, fishway structure is widely used to facilitate the communication path between downstream and upstream of hydraulic structures crossing the river and to eliminate the inability of fish to swim upstream and also to facilitate their movement downstream of dams. The different types of this structure should be designed to absorb the type of migratory fish in the area and to pass them safely and out of the outlet, without injuring the fish or creating unnecessary delays for the adult spawning fish. Therefore, in the present study, in order to determine the optimal configuration of the T shape baffles used in the path, three types of arrangements were numerically simulated using OpenFOAM software and K-ε turbulence model. These three types of arrangements are consecutive, alternate and also reversed. Then, the results of the numerical model were validated by comparing it with the results of the related laboratory model. The findings indicate that the numerical model is in good agreement with the laboratory results. Among the three configurations, taking into account different factors, the reverse location of T-shaped baffles with 68.3% backwater, 86.2% flow at less than 0.5 m/s, 84.1% turbulent kinetic energy values less than 0.02 square meters per square second and also 61% energy dissipation percentage, had the best performance.

Keywords: Fishway Structure, T Shape Baffle, OpenFOAM, Turbulent Kinetic Energy, Energy Dissipation.

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1. Introduction

There are different species of fish that swim in the opposite direction of the water to reach their homeland. This instinctive behavior has become a factor in the survival and reproduction of this type of fish. On their way upwards, the fish try to cross the obstacles in any way possible. Their instinctive efforts will endanger their lives if they do not succeed. Lack of spawning, reduced reproduction and extinction of many species are the adverse effects of fish not reaching upstream. For this purpose, it is necessary to pay attention to the design and construction of hydraulic structures called fishways in the vicinity of intersecting structures with waterways. Although the construction of fishways alone will not solve all of the aquatic-related environmental problems, it is undoubtedly the only way for fish to migrate upstream of obstacles. Nowadays, environmental issues are one of the major concerns in the planning and implementation of projects related to water resources. Diversion and regulation dams, by blocking the river, create the greatest difficulty in the movement and migration of fish [1,2].

The design of the fishway should be such that it can attract migratory fish, pass them and take them out safely, without injuring the fish or causing unnecessary delays for the spawning fish. The most commonly used types of fishways are Denil [3,4,5], pool and weir [6,7,8], vertical slot [9,10,11] and culvert type. The pattern of water flow in the fishway has a very important effect in determining the path of fish. Factors affecting the swimming of fish are not only the velocity field and depth of water, but also factors such as flow pressure, kinetic energy of the flow, which determines the degree of turbulence of the flow, and the rate of energy dissipation in the fish path can be effective parameters. In the last decade there has been a great deal of interest in adding elements that increase the roughness inside the fishway. These elements, which act as barriers, disrupt the laminar flow and lead to the formation of turbulence in the flow, which facilitates the movement of fish. Different types of materials and with different locations have been tested, including: stones or wooden blocks, side clamps, chains or ropes, pre-cast cones and spoiler baffles. The addition of rough elements is usually limited to places with a long period of water in high stage and steady state, or where the total change of the water head is relatively small. There are several options for retrofitting roughness units in intakes, depending on the species of fish and the flow rate. The purpose of increasing the roughness is to create a local turbulent flow through which small and medium-sized fish can be transported.

Due to the importance of this structure in maintaining the survival of different species of fish, optimization of fishways has been considered by researchers today. In this regard, an attempt is made to simulate the flow pattern in this structure by using computational fluid dynamics (CFD) software. Also, by changing the geometry of the structure and locating the obstacles placed in the fishway, it is tried to provide suitable conditions for the fish to overcome the flow velocity and also to create a safe place for the fish to pass upstream. Katopodis and Rajaratnam [5] conducted studies to design Denil fishway using a physical model. They named the Denil fishway with the characteristics of the flume width of 56 cm, the inner width of the frame equal to 36 cm and the slope of the frame 45 degrees to the floor as the standard Denil fishway. Then, by changing the dimensions and installation distance of the frames inside the fishway, they evaluated the effect of the parameter of the width of the frame to the width of the flume, the trend of flow changes and profiles of flow velocity inside the fishway.

Using shallow water numerical model and applying three Turbulence models: mixing length, k-ε and algebraic stress, Cea et al. [13] simulated a vertical opening type path. Their results showed that the use of the k-ε turbulence model can be used as a reliable option in simulating the flow in a fishway.

Using numerical modeling in Fluent software as well as laboratory studies, Mao et al. [14] tried to design a fishway for migratory fish that had less jumping power than salmon. They used the volume of fluid (VOF) method and the K-ε turbulence model to simulate the free surface flow profile. In their study, the flow velocity in each T-shaped fishway ranged from 0.42 to 1.22 m/s and for this velocity profile, no large vortex zone was formed on the fishway. This study showed that the T-shaped fishway can fully meet the specific requirements of these migratory fish in terms of velocity and flow patterns.

Mao [15] in a study examined the hydraulic characteristics of areas where feeding and spawning behaviors occur and investigated the hydraulic problems associated with the fishway. The results showed that if the hydraulic conditions of the fish were compatible with the hydraulic conditions of the spawning site, the fishway would be better suited to the instinctual needs of the fish and as a result, the success rate of fish migration through fishway is greatly increased. Also, Mao et al. [16] in another study using numerical simulation in Fluent software, investigated the issue of optimal control in relation to the optimal management of the T-shaped fishway. In the mathematical model, to solve the three-dimensional Navier-Stokes equation, the k-ε turbulence model and the volume of fluid method were used. The results of the numerical model developed by Mao et al. [16] were compared with laboratory studies and the overall error was approximately 8%, which shows a good agreement. In another study, Mao et al. [17] performed a quantitative description of flow velocity, turbulence, and other hydraulic parameters to evaluate the behavior of fish in the path of the fishway. Finally, they identified the response mechanisms between the behavioral characteristics of the target fish and the hydrodynamic characteristics of the fishway. Finally, by introducing criteria of flow hydraulic characteristics based on flow velocity and kinetic energy of turbulence, they introduced species of target fish that are suitable for the western plateau of China.

In previous researches, only limited parameters of flow in the T-shaped fishway, such as flow velocity and kinetic energy of turbulence, as well as limited forms of configuration of barriers, have been investigated. Hence, in the present study, for the first time, in addition to the consecutive form, alternate and reverse forms of T-shaped barrier configuration are introduced. Then, in order to select the best configuration using OpenFOAM open-source software, the hydraulic characteristics of the flow such as velocity, pressure, kinetic energy, turbulence and dissipation along the path of the fishway are examined.

2. Materials and methods

In the present study, in order to investigate the flow in the fishway with T-shaped obstacles with different configurations, a numerical model corresponding to the dimensions of the problem solved by Mao et al. [16] was used. Laboratory flume had a length of 24.5 m, a width of 2 m, a height of 1.2 m, a slope of 2.6%, as well as T-shaped and rectangular barriers in different positions along the flume. The flow rate in the physical model at the channel inlet is 0.4 cubic meters per second. The position of the rectangular and T-shaped obstacles along the path is shown in Figure 1 and the three-dimensional view of the flow blocks in the laboratory flume is shown in Figure 2.

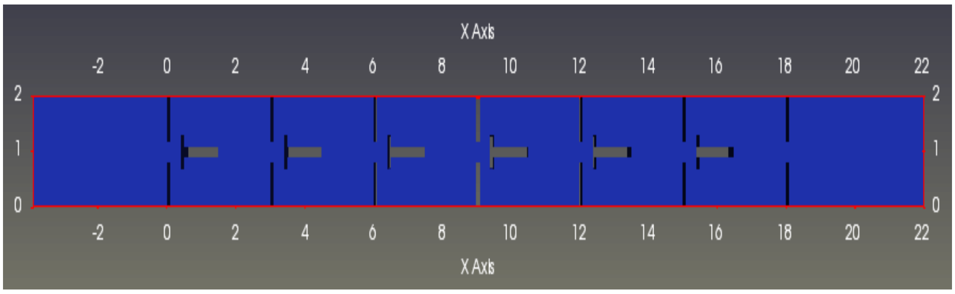

Figure 1. Plan of the laboratory model, and position of rectangular and T-shaped baffles

Numerical simulation in the present study was performed with a scale equal to the laboratory model in order to validate the model and after ensuring the accuracy of the model, the changes considered in the research are applied. To ensure uniform flow in the first pool and also not to affect the flow results in the final pool, the channel length in the numerical model was considered 26 meters. Excess length of 24.5 m was applied in two first and final pools. OpenFOAM open-source software was used to perform three-dimensional flow simulation in the present study. This software is one of the most powerful open-source software for computational fluid dynamics (CFD). All OpenFOAM code, solvers, and libraries are written in the C++ programming language, which is an object-oriented, high-level language. In this software, by default there is a tool called BlockMesh to create geometry. However, the possibility of receiving a meshed model with considered boundary condition from other software such as Gambit and Netgen is also foreseen. One of the advantages of OpenFOAM software compared to other commercial software such as Fluent or Ansys is in defining the required parameters of the system and choosing a suitable solver according to the problem conditions.

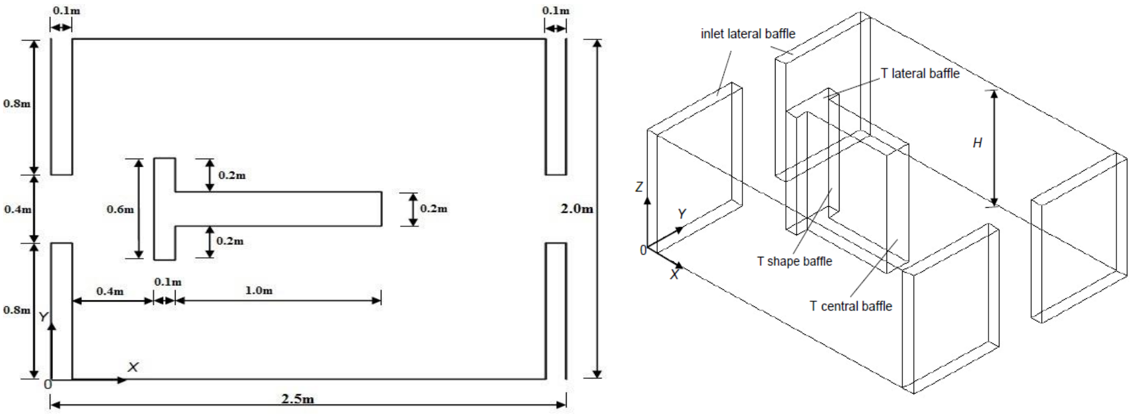

Figure 2. Three-dimensional view of the flow blocks of each pool in the laboratory model

Finite volume, finite element, boundary element and finite difference methods can be used to solve the equations governing two-phase flow and find unknown values. Solving the above equations involves discretizing and defining the set of equations in the desired intervals of the solution domain for unknown variables. In the present study, according to previous researchers [18], the interFoam solver, which is based on the finite volume method, was used for numerical simulation. The finite volume method is one of the most common methods for discretizing the governing equations and the steps of this discretization are described below. In the volume of fluid (VOF) model, the continuity equation between the two phases must be satisfied to simulate the interface between two flow phases. The continuity equation for each of these phases is expressed by assuming that they are incompressible. The fuzzy continuity equation is rewritten to keep the model in single-phase mode and to maintain the volume fraction distribution of each phase between zero and one. The phasic continuity equation is rewritten to keep the model in single-phase mode and to maintain the volume fraction distribution of each phase between zero and one [19]. Thus, the phasic velocity is rewritten in terms of relative and average velocity. Finally, the phasic continuity equation is given as follows.

$$\frac{\partial \alpha}{\partial t} + \nabla.(\alpha U) + \nabla.(u_r \alpha (1-\alpha)) = 0 \tag{1}$$

In which U = relative velocity, u_r = phasic velocity and α = phasic volume fraction. The nonlinear term in the above relation is solved by a completely implicit and iterative method and presents a finite solution for the phase fraction distribution. The momentum equation is rewritten in an unstable form to extract the volume fraction from the transfer term:

$$\frac{\partial (U_a)}{\partial t} + \nabla.(U_a U_a) + \nabla.(\frac{\tau_a}{\rho_a}) + \frac{\nabla \alpha}{\alpha} \nabla p_a (\frac{\tau_a}{\rho_a}) = \frac{\nabla_p}{\rho_a} + g + \frac{M_a}{\alpha \rho_a} \tag{2}$$

$$\frac{\partial (U_b)}{\partial t} + \nabla.(U_b U_b) + \nabla.(\frac{\tau_b}{\rho_b}) + \frac{\nabla \beta}{\beta} \nabla p_b (\frac{\tau_b}{\rho_b}) = \frac{\nabla_p}{\rho_a} + g + \frac{M_b}{\alpha \rho_b} \tag{3}$$

In which $U_{a,b}$ = phasic velocity, τ_a and τ_b = stress tensors of phases in a and b, p = pressure, ρ = liquid density and $M_{a,b}$ = Interfacial force per unit volume. To build a numerical model, pre-processing is required, including model geometry, meshing, and implementation of boundary conditions. Due to the existence of three-dimensional geometry in the present study and also in order to take advantage of various types of meshes that do not exist in the BlockMesh environment, geometry and meshing were made in the Gambit software environment. For this purpose, first the pages were defined and then the volume. A volume was considered for each pool and T-shaped baffles were installed inside the pools. After defining the numerical model, meshing and determining the dimensions of computational cells were performed. First, node values were adopted for the model lines. Then the model pages and each of the volumes were meshed (Figure 3).

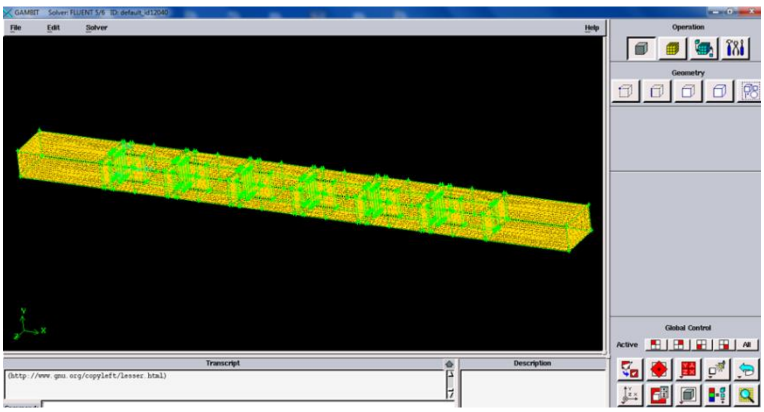

Figure 3. Model geometry and meshing in Gambit software environment

In order to investigate the sensitivity of the model to the mesh dimensions and eliminate the adverse effects of mesh size on the hydraulic results of the flow, different number of meshes were used in the form of three designs. Finally, design No. 1 with a mesh number of 720,000 was selected in order to achieve the best numerical results. Table 1 presents the parameters related to the error rate for the number of meshes used on the numerical results. In Table 1, RMSE = root mean square error and R^2 = correlation coefficient. Applying boundary conditions is another step in the preprocessing of the numerical model, which was done here by Gambit software.

Table 1. Error parameters for the number of meshes used

Senario Number	Mesh number	RMSE	R^2
1	720000	0.089	0.96
2	525000	0.71	0.88
3	251000	1.4	0.65

The boundary conditions applied to the model are: mass flow rate at inlet, pressure at outlet, wall for floor walls, sidewalls and T-shaped and rectangular barriers, as well as pressure outlet and atmospheric for free surface (Figure 4).

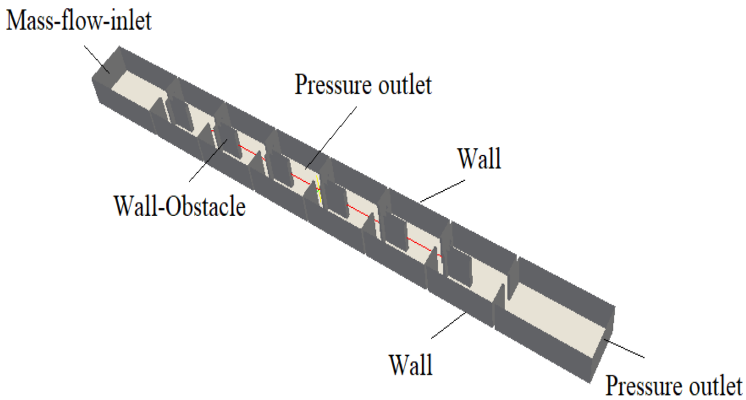

Figure 4. Boundary conditions used in simulation of fishway structure

Although more research has referred to the K-ε model in previous researches, in order to determine the best turbulence model in the numerical model, modeling for three turbulence models K-ε, RNG K-ε and K-ω were performed (Table 2).

Table 2. Error parameter of numerical and laboratory results for turbulence models

Senario Number	Turbulent Number	RMSE
1	k-ε	0.76
2	RNG K-ε	0.82
3	K-ω	1.7

The performance of different turbulence models has been compared through RMSE statistical index and laboratory model results. By evaluating the RMSE index between the velocity data measured in the laboratory and its corresponding value in numerical simulation, it was found that model K-ε shows better results than other turbulence models.

3. Validation of numerical model results

In this study, in order to investigate the effects of T-shaped baffle arrangement on the hydraulic characteristics of the flow and to select the most optimal configuration, three different types of geometric arrangement were produced. Then, by examining the flow characteristics including velocity, pressure, kinetic energy of turbulence and also the rate of kinetic energy dissipation along the path, the optimal configuration was selected. To evaluate the accuracy of the numerical model, the hydraulic results of the flow velocity at the same points in the numerical and laboratory models were compared and evaluated. This comparison was made in the width of the flow block, ie in the width of 2.5 meters of the block and in the height of the block. The results of numerical and experimental model error parameter, root mean square error (RMSE) and mean square error (MSE) are 0.31 and 0.098, respectively. These values indicate a satisfactory agreement of the numerical model with the laboratory results (Figure 5). The vertical axis refers to the velocity of the flow and the section is located at a distance of 10 cm from the wall along the block.

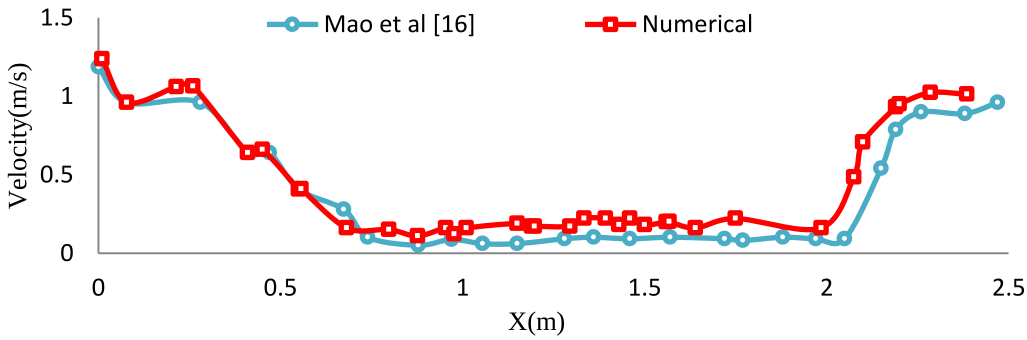

Figure 5. Comparison of flow velocity values at the same points of laboratory and numerical models

4. Results and discussion

In order to evaluate the optimal arrangement of the obstacles in the fishway, three types of configurations were used, including the arrangement of consecutive, alternate and reverse T-shaped baffles. All three configurations are simulated for an input flow rate of 0.4 m^3/s. The canal consists of a total of eight pools. Except for the first and last pools, all pools have T-shaped baffles. The form of T-shaped barriers in the first pool is the same for all three configurations provided to create the same input flow conditions (Figure 6).

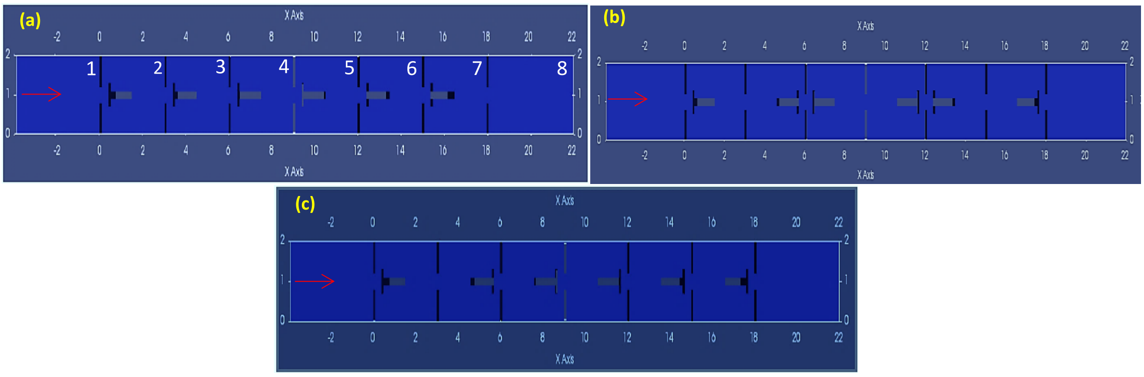

Figure 6. Arrangement of T-shaped baffles as a) Consecutive b) Alternate c) Reverse

One of the best ways to study the flow behavior in the fishways is to provide flow patterns. In this regard, Figure 7 shows the patterns of flow behavior in the fishway in different configurations in the four middle pools (3, 4, 5 and 6). In the consecutive form of baffles, the formation of the maximum velocity occurred only in the areas adjacent to the wall, while in other forms, the formation of this maximum velocity was observed in different parts of the channel. The formation of rotational and reciprocating currents at low velocities is another important point in recent configurations.

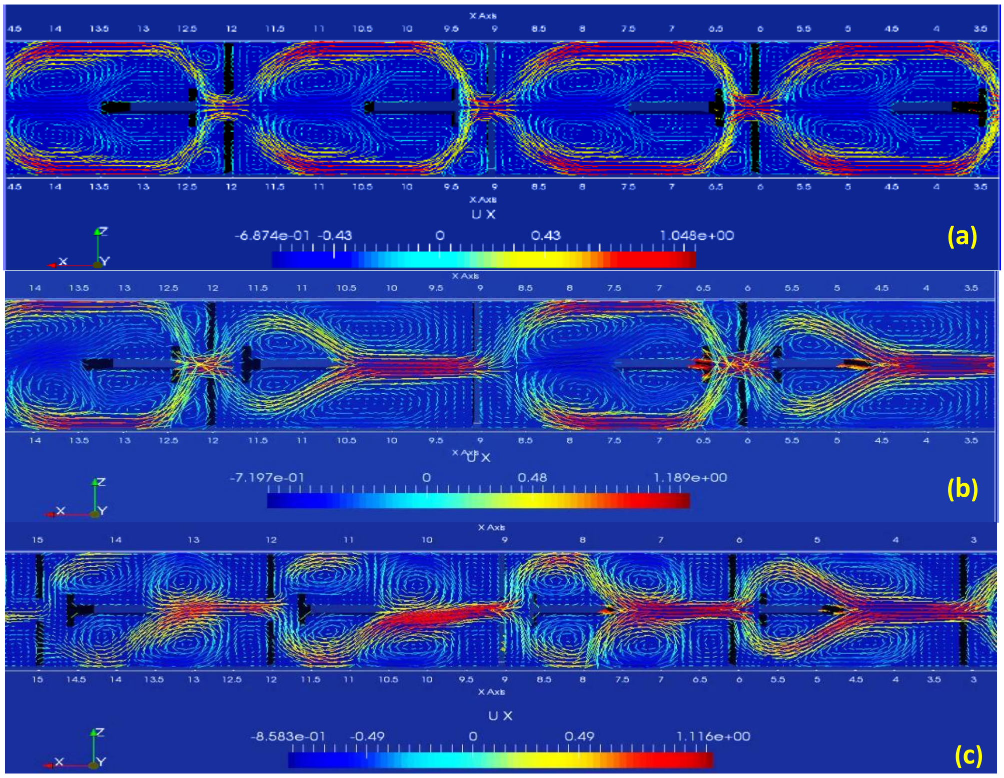

Figure 7. Two-dimensional flow nomogram in configuration with a) Consecutive b) Alternate c) Reverse

4.1. T-shaped baffles

Figure 8 shows the changes in the velocity in the direction of the flow Ux (m/s) in different configurations of T-shaped baffles. The output indicates the formation of minimum and maximum velocities in different parts of the channel, which are formed depending on the configuration on the side and middle range of the channel. In addition, the formation of rotational and reciprocating currents has led to minimum flow velocities that have made it easier for fish to move along the path.

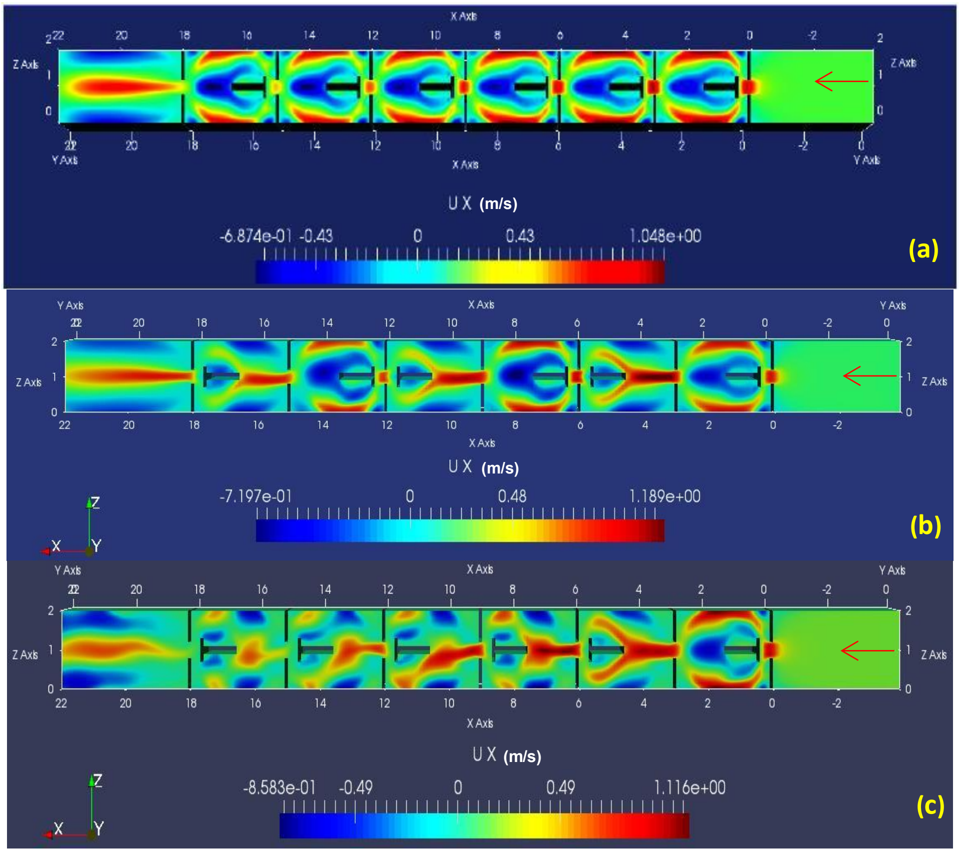

Figure 8. Flow velocity in configuration with a) Consecutive b) Alternate c) Reverse T-shaped baffles

The graphic results characterizing the relative flow pressure along the path for all three types of configurations indicate a decrease in this component along the path for all three types of configurations. However, the rate of this decrease in the reverse form occurs with a steeper slope, which helps to reduce the flow pressure faster (Figure 9).

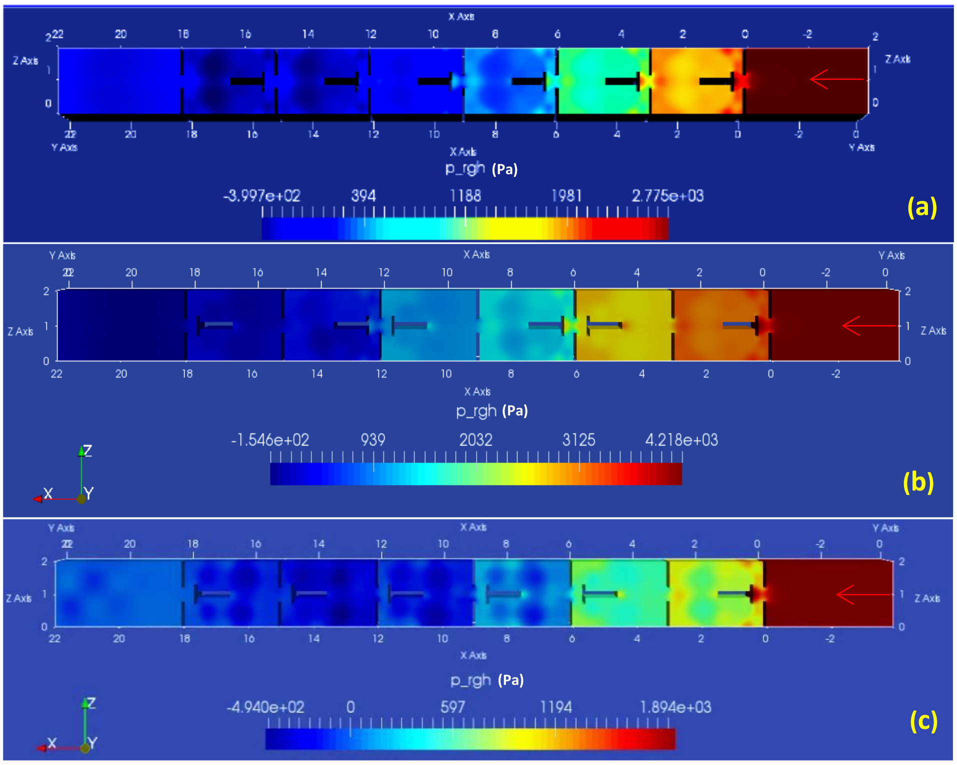

Figure 9. Flow pressure in the configuration with a) Consecutive b) Alternate c) Reverse T-shaped baffles

The turbulence kinetic energy (TKE) is one of the most important parameters in the design of the fishway. If the amount of this energy exceeds a certain threshold, the turbulence created during the flow will increase and the path of the fish will fluctuate [8]. Therefore, in selecting the optimal configuration, this parameter is of great importance. The turbulence kinetic energy per unit mass (K) is defined as follows:

$$K = \frac{1}{2}\left(\overline{u'^2} + \overline{v'^2} + \overline{w'^2}\right) \qquad (4)$$

In which, u′, v′ and w′ are velocity oscillating components based on Reynolds decomposition which are displayed as averaged over time. How this parameter changes in the three configurations indicates that the upper limit of its value in reverse, alternate and consecutive forms is equal to 0.030, 0.040 and 0.038 m^2/s^2, respectively. These values indicate better performance of the reverse form in controlling the turbulence kinetic energy (Figure 10).

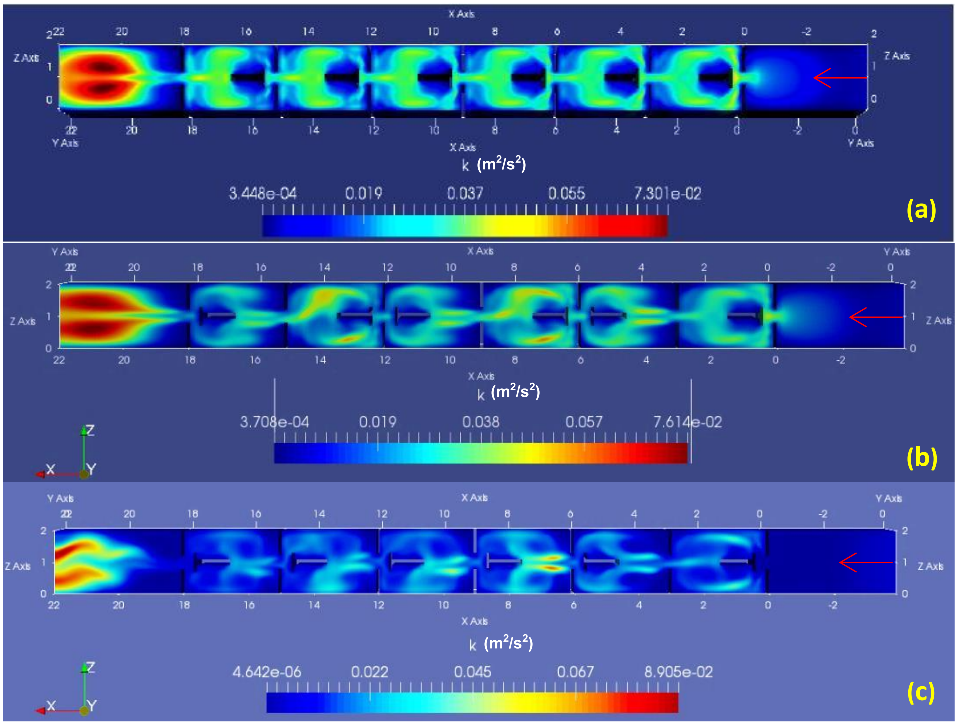

Figure 10. Turbulence kinetic energy of flow in configuration with a) Consecutive b) Alternate c) Reverse T-shaped baffles

The flow energy dissipation rate parameter (ω) in the fishway is one of the influential components in choosing the optimal configuration. That is, any configuration that leads to the highest rate of energy dissipation greatly facilitates the transport capacity of fish in the fishway [10]. Flow energy in channels is expressed by the following relation that the percentage of changes along the path and energy loss due to the presence of T-shaped baffles, represents the percentage of energy dissipation in the path of the fishway canal:

$$H = Z + \frac{P}{Y'} + \frac{V^2}{2g} \tag{5}$$

The graphical output of the numerical model for the three configurations shows that the upper limit of the energy dissipation percentage parameter in reverse, alternate and consecutive forms is 19.8, 19 and 15, respectively. This means that the reverse form of the T-shaped barriers causes more flow to be dissipated (Figure 11).

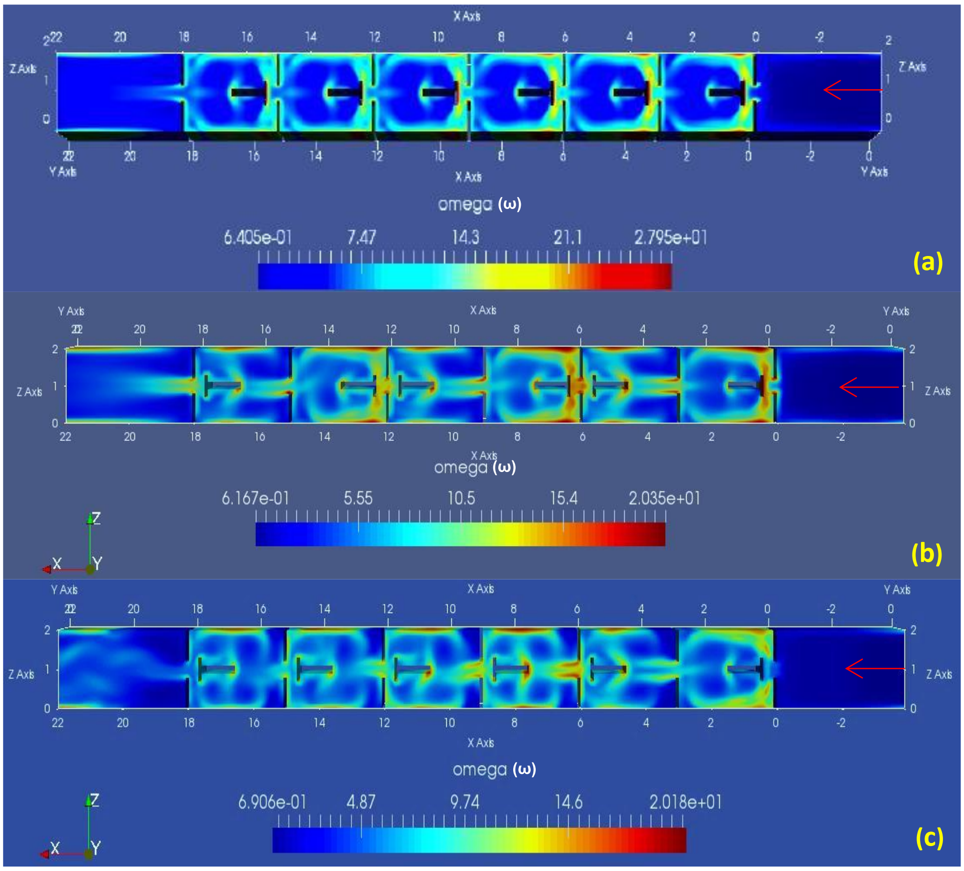

Figure 11. Flow energy dissipation pattern in configuration with a) Consecutive b) Alternate c) Reverse T-shaped baffles

In order to compare the flow characteristics in the fishway for three different configurations of T-shaped baffles, the longitudinal profile of the flow velocity is presented in Figure 12. The results presented for all profiles are from the beginning of pool number one in the direction of flow (X=0 m) to the end of the channel (X=22 m) and do not include the inlet pool. Longitudinal profiles are provided at a distance of 0.2 m from the side walls. Due to the symmetry of the geometry as well as the placement of T-shaped barriers in the middle range of the channel width, the longitudinal profile was extracted at Y=0.2 m. Longitudinal flow profiles for three different configurations show velocity variations in the range of -0.6 to 0.85 m/s.

Negative velocities indicate reverse flows along the path, which can greatly facilitate the movement of fish along the fishway. Therefore, the reverse flow in each pool is considered as an effective component for the movement of fish. In order to compare the different configurations of T-shaped baffles, two criteria: threshold velocity of 0.5 m/s and percentage of reverse flows along the fishway were evaluated. This threshold of velocity was considered according to the researchers [20] in order to pass the highest percentage of immature and weak fish (sustained swimming speed of 0.5 m/s). Based on the results, it was found that in the configuration with consecutive, alternate and reverse T-shaped baffles, 34.6%, 24.7% and 13.8% of the velocity data have values greater than the threshold of 0.5 meters per second, respectively. In addition, the study of reverse flows along the fishway in consecutive, alternate and reverse T-shaped configurations showed that 23.7%, 43.5% and 68.3% of the velocity data along the fishway are reverse flows, respectively. Comparison of the results for the three configurations shows that in both the threshold velocity and return current criteria, the inverse form of the T-shaped barriers resulted in better performance. .

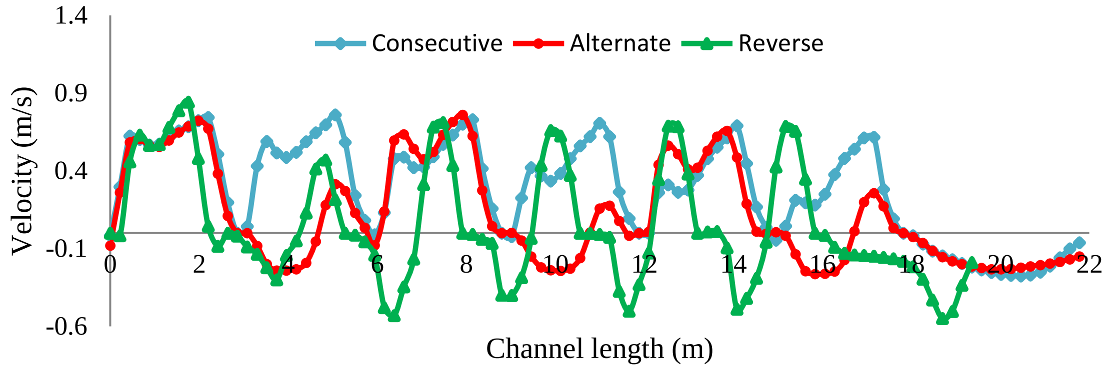

Figure 12. Comparison of longitudinal flow velocity profile for three configurations at Y=0.2 m and Z=0.8 m

Comparison of the longitudinal profile of the flow pressure indicates that in all three configurations the flow pressure along the fishway has decreased. All three configurations have performed well to gradually reduce the flow pressure along the path from one block to the next one (Figure 13).

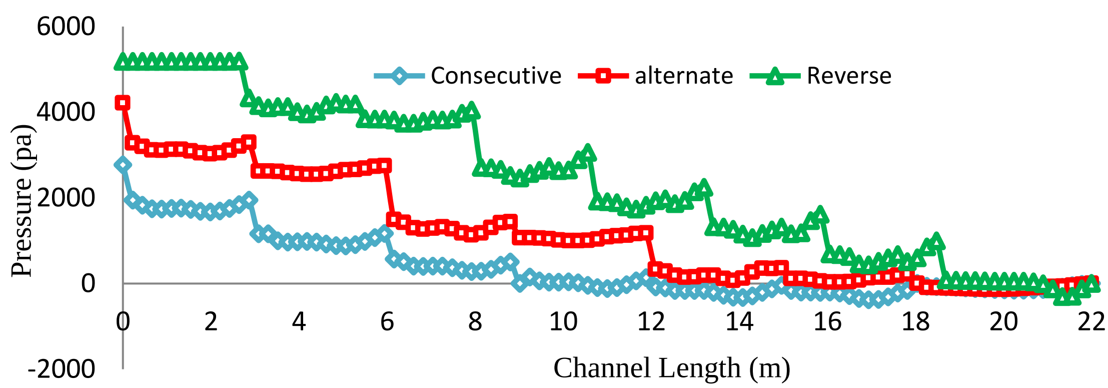

Figure 13. Comparison of longitudinal flow pressure profiles for three configurations at Y=0.2 m and Z=0.8 m

In order to compare the turbulence kinetic energy characteristic of the flow which can lead to the turbulence in the path, the longitudinal profile of these characteristics was compared at the transverse position of Y=0.2 m of the channel (Figure 14). The range of changes of this characteristic was in the range of 0 to 0.045 m^2/s^2. In order to compare the turbulence kinetic energy results along the path, the criterion of the mean limit value of the range of results was selected to be 0.02 and the results of the data of this characteristic along the path were compared to it. This threshold was selected to detect the turbulence energy percentage below the mean among the values obtained for the various configurations. It was found that in the configuration with consecutive, alternate and reverse T-shaped baffles, 25.7%, 36.6% and 84.1% of the turbulence kinetic energy data have values below the threshold of 0.02, respectively. Therefore, it was found that the reverse T-barrier configuration was able to control the kinetic energy of the flow compared to other configurations in the lateral regions. This helps the fish move more easily and can make this configuration more priority than other configurations.

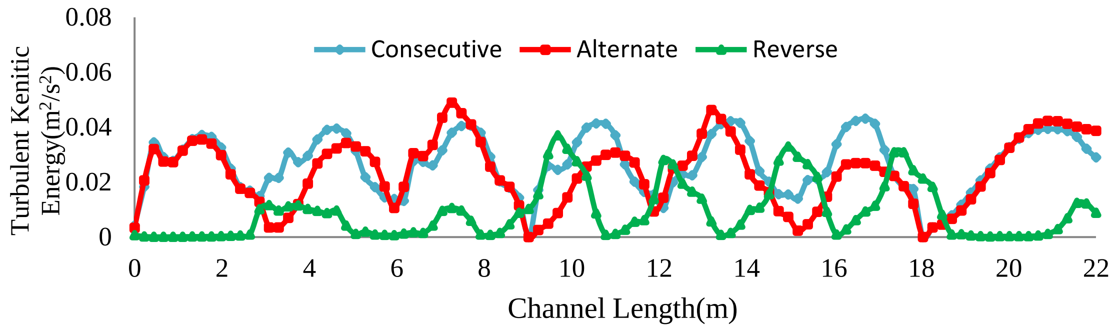

Figure 14. Comparison of longitudinal turbulence kinetic energy profile for three configurations at Y=0.2 and Z=0.8 m

The flow energy dissipation characteristic, which can help to select suitable paths for fish to move and rest, was compared by showing its longitudinal profile in different configurations at the position of Y=0.2 m (Figure 15). The range of changes in this characteristic is in the range of zero to 22%. In order to compare energy consumption along the path, the criterion of a limit value of 8% was selected and the results of the data of this characteristic along the path were compared to this number. After investigation, it was found that in the configuration with consecutive, alternate and reverse T-shaped barriers, 27%, 14% and 61% of the flow energy dissipation data along the fishway have values higher than the threshold of 8%, respectively. Therefore, the reverse T-barrier configuration in this feature also offers better and more uniform performance than other configurations. The channel axis, on average, provided the highest dissipation rate along the channel. In the vicinity of the walls, although locally the other configurations performed better, the inverted configuration performed more uniformly than the other configurations. Therefore, it can be said that it has a priority of choice from the point of view of this characteristic.

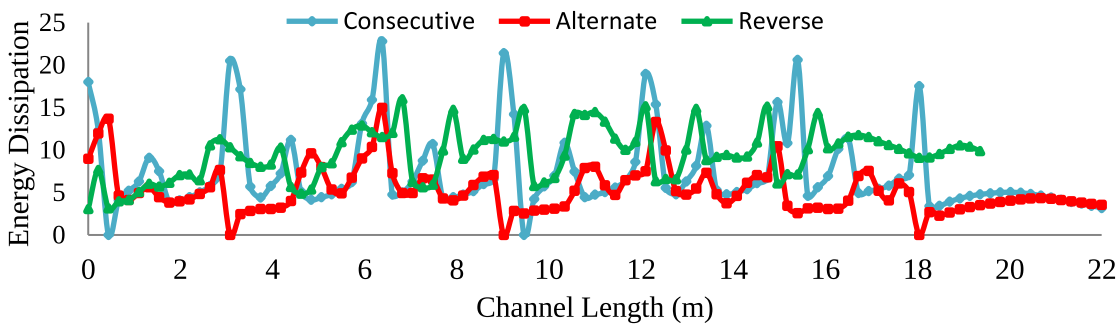

Figure 15. Comparison of longitudinal energy dissipation profile for three configurations at Y=0.2 and Z=0.8 m

By examining the various hydraulic parameters involved in the flow in the fishway, significant results were obtained that can help designers to select the best configuration of baffles in the pools. Among the studied parameters, the flow pressure in all configurations has the same and specific trend and the presence of different barriers has led to a decrease in pressure along the path. However, other parameters have given their own results due to the change in the configuration form. A summary of the results of comparing the different flow characteristics in the fishway including velocity, kinetic energy, turbulence and energy dissipation is given in Table 3. This table summarizes the results of comparing the different flow characteristics of the fishway, including velocities less than 0.5 m/s, turbulence kinetic energy less than 0.02 m^2/s^2, and energy dissipation percentage greater than 8 for all three configurations. Comparison of the results shows that in all three flow characteristics including flow velocity, kinetic energy, turbulence and energy dissipation, the configuration of reverse T-shaped barriers has a better performance. To evaluate the flow velocity, two criteria of limit velocity and percentage of reverse flow were considered.

Table 3. Comparison of flow characteristics in the fishway path for different configurations

T-shaped barrier configuration type	Hydraulic characteristics of the flow along the fishway path			
	Energy dissipation	Turbulence kinetic energy	Flow velocity	
	Criterion: Threshold	Criterion: Threshold	Criterion : Threshold	Criterion: Reverse flow
	Disspation percentage greater than 8	Turbulence energy percentage less than 0.02	Percentage of velocities less than 0.5 m/s	Percentage of velocities less than zero (reverse flow)
Consecutive	27%	25.7%	65.4%	23.7%
Alternate	14%	36.6%	75.3%	43.5%
Reverse	61%	84.1%	86.2%	68.3%

5. Conclusions

Adding auxiliary blades to the pools of the fishway structure usually benefits the fish. The simple design and relatively few materials required to implement the auxiliary blades make them a good choice for optimizing existing fishways. These blades facilitate the process of passing fish from one pool to the next. In addition, they help smaller fish that have less physical ability and swimming skills to successfully cross the structure. Fish can use their burst swimming speed for a limited time (about a few seconds). The auxiliary blades provide more space in the pool for them to rest and recover their energy. In this way, the fish are able to swim longer distances and successfully cross the entire length of the fishway. In the present study, T-shaped blades and obstacles were used in the form of consecutive, alternate and reverse configurations, and then the best configuration was selected by comparing different hydraulic parameters. Based on the studied cases, the following results can be summarized:

1- OpenFOAM open-source model has the ability to simulate the flow in the path of the fishway with high accuracy, so that it has the error MSE=0.098 and RMSE=0.31 for numerical and laboratory results.
2- The reverse form of T-shaped barriers with 68.3% reverse flow rate along the canal and 86.2% occurrence at speeds of less than 0.5 m/s had the best performance among other configurations.
3- 3- The reverse form of T-shaped baffles with the occurrence of 84.1% of the turbulence kinetic energy less than 0.02 m^2/s^2 compared to other configurations, had the lowest amount of this destructive energy. This can help the fish to move slowly and away from turbulence.
4- The reverse form of T-shaped baffles had the highest energy dissipation percentage with 61% among other configurations. This is also a very sensitive factor for the smooth movement of fish.
5- The reverse form of T-shaped baffles in the fishway was presented for the first time in this research and by comparing the hydraulic characteristics, it has the most optimal form compared to other configurations of T-shaped barriers.

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