

Investigation of innovative designs of high-velocity channels for damping kinetic energy of flows

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ABSTRACT

In our contemporary world, demanding sustainable resource management, the study focuses on innovative fast flow channel designs. It investigates their efficacy in reducing flow kinetic energy, aiming to optimize water and energy management and diminish flood risks. Employing diverse methodologies, it analyzes and develops these designs, proving their substantial impact on stream energy management. These innovations not only enhance energy efficiency but also mitigate risks associated with excess kinetic energy, promoting safer stream management. This research significantly contributes to fluid dynamics and engineering, deepening the understanding of kinetic energy control in flows and offering potential solutions for water supply, environmental sustainability, and infrastructure safety challenges.

Key words: artificial roughness, environmental sustainability, hydraulic structures, reclamation canals, reinforced concrete fast flow, water flow energy damper

HIGHLIGHTS

- Investigating ways to reduce flow kinetic energy for better resource management.
- Exploring rapid flow channel structures for effective energy mitigation.
- Innovative designs enhance energy management in streams and reduce risks.
- Enhancing understanding for innovative water management solutions.

INTRODUCTION

Exploring the subject of developing innovative designs of fast flow channels to dampen the kinetic energy of flows is critical in today's world facing increasing challenges in water and energy management, as well as infrastructure and environmental safety (Wan *et al.* 2023). Global climatic changes associated with increasing frequency and intensity of extreme weather events such as floods and natural disasters emphasise the need to develop effective methods to control and manage water and fluid flows. Exploring innovative approaches to dampening the kinetic energy of flows has the potential not only to optimise the use of water resources, but also to reduce flood risks and the devastating effects associated with infrastructure damage (Xiong *et al.* 2023). In the context of limited natural resources and the pursuit of sustainable development, the development of new rapid canal designs can help to reduce energy consumption and improve the efficiency of water supply systems, which are important both locally and globally.

The scope of this study covered several key aspects related to the damping of kinetic energy of flows through the development of innovative fast flow channel designs. Existing methods for managing water and fluid flows may not be sufficiently effective in the face of changing climatic conditions and the increasing need for sustainable engineering solutions. This leads to the need to research and develop new, more efficient designs that can dampen the kinetic energy of flows more accurately and reliably. The lack of optimal solutions for kinetic energy damping can have serious practical consequences such as infrastructure damage, flooding, deterioration of water resources and environmental disruption. Inefficient flow management can also cause energy and economic losses due to excessive consumption of resources (Abidar *et al.* 2023).

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According to [Zholamanov et al. \(2023\)](#), the development of high-velocity channels represents a significant step in increasing the efficiency of flow control systems, which directly contributes to reducing the probability of flooding and optimising the use of water resources. [Koshumbaev et al. \(2017\)](#) noted that engineering solutions that consider environmental sustainability in damping the kinetic energy of flows have proven to be effective in maintaining biodiversity and preserving natural resources, which is a key aspect in modern scientific practice. However, the impacts of long-term use of such solutions on ecosystems, as well as their influence on changes in climate indicators, have been understudied, which requires further research and an integrated approach to analyses. According to [Kerteshev \(2012\)](#), efficient management of water flows using innovative designs of fast flowing canals can lead to reduction of excessive energy and resource consumption, which in turn contributes to reduction of anthropogenic impact on the environment.

According to [Rustem et al. \(2021\)](#), the study of innovative designs of spillway channels with artificial roughness is a relevant and promising area of hydraulic engineering research. The roughness of spillway channels plays a vital role in regulating water flow, preventing erosion and washaway, and ensuring the safety and efficiency of hydraulic structures. [Lavrov \(2001\)](#) addresses the fact that integration of social aspects into the development of fast flow channel designs has a positive impact on mitigating potential social and economic impacts such as population resettlement or disruption of agricultural practices. Added research and consideration of a wide range of social factors is important to create sustainable and socially responsible engineering solutions in this area. As [Ibraev & Lee \(2016\)](#) note, innovative designs of high-velocity channels have the potential to become a key element of infrastructure development, providing an opportunity for balanced water supply, efficient flow management and contributing to solving complex water management issues. However, the impacts of these structures on hydrological and ecological systems, as well as their long-term impacts on biodiversity and water resources, are still understudied, requiring further research to ensure the sustainability and effectiveness of such engineering solutions.

The purpose of this study was to investigate the innovative designs of high-velocity channels that consider an integrated approach to water and fluid flow management, and provide a balance between technical efficiency, environmental sustainability, and social aspects.

MATERIALS AND METHODS

The study was conducted at the research laboratory 'Hydrological and technical safety of hydraulic structures' at the Department of Water Resources of M.Kh. Dulary Taraz Regional University.

The research was performed by reviewing existing literature and research articles related to innovative designs of high-velocity channels for damping kinetic energy of flows. The literature review involved searching multiple scientific databases such as ScienceDirect, Web of Science, Scopus, and Google Scholar. Keywords such as 'high-velocity channels', 'kinetic energy damping', 'hydraulic structures', 'fluid flow control', 'water management', and combinations of these terms were used to identify relevant publications.

The analytical method helped to expand the understanding of dynamic flow characteristics and kinetic energy dissipation processes in fast flowing channels. Through mathematical modelling, it was possible to identify the main factors affecting the effectiveness of different flow control designs and techniques. This method enabled a systematic analysis of the influence of different channel geometrical parameters, obstacle locations, and airfoils on energy dissipation processes. In addition, the analytical study helped to determine the optimal conditions for reducing kinetic energy and creating efficient damped flows.

Using statistical method, it was possible to confirm and refine the obtained results, enriching them with empirical data from real conditions. Application of statistical methods allowed covering the considerable dependences between various parameters of fast flow channel designs and the efficiency of kinetic energy damping. The study of substantial amounts of data on flow behaviour under different conditions highlighted the best technical solutions for different types of applications, including water flow control in rural water supply systems and coastal protection.

By applying the functional method, not only efficient designs of fast flow channels, but also optimal strategies for their utilisation in different scenarios were identified. This approach allowed the system to be considered as a whole, considering the interrelationships and interactions between the flow components, the structure, and the environment. The functional method also helped to assess the potential for integrating innovative designs into existing infrastructure. Investigating the impact on overall system performance and the ability to optimise the interaction with other elements has enabled the development of more flexible and adaptive solutions.

The structural-functional method helped to carry out a comprehensive study of the relationships between the structure of high-velocity channel designs and their functional characteristics. This approach allowed finding how different elements and parameters of structures affect the processes of kinetic energy damping and flow control. The use of the structural-functional method also contributed to the optimisation of the designs by investigating their structural elements. The study of the internal relationships and hierarchy of the components enabled the identification of the optimum shapes, sizes, and materials to maximise the energy damping efficiency.

The method of deduction helped in clarifying and confirming theoretical assumptions identified in the study of other methods. The application of this method made it possible to deduce particular laws and dependencies based on generalisation of observed phenomena and previously established facts. Examination of the results obtained with other methods, using the method of deduction, enabled a more profound logical consideration of the processes of damping the kinetic energy of the flow in the channel. This helped to identify hidden factors that can influence the performance of high-velocity designs and that might have been missed by superficial examination.

By applying a synthesis method, a holistic and innovative view of innovative high-velocity channel designs was created. Using the synthesis method, innovative designs were developed that consider a variety of aspects, from technical efficiency to environmental sustainability and social acceptability. The integration of various elements and parameters has enabled the creation of complete solutions able to cope with the complex challenges of water and fluid flow control in canals.

RESULTS AND DISCUSSION

The programme of construction and modernisation of hydraulic structures of water management systems, which is currently being implemented in the Republic of Kazakhstan, requires the use of innovative economical and reliable engineering structures. To date, about 60 large (with a flow rate of more than 100 m³/s) and many medium and small irrigation canals are in operation in various climatic and geological conditions (Azimov & Avezova 2022). One of the most widespread hydraulic structures included in the complex of structures on reclamation canals, especially in the conditions of rugged terrain, are slope-regulating structures. The role of the latter is increasing due to the reclamation of agricultural lands in the previously undeveloped territories of mountainous and foothill areas of Kazakhstan. The juxtaposition of channel sections located at different elevations, in places where the terrain drops, should be carried out with the highest possible degree of damping of the kinetic energy of the flow, provided that a favourable hydraulic regime is ensured over the entire range of flow rates. Preventive maintenance facilities must meet the requirements of cost-effectiveness, reliability, and environmental friendliness.

The Ministry of Ecology and Natural Resources of Kazakhstan has announced measures to alleviate social tensions related to water scarcity in Zhambyl region. For Taraz and its neighbourhood the problem of water resources shortage is becoming urgent. The region is facing the fact that irrigation in Talas and Korday districts has been completely stopped due to severe water shortages. According to information provided by the Ministry of Ecology and Natural Resources, the current water volume at the Talas hydroscheme, including recharge from collector water, is 7.26 m³/s. These water resources are distributed between Zhambyl and Baizak districts according to certain proportions, but Talas district is completely deprived of irrigation (Kaderova & Aldwijk 2020). High-velocity channel designs, used to dampen the kinetic energy of flows, are typically used in the regions where fluid flows need to be controlled to prevent damage or create certain conditions. These structures can be used in various engineering and industrial structures such as turbine systems, water and wastewater systems, and in aerodynamic and hydrodynamic testing (Willis *et al.* 2019).

High-velocity channels are hydraulic structures that are in the upper part of the water stream quickly and without separation and direct it to the lower channel following the flume. They include an input segment, a chute (or transit portion), and an output segment that acts as a shock absorber (Figure 1). The following is an overview of several variations of fast flow channel designs that have found widespread use in various engineering applications. These diverse types of designs are effective solutions for controlling fluid flow, providing control over its energy and direction.

The cross section of the fast flow can have different shapes such as rectangular, trapezoidal, triangular, and polygonal. However, from a hydraulic standpoint, a rectangular cross-section is considered to be optimal, as other shapes can lead to a concentration of flow in the centre section, which creates instability. If a rectangular cross-section of the rapid flow is used, the side walls are designed as retaining walls and their dimensions are determined based on static calculation. Diffusers are engineering structures used to control fluid flows by slowing them down and simultaneously increasing their pressure

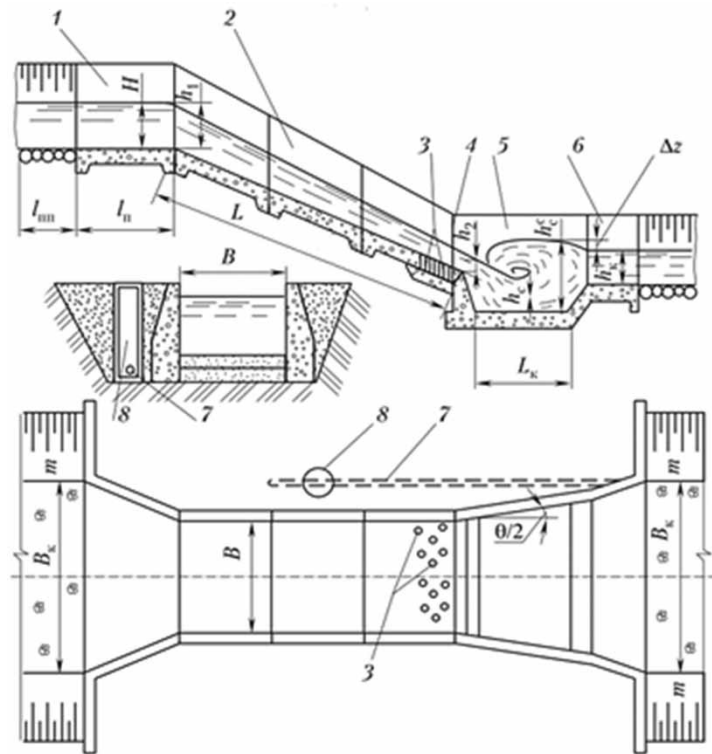


Figure 1 | Reinforced concrete fast track. Note: 1 – inlet; 2 – flume; 3 – holes in slabs; 4 – joint; 5 – water well; 6 – outlet; 7 – wall drainage; 8 – control well.

(Wang *et al.* 2020). This process is achieved by gradually widening the cross-section of the channel through which the flow passes. The basic idea of diffusers is to redistribute the kinetic energy of the flow over a larger area, resulting in higher static pressure.

Diffusers are a variety of shapes adapted to the specific requirements of each application. Conical diffusers are designs with a gradual widening of the cross-section, forming a cone shape. This allows the flow to gradually move from the narrower part of the channel to the wider part, ensuring a smooth and efficient process of slowing down and increasing pressure. Radial diffusers change the channel cross-section in the radial direction, which is particularly useful when dealing with flows that have rotational motion, such as fans or turbines. This allows for efficient redistribution of energy in the flow, which can be important to ensure optimal performance of rotating systems. Combination diffusers, on the other hand, combine elements of different shapes to best adapt to the application (Vasilenkov & Topalov 2018). They can combine conical and radial components to maximise the efficiency of flow retardation and pressure boosting.

Deflectors are functional components designed to actively control fluid or gas flows in a variety of engineering contexts (Huang *et al.* 2021). The main purpose of deflectors is to change the direction of flow in a certain way to control kinetic energy and prevent undesirable effects on surrounding objects or systems. One of the main aspects of deflectors is the ability to direct the flow in a particular direction. By changing the direction of the moving fluid or gas, deflectors can create controlled flows, which can be important for avoiding collisions with objects, ensuring uniform flow distribution, or preventing undesirable environmental impacts. Another important aspect of deflectors is their ability to create vortices in the flow. By special orientation of the deflectors, flow swirling can be induced, which can be useful in various technical studies and applications such as aerodynamic tests or fluid flow characterisation studies.

Aerators are technical devices widely used in water supply and drainage systems to improve the characteristics of fluid flows. The main function of aerators is to introduce air intensively into the fluid flow, which helps to achieve several important objectives such as reducing kinetic energy, preventing overpressurisation and reducing turbulence. The process of aerators begins with the introduction of air into the fluid flow. This creates many air bubbles that mix intensively with the liquid. Through this intensive mixing, the aerators help to dampen the excess kinetic energy of the flow. The kinetic

energy of the liquid is converted into turbulent motion of air bubbles, which leads to a decrease in the flow velocity and its energy characteristics. However, aerators not only provide kinetic energy damping, but also help prevent overpressures. By creating added resistance and reducing flow velocity, aerators help to reduce pressure, which can be particularly important in high flow rate systems. Turbulence reduction is also a vital aspect of aerator performance. Turbulence can cause undesirable effects such as equipment wear, corrosion, and inefficient mixing in the system. By intensively mixing and stabilising the flow, aerators help to prevent turbulence and provide more stable hydraulic conditions.

An integrated approach to channel design for high velocity flows is proposed, combining various innovative techniques to effectively reduce kinetic energy. This integrated design includes several key elements. First, a diffuser-based inlet section that gradually reduces flow velocity while simultaneously increasing pressure. This section includes a tapered or rectangular diffuser designed to smoothly decelerate the incoming flow, converting kinetic energy into pressure energy. Optimizing the expansion angle and length of the diffuser will be critical to minimize flow separation and maximize pressure recovery. Second, deflector vanes will be strategically placed along the length of the channel to create controlled vortices and dissipate kinetic energy. These vanes will help break up the flow and create turbulence, thereby aiding in energy dissipation.

Third, strategically placed aerators introduce air into the flow, further reducing turbulence. By enhancing air-water interaction, these aerators help dissipate kinetic energy, especially in areas of high turbulence. Fourth, an outlet section lined with absorbent materials with high energy absorption capacity is used to capture residual kinetic energy. By lining the outlet section with materials such as porous concrete or rubberized coatings, the residual kinetic energy will be absorbed through material deformation and friction, further reducing the velocity of the outgoing flow. Finally, artificial roughness elements will be placed on the channel surface to create microscopic turbulence and promote additional energy dissipation. These roughness elements, strategically placed along the channel, will induce turbulence, effectively slowing the flow and dissipating kinetic energy.

By integrating these different techniques in a modular and optimized manner, the proposed design aims to provide highly efficient kinetic energy damping according to the specific flow conditions and application requirements. However, further research, numerical modelling, and experimental validation are recommended to refine and evaluate the effectiveness of the proposed integrated solution. Through iterative refinement and verification, the integrated design approach can be optimized to achieve the maximum efficiency of kinetic energy damping in channels with high-speed flow, which will contribute to the progress of hydraulic engineering and water resources management.

Absorbers represent key components in the field of engineering and technical systems where flow energy management is an important challenge (Miraglia *et al.* 2022). They are designed to effectively absorb excess kinetic energy that may occur in liquid or gas flows. This process is carried out by directing the flow through a specially selected material with high absorption capacity. The basic mechanism of action of absorbers is to convert the kinetic energy of the flow into other forms of energy such as heat or mechanical deformation of the material. To achieve this goal, absorbers typically use special absorbent materials that can convert the energy of the flow into the internal energy of the material. The application of absorbers has a wide scope of applications in various fields. In acoustics, for example, absorbers can be used to absorb sound energy and reduce echoes and noise. In aerodynamics, absorbers can help control vibration and excess dynamic energy in air currents. For optimal results, the choice of absorbent material plays an important role. This material must have a high absorption capacity while maintaining structural and functional stability when exposed to flow. Engineers often select materials by considering their mechanical, thermal, and chemical properties to ensure optimal absorber performance.

The design criteria for an integrated high-speed channel structure designed to effectively reduce the kinetic energy of fluid flows are divided into three main sections: inlet section, channel section, and outlet section. In addition, it is important to consider additional factors affecting the overall design. The main task of the inlet section is to effectively reduce the velocity of the incoming high velocity flow. The proposed approach utilizes a conical or rectangular diffuser section that is progressively widened. The focus is on optimizing the angle and length of the diffuser expansion to minimize flow separation and maximize pressure recovery.

To minimize form resistance, it is recommended to maintain a rectangular cross-section with smooth concrete surfaces when transitioning to the channel section. Deflector vanes are proposed as a means to create controlled vortices and facilitate kinetic energy recovery from turbulent processes. Computational fluid dynamics (CFD) simulations are advantageously used to optimize the angle and spacing of the deflector blades. In addition, aerators are proposed as a means to reduce turbulence by utilizing the interaction between air and water. The specific design and location of the aerators will be determined through experimental testing and flow visualization studies. Preferably, the outlet section should gradually widen and have a large cross-sectional area to further reduce the flow velocity. The walls and floor of this section should be covered with energy-

absorbing materials, and it is recommended to include artificial roughness components to promote further energy dissipation due to microscopic turbulence. The focus is on optimizing the size, shape, and distribution of the roughness elements.

The design includes several key aspects such as conducting thorough hydraulic simulations to validate and optimize the system, ensuring structural integrity and durability, integrating monitoring and instrumentation systems for real-time performance evaluation and control, assessing environmental impact, and developing operation and maintenance protocols. To validate and improve the proposed solution, it is advisable to conduct comprehensive experimental testing, numerical modelling, and iterative design refinement. This methodology ensures that a fault-tolerant and efficient high-speed channel configuration that is fit for purpose, taking engineering and environmental considerations into account.

Hydraulic structures are a variety of engineering elements and structures used in water supply and drainage systems to control and regulate fluid flows (Epicum *et al.* 2020). These facilities form an integral part of the infrastructure that ensures the optimal operation of water supply and wastewater disposal systems, as well as preventing adverse consequences associated with excessive energy flows. In the context of water supply and wastewater disposal systems, hydraulic structures fulfil several essential functions. The steps and elevation differences within them contribute to gradual changes in fluid levels in channels and streams. This achieves controlled flow deceleration, converts excess kinetic energy into static pressure, and effectively controls flow velocity (Ostanin 2022). The smooth changes in fluid levels created by these structures help to minimise pressure and prevent turbulence, contributing to a more stable and efficient system.

Artificial roughness is another type of hydraulic structures that play a significant role in controlling the energy of flows. They create a narrow narrowing of the channel cross-section, which leads to an increase in flow velocity and a corresponding change in pressure (Hadian *et al.* 2023). Artificial roughness is actively used to control and regulate flows in water supply systems, helping to reduce kinetic energy and maintain optimum hydraulic conditions. Thus, hydraulic structures are key elements in the field of engineering to ensure efficient management of fluid flows in water supply and wastewater disposal systems. Steps, height differences, stops, and other structures help to dampen excess energy, ensure stable system operation and minimise the negative impact on the environment and equipment.

High-velocity channel designs form an integral part of engineering systems designed to manage and control fluid or gas flows with high velocities and energy (Moshe *et al.* 2020). However, selecting a particular design for such channels is a complex process that requires consideration of many factors related to flow characteristics and system requirements. The key parameters affecting design selection are flow velocity, pressure, temperature, roughness, and other physical properties of the process medium. For instance, high velocity flows may require specialised airfoils to effectively control flow and minimise energy loss. For aggressive environments or elevated temperatures, special materials resistant to corrosion and high temperature may be required. It is also critical to consider physical laws and principles when designing and selecting the design of fast flow channels (Gorobets 2018). The laws of conservation of mass, momentum and energy must be carefully considered in the design to ensure energy balance and optimum system performance. Safety requirements must also be considered to prevent emergencies and minimise risks to personnel and equipment.

The research topic represents an important and relevant area in the field of hydraulic engineering and technology. In today's context, where climate change is leading to an increase in extreme weather events such as intense rainfall and flooding, effective water management becomes particularly critical. Research into innovative high-velocity channel designs is aimed at developing innovative methods for controlling and managing water flows. The use of the new structures allows the kinetic energy of the flows to be dampened more effectively, which helps to reduce flood risks as well as minimise the damaging effects on adjacent infrastructure.

This research has implications for various aspects including safety, environmental sustainability and optimisation of energy resources. Suitable canal design can also lead to improved water supply, especially in rural areas where water resources are often limited. One of the key strengths of the research is its potential for practical implementation. The results can provide a basis for the development of new engineering and design solutions and the implementation of more efficient water flow control systems. Such a study has a wide range of applications including water supply, energy, agricultural sectors, and urban planning. It emphasises the importance of innovation in engineering and applied sciences to address the complex challenges of changing climatic conditions and sustainable development. Thus, the study of innovative high-velocity channel designs represents an important contribution to the field of hydraulic engineering, enriching the understanding of water interactions and providing new tools for flow management and natural disaster risk reduction.

According to recent studies, hydrokinetic energy technologies represent an innovative and promising approach to generate electricity from the movement of water flows (Ibrahim *et al.* 2021). This method is based on the kinetic energy carried by

ivers, tides, and sea currents. One of the key advantages of this approach is its sustainability and continuity: water movements occur regardless of time of day or weather conditions, making hydrokinetic energy a more reliable and predictable source than, for example, wind or solar power. This type of technology has high potential for sustainable energy production in remote areas where access to conventional energy sources is limited. It can also play an important role in diversifying the energy matrix and reducing dependence on fossil fuels, which is relevant in the pursuit of environmental sustainability. However, the development and application of hydrokinetic energy technologies are also fraught with challenges. The technical complexity of creating efficient kinetic energy harvesting and conversion devices will require significant engineering and investment. Furthermore, the environmental impact of such devices needs to be carefully studied to avoid negative effects on the ecosystems of rivers, seas, and oceans.

Maharana *et al.* (2023) define that layered reactive flow is characterised by smooth fluid movement along a channel or river where different layers of fluid move at different velocities. This phenomenon is conditioned by the interaction of viscous effects and flow inertia. An essential aspect of the stability of such a flow is its ability to preserve its structure and characteristics under various influences. The study of the stability of layered reactive flow in a channel is of practical importance in the design of hydraulic structures such as spillways, sluices, hydroelectric power plants, and other infrastructure facilities. Determining the stability of layered reactive flow requires a comprehensive approach involving both theoretical models and experimental studies. Modelling using numerical methods allows analysis of various flow parameters and prediction of flow behaviour under different conditions. Experimental studies are carried out in hydrodynamic laboratories using physical mock-ups to visualise and measure flow characteristics.

1. Ghaith *et al.* (2020) determined that a hybrid approach using hydrological data is an important tool in the field of river flow forecasting on a daily basis. This method combines the advantages of numerical hydrological models and statistical methods to improve the accuracy and reliability of forecasts. The use of hydrological data such as water levels, river discharge, precipitation, and water temperature provide a more accurate assessment of current hydrological conditions. Combining these data with numerical models makes it possible to account for the dynamics of runoff changes over time. The main advantage of the hybrid approach is its ability to adapt to a variety of hydrological conditions and geographical features, making it an effective tool in different regions. Furthermore, this method can consider historical data, which helps to improve predictions when current data are insufficient. However, the hybrid approach requires high quality and relevant data to train the model and validate its performance. It is also necessary to regularly calibrate and verify the model to maintain its accuracy.
2. Bazarov & Vokhidov (2021) determined that damping of excessive flow energy in spillway structures is an important engineering process aimed at controlling and regulating the kinetic energy of water flows to prevent possible damage or adverse impacts on the surrounding infrastructure and adjacent areas. Various technologies are used to dampen excessive flow energy in spillway structures. These can be special hydraulic structures such as diffusers, cushioning basins, energy recovery systems. These structures allow for the smooth dissipation of the kinetic energy of the flow, reducing its speed and intensity. This is especially important in cases of heavy rainfall, snowmelt, or other situations where water flow can increase significantly. Extinguishing the excess energy of water flows in spillway structures is of practical importance to ensure the safety of the public and infrastructure. Proper management of kinetic energy can prevent damage to hydraulic structures, preserve adjacent areas and minimise flood risks. Such technologies also contribute to optimise the use of water resources and improve the efficiency of hydropower plants. In summary, dampening excess flow energy in spillway structures is a vital component of engineering solutions to ensure safe, sustainable, and efficient water management.
3. Piller *et al.* (2020) showed that content-based computer-aided manufacturing (CAM) active recruitment method is an innovative approach for modelling water distribution systems with flow controllers, especially under pressure-dependent conditions. This method focuses on improving the efficiency of water management and optimising the performance of water supply systems. CAM is based on analysing system content, i.e., system characteristics and parameters such as pressure, flow, pipe diameters. Using machine learning and optimisation algorithms, CAM actively selects the optimal points for measurement and control in the system. This allows a more exact assessment of the system condition, water distribution dynamics and optimal settings of flow controllers. The advantage of CAM is that it considers the pressure dependence of the system. This is especially important because in water distribution systems, pressure can vary widely depending on time of day, load, and other factors. Proper control of flow controllers at different pressure levels can considerably improve system efficiency, reduce losses, and provide a more stable water supply.

As Wozniak & Carlson (2020) note, the research of high-efficiency solar-based atmospheric water harvesting represents a promising direction in the field of providing access to clean drinking water. This concept utilises nanoporous carbon derived from a metallic organic framework, which exhibits high adsorption capacity to water molecules. The principle of operation is based on the use of solar energy to drive water molecules in the atmosphere into a state of condensation on the surface of nanoporous carbon. The microscopic channels in this material allow for rapid diffusion of the collected water, which helps to increase the productivity of the process. This method is important in regions with limited access to fresh water, especially in environments where solar energy is abundantly available. It can serve as an alternative to conventional water supply sources, eliminating the need to depend on freshwater sources. However, there are some limitations to consider. For example, the effectiveness of this technology can be highly dependent on climatic conditions and humidity in a particular area. The stability and durability of the materials used for the nanoporous carbon are also an important aspects to ensure the long-term performance of the system.

CONCLUSIONS

This study, through an extensive review of the existing literature, provided a comprehensive understanding of innovative designs of high-speed channels aimed at efficiently damping the kinetic energy of fluid flows. The conclusions highlighted in this paper have important practical implications and can contribute to the development of effective engineering solutions in various industries. One of the key practical applications of the innovations under consideration is water resource management and flood control. The proposed channel designs, which include diffusers, deflectors, aerators, and artificial roughness elements, can be implemented in irrigation systems, drainage networks, and flood mitigation structures. By effectively dampening the kinetic energy of water flows, these structures can help reduce the risk of infrastructure damage, minimize erosion, and improve the overall efficiency of water management, leading to more sustainable use of water resources.

The innovations under consideration have potential applications in hydropower. The ability to control and regulate high-speed water flows can optimize the operation of hydroelectric power plants, ensuring efficient energy conversion, minimizing turbulence and excessive wear and tear on equipment. The principles and methods discussed in this research can be adapted for use in various industrial processes involving fluid flows, such as chemical processing, manufacturing, and transportation systems. Effective damping of kinetic energy can improve safety, reduce the risk of accidents, and increase the overall efficiency of these processes.

From an environmental point of view, the implementation of the considered channel designs can help mitigate the negative impact of high-speed flows on natural ecosystems. By controlling the energy of water flows, these structures can help prevent habitat degradation, minimize erosion, and protect sensitive aquatic environments. This study laid a solid foundation for further research and practical implementation of innovative high-speed channel designs. The results contribute to the development of hydraulic engineering and fluid dynamics, offering sustainable solutions to current and future challenges in water management, energy production, industrial processes and environmental protection.

AUTHOR CONTRIBUTIONS

KY, EA, and AA conceived the idea of the study; ER, TO, and EA conceived the idea for the analysis; ER, KY, and AA performed the analyses; EA, AA wrote the manuscript; ER, TO were major contributors in writing the manuscript, and all other authors commented on the manuscript. All authors read and approved the final manuscript.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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