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ADVANCES IN HYDRAULIC RESEARCH

BOOK OF ABSTRACTS

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LECTURES

The RIBES project and the Marie Skłodowska-Curie Doctoral Networks

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ABSTRACT

Freshwater ecosystems host a very large fraction of the world's total biodiversity, but water infrastructures development, growing needs for water use and climate change are causing fast population declines and increased extinction risk for many freshwater organisms.

Balancing the conflicts among the ambitious targets set by the EU Biodiversity Strategy 2030 and those of other EU Directives (Renewable Energy Sources, Flood Directive, etc.) that put additional pressures on freshwater habitats, represents a challenging issue.

Under this scenario, the EU-funded RIBES (RIver flow regulation, fish BEhaviour and Status) project aims at training 15 Early Stage Researchers in the interdisciplinary field of Ecohydraulics to find innovative solutions for freshwater fish protection and river continuity restoration in anthropogenically altered rivers, within a interdisciplinary and intersectoral Network of European Universities, consultancy companies, public agencies and hydropower industry.

The main features of the RIBES project and the significant opportunities offered by the Marie Skłodowska-Curie Doctoral Networks to implement innovative doctoral programmes advancing knowledge in the field of water research, will be presented.

Shallow water flow simulation: from mathematics to reality

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ABSTRACT

Nowadays, the great power of modern computers combined with well-designed numerical models allows to develop computational models able to deal with simulations of several coupled phenomena over detailed complex topography. An efficient and properly calibrated computational model represents a useful tool to provide insight into the catchment dynamics at hydrological and geomorphological levels. In addition, it allows to develop detailed risk management and conservation plans. The challenge of finding a compromise between computational time and level of accuracy and robustness has traditionally expanded the use simplified models (2D) rather than full three-dimensional models for flood simulation. This work presents a GPU accelerated 2D shallow-water model for the simulation of flood events over non-erodible and erodible bed in real time. In particular, an explicit first-order finite volume scheme is detailed to control the numerical instabilities that are likely to appear when used in complex topography. The model is applied to reproduce real events in a reach of the Ebro River (Spain) and the Cinca River (Spain) in order to compare simulation results with field data in a large domain and long flood duration allowing an analysis of the performance and speed-up achieved by different GPU devices. The high values of fit between observed and simulated results as well as the computational times achieved are encouraging to propose the use of the model as forecasting system.

Keywords: Computational mesh, Shallow water flow, Exner equation, GPU Real time flood prediction

Solute mixing from estuaries to pipes

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ABSTRACT

Predicting the effects of management strategies and interventions on the water quality in catchments, urban drainage, and water distribution systems, requires knowledge of the hydrodynamic processes. These processes cover spatial scales of a few millimeters (turbulence) to several kilometers (catchments), with a similarly large range of timescales from seconds to weeks. Water quality models, whether 1D, 2D or 3D, generally employ solutions to the advection-dispersion equation, which require parameters to describe and integrate all the mixing processes related to the temporal and spatial averaging processes. This presentation will summarise some field and laboratory fluorescent tracer studies which quantify mixing processes in estuaries, river channels, urban drainage structures and pipe flows. These studies cover a range of spatial and temporal scales and investigate the effects of unsteady flow conditions and non-uniform shapes. The overall aim is to improve understanding of the dominant mechanisms and to provide simple numerical descriptions to quantify the mixing processes, for inclusion in water quality models.

40 years of the School of Hydraulics. Past, presence, future

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ABSTRACT

Every jubilee usually consists of three separate parts. **Part one** concerns the past, **Part two** deals mainly with the presence and **Part three** concerns the future. Part one is rather simple, however, its main problems is the assessment whether the aims formulated in the beginning, have been achieved. Part two must give the answer whether we are going in the right direction and part three is very difficult, especially now when our future is unknown to a great extent. I can present a full account from the first 25 Schools, which were under my chairmanship. I do not feel authorized to estimate the results of the remaining 14 Schools, which I expect will be done by their chairmen. Based on my own experience I will try to provide some views concerning the presence and the future of hydraulic research.

1. Establishment and organization of the School of Hydraulics

The School of Hydraulics was established in 1981 under the auspices of the Committee for Water Resources Management of the Polish Academy of Sciences (PAS). The initiator of the School was prof. Bolesław Kordas, chairman of the Committee. Associate professor Wojciech Majewski from the Institute of Hydroengineering (IoH) of the Polish Academy of Sciences in Gdansk was appointed as the organizational and scientific chairman of the School. This Institute became also the main organizer of the School. The School was selffinancing and there was no additional support from the PAS. This means that the participants' registration fees for each meeting had to cover the lodging and food expenses. It was decided that the School meeting would be organized annualy for one week (Monday - Friday) in autumn and would be connected with a visit to a hydraulic project, either operating or under construction.

Each School was devoted to a separate subject. It consisted of lectures, papers presented by the participants, and communications, which were not completed projects or subjects. Initially all presentations were in Polish. Participants were obliged to send an abstract and a Book of Abstracts was prepared before the School started. Initially organizers accepted most papers, however, later there was the selection of papers by scientific committee, taking into account their scientific or engineering value and its relevance to the main topic. Each School meeting was attended by about 40 - 50 participants from higher schools, research institutes, consulting offices, and water boards. During the first 25 years about 200 participants attended the Schools. After School No 10 organizers started to issue proceedings from each School. This was done by the publishing section of the IoH. Although IoH was the main organizer of the Schools many institutions collaborated helping in the preparation of technical visits or local means of transport.

2. The main idea of the School of Hydraulics

The School of Hydraulics was intended as a kind of regular conference/meeting aimed to provide a forum for discussion among scientists and engineers working in the broad field understood as hydraulics and hydraulic engineering. By bringing together experts, academics, and practitioners as well as young scientists, the organizers wanted to create a good atmosphere for scientific debate and the increase of knowledge, but also to create a friendly and enjoyable atmosphere for the participants initially from Poland only and later from Europe and the whole world. The main emphasis was on engineering hydraulics connected with various kinds of hydraulic structures, flow in rivers and channels, various types of floods, stratified flows and ice phenomena. Although, technical and engineering hydraulics were of main interest ecological aspects were also taken into account. A lot of interest was devoted to hydraulic model investigations of hydraulic structures and also first attempts to solve many flow problems by means of mathematical models. An important issue was to increase the knowledge of School participants in hydraulic research and its connection with this realm in world hydraulics laboratories.

3. Achievements of Schools

The knowledge of hydraulic engineering increased considerably among participants as the result of international contacts. More often Polish scientists appeared at the international conferences. School participants acquired 42 degrees of doctor habilitated and 13 of them scientific titles of professor. English was more often used during school meetings. The last two schools (24 and 25) were organized by the IoH as international in English, with many participants from abroad.

4. Changes since 2005

In 2005 the new director of the IoH was not interested any more in further organizing the Schools and they were transferred to the Institute of Geophysics (IoG) in Warsaw. Prof. Paweł Rowinski became chairman of the School. Then the chairman of this School was associate professor Monica Kalinowska also from the IoG. After discussions it was decided that it is still necessary to continue the Schools of Hydraulics in Polish. It was organized every two years and was taken over by the Agriculture University in Kraków. Prof. Wojciech Bartnik was appointed chairman, and now the chairman of the School is associate professor Leszek Książek.

5. The present situation in hydraulic research and future prospects

I would like to add only some of my personal remarks. Research in hydraulic engineering very often reflects the activity in engineering. Now more attention is directed towards environmental engineering, water supply and water quality. Not much attention is directed to flood protection and the increase of retention. For the first time in postwar hydraulic engineering such ecological disaster appeared in the Polish River Odra where hundreds of tons of fish were poisoned. The true reason of this catastrophe was not revealed. In my opinion a very important problem, which cannot wait for solving, is provided by climate changes.

Most interesting research topics were presented at the 39th IAHR World Congress Report (Sanchez M.O. 2022) and proposal topics for 40th IAHR World Congress (Hydrolink 3/2022).

Fig. 1. The View of Czorsztyn-Niedzica dam.

Fig. 1. Dry river bed caused by meteorological drought

Acknowledgements

I would like to express my thanks for the invitation to the 40th jubilee of the School of Hydraulics. I would like to take this opportunity to thank the ISH for 25 years of supporting the organization of the School of Hydraulics. I also wish to express my appreciation to all institutes and individuals, who voluntarily supported the organization of the School of Hydraulics. My wishes for further success go to the present School organizers.

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Sanches MO 2022, 39 IAHR World Congress Report, Granada, Spain, Hydrolink IAHR, 3/2022
40th IAHR World Congress, 2022, Vienna, Austria, Hydrolink IAHR, 3/2022

On the scaling of fish locomotion and fatigue

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ABSTRACT

Quantifying swimming endurance is key for the design of effective fish passage solutions. Such solutions are urgently needed to restore continuity in rivers where man-made water-infrastructures represent barriers for fish migration and hence a major cause of biodiversity loss in freshwater ecosystems, as reported extensively in the literature. Unfortunately, despite years of research, modelling endurance is still strongly based on weak empirical grounds lacking any theoretically supported framework of analysis. This lecture will present some work that has been recently carried out to bridge this knowledge gap, by a multidisciplinary group of scientists working at the interface between fish biology and fluid mechanics. The aim of the proposed work is to provide evidence that endurance curves pertaining to the anaerobic swimming regime (i.e. the most relevant regime for fishway design), display a universal scaling that is susceptible to theoretical scrutiny. The proposed scaling is derived by combining principles of fish energetics and locomotion and is tested over an extensive dataset that was retrieved from the literature. Results demonstrate that, despite some scatter and some issues related to the heterogeneity of the retrieved dataset, experimental data confirm well theoretical predictions.

A discussion about the practical applications of our results and some perspectives for future research work will be presented in the final part of the seminar.

Keywords: Fish drag, Boundary layer theory, Endurance, Scaling

Multiphase flow modelling using Smoothed Particle Hydrodynamics

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ABSTRACT

Environmental applications of multiphase flows include sediment transport and phenomena involving air-water interfaces (dealt with as either free-surface or interfacial multiphase systems). Computational treatment of the latter may involve interface tracking or capturing that remains a challenge for modelling, in particular in the Eulerian approach. Arguably, this is one of the advantages of the Lagrangian particle methods such as Smoothed Particle Hydrodynamics (SPH). The meshless nature of SPH may represent some advantage for fluid-solid interaction problems (such as moving/floating bodies) and for the treatment of complex geometries; however, it is problematic for adaptive refinement or variable resolution in space. Upon the spatial discretisation using interpolation points, or particles, the flow dynamics in SPH is represented by a system of ordinary differential equations for particle's advection and the evolution of carried-on quantities (mass, momentum, phase indicator, etc.).

In this talk, we will present the basic features and problems of SPH in terms of its capacity to describe physical phenomena, the convergence and accuracy of the approach along with its computational complexity, and the numerical implementation issues. We will then present several application cases such as sediment transport, bed scour, free surface flows, flow regime changes in gas-liquid systems. We will also discuss the weaknesses of the approach, and perspectives to overcome them.

Keywords: Lagrangian particle methods, Smoothed Particle Hydrodynamics (SPH), interfacial multiphase flows, free surface flows

Flow from a fish's perspective: how live fish, bioinspired sensors and AI can be used to improve fish passage

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ABSTRACT

Fish sense in the water environment using their lateral line system. It consists of tiny arrays of flexible masts on the outer surface of the body, as well as tunnels within the body surface itself. Understanding how fish sense and respond to flows requires us to interpret them through the lens of their lateral line system. In this talk, the mechanosensory system of freshwater fish is presented, including the physical ranges and speeds at which fish can process flow information. Furthermore, bioinspired fish-shaped probes are introduced which mimic some of the ways fish experience the flow. Novel methods to process and interpret these data to improve fish passage are presented, including a new way to modify velocity data into maps which take into account how the fish's body modifies the flow field itself. The use of machine learning to identify and classify complex data sets from fish-like sensors is discussed, as well as challenges and new opportunities for ethohydraulic studies in the lab and in the field. Improving fish passage is a major challenge, and will require new and innovative methods to understand and interpret the complex underwater environment inhabited by freshwater fish. The bioinspired devices and data processing methods presented in this talk are the beginning of a promising new and challenging paradigm shift in ecohydraulics: to consider "flow from a fish's perspective".

Keywords: fish, sensors, passage, machine learning, flow

PRESENTATIONS AND POSTERS

Particle Image Velocimetry of 3D-printed microchannel models

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ABSTRACT

The study of fluid velocity fields in complex geometries with mechanical inaccessibility using non-intrusive visualizing methods on a micro-scale has become possible using a proper 3D printing process. In this work, the flow of glycerin and water solution was studied. Sodium iodide (NaI) was used to adjust the refractive index (RI) of the solution to that of the 3D printed object for reduction of optical distortions, and xanthan gum (XG) was added to the fluids to give them non-Newtonian properties. Results of Particle Image Velocimetry (PIV) are comparable with computational fluid dynamics (CFD) with the same conditions. Compared can be parameters like averaged velocity distribution, maximum velocity location, profiles across the flow, and other derived values of vector maps. This work presents the results of PIV as multi-stitched, color-coded vector maps from the axis cross-section along the whole 3D- printed biomedical model. The obtained data allowed a resolution of 100 x 100 μm per single vector to be achieved. Furthermore, the results of the stitched 16 base images of the artery and the 3D-printed model prepared were included. The results of this study show that 3D prints allow for the creation of any of the desired geometry.

1. Introduction

The Particle Image Velocimetry is a well-known measurement technique that allows to obtain instantaneous velocity vector maps in a cross-section of the flow in non-intrusive way. One of the main challenges relating the use of PIV results for CFD validation in complex models are difficulties to fabricate transparent models, that are possible to describe numerically. One of the used methods might be the silicone model (Triep et al., 2015), but 3D printing seems to be more available technique (Aycock et al., 2017). Other challenge is to find a compromise between a right refractive index matched of a transparent resin and the transparent fluid with the required parameters (Ho et al., 2020). The experimental results might be compared with CFD simulations for the same conditions as in the experimental set-up.

2. Materials and methods

2.1. Printed model and liquid solution

Geometries of printed models were obtained via Computer Tomography of patient with atherosclerosis. The geometry was modified by adding a necking to simulate atherosclerosis. Considered geometries are one of arteries with diameter about 4 mm. Model was printed on Forms3 3D-printer from FormLabs using transparent resin. After printing, the model was cleaned of residual resin using isopropanol and distilled water, dried, UV radiation cured, and polished on the outer walls. The refractive index of the prepared object was measured with a refractometer. Solution of distilled water and glycerin allows to obtain a proper viscosity which substituted blood, adding sodium iodide allows to maintain appropriate refractive index as 3D-printed object, xanthan gum makes the solution with non-Newtonian properties. In addition, solution containing sodium iodide undergoes oxidation which leads to a yellowing of the solution. To prevent or undo this process sodium thiosulfate can be used. A fluorescent rhodamine-B-labeled poly(methyl methacrylate) particles with a mean diameter of 10 μm were used as seedling particles. Measurements with the solution were performed as a closed loop using a syringe pump with constant flow rate.

2.2. PIV system

PIV experiments were conducted using a typical PIV system based on a double-pulsed 532 nm laser with a <10 ns pulse duration and a double-frame camera was used with a resolution of 2048 x 2048 pixels, a 7.4 μm

pixel size, and a 12-bit pixel depth. For camera optics, a microscope with the view of 4.85x4.85 mm^2 with a long-pass filter that blocks <550 nmlight (including laser light) was used. Everything was managed using DynamicStudio v7.5 fluid measurement software and the TimerBox TTL synchronization unit. The 3D-printed object was placed horizontally on an XYZ translation stage with a micrometer screw that allowed for the object to be accurately positioned in relation to a field-of-view (FOV) camera. This also ensured stability between the microscope and the test object. Even small shocks, e.g., using an accidental table hit, generated small vibrations that were recorded with the camera and affected the measurement run.

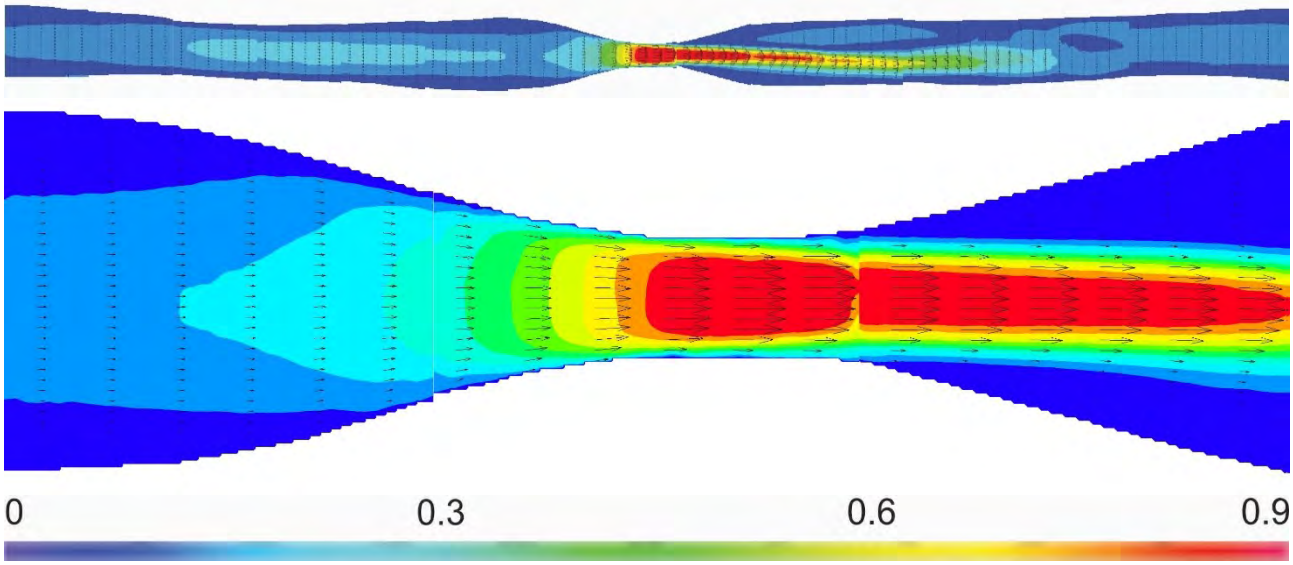

Fig. 1. Vector statistics and velocity magnitudes m s^{-1} (along the whole blood vessel for Re = 72 (bottom) and enlarged central part (bottom).

3. Results and conclusions

The results of 2D PIV measurements are presented in Fig. 1. Measurements were done for 3 Reynolds (Re) numbers on inlet. The results show color-coded velocity vector maps of the entire 3D-printed vessel. The connections between consecutive images were seamless and consistent. We observed that the velocity values increased proportionally, while the structure changed typically as expected. No boundary defects were noticed. Everything can be compared with CFD results thanks to the geometry mapping using a 3D printer.

This study aimed to find the best solution when using 3D printing technology to measure the geometry data of numerically indescribable objects. The described methodology indicates the great potential of the selected 3D printing technology and material for printing difficult geometries. Obtaining comparable refractive indices of the material and fluid is extremely important.

One of the disadvantages of using a resin material for 3D printing is the relatively high refractive index (which is 1.503 and is impossible to obtain with only a glycerin and water solution). Sodium iodide or other similar additives are required to maintain the RI of 3D-printings. In addition, the calibration tool has to be custom-designed and, even better, certified.

Further work should aim to measure longer flow periods and flows for larger Re numbers for some geometries. We plan to apply our findings in future studies that will include measurements of paravalvular leaks in the human heart. Hence, future work with time-resolved PIV is planned to resolve the true nature of the flow in natural heart pulse conditions. Another important extent is the use a stereoscopic microscope for Stereo μPIV analysis since 2D measurement cannot explain the behavior of 3D flows.

Acknowledgements

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Fish swimming performance: effect of flume length and different fatigue definitions

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ABSTRACT

Swimming performance is important for a range of fish behaviors. Quantifying fish swimming performance in experimental facilities is influenced by channel geometry, size and length. Also, the lack of a standard fatigue definition potentially affects the assessment of the fish swimming performance. Experiments on juvenile Vairone (*Telestes muticellus*) were conducted to elucidate the effect of different flume lengths and fatigue definitions on swimming performance estimates using a fixed velocity protocol. Three swimming arena lengths of 15, 30, and 100 cm in an open channel flume were tested under two different mean flow velocities, 35 and 45 cm s^{-1}. The effect of two different criteria for determining time-to-fatigue was studied: (1) untapped fatigue, i.e. fish were considered fatigued when resting on the downstream grid for ≥ 3s. (2) tapped fatigue, i.e. when fish rested on the grid it was gently tapped to encourage swimming. The third time it returned to the downstream grid, it was considered fatigued. Difference in time to fatigue of vairone was statistically significant between the two treatment velocities, i.e. 35 and 45 cm s^{-1}. Flume length affected swimming performance based on untapped but not on tapped fatigue definition. It is concluded that the criteria used to define fatigue may have an influence on the conclusions drawn from fish swimming experiments.

Discharge capacity of an improved form of labyrinth weir

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ABSTRACT

The aggravation extreme weather events have greatly increased interest in the safety of flood control structures, especially the safety of dams and reservoirs. Non-linear weirs such as labyrinth weirs represent an effective option for improving the safety and resilience of these types of facilities. The labyrinth weir designed with trapezoidal and triangular shape in view plan has been used in research and application for several decades. However, the rectangular plan form can also be a more efficient and cost-effective structure. This study used experimental and numerical modeling to investigate some improvements to the standard labyrinth weir shape. The tested models, three models of rectangular labyrinth weir and two models having trapezoidal shape, were examined in rectangular channel conditions for developed crest length ratios (L/W) equal to 4 and 5. In addition, to verify the potential of the overhangs for the labyrinth weir, three overhang arrangements were tested: with upstream and downstream overhangs (symmetrical); with only upstream overhangs; and, with only downstream overhangs. The obtained results confirmed the performance improvement of this type of weir by the adoption of an improved form of the labyrinth.

Key words: Non-linear weir, Experimental modeling, Numerical modeling, Discharge efficiency.

Refining velocity measurements protocols in a lowland vegetated channel

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ABSTRACT

The hydrometric measurements in the Warszawicki Channel, located in central Poland (Fig. 1), were conducted using the electromagnetic flowmeter Valeport Model 801. The velocity of the water flow and the morphology of the channel were measured as a part of a preliminary study and preparation for the tracer experiment to find the most efficient way of conducting such measurements during the planned study. Obtained velocity distributions lacked a logarithmic profile in the considered small channel due to, e.g. low water depth and bed vegetation. Consequently, the best formula for calculating the mean velocity was found to bethe average of all velocity measurements rather than the commonly used formulas assuming the logarithmic profiles. Moreover, conducting the measurements every 10% of the water depth considerably increases the accuracy of discharge estimation in considered conditions.

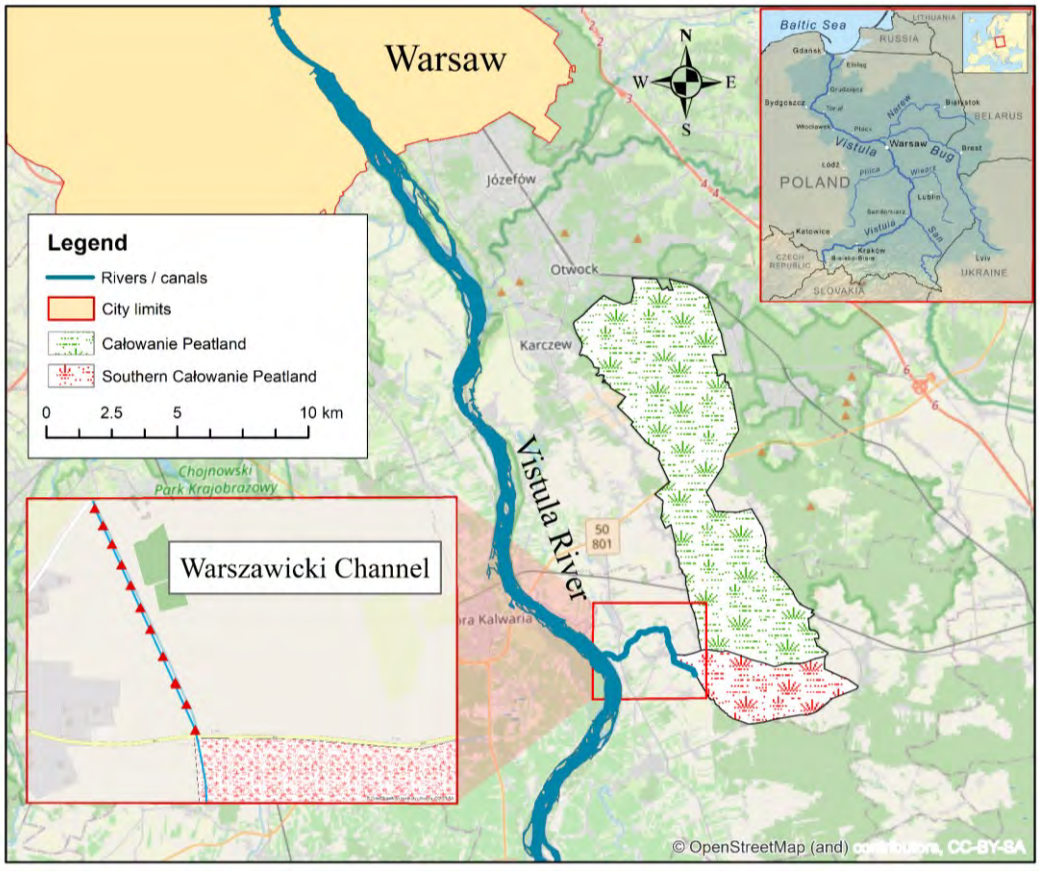

Fig. 1. Location of the Warszawicki channel with measurement points (red triangles). © OpenStreetMap contributors 021. Distributed under the Open Data Commons Open Database License (ODbL) v1.0. Small top, right map of Poland, adapted from Nones (2021).

1. Introduction

Hydrometric measurements are essential in many studies, such as flood simulation or modelling the transport of pollutants. To measure water velocity in watercourses devices such as an electromagnetic flow meter, Acoustic Doppler Current Profiler (ADCP) and Acoustic Doppler Velocimeter (ADV) are used. An electromagnetic flow meter was used in the analyzed channel due to its ease of use in the given conditions and the desired accuracy. Hydrometric measurements in the field are time-consuming, therefore it is crucial to determine the most effective way to conduct the measurements.

2. Results and discussion

The channel bathymetry was measured in 11 cross-sections along the selected reach of the Warszawicki Channel (as marked in Fig. 1, red triangles). Flow velocity was measured in the selected cross-sections at 10% depth increments for each vertical profile (every 0.5 meters) using the electromagnetic flowmeter Valeport Model 801, which uses Faraday's law of electromagnetic induction. It is suitable for working in shallow and overgrown watercourses (Kałuża et al., 2013). The obtained hydrometric data were used to burn the channel into a Digital Elevation Model to perform future steady flow simulation (Fig. 2). Velocity for each vertical was calculated using three formulas:

1. If the depth < 0.2 m: $V_{40\%h}$; If the depth $\geq$ 0.2 m $(V_{20\%h} + 2V_{40\%h} + V_{80\%h}) / 4$; (1)

2. $(V_{20\%h} + 2V_{40\%h} + V_{80\%h}) / 4$; (2)

3. The arithmetic average of all obtained measurements in the given vertical profile; (3)

where $V_{20\%h}$ – velocity measured at 20% of the depth in a vertical [m s^{-1}], $V_{40\%h}$ – velocity measured at 40% of the depth in a vertical [m s^{-1}], $V_{80\%h}$ – velocity measured at 80% of the depth in a vertical [m s^{-1}].

The obtained velocity values were used to calculate the flow discharge (Q) for each of the selected cross-sections (Tab. 1). The most accurate formula was the third, which used all measurements (the smallest differences between obtained flow discharge values in different cross-sections). Moreover, the difference in the obtained flow discharges was calculated using the velocity measurements at every 10% and 20% of the depth. The analysis showed a notable difference, suggesting dense measures in vertical profiles whenever possible.

Table 1. Flow discharge (Q) calculated with different formulas in selected cross-sections.

Cross sections	Q_{v1} [m^3 s^{-1}]	Q_{v2} [m^3 s^{-1}]	Q_{v3} [m^3 s^{-1}]
P1_1	0.13	0.13	0.142
P1_2	0.108	0.126	0.139
P2	0.153	0.207	0.131
P3	0.169	N/A	0.144
Max difference	0.061	0.081	0.013

where Q_{v1} – discharge calculated with the first formula (1), Q_{vs2} – discharge calculated with the second formula (2), Q_{vs3} – discharge calculated with the third formula (3).

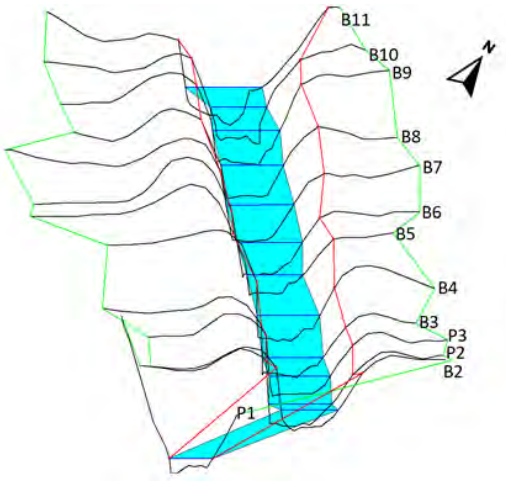

Fig. 2. Visualization of the morphology of Warszawicki Channel with marked cross-sections.

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Application of animal movement models to acoustic telemetry positioning

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ABSTRACT

Over the past decade, acoustic telemetry has become common-place in studies on fish movement and behaviour. Over small spatial scales, arrays of acoustic receivers can be used to estimate movement paths in 2- or 3-dimensions along high temporal resolutions. Despite the growing prevalence of acoustic telemetry arrays, guidelines on how to generate robust position estimates - and further utilize this data in animal movement models such as hidden Markov models or step selection functions - are sparse. As animal movement models generally require either true positions or accurately specified spatial error distributions, understanding positioning error is crucial for behavioural inference. Here, current methods of telemetry positioning are reviewed. Simulated case studies are used to highlight the effect of state space model parameter selection on positioning accuracy, and in turn, the fitting of animal movement models.

A Lagrangian analysis of the surface flow in a jet dissipation basin at equilibrium

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ABSTRACT

A jet, imping on a loose bed stilling basin will induce a scour hole, thus changing the bed geometry, which will also affect the flow field in the stilling basin. The erosion caused by the jet will create a scour hole and a decomposition bar. Both will evolve in time until, hopefully, they reach an equilibrium. As the bed reaches the equilibrium, it is also expected, if the flow rate stays constant, that the flow in the stilling basin will become steady and can be easily analyzed by imaging methods. In this paper an analysis of the surface velocity field in the stilling basin at the equilibrium is made with emphasis on the flow above the decomposition bar. Two techniques are used: Particle Image Velocimetry for an overall analysis of the flow, allowing to characterize the recirculation areas in terms of size and intensity and Particle Tracking Velocimetry allowing for a Lagrangian analysis of the flow, and therefore allowing to directly compute the trajectories of individual particles. Particle Tracking Velocimetry allows also to compute the velocity field in region of the flow where the seeding concentration is low.

Hydrodynamics of fish-shaped rigid bodies: velocity-drag coupling

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ABSTRACT

This study provides insights into the mechanisms of drag generation on fish-shaped bodies in turbulent open-channel flows. We conducted a set of experiments with rigid 3D-printed models of rainbow trout (*Oncorhynchus mykiss*), recording velocities upstream and downstream of a model along with drag force. For a range of fish Reynolds numbers, we have (1) assessed mean values of drag and drag coefficients, and (2) investigated drag force fluctuations and their link with upstream undisturbed turbulence. Correlation functions confirm a direct link between upstream velocity fluctuations and drag force fluctuations, although other mechanisms contributing to drag force fluctuations are likely and remain to be studied further. Insights into the hydrodynamics of fish-shaped bodies may lead to improvements in the design of fish passageways.

Application of wavelet transform for analysis of river discharge

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ABSTRACT

The study demonstrates the ability and application of wavelet transform for regional clustering of non-stationary river discharge datasets. The wavelets can provide detailed information on time-dependent components in time series with varying frequencies by overcoming nonstationary behaviour in the time series datasets (e.g. river's discharge). The method was analysed with the use of monthly maximum discharge data for selected gauging stations. Monthly data were used because they constitute the basis for classifying hydrological regimes in Poland. Continuous wavelet transforms for six levels of decomposition were used in the study to identify the changes at 3 months (0.25 years), seasonal (0.5 years), annual (1 year), 2, 4, and 8 years. The data were processed with the mother Morlet wavelet using the WaveletComp package in R.

1. Introduction

The hydrological characteristics of a catchment are represented by the stream flow influenced by internal catchment parameters like geographical, geological vicinity, land cover, and external elements e.g. meteorology (rainfalls). Because of the integrated effects of all these factors and others which may act at different scales, the stream flow can be regarded as the catchment's signature (Zoppou et al,2002). A non-stationary time series can be decomposed using wavelets into several temporal scales and each scale can be used to withdraw hidden historical information (Hadi and Tombul, 2018). A wavelet can represent the time and frequency state by breaking down the signal into small waves which are escalated and relocated versions of the mother wavelet (Dadu and Deka, 2016). The continuous wavelet transform is suitable for the analysis of seasonal and interannual changeability in river discharges (Potočki et. al, 2013).

In this study, we apply continuous wavelet transform to the monthly maximum discharge data to show how wavelets can capture discharge signals at different levels which are 3 months (0.25 years), seasonal (0.5 years), annual (1 year), 2, 4, and 8 years. The WaveletComp package in R was used to make the wavelet power spectrum. The aim of the study is to show how the wavelets methodology detects the high and low discharges in selected gauges on Polish rivers.

2. Method

We have used the continuous wavelet transform method for our study, as it can reveal the features under the multi-temporal scale (Sang, 2013). In the study we used the WaveletComp package in R (Schmidbauer and Roesch, 2018) apply the Morlet (1982) wavelet to transform the discharge signals:

$$a(t) = \pi^{-1/4} \mathrm{e}^{\mathrm{i}\omega t} \mathrm{e}^{-t^2/2} \quad (1)$$

Where *a(t)* is the Morlet wavelet, *i* is the imagery operator (*i* = sqrt(-1)), time is *t*[s] and the rotation rate is given by the angular frequency *ω*[rad s^{-1}]. For a signal *x*(*t*), the continuous Morlet wavelet transform is a merged series of a set of daughter wavelets originating from the mother Morlet wavelet obtained by shifting in time by *τ* and scaling by *s:*

$$wave(\tau, s) = \sum_t x(t) \frac{1}{\sqrt{s}} a^* \left(\frac{t-\tau}{s}\right) \quad (2)$$

Where *a** is the complex signal corresponding to *a*(*t*). 1 sqrt*(s)*$^{-1}$ standardizes the energy at varying time and scales. The wavelet power spectrum is given by

$$Power(\tau, s) = \frac{1}{s} \cdot |Wave(\tau, s)|^2 \quad (3)$$

Using Eq.(4) the wavelet power across all scales can be estimated. The fluctuation of discharges at various frequencies is very conveniently described by the wavelet power spectrum.

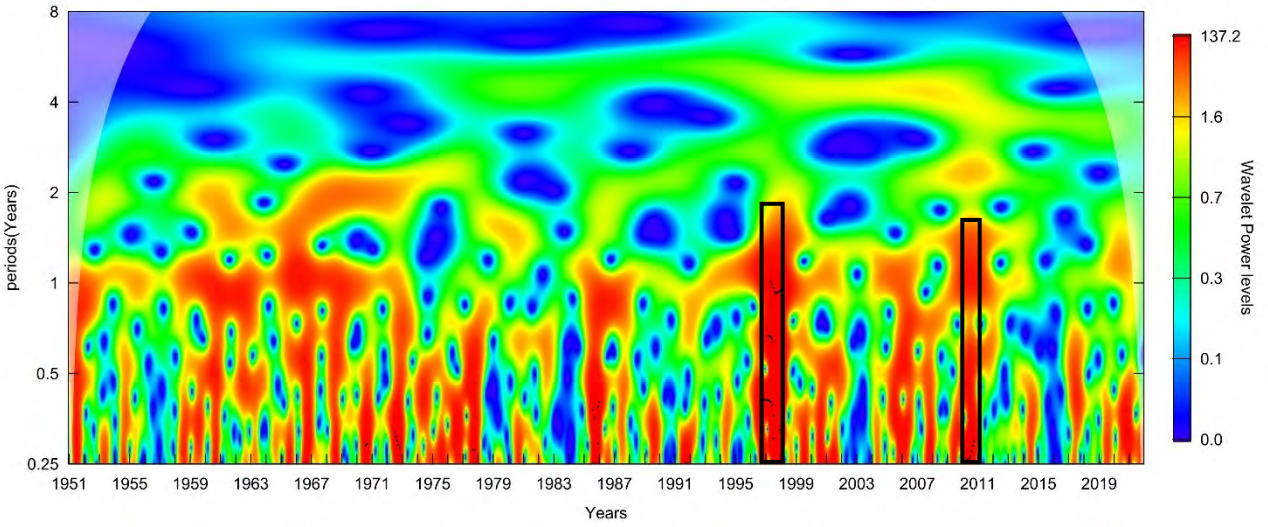

Fig. 1. Wavelet power spectrum capturing the 1997 and 2010 floods in Poland for the gauging station Chalupki located on the Oder river(western Poland).

3. Results

Figure.1 shows an example of the wavelet power spectrum for monthly maximum discharges at the gauging station Chalupki located by the River Oder (Western Poland). A study by Dubicki et al.(2005) showed that the gauges in the Oder river and its tributaries have been at high alarm levels several times from 1945 till 2004 which is captured by the wavelet power spectrum(red colour). The 1997 floods and the recent 2010 flood in the Oder River are displayed with the highest power.

4. Conclusion

The wavelet method is a suitable approach for the analysis of non-stationary time series as it estimates spectral characteristics as a function of time. It can also provide an additional benefit to hydrological regionalisation by using the non-stationary parameters which are necessary for current climatic scenarios.

Acknowledgement.

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Laser scanner as a tool for investigating sediment transport under laboratory conditions

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ABSTRACT

In the year 2022, a series of experiments were carried out in the hydraulic laboratory of the Institute of Hydro-Engineering of the Polish Academy of Sciences. The experiment was carried out in a laboratory channel with groynes and a movable bottom. The experiment involved 5 flows**,** each lasting for five hours. The 3D scans were taken after each flow, from which point clouds and differential maps were developed. Preliminary results confirmed that scanning significantly facilitates the analysis of results and the calibration of sediment transport phenomena in mathematical modelling.

1. Introduction

3D scanning technology is commercially widely used in civil engineering and shipbuilding for scanning installations, structures, and equipment. In hydrology, the technology is used to observe large-scale changes, such as rebuilding a river bank, reconstruction of a beach after a storm, and changing the shape of floodplains after a flood wave has passed. Due to the accuracy of the obtained results and the easy digitalization of the scanned objects, this technology has great potential when studying sediment transport and changes in bottom bathymetry under laboratory conditions. In this experiment, the 3D scanning technology was used to digitize the rebuilt channel bottom due to increasing flows to mimic a flood wave.

2. Methods

2.1. 3D scanning technology

The FARO FOCUS 70s scanner was used in the experiments. It utilizes laser technology to create extremely detailed 3D images of the investigated object. The resulting images are a collection of millions of points in 3D space. The scanner sends an infrared laser beam to the centre of its rotating mirror. The mirror deflects the laser beam vertically around the scanned environment. Scattered light from surrounding objects is then reflected back to the scanner and analysed. The main difficulty in carrying out sediment transport research is that there must be no water in the channel.

2.2. Experimental procedure

The research was conducted in a laboratory channel representing a river section with a system of 5 pairs of symmetrical groynes spaced 2.5 m apart. The laboratory channel was 60 m long and had a trapezoidal cross-section with a base of 3 m and slopes inclination of 1:2.

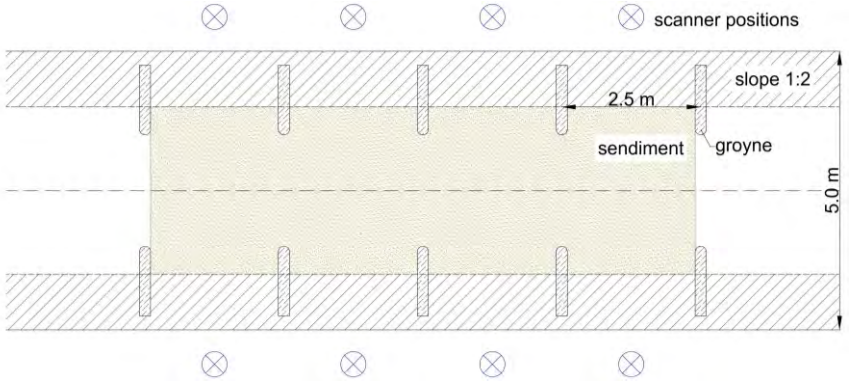

Fig. 1. Scanner positions around the laboratory channel.

The channel bed between all groynes was covered with a 0.18 m layer of fine sand (~30 m^2). Experiments were carried out for Q = 50, 75, 100, 125, and 150 l s^{-1}, and each of them lasted for 5 hours. During this time, a constant water level of 0.22 m was maintained relative to the initial sediment alignment. This increasing flow was intended to simulate the rising phase of the flood wave. Between flows, the morphology of the resulting bottom was not brought back to its original appearance. After every 5 hours, the laboratory channel has been drained and a 3D laser scan was performed. Eight scanner positions outside the channel were used; scanner lens was always located halfway between the groynes (Fig.1).

From each position of the scanner, a full image of the visible object was obtained. The eight scans, covering the channel section with sediment at the bottom, were then processed in Scene software; in the presented area the cloud of points consists of around 700 million elements.

3. Results

The results of the experiment are depicted as sets of point clouds representing the evolution of the bottom morphology after each flow. Each cloud consists of 8 scans composed based on characteristic points occurring in the laboratory channel. The accuracy shown in the software report was 1.5 mm. The obtained point clouds can be used in many ways in the analysis of the studied phenomenon. Figure 2a. shows the point cloud of initial condition with the original colours additionally applied.

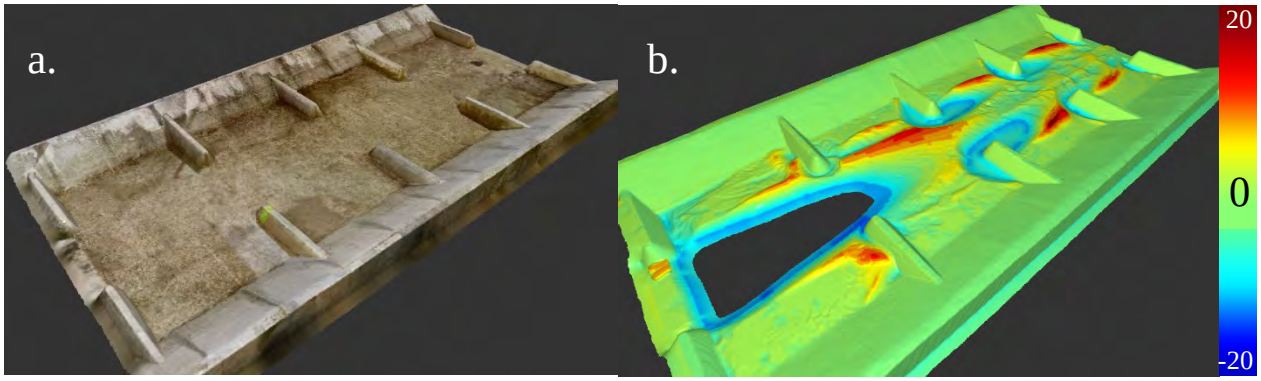

Fig. 2. a) Point cloud with actual colour mapping before the start of the experiment (scan '0'). **b)** Differential map between the state after 25 hours of experiment and the initial state.

The results of the experiment were compiled in the form of the difference maps as follows: 1. comparing the state of the bathymetry after a given flow in relation to the initial state and 2. comparing the state of the bathymetry between two consecutive flows. The map given in Fig. 2b compares the first '0' scan taken after sand placement (initial condition) and the last scan after 25 hours of experiment. In this visualisation, a colour legend was added. Green colour indicates unchanged areas (e.g. groynes), blue indicates areas where sediment has been lost, while yellow and red indicate areas where sediment has been accumulated. The Scene program provides a wide range of tools to facilitate the analysis of scans, such as the creation of cross-sections, length measurements in all planes, or adjusting the graphical setting of the obtained data to facilitate the analysis. For example, the user can identify the places where the sediment accumulation is greater than 0.15 m.

The resulting map allows for an accurate analysis of morphology changes between cases. It is relatively easy to obtain a required data set, and operate scanner by a single person. However, the main advantage of using a 3D scanner for sediment transport research is that results from laboratory conditions can be easily compared with results from mathematical modelling, facilitating calibration/verification process.

The main disadvantage of using a 3D scanner to study sediment transport is necessity to scan the laboratory channel without water; this is due to the fact that water scatters the laser beam and distorts the results. The effect of not deleted water between the first pair of groynes is well seen in Fig. 2b.

The results of the preliminary experiments are satisfactory and further studies using the technology described above are planned.

Acknowledgements
We would like to thank TPI in Gdansk, particularly Mr Karol Derejczyk for his support during the data processing.

Comparison of HEC-RAS and Iber simulations for the assessment of waterway safety under the bridge in the Kaunas city

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ABSTRACT

The main problem presented in this paper is the safety inlet navigation of the waterway below the bridge in the city of Kaunas in Lithuania. The analyzed reach is located in the Nemunas river downstream of the Kaunas dam. It is a part of the waterway E–41 leading to the Klaipeda harbor on the southern coast of the Baltic Sea. The work was initiated by the Lithuanian company UAB "Inžinerinis projektavimas" with funds from the EU TEN-T project. The main requirement imposed along this reach is to keep sufficient depth even if the hydraulic conditions are in the range of the lowest flows. Specifically, the depth is considered to be sufficient in the investigated reach if it is not lower than 1.15 m for minimum flows such as $Q_{95\%}$ and $Q_{95\%}$ with ice. However, the required depth is greater and equals 1.40 m below the city. Hence these two depths are taken into account to assess the risk to inland navigation. The hydraulic conditions for maximum flow $Q_{50\%}$, $Q_{5\%}$, and $Q_{1\%}$ are also taken into account for control because the threat of hydraulic jump generation was noticed. The values of tested discharges are presented in Table 1.

Table 1. Provided hydrologic information (source: Lithuanian Hydrometeorological Service).

type	minimum flows		maximum flows		
probability of exceedance	95%		50%	5%	1%
specific conditions	without ice	with ice	-		
symbol	$Q_{95\%}$	$Q_{95\%,ice}$	$Q_{50\%}$	$Q_{5\%}$	$Q_{1\%}$
value [$m^3 s^{-1}$]	71.6	91.5	1212	2143	3079

The research is based on geo-referenced data from public and non-public sources. These include the digital terrain model of the standards required by the EU Flood Directive, ortophotomap, land cover layers as well as the design of the modeled bridge in the CAD format. The hydrologic data were received from the Lithuanian Hydrometeorological Service. Additionally, the current bathymetry of the investigated reach was measured and reconstructed by spatial interpolation. The tools available in the ArcGIS software were applied to prepare the basic data for numerical simulations. Both active versions were used, ArcGIS Desktop and ArcGIS Pro.

Two different pieces of software were tested. These are well-known models (1) HEC-RAS and (2) Iber. The first is developed by Hydrologic Engineering Center (HEC), USA (Brunner, 2020). The model consists of a quite developed 2D flow module. The simulations may be done with full shallow water equations as well as a simplified version called diffusive wave. The computational module is supplied with a unique mesh generator. The mesh fitness to the irregular boundaries is satisfied with the polygons of the more complex shape, but the computational efficiency is achieved by the implementation of simple rectangular cells in the internal parts of the modeling region. The software is also supplied with other computational techniques increasing the efficiency of the 2D module, e.g. high resolution subgrid model. The HEC-RAS is a good example of computational river hydraulics, where sophisticated numerical techniques like finite volume methods are combined with semi-empirical approaches and more practical engineering methods.

The second applied model, called Iber, is a product of cooperation between main Spanish institutions like GEMA and Flumen Institute (Sanz-Ramos et al., 2022). The model utilizes the GID package created by CIMNE. The numerical approximation of the shallow water equations is the basis of the computational module. The applied method is a finite volume with Roe scheme on the general unstructured mesh with triangle and quadratic elements. The model is a pure computational dynamic approach with very few simplifications. Experience and carefulness are necessary to properly set the modeling parameters.

The methods of spatial data introduction to both programs are not the same due to the differences in the processing of this data. While the HEC-RAS transforms digital terrain models and other spatial data into HDF

format, Iber processes the data stored as separate layers like SHP, TIFF, ASCII, etc. The preparation of the model in the HEC-RAS package may be a little bit longer, but the usage of the HDF format enables effective access to the data during computations. On the other side, processing the results requires a transformation of layers stored in HDF files into formats readable by GIS software. On the other side, Iber simulations are based on the standard GIS layers and the results are mainly written in ASCII files. It simplifies the preparation of the model and makes access to the results straightforward, but computations may last longer. This is compensated by the effective usage of computational resources.

The models were validated based on physical model experiments. The physical model was created in the Water Laboratory at Poznan University of Life Sciences, Poland (Dysarz et al., 2023). Three experiments were conducted in the laboratory with scaled values of $Q_{95\%}$, $Q_{5\%}$, and $Q_{1\%}$.

Table 2. Classification of risk.

level of risk	depth [m]		velocity [m s^{-1}]	
	min	max	min	max
low	0.00	1.15	0.00	0.75
medium	1.15	1.40	0.75	1.50
high	1.40	-	1.50	-

The validated numerical models were implemented to test different values of the unknown roughness of the channel bottom. The results of the simulations with flows $Q_{95\%}$ and $Q_{95\%,ice,}$ and $Q_{50\%}$.were depth and velocity. These maps were classified into zones of no risk, middle risk, and high risk (Table 2).

The application of ArcGIS in the post-processing phase lets to identify the locations of the hazards. The magnitude of risk was expressed in terms of minimum depth achieved, maximum velocity observed, as well as the length of the reaches with high risk related to these two factors. Additionally, the opportunity to generate the hydraulic jump is analyzed. Such risk was mentioned in the phase of the project preparation. Conducted results confirmed that the combination of hydrodynamic simulations and geoprocessing in the stage of pre- and post-processing could be a powerful tool in hydraulic engineering analyses. Additionally, is worth noticing that numerical modeling enables a wider analysis of potential conditions than could be possible with a physical model only.

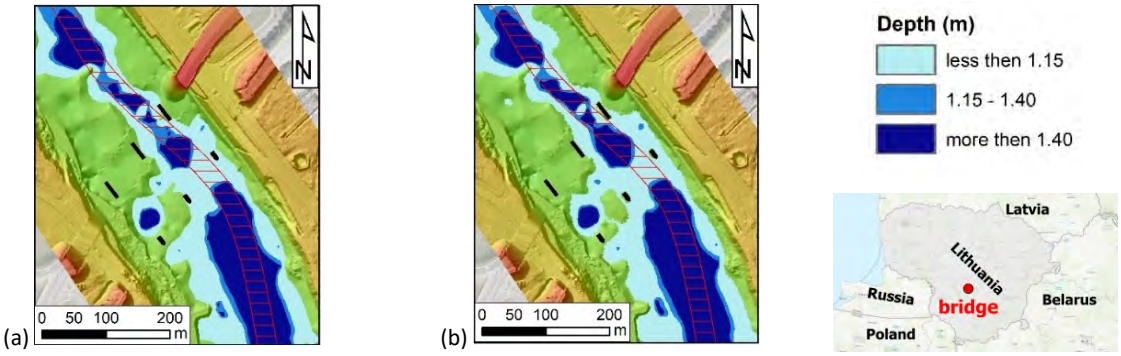

Fig. 1. Comparison of results for minimum flow $Q_{95\%}$ and roughness 0.015 s m$^{-1/3}$.
(a) HEC-RAS results with dynamic wave model, (b) Iber results with 1st order scheme

In general, the models provide compatible results, but some differences are visible. The example is presented in Fig.1. The maps present a comparison of depths in the most problematic area located just below the bridges. Although the zones of the maximum depth are compatible, it is well visible that the inundation areas and classes of depth differ a little bit. Similar compatibility is observed in the comparisons of the velocity fields. However, both models let to draw the same conclusions based on the minimum depth, the zones of depth scarcity, and values of the velocity.

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Methods for the assessment of fishways (upstream fish passage)

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ABSTRACT

Fragmentation of rivers by manmade barriers have impeded the ability of riverine fish to move freely. Barriers can be improved by fishways that can partially mitigate the negative impacts by acting as aquatic corridors. Effective fishways require knowledge about the physiological and spatial demands of fish species, but existing knowledge largely derives from laboratory settings. Evaluating fishway performance is needed for optimisation of their hydraulic design and positioning. Qualitative methods include trapping, electrofishing, and camera observations to estimate numbers of individuals passing (effectiveness). For quantitative assessment, the study of individual fish behaviour can identify fishway sections in need of improvement and estimate associated efficiencies. This can be accomplished by telemetric techniques such as PIT tagging, radio, and hydroacoustic telemetry.

Fish observations and hydraulic measurements on a nature-like unstructured block ramp

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ABSTRACT

The hydraulic design of nature-like unstructured block ramps is based on empirical approaches hampering the proof of passable migration corridors for fish. The research project “MigRamp” aims at identifying and quantifying migration corridors of upstream migrating fish on nature-like unstructured block ramps by linking fish trajectories, bed topography and local flow field. For this purpose, combined fish-biological and hydraulic investigations were carried out on an existing nature-like unstructured block ramp in the field and laboratory tests. This paper describes the field measurements and reports preliminary results of an identified migration trajectory of a brown trout and its correlation with hydraulic parameters.

Applying hidden Markov modelling to fine-scale telemetry

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ABSTRACT

Recent developments in fine-scale acoustic telemetry have resulted in large datasets containing highly detailed information on fish movement. A common tool in movement ecology is the application of hidden Markov models (HMMs) to uncover hidden behavioural states from telemetry data. Currently data collection can take place at a finer temporal scale than is typically used for HMMs. Although HMMs can still provide valuable insights into fish behaviour the current fine-scale data can introduce some conceptual and practical challenges in model development.

In this paper we look at the potential of straightness index. This index retains fine-scale movement data while smoothing movement data, allowing for the development of HMMs. Using such an approach can be essential in finding behavioural responses of fish to the ecohydraulic environment, and might, in turn, inform fishway design.

Consider the bigger picture: The effect of multimodal sensory integration on fish passage behaviour

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ABSTRACT

Fish passes are an important tool for minimizing the negative impacts of in-stream infrastructure on ecologically and economically important fish species. However, their efficacy is not perfect, and fish do not always respond to these structures as expected. One reason for this is that we do not have a complete understanding of what sensory stimuli influence fish passage behaviour. While considerable work has gone into quantifying the effect of the hydrodynamic environment on these behaviours, much less is known about how other sensory channels affect them, despite evidence that visual, auditory, and even olfactory stimuli play a role in governing these behaviours. Thus, we call for an increased consideration of how fish passage behaviours are impacted by information detected across multiple sensory channels. Developing this knowledge will aid the retrofit and improvement of exisiting fish pass structures, along with the design of new fish pass structures in the future, and the development of new predictive models designed to explain the behaviour of fish in the proximity of instream barriers.

Flood routing using models based on input and output flow or stage data

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ABSTRACT

Convolution or linear-systems methods for simulation have not received much attention in hydraulics, although well-known in hydrology. They can be conveniently used in the common situation where stage hydrographs from two rivers measure ng stations are known. No details of river geometry or resistance data are required. The principal problem is to determine the propagation characteristics of the river reach, for which optimization methods are shown to be convenient and can be simply extended to cases with several inflows. Using water level has advantages: it is that which is usually measured, no rating curves are necessary, unsteadiness is not a problem, the range of variation of level is less than that of flow so the equations are ,more valid, and it is the effect of high water level that causes flooding anyway. The methods are shown to be not as accurate for large floods, but then other stimulation methods require physical data that may not be well known. As a simple and stable computational tool the methods examined here might have a role to play.

Key words: Rivers, unsteady flow, simulation, stage data, optimization methods.

Active flow zones distribution along the upper Vistula River established with the use of 1D and 2D modelling

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ABSTRACT

2D numerical modeling of hydraulic flow conditions was performed and calibrated on the Vistula River sector between Zawichost and Słupia Nadrzeżna. The results of the modeling were used to calculate the active cross-section flow zone according to the Pasche method. The range of the active flow zone was used in the 1D modeling to compare the results. Values of flow, water velocities, and unit discharge were used to analyze active flow zones and energy exchange between the main river channel and floodplain. As the result, the size of the active zone was compared, and the effectiveness of the method was established by indicating similarities and differences from the 2D model. The study shows that all relations among the three main determining parameters of Pasche's method were found. Dimension of the active zone, relations between depth in the river channel and on the floodplain, and roughness contrasts appear in all versions. The analyzed river's part can be as wide as the accessible space between banks and dikes or almost nonexistent caused both by humans and nature. The floodplain can be low and accessible from the river or high and hardly available for the energy exchange. A positive correlation between the calculated and real active zone size is always reached when spatial changes in the floodplain are taken into account along the river. Active zone size can be established using both 1D and 2D models; however, the 1D model in the presence of the connected oxbow lakes cannot guarantee full accuracy.

Numerical reconstruction of pore pressure distribution in tailings dams

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ABSTRACT

One of the most important results of numerical analyses for tailings dams is the factor of safety (FOS), essential for evaluation of dams safety. The distribution of the pore pressure, generated by the build-up of embankments and filling of the reservoir with slurry, significantly influences FOS values. Proper reconstruction of the pore pressure field increases chances of obtaining realistic FOS values. One of the most popular methods for determining FOS, the strength reduction method, requires pore pressure and stress distributions as initial conditions. In order to obtain these fields, it is necessary to perform calculations with poromechanical coupling that reconstruct the history of dam rise. The tailing dam's rise, i.e. the change in geometry and the increase in weight, in finite element method (FEM) analyses is usually realized by adding of subsequent FE layers. The process of rising water table, associated with soaking and sedimentation, is difficult to model by means of constitutive relations used to describe soils. On the other hand, these constitutive laws are necessary to calculate FOS values. However, researchers dealing with this subject do not focus on the modelling method, usually providing a brief overview and final results (e.g. Różański et al., 2022, Zardari et al., 2017).

This article presents a method for numerical modelling tailings dam rise that considers the time-varying computational domain and relies on Darcy's law to describe the phenomenon of seepage in deposits and subsoil. This method is suitable for analyses of dams built using the upstream method with monitoring system installed, that collects data on pressure distribution and location of phreatic surface. The proposed modelling method involves distinguishing four main material zones (Fig. 1). The parameters of the first two, the subsoil and starting dams (dikes), are assumed to be known. The next group includes sediments that tend to be fully saturated with water. The fourth group is the transition zone between dams and sediments. In this zone, soaking and sedimentation occur, but soils may be partially saturated. The parameters of the transition zone and the sediment zone are unknown. Furthermore, pressure boundary conditions are implied in the sediment zone to reproduce the rise of the water level.

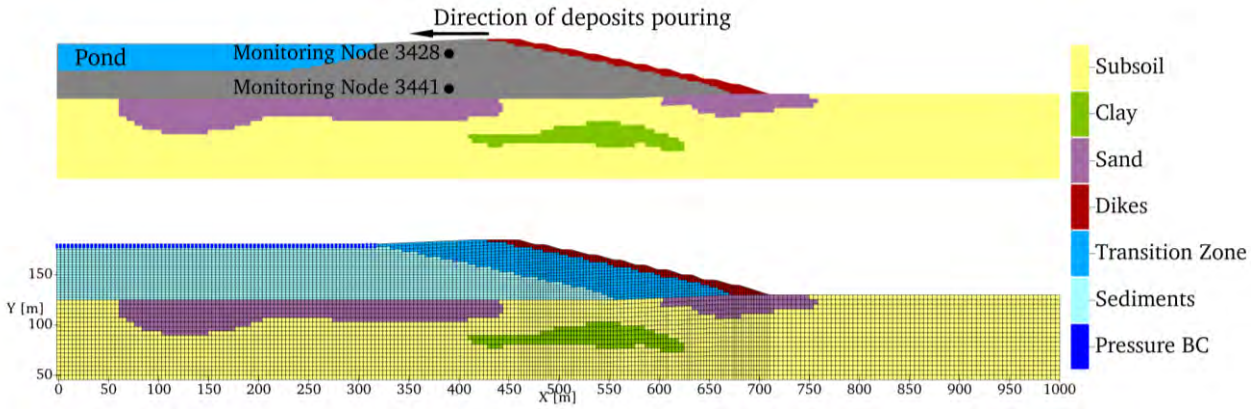

Fig. 1. The tailing dam scheme (above) and the proposed numerical model with material zones (below).

The main goal of the calibration involved mapping of the phreatic surface and nonhydrostatic pore pressure distribution in sediments (Tschuschke et al. 2020, Whittle et al., 2022). Therefore, the calculations were carried out only for the seepage problem following Darcy's law and the van Genuchten (1980) model for partially saturated zone without poromechanical coupling.

The modelling method includes seven parameters that require calibration. These are the range (width) of the transition zone, the value of the pressure applied in the sediment zone, the horizontal and vertical coefficients of permeability for the sediment and transition zone and the van Genuchten's α parameter for the transition zone. Calibration of the numerical model was treated as an optimization problem that was solved using a

genetic algorithm (GA). The difference between the pressure measurements collected by the monitoring system and the results of the numerical model was adopted as an objective function and minimized. For evaluating the values of the objective function, GA was combined with finite element method software. The monitoring data, consisting of measurements from 14 pressure gauges, was synthesized artificially from data available in the literature from real tailing dams (Różański et al. 2022, Whittle et al., 2022).

The five calibrations were performed and all yielded similar values of the objective function. Figure 2 shows results of a single calibration, pore pressure distribution in sediments, and improvement of the fit to monitoring data for two out of 14 nodes. Furthermore, all calculated FEM cases were used to determine the influence of calibrated parameters on the objective function. However, it was impossible to distinguish most important parameters, which implies the nonlinearity and complexity of the problem. Therefore, the assumption of using a heuristic optimization was correct.

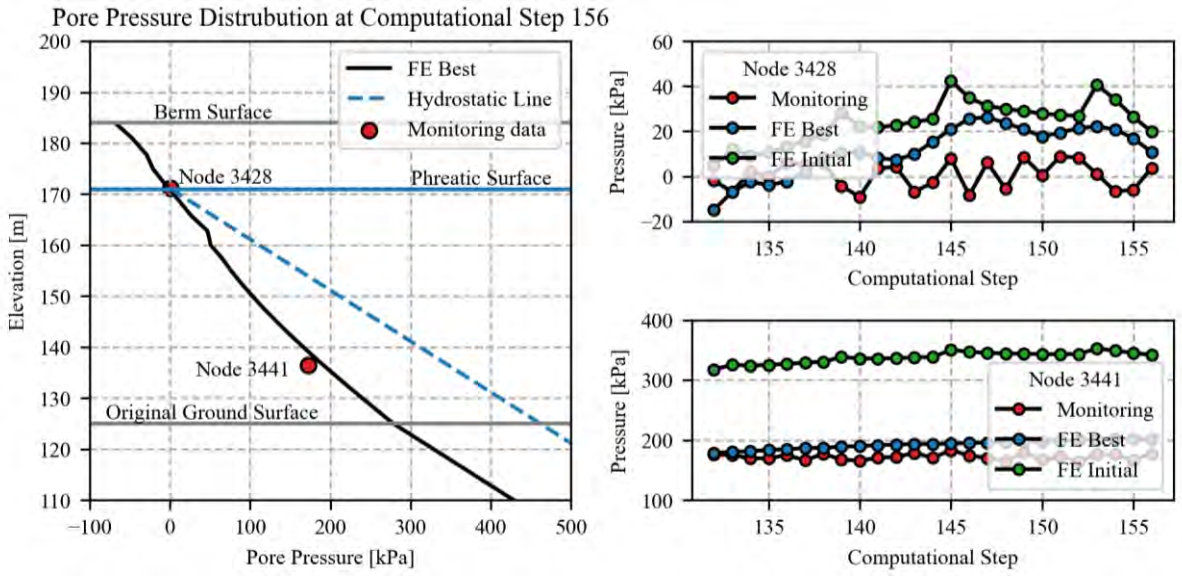

Fig. 2. Distribution of the pore pressure in the cross section X = 390 m (left) and fit to monitoring as a function of the computational step for the best and one of the initial solutions obtained in a single calibration (right).

However, as mentioned above, poromechanical coupling is necessary to calculate the FOS values. Therefore, calibrated sets of parameters were used for the consolidation analysis. Calculations were carried out for six different, in terms of permeability and mechanical properties, subsoil systems and for different Young modulus of sediments (ranging from 3 MPa to 20 MPa). The phreatic surfaces and pore pressure distributions obtained in all consolidation analyses were shown to be very similar to those derived from uncoupled flow analyses, i.e. best results from calibration. In case of parameters ranges, geometry of model and monitoring data adopted for the research, it can be concluded that pore pressure distribution in sediments was barely influenced by subsoil parameters.

The results indicate that the proposed method of tailing dam modelling can be adopted for the calculation of the factor of safety, as it enables proper reconstruction of the pore pressure field and consequently more realistic FOS values. It is noteworthy that during such calculations calibration of mechanical properties may also be required. In that case, the presented genetic algorithm-based optimization model can be considered as a first step allowing identifying sediments parameters. Then the subsoil parameters can be determined, based on displacement monitoring data and soil field tests.

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Methods of measuring the difference in water levels between sections in rivers and channels

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ABSTRACT

Water level measurement in rivers or canals is still a challenging task in terms of measurement accuracy and measuring methods evolve (Wang *et al.*, 2022). In this study, we used a precise total station to measure the head on a weir in the Bóbr River (Poland) in order to verify the precision of this method in field conditions. The difference in the position of the upper and lower water levels was measured using a floating benchmark (360 prism) (Figs.1-2).

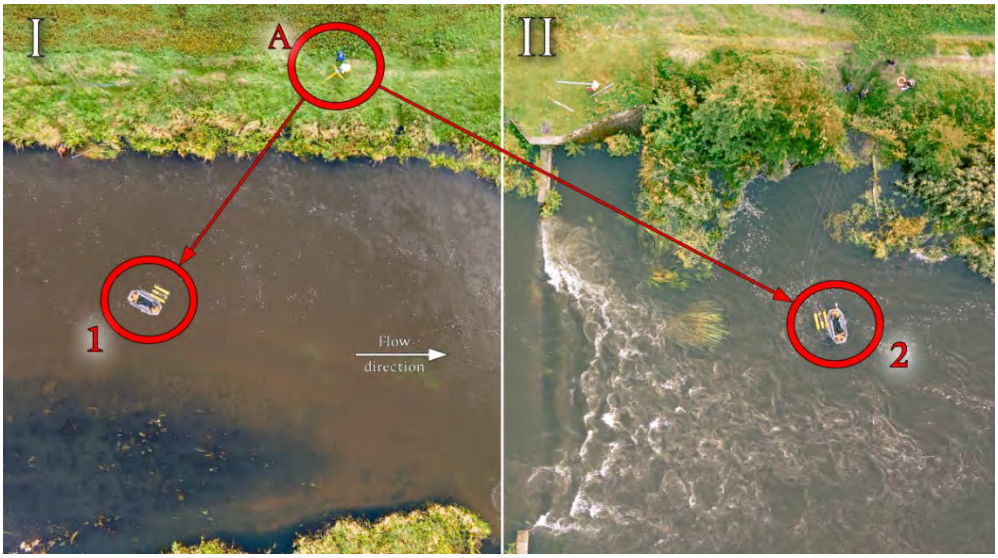

Fig. 1. Positions of the (A) precise total station, floating prism at the (1) upper and at the (2) lower position of the weir (UAV top-down photo).

Fig. 2. Scheme of measuring stand. (1) Floating benchmark, (2) 360 prism, (3) precise total station.

The main assumption of the technique was to achieve high measurement accuracy by using a modern total station which tracked the geodetic benchmark (360 prism) installed on a multihull floating platform. The determination of the position in three axes and tracking of the benchmark was performed automatically in real-

time. To average the position, at least 200 to 400 measurements were taken, depending on the water surface fluctuations. Fig. 3 present the outcomes of utilizing a precise total station to make floating benchmark (360 prism) observations. A total of more than 800 observations were conducted, and the average was determined to determine the position of the water table in the measurement cross-section.

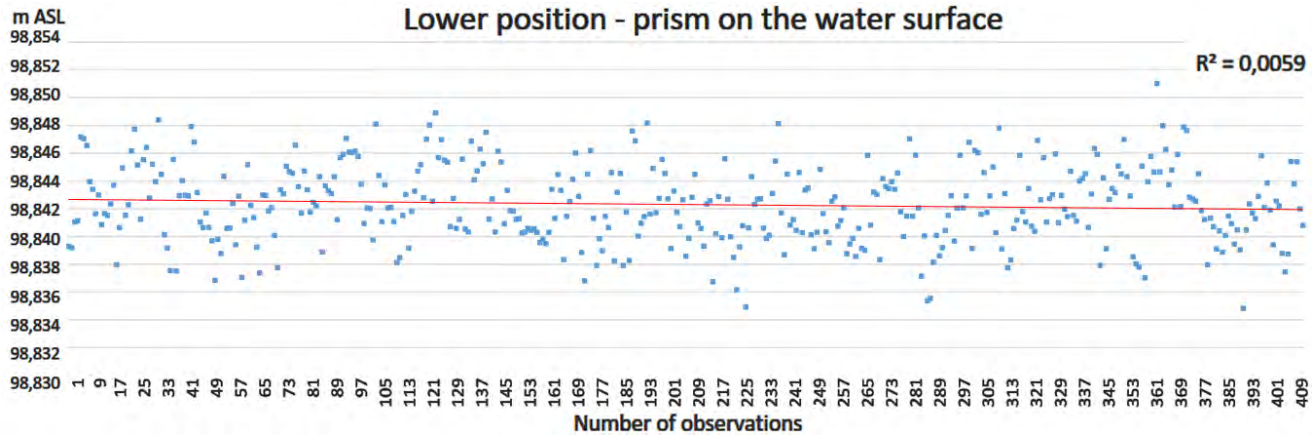

Fig. 3. Example of the results of floating benchmark (360 prism) observations using precise total station at lower position.

A levelling rod placed on the water surface in sections was used as a reference method. Although this is a standard method, it is burdened with a significant error resulting from the subjective assessment of the average water level and the skills and strength of the person holding the leveling rod (Fitzpatrick *et al.*, 1998). Results of the measurements are presented in Table 1.

Table 1. Results of measurements

	Levelling rod (reference) (No. 1)	Levelling rod (reference) (No. 2)	Floating 360 prism (No. 1)
Upper position [m]	2.7847	2.9337	99.02626
Lower position [m]	2.6010	2.7507	98.8423
Level difference [m]	0.1837	0.1830	0.1840

The aim of the study was to develop a technique that would be used to measure the slope of the water level in the lateral channel of the Dychów hydroelectric power plant (Poland). During maximum performance, the average slope of the water level in the channel was 0.06 per mile. The measurement sections on the channel were determined to be 1 km long, resulting in a water level difference of approximately 60 mm on the section. The required accuracy of the water level slope measurement in the channel was +/- 2 mm. However, due to the small differences, researchers seek a method with high accuracy, which will minimize errors resulting from the subjective assessment of the researcher. The significance of this is particularly noteworthy in situations involving hydroelectric power plants of considerable size.

During the measurement campaign, problems with water level fluctuation were encountered in some locations (Marchand, Jarret and Jones, 1984). This issue was resolved by adjusting the observation time and averaging the results. Knowing and understanding these types of problems and how to solve them can be extremely valuable for other water-related projects that face similar problems. This study is important because it presents a technique for accurately measuring water level slope in the channels and rivers, which is essential in many fields such as water construction, hydrology, ecology and even hydropower plants.

Acknowledgements

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Impact of land use and land cover changes on the surface runoff in Gdańsk, Poland

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ABSTRACT

This study evaluates the changes in land use and land cover between 1985, 1995, 2005, 2015, 2022, and 2050 and their impact on runoff in Gdańsk, Poland, using remote sensing/geographic information system (RS/GIS), utilizing the soil conservation service (SCS) curve number method.

1. Introduction

It is likely that floods will occur more frequently in the future and determining their extent will be challenging. Although it cannot be denied that urbanization is an ongoing global trend that has altered land use and land cover (LULC). Urbanization contributes significantly to pluvial floods by increasing impervious surfaces that lower infiltration and resistance to flow (Bulti and Abebe, 2020). Consequently, the volume and flow rate of the runoff rise, exceeding the capacity of the local drainage system.

2. Methodology

2.1. Study area

Gdańsk is the largest city in northern Poland and is located on the southern coast of the Baltic Sea in the Gulf of Gdańsk, as shown in Fig.1. The coastal zone consists of Vistula Split, the Vistula Delta Plain, and the eastern part of Kashubian Coast. The city has an area of 262 km^2. On the western side of Gdańsk city, the post-glacial hills are dominant, with elevations up to 200 m above sea level. The southern part of the city is a dense residential area, while the northern and central parts are dominated by moraine hills (Szpakowski and Szydłowski, 2018). The mean annual precipitation is 659 mm (Szpakowski and Szydłowski, 2017).

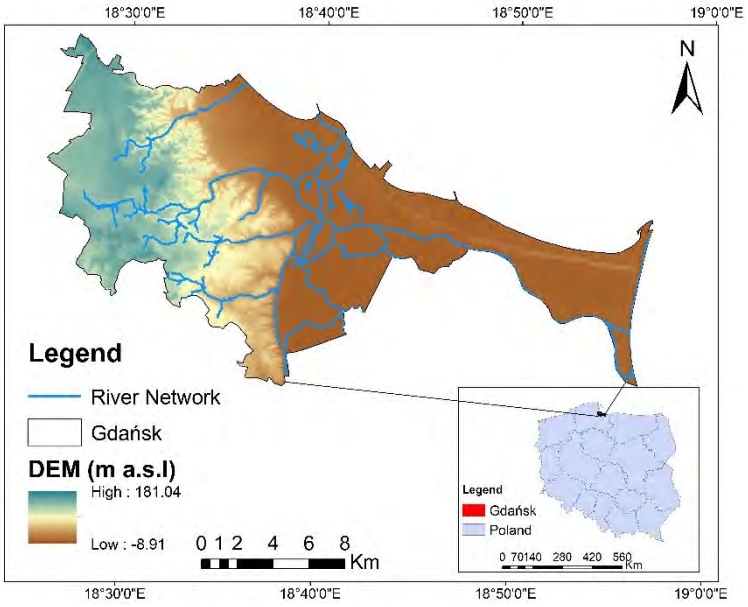

Fig. 1. The geographical location of the study area: Location map of Gdańsk in Poland (bottom right), Gdańsk (top left).

2.2. Methods

This research utilized the cloud-based platform Google Earth Engine (GEE) to prepare LULC maps. Remote sensing data was directly assessed from GEE and preprocessed using a cloud mask for each pixel. A random forest (RF) machine learning algorithm was used for pixel-based classification and the RF model was trained

using LULC classes of Gdańsk. Region-of-interests were identified for all classes in the training and validation dataset using ESA WorldCover (10 m) LULC map, ESRI LULC (10 m), and imagery observation. Post-processing of LULC maps was conducted using ArcMap. To predict the future LULC of Gdańsk for the year 2050, the Land Change Model (LCM) within the TerrSet software system was employed.

To quantify the impact of LULC changes on runoff, a simple hydrological method, the Soil Conservation Service-Curve Number (SCS-CN), was utilized to estimate the rainfall-runoff transformation process. Daily maximum rainfall data from 1974 to 2000 (P=93.38 mm) was used in this study and the hydrological analysis used rainfall with p=1% (return period 100 years) and T=24 h. A CN grid was prepared in ArcMap using LULC and the soil map of Gdańsk. The SCS-CN formula (Eq. 1) for the estimation of direct runoff depth was calculated in ArcMap.

$$Q = \frac{(P-0.2S)^2}{P+0.8S}, \quad S = \frac{25400}{CN} - 254 \tag{1}$$

where P is the total rainfall[mm], S is the potential maximum retention, CN is the curve number, while Q is the direct runoff[mm].

3. Results

Figure 2 depicts the distribution of LULC classes between 1985 and 2050. The results demonstrate significant changes in the built-up area, vegetation cover, cropland, and woodland. It was observed that in 1985, built-up covered 63.42 km^2, which increased to 79.87 km^2 in 2022 at the expense of agricultural areas. The successive increase in forest cover (from 28.31 to 31.28 km^2) in Gdańsk can be attributed to the agroforestry programs implemented in Poland. The predicted LULC map of 2050 indicates that the built-up area is expected to increase up to 105 km^2 in the Gdańsk, along with a decrease in vegetation (51 km^2), cropland (12 km^2) and bare land (20 km^2), respectively.

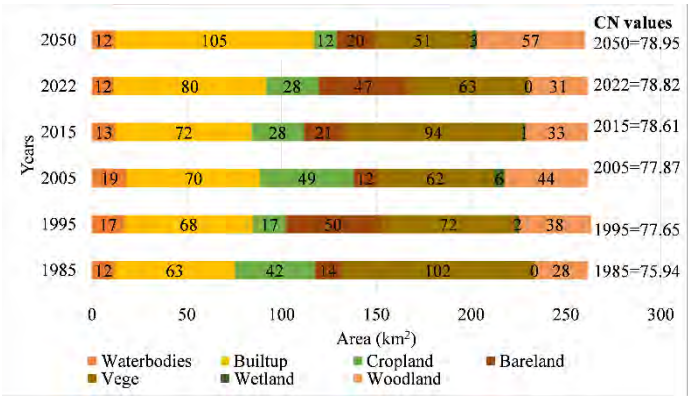

Fig. 2. LULC changes between 1985 to 2022 and 2050 prediction

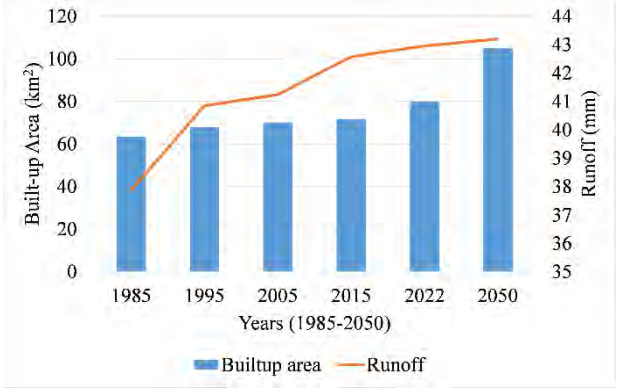

Fig. 3. Comparison between the increase of built-up areas and the runoff

The LULC changes ultimately caused changes in the runoff. The changes in the built-up area and its role in runoff are shown in Fig. 3, which displays the effect of urban area expansion on runoff. Runoff increased from 37.86 to 42.95 mm between 1985 and 2022, assuming total rainfall P=93.38 mm and could further increase to 43.19 mm by 2050.

4. Conclusion

This study aims to examine the long-term effects of urbanization on runoff in the Gdańsk. Land use changes over 37 years were quantified and predicted for 2050 and the corresponding runoff changes were analyzed during this period (1985–2022–2050). The built-up area is the primary factor contributing to runoff in urban areas. This research suggests that decision-makers should consider future LULC changes and incorporate appropriate climate-change adaptation strategies to reduce the risk of flooding.

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Information entropy theory-based optimizing of gauge networks for hydrological modelling - A case study in the Loess Plateau, China

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ABSTRACT

Runoff prediction based on error analysis is paramount in flood monitoring and early warning, as well as in flood management. Precipitations are one of the most important input parameters in developing hydrological models to simulate runoff, and they can be represented accurately with a low-cost and well-designed rain gauge network. This study aims to use information entropy to optimize the rain gauge network of the Chabagou Watershed (CW) located in the Loess Plateau, China, as this area is largely affected by extreme precipitation and flood events. There are 13 rain gauges in the CW, and the optimal network is examined by using the Soil and Water Assessment Tool (SWAT) model to simulate the runoff. The results are i) the gauge network composed of 10 stations performs similarly to the network formed by 13 stations; ii) the performance of the SWAT model with different rain gauge distribution is stable, but the performance increases with the increase of rain gauge number. In summary, the information entropy-based optimization strategy helps to improve the performance of the gauge network, eventually helping in developing reliable regional hydrological models to be used in flood management.

Keywords: Information entropy, rain gauge network optimization, SWAT model, Loess Plateau

High-resolution water surface slope of Polish rivers from multi mission satellite altimetry

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ABSTRACT

Water surface slope (WSS) of rivers is an essential parameter in hydrological and geomorphic modelling. It determines the transport and erosion capacity of a river; it also allows for a calculation of the flow velocity and river discharge. On a local scale, WSS can be measured with a GNSS receiver mounted on a boat or using remote sensing techniques, such as airborne lidar, radar, or photogrammetry. On the other hand, such measurement campaigns are associated with high costs. WSS can also be obtained from a Digital Elevation Models (DEM). However, DEMs mostly refer to the topography and not the water level of rivers, whereby smaller rivers are not taken into account due to the spatial resolution of the DEM. The most accurate method to measure WSS avoiding field campaigns is based on Water Surface Elevations (WSE) measured at *in-situ* stations, which are referenced to a common vertical datum. However, the spatial distribution of gauges is uneven, and the number of gauge measurements is decreasing over the past decades. Therefore, in poorly gauged rivers the distance between neighboring gauges can be up to hundreds of kilometers, which precludes observations of a spatial variability of a river profile.

The gap in decreasing number of gauge readings is partially filled with satellite altimetry, which has been providing WSE of oceans and inland water bodies for over 25 years (Abdalla et al., 2021). Altimetry based WSE can be used to calculate WSS between neighboring measurements (Halicki et al, 2023). However, satellite observations are also limited by the temporal resolution which varies between 10 days (Jason-3) and 369 days (CryoSat-2) and the spatial coverage which varies between ~7.5 km (CryoSat-2) and ~300 km (Jason-3) inter-track distance at the equator. Therefore, in order to properly capture the spatial variability of WSS, it is worth using measurements from multiple satellites. In this study, we present a new innovative approach for estimating high-resolution WSS, which is based on a Least Square Adjustment using water levels derived from multi-mission satellite altimetry of almost 30 years.

In this study, we used measurements from the following altimetry missions: CryoSat-2, Envisat, ERS-1E/-1F, ICESat-1/-2, Jason-2/-3, SARAL, Sentinel-3A/-3B and Sentinel-6A. The observation epoch ranges from 1994 to 2022. The accuracy of altimetry measurements over Polish rivers (RMSE of 12-44 cm) has been confirmed by Halicki and Niedzielski (2022). We extracted the river centerlines from the global "SWOT Mission River Database" (SWORD, Altenau et al., 2021). In order to validate the obtained results, we used WSE from 81 gauges, which are maintained by the Institute of Meteorology and Water Management – National Research Institute (IMGW-PIB). The WSE measurements are referenced to the Kronsztadt'86 vertical datum (by adding WSE to gauge-zero of each station) and they range from 01.2016 to 05.2022. Additionally, we used the reach-scale "ICESat-2 River Surface Slope" (IRIS, Scherer et al., 2022) and the DEM-derived WSS values from SWORD.

To obtain WSS, we first had to determine WSE at each satellite pass over a river. Next, rivers were split into sections without dams/reservoirs, and the Support Vector Regression (SVR) has been applied to reject outliers. Then, water levels were assigned to a given river kilometer (bin) and for each bin a median height has been calculated. Finally, we calculated WSE at river sections between bins, excluding sections disrupted by hydraulic structures. We applied a Least Square Adjustment with an additional Gradient and Laplace condition to obtain bin-wise WSE for each river kilometer, except those near hydraulic structures.

The resulting WSE are then used to derive the WSS between adjacent kilometer bins. The preliminary WSS variability of the Vistula River is presented in Fig. 1. The slope values calculated with the proposed approach agree well with the slope calculated using median WSE at neighboring gauges. Further, the multi-mission approach enables capturing the spatial WSS variability to a much greater extent. It is also worth noting, that we obtained an almost flat river profile on the chainage 210-250 km, which refers to the Włocławek reservoir. This confirms the accuracy and reliability of the proposed approach.

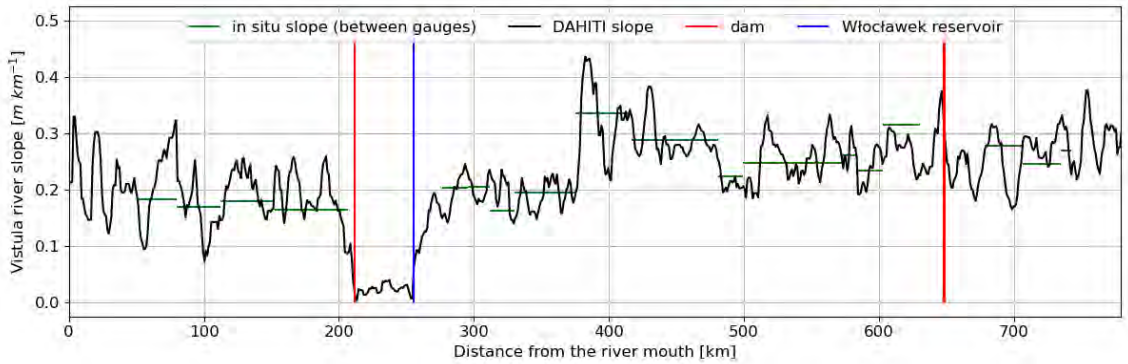

Fig. 1. Water surface slope of the Vistula River calculated using the new approach compared with slope calculated using water levels from closest neighbouring gauges.

Table 1. The preliminary Root Mean Squared Error (RMSE) of three water surface slope sources. For the sake of comparison, for each source we calculated average slopes for sections between IMGW-PIB gauges and compared them with the corresponding gauge-based slopes.

River	Gauge sections	RMSE [mm km^{-1}]		
		This study	ICESat-2	SWORD
Vistula	82	11.9	16	68.2
Oder	46	5.9	33.1	40.2
Warta	67	25.1	32.4	63.6
Bug	45	4.3	6.2	29.1
Narew	10	10.3	9.2	30.2
San	11	80.3	86.5	96.9
Pilica	3	3.0	5.2	68
Dunajec	9	69.1	386	272.9
Mean	-	26.2	71.8	83.6

We compared the obtained WSS with the slopes between IMGW-PIB gauges (Table 1). Large rivers (Vistula, Oder, Bug) were characterized by the highest accuracy (RMSE < 15 mm km^{-1}), while smaller, mountain rivers (San, Dunajec) were characterized by a slightly larger error (RMSE ~70-80 mm km^{-1}). We also compared our accuracies with those from the IRIS and SWORD databases. On average, the multi-mission approach revealed the highest accuracy. It can be concluded that the proposed method allows for an accurate high-resolution water surface slope estimation, which can easily be used for hydrological modelling. Further, this method is based on satellite data and a global river centerlines dataset, therefore it can be globally applied to almost every river.

Acknowledgements

A detailed description of the proposed approach is planned to be published as a full research paper. The high-resolution WSS dataset for Polish rivers will also be freely available. This study has been carried out in frame of the research project No. 2020/38/E/ST10/00295 within the Sonata BIS program of the National Science Centre, Poland, as well as in frame of the Doctoral School of the University of Wrocław, Poland. We also acknowledge the ERASMUS program, which enabled this cooperation.

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Hydraulic properties of Sulejów Reservoir in Poland as a driving factor of sedimentation processes

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ABSTRACT

In the 1970s, a large artificial lake – the Sulejow Reservoir – was installed in the middle course of the Pilica River in Poland. The reservoir has a length of 15.5 km, a maximum width of 2.1 km, a surface area of 22 km^2, and a total storage capacity of 77.6 x 106 m^3. It has a very long water retention time of more than 30 days. The Sulejow Reservoir suffers from significant eutrophication due to the supply of nutrient compounds from both point and nonpoint (diffuse) sources. In understanding the role of the reservoir as a storage or source of nutrients it is very important to have a good description of the abiotic properties of the reservoir in the longitudinal profile. With the improvement of hydrodynamic models, it is possible to approach that problem using Computational River Dynamics (CRD) methods. In this study, 1D hydrodynamic model (HEC-RAS) was used to study the distribution of hydraulic parameters in the longitudinal profile of the reservoir. The very accurate DTM of the reservoir was calculated from the newest echo-sounding data obtained in the year 2016. The new value of the reservoir volume was calculated. In the longitudinal profile of the reservoir, it was delineated zones of the riverine, transitional, and lacustrine conditions. The distribution of velocities in the longitudinal profile shows the different roles of reservoir sub-basins as sediment traps.

Practitioner friendly introduction to bayesian flood frequency analyses

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ABSTRACT

Flood frequency analyses are an effective means to describe flood magnitudes and recurrence probabilities for monitored rivers. In data-limited situations predictions become uncertain and of limited use for management. Bayesian approaches provide a formal way to bring in domain knowledge (as “priors”), which can help in data limited scenarios. While application of Bayesian estimation techniques to flood frequency is not unique, our presentation of a Bayesian workflow is. We provide a case study of using both historical and contemporary discharge monitoring information for the longest river in Sweden, the Klarälven. Our workflow includes 5 steps for applying Bayesian techniques for flood frequency analyses, 1) specifying priors for each parameter, 2) sampling from the prior predictive distribution, 3) fitting candidate distributions to data, 4) performing posterior predictive checks for each distribution, and 5) performing sensitivity analyses. The resulting workflow serves as proof of a concept that can be readily applied in other river systems.

Comparison of results of 2D numerical hydraulic modelling using different Digital Bathymetric Models (DBMs)

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ABSTRACT

In this contribution, the output of a 2D numerical model created with the use of various DBMs as input is presented and discussed. A short reach of the canalised part of the Odra River is modelled using HEC-RAS under flow conditions, which are appropriate for inland navigation. The interpolation methods that were used to build the bathymetry of the model are the TIN (Triangulated Irregular Network), NN (Natural Neighbour) and IDW (Inverse Distance Weighted). Some discussions and conclusions are stated for this case study.

1. Introduction and case study

Numerical modeling of river flow is essential for the analysis of various civil and environmental engineering issues. A key step in the creation of a well-performing numerical model is the proper definition of its geometry. Above all, the bathymetry of the analyzed waterbody. Many professionals in the water sector require bathymetric surveys, which are sometimes inaccurate, time consuming, or economically expensive (Herrera-Granados, 2020). However, with the usage of appropriate interpolation methods, an economical and close to reality DBM can be created (Uciechowska-Grakowicz and Herrera-Granados, 2021). In this contribution, the output of a 2D numerical model, which geometry is based on three different DBMs created with the usage of different interpolation methods as input, is presented and discussed.

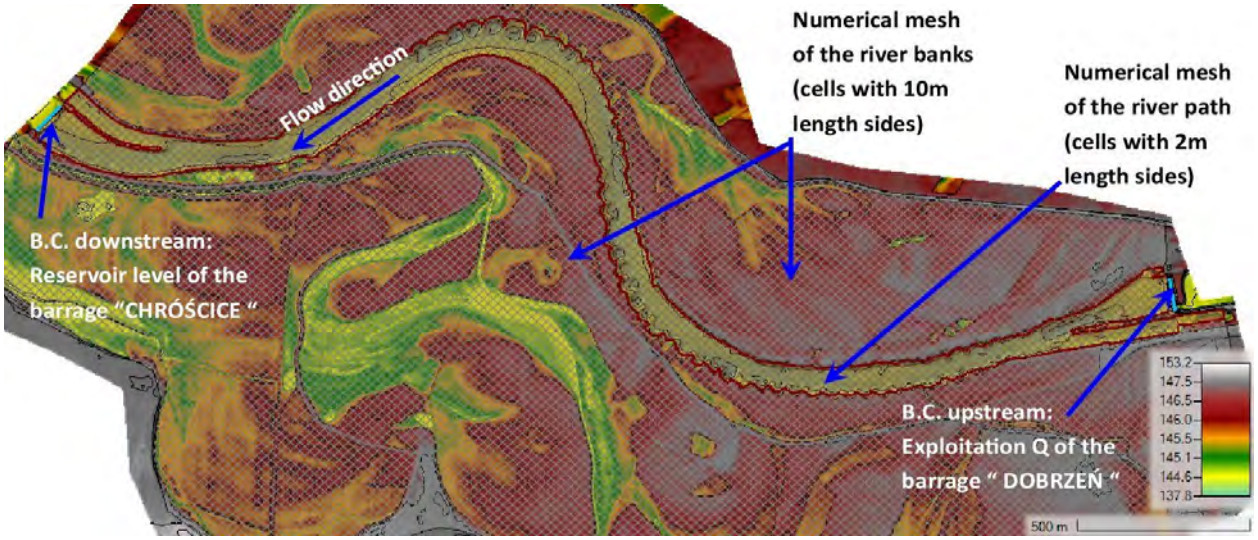

Fig. 1. DEM with TIN bathymetry of the canalized part of the Odra River (Poland) from the barrage Dobrzeń to the barrage Chróścice with the computational domain (numerical meshes) and boundary conditions that were used for the computations.

A short reach of the canalized part of the Odra River (Fig. 1) is modelled using HEC-RAS under proper flow conditions for inland navigation, namely, the average flow with the probability of occurrence of 276 days per year (Q_{276} upstream), which meets the minimal conditions for inland navigation (Herrera-Granados, 2022). The analyzed river reach is from the barrage Dobrzeń (upstream) to the barrage Chróścice (downstream) in the middle course of the Odra River, where this waterway is heavily modified. Downstream, the operational reservoir level of the barrage Chróścice was used as downstream boundary condition. Three numerical meshes were defined: two for the left and right over bank (cell sides of approximately 10m length) and one more for

the river channel, where three different DBMs were used for their comparison. The digital elevation model (DEM) of the floodplains and terrains beyond the river bed was the same; just the bathymetry is different and obtained using different interpolation methods based on the same survey points registered onsite in 2018.

2. Results, Discussion, and Conclusions

Figure 2 depicts the results of the computed water depth for Q_{276} and using the DBM based on the TIN method. Additionally, the maximal flow rate Q_{14} suitable for inland navigation was also analyzed. By analogy, Q_{14} is the average flow with the probability of occurrence of 14 days per year or less. Above this flow rate, inland navigation shall not be allowed along the waterway.

Fig. 2. Computed water depth along the study case river reach (TIN bathymetry) under Q_{276} flow conditions.

The first model was carried out using the TIN method for calibration and validation purposes (Herrera-Granados, 2022). The calibration of the model was based on the comparison of the Water Surface Elevation (WSE) values with the previously registered. Once an acceptable error was achieved, the validation of the model was carried out on the same comparison, but running the model under Q_{14} flow conditions.

Table 1. Comparison of the computed results using different DBMs

A) DBM	B) Q_{276} depth error with measured values [%]	C) Q_{276} WSE difference [m]	D) Computed velocity Q_{276} [m s^{-1}]	E) Computed velocity Q_{14} [m s^{-1}]
TIN (Triangular Irregular Network)	0.66	0.023	0.222	0.898
NN (Natural Neighbor)	1.00	0.035	0.228	0.901
IDW (inverse distance weighted)	1.82	0.064	0.241	0.910

In Table 1, a summary of the results of the models is presented. Column B presents the relative error of the calculated depth value in the central part of the channel based on the registered values of the Odra River in three different cross sections. Columns D and E represent the average modelled velocity for Q_{276} and Q_{14} along the river centerline from the barrage upstream to the hydraulic gates downstream. It is possible to appreciate that regardless of the discrepancies in the results, the three DBMs present results that are close to the reality. Larger discrepancies derived from the output of the models with different DBMs are appreciated where the local geometry has a direct impact, such as in the case of groyne fields, where the accuracy of the survey impacts on the modelling results. Based on the briefly described analyses, the authors conclude that the most convenient method for this case study is the TIN method (Table 1). However, the appropriate DBM can vary depending on the specific flow conditions, needs and characteristic of the survey, as well as other parameters.

Acknowledgements

The data used for this contribution was obtained from the project "Research and Development Conception on the modernization of the canalized reach of the Odra River to a navigable waterway of class Va" under the sponsorship of the Szczecin and Swinoujscie Seaports Authority SA, the Azoty Group and Polsteam. This project was carried out by the Wrocław University of Science and Technology.

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Analysing Pressures and their impacts on water quality in a Mediterranean basin. The Case study of Lissos River, N. Greece

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ABSTRACT

While water is precious for life, it is also a finite and shared resource. As the population grows, the need for water escalates. Consequently, sustainable water management is urgent and should be aspired by policymakers, stakeholders, and scientists across Europe by starting to solve water-related problems on a local level. European Member States have reported that agricultural pollution is a major issue in 90% of River Basin Management Plans (RBMPs) while water abstraction for irrigation is also an important pressure on European water bodies. At the same time, point pollution sources as industrial activity, livestock, co-exist exerting organic load and priority substances to water bodies. This becomes more urgent in Mediterranean basins which are more vulnerable to water scarcity subjecting also to multiple pressures. The objective of the present study is to map the pressures in Lissos river basin (Thrace, North-Eastern Greece) detecting the point and non-point pollution sources along with its hydrological regime. The identification of pressures and their resulting impacts on water ecosystem services will contribute to the design of effective management measures taking into consideration also socio-economic factors. Field monitoring campaigns engaged with laboratory analyses and modeling tools were performed during the wet and dry hydrological periods. Preliminary results highlight the most affected areas based on the identified pollution sources as well as the impacts on water quality in relation to flow regime.

1. Introduction

Water is a renewable but limited resource, while the extensive anthropogenic activities induce further limitations in water availability. The notable population growth and its upscaling needs have led to the overexploitation of water resources and water quality degradation at an alarming point. As a result, one of the main objectives of the Water Framework Directive (WFD) is the identification of pollution sources to reduce their effects in aquatic systems and avert from further deterioration by establishing river basins as the basic integrated water management model. Riverine systems are recipients of multiple pressures, while agricultural activity is reported as the primary driving force of pollution, enriching water bodies with priority substances harmful to the environment and public health. At the same time, rivers are a source of economic development and welfare making integrated water management even more urgent.

Sustainable water management and the implementation of the objectives of the WFD are considered imperative in Mediterranean basins, while the numerous anthropogenetic stressors intensify their susceptibility. Likewise, Lissos river basin, located in Thrace, in North-Eastern Greece, is a Mediterranean river basin where the natural resources of the region are important drivers of social and economic development. However, the river is subject to multiple pressures such as industrial wastewater treatment plant outflows, organic loads and priority substances, as well as sand extractions, and flow intercepting constructions. Consequently, water quality degradation and the need of natural resources conservation are of great concern for the local community.

Therefore, a 2-year research was carried out to map the pressures along the river basin by identifying the point and diffuse pollution sources with field campaigns, determining the chemical status with lab analysis, and setting up models to simulate the river's flow regime coupled with different scenarios of pollutant loads. The main objective is to pinpoint the pollution sources that impair the river's water quality and predict the expansion of their impact along the river basin. Then, integrated water management can be accomplished, and drastic measures can be established to ensure long-term sustainable water use and prevent further degradation.

2. Applied Methodology

2.1. Field Campaigns and Lab Analysis

A sampling network of 12 stations was configured along the main channel of the river and its tributaries, in order to obtain a primary estimation of the water's quality and hydrodynamics condition. The sampling stations were selected by utilizing available data from previous studies, while the frequency was determined based on the seasonal fluctuation of the wet and dry hydrological period. During the field campaigns, in-situ physicochemical quality parameters such as Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Electrical Conductivity (EC), Salinity, Temperature, and pH were measured, as well as the hydraulic characteristics of the river, while a sufficient number of samples were collected, transported to the laboratory, and stored for further analysis.

Then, an integrated water analysis occurred by analyzing the water samples in a well-equipped laboratory to determine the concentration levels of common pollutants such as Biochemical Oxygen Demand (BOD_5), and Chemical Oxygen Demand (COD) based on standard methods for surface waters (Baird et al., 2017). Furthermore, an Ion Chromatograph (IC-6000, Dionex) was used to determine Ammonium-Nitrogen (NH_4-N) and Orthophosphates ($P\text{-}PO_4$) concentrations in the water.

2.2. Hydraulic Analysis

The final step entailed the simulation and hydraulic analysis of the river by setting up a 1-dimensional hydraulic model using the Hec-RAS software. Hec-RAS was utilized to comprehensively imprint the river's flow regime by performing an Unsteady Flow Analysis while it was calibrated by using discharges derived from in-situ measurements that occurred during the field campaigns. Thus, a water quality analysis was performed employing the estimated concentrations derived from the laboratory analysis as boundary conditions to study the river's response to concurrent pollution sources and depict their diffusion along the river channel.

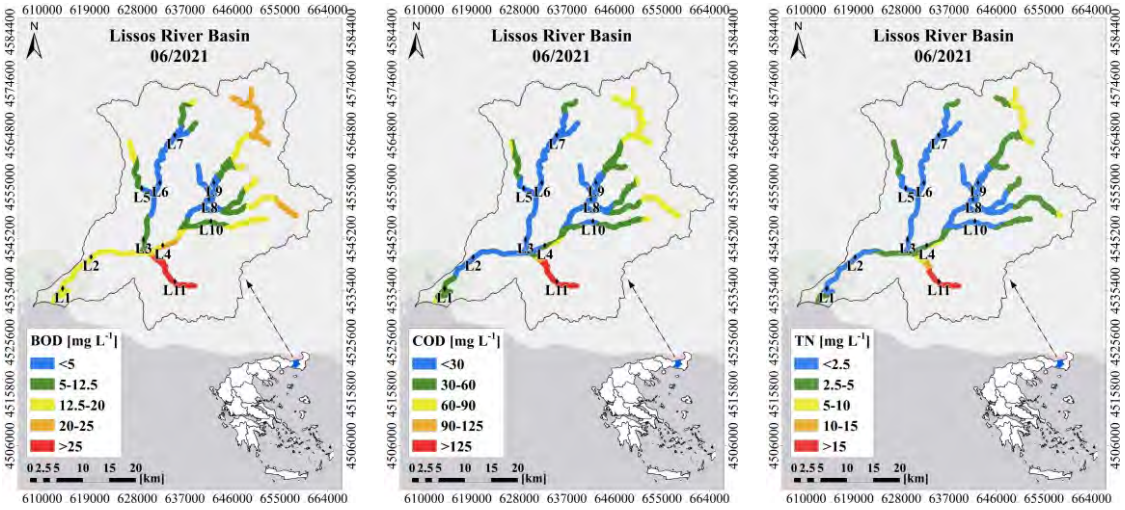

Fig. 1. Map distribution of BOD [mg L^{-1}], COD [mg L^{-1}], and TN [mg L^{-1}] concentrations along the Lissos river basin based on water analysis results. The L1-11 placemarks refer to the sample stations.

3. Results and Discussion

The study has contributed to the settlement of an integrated monitoring suite with respect to the EU legislation by providing a comprehensive overview of the Lissos river basin focusing on pressures, human activities & hydromorphological alterations. Field and lab analysis revealed the quality status of the river by highlighting the pressures with the most crucial impact, while the hydraulic analysis delineated the diffusion of pollutants along the riverine identifying the most vulnerable areas. Consequently, effective measures can be taken to mitigate the environmental footprint of the Primary and Industrial sector and encourage sustainable water management in order to ensure the conservation of water and natural resources.

Acknowledgments

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Development of a generalized criterion for selecting optimal MRF rotation zone for CFD simulation of stirred tank reactors

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ABSTRACT

Due to increasing industrial concern towards the development of computational models of stirred tank reactors, it is necessary to enhance the accuracy of the model predictions. The rotation of impeller in a reactor vessel is mainly simulated using the pseudo-steady Multiple Reference Frame (MRF) technique. Earlier studies have highlighted the importance of extents of rotating domain defined for the modelling process while definite idea regarding the selection of the same is not specified so far. The present study aims to develop a generalised criterion for selecting the optimal MRF extents for any configuration of the reactor. The radial and axial extents of MRF boundary were systematically varied in a baffled reactor vessel and the optimal extents of the same were determined from the predictions of underlying flow field characteristics. The balance between Power number (N_{pt}) computed from the torques of rotating and stationary walls which is based on the principle of conservation of angular momentum is determined as the generalised criterion for selecting the optimal extents of rotating domain.

Photo-monitoring of vegetation in Warszawicki channel – citizen science project results

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ABSTRACT

Vegetation is commonly found in rivers and channels, and its importance in aquatic environments has been the subject of numerous scientific studies (e.g. Rowiński et al., 2018, Kalinowska et al., 2023). The article presents the results of vegetation photo-monitoring in the Warszawicki channel located in central Poland, near the boundaries of the Całowanie Peatland, the largest peat bog in Mazovia and approximately 40 km southeast of Warsaw, in the Vistula River valley. Selected photos of the channel, taken by students from a primary school in Warszawice, show the situation from the winter conditions before vegetation started to grow until the channel maintenance cleaning in summer (Fig. 1).

Fig. 1. Selected photos from photo-monitoring of the Warszawicki channel. Photos show the situation from the winter conditions – before vegetation started to grow until the channel maintenance cleaning in summer. The monitoring was carried out as part of the BRITEC citizen science project (https://britec.igf.edu.pl/). Photos were taken by the pupils from primary school in Warszawice.

The photo-monitoring of the channel was carried out as one of the pilot activities of the BRITEC citizen science project (https://britec.igf.edu.pl/), which aimed to observe the seasonal changes of river vegetation by students from schools in different parts of Poland. The project main goal was to introduce citizen science into schools and increase students' understanding of complex natural environmental conditions. The involvement of students in practical activities using their senses is expected to improve their learning and understanding of science. The project results showed that citizen science is an effective way to monitor riverine and riparian vegetation, contributing to a better understanding of the environment and the processes that occur in and near river channels. The use of citizen science can promote the involvement of ordinary citizens in scientific research, enhancing their knowledge and awareness of environmental issues. The observations provided data for further scientific analysis, enabling monitoring changes in various types of rivers and channels. The

project's success demonstrates the potential of citizen science in engaging students in science and promoting environmental education.

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Enhanced signals of changes in soil moisture conditions in the first decades of the 21st century - Vistula catchment study

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ABSTRACT

In the last two decades, a significant deterioration of soil moisture conditions has been observed in Poland. Ongoing climatic changes result in shifts in the beginning and duration of thermal seasons as well as periods of occurrence and accumulation of snow cover. The aggregate adverse effects of these alternations are putting intense pressure on the natural environment. Soil moisture shortages in the first phases of the growing season are particularly severe. They limit the possibilities of carrying out agro-technical work and maintenance treatments such as fertilising or spraying, contributing to significant losses in agricultural cultivation.

A more detailed analysis of this phenomenon is needed, mainly looking at the long-term trends of soil moisture conditions on a seasonal basis, which remain unclear, especially for the early spring period. This study examines changes in soil moisture and evaporative stress conditions for the period 1980-2020. The analysis is based on daily data derived from the model-based estimates of soil moisture and evapotranspiration - Global Land Evaporation Amsterdam Model (GLEAM).

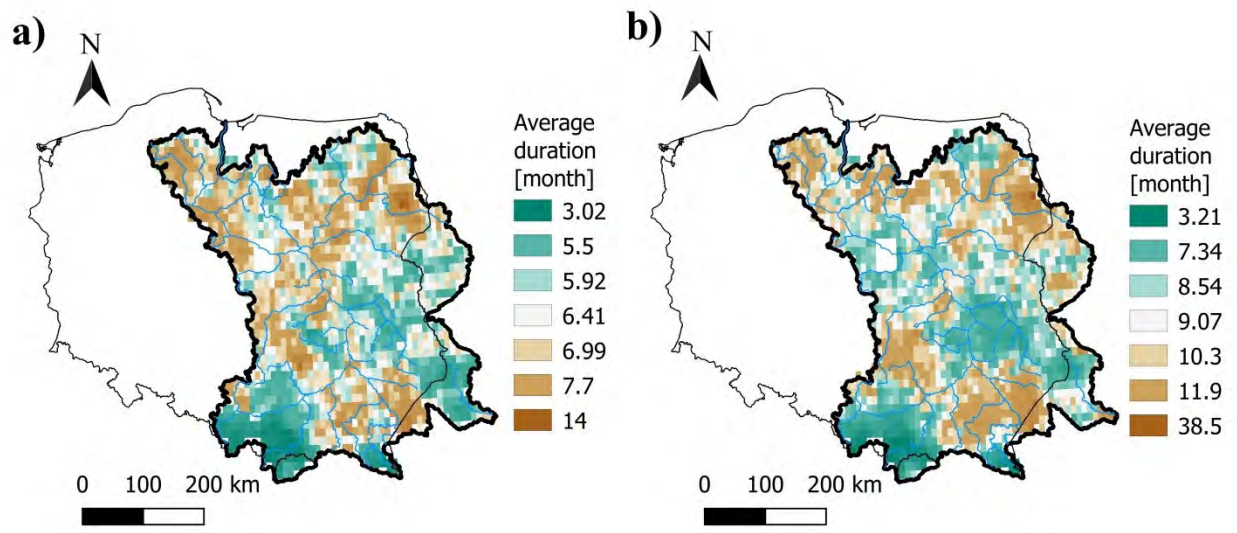

Fig. 1. The average duration of soil moisture deficit in Vistula catchment (1980-2020) based on a) Standardized Surface Soil Moisture Index; b) Standardized Root Zone Soil Moisture Index.

Acknowledgements

This work was supported by the project HUMDROUGHT, carried out in the Institute of Geophysics Polish Academy of Sciences and funded by National Science Centre (contract 2018/30/Q/ST10/00654).

Aerial images for assessing vegetation coverage in open channels

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ABSTRACT

With the increasing possibility of acquiring high-resolution remote sensing imagery, their use for monitoring and analysing the riverine environment is constantly growing. This new potential in characterising, quantifying and detecting changes in the riverscape (i.e., water, sediment and vegetation) is the impulse for a more precise investigation of open channels flow hydraulics at the local scale. Focusing on the Warszawicki Channel's (Fig. 1) agricultural ditch (Poland), we used UAV-based imagery to monitor riverine vegetation dynamics during the growing season. The study aimed to determine surficial vegetation coverage at different stages of growth for selected parts of the surveyed reach. We use DJI Phantom 4 drone instrumented with an RGB camera for image collection to fulfil our goal.

Based on acquired images, we generated orthophoto maps using Agisoft PhotoScan software, applying Structure-from-Motion (SfM) method. Then, we analyse obtained maps in the open-source Quantum Geographic Information System (QGIS) to quantify surficial vegetation coverage in the ditch.

Variation in vegetation coverage during the growing season is essential for local hydrodynamics, influencing flow conditions. Our results can be used in further analysis to study the influence of natural vegetation on flow hydraulics and to determine the empirical relationship between flow conditions and the degree of natural vegetation cover. The vegetation coverage can be treated as easily measurable physically based parameters that can be used to recognise better the influence of channel vegetation's presence at different growth stages on the flow and mixing processes. Our work highlights that remotely sensed information can provide new insights to flow hydraulics studies.

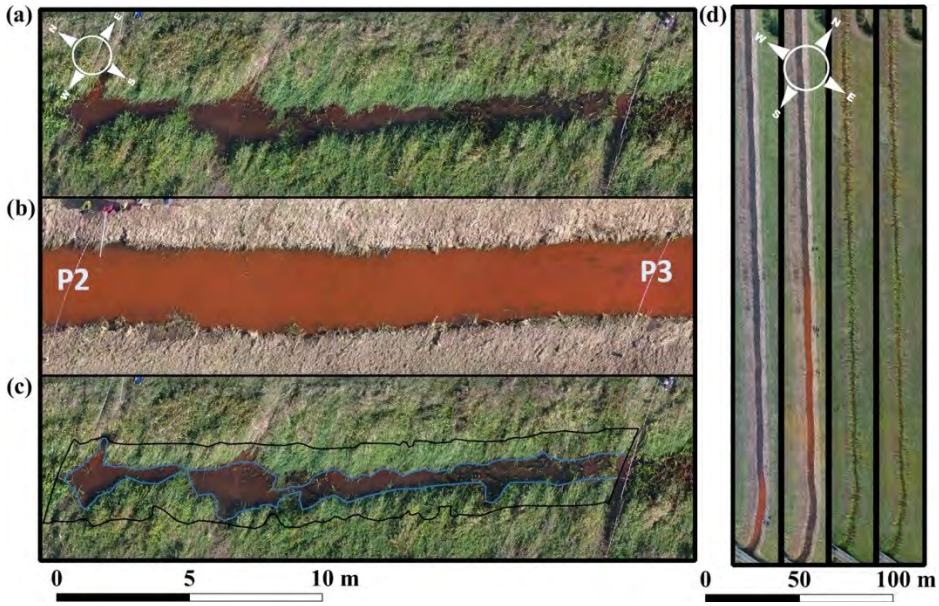

Fig. 1. Fig. 1. Orthophoto map of studied part of Warszawicki Channel. Example of (a) fully vegetated and (b) fully cut conditions in the channel. (c) Delineation of surface coverage of vegetation. (d) Example orthophotos of the entire studied reach taken during the field measurement campaign (tracer experiments with Rhodamine WT) (Reprinted from: Kalinowska et al. 2023)

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Comparison of near-body flow fields of a gudgeon and NACA0013 profile

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ABSTRACT

Hydrodynamic sensing using the lateral line system allows fish to detect, localize and classify minute flow field fluctuations filtered through the boundary layer. These near-body flow fields provide valuable information about the current state of the flow environment during a swimming gait cycle and at rest. Previously, fish-like sensors have been developed for ecological studies using a simplified NACA0013 axisymmetric streamlined profile, which is a considerable simplification compared to the geometry of fish. To investigate potential differences in the near-body flow field resulting from the differences in body geometry, a comparison of the flow fields around a NACA0013 profile and a digital model of a bot-tom-dwelling gudgeon (Gobio Gobio) fish (length=15 cm) was performed. The time-averaged velocity fields around a gudgeon body and NACA0013 profile were obtained numerically using the open-source tool OpenFOAM at 0.25 and 0.55 ms^{-1}. The results show that the streamwise velocity distribution in the lateral direction around the gudgeon body has minor deviations from those observed around the NACA profile. Specifically, near the surface of the fish-shaped body and NACA, a well-developed boundary layer was observed, with turbulent behavior in the posterior region near the tail fin. The results of this study indicate that the use of the NACA profile for boundary layer studies in ecologically relevant flows would be a suitable approximation of the Gudgeon.

Experimental measurement of ice load on a hydraulic structure

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ABSTRACT

This study is related to a laboratory measurement of ice load on a hydraulic structure. The formation of ice was simulated by polypropylene parcels, forming jam around a rectangular cylinder as the hydraulic structure. For capturing sufficient interlock between the parcels, two different sets of parcels were used for the simulation. This study was conducted in Hydraulic Laboratory of Gdansk University of Technology. A constant discharge was considered through the entire experimental period. For measuring the ice jam load, an electronical device with three load sensors was developed based on the aim of this study. The sensors were located on the cylinder, and at the water level to measure normal forces imposed by polypropylene parcels. The device was calibrated to interpret the load results based on the imposed weights on the device. By the jam formation of the ice parcels around the cylinder, the load results could be collected by the sensors. The ice parcels had to be in direct contact with the sensors for the loads to be recorded. The recorded values from the three sensors were averaged as the final loads. Simulated ice accretion around the structure, caused various jam thicknesses in front of the cylinder (with the maximum height of approximately 5 times as larger as the single thickness of the parcels). For the velocity measurement under the ice jam, different measurement points along the width of the channel were considered.

1. Introduction

One important aspect of the ice-structure interaction is to calculate the loads imposed on the structure (Ashton 1986). Polymer pallets like polypropylene can be a substitute of ice parcels in experimental studies, due to eliminate the need for refrigerated materials (Zufelt and Ettema 1996). It is possible to use cut polypropylene material as the ice parcel for simulating post break-up condition. This is an ice phenomenon usually following water level increase. In the case of existing ice cover, it can fragment ice cover into ice pieces (Shen and Wang 1995).

The study was performed to simulate static load on a structure by ice accumulation. Laboratory experiment will provide data for mathematical model calibration process. In this study, static loads imposed on a cuboid were experimentally measured. The loads were imposed by polypropylene parcels resembling ice parcels in a post break-up condition. The load imposed on the structures due to the ice jam are mainly related to the wind effect, see (Kolerski, et al., 2019; Kolerski, et al., 2021).

2. Experimental setup

The study was done in a channel in the Hydraulic Laboratory of Gdansk University of Technology. Polypropylene pallets were cut in rectangular shapes in the edge sizes of 60x60 and 40x40 mm, as well as the thickness of 10 mm. The channel width was 62 cm. The specific gravity of Polypropylene is close to that of ice (918 kg m^{-3}), making it a good substitute for ice. Water discharge of 37.8 l s^{-1} and the water level of 34.3 cm were considered as the upstream boundary condition. The reason for using these values for water level and discharge was to set the water level at the location on a set of sensors located on the cuboid. The cuboid was located inside the channel and the sensors would measure the loads imposed on the cuboid. The parcels were released to channel and transported by the water flow. The time dedicated to each experiment was 35 seconds.

3. Load measurement device

For the load measurement three conventional load sensors were installed on the cuboid at the edge vertical to the flow direction, to measure the normal loads imposed on the cuboid. It could simulate the loads imposed on a structure by the ice jam formation around an object. Other types of commercial sensors were examined, but they were excluded, due to not fulfilling experiments' expectations. Sensors had to be calibrated, before the experiments, by imposing known loads on the sensors. In Fig. 1, the location of the cuboid inside the channel with the formed jam around it, is presented.

Fig. 1. Location of the cuboid inside the channel with the jam formation.

4. Results

Several tests were conducted. The excluded ones were related to sensors being out of touch with the parcels. The parcel accumulation process showed, the accumulation was with its highest thickness around the cuboid and extended with less thicknesses at the longitudinal and to the upstream direction. The accumulation was first observed at the side edges of the cuboid, then extended to the front edge. The maximum thickness of the jam accumulation (0.6 m) was at the 0.5^{th} of the channel width from the front length of the cuboid.

The ultimate value as the normal load, was the average over the recorded values from the three sensors, divided by the length of the sensors at the transactional direction of the channel. fluctuations in the recorded values were observed, in the spatial direction. This could be due to noises from water pumping and reflection from the regulating hatch upstream of the channel. The measurements showed two stages of the ice jam around the pier. First stage took 15 s long. It was related to the cuboid being hit by the first parcel till beginning the jam formation. The next stage was attributed to equilibrium in jam formation around the cuboid, starting with increasing the jam thickness around the cuboid. The maximum load observed for the first and second stages were 4 and 6.5 N m^{-1}, respectively. Although, prior the jam formation 3.5 N m^{-1} load was observed on the cuboid. More fluctuations were observed during the first stage.

The calculation of the resistance coefficient underside the jam varied between 0.025 to 0.046, which was related to different height of the ridges under the jam, across the width of the channel.

5. Conclusions

The study was dedicated to ice jam formation loads on a cuboid. Based on the experimental results the loads were measured and values are important variables for numerical simulations. Two stages of the ice load on the cuboid were observed (with the maximum ice thickness of 0.6 [m]); first was related to cuboid being hit by the parcels (maximum load of 4 N m^{-1}) and second was the equilibrium in the jam formation (6.5 N m^{-1}).

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Fish movement analysis in diagonal brush fish pass: innovative approaches

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ABSTRACT

The fish behavior and flow structure of the diagonal brush fish pass was monitored and investigated simultaneously at the Incirli Small Hydropower Plant (SHP) which is in the Eastern Black Sea in Turkey. It has been shown that the reduced velocity and turbulence regions behind the brush blocks constitute important resting sites for fish and the macro-scale vortices with vertical axis formed in the stream environment can help fish in their upstream migrations Also, the passage efficiency of the brush fish pass assessed by using biotelemetry method. The main advantage of brush fish pass appears to be it provides passage for small-bodied fish (L<150 mm) in a high gradient bed slope of 10%. We propose a computer vision-based approach for fish movement analysis. The proposed approach detects fish and estimates the fish tail beat frequency automatically, while the fish trajectory is obtained manually. The framework is tested using visible-range videos captured by cameras installed in the lab environment and in the field. The fish presence heatmaps are generated for the laboratory recordings. The field measurements reveal that a wide spectrum of different flow characteristics is provided in diagonal brush fish pass. The cleverness of the fish is used to seek the convenient corridors and to avoid zones not suitable for their migration preferences.

1. Introduction

Hydraulic and kinetic measurements of fish locomotion are important tasks to understand the efficiency of the fish pass. Moreover, fish tail beat kinematics, especially Strouhal number, are important parameters and indicators of fish energy expenditure and swimming performance. Eloy (2012) calculated the optimum Strouhal number for 53 distinct fish species. Diverse techniques are used in previous works of image analysis based on fish movement analysis. Our contribution is to provide a computer vision-based framework for fish detection in visible-range videos installed in the fish passage. Moreover, the fish tail beat frequency is determined automatically using an average magnitude difference function (AMDF) based approach by analyzing the fish regions in image sequences (Yıldırım et al., 2018). We tested our methodology using both a physical model in the laboratory, as well as a prototype in the field.

2. Methodology

Detection of the fish in images is needed for generating a heatmap of fish movement patterns. We combine background subtraction with fish detection by exploiting spatial and temporal features of fish regions. We perform gamma correction in input frames as a preprocessing step. Adaptive background subtraction is performed using the variant of the Gaussian Mixture Model (GMM) and used as an extended foreground mask. Then, we perform feature extraction followed by supervised feature learning for fish detection. For this task, we benefit from deep Convolutional Neural Networks (CNN) for feature extraction. For fast classification of candidate regions, we used a variant of a randomized learning network called Extreme Learning Machines (Yıldırım et al., 2018). Measurement of fish movement is an important task for evaluating fish passage efficiency. Accordingly, we placed 2 video cameras (GoPro Hero 5) underwater the fish passage (Kucukali et al., 2019). We extracted positive sample regions from the underwater fishway videos and labeled fish trajectories in scale by using AutoCAD. In order to evaluate the performance of our system, in addition to actual fish regions which constitute positive samples, we generated 250x250 cropped background regions from the background fish passage objects as well as other underwater images that do not contain fish and form the set of negative samples (Yıldırım et al., 2018). Fish Strouhal number (Stf) is calculated from (Eloy, 2012):

$$St_f = \frac{w_f A_f}{V_{fish}} \quad (1)$$

where w_f is the tail beat frequency, A_f is the peak-to-peak amplitude at the tail tip, and V_{fish} is the average fish swimming speed.

3. Results and Discussion

Sample drawings from labeled fish trajectories in the fishway plan are shown in Fig. 1. We observed that fish use the back of the brush blocks which are characterized by reduced velocity and turbulent kinetic energy regions, as resting areas. Fish move through the brush blocks by following the main flow region which is beside the small brush block (Fig.1). Also, Fig. 1a reveals the importance of the bottom macro-roughness elements for Ponticola rizeensis to move through the structure. Moreover, Barbus tauricus selected a completely different trajectory (Fig.1b), which is beside the side wall that is characterized by high local velocity due to jet formation. In response to this local flow condition, the tail beat frequency of the fish increased by a factor of about 3 from 11 Hz to 30 Hz. This finding implies that local flow conditions may have important effects on individual fish movement and fish tail bait frequency (i.e. energy expenditure).

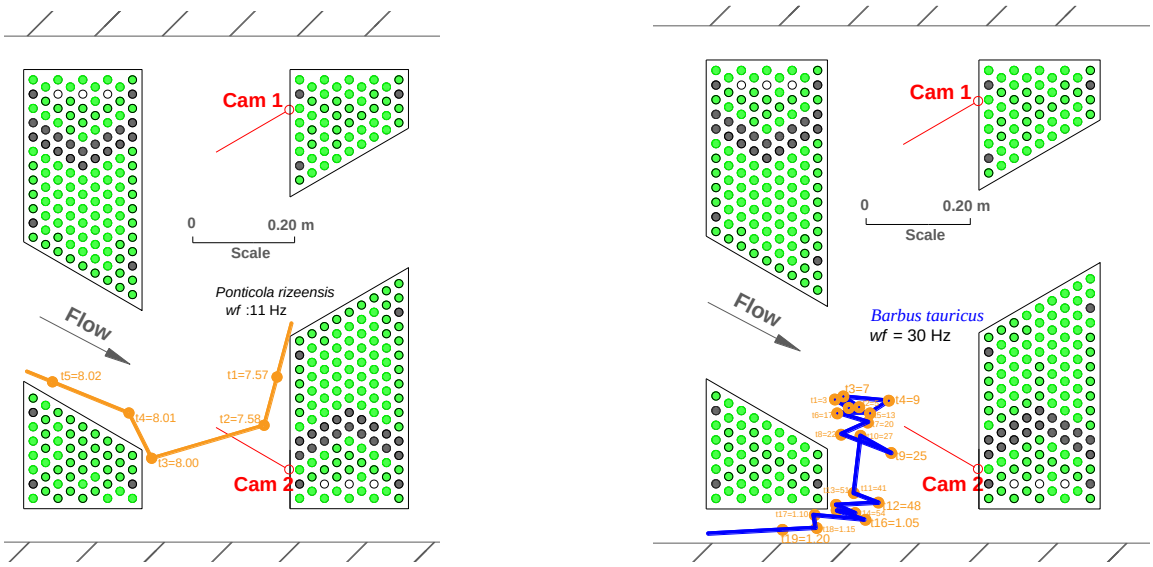

Fig. 1. Fish trajectories in the brush fish pass: (a) *Ponticola rizeensis* (L_f=70 mm), and (b) *Barbus tauricus* (L_f=190 mm). L_f denotes fish body length and w_f denotes fish tail beat frequency.

4. Conclusions

Fish energy expenditure and fish behavior are crucial to evaluate fish pass structures. For this purpose, we propose a computer vision-based approach for fish movement analysis. The proposed framework is tested both in the lab environment and in the field. Results indicate that such a solution would be useful for quantifying fish movement related to the flow field. This will pave the way for a deeper understanding of how fish process and use the flow information.

Acknowledgements

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Identifying hydraulic preferences of riverine fish, using fine-scale fish tracks and hydraulic data

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ABSTRACT

Rivers worldwide are becoming increasingly changed by human activities. Barriers, such as dams, are a frequent feature in rivers and have many impacts, from altering river hydraulics to impeding fish migration. Hydraulic conditions around a barrier and pass may be very different to natural systems and confuse approaching fish as they attempt to pass. Advancing technologies such as fine scale 2D acoustic telemetry and computational fluid dynamic models have led to a wealth of data on fish movement and corresponding hydraulics in rivers. Such data can be analysed to determine fish habitat preference - whether fish avoid or prefer certain environmental conditions. Two approaches for analysing habitat preference are resource selection functions and step selection functions. Both methods statistically analyse habitat usage patterns of animals. In this paper, we provide an overview of the approaches and a brief review of their limited applications so far in riverine environments. With increasing data accumulation on fine scale habitat usage of riverine fish, habitat preference analysis is a promising tool for identifying hydraulic preferences of migrating fish.

Aggregation in riverine fish: a review from a fish passage perspective

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ABSTRACT

According to the most recent Living Planet Report, freshwater fish species are among the most threatened species on Earth, with many of them showing a decline in population due to altered river connectivity caused by barriers. Fish passages are conservation measures aimed at mitigating the impact of such obstructions for migrating freshwater fish, providing corridors that should not harm, kill, stress, or excessively delay fish movement. Fish passage efficiency, however, is highly variable and often unknown, particularly for non-salmonids. Despite many species being gregarious, research aiming at assessing and improving passage efficiency has focused almost solely on behaviour and swimming performance of individual fish. Collective behaviour can, in fact, affect the way fish approach, enter, and pass a fishway. The mechanisms for which group behaviour affects fish movement in hydrodynamically complex environments, such as those occurring within fish passages, are multiple and not limited to: reduced energy expenditure, better navigation, reduced stress levels, increased exploratory behaviour, and change of predation dynamics. In this work, we review current research to illustrate how collective behaviour can be relevant for fish passage research. Our aim is to provide an overview of how collective behaviour might affect fish passage efficiency and how future research could improve fish passage design.

Keywords: freshwater fish, biodiversity conservation, artificial barriers, fish passage, collective behaviour

Laboratory study on sinking behaviour of microplastics in seawater with rheology modified by dispersed exopolymers

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ABSTRACT

Exopolymers (EPSs) secreted by algae and bacteria are common in all water environments. However, when secreted in excess, e.g. during algal blooms, they may seriously affect surrounding environment and related physical processes. This problem has been reported in some closed seas and coastal regions where high loads of EPSs temporarily modify bulk rheological properties of seawater by increasing its viscosity and inducing viscoelastic properties. This may have serious effects on local sedimentation of marine particles, including microplastics (MPs), i.e. plastic particles with the longest dimension between 0.001 and 5 mm, which poses a serious threat to marine ecosystem and human health. The aim of this study was to examine to what extent EPSs may modify sinking dynamics of variously-shaped MPs compared to their sinking behaviour in seawater. We used two types of polysaccharides – bacterial xanthan gum and algal kappa-carrageenan as surrogates for marine EPSs. We performed a series of lab-scale experiments using shadowgraph method and Particle Tracking Velocimetry to examine MPs sinking in artificial seawater and in seawater with EPSs. By combining sinking behaviour with rheological measurements, we identified various effects of EPS gel-like polymer network on MPs sinking including the decrease of sinking velocity, reorientation of MP particles and fluctuating instantaneous settling velocities induced by modified flow properties of seawater and viscoelasticity. These results suggest that excessive content of EPSs may significantly affect microscale physics of marine environment, with further implications to MPs fate and sedimentation processes.

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Satellite-based monitoring of drought at the watershed scale

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ABSTRACT

Drought is a complex and multivariate phenomenon influenced by diverse physical and biological processes, as this derives from the accumulative effects of climatological and hydrological variables over a certain period. Worldwide, droughts are becoming a very frequent phenomenon also in regions historically not affected by them, such as Poland. To tackle this phenomenon and investigate its drivers, multiple approaches are being developed, based both on in-situ data and satellite-based observations, also thanks to recent advancements in numerical modelling and spatio-temporal resolution of satellite data. Focusing on the Vistula River basin in Poland, the present research uses selected drought indexes to infer spatio-temporal changes of drought over the last few decades. The opportunity to use freely-available satellite information, processed with Google Earth Engine, allows for deriving trends at the watershed scale, providing spatially-distributed medium to long-term changes. The present analysis shows that, nowadays, drought is a major concern also for a country that used to be wetter in the past.

Cross-cut through Vistula Spit

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ABSTRACT

The artificial cross-cut through Vistula Spit was officially opened on 17th September 2022. Its design and construction had been preceded by extensive studies carried out by the IBW PAN research team. The investigations were related to wave phenomena, including deep-water wave climate and processes of wave transformation in the coastal zone and in the harbour dedicated to shielding of the cross-cut entrance from the Gulf of Gdańsk side. The influence of harbour breakwaters on the adjacent beach constituted a separate important problem. Theoretical modelling showed that the cross-cut location is most advantageous in terms of longshore sediment transport patterns and no serious negative coastal effects, like erosion should be expected in the cross-cut region. An artificial island is being formed in the Vistula Lagoon to store the sediments coming from the earthworks and – recently – dredging. Therefore, the modelling was also focused on impacts of the island on the Lagoon shores and its environment in general.

1. Introduction

Until September 2022, the Baltiysk Strait (also known as the Pilawa Strait) was the only connection between the Vistula Lagoon and the Baltic Sea (the Gulf of Gdańsk). The newly constructed artificial cross-cut (with a lock) through Vistula Spit ensures an independent access to the Polish part of the Lagoon. The project facilitates operation of the Polish harbours, especially Elbląg which gains perspectives for rapid development. In the phase of design, the idea of the cross-cut was checked thoroughly vs. hydrodynamic and lithodynamic impacts. Extensive theoretical modelling was carried out to predict – among others – the influence of the cross-cut breakwaters on the adjacent beaches of Vistula Spit. The modelling yielded the optimal layout of the breakwaters as well as the quantitative assessment of future coastal morphodynamics in the cross-cut vicinity (Szmytkiewicz et al., 2017). The activities related to the cross-cut construction, in the form of both earthworks and dredging, required a sustainable management of huge amounts of sediments. An artificial island is being built in the Vistula Lagoon to store these sediments. A part of the modelling effort was devoted to determine how this island will affect the Lagoon environment in the long run (Szmytkiewicz et al., 2018). The layout of the cross-cut through Vistula Spit, the waterway and the artificial island in the Lagoon is given in Fig.1.

2. Layout of the harbour breakwaters

The optimal layout of the harbour breakwaters was obtained within the modelling of wave processes in the harbour basin. These comprised mostly wave diffraction around breakwaters heads, wave reflections inside the harbour and interference of incident and reflected waves. Due to the wind fetch characteristics, resulting from the shape of the Baltic Sea coastline, the highest waves in the region of the cross-cut location are generated from the sector NNW-N, while the waves of the smallest heights can be expected from W and ENE. The most convenient navigable approach to the cross-cut, implied by the navigation routes from the nearby harbours of Gdańsk and Gdynia, is from the sector W-NW. The final shape of the harbour, with the entrance from WNW, is shown in Fig. 1.

3. Sediment transport and coastal morphodynamics in the cross-cut vicinity

The Vistula Spit length and width amount to about 90 km and 1-2 km, respectively. The Spit – in the geomorphological sense – stretches from the Baltiysk Strait (the Pilawa Strait) to the Vistula river mouth. The Polish-Russian border is situated about 25 km SW of the Baltiysk Strait, while the cross-cut is located about 24 km SW from the border. The sediment transport studies were carried out to find out both the local influence of the harbour breakwaters on coastal morphodynamics and to identify the possible transboundary impacts.

The Polish part of Vistula Spit is the longest segment of the shore in Poland which is not subject to any serious ("hard") coastal protection measures. The Spit natural shores are stable and there are very few locations at which local (non-intensive) erosion is sporadically observed. The numerical simulations of the longshore

sediment transport in the decadal scale yielded the conclusion that there are two opposite sediment fluxes converging near the cross-cut which means that the long-term net sediment transport is negligibly small there (3000 m^3/year). Consequently, according to the modelling results, the evolution of the shoreline position in the region cannot exceed several metres and the longshore range of the changes will be below 200 m.

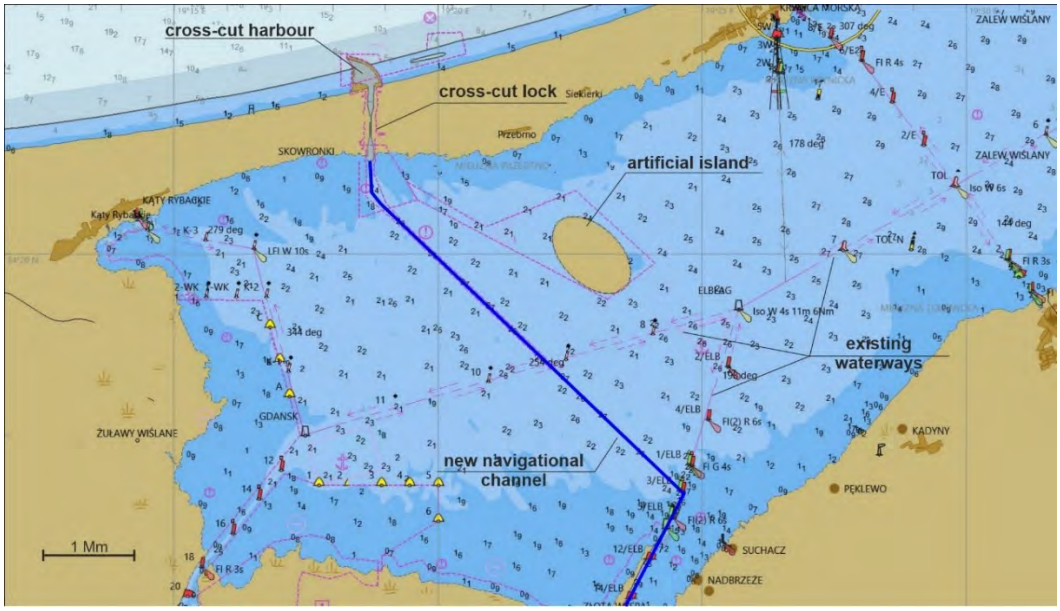

Fig. 1. Cross-cut through Vistula Spit between the Gulf of Gdańsk and the Vistula Lagoon, waterway and artificial island in the Lagoon.

4. Influence of the artificial island on the Vistula Spit shores at the Lagoon side

Each island-type object situated in the shoreline vicinity can affect coastal sediment transport processes. Here, the wave diffraction plays an important role. This phenomenon influences wave-current fields and distinctly modifies the sediment transport patterns. The presently constructed artificial island is an ellipse with the dimensions 1932 m x 1192 m and its distance from the shoreline equals about 1700 m. Such parameters could have suggested a significant influence of the island on nearshore lithodynamics. Detailed modelling revealed, however, that due to relatively mild hydrodynamic conditions occurring in the Vistula Lagoon the influence of the island on the shoreline will be negligibly small.

5. Artificial island as an environmental compensation of the project impact

The cross-cut through the Vistula Spit will cause some disturbances to the nature. Certainly, possibilities of migration of animals along the Spit can somehow be limited, although the system of two moveable bridges provides an uninterrupted passage via one of them all the time. Water characteristics in the Vistula Lagoon will not change (local turbidity can occur sporadically during maintenance dredging of the navigable channel). Birds are not expected to suffer considerably from the existence of the investment. The artificial island is, however, intended to create a biodiversity restoration area (Różyński and Szmytkiewicz, 2022) which will constitute an environmental compensation of the technical venture considered here. This aim will be achieved by the managed vegetation on the island and provision of the habitat for targeted birds, especially ground-nesting birds. In particular, the grassland on the island surface will be kept to discourage cormorants (overabundant in the area) and encourage desired birds: ducks and nesting species – very important for local ecosystem. The latter issues lie beyond the IBW PAN expertise and are dealt with in close cooperation with the competent partner institutions.

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Monthly changes in physicochemical parameters of the groundwater in Nida valley, Poland (case study)

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ABSTRACT

The groundwater of the Nida valley was investigated to assess the quality of water source and monthly variations of the physicochemical parameters. Groundwater samples were collected from 7 locations from June 2021 to May 2022. Parameters such as temperature, Electric Conductivity (EC), Dissolved Oxygen (DO), pH, Total Dissolved Solids (TDS) were measured in-situ by using handheld device. Meanwhile, Total Nitrogen (TN), Total Phosphorus (TP), chloride (Cl^-), sulfate (SO_4^{2-}), manganese (Mn), iron (Fe), zinc (Zn), cadmium (Cd), lead (Pb), copper (Cu), Chemical Oxygen Demand (COD) were analyzed in the laboratory. According to the classification of Ministry of Marine Economy and Inland Navigation in Poland (MMEIN) 2019, some investigated parameters are classified as unsatisfactory quality waters (class 4) and poor-quality waters (class 5) for a few specific months. Statistical methods were used as: Shapiro-Wilk test ($\alpha = 0.05$), ANOVA test and Post-hoc Tukey test ($\alpha = 0.05$), Kruskal-Wallis test and Wilcoxon (Mann Whitney) rank sum test ($\alpha = 0.05$) estimated the significant differences in sampling months. Pearson correlation analysis ($\alpha = 0.01$ and 0.05), Principal Component Analysis (PCA) showed correlation between the parameters and sampling months.

1. Introduction

The Nida valley lies in the middle run of the Nida river in Poland. This valley is a lowland and mainly natural area of Nadnidziański landscape park (Strużyński et al., 2015). Over time, the flow of the Nida has been changed many times for the purpose of regulating flow and reducing flooding in this valley, leading to a change in the ecological function of some areas (Łajczak, 2004). We hypothesize that, the groundwater in this area varies from month to month depending on natural factors such as air temperature, precipitation, and groundwater flow in this area. Hence, the current study was performed to clarify this hypothesis.

Objectives:

- Assessment of groundwater quality through comparison with regulations of MMEIN 2019 (Ministry of Marine Economy and Inland Navigation).

- Assessment of changes in physicochemical properties of regional groundwater.

- Evaluation of relationship between physicochemical parameters of groundwater.

- Evaluation of relationship between sampling months through physicochemical parameters

2. Matreials and methods

The study area stretches from the Nida river to the Smuga branch located between the boundaries of the Pińczów and Kije communes in the Pińczów district. A total of 84 water samples were collected at 7 sampling sites during 12 months period from June 2021 to May 2022. Sampling frequency was once per month.

Physical parameters such as temperature, dissolved oxygen (DO), electric conductivity (EC), pH, total dissolved solids (TDS) were measured in-situ during sample collection by handheld device. Besides, chemical parameters such as total nitrogen (TN), total phosphorus (TP), chloride (Cl^-), sulfate (SO_4^{2-}), manganese (Mn), iron (Fe), zinc (Zn), cadmium (Cd), lead (Pb), copper (Cu) and chemical oxygen demand (COD) were measured in the laboratory according to the standard methods recommended by American Public Health Association (APHA, 1998) and Environmental Protection Agency (EPA, 1983).

Statistical methods were used as: Shapiro-Wilk test ($\alpha = 0.05$), ANOVA test and Post-hoc Tukey test, Kruskal-Wallis test and Wilcoxon (Mann Whitney) test ($\alpha = 0.05$) to assess the changes in physicochemical properties of regional groundwater. Pearson correlation analysis ($\alpha = 0.01$ and 0.05) evaluate the relationship between

physicochemical parameters of groundwater. Principal component analysis (PCA) evaluates relationship between sampling months through physicochemical parameters. These analyses were performed in the R program.

3. Results and Conclusions

In general, the quality of groundwater in the study area is good or satisfactory. Most of the parameters are classified into classes 1, 2 and 3. Except for a few specific parameters in a few months are classified into classes 4 and 5 as unsatisfactory and poor quality waters. TP values obtained in June and January are classified as class 4. High sulfate concentrations are mainly in June, July and August. These months are sorted in class 4 and 5. Except for January, all other months showed very high Mn values. These Mn values are classified in class 5. The highest Fe value in November is classified in class 5 and in June, July, August, September and March are arranged in class 4. High value Cd was found in June and these values are classified in class 5.

Shapiro-Wilk test ($\alpha = 0.05$), Kruskal-Wallis test and Wilcoxon (Mann Whitney) rank sum test ($\alpha = 0.05$), ANOVA test and Post-hoc Tukey test ($\alpha = 0.05$) were used and showed the significant difference between months for temperature, DO, pH, TN, TP, Cl^-, SO_4^{2-}, Zn, Cd and COD. Pearson correlation coefficient analysis ($\alpha = 0.01$ and 0.05) was performed in order to examine possible relationship between the physicochemical parameters. A very strong correlation was found between TN and Cl^-, Mn and temperature, Mn and DO, Fe and pH, temperature and DO in this study. The results of the principal component analysis (PCA) are presented in Fig.1 by using Biplots. The associations of parameters and months was found and described a strong dissimilarity between January and November, June and September, January and December and strong similarity between June, July and August. The obtained results are consistent and reliable. They can be used as reference data for groundwater studies in the Nida valley.

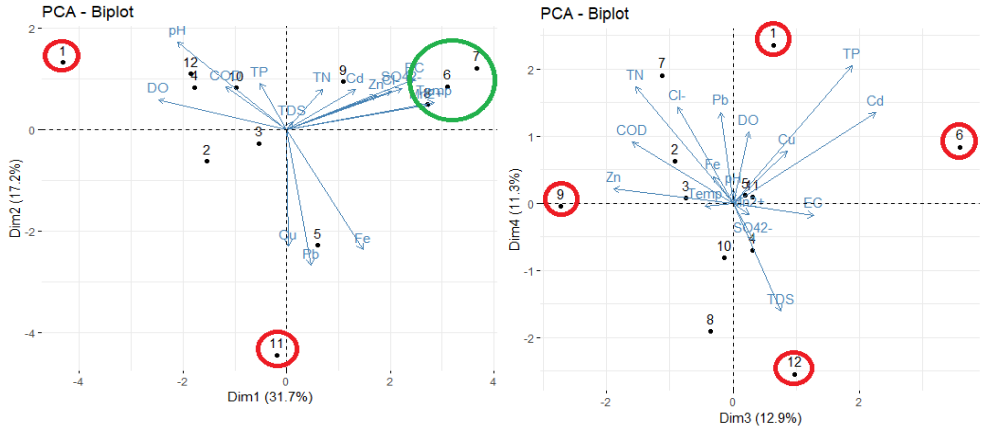

Fig. 1. Biplot – resulting from the principal component analysis

Explanation: 1. Jan, 2. Feb, 3. Mar, 4. Apr, 5. May, 6. Jun, 7. Jul, 8. Aug, 9. Sep, 10. Oct, 11. Nov, 12. Dec

Red and green circles indicate strong dissimilarity and strong similarity respectively.

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Analysis of macroplastic transport in a river regulated by groynes

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ABSTRACT

The transport of buoyant macroplastic litter in the presence of concrete groynes and vegetation in a straight channel was investigated. Four variants of channel configuration were tested during laboratory measurements. Water velocity fields were measured using ADV current meter, while floating plastic particles' paths were registered using PTV (Particle Tracking Velocimetry) technique. Preliminary research using numerical model Delft3D was carried out to reproduce the observed physical phenomena.

1. Introduction

Nowadays, most rivers are polluted by both smaller and bigger plastic waste. One of those, macroplastic, usually floats on the surface. There are few studies on small-scale transport of macroplastic litter, where, for example, hydraulic structures and vegetation can play a role (Cesarini and Scalici, 2022; Tominaga et al., 2018). Such knowledge and elaboration on that research can be useful for plastic pollution management. This study aims to search for potential places of macroplastic accumulations in rivers regulated by groynes, by analysis of hydrodynamics effect on particles movements in a high temporal resolution, as recommended by Grosfeld (2022). For this purpose, we carried out laboratory experiments and applied numerical modelling for comparison of the velocity field.

2. Methods

The flow field in the regular open channel (length 60 m; width 5 m, slopes 1:2) with a system of 5 pairs of groynes (length 1.2 m, height 0.4 m, width 0.5 m at the bottom and 0.1 m at the top) was measured using ADV current meter in the hydraulic laboratory of the Institute of Hydro-Engineering of Polish Academy of Sciences. Four channel variants were tested: 1 – a system with regular groynes; 2 – vegetation in a single groyne field; 3 – extended one groyne; 4 – a combination of extended groyne and vegetation in the groyne field. Macroplastic elements were in form of polypropylene square plates (few centimeters long sides, material density of 900 kg m^{-3}), which in general represent solid, floating plastic litter, like from broken household objects. Three different discharges (Q = 0.100, 0.175, 0.250 m^3s^{-1}) were tested for each case with measurements taken during the uniform flow conditions.

2.1. PTV analysis

The PTV (Particle Tracking Velocimetry), developed in the recent decades, has contributed to more advanced measurement method of fluid flow (Jolly et al., 2021). The PTV algorithm helps to describe flow in a Lagrangian approach. Records from a camera fixed above the laboratory channel were used by the PTV software to pinpoint the floating plastic plates and draw their trajectories.

2.2. Modelling in Delft3D

Some tests were conducted to reproduce flow fields in the laboratory conditions using the Delft3D (Deltares, 2015) model. In the first approach, the regular grid 0.03 x 0.03 m was applied in horizontal plane, while in vertical plane, the depth-averaged approach (2D model) was proposed. In these calculations, horizontal eddy

viscosity was set as uniform (0.005 m^2s^{-1}) and slip conditions at the walls were applied. In addition, groynes were applied as emerged structures. Several tests using different bottom friction conditions (Manning n=0.01, Chézy C=10 $m^{0.5}$ s^{-1}) were carried out.

3. Results

Laboratory experiments have shown differences in flow patterns and transport of plastic litter based on the channel variant. In case of groynes of equal length and spacing, plastic particles inflowed occasionally to the recirculation zones of the groyne fields and stayed there for some time. The extension of a single groyne modified the flow leading to its distortion, which resulted in changing the intensity of plastic particles inflowing to groyne fields. From the experiments, it is clear that vegetation in the groyne field reduced flow velocity (Fig 1). The numerical model reproduced flow pattern but not the velocity magnitudes.

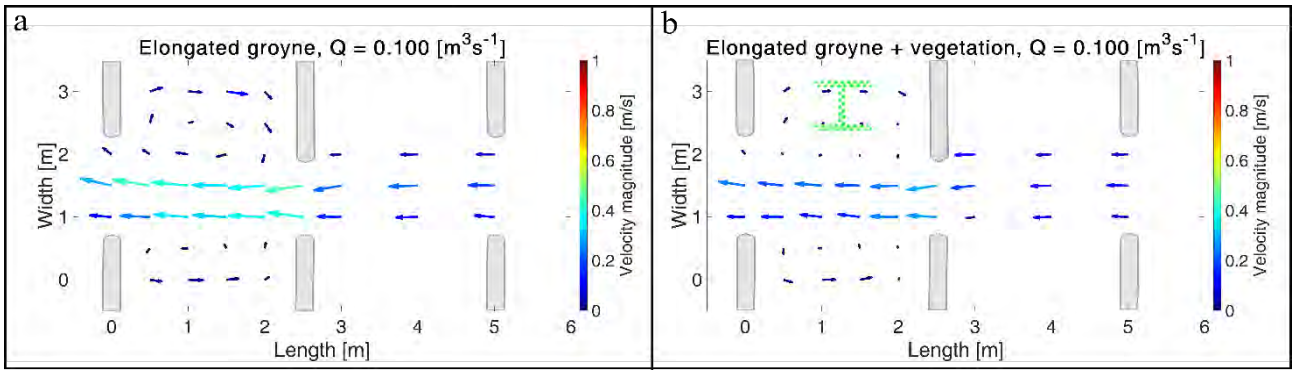

Fig. 1. Flow field measured by ADV in the channel with extended groyne (a) and vegetation patch (b) for discharge Q = 0.100 $m^3 s^{-1}$.

The application of PTV technique allowed to trace positions of single particles and, in the next step, to determine their velocities (Fig. 2.).

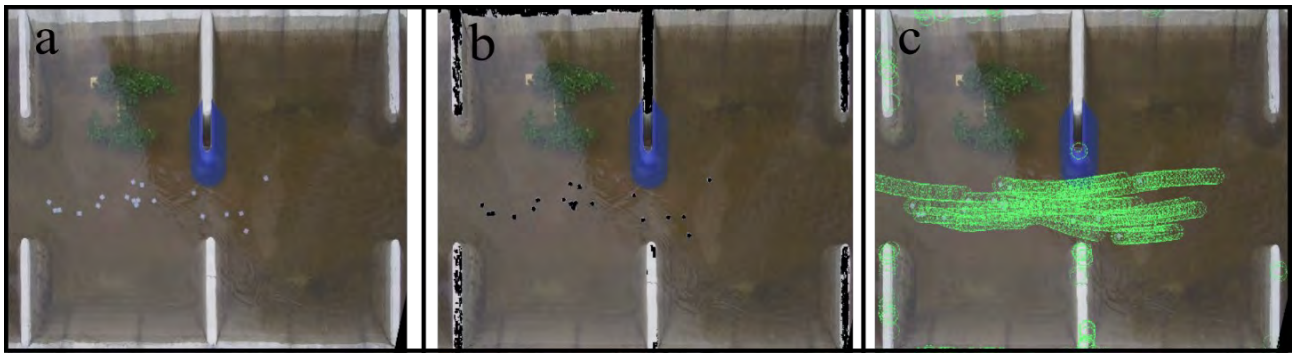

Fig. 2. Macroplastic particles registered by camera (a); particles colour detection by PTV software (b); traced particles (c); Q = 0.100 [$m^3 s^{-1}$].

In conclusion, numerical simulations using 2D set-up are not sufficiently comparable with the measured values and they require further analysis. This may be due to the fact that flow pattern in case of 2D approach represent depth averaged values instead of flow conditions in the surface layer. The PTV technique allowed to accurately follow the plastic particles behavior.

Acknowledgements

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Evaluating Management Practices to reduce sediment yield in the Fincha Watershed, Ethiopia

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ABSTRACT

Ethiopia is experiencing severe environmental issues such as land degradation, which significantly lowers the country's productivity, with consequent poverty and food insecurity. Based on a predicted land use land cover map for the future decade, the study used the well-known Soil & Water Assessment Tool (SWAT) to evaluate the rate of soil erosion and identify hotspots characterized by a high risk of soil loss, to eventually apply different management practices. Four Best Management Practices (BMPs), namely Contour, Filter strip, Soil/Stone bund, and Terracing were modelled, and their effects were investigated by comparison with a baseline scenario. The mean annual sediment yield expected in 2030 across the Fincha watershed was 46.20 tons per hectare. After applying Contour, Filter Strip, Soil/Stone Bund, and Terracing, the annual sediment yield is expected to reach 11.78, 18.6, 12.90, and 11.17 tons per hectare, respectively, meaning that these BMPs have an efficacy of 74.50%, 59.75%, 72.09%, and 75.82%, respectively. With Terracing being the most and Filter strips the less effective BMP, the simulations proved that BMPs can help in reducing soil loss at the watershed scale.

Navigation analysis at the entrance to the bypass channel of Siarzewo barrage

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ABSTRACT

Naviation safety is the most important issue on any waterway. Plans to use the lower Vistula as an inland waterway come from 60'ies of the 20th century. As the first stage of regulation works Włocławek barrage, located at km 674.850, was constructed in the years 1962-1970. At present, further regulation by constructing the second barrage in Siarzewo (km 706.380), is under consideration by the State Water Holding Polish Waters. The on-going analysis covers all elements of barrage composition, including weirs, hydro-power station, fish passes, a bypass channel and a twin lock. Design of proposed barrage assumes a lock to be situated on the right riverbank. The proposed distance between the entrances to the upper lock and the bypass is relatively small, not exceeding 50 m. This fact raises navigation concerns due to possible interaction between river flow along the navigation channel and inflow to the bypass. In-situ observations of navigation channels show negative influence of a crossflow on ship trajectory, leading to reduced navigation safety. Analysis of hydrodynamic conditions at the entrance to the bypass channel at Siarzewo barrage, and their influence on vessel maneuverability are presented.

Numerical approaches to evaluate the hydraulics of Vertical Slot Fishways: A comparative study of 2D and 3D simulations

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ABSTRACT

Natural flows in rivers have been strongly impacted by anthropogenic development and water use. Many barriers have been placed in stream corridors, affecting two thirds of rivers world-wide. Fishways have been widely used as a solution to restore river connectivity, with Vertical Slot Fishways (VSF) as the most common type. However, desired passage efficiency is difficult to achieve. A numerical study was conducted to analyze the properties of the flow for two different VSF geometries using computational fluid dynamics. OpenFOAM and TELEMAC-2D were used to perform 3D and 2D depth-averaged flow simulations, respectively. Due to high computational requirements, the 3D simulations were limited to two different cell sizes and no wall roughness, whereas nine different cell sizes and four values of the friction coefficient were tested in the 2D simulations. In all cases, the simulations were found to satisfy the validation criteria. For the steepest VSF, 3D simulations better represented turbulent kinetic energy in the jet zones, while 2D simulations tended to overestimate it. Small variations in the roughness coefficients did not significantly affect the simulation results. Higher 2D grid resolutions improved flow velocity predictions in both cases, but predictions of turbulence did not improve for the steepest VSF. Overall, the 2D simulations had a much lower computational time and still represented the hydraulics of both structures well.

Key words: CFD, Shallow Water Model, Vertical Slot Fishway, VSF, OpenFOAM,Telemac2d

River runs dry: Movement patterns of Telestes muticellus (Cypriniformes: Leuciscidae) in an intermittent river stretch

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ABSTRACT

Intermittent flow is a natural phenomenon in many stream systems worldwide. At the same time, droughts are an increasing threat to ecosystems as a consequence of climate change and water diversion. Severe droughts can change once suitable habitats into ecological traps that cannot support fish communities. Although individual fish movements can allow populations affected by drought to persist, the knowledge about individual fish movement between intermittent and perennial stretches remains limited. Here we present Italian riffle dace (Telestes muticellus) movement patterns (n = 17) in an intermittent and a neighbouring perennial stream stretch before and after a severe summer drought. Fish initially resident in the intermittent section had similar summer survival as fish from the perennial section. The majority of fish from the intermittent river stretch survived the drought by upstream movements to perennially watered reaches (87.5%). Fish from the intermittent stretch showed an average upstream movement of about 100 m, whereas fish from the perennial stretch remained relatively stationary within the stream. Our result highlights the ability of Italian riffle dace to cope with drought by a directed migration to river reaches with the perennial flow. It also underscores the need to preserve longitudinal river connectivity in the face of increasing water scarcity and associated intermittent flows.

Stress evaluation using physiological biomarkers on fish tested in the hydraulic facility

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ABSTRACT

Understanding fish's swimming ability is crucial to assess their fitness and survival, impacting behaviors, including breeding, interactions between predators and prey, dispersal, and habitat choice. Fatigue curves are commonly used to describe swimming performance, neglecting physiological markers of stress level. This study aims to investigate the use of physiological data to deepen our comprehension of fish swimming performance. Experiments were conducted using a portable flume system in which fish were exposed to two different mean flow velocities (35 and 45 cm s^{-1}) until fish stopped swimming or at lower velocities to a maximum exposure time of 1800 sec. Levels of cortisol, the major stress hormone in fish, and the oxidative damage of lipids and proteins were measured in the muscle tissue of the experimental animals. Fish showed tendential lower stress levels (oxidative stress and cortisol responses) at higher water velocities than lower ones. One biochemical parameter increasingly associated with the metabolic activity is lactate, produced when glucose is consumed under anaerobiosis. In the experiments, lactate levels did not differ between low and high velocities, suggesting that there was no significant difference in the level of physical activity between the fish exposed to low and high water velocities in the flume system. Our article highlights the challenges of studying fish in the wild due to individual variability but emphasizes the importance of a more comprehensive understanding of fish behavior and physiology in natural environments. Studying fish in the wild is necessary for developing effective management strategies to promote their health and sustainability.

Reach unified channel characteristics for the transverse advection-dispersion equation

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ABSTRACT

Transverse dispersion is of interest in natural watercourses, especially near outfalls. The application of simple analytical solutions to the transverse advection-dispersion equation in these scenarios, however, is challenging due to variations in channel characteristics. Thus, a new method has been developed for averaging reach characteristics to account for longitudinal variability when using analytical solutions to the advection-dispersion equation by combining travel time and length weighting. The new 'reach unification' approach incorporates the characteristics (such as velocity, width, or dispersion coefficient) of each different sub-reach into to the equivalent single reach values needed to make a direct downstream prediction. To demonstrate reach unification, synthetic concentration profiles from a continuous injection into a simplified rectangular channel with three sub-reaches of varying velocity, depth, and friction, have been generated using finite difference modelling. The characteristics of these sub-reaches when combined with reach unification made perfect downstream analytical predictions, confirming the approach. The use of the streamtube model to represent changes in channel width is investigated. It is also shown that reach unification is of significant benefit to the inverse problem, analysing recorded concentration profiles to estimate the dispersion coefficient and relating it to reach characteristics.

Performance analysis of a pump-as-turbine under cavitating conditions

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ABSTRACT

Market liberalization in the power sector has led to the emergence of micro-hydropower schemes that are dependent on the use of a pump-as-turbine in applications that were not suitable as potential hydropower sites in earlier years. As a result, there has been an accelerated adoption of pump-as-turbine technology due to the economic advantages it presents in comparison to the conventional turbines in the micro-hydropower space. The performance of this machines under cavitation conditions, however, is not well understood as there is a deficiency of knowledge in literature focused on their turbine mode of operation. In hydraulic machines, cavitation is a common occurrence which needs to be understood to safeguard them and prolong their operation life. The overall purpose of this study is to investigate the effects of cavitation on the performance of a pump-as-turbine system over its entire operating range. At various operating speeds, the cavitating region is identified experimentally while monitoring the effects this has on the power produced by the machine. Results indicate that the occurrence of cavitation coincides with zero power output from the machine implying that cavitation free operation also ensures that the machine serves its purpose without the need of drawing more power from the grid.

Revitalization of a river valley based on the results of two-dimensional modelling

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ABSTRACT

The Inland Delta of the Nida River is a fragment of the valley extending from 2-3 km to about 6 km, created in a tectonic sinkhole, limited to the south by the Pińczów hill. Currently, the river has three arms here: the Umianowicka Stream - the former riverbed flowing near the village of Umianowice, Stara Nida - the riverbed that was active until recently, and the main riverbed. The Inland Delta of the Nida River belongs to the Natura 2000 habitat site Ostoja Nidziańska (PLH260003). The vegetation cover of the area is semi-natural, and its existence determines the method of agricultural and pastoral management established for centuries. Meadow and peat bog communities as well as riparian forests are also well developed and preserved. The flat and wide bottom of the Nida valley is covered with meadows and rushes. Increasing the biodiversity of this area depends to a large extent on the improvement of water conditions. This research material is part of the need to ensure a constant supply of water to the delta region which can be done by water supply to the area of the river delta and the Nida oxbow lakes, water distribution in the delta area and ensuring adequate water levels in the breeding area of amphibians, reptiles and birds. In the delta area, a number of computer simulations were carried out to propose an optimal water distribution system in the area in question. Conditions will also be created that are conducive to settling the activated oxbow lakes by fish (Strużyński et al. 2012, Wyrębek 2013). The work is carried out as part of the Life project (LIFE17 NAT/PL/000018).

1. Optimization of the water distribution on the inland delta

In the area of the inland delta there are many oxbow lakes of Nida, which are currently undergoing revitalization works. In order to determine the demand for water in the revitalized area, a number of field measurements and analyses of archival data were carried out. A cross-section through the Nida valley made in the study area shows the high permeability of the sandy substrate sealed only with a thin organic layer. An interesting feature of this area is the middle bed of the Nida oxbow lake (Stara Nida), which flows in the highest part of the valley. In the past, it was a source of water spilling and seeping into many depressions in the area created after the Nida riverbed move. Starting from February 1, 2023. water is flowing in it again. In this way, the area of wetlands that had been lost for many years was been restored.

1.1. Numerical modelling

Numerical modelling was performed based on the HEC-RAS 2D program (HEC-RAS 2D manual 2023) on a terrain model with a resolution of 1m. As a result of performing several variants of the simulation, a scenario of field work was prepared. The division of the amount of water flowing in the revitalized riverbeds of the Stara Nida and Smuga Umianowicka as well as the ordinates of the water table in the profiles of both watercourses were determined. The optimal place for water supply from Stara Nida (Fig. 1a, left-upper corner) to the "delta" region and the height of water back-up on the gate located on the Smuga Umianowicka (Fig. 1a, the watercourse flowing from the right) were determined. The results of the simulation made it possible to determine the range of stagnant waters and to carry out field work consisting in cleaning the periodically dried and overgrown old channels of the Nida River (Fig. 1b).

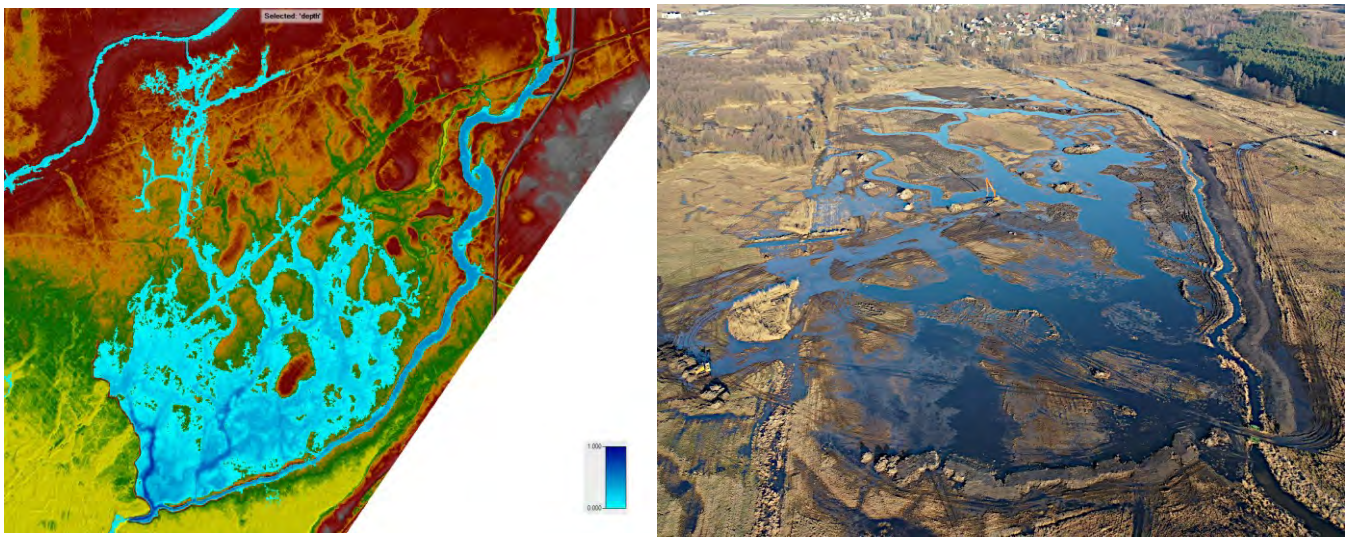

Fig. 1. Inundation area in the land localized between Stara Nida and Smuga Umianowicka streams.
The presented are: a) on the left, the modeling results, b) on the right, the state during revitalization works (from January 2, 2023)

In the spring of 2023, revitalization works are planned to be completed and measurements to be made again. It is also planned to create further numerical models illustrating the distribution of water in the revitalized area. This model will make it possible to analyse the depth and flow velocity of water in the area of middle delta and to achieve hydraulic parameters in the activated river arms that slow down the process of their overgrowing and at the same time favor the occurrence of fish and other aquatic creatures.

Acknowledgements

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Assessment of models' performance in determining flood hazard from ice jams

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ABSTRACT

Ice phenomena, especially ice jams, remain an important object of interest in Polish water management. They regularly appear on the Oder and the Vistula Rivers causing occasionally a significant increase in flood hazard and difficulties for inland navigation. In our study we tested the feasibility of modelling ice jams and determining flood hazard using HEC-RAS and Mike21FM, models often applied in water management. In addition, similar tests were conducted using DynaRICE, a model dedicated to simulations of the dynamics of ice phenomena formation and transport. The results showed the feasibility of modelling ice jams with the numerical tools tested however, some limitations in the ice configuration were observed.

1. Introduction

Ice phenomena, especially ice jams, remain an important object of interest in Polish water management. They regularly appear on Poland's rivers, including the major watercourses the Oder River and the Vistula River (Kolerski, 2019; Pawłowski, 2017). Subsequently, ice events may cause an increase in flood hazard and difficulties for inland navigation. The leading country where ice phenomenon modelling tools are being developed very strongly, and where many analyses of forfeiture studies are being performed, is Canada (e.g., Beltaos and Burell, 2015; Lindenschmidt, 2010). In Poland, as well as other European countries affected by ice phenomena, flood hazard from ice jams is still rarely analysed (e.g. Aaltonen and Huokuna, 2017; Kolerski, 2019). The reason for this is the lack of detailed data, the difficulty in modelling ice phenomena, and the lack of uniform guidelines on modelling procedures and tools. Thus, in our study we tested the feasibility of modelling ice jams and determining flood hazard using HEC-RAS and Mike21FM, models often applied in water management (e.g. Beltaos et al., 2012). In addition, tests were conducted using DynaRICE, a model dedicated to modelling the dynamics of ice phenomena formation and transport (Kolerski, 2019).

2. Materials and methods

The analyses were conducted on a study section of the Oder River, the longest trans boundary river in Poland (Fig. 1). The study section was located near the water gauges Bielinek and Widuchowa, and was selected based on historical observations of ice events and the availability of detailed information on ice phenomenon. The river reach for the 1D modelling (HEC-RAS tests) had a length of 38 km, while tests in the 2D models (Mike21 FM, DynaRICE) were performed on a section of length 17 km (Fig. 1). The geometry of the models was built based on Digital Elevation Model of the floodplains (grid files with the cell size 1 m), and cross sections of the riverbed, measured in 2012 (Fig. 1). Hydrological data needed to calibration and computations of the flood scenario were obtained from the Bielinek and Widuchowa water gauge stations. The tests of the models HEC-RAS 6.0., Mike21 FM (version from 2012) and DynaRICE included: (1) calibration for open water conditions (calibration for flood event 2010), (2) computation of historical ice jam event (event from 2014), and (3) modelling the flood scenario from ice jams and ice cover (modelling water state for ice jams and ice cover with a probability of exceedance of 1%).

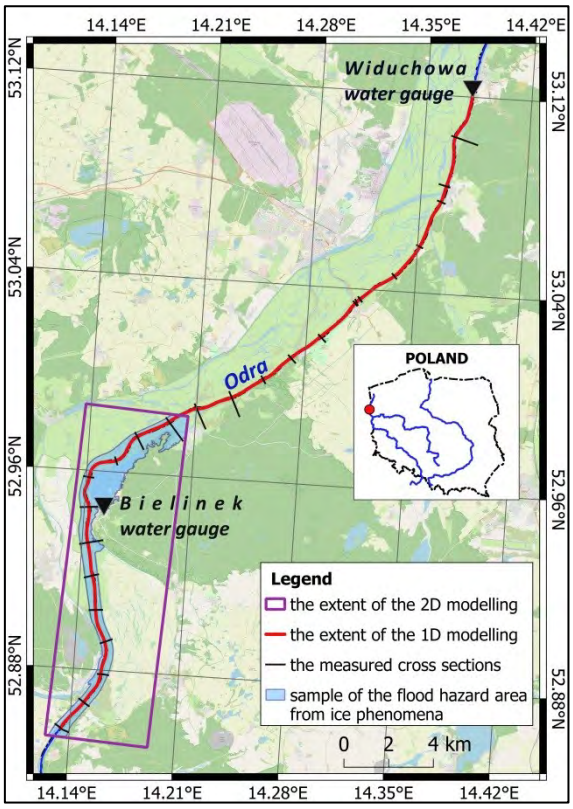

Fig. 1. Location and the extent of the study section of the Oder River.

3. Results and discussion

Calibration results for the open water table did not differ significantly between the models tested. Similar result was observed for the test of calibration ice parameters by modeling historical ice jam event. All models were capable to reflect the water state during the 2014 ice jam event however, Mike21 FM was highly unstable after introducing ice cover and not all ice parameters were working correctly (e.g., ice concentration). The flood scenario modeling tests showed that HEC-RAS and Mike21 FM were able to reflect the assumed water levels at the Bielinek water gauge (6.16 m a.s.l.), similarly to the DynaRICE model, which specializes in modeling the dynamic of ice phenomena. The differences between water state for ice jams and ice cover with a probability of exceedance of 1% and models' results were 2 cm, 3cm and 11 cm respectively. It should be noted, however, that in DynaRICE calculated ice thickness was closer to historical observations (in HEC-RAS and Mike21 FM ice thickness was a model input parameter). The results showed the feasibility of modelling ice jams with the numerical tools tested. In addition, the modeling process revealed the importance of standardizing observations of ice phenomena, to providing the required accuracy of the input data. However, to indicate guidelines for modeling flood hazard form ice phenomena further tests, especially regarding to stochastic approach, should be performed (Lindenschmidt, 2020).

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What if it was possible to fully open the lock in the Nowy Świat canal? Modeling the hydrodynamics of the Vistula Lagoon and the potential water exchange through the ditch in Vistula Spit

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ABSTRACT

The decision to build a new canal in the Polish part of the Vistula Spit was made in 2017. The new connection (ditch) between the Gulf of Gdańsk (Baltic Sea) and the Vistula Lagoon was planned as an navigable channel with a lock and a small port. The construction of the Nowy Świat canal was completed in 2022 and its official opening took place on September 17, 2022. According to the operating instructions for the water device, both during regular use as well as storms and wind tides in the gulf or in the lagoon, the lock must be closed and sluicing is be required for vessels to tackle the Vistula Spit. However, this extended abstract presents some results and conclusions of the research carried out by the author in the years 2018-2022 on the potential impact that a new canal could have in a hypothetical situation of its permanent and complete opening.

Fig. 1. Location of the Vistula Lagoon (Szydłowski and Kolerski, 2020).

1. Study area - Vistula Lagoon and new navigable canal

The Vistula Lagoon is located on the southern coast of the Baltic Sea, in the east part of the Gulf of Gdańsk (Fig. 1). The length of the lagoon is 90.7 km and its width varies from almost 6 km up to 13 km. The mean width is 8.9 km. The lagoon is a very shallow basin with a mean depth of only 2.75 m. It is separated from the Gulf of Gdańsk by the Vistula Spit of a length of about 65 km. The only permanent connection between the Vistula Lagoon and the Baltic Sea is through the Strait of Baltiysk, which is 2 km long, 440 m wide and approx. 8.8 m deep. The total area of the lagoon measures 838 km^2, of which 472.5 km^2 belongs to Russia. The shore line is 270 km long, with a water volume of 2.3 km^3 (Cieśliński and Chlost, 2017; Szydłowski et al., 2019).

The Nowy Świat canal's (Fig. 1) width at the widest sections is 120 m. The total length is 1536 m. It can be divided into three parts - the northern section between the port and the lock, 701 m long, the lock, 269 m long, and the southern section between the lock and the Vistula Lagoon, 566 m long. A constructed sluice is 25 m wide and 5 m deep (Szydłowski and Kolerski, 2020).

2. Hydrodynamics of the Vistula Lagoon and flood risk in the Żuławy lowland

The first own analysis of the Vistula Lagoon hydrodynamics during short-time surges driven by the wind was presented by Szydłowski et al. (2019). A two-dimensional shallow water equation (SWE) model was used to

simulate the free surface water flow in the lagoon. It was concluded that the hydrodynamic conditions of the Vistula Lagoon are often driven by strong winds and storm surges; long-lasting N or NE winds can result in water accumulation in the southern part of the lagoon; the new connection of the Gulf of Gdańsk with the Vistula Lagoon can change the hydrodynamics of the lagoon, but only if the lock is open during the surge event and a difference exists between water levels in the lagoon and the sea; the new canal can intensify the water exchange between the sea and the lagoon reducing water stagnation in the southern part of the reservoir. It was also mentioned that the rising of the water level in the southern part of the lagoon, often exceeding 1.0 m.a.s.l., can be dangerous for the Żuławy Elbląskie, causing the inundation of the polders adjacent to the lagoon. The fully open canal could be reducing the water level in such cases by up to 0.3 m.

3. Water exchange between through the Strait of Baltiysk

The marine water exchange through the Strait of Baltiysk was investigated and described by Szydłowski (2020) and Szydłowski et al. (2021). The SWE model was applied to simulate the free surface water flow in the lagoon for long periods. First, the numerical simulations of the hydrodynamics of the lagoon were validated and then used to calculate the flow discharges in the strait and to determine the total accumulative inflow and outflow of sea water entering and leaving the lagoon in 2017 (Szydłowski, 2020). The annual marine water inflow into the Vistula Lagoon in this year was calculated to be equal to 15.73 km^3. Then the average annual inflow for the period 2008-2017 was estimated as 15.87 km^3 and the range of total annual sea water inflow was found between 14.31 km^3 and 17.78 km^3 (Szydłowski et al., 2021).

4. Water exchange between through the Nowy Świat canal

During controlled (or uncontrolled) opening of the lock, high flow rates may occur in the canal, changing the water exchange between the lagoon and the gulf. The paper by Szydłowski and Kolerski (2020) presents the mathematical modeling of the hydrodynamics of the Nowy Świat canal, based on the solution of SWE model considering the different water levels in the Gulf of Gdańsk and the Vistula Lagoon. The numerical simulations allowed the values of the flow rates in the navigable channel to be determined for the adopted range of water stages. Using the data from the cited work, it became possible to develop a navigable channel flow rate curve for the conditions of its full opening. Regardless of the direction of flow in the canal, the flow rate curves are similar to each other. Considering this similarity, the same simplified hydraulic head (H) - discharge (Q) relation ($Q = 500\ H^{0.5}$) was assumed to calculate the flow rate in the navigable channel for both flow directions. It was found that if the Nowy Świat canal is fully open, annual water inflow from the sea via this canal for the period 2008-2017 would be approximately equal to 1.4 km^3, while outflow to the sea would be equal 2.14 km^3.

5. Vistula Lagoon water balance

Nowadays (Cieśliński and Chlost, 2017), the hydrology of the Vistula Lagoon is controlled by marine water inflow (18.13 km^3per year) and freshwater gain, which consists of catchment runoff (4.97 km^3 per year), precipitation (0.55 km^3 per year) and evaporation (a loss of 0.53 km^3 per year). The total outflow from the Vistula Lagoon to the sea is estimated to be equal to 23.69 km^3 per year. The water balance is complemented by the flow groundwater flow. The lagoon water balance will be updated by Cieśliński et al. (2023) considering the new available estimations of sea water exchange through Strait of Baltiysk and the Nowy Świat canal. Preliminary results have showed that the new canal will not significantly change the water balance of the Vistula Lagoon, even if it is fully opened.

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Behavioural guidance systems for downstream migrating fish: a mini-review

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ABSTRACT

The lack of free-flowing rivers worldwide is one of the factors driving the decline of freshwater migratory fish populations, as dams obstruct migratory pathways. To restore river connectivity, downstream solutions are necessary, in addition to upstream efforts. Fish tend to follow bulk flow as they swim downstream, so the fish often need to be guided towards a bypass. Guidance systems can be classified as mechanical, behavioural or hybrid. Some mechanical barriers have been proven effective for guiding out-migrants, but often there are high costs associated with scaling up these barriers for large hydropower plants. Although higher approach velocities often limit behavioural barriers, they are continuously developed and implemented, due to the lower costs associated with their operation. Furthermore, the fish are less likely to get injured or impinged with a behavioural system, due to the lack of mechanical components. I discuss some of the currently existing behavioural guidance systems, their potential and drawbacks.

Measurements of the resonance properties of dummy fish swim bladders

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ABSTRACT

The resonant properties of fish swim bladders have been widely discussed and utilised in the application of marine biology like fish school localization, species classification and biomass estimation. Measurements and analysis of swim bladder resonance had been carried out mainly on saltwater species using the ring method and the ultrasound that required complicated experimental arrangements and conditions. For freshwater ecosystems, the application of resonant properties of fish swim bladders is not sufficiently established. Hence, a new method was developed for the purpose of measuring the resonance frequency and damping of fish swim bladders using an impedance tube. This tube was designed to be operated in the limit for frequencies below the lowest tube resonance, which was near 400 Hz. As a special form of bubbles in water, the acoustical properties of fish swim bladders can also be measured using the same method developed for measuring free bubbles and large encapsulated bubbles. Resonance frequencies and quality factors for dummy swim bladders of various sizes were measured for the purpose of simulating measurements on fish of various sizes.

Restoring the continuity of the Jasiołka River: the hydraulics of water flow through a fish ladder. Case study - Szczepańcowa, Poland

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ABSTRACT

Optimization of the fish ladder is proposed using physical and numerical modelling to create a fish ladder with appropriate hydraulic condition. The main contribution from the three physical models is the optimal solution with the location and size of the slots. This information was used to create and calibrate a numerical model of the entire fish ladder with the weir and river section. The results show that the proposed solution prevents the formation of a large vortex in the pool. Velocities in the pool and in the main slot do not exceed the limits set by the swimming capabilities of the target fish species, and energy dissipation is correct. The entrance has also been designed outside the turbulence zone created by the weir, and the attraction flow is protected in terms of predicted discharges.

1. Optimization of the fish ladder functionality

The water weir located in Szczepańcowa on the Jasiołka River (river kilometer 27 + 960) the upper Vistula River tributary was constructed in the 1930s. Currently, its purpose is to secure water intake. The hydraulic height is 5.5 m and the length 45 m. Existing fish ladder is incapable to meet the necessary criteria and the new close to nature solution is designed. Conceptual bypass will simulate natural river's section, meandering and located on left river bank. The parameters of the fish ladder were based on the swimming capabilities of the targeted fish species: length 165 m, 40 pools (dimensions of each 3.3 x 4.5 x 0.9 m) (Sobieszczyk 2017), slope 3.3%. The width of the main slot is at least 0.3 m. An additional condition was set: removal or at least limitation of the pool vortexes.

Of the 12 million km analysed by Grill et al. (2019) rivers, free-flowing rivers with length over 1000 km represent only 37%. Dams and water reservoirs are the main cause of the loss of ecological continuity. Methodology aiming for the reclamation of ecological state and the potential of the rivers are: riverbed continuity restoration (construction or modification (Masumoto et al. 2022) of fish ladders), recreation of fish habitats) diversification of water flow parameters (supplementation of sediment, oversized stones deposition, initiation of side erosion).

The effectiveness of the fish pass is assessed by the percentage of fish [%] and time delay [hours or days] to pass the obstacle. Fish swimming abilities has to be considered within the design of the fish ladder. Important are the depths in the pools and slots as well as the water velocities at the entrance, the exit and in general. Additionally, at the exit from the fish ladder attraction flow needs to be secured. The properly designed fish pass works in the range of discharges from low to the medium water levels.

1.1. Physical modelling

The model was created from the sequence of 4 edges and pools. Irregular stones were exchanged for the regular rectangular shaped. Cross-section area was kept as a constant value. The singular main slot was W=0.12 m and the rest was variable s=0.02 m (F_W/F_S = 0.67/0.33), s=0.01 m (F_W/F_S = 0.80/0.20) and s=0 m (no small slots version, F_W/F_S= 1.00/0.00) (Fig. 1). The main slot was placed alternately so that the main current was directed from one side of the pool to the other. Measurements of the velocities were performed with the use of the ADV device under the conditions: 3 different slopes and discharges. The lowest observed velocities in the pool were measured for the version with only one major slot present (F_W/F_S= 1.00/0.00). The whole discharge passes by the main slot and after entering the pool rapid direction change is followed by turbulence creating large vortexes. Implementation of the additional slots on the edge cleared the turbulence and equalized velocities

distribution in front of the additional slots. With the increase of the secondary slots size pool's velocities have also been increased.

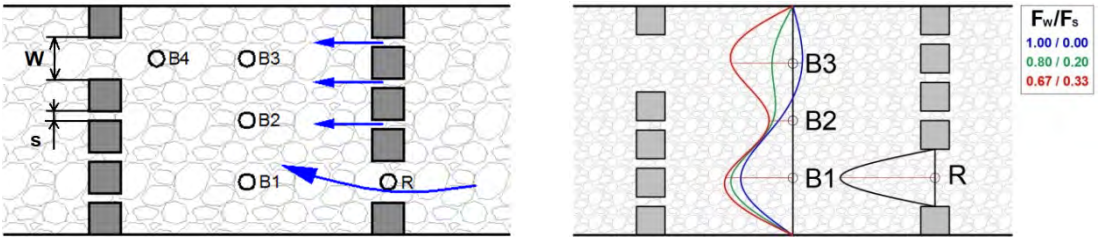

Fig. 1. Water flow in the fish ladder model; a) location of the hydrometric vertical profiles R – main slot, B1, B2 and B3 – pool, b) averaged velocity profiles for different active flow areas F_W/F_S

1.2. Numerical modelling

A numerical model of the real-size fish ladder was created using CCHE2D®. It is a depth-averaged two-dimensional numerical model for simulating unsteady, turbulent, free-surface flow in open channels with unstable (loose) bed. The stages of model development are: i) design and construction of a complex structured mesh system, ii) preparation of initial and boundary conditions, iii) setup of model parameters, iv) run numerical solutions, and v) visualization of modelling results.

Modelling was performed at the discharges of Q_{MLF}=0.33 m^3s^{-1} (Mean Low Flow), Q_{300}=0.95 m^3s^{-1} (guaranteed flow corresponding to 300-day flow per year) and $Q_{2.5\times AAF}$=11.04 m^3s^{-1}. (Average Annual Flow). The lower boundary condition was established on a rating curve calibrated with the use of field measurement. The range of physical modelling flow conditions exceeded the corresponding hydraulic model conditions (ΔH between pools: scaled physical model 0.08-0.2 m; hydraulic model 0.1-0.12 m). In the first stage river channel, weir, entrance, and exit to the fish ladder were calculated. The next stage was to focus on fish ladder hydraulic conditions (Fig. 2). On the basis of the water surface elevation in the river channel the fish ladder was calculated. In the third stage, the attraction flow condition was located on the natural path of migrating fish.

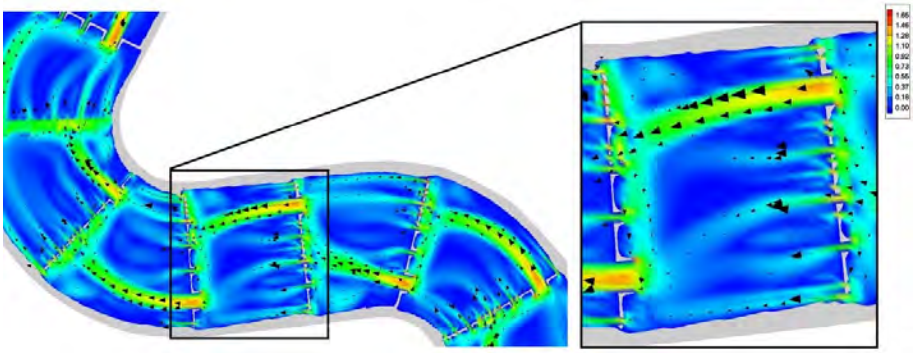

Fig. 2. Spatial velocity distribution represented by colour and vectors, discharge Q_{300}=0.95 m^3s^{-1}

Depending on the flow rate, two types of flow formation occur: flow only through the slots (lower discharge), and for higher discharge, flow through the slots and above them. In the main slot, the average water velocity locally reaches 1.50 - 1.80 ms^{-1}, and in the pools 0.1 ms^{-1}. The highest water velocity occurs above the overflow (corresponds to the edge level) edge and it is approximately 2.0 ms^{-1} (locally 3.0 ms^{-1} for the $Q_{2.5xAAF}$). The volumetric dissipated power ranges from 80 to 150 Wm^{-3}. The numerical simulations also allowed to determine the discharge necessary for creating attraction flow at the entrance to the fishway.

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Impact of wicker deflectors on the ecological restoration of regulated lowland watercourses. A case study of the Flinta River

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ABSTRACT

Over the past century, many watercourses have been straightened as a result of measures to improve the hydraulic capacity of river channels and regulatory measures related to various socio-economic needs. At present, ecological restoration measures are being carried out wherever possible to improve the ecological status of rivers, thereby restoring the semi-natural state of these watercourses. Deflectors are simple hydraulic structures that initiate restoration and accelerate the meandering processes of a river. This study presents the effect of 3 in-stream deflectors on changes occurring in the channel of a small lowland river, the Flinta (Poland). The research was carried out using a simple construction - wicker deflectors. According to current regulations (WFD 2000), all watercourses must achieve at least good status. This implies an improvement in both ecological and hydromorphological status and the Flinta River has been classified as Class IV based on RHS studies (Szoszkiewicz et al. 2020).

1. Methodology and materials

The methodology included systematic measurements of the variability of the river bed geometry, velocity distribution and the granulometric composition of the sediment in the studied section. Measurements were carried out on an estuarine section of the Flinta River of approximately 150m length and a gradient of 1.2 ‰. As part of the study, 3 wicker deflectors placed according to the literature recommendations (Pagliara and Kurdistani, 2017) at a distance of 15 m from each other alternately positioned in the channel at an angle of 70° -80°were introduced in the channel to initiate meandering processes (Fig.1.). Measurements were carried out in designated fixed 28 cross sections which were spanned between leveled pairs of piles. Regular measurements of the trough geometry were carried out using a Nicon AX-2s optical leveller and a GPS RTK. This provided data with an accuracy of 0.002 m vertically and 0.02 m horizontally. Velocity measurements were measured in 15 cross sections also between piles. A Valeport electromagnetic mill was used for the measurements. This allowed changes in both geometry and velocity distribution to be accurately represented. During the surveys, observations were made of the variability in the composition of the sediments. Samples taken always from the same points in the river were dried after transport to the laboratory and sieved according to the same standards (PN-EN ISO 17892-4:2017-01). In addition, hydrological data from the water gauge station in the nearby village of Ryczywół were used. The River Habitat Survey (RHS) and Macrophyte Method for River Assessment methods were used to assess ecological status in accordance with the WFD.

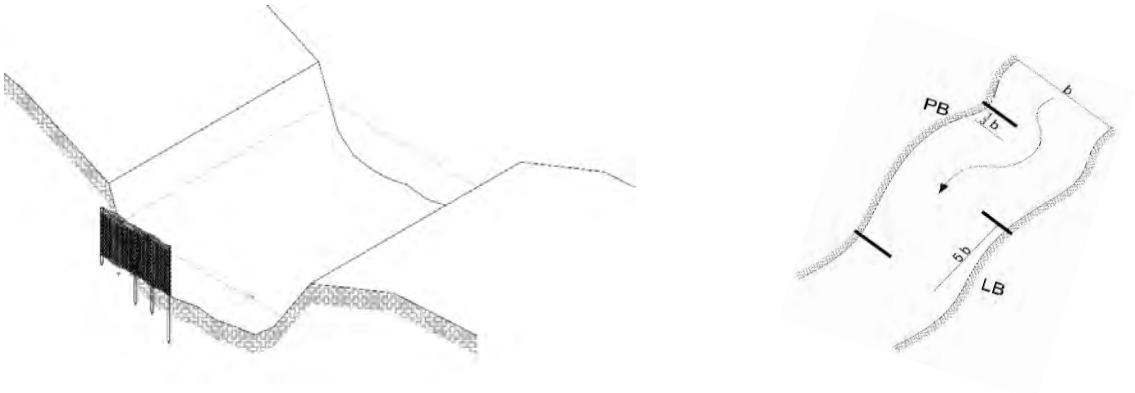

Fig. 1. The deflector scheme and placement along the studied section of the Flinta River: a) completed deflector in the river; b) scheme of the location of deflectors in the river.

2. Results

The geodetic survey carried out between 2018 and 2022 showed significant changes in the lateral bottom pattern. In the vicinity of deflector I (cross section no. 8 Fig. 2), the lateral erosion amounted to about 1 m which in the aspect of only 4 years, is an astonishing result. Also, the changes observed in the change in the bed pattern reached 0.40 m in places, which was observed during bed erosion for prolonged low water tables. On the other hand, areas of accumulation of small material ranging from $d_{50\%}$ 0.18 - 0.3 mm in diameter were observed in areas shaded by deflectors. At the current and highest velocities, bottom cobbles occurred and diameters in the range of $d_{50\%}$ 3.8 - 4.2 mm were observed. The variation in velocity distribution created the conditions for the formation of the previously mentioned bottom formations, creating zones of diversified velocity in both the current and longitudinal sections. Such a condition creates preferred conditions for the existence of various species, which positively translates into the impact of the observed biodiversity. Hydrological data has shown that from 2020 onwards, flows has been observed significantly below the average for practically 80% of the year. Thus, the observed measurement and analysis results demonstrate an even greater impact of the deflectors on the restoration of the watercourse. RHS surveys showed a significant increase in observed channel formations (from 0 in 2012 to 14 in 2022) classifying it into high hydromorphological status (in 2012 bad hydromorphological status). MMOR surveys showed a marked increase in ecological diversity (from 8 in 2012 to 28 species in 2022) achieving good ecological status.

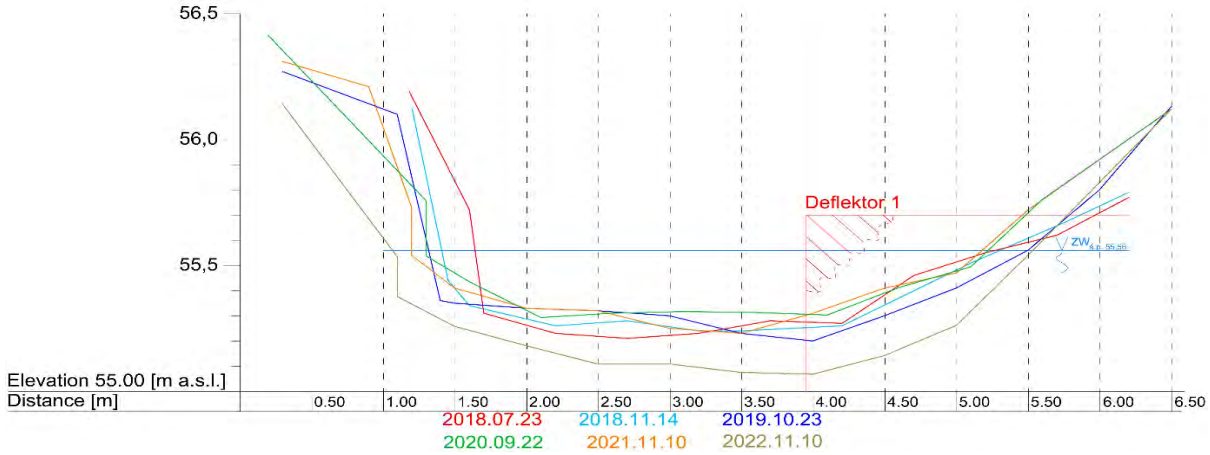

Fig. 2. Changes in cross sections no 8 between 2018 and 2022.

3. Conclusions

The introduction of wicker deflectors into a small lowland river had a positive effect on the conditions in the river. The deformation of the current has influenced the initiation and decisive acceleration of meandering processes. This is particularly evident in Fig. 2. The changes in the channel system contributed to an increase in the length of the watercourse and thus began to reduce the gradient of the channel. This in turn prolongs the outflow of water from the catchment area, which has a positive effect on channel retention. Deflectors have also had a positive effect on the variability of velocity distribution. This has a huge impact on the diversity of habitat conditions for various forms of living organisms. The sediment movement phenomena in combination with the deflectors are also starting to gain in intensity. Previously unobserved bottom forms such as accumulation zones and paved bottoms with coarse gravel have appeared in the channel. This has created new habitats for macrobenthos.

The introduction of deflectors into small and modified streams is able to effectively improve both the hydromorphological and hydrological status and increase the dynamics of the changes taking place in the channel (own research in process of being published).

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Impact of mesh size in CFD analysis on the accuracy of modelling different-scale hydraulic phenomena during the flow through a flap weir

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ABSTRACT

Modelling of hydraulic phenomena is an important element in the design of hydrotechnical structures. Usually, in order to verify the correctness of the adopted design solutions, tests are performed on physical models. This type of research is time-consuming and expensive and requires a properly equipped laboratory and advanced measuring devices. An alternative to physical models are numerical models, the use of which can significantly reduce the cost and time of research. Furthermore, numerical research allows for easier introduction of changes and the search for optimal solutions. Nevertheless, it still has some limitations or gaps in the reproduction of many physical phenomena, especially when applied to complex flows, such as turbulent flows. Numerical models are all the more useful, the better they represent the real problem, but this is not always possible, or it is possible but with more or fewer simplifications. (Antunes do Carmo, 2020). One of these 'simplifications' is the result of using a turbulence model, which is necessary to rationally shorten the calculation time. In the presented article, the author focused on the impact of the mesh size on the accuracy of modelling hydraulic phenomena at various scales using the Large-eddy turbulence model.

The numerical model was built as an imitation of the physical model of a flap weir made in the laboratory of the Wroclaw University of Science and Technology. The model was built in FLOW-3D v12.0 software. This model provides analyses for a single selected case for specific flap position. The numerical model covered a section of the structure containing a weir, flap, and stilling basin. The entire mesh area was 4.2 m long and 1.0 m high. Due to the treatment of the phenomenon, as a two-dimensional model was only 0.01 m in width, which reduced a computation time. The shape of the geometry is shown in Fig.1. The boundary conditions were as follows: upstream water level at 0.96 m, downstream water level at 0.83 m, the boundary condition was set as symmetry and free surface at the top. The initial condition was established as the water level of 0.96 m in the whole region, so the simulation was started by the outflow of water above the downstream boundary condition. About 20 seconds were needed. to reach a nearly steady flow.

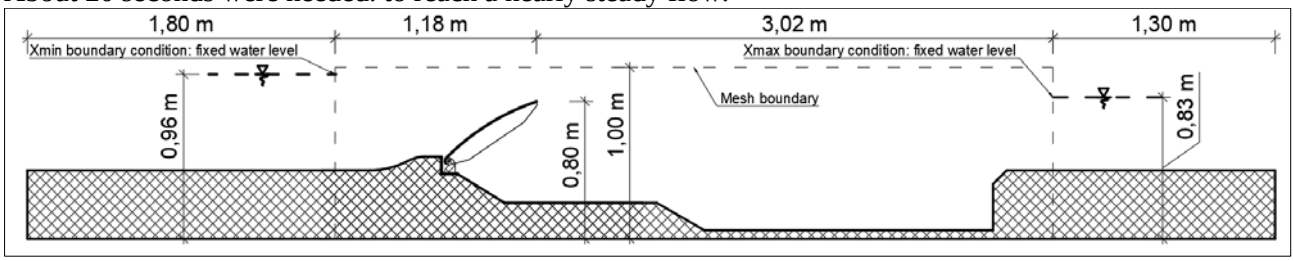

Fig. 1. Model geometry and boundary conditions.

Turbulence was calculated as a Large-eddy simulation (LES). In this method large-scale fluid movements (large vortices) in turbulent flow are calculated directly and only small-scale movements are modelled. The turbulence of dissipative vortices is not as strong and contributes less to Reynolds stresses and can be implemented on the subgrid-scale grid much thicker than the Kolmogorov length scale (Kostecki and Herrera-Granados, 2021). Comparing the nature of the phenomena with the observations from the physical model, it was found that the LES model provides an accurate representation.

The study includes six cases of different cell sizes and analyses of total computation time, average inflow, and average vorticity. The vorticity field was calculated because the physics of a given fluid flow is often more effectively illustrated through vorticity than through velocity fields (Brøns et al., 2014). The average inflow and the average vorticity were determined in the time interval from t= 30 s to t=90 s The results are shown in Table 1. The instantaneous velocity fields were presented on Figs. 2-3.

Table 1. Summary of the Results

Case number		1	2	3	4	5	6
a	[m]	0.030	0.010	0.008	0.006	0.005	0.004
n	[-]	13 860	420 000	787 500	1 987 300	3 360 000	6 562 500
T	[min]	2	36	145	440	1170	4425
Q	[m^3 s^{-1}]	0.01413	0.01346	0.01345	0.01317	0.01323	0.01312
ΔQ	[%]	-	4.74%	0.07%	2.08%	-0.46%	0.83%
ω	[s^{-1}]	3.079	6.361	6.977	7.792	8.304	9,563
$\Delta\omega$	[%]	-	-106.59%	-9.68%	-11.68%	-6.57%	-15.16%

Where a – cell size [m], n – total number of cells, T – total computation time [min], Q – averaged inflow in the time range of 30 to 90 second, ω – averaged vorticity in the time range of 30 to 90 second, ΔQ and $\Delta\omega$ - percentage difference of Q and ω from the previous case.

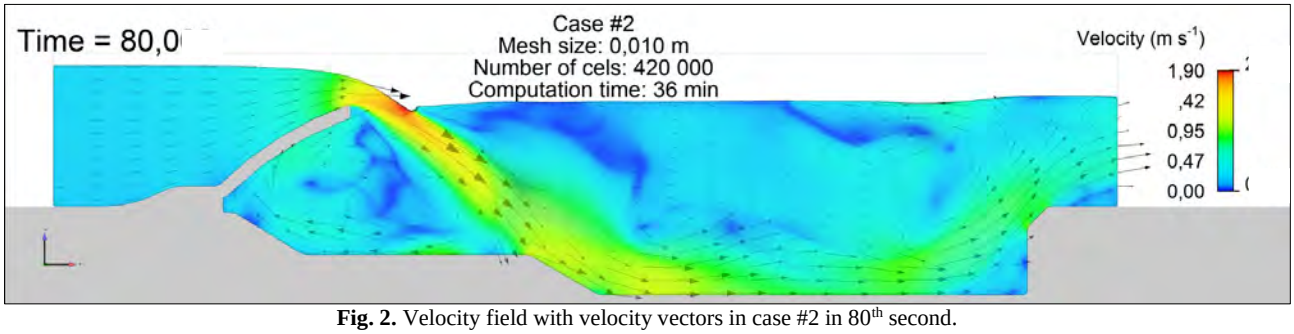

Fig. 2. Velocity field with velocity vectors in case #2 in 80th second.

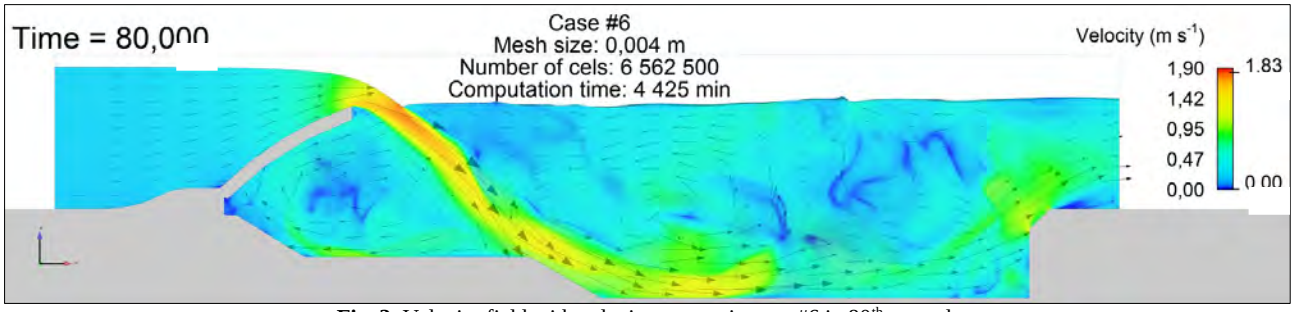

Fig. 3. Velocity field with velocity vectors in case #6 in 80th second.

The results obtained show that the size of the mesh has a significant influence on the computation time. The number of cells increases with the third power of decreasing the cell size. Furthermore, the increase in computation time is even greater, according to the Courant–Friedrichs–Lewy convergence condition. It is desirable to use the largest possible mesh cells to shorten the calculation time.

Calculations of the average flow, based on a 3% confidence interval, indicate that a cell size of 10 mm is sufficient to determine the correct flow value. The differences between case 2 and cases 3 to 6 are lower than 3%, suggesting that there is no need to increase the mesh density beyond 10 mm. However, significant changes in vorticity (more than 3%) between consecutive cases imply that assuming that a cell size of 10 mm is sufficient for this phenomenon is incorrect.

This implies that selecting a cell size based on phenomena that depend only on the average velocity values (such as the flow rate) does not ensure that the model is properly calibrated for phenomena based on fluctuations of the velocity vector. It could be expected that the LES model allows us to analyse, e.g. pressure fluctuation affecting dynamic load on a construction; however, if the calibration is solely based on average flow phenomena, the fluctuation part could still be inaccurate. It is important to determine at the beginning of the study which phenomena will be analysed and then to perform calibration based on phenomena that are equally dependent on velocity fluctuations.

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Analysis of the parameters of the phenomenon of two-dimensional horizontal dispersion in a coastal zone based on tracer studies using a drone

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ABSTRACT

This work describes the results of experimental research in the form of tracer studies carried out in a coastal zone. Two substances were used: Rhodamine WT (Water Tracer) and Uranine (Fluorescein Sodium). The doses of the tracer were released in a profile in the river, sufficiently distant from the mouth. Then the tracer was tracked to the estuary and coastal zone. Commercial unmanned aerial vehicle (UAV) imaging was used to determine the concentration of the tracer. The color-based concentration recognition method was used to analyze the images. The basic parameters describing the horizontal dispersion were determined using Fischer's statistical method.

1. Introduction

Due to the fact that rivers deliver pollutants to the seas, it becomes necessary to model the phenomena occurring in estuaries and the propagation processes of pollutants flowing into salty waters. Two approaches are used to study the spread of pollutants in the water environment, either tracer studies or mathematical modeling. The latter, however, may require tracer tests to identify the modeling parameters. Tracer studies involve administering a safe substance (fluorescent dye) into the environment. The dye mimics contamination, which enables information to be obtained regarding the time of arrival, peak concentration, and the dimensions of the dissolved component cloud floating in the water.

2. Materials and methods

2.1. Study area

Research was carried out at the mouth of the Gizdepka River into Puck Bay. Puck Bay is part of the Gulf of Gdańsk (Southern Baltic Sea). Gizdepka is a minor watercourse, with a catchment area of 37.2 km^2. The average annual flow rate falls within a range of 0.16 to 0.19 m^{3}s^{-1}. This river passes through an agricultural area and carries typical impurities from this area. This is the reason why it was decided to conduct research on pollution transport processes.

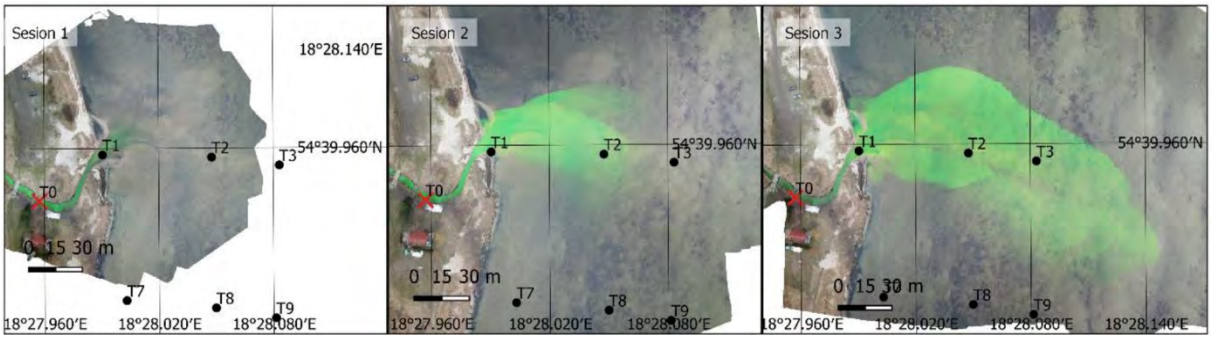

Fig. 1. An orthophoto depicting the first three sessions on day 1 (fluorescein) with time interval 5 min.

2.2. Tracer studies using UAV imaging and a fluorometer

Tracer studies were carried out using commercial UAV (drone) imaging with a camera and a fluorometer (Trilogy, Turner Designs). The tests were scheduled and conducted in 2019, in early spring, when the chlorophyll concentration in the water is the lowest and water transparency is as high as possible. The study period involved completing three full test sessions in several-week intervals. Each session comprised several UAV flights at regular time intervals, and simultaneous manual sampling for fluorometer testing at strictly specified spots. Two doses of Uranine at concentrations of 250 and 500 g/10 dm^3 H_2O, and one dose of 1 dm^3

of Rhodamine WT at 20% concentration were released into the waters of the river. In each case, the dye was released into the river as an impulse at a drop point located 750 m from the river mouth. Sample photos from day 1 are shown in Fig.1. The details of these operations are presented in (Burdziakowski et al., 2021).

2.3. Determination of the dispersion coefficients

The phenomenon of dispersion is described by the longitudinal D_L and transverse D_T dispersion coefficient (Elder, 1959). There is a simple relationship between D_L and D_T, and D_L can be determined from measurements. Fischer's statistical method (Fischer et al., 1979) was used to determine the coefficient of the longitudinal dispersion D_L [$m^2 s^{-1}$]:

$$D_L = \frac{(\bar{u})^2\left(\sigma_2^2 - \sigma_1^2\right)}{2\Delta T} \tag{1}$$

where: $\bar{u}$ – average spreading velocity of the tracer m s^{-1}, σ_i^2 – standard deviation of *i* series, ΔT – time interval between series peaks s.This coefficient was calculated for the estuary section of the river and then calculated in the coastal zone. In the case of the river, information about the dose of the tracer, which was dropped at the drop point (Crank, 1975), and the results obtained from photographs at the mouth of the river into the sea were used. The dispersion in the coastal zone was determined on the basis of the results from photographs at 2 points: at the river mouth into the sea and at a point 200 m away in the area of the coastal zone. The results of this operation are shown in Fig.2.

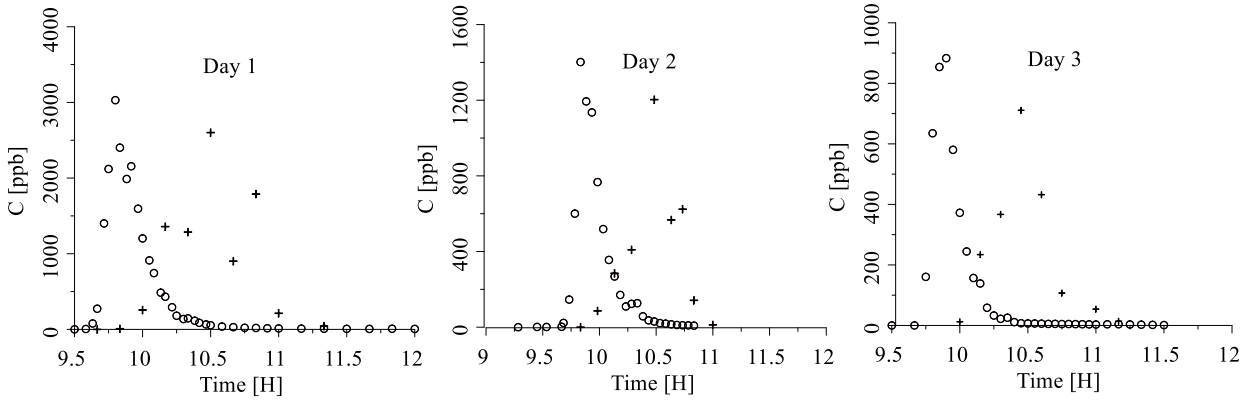

Fig. 2. Results obtained from 2 points: at the river mouth into the sea (circles) and at a point 200 m away in the area of the coastal zone (crosses) - from photographs.

3. Results and conclusion

The method of conducting research on dispersion using UAVs is becoming more and more popular (e.g. Johansen et al., 2022). The results of the calculations of the longitudinal dispersion coefficient are presented in Table 1. The longitudinal dispersion coefficient changes from 1.33-2.57 $m^2 s^{-1}$ for the river to 0.35-0.56 $m^2 s^{-1}$ for the coastal zone. It can therefore be said that in the coastal zone, in relation to the estuary section of the river, a decrease in the dispersion coefficient was observed. This is also confirmed by other studies.

Table 1. Results of the conducted research

Name	Date	Tracer	Dose	D_L [$m^2 s^{-1}$] (river)	D_L [$m^2 s^{-1}$] (costal zone)
Day 1	17 February 2019	Uranine	500 g/10 dm^3 H_2O	1.33	0.35
Day 2	2 March 2019	Uranine	250 g/10 dm^3 H_2O	2.57	0.56
Day 3	23 March 2019	Rhodamine WT	1 dm^3 Rhodamine WT @20%	1.66	0.48

Acknowledgements

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CONTENTS

Lectures

Claudio COMOGLIO
The RIBES project and the Marie Skłodowska-Curie Doctoral Networks 7

Pilar GARCIA-NAVARRO
Shallow water flow simulation: from mathematics to reality 8

Ian GUYMER
Solute mixing from estuaries to pipes 9

Wojciech MAJEWSKI
40 years of the School of Hydraulics. Past, Presence, Future 10

Costantino MANES
On the scaling of fish locomotion and fatigue 12

Jacek POZORSKI
Multiphase flow modelling using Smoothed Particle Hydrodynamics 13

Jeffrey A. TUHTAN
Flow from a fish's perspective: how live fish, bioinspired sensors and AI can be used to improve fish passage 14

Presentations and posters

Arkadiusz ANTONOWICZ
Particle Image Velocimetry of 3D-printed microchannel models 17

Muhammad Usama ASHRAF
Fish swimming performance: effect of flume length and different fatigue definitions 19

Mosbah Ben SAID
Discharge capacity of an improved form of labyrinth weir 20

Adrian BRÓŻ
Refining velocity measurements protocols in a lowland vegetated channel 21

James Adam CAMPBELL
Application of animal movement models to acoustic telemetry positioning 23

Elsa CARVALHO
A Lagrangian analysis of the surface flow in a jet dissipation basin at equilibrium 24

Miriam CASTAGNA
Hydrodynamics of fish-shaped rigid bodies: velocity-drag coupling 25

Geetika CHAUHAN
Application of wavelet transform for analysis of river discharge 26

Zuzanna CUBAN
Laser scanner as a tool for investigating sediment transport under laboratory conditions 28

Tomasz DYSARZ
Comparison of HEC-RAS and Iber simulations for the assessment of waterway safety under the bridge in the Kaunas city 30

Florian EGGERS
Methods for the assessment of fishways (upstream fish passage) 32

Ralph EIKENBERG
Fish observations and hydraulic measurements on a nature-like unstructured block ramp 33

Jelger ELINGS
Applying hidden Markov modelling to fine-scale telemetry 34

Philip S. ERICSSON
Consider the bigger picture: The effect of multimodal sensory integration on fish passage behaviour 35

John D. FENTON
Flood routing using models based on input and output flow or stage data 36

Jacek FLOREK
Active flow zones distribution along the upper Vistula River established with the use of 1D and 2D modelling 37

Szczepan GROSEL
Numerical reconstruction of pore pressure distribution in tailings dams 38

Maciej GRUSZCZYŃSKI
Methods of measuring the difference in water levels between sections in rivers and channels 40

Khansa GULSHAD
Impact of land use and land cover changes on the surface runoff in Gdańsk, Poland 42

Yiwei GUO
Information entropy theory-based optimizing of gauge networks for hydrological modelling – A case study in the Loess Plateau, China 44

Michał HALICKI
High-resolution water surface slope of Polish rivers from multi mission satellite altimetry 45

Peshang Nawshrwan Hama KARIM
Hydraulic properties of Sulejów Reservoir in Poland as a driving factor of sedimentation processes 47

Henry H. HANSEN
Practitioner friendly introduction to bayesian flood frequency analyses 48

Oscar HERRERA-GRANADOS
Comparison of results of 2D numerical hydraulic modelling using different Digital Bathymetric Models (DBMs) 49

Parthena A. IOANNIDOU
Analysing Pressures and their impacts on water quality in a Mediterranean basin. The Case study of Lissos River, N. Greece 51

Krishna IYER
Development of a generalized criterion for selecting optimal MRF rotation zone for CFD simulation of stirred tank reactors 53

Monika B. KALINOWSKA
Photo-monitoring of vegetation in Warszawicki channel – citizen science project results 54

Emilia KARAMUZ
Enhanced signals of changes in soil moisture conditions in the first decades of the 21st century – Vistula catchment study 56

Emilia KARAMUZ
Aerial images for assessing vegetation coverage in open channels 57

Ali Hassan KHAN
Comparison of near-body flow fields of a gudgeon and NACA0013 profile 58

Tomasz KOLERSKI
Experimental measurement of ice load on a hydraulic structure 59

Serhat KUCUKALI
Fish movement analysis in diagonal brush fish pass: innovative approaches 61

Rachel MAWER
Identifying hydraulic preferences of riverine fish, using fine-scale fish tracks and hydraulic data 63

Gloria MOZZI
Aggregation in riverine fish: a review from a fish passage perspective 64

Magdalena MROKOWSKA
Laboratory study on sinking behaviour of microplastics in seawater with rheology modified by dispersed exopolymers 65

Michael NONES
Satellite-based monitoring of drought at the watershed scale 66

Rafał OSTROWSKI
Cross-cut through Vistula Spit 67

Cong Ngoc PHAN
Monthly changes in physicochemical parameters of the groundwater in Nida valley, Poland (case study) 69

Łukasz PRZYBOROWSKI
Analysis of macroplastic transport in a river regulated by groynes 71

Motuma Shiferaw REGASA
Evaluating Management Practices to reduce sediment yield in the Fincha Watershed, Ethiopia 73

Małgorzata ROBAKIEWICZ
Navigation analysis at the entrance to the bypass channel of Siarzewo barrage 74

Marcelo X. RUIZ-COELLO
Numerical approaches to evaluate the hydraulics of Vertical Slot Fishways: A comparative study of 2D and 3D simulations 75

Alfredo SCHIAVON
River runs dry: Movement patterns of Telestes muticellus (Cypriniformes: Leuciscidae) in an intermittent river stretch 76

Sophia SCHUMANN
Stress evaluation using physiological biomarkers on fish tested in the hydraulic facility 77

Fred SONNENWALD
Reach unified channel characteristics for the transverse advection-dispersion equation 78

Calvin STEPHEN
Performance analysis of a pump-as-turbine under cavitating conditions 79

Andrzej STRUŻYŃSKI
Revitalization of a river valley based on the results of two-dimensional modelling 80

Ewelina SZAŁKIEWICZ
Assessment of models' performance in determining flood hazard from ice jams 82

Michał SZYDŁOWSKI
What if it was possible to fully open the lock in the Nowy Świat canal? Modeling the hydrodynamics of the Vistula Lagoon and the potential water exchange through the ditch in Vistula Spit 84

Stoilova VELIZARA
Behavioural guidance systems for downstream migrating fish: a mini-review 86

Luocheng WU
Measurements of the resonance properties of dummy fish swim bladders 87

Maciej WYRĘBEK
Restoring the continuity of the Jasiołka River:the hydraulics of water flow through a fish ladder. Case study – Szczepańcowa, Poland 88

Stanisław ZABOROWSKI
Impact of wicker deflectors on the ecological restoration of regulated lowland watercourses. A case study of the Flinta River 90

Krzysztof ZAMIAR
Impact of mesh size in CFD analysis on the accuracy of modelling different-scale hydraulic phenomena during the flow through a flap weir 92

Piotr ZIMA
Analysis of the parameters of the phenomenon of two-dimensional horizontal dispersion in a coastal zone based on tracer studies using a drone 94

XL

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