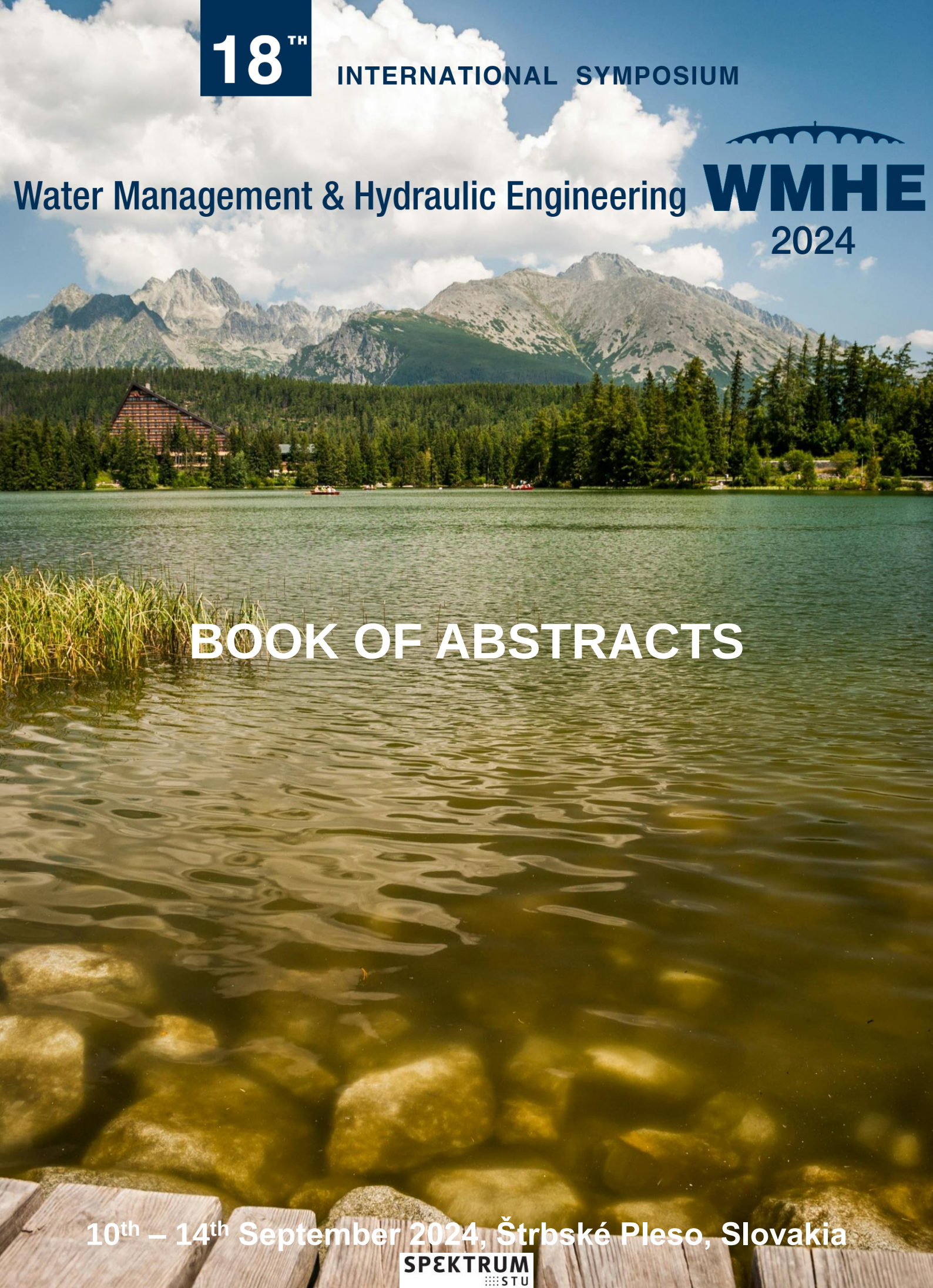


18TH INTERNATIONAL SYMPOSIUM

Water Management & Hydraulic Engineering WMHE 2024

BOOK OF ABSTRACTS

10th – 14th September 2024, Štrbské Pleso, Slovakia

SPEKTRUM STU

18TH INTERNATIONAL SYMPOSIUM

Water Management & Hydraulic Engineering

WMHE 2024

Book of Abstracts

10th – 14th September 2024, Štrbské Pleso, Slovakia

18th International Symposium
WATER MANAGEMENT & HYDRAULIC ENGINEERING WHME 2024
10th – 14th September 2024, Štrbské Pleso, Slovakia

SYMPOSIUM PROCEEDINGS

Editors	Michaela Červeňanská, Alexandra Vidová, Andrej Šoltész
Published by	Slovak University of Technology in Bratislava
Published in	2024 [e-Proceedings]
Cover Design	Michaela Červeňanská
Web site	https://wmhe2024.hydrotechnika.sk/

Note: The abstracts were read and selected by the Scientific Advisory Committee of the conference as possible papers for the conference.

ORGANIZED BY
Slovak University of Technology in Bratislava
Faculty of Civil Engineering, Bratislava, Slovak Republic

IN COLLABORATION WITH
Univeristy of Zagreb
Faculty of Civil Engineering, Zagreb, Croatia
Gdańsk University of Technology
Faculty of Civil and Environmental Engineering, Gdańsk, Poland
Ss. Cyril and Methodius University in Skopje
Faculty of Civil Engineering, Skopje, Republic of North Macedonia
Brno University of Technology
Faculty of Civil Engineering, Brno, Czech Republic

ISBN 978-80-227-5423-1

SYMPOSIUM CHAIRMEN

Eva Ocvirk
University of Zagreb, Faculty of Civil Engineering, Zagreb, Croatia
Michał Szydłowski
Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, Gdańsk, Poland
Andrej Šoltész
Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Bratislava, Slovakia
Josif Josifovski
Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, Skopje, Republic of North Macedonia
Jaromír Říha
Brno University of Technology, Faculty of Civil Engineering, Brno, Czech Republic

SCIENTIFIC ADVISORY COMMITTEE

Eva Ocvirk, Dalibor Carević, Ivan Halkijević, Kristina Potočki
University of Zagreb, Faculty of Civil
Engineering, Zagreb, Croatia
Michał Szydłowski
Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, Gdańsk, Poland
Andrej Šoltész, Silvia Kohnová, Štefan Stanko, Jana Frankovská
Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Bratislava, Slovak Republic
Josif Josifovski
Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, Skopje, Republic of North Macedonia
Jaromír Říha
Brno University of Technology, Faculty of Civil Engineering, Brno, Czech Republic

ORGANIZING COMMITTEE

Gordon Gilja, Domagoj Nakić, Damjan Bujak
University of Zagreb, Faculty of Civil Engineering, Zagreb, Croatia
Piotr Zima
Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, Gdańsk, Poland
Michaela Červeňanská, Alexandra Vidová, Adela Rutzká, Natália Bilčíková, Réka Wittmanová, Jana Lehotová Nôtová
Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Bratislava, Slovak Republic
Violeta Gjesovska
Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, Skopje, Republic of North Macedonia
Tomáš Julínek
Brno University of Technology, Faculty of Civil Engineering, Brno, Czech Republic

TABLE OF CONTENTS

Preface ... 8
Keynote Lectures ... 9
Anticipating Emerging Flood Risks ... 10
A Look at the Potential of Regional Process-Oriented Look at Bivariate Flood Frequency Analysis from the Perspectives of Engineering and Comparative Hydrology ... 12
Hydraulics and Hydraulic Structures ... 13
Optimizing Manning's Roughness Coefficient with Coupling Simulator and Optimizer ... 14
Effect of Blockage on Scouring Downstream the Culverts ... 15
Calibration of the Xbeach-Gravel Model ... 16
Effect of Different Methods on the Manning's Roughness Coefficient Determination for the Close to Nature Fish Pass ... 17
Analysis of Experimental Flow Velocity Data under Immobile Bed Conditions next to Bridge Pier ... 18
Analysis of Experimental Flow Velocity Data under Mobile Bed Conditions next to Bridge Pier ... 19
Numerical Study of the Sea Wave Loading on a Vertical Parapet Wall and Overtopping ... 20
Effective Methods for the Hydraulic Assessment of Combined Functional Structures Involving Small Water and Dry Reservoirs ... 21
Numerical Study of Scour Hole Development Downstream of Riprap-Protected Bridge Piers ... 23
Estimation of the Transmission Coefficient for a π-Type Floating Breakwater in the Presence of Spectral Waves and Variable Depth ... 24
A Water Flow Models Calibration using Heuristic Methods ... 25
Experimental and Numerical Model for Analysis of the Water Hammer in Pump Water Supply System ... 26
Vegetation Effects on Flow Characteristics and Sediment Storage in a Lowland River Channel over Time ... 28
Analysis of the 2D Hydraulic Equations for the Fish Pass Modeling ... 31
Assessment of Velocity Distribution and Turbine Power Output in Water Courses ... 32
Assessment of Velocity Distribution and Turbine Power Output in Water Courses ... 34
Mathematical Model for the Analysis of Unsteady Flow during a Pressure Pipeline Break using the Method of Characteristics ... 36
Water Resources Management and Hydrology ... 38
Water Management in Arid Regions under Climate Change ... 39
Prediction of Monthly Flow by Supervised Learning Ensemble Chain Models ... 41
Reliability of Standard Rain Gauge Precipitation Measurements in Relation to Lysimeter Observations ... 42
Analysis of Selected Soil Water Balance Members Obtained by Calculation and Lysimetric Measurement ... 43
The Numerical Modelling of Dam Reservoir Siltation Cycles: the Case Study in Algeria ... 44
A Holistic Approach to the Assessment of E-Flow Under the Climate Change Impact in Data - Limited River Basin ... 45

Testing the Parameters of Two-Dimensional Horizontal Dispersion Phenomenon in the Coastal Zone 47
Performance Evaluation of a Combined Drought Index for Multivariate Drought Assessment in Maharashtra, India 48
Impacts of Man-Made Structures on Flood Water Regime of Toponička River in Serbia 50
Mapping Water erosion Susceptibility through Integration of Geospatial Data and Machine Learning: a Case Study of the Isser Basin, Northern Algeria 52
Concept of the Water Management and Technical Solutions of Selected Reservoirs from the General LAPV the Dyje and Morava Basin 53
Problems of Hydrometric Approach to Determine the Thermal Mineral Water Flow to the Bečva River in the Teplice Spa 55
Estimation of Recharge and Evaporation in the North-Western Sahara Aquifer System (Algeria-Tunisia) Using Stable Isotope Profiles in Soil Water, Modelling and Management 57
Monte Carlo Approach to Local Scour: The Sava River Bridge, Zagreb Case Study 58
Possibilities of Water Regime Improvement in the Klátov Branch National Nature Reserve 59
Analysis of Annual and Seasonal Precipitation of Three Representative Croatian Regions 60
Water Crisis of the Ponds in Kopački Rit Wetland 62
Investigation of Changes in the Rainfall-Runoff Modeling Caused by Climate Change 63
Identification of Flash Drought Events in Danubian Lowland Using the Rapid Intensification Rate 64
Trend and Correlation Analysis of Groundwater Quality at the Bartolovec Wellfield in Croatia 65
Integrated Water Resource Management in Fiji: A Novel Approach to Enhancing Water Supply and Mitigating Flood Risks 66
EU Strategy for Danube Region - Prosperity through Diversity 67
Balancing Water Flows in the Rye Island for the Purpose of Supplying Water to Irrigation Pumping Stations 69
Water Scarcity Management in Slovakia – Current State 71
New Methodology on E-Flow Determination in Slovakia 72
A Precipitation Trend Investigation Research of Humenne, Slovakia 73
Water Economy Planning on River Scale Extent by Simulation Model 74
Sanitary and Environmental Engineering, Sustainable Water Use 75
Analysis of Occurence and Transport of Microplastic Waste in the Adriatic Eea with Croatian Legislative Framework 76
Hydraulic Analysis and Optimization of a Part of the Water Supply System of the Buzet City 77
Comparison of Operation on the Wastewater Treatment Plant Using SBR and MBR Technology 79
Prediction of E. coli Bacteria on Drinking Water Treatment Facility Butoniga 81
Energy Consumption and Idle Energy Compensation on Drinking Water Treatment Facility Butoniga 83
The Effects of Ultrasound in Oily Wastewater Treatment 85
Electrochemical Removal of Pesticide Acetamiprid 86
Ammunition Factory Wastewater Treatment by Electrocoagulation 87
The Potential of Using Residue from Sewage Sludge Gasification in an Experimental Plant 89

Mathematical Modelling of the Batch Reactor for Water ph Control 90
Application of the AHP Method to the Selection of Sewage System Type 91
Anthropological Impact on Small Natural Water Resources on Pag Island 92
Measures to Mitigate the Negative Impact of Rainfall Runoff in Non-Infiltration Areas 94
Water Treatment in Slovakia - past and present 95
Changes of Thermocline in Two Different Reservoirs for Drinking Water Supply in Slovakia 97
Surface Runoff as a Potential Source of Environmental Pollution 99
Geotechnical Engineering 100
Stability of Structures during Floods 101
Measuring Filtration Velocities in the Observation Wells of Dam and Their Time Development 102
The Use of Terrestrial and Airborne Laser Scanning in the Geometrization of a 3D Numerical Model of Geotechnical Objects 103
Climate Change and Flood Risk Management 104
Impact of Climate Change on Rainwater Management in the City of Gdańsk (Poland) 105
Analysis of Two Normal Periods in Terms of Basic Hydrometeorological Elements 107
Hydrological Processes in the Water Unsaturated Soil Environment on the East Slovak Lowland in the Extremely Dry Vegetation Season of 2022 108
Effect Evaluation of Different Adaptation Measures Applied on Urban Catchment 110
Improving Coastal Flood Assessment through the Use of LiDAR Data - A Case Study of Rovinj City 112
Uneven Shifts: How Climate Change Alters Seasonal Discharge Patterns in Slovak Rivers 113
Process of Washout of the Geotechnical Embankment due to Overflow of Water Above the Crest Based on Physical Tests 114
Advancing Hydrological Forecasting: Machine Learning Approaches for Enhanced Water Flow Prediction in the Bednja River, Croatia 116
Analysis of Flood in an Urban Area- Case Study: Skopje 2016 117
Proposal of Water Retention Measures in Hodkovce Village 118
Proposal of Water Retention Measures in Turany nad Ondavou Village 119
Research of the Influence of Flood Flows on the Area between the Antošov Irrigation Channel and the Lamačský Stream 120

PREFACE

The 18th International Symposium on Water Management and Hydraulic Engineering (WMHE 2024) is organized by the Faculty of Civil Engineering at the Slovak University of Technology in Bratislava from 10–14 September 2024 in Štrbské Pleso – the heart of the beautiful nature of the High Tatras in Slovakia. The WMHE 2024 Symposium is the next in the series of International Symposiums in the field of Water Management and Hydraulic Engineering, organized with the participation of the University of Zagreb (Croatia), Gdańsk University of Technology (Poland), Slovak University of Technology in Bratislava (Slovak Republic), Ss. Cyril and Methodius University in Skopje (North Macedonia), University of Natural Resources and Applied Life Sciences in Vienna (Austria) as well as Brno University of Technology (Czech Republic).

The main goal of the conference is to share transboundary and interdisciplinary knowledge and experience between scientists and experts from Central Europe, from older and new EU member states as well as from South-East European candidate countries.

The first Symposium of this type was organized as a bilateral activity between the faculties of Gdańsk University of Technology and Zagreb University. Since 1998 (in Dubrovnik), the Slovak University of Technology, the Ss. Cyril and Methodius University in Skopje and BOKU University of Natural Resources and Applied Life Sciences in Vienna have joined this biannual symposium series. In 2013 Brno University of Technology, Czech Republic, joined the steering group of WMHE too.

The aim of the Symposium is to encourage and facilitate communication and exchange of experience from recent research work between scientists, engineers and professionals on different aspects of water and environmental management and hydraulic engineering, including physical and mathematical modelling. Topics of the symposium have been chosen to cover the main elements of integrated water resources management, hydraulic engineering, sanitary engineering and sustainable water use, hydrology, hydraulics, geotechnical engineering as well as environmental engineering, climate change and flood risk management. This successful series started in 1984 and is now regularly organized as a two-annual symposium meeting. During the symposium, two lectures will be given by invited internationally renowned scientists Prof. Hans – Peter Nachtnebel from BOKU University in Vienna and Prof. Jan Szolgay from STU in Bratislava.

The Symposium is co-organized by the Slovak Society of Environmental Technology under the auspices of Prof. Dušan Petráš.

We are honoured and delighted to invite you to enjoy the symposium in the beautiful nature of the High Tatras in Slovakia.

Andrej Šoltész

KEYNOTE LECTURES

ANTICIPATING EMERGING FLOOD RISKS

NACHTNEBEL HANS PETER[1], NEUHOLD CLEMENS[2]

[1] Prof. em. Dipl.Ing.Dr. Dr. hc., Department of Water-Atmosphere-Environment,
University of Natural Resources and Life Sciences. Vienna, Austria.
hans_peter.nachtnebel@boku.ac.at
[2] Dipl.Ing. Dr, Deputy Director, Directorate I/6 - Flood Risk Management
Austrian Federal Ministry of Agriculture, Forestry, Regions and Water Management, Vienna, Austria
<clemens.neuhold@bml.gv.at>l

Abstract

The EU-Flood Directive targets the reduction of existing flood risk and the avoidance of emerging new risks. Future risks depend on climate-induced changes in rainfall patterns, but also land use changes related to societal development are relevant.

Here, a methodology for assessing future flood risk in a changing environment will be presented by the help of a case study executed at the regional scale. The province of Upper Austria encompasses an area of 11 982 km2 with 1,437 Mio inhabitants living in 444 municipalities. The land use maps provided data for each municipality including residential area, public buildings, industrial and commercial areas, infrastructure, recreation and agriculture. Data were analysed for the recent status and under the assumption that the local land development plans are fully implemented. The latter constitutes an estimate of the worst-case scenario.

The recent flood risk is estimated for observed conditions while future climate induced flood risk is derived by considering the sensitivity of recent flood risk to changing inundation area and respective damage potential. The area of buildings in flood plains has been selected as a risk indicator. In twenty-one municipalities more than 100000 m^2 of buildings are recently exposed to floods with a return period larger than 200 years. In eleven municipalities, all the residential areas are located outside the flood plain. The data are categorized according to Fig.1.

Second, flood risk changes are assessed considering socio-economic development, characterised by regional demographic changes and the respective land development plans. This information provides the basis for assessment of emerging risk areas. According to internal migration trends it can be concluded that in surrounding areas of already highly developed centres the population is expected to grow, and as a consequence, residential buildings will be developed from which a substantial part may be located in flood prone areas. As a result two maps, recent risk and emerging risk, would be obtained (Fig. 2).

To prioritise the municipalities with respect to recent and emerging risks the two layers (today and future) have to be combined. As an example, as displayed in Fig. 1, we simply combined the various categories (category layer 1 + category layer 2). Of course, dependent on the weights given to recent and emerging risk different results could be obtained. However, the hot spot areas remain always clearly visible.

Then, climate induced changes in flood magnitude and corresponding inundation area were assessed. Either different regional climate model outputs could be used to generate flood events or sensitivity studies could be executed to learn about the response of inundated areas. E.g. which changes in the flood plane would occur if the flood peak would be 10% higher.

Based on Fig. 2 conclusions can be taken where land development and/or climate change impacts are dominating. Further, a clear ranking of municipalities is possible to avoid emerging risks, either by a modification of land development plans or by developing protective measures.

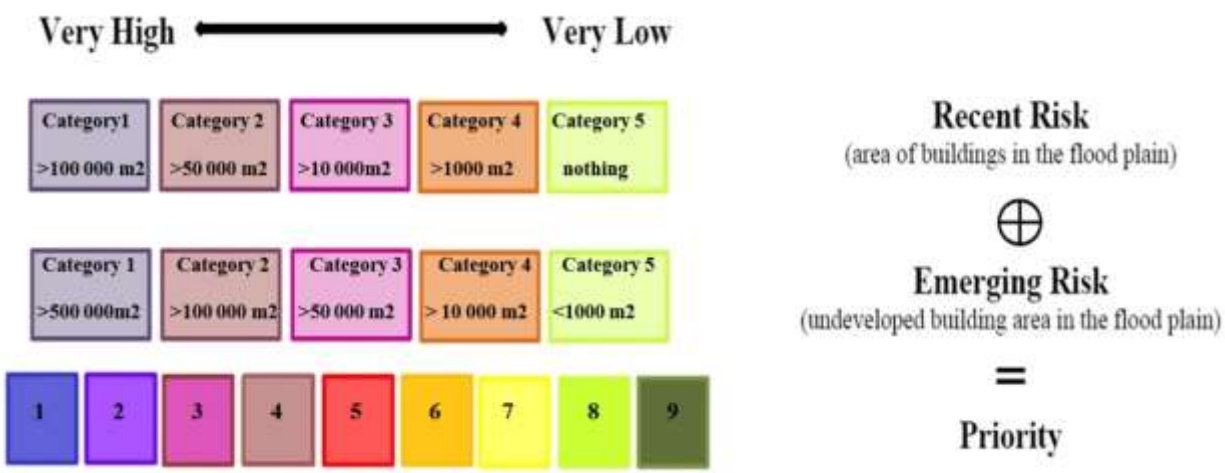


Figure 1. Classification of recent and emerging flood risk

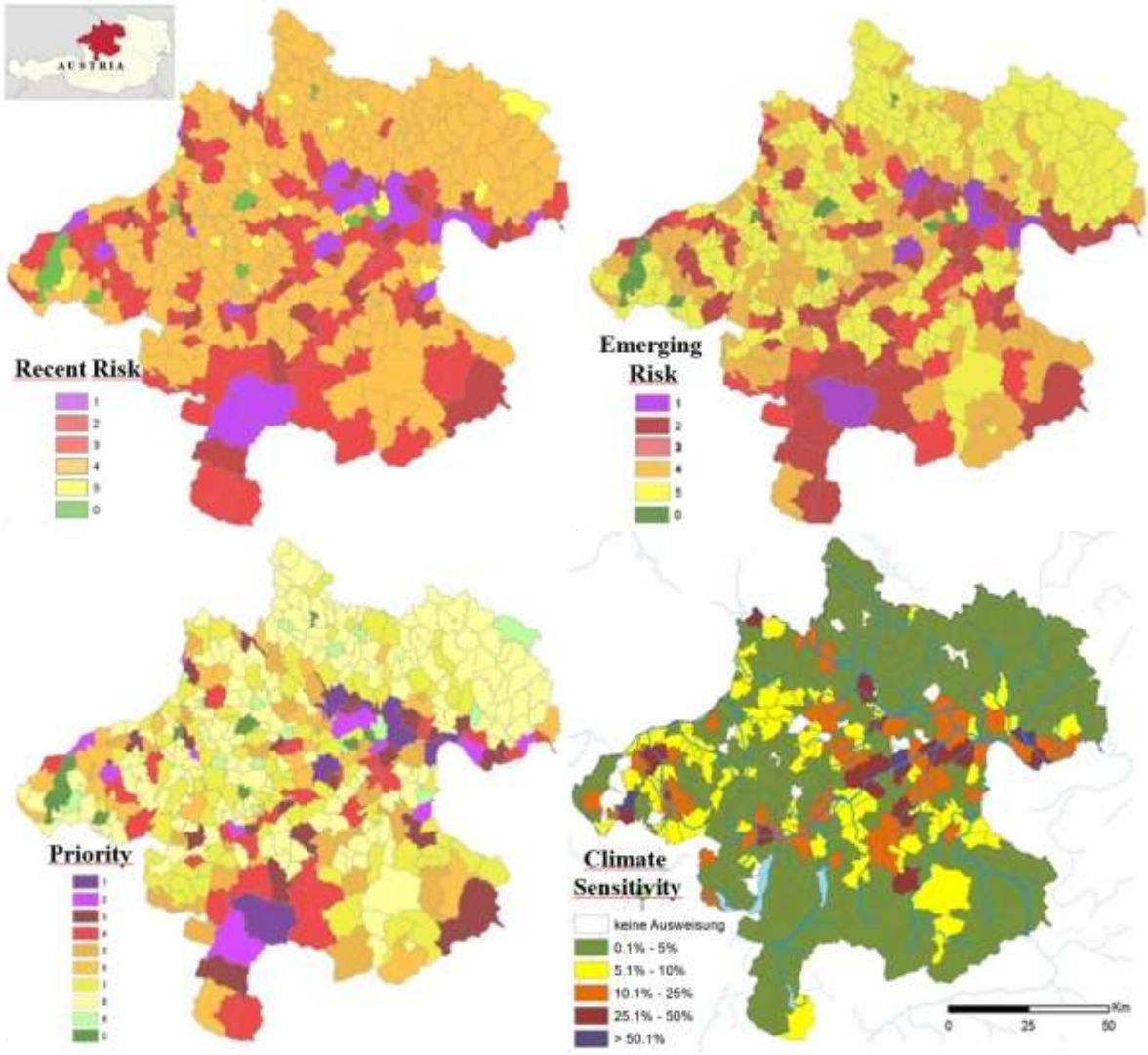


Figure 2. Indicator of recent risk (upper left), indicator of emerging risk (upper right)

Keywords: flood risk assessment, climate sensitivity, risk priorization

A LOOK AT THE POTENTIAL OF REGIONAL PROCESS-ORIENTED LOOK AT BIVARIATE FLOOD FREQUENCY ANALYSIS FROM THE PERSPECTIVES OF ENGINEERING AND COMPARATIVE HYDROLOGY

JAN SZOLGAY [1]

[1] *Department of Land and Water Resources Management, Slovak University of Technology, Slovakia, jan.szolgay@stuba.sk*

Abstract

The seasonality of hydrological characteristics is one of the many vital factors controlling the development and stability of natural ecosystems and determining flood and drought hazards. From a hydrological perspective, seasonality analysis of runoff is appealing for inferring flow generation mechanisms. That, in turn, supports engineering hydrological applications, such as hydrological regionalization of extremes and design values, which are crucial inputs for water resources management, engineering design and landscape planning.

In contrast to studies that primarily focus on the statistical aspects of statistical models, we illustrate here, using comparative analysis, the potential of such an approach in bivariate frequency analysis. We aim to analyse the relationships between flood peaks and volumes, explicitly focusing on flood types by the seasonality of flood generation processes. That leads us to study, instead of the usual approach that deals with an analysis of the annual maxima of flood events, to include an analysis of seasonal flood events. That enables us to distinguish the controls on flood generation represented by their duration and flood wave shapes based on the concept of comparative hydrology. Moreover, we can, rather than modelling a single catchment in detail, regionally compare catchments with contrasting characteristics in order to understand the controls holistically and describe the functioning of climatic controls such as storm type (synoptic and convective storms, rain-on-snow, snowmelt) and catchment controls such as soils, soil moisture, geology, and landform.

From the engineering perspective, the following types of flood processes were considered here in more detail: summer/winter floods, synoptic floods, flash floods and snowmelt floods in illustrative examples. In order to increase the sample size and the homogeneity of the samples for the statistical analysis, hydrologically independent flood events can be isolated and assigned to one of the flood process types. To comply with the IID principle, flood events are proposed to be considered independent when they originate from distinguishably different synoptic/meteorological situations and identically distributed according to the regional flood type.

When applying such an analysis, it is helpful to compare empirical copulas regionally first to verify whether the flood processes considered are discernible regarding the corresponding bivariate flood-peak relationships. Next, the types of copulas frequently used in hydrology can be fitted, and their goodness-of-fit examined in a regional scope. The spatial similarity of copulas and their statistical rejection rate, depending on the flood type, region, and sample size, can be examined, too. The methods are demonstrated in pilot studies of selected regions in Austria, Slovakia and the Czech Republic.

Based on our experience, treating flood processes separately in such way is beneficial, both hydrologically and statistically, since experience shows that flood processes and their relationships are discernible locally and regionally in pilot regions. However, the uncertainties inherent in the copula-based bivariate frequency analysis itself (caused, among others, by the relatively small sample sizes for consistent copula model selection, upper tail dependence characterization and reliable predictions) may not be entirely overcome even in the scope of such regional comparative analysis.

Keywords: flood types, process-based classification, regional analysis, flood peaks, flood volumes, copula models

HYDRAULICS AND HYDRAULIC STRUCTURES

OPTIMIZING MANNING'S ROUGHNESS COEFFICIENT WITH COUPLING SIMULATOR AND OPTIMIZER

KAZEM SHAHVERDI [1], SAEED GOHARI [2]

[1] Assistant Professor, Department of Water Science and Engineering, Bu-Ali Sina University, Hamedan, Iran, k.shahverdi@basu.ac.ir
[2] Assistant Professor, Department of Water Science and Engineering, Bu-Ali Sina University, Hamedan, Iran, s.gohari@basu.ac.ir

Abstract

Hydraulic models have a substantial role in the simulation of rivers due to their high accuracy and low cost. One of the most practical hydraulic models is HEC-RAS capable of simulating all flow conditions in watercourses. Floods occurring in rivers are highly dependent on Manning's Roughness Coefficient (MRC). Its optimization, calibration, and uncertainty analysis are necessary. Different methods, mostly with HEC-RAS as a simulator, have been presented and applied to find an appropriate optimal value for MRC as an important parameter in rivers. MRC is highly variable with time and place affected by many uncertain sources, which makes it a very complicated task. Therefore, an optimization method is needed to find the most appropriate and optimal MRC. The challenging issue is that running HEC-RAS many times to search and find an optimal MRC is time-consuming and impossible manually. To the best of our knowledge, there is no research on linking optimizers with HEC-RAS. The novelty of this research is developing a systematic approach to control HEC-RAS automatically and linking it with an optimizer to run HEC-RAS and optimizer iteratively. Therefore, the main objectives considered are: i) to develop a MATLAB 2019 program to automate HEC-RAS (version 5.0.7), ii) to link HEC-RAS with PSO as an optimizer, and iii) to find optimal MRC using the developed model in the Shahab river in Hamedan province (Iran).
The results showed that the MRC in the three distinguished reaches (from upstream to downstream) were respectively obtained as 0.061, 0.057, and 0.040 in the main channel and 0.069, 0.059, and 0.046 in the floodplain. Comparing the obtained values from optimization and estimated values by traditional methods revealed that the optimal values are lower than the estimated ones. The results of the uncertainty analysis of six hydraulic parameters showed that the uncertainty of the velocity is higher than the others. According to the results, the uncertainty is high, therefore, it is recommended MRC is determined with sufficient accuracy to reduce the financial costs and human losses caused by floods.

Keywords: HEC-RAS, calibration, optimization, river, simulation

EFFECT OF BLOCKAGE ON SCOURING DOWNSTREAM THE CULVERTS

SOMAYEH KARIMPOUR [1], SAEED GOHARI [2]

[1] *Ph.D. student, Department of Water Science and Engineering, Bu-Ali Sina University, Hamedan, Iran, s.gohari@basu.ac.ir*

[2] *Associate Professor, Department of Water Science and Engineering, Bu-Ali Sina University, Hamedan, Iran, s.gohari@basu.ac.ir*

Abstract

Culverts are hydraulic structures constructed under transportation facilities to convey surface runoff and also seasonal runoff from one side to the other side of roads. These structures are commonly used in drainage and water management systems in urban and residential areas. Scouring around culverts and other hydraulic structures is a critical problem that affects their operation and stability The suspended and bed sediment, flotsam and wood transported into the river during a flood event can cause blockage of hydraulic structures. The models of box culvert and circular culvert were made of glass and smoothed pipes, respectively. The laboratory channel (10 m length × 0.5 m width × 0.6 m height) consisted of transparent side walls made of glass plates. The moving bed downstream of the culvert outlet was covered with uniform non-cohesive sand (d_{50} = 2 mm). As a result, this phenomenon leads to local scour downstream of the structures. In this paper, the effect of plugging in the culvert inlet on local scour downstream of the culvert is investigated. While the experiments were carried out using 4 culverts with different shapes and degrees of plugging over a non-cohesive uniform sand bed. The results showed that the shape and number of culverts had a significant effect on the downstream scour volume and the size of the scour hole in clear water. At the same time, the scour dimensions also changed under the different flow conditions. A new experimental relationship was proposed to predict the dimensions of the scour using the collected data sets.

Keywords: culvert barrel shape, culvert capacity, local scouring, blockage

CALIBRATION OF THE XBEACH-GRAVEL MODEL

HANNA MILIČEVIĆ [1], DALIBOR CAREVIĆ [2], DAMJAN BUJAK [3]

[1] Faculty of Civil Engineering, University of Zagreb, Croatia, hanna.milicevic@grad.unizg.hr
[2] Faculty of Civil Engineering, University of Zagreb, Croatia, dalibor.carevic@grad.unizg.hr
[3] Faculty of Civil Engineering, University of Zagreb, Croatia, damjan.bujak@grad.unizg.hr

Abstract

The Croatian east coast of the Adriatic Sea is highly valued for its biodiversity and small, fetch limited gravel beaches, which have been intensively used by humans for centuries. All values can be affected by the current growing tourist demand for beach capacity, which has led to the construction of artificial beaches, especially pocket gravel beaches, along the Croatian east coast without sufficient knowledge of the most suitable parameters for design, as well as natural pressures such as storm events that cause morphological changes (sediment transport). Despite the importance of preserving gravel beaches in Croatia, there is also a lack of knowledge on how the beach can withstand various wave forcings and the frequency of storm events, as well as a lack of dedicated numerical models that predict the morphological response of the beach to storm events.

The results of the BEACHEX research project on the artificial gravel beach Ploče in the northwestern part of the city of Rijeka in Kvarner Bay aim to address this lack through an integrated research approach that includes field surveys (unmanned aerial vehicles) and numerical modeling (Xbeach-Gravel).

This paper summarizes the calibration results of the 1D Xbeach-Gravel model for predicting the response of the gravel beach Ploče to strong wind waves in winter. Two free model parameters related to sediment transport that were used for model calibration are the angle of repose (Φ), which controls avalanching and affects sediment transport on sloping beds, and the transport coefficient (γ), which linearly scales the transport rates and gradients. To evaluate the predictive power of the numerical model, three different values for the sediment transport parameters (Φ- 35°,45°,55° & γ- 0.5, 1, 3) were used to find the combination that is best suited to describe berm formation. The model simulation results show that XBeach-G is able to reproduce the observed change in the cross-shore profile (Figure 1) under different wave conditions with high quantitative accuracy (BSS≥0.6).

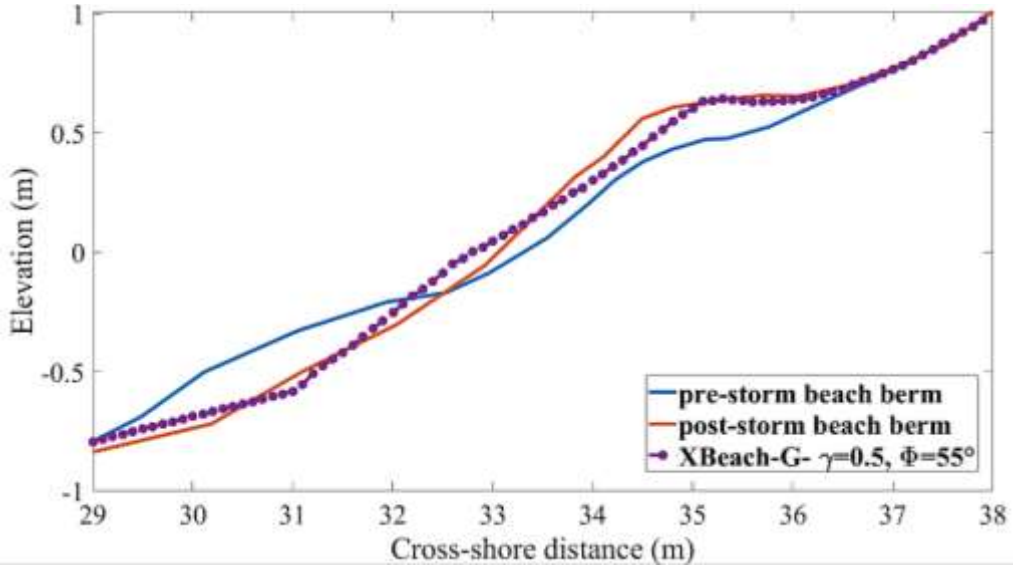


Figure 1. Position and height of the most suitable combination of sediment transport parameters (Φ, γ) for berm formation

Keywords: Xbeach-Gravel, Artificial beaches, Gravel, Modelling, Storm morphology

EFFECT OF DIFFERENT METHODS ON THE MANNING'S ROUGHNESS COEFFICIENT DETERMINATION FOR THE CLOSE TO NATURE FISH PASS

LEA ČUBANOVÁ [1], JÁN RUMANN [1], PETER DUŠIČKA [1]

[1] *Faculty of Civil Engineering STU in Bratislava, Radlinského 2766/11, 810 05 Bratislava, Slovak Republic, lea.cubanova@stuba.sk, jan.rumann@stuba.sk, peter.dusicka@stuba.sk,*

Abstract

Manning's roughness coefficient is a crucial parameter in hydraulic calculations for open channels. Its values are typically listed in tables based on material or vegetation descriptions, providing an initial estimation of channel roughness coefficient. However, its accurate evaluation for hydraulic calculations on hydraulic structures can be challenging.

Nature-like fish passes are a modern preference in fish pass constructions. Achieving the required hydraulic parameters can be a significant problem. A fish pass designed to mimic the natural stream environment enables fish to move upstream and downstream more naturally, reflecting the conditions found in the watercourse. In this type of fish pass, water flow is guided by natural elements such as single stones, also known as perturbation boulders. These boulders serve to decrease velocities and enhance water depths.

Determining Manning's roughness coefficient for close-to-nature fish passes can be challenging, as it may be overestimated to achieve the desired depths and velocities using simple calculation equations. Measurements of hydraulic parameters (discharge, water surface elevation, velocities, and geometric characteristics) were conducted on selected fish passes, and pictures in 1 x 1 m frame were taken for grain size distribution curve analysis. The ImageJ Analyze Parts algorithm was used for the grains (segmented particles) determination. Based on the measurements, roughness coefficients were analyzed using various approaches, including empirical relationships based on the characteristic diameter of the grain, Cowan's method, and the step-by-step method from the measured hydraulic characteristics of the profiles. The values obtained by different approaches indicate a considerable dispersion of the Manning's roughness coefficient.

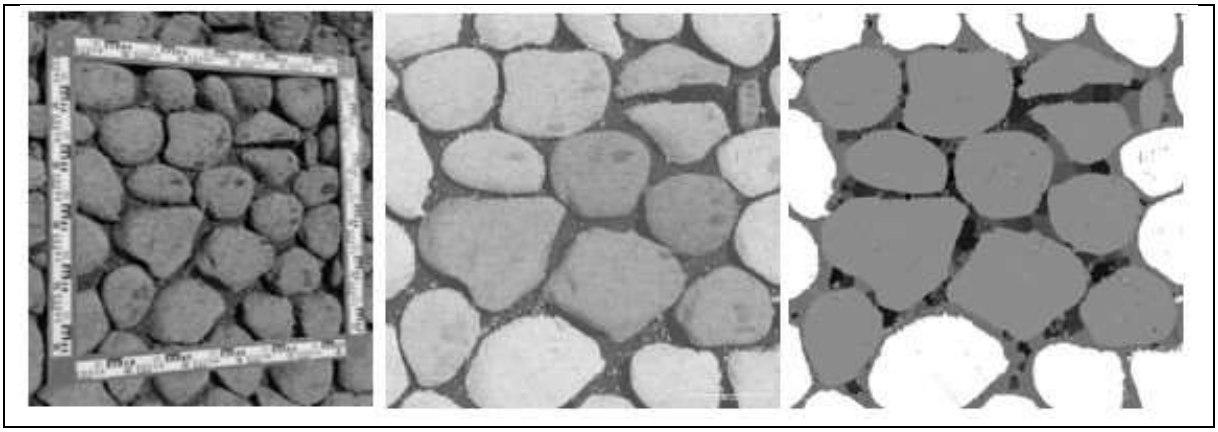


Figure 1. Grain size analysis of a nature-like fish pass riverbed

Keywords: fish pass, in situ measurement, grain size distribution curve, image-processing procedure, Manning roughness coefficient

ANALYSIS OF EXPERIMENTAL FLOW VELOCITY DATA UNDER IMMOBILE BED CONDITIONS NEXT TO BRIDGE PIER

GORDON GILJA [1], LUKA OPAČAK [2], ANTONIJA HARASTI [3], MANOUSOS VALYRAKIS [4]

[1] University of Zagreb Faculty of Civil Engineering, Croatia, gordon.gilja@grad.unizg.hr
[2] University of Zagreb Faculty of Civil Engineering, Croatia, lopacak@student.grad.hr
[3] University of Zagreb Faculty of Civil Engineering, Croatia, antonija.harasti@grad.unizg.hr
[4] Department of Civil Engineering, Aristotle University of Thessaloniki, Greece, mvalyra@civil.auth.gr

Abstract

Bridge piers in rivers locally alter flow conditions in their vicinity, inducing scour and exposing bridge elements to increased loads that can lead to bridge failure. Installing scour countermeasures alleviates immediate hazard to bridge safety but can also induce changes in the riverbed downstream, consequently increasing hazard for adjacent structures. Scour development and flow environment over the scoured riverbed can be simulated experimentally or numerically, depending on the required data extent and data resolution. For this research, hydraulic flume was set up with erodible sand-bed and bridge piers protected with riprap sloping structure. Combinations of flow rates and flow depths was selected to include the flow conditions for incipient motion and below, targeted to investigate the higher order turbulence statistics (turbulent kinetic energy and Reynolds stresses) in the near-bed region that doesn't result in bed change, i.e. that sustains clear-water conditions. Experimental data was measured using the Acoustic Doppler Velocity Profiler (ADVP) in the bed vicinity with 1mm resolution and 100Hz frequency over the 12 min duration. The aim of the paper is to investigate the higher order turbulence statistics associated with immobile bed conditions and compare the differences to incipient motion conditions. The results show that turbulent kinetic energy and Reynolds stresses are positively correlated with flow rate. Once the incipient motion threshold is reached, distinct differences are visible in the velocity profile, and profiles derived from higher-order turbulence data, indicating that conditions close to incipient motion threshold should be approached with caution in order not to introduce bias into clear-water scour investigations.

Keywords: ADVP, bridge pier, turbulence, turbulent kinetic energy, Reynolds stress

ANALYSIS OF EXPERIMENTAL FLOW VELOCITY DATA UNDER MOBILE BED CONDITIONS NEXT TO BRIDGE PIER

GORDON GILJA [1], IVAN ČOLAK [2], ANTONIJA HARASTI [3], MANOUSOS VALYRAKIS [4]

[1] *University of Zagreb Faculty of Civil Engineering, Croatia, gordon.gilja@grad.unizg.hr*
[2] *University of Zagreb Faculty of Civil Engineering, Croatia, icolak@student.grad.hr*
[3] *University of Zagreb Faculty of Civil Engineering, Croatia, antonija.harasti@grad.unizg.hr*
[4] *Department of Civil Engineering, Aristotle University of Thessaloniki, Greece, mvalyra@civil.auth.gr*

Abstract

Bridge piers can directly influence the bed development in their vicinity, causing deposition of the scoured material in the pier shadow and subsequent development of bed features downstream that change the flow pattern. Bridges can be locally protected from scour with larger stones, which in turn increases the turbulence and requires detailed flow investigation to evaluate the effect on the surrounding riverbed. Flow environment can be simulated experimentally or numerically to investigate scour development and hydraulics associated with the scour hole. Numerical data can cover larger extent of the research area, while experimental data can provide more detailed insight into the turbulent flow. This research was conducted in hydraulic flume set up for bridge scour experiments with bridge piers placed in the erodible bed and protected with a riprap sloping structure, targeting to determine flow conditions associated with mobile bed. Experimental data was measured using the Acoustic Doppler Velocity Profiler (ADVP) for a range of boundary conditions - flow rates and flow depths. Combinations of flow rates and flow depths was selected to include the incipient motion condition and above, targeted to collect the difference in near-bed flow that transports bed sediment downstream. The aim of the paper is to investigate the higher order turbulence statistics (turbulent kinetic energy and Reynolds stresses) and the bed elevation change in the near-bed region. The analyzed data is used for comparison with flow measurements in the scour hole vicinity to quantify the increase in the turbulent kinetic energy and Reynolds stresses contributing to scour hole development. The results show that turbulent kinetic energy and Reynolds stresses show distinct patterns, depending on the bed development stage.

Keywords: ADVP, bridge pier, turbulence, turbulent kinetic energy, Reynolds stress

NUMERICAL STUDY OF THE SEA WAVE LOADING ON A VERTICAL PARAPET WALL AND OVERTOPPING

DALIBOR CAREVIC [1], GORAN LONČAR [2], DAMJAN BUJAK[3], STJEPAN VIDOJEVIC[4]

1 Faculty of Civil Engineering, University of Zagreb, Croatia, dalibor.carevic@grad.unizg.hr
2 Faculty of Civil Engineering, University of Zagreb, Croatia, goran.loncar@grad.unizg.hr
3 Faculty of Civil Engineering, University of Zagreb, Croatia, damjan.bujak@grad.unizg.hr
4 Faculty of Civil Engineering, University of Zagreb, Croatia, stjepan.vidojevic@student.grad.hr

Abstract

The pressures along the outer contour of the parapet wall on the vertical breakwater without rubble mound were analysed under the action of spectral (JONSWAP; γ= 3.3, σ_1 = 0.07, σ_2 = 0.09) and monochromatic waves, as well as the overtopping only under the action of spectral waves. Significant wave heights Hs and peak wave periods Tp (Hs = 3 m, Tp = 6.3 s; Hs = 3.5 m, Tp = 6.9 s) for spectral waves, i.e. wave heights H and periods T for monochromatic waves (H = 3 m, T = 6.3 s; H = 3.5 m, T = 6.9 s ; wave steepness L/H = 21), and depths in front of the breakwater (8 m, 6 m and 4 m) were varied as part of the analysis. The slope of the bottom was constant (1:30) in all conducted simulations. The parapet wall was analysed in two configurations, the first with the wall on the outer side of the breakwater and the second with the alignment at the centre of the breakwater.
When the parapet wall is erected in the centre of the structure, the maximum forces increase almost fourfold compared to the forces acting on the parapet wall at the beginning of the structure, and the maximum recorded pressure occurs at the connection between the breakwater cover plate and the parapet wall. The overtopping intensities determined with the numerical model agree with the overtopping calculated on the basis of empirical equations. The results of the analyses show that the overtopping is on average 20% lower in all simulations if the parapet wall is positioned in the centre of the breakwater.

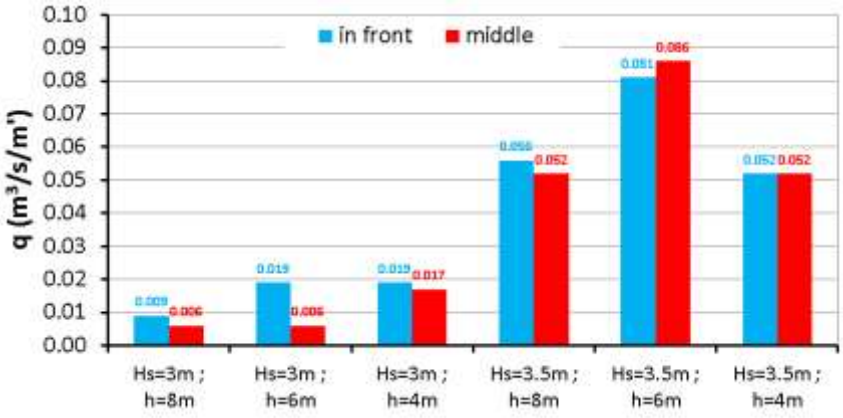


Figure 1. Comparison of the overtopping intensity for the parapet wall on the outer side of the breakwater (wall in front) and with a displacement of 3m (wall in the center)

Keywords: vertical breakwater, parapet wall, wave pressures, overtopping

EFFECTIVE METHODS FOR THE HYDRAULIC ASSESSMENT OF COMBINED FUNCTIONAL STRUCTURES INVOLVING SMALL WATER AND DRY RESERVOIRS

JIŘÍ SKOKAN [1], ALEŠ DRÁB [2], DAVID DUCHAN [3]

[1] *Brno University of Technology, Czech Republic, 212397@vutbr.cz*

Abstract

The paper explores current options for the hydraulic assessment of combined functional structures involving small water and dry reservoirs. The pursuit of cost savings often leads to the use of this type of flow control structure, which can pose significant hydraulic challenges. Economically, experimental research using physical models is typically not feasible for assessing hydraulic designs in such cases. Consequently, the paper primarily emphasizes the use of analytical and numerical calculations.
For a thorough hydraulic assessment of the associated structure, a 3D numerical model was employed, encompassing all components of the structure, including safety spillways, stilling pools, aprons, and bottom outlets. Analytical calculations, coupled with a 1D numerical model, were applied for preliminary designs of the basic dimensions of the structure and comparison with the results of the 3D numerical model. The proposed computational procedures were verified through their application in the design of a dry reservoir in the locality of Kroměříž in the Czech Republic. The visualization of the proposed structure is in Figure 1.
In conclusion, the authors delve into a detailed discussion of the obtained results and provide recommendations for the practical application of these findings in engineering practice and within other research endeavours.

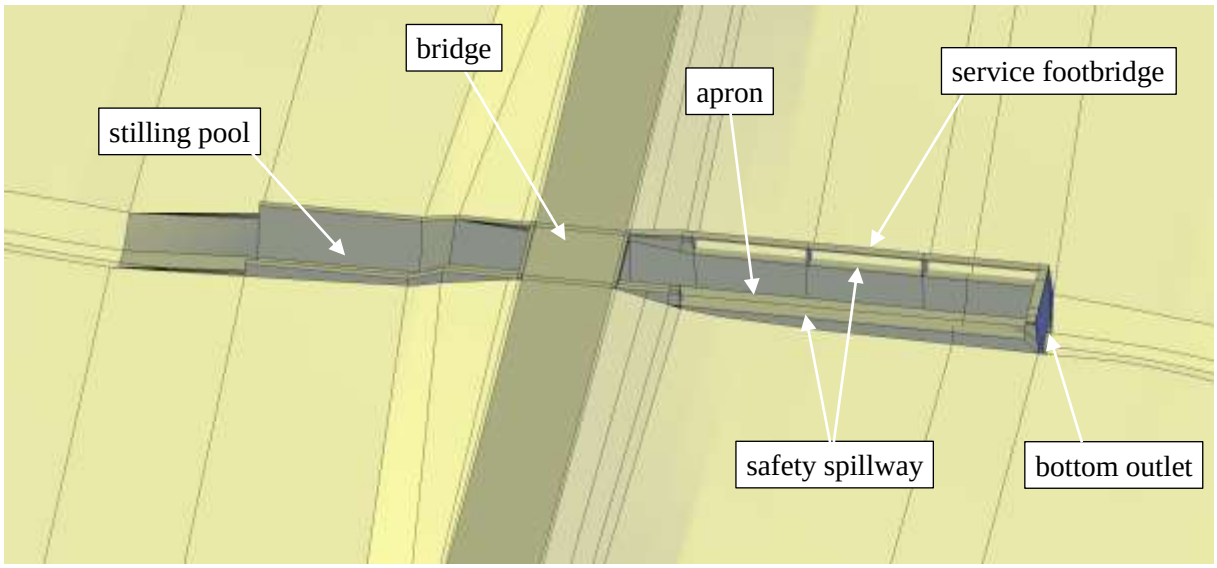


Figure 1. Visualization of the designed hydraulic structure of the dry reservoir

In the conclusion, the authors focus, among other things, on a detailed analysis of the difference in results between the calculation methods used. It was found that in the area of maximum discharges with a return period of 500 years or more, the analytical and 1D numerical calculations are already insufficient and show significantly different results in the water surface elevation, capacity of flow control objects and hydraulic jump evaluation from the 3D model. The differences in the determined capacities of the flow control objects are further reflected in the transformation of the theoretical flood waves. These findings have implications for the assessment of the hydraulic structures for the required level of flood protection according to Czech technical standard CSN 75 2935. Figures 2 to 4 show selected results from the performed calculations. Further significant findings will be presented in the full version of the paper.

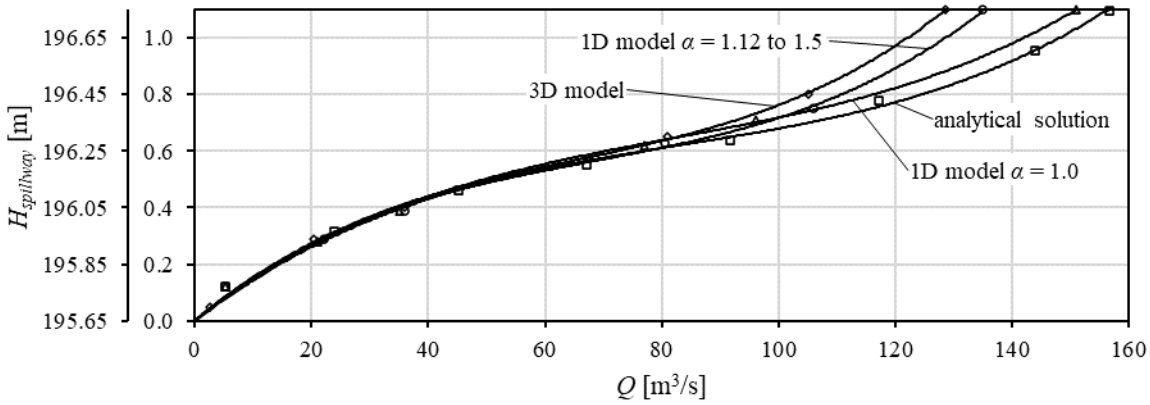


Figure 2. The results of the safety spillway capacity assessment by the proposed methods

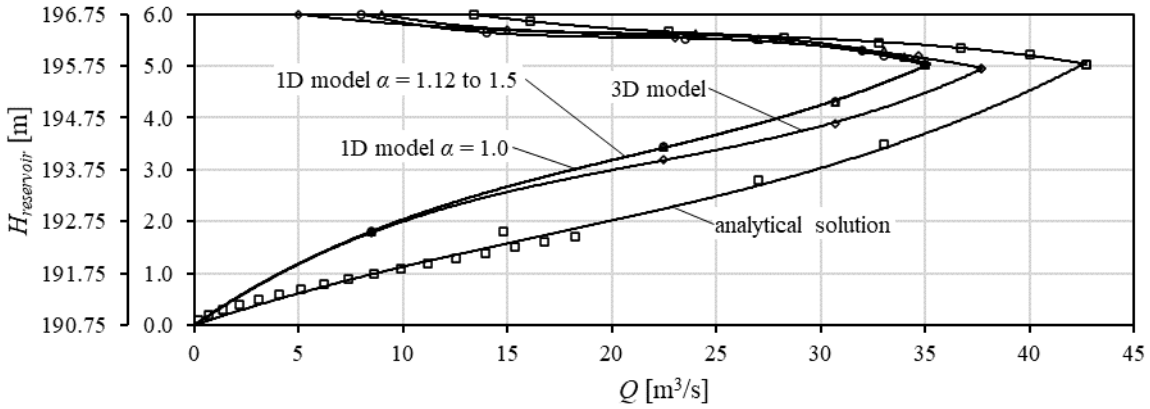


Figure 3. The results of the bottom outlet capacity assessment by the proposed methods

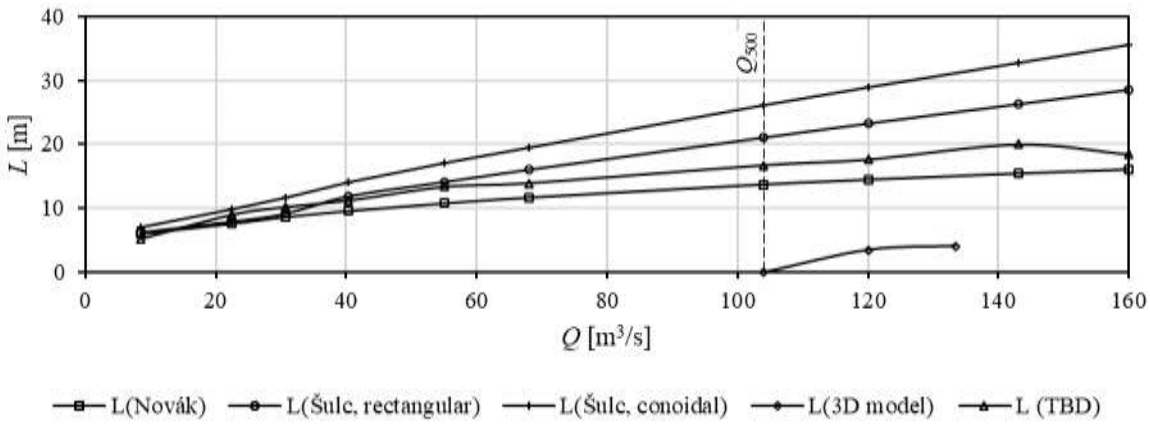


Figure 4. The hydraulic jump lengths evaluated by selected methods

Keywords: dry reservoirs, small water reservoirs, hydraulic structures, flow control objects, 1D model, 3D model, safety, flood wave

This article was elaborated with the support of the project: **FAST-S-24-8513** Analysis of the influence of input variables on the results of numerical models used in the safety assessment of water structures.

NUMERICAL STUDY OF SCOUR HOLE DEVELOPMENT DOWNSTREAM OF RIPRAP-PROTECTED BRIDGE PIERS

ANTONIJA HARASTI [1], GORDON GILJA[2], NIKOLA ADŽAGA[3], MARK ŽIC[4]

[1] University of Zagreb Faculty of Civil Engineering, Croatia, antonija.harasti@grad.unizg.hr
2 University of Zagreb Faculty of Civil Engineering, Croatia, gordon.gilja@grad.unizg.hr
3 University of Zagreb Faculty of Civil Engineering, Croatia, nikola.adzaga@grad.unizg.hr
4 Division of Materials Physics Ruder Boskovic Institute, Croatia, Mark.Zic@irb.hr

Abstract

The erosion of sediment around bridge piers is a common occurrence in river channels. One of the most widely used methods to mitigate the impact of scouring on bridge piers is riprap countermeasure. Riprap protection involves placing launchable stones radially around the bridge pier, extending above the original riverbed level.
This configuration of riprap induces secondary currents, causing the scour hole to move downstream of the toe of the riprap. Thus, the key characteristic of this structure is the occurrence of the scour downstream, in contrast to single piers where scour can be observed at the upstream pier nose.
The aim of this paper is to investigate downstream scour phenomena as a result of riprap placement around bridge pier. Since riprap-protected piers lead to an increase in shear stress and velocity field, these two parameters are numerically evaluated to understand their impact on scour hole development. Sediment transport simulations are conducted using Flow-3D software. To replicate a representative natural fluvial environment, the characteristic geometry of the riprap structure is established in a small-scale flume. The experiments focus on varying different boundary conditions, while characteristic riprap dimensions remain the same. The established numerical model is calibrated based on results from a physical model in the laboratory.
The results shed light on influencing hydrodynamic parameters in scouring process downstream of the riprap protection. Understanding these parameters is important for effectively addressing this relatively unexplored phenomenon. Given that scour around riprap protection presents a global challenge in many regions, the conclusions of this study are aligned with the broader context of scour monitoring in river management.

Keywords: bridge pier, local scour, riprap protection, numerical model, Flow-3D

This work has been supported in part by Croatian Science Foundation under the project R3PEAT (UIP-2019-04-4046).

ESTIMATION OF THE TRANSMISSION COEFFICIENT FOR A Π-TYPE FLOATING BREAKWATER IN THE PRESENCE OF SPECTRAL WAVES AND VARIABLE DEPTH

DAMJAN BUJAK [1], ANTONIJA TOPIĆ [2], DALIBOR CAREVIĆ [3], HANNA MILIČEVIĆ [3]

[1] University of Zagreb, Faculty of Civil Engineering, Croatia, damjan.bujak@grad.unizg.hr
[2] Hidroing Osijek, Croatia, antonija.topic@hidroing-os.hr
[3] University of Zagreb, Faculty of Civil Engineering, Croatia, dalibor.carevic@grad.unizg.hr
[4] University of Zagreb, Faculty of Civil Engineering, Croatia, hanna.milicevic@grad.unizg.hr

Abstract

The harbor area plays a crucial role in maritime traffic, port management, and ensuring navigational safety, making it essential to adequately protect this area. Floating breakwaters are frequently employed to safeguard harbors and ships in ports, particularly in partially sheltered areas like the eastern Adriatic coast. Consequently, it is essential to thoroughly assess the transmission of wave energy beneath the floating breakwater.

The objective of this research is to assess the precision of the formula proposed by Ruol et al., 2013 for estimating the transmission coefficient of wave energy. We examine the behavior of a π-type floating breakwater in the presence of spectral waves. Moreover, an examination of the influence of water depth on the transmission coefficient in wave transmission is included.

A series of measurements were undertaken in a wave flume, employing a 1:21 scale model of a π-type floating breakwater. The parameters of the incident and transmitted waves were measured using a total of eight measuring probes. The transmission coefficient was determined based on the measured significant wave height in front of and behind the floating breakwater.

The analysis of data has indicated that an elevation in water depth leads to a corresponding rise in the transmission coefficient. It was found that the formula proposed by Ruol et al., 2013 underestimates measurements by 25% for small values of T_p/T_h ($1.0<T_p/T_h<1.20$) across all water depths. In cases where T_p/T_h values are larger ($1.30<T_p/T_h<1.60$) and depths are shallow, the formula tends to overestimate by 15%. Nevertheless, the formula proves to be highly accurate when exploring greater depths in the same T_p/T_h range. Ultimately, a polynomial expression was formulated to establish the relationship between the peak wave period, the breakwater's natural heave oscillation, and the transmission coefficient measured in this study.

Keywords: floating breakwater, wind waves, transmission coefficient, sheltering harbors, marinas

A WATER FLOW MODELS CALIBRATION USING HEURISTIC METHODS

PETER ŠULEK [1]

[1] *Department of Hydraulic Engineering, Faculty of Civil Engineering,*
Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia;
peter.sulek@stuba.sk

Abstract

Currently, the water flow models play a significant role in various phases of the design, reconstruction, and operation of hydraulic structures. The water flow models provide an estimate of water behavior during its flow directly on/in objects or in their vicinity, rather than representing their entire reality, because hydraulic models are susceptible to various sources of uncertainty.
Uncertainties have various causes: the complexity of dynamic phenomena, uncertainties in model structures, and uncertainties in the input data and parameters of these models. Model parameters can be static (e.g., pipe roughness) or dynamically changing over time or space (e.g., bed roughness).
Parameters of the water flow models can be estimated based on empirical experience or field measurements analysis, or their combination. Calibration of a water flow model is a process that adjusts model parameters to minimize differences between simulation results in the model and actual measurements.
Due to the complexity of water flow issues (a large number of parameters subject to spatiotemporal change), the determination of model parameters by the "trial and error" method is methodically complicated and time-consuming. From this perspective, heuristic methods appear suitable for solving such problems.
The aim of the paper is to explore the possibilities of using heuristic methods (especially evolutionary algorithms, i.e., search methods guided by a certain strategy, suitable for solving problems for which there is no adequate specific algorithm or straightforward numerical method).

Keywords: water flow models, calibration, heuristic methods, evolutionary algorithms

EXPERIMENTAL AND NUMERICAL MODEL FOR ANALYSIS OF THE WATER HAMMER IN PUMP WATER SUPPLY SYSTEM

GOCE TASESKI [1], NIKOLA KRSTOVSKI [2], …

[1] Faculty of Civil Engineering Skopje, N. Macedonia, taseski@gf.ukim.edu.mk
2 Faculty of Civil Engineering Skopje, N. Macedonia, nikolatudence@gmail.com

Abstract

Water supply systems as complex systems are most often analyzed hydraulically in practice, by assumed quasi-steady flow regime. In general, hydraulic regime in all water supply systems is unsteady, but very often in planning, the hypothesis of quasi-steady regime is justified. However, in water supply systems with pumping plants, their switching on and off leads to a state of transient hydraulic regimes. In such transient regimes the phenomenon of water hammer occurs, which causes sudden increase or decrease of flow and pressure in sections and/or in the entire water supply system. Water supply systems in such transient regimes should be hydraulically analyzed by means of basic equations for unsteady flow. For the needs of this research, by using the method of characteristics, a custom mathematical model HTM (Hydraulic Transient Model) is developed for the purpose of water supply network analysis in conditions of unsteady flow, i.e. with this mathematical model, the characteristics of the water hammer in closed systems for water transport under pressure can be seen. In addition, physical model in ratio 1:1 has been made for in-situ analyses of pressure change in occurrence of water hammer in the water supply system, by which this methodology applied in field research, according to the configuration, dynamics and measuring equipment are author's original and innovative ideas.

Starting points in the mathematical description of the water hammer are the basic equations in fluid mechanics:

- Law of maintaining the amount of movement and
- Law of maintaining weight

The method of characteristics exceptionally solved both positive and negative pressure waves and has remained one of the widely applied methods. Therefore, the method of characteristics has been proven in the research so far as a method of exceptional compatibility with numerical solutions and the same one is applied in this research. By the method of characteristics, the basic partial differential equations which are not integrable in closed form are transformed in ordinary differential equations which have solution in closed form.
The mathematical model HTM is created in a way that it can analyze water supply system only in unsteady regime. The steady regime which dominates in the system before the occurrence of the unsteady state is taken from already made up-to-date software packages for analysis of systems under pressure.
For the calibration of the mathematical model HTM in this research, suitable measuring equipment has been made and built-in at certain critical places of the real water supply system, which is actually physical model in ratio 1:1. The real water supply system is a pumping water supply system where the quantity of water being pumped is firstly distributed into the water supply network and then into the tank – pumping system with tank beyond an inhabited place. The water supply network is of branching system and all of it is carried out from polyethylene pipes (HDPE pipes). A characteristic of this water supply system is that the distribution of the consumers – households is at a large difference in height, i.e. from the minimum peak elevation of 724 m up to the maximum of 810 m, while the maximum water level in the tank is 824 m, i.e. such water supply system has a hydrostatic pressure from 14 to 100 m.
From the analysis of water supply network, terrain configuration, distribution of consumers and geometrical characteristics of the lines, the need for selection of a total of twenty measuring places emerged, by which entire coverage of network was provided.

As it was previously mentioned in this paper, the need for this research was imposed by the fact to find

out reasons for occurrence of defects in real water supply system which is subject to analysis. Namely, in the analyzed system from the very beginning of its exploitation of sections with small pressures, frequent occurrence of defects has been noticed (part in measuring device M-7), and defects of the pumping system pipeline near the pump station (M-1) have started appearing later.

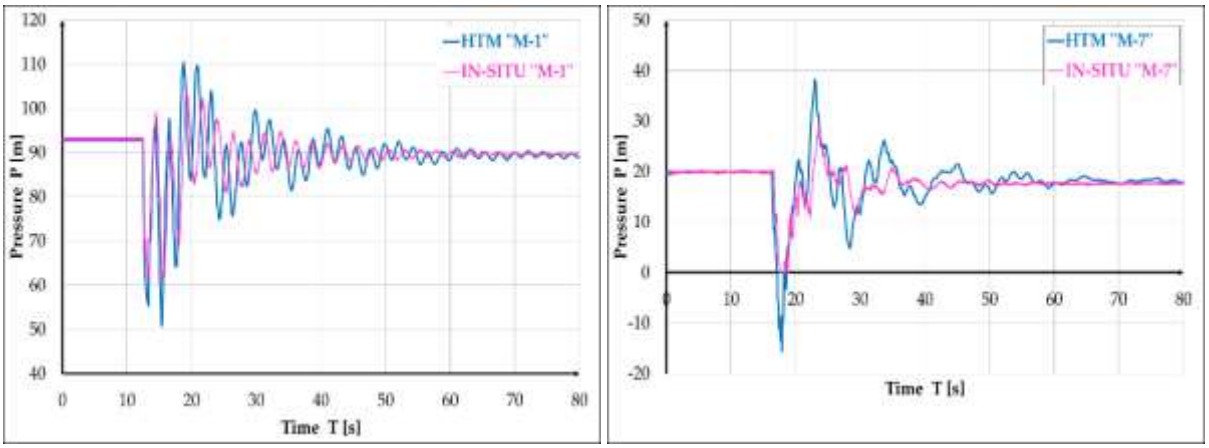


Figure 2. Characteristics of water hammer, experimental from performed in-situ measurements and analytical from HTM model during pump switching off

From the aspect of hydraulic analysis, water supply systems where occurrence of water hammer is expected should be analyzed and dimensioned in such manner that they can be "adjusted" to both steady and unsteady flow regime. This recommendation should especially be respected in water supply systems in which in the exploitation phase there is even slightest possibility of water hammer occurrence, such as pumping water supply systems with reservoirs beyond inhabited place, i.e. as the analyzed system in this research. Actually, as it can be seen from the results in this research of the subject, it is significant to analyze the locations with increased pressure, but also the locations with minimum pressures in order to avoid occurrence of vacuum in these sections.

Keywords: Water supply system; water hammer; mathematical model (HTM); experimental (in-situ) model

VEGETATION EFFECTS ON FLOW CHARACTERISTICS AND SEDIMENT STORAGE IN A LOWLAND RIVER CHANNEL OVER TIME

SAEID OKHRAVI*, VALENTÍN SOČUVKA, RADOSLAV SCHÜGERL, MAREK SOKÁČ, RENÁTA DULOVIČOVÁ, YVETTA VELÍSKOVÁ

Institute of Hydrology, Slovak Academy of Sciences, Dúbravská cesta 9, 84104, Bratislava, Slovak Republic
**Corresponding author: Saeid.okhravi@savba.sk*

Abstract

Vegetation significantly influences fluvial system dynamics and plays a central role in river management. This study specifically examines in-channel aquatic macrophytes, both submerged and emergent, which are vital components of many lowland river ecosystems. In-channel vegetation increases local and boundary flow resistance [1,2], traditionally viewed as problematic due to increased energy losses [2]. Consequently, mean velocity decreases, limiting the river channel's capacity to convey discharge, potentially heightening flood risks by increasing depth [2]. This study emphasizes addressing the resistance aspect of aquatic vegetation in fluvial hydrodynamics, particularly in areas where vegetation reduces the river's conveyance capacity.

Studies on vegetated river flows have typically examined the impact of vegetation on flow velocity profiles and stress distributions, both in fully vegetated beds and around patches of vegetation [1,2]. Researchers have scrutinized the influence of vegetation elements, whether rigid or flexible, as sources of drag within water flow, employing laboratory experiments [3] and numerical modeling [4] to understand vegetation-flow interactions and analyze flow fields, particularly velocity profiles and turbulence [1], as well as energy loss [2]. Initially, they have developed methods to predict drags of aquatic vegetation based on characteristics such as plant form, morphology, size, height and density of vegetation patches [1,5]. This is crucial for facilitating parameterizations of aquatic vegetation-induced flow resistance. One aspect of interactions among vegetation, river flows and transported sediments that has received little research attention is their contribution to within-channel storage of relatively fine sediment, potentially crucial in understanding the sediment budget of river reaches and catchments [6]. Our focus lies on in-channel vegetation and its effects on flow and sedimentation changes over years, aiming to evaluate sediment storage within the active channel of a lowland river.

This study uses measured data from a 4-kilometer reach of the Gabčíkovo-Topoľníky channel in south-western Slovakia. This reach includes four uniformly spaced cross-sections: two upstream and two downstream of a bridge location prone to accumulated vegetative debris (Fig. 1). Field velocity measurements were performed using the SonTek RiverSurveyor-M9 during two field visits in 2018 and 2023. Analysis of bathymetric data and streamwise velocity distribution was conducted to examine sediment storage changes across the reach over time. Measured and calculated hydraulic parameters for the corresponding years are summarized in Tables 1 and 2. The relevant parameters are: flow depth h, river width w, wetted area A and perimeter P, hydraulic radius R, longitudinal slope of water surface S_f, flow velocity u, shear velocity u_*, flow discharge Q, area of fine sediment A_s (the area between the base and the surface level of fine sediment in each river cross-section - Fig. 2), Froude number Fr, and roughness coefficients n.

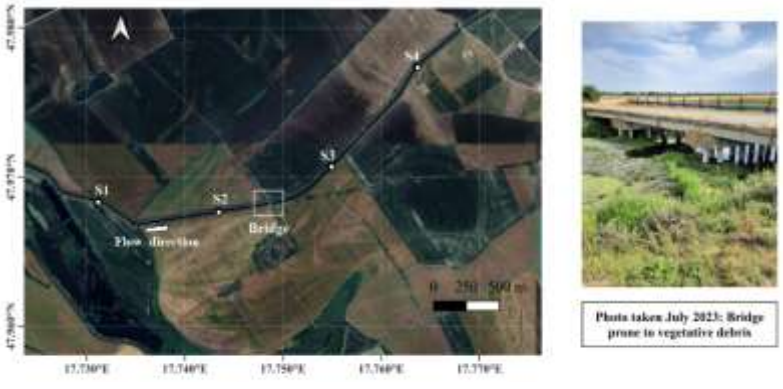


Figure 1. Location of four cross-sections at the Gabčíkovo-Topoľníky channel

Despite the complexity of flow-vegetation interactions, the representation of the vegetation in predictive equations commonly relies on semi-empirical formulas (e.g., the Manning or Darcy-Weisbach equations). The results showed the decrease in total discharge and section-averaged velocity in 2023, attributed primarily to denser vegetation in 2023 compared to 2018, where cross

sectional geometric shapes maintained almost unchanged along the river reach (Fr and R remained nearly constant for each corresponding section). This led to changes in the Manning coefficient values ($n_m = R^{2/3} S_f^{1/2}/u$) and the one developed ($n_r = 0.32 q^{*-0.978}$) under the previous research work of the authors [2], where $q^* = \left(Q/w\right)/\sqrt{gR^3 S_f}$. It is worth noting that n_r indicated a good fit compared to n_m estimations, despite a 20% underestimation.

Table 1. Hydraulic parameters of four selected cross-sections: May 2018 measurements

Sections	h (m)	w (m)	A (m^2)	P (m)	R (m)	S_f	u (m/s)	u_* (m/s)	Q (m^3/s)	A_s (m^2)	Fr	n_m	n_r
S1	1.49	16	22.41	18.73	1.20	0.000038	0.120	0.021	1.88	2.73	0.035	0.08	0.07
S2	1.41	16.5	21.36	19.10	1.12	0.000014	0.115	0.012	1.90	2.54	0.035	0.04	0.04
S3	1.57	14.5	21.77	17.85	1.22	0.000016	0.103	0.014	1.93	1.75	0.03	0.05	0.04
S4	1.76	17.0	27.03	20.13	1.34	0.000053	0.090	0.026	2.00	2.47	0.025	0.12	0.10

Table 2. Hydraulic parameters of four selected cross-sections: June 2023 measurements

Sections	h (m)	w (m)	A (m^2)	P (m)	R (m)	S_f	u (m/s)	u_* (m/s)	Q (m^3/s)	A_s (m^2)	Fr	n_m	n_r
S1	1.59	16.5	25.25	19.4	1.3	0.000092	0.062	0.034	1.39	3.62	0.017	0.21	0.17
S2	1.48	15.5	20.86	18.35	1.14	0.000057	0.061	0.025	1.31	2.62	0.018	0.13	0.11
S3	1.60	14.5	22.15	17.89	1.24	0.000066	0.064	0.028	1.69	2.62	0.018	0.12	0.10
S4	1.70	17.0	27.23	20.14	1.35	0.000043	0.044	0.023	1.47	3.27	0.012	0.15	0.12

Patches of aquatic vegetation can impact the sedimentation process by creating areas of reduced flow velocity through the capture of flow momentum [1], thereby promoting sedimentation. A similar pattern can be observed when comparing the corresponding values of A_s in each cross-section. The rate of increase in A_s could be as high as 50% (S3 in Tabels 1&2 and Fig. 2) due to the presence of vegetation and the resultant lower velocity. This points to the role of aquatic vegetation in influencing sediment storage [6], primarily through the retention and stabilization predominantly sand and finer sediments within the channel. The findings of our study indicate significant retention of fine sediment (0.001-2 mm) by aquatic vegetation in the Gabčíkovo-Topoľníky channel, which are important insights for prediction of sediment budgets and river functioning. Future research will extend to assess fine sediment proportions retained by aquatic vegetation over larger river reaches and time frames.

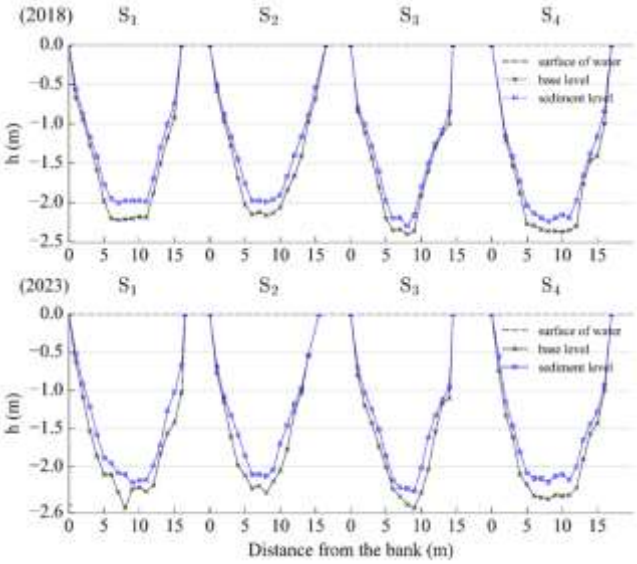


Figure 2. Four river cross-sections (S1-S4) in 2018 and 2023

Keywords: River, Aquatic vegetation, Flow characteristics, Velocity distribution, Sediment storage

References

[1] Marjoribanks, T.I., Hardy, R.J., Lane, S.N. (2014). The hydraulic description of vegetated river channels: the weaknesses of existing formulations and emerging alternatives. Wiley Interdiscip. Rev.:Water, 1(6), 549-560.
[2] Okhravi, S., Schügerl, R., Velísková, Y. (2022). Flow resistance in lowland rivers impacted by distributed aquatic vegetation. Water Resour. Manage., 36(7), 2257-2273.
[3] Zhang, J., Zhong, Y., Huai, W. (2018). Transverse distribution of streamwise velocity in open-channel flow with artificial emergent vegetation. Ecol. Eng., 110, 78-86.
[4] Anjum, N., Tanaka, N. (2019). Numerical investigation of velocity distribution of turbulent flow through vertically double-layered vegetation. Water Sci. Eng., 12(4), 319-329.
[5] Vargas-Luna, A., Crosato, A., Uijttewaal, W.S. (2015). Effects of vegetation on flow and sediment transport: comparative analyses and validation of predicting models. Earth Surf. Processes Landforms, 40(2), 157-176.
[6] Gurnell, A.M., Bertoldi, W. (2022). The impact of plants on fine sediment storage within the active channels of gravel-bed rivers: A preliminary assessment. Hydrol. Processes, 36(7), e14637.

ANALYSIS OF THE 2D HYDRAULIC EQUATIONS FOR THE FISH PASS MODELING

ALEXANDRA VIDOVÁ [1], LEA ČUBANOVÁ [1]

[1] *Faculty of Civil Engineering STU, Department of Hydraulic Engineering, Radlinského 2766/11, 810 05 Bratislava, Slovakia, alexandra.vidova@stuba.sk, lea.cubanova@stuba.sk*

Abstract

A 2D mathematical model is used to simulate water flow in two-dimensional space. The most common software is used the U.S. Army Corps of Engineers, Hydrologic Engineering Center's River Analysis System (HEC-RAS). The calculation is based on mathematical equations which describe basic physical principles such as the conservation of momentum and energy, which have the greatest influence on the results. Another possibility of the software is the possibility of turbulence modeling, which brings the calculation closer to the real state. It is also necessary to choose a suitable computing time step for the correct modeling of the computing network, that means the Courant criterion must apply. This criterion is very important during creating mathematical model because it determines the stability of the computation. The performed model allows to simulate the water flow in different conditions. From the modelled results, we can analyse many hydraulic parameters. Then comparing these parameters with the measured values from the field a calibrated model can be obtained. Parameters, such as velocities and depths, are the most important by the fish pass design, because they affect the functionality of the fish pass, it means its passability for fish and ichthyofauna. By analysing the results, we can evaluate the expected efficiency of the fish pass and propose structural changes even in the project phase before its construction, which is also cheaper, or we can design modification of existing one if calibrated model is available. Mathematical modeling of fish passes is challenging due to the need for precise geometric descriptions of the internal environment, detailed computational meshing, and compliance with the Courant criterion for time step selection. Choosing the appropriate mathematical procedure for detailed modeling within fish pass facilities is a key task in achieving more accurate results. Comparing 2D and 1D approach, a 2D model is more time-consuming than a 1D model but produces more accurate results. Such mathematical modeling can be used not only for fish passes, but also for the assessment of various situations, such as floods, channel flow or for the design of hydraulic structures and for each problem the proper governing mathematical equations must be used.

Keywords: fish pass, HEC-RAS, 2D model, shallow water equations, diffusion wave equations, Courant number

ASSESSMENT OF VELOCITY DISTRIBUTION AND TURBINE POWER OUTPUT IN WATER COURSES

BOJAN ĐURIN [1*], MARIO SVRTA [1], FARHAD BAHMANPOURI [2], SILVIA BARBETTA [2], TOMMASO MORAMARCO [2]

[1]*University North, Department of Civil Engineering, 42000 Varaždin, Croatia. bojan.durin@unin.hr, masvrta@unin.hr*
[2]*Research Institute for Geo-Hydrological Protection, National Research Council (CNR), 06128 Perugia, Italy. farhad.bahmanpouri@irpi.cnr.it, silvia.barbetta@cnr.it, tommaso.moramarco@cnr.it*

Abstract

This research outlines a comprehensive analysis of river velocity data utilizing entropy models for prediction and metrics of the velocity distribution. The analysis will be based on an actual case study of the locations of rivers in Croatia. For the Plitvica example, the Acoustic Dopler Velocity Meter (ADV) provided field measurements, as seen in Figure 1.

Figure 1. Field measurements of the river velocity

The distribution of velocity based on the entropy method along the verticals can be defined as (Bahmanpouri et al., 2022, a, b):

$$U(x_i, y) = \frac{U_{\max v}(x_i)}{M} \ln\left[1 + (e^M - 1)\frac{y}{D(x_i) - h(x_i)} \exp\left(1 - \frac{y}{D(x_i) - h(x_i)}\right)\right] \quad i = 1...N_v \quad (1)$$

Where U is the time-averaged velocity, $U_{maxv}(x_i)$ is the maximum value of U along the ith vertical, x_i is the distance of the ith sampled vertically from the left bank, $h(x_i)$ is the dip, i.e., the depth of $U_{maxv}(x_i)$ below the water surface, $D(x_i)$ the flow depth, y is the distance of the velocity point from the bed, and N_v is the number of verticals sampled across the river section. M is the entropic parameter and can be calculated using the linear entropic relation (Bahmanpouri et al., 2023):

$$U_m = (\frac{e^M}{e^M - 1} - \frac{1}{M})U_{max} = \phi(M)U_{max} \quad (2)$$

U_{max} surmises the maximum value of $U_{maxv}(x_i)$ sampled in the cross-sectional flow area.

Figure 2 shows the estimation of the cross-sectional velocity distribution for the river Plitvica.

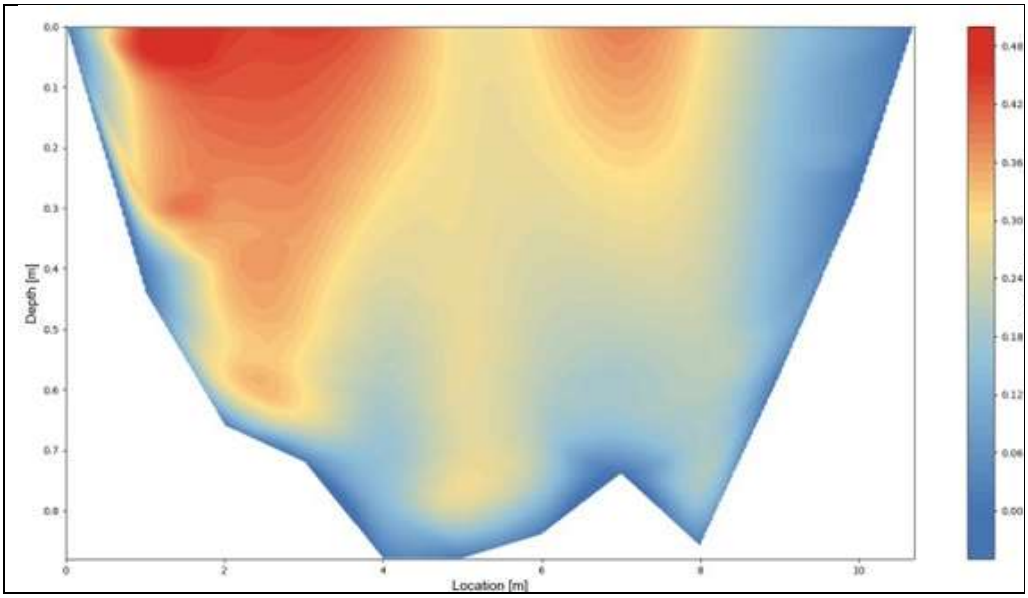


Figure 2. Velocity distribution in the cross-profile section of the river Plitvica

Leveraging linear regression techniques and rigorous evaluation metrics facilitates accurate velocity predictions, fostering a deeper understanding of river dynamics and facilitating informed decision-making in water management.

Keywords: River velocity, Data analysis, Entropy, Model evaluation, Prediction

References

Bahmanpouri, F., Barbetta, S., Gualtieri, C., Ianniruberto, M., Filizola, N., Termini, D., & Moramarco, T. (2022). Prediction of river discharges at confluences based on Entropy theory and surface-velocity measurements. *Journal of Hydrology*, *606*, 127404.

Bahmanpouri, F., Eltner, A., Barbetta, S., Bertalan, L., & Moramarco, T. (2022). Estimating the Average River Cross-Section Velocity by Observing Only One Surface Velocity Value and Calibrating the Entropic Parameter. *Water Resources Research*, *58*(10), e2021WR031821.

Bahmanpouri, F., Lazzarin, T., Barbetta, S., Moramarco, T., & Viero, D. P. (2023). Estimating flood discharge at river bridges using the entropy theory. Insights from Computational Fluid Dynamics flow fields. *Hydrology and Earth System Sciences Discussions*, *2023*, 1-29.

ASSESSMENT OF VELOCITY DISTRIBUTION AND TURBINE POWER OUTPUT IN WATER COURSES

BOJAN ĐURIN [1*], MARIO SVRTA [1], MOSÈ ROSSI [2], MARKO ŠRAJBEK [3]

1University North, Department of Civil Engineering, 42000 Varaždin, Croatia. bojan.durin@unin.hr, masvrta@unin.hr
2 Department of Industrial Engineering and Mathematical Sciences, Marche Polytechnic University, Via Brecce Bianche 12 – 60131 Ancona, Italy, mose.rossi@staff.univpm.it
3 Department of Water Research, Faculty of Civil Engineering, University of Zagreb, Fra Andrije Kačića-Miošića 26, 10000 Zagreb, Croatia, marko.srajbek@grad.unizg.hr

Abstract

This study analyzes velocity distribution and turbine power output within a hydrodynamic system for rivers in Croatia. An example of the data acquired from the location ‘’Dedin mlin’’ along the Plitvica River using Acoustic Doppler Velocimetry (ADV) will be presented in Figure 1. The linear regression method calculates the velocity distribution based on depth and location parameters. In fluid flow and hydrokinetics, a velocity of 0.5 (m/s) is often considered a low limit because available energy is limited, making it challenging to generate significant power [2], Figure 2.

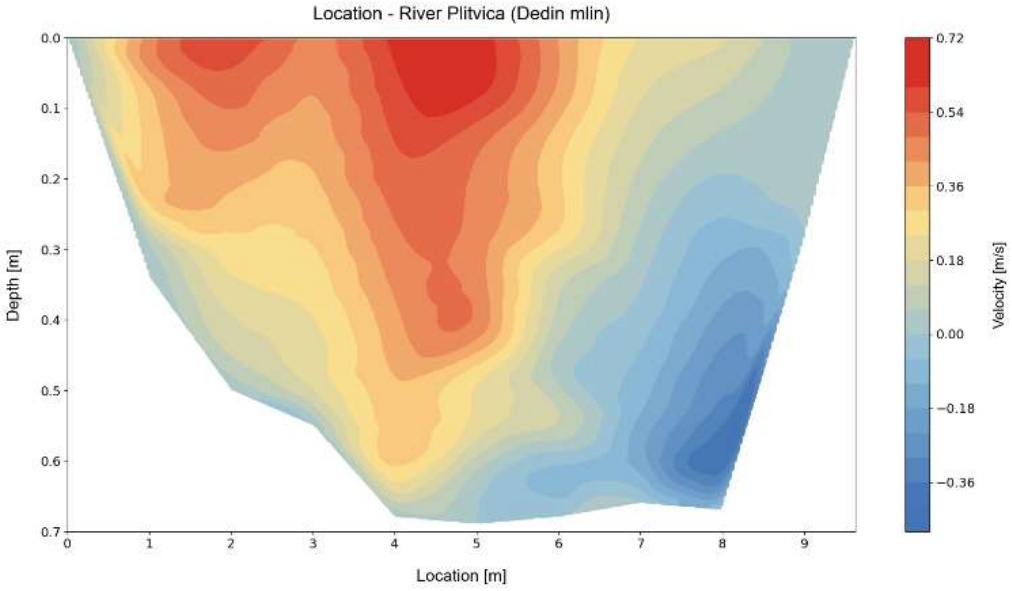


Figure 1. Velocity distribution is based on linear regression

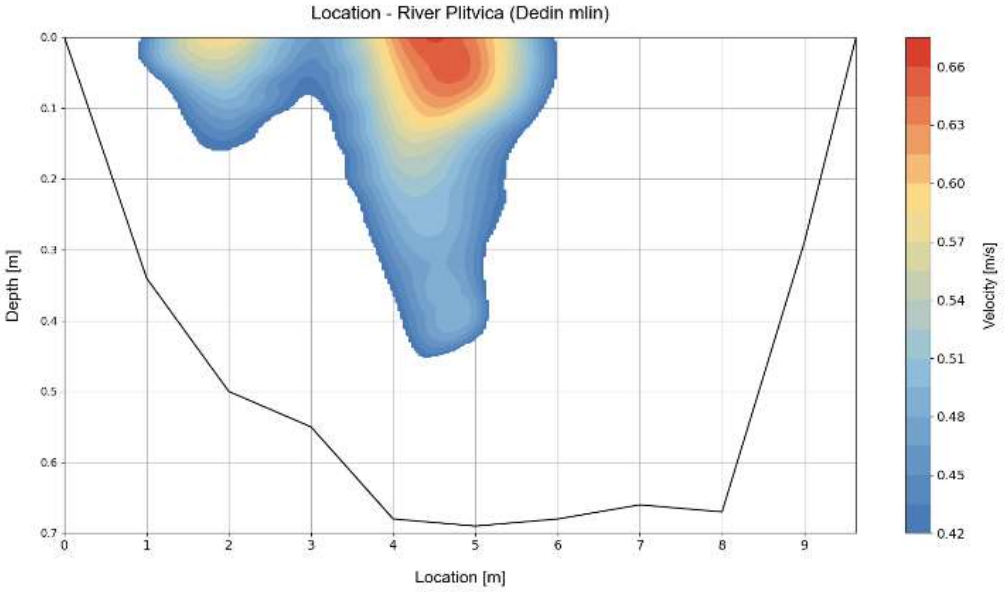


Figure 2. Velocity distribution average higher than 0.5 m/s

The power equation for a turbine harnessing fluid kinetic energy is expressed as:

$$P = \frac{1}{2} \cdot \rho \cdot A \cdot v^3 \cdot \eta \qquad (1)$$

where P represents the turbine power (W), ρ is the fluid density in kilograms per cubic meter (kg/m^3), A is the cross-sectional area of the flow in square meters (m^2), v is the fluid velocity in meters per second (m/s), and η denotes the turbine efficiency, between 0 and 1.

From Mask regions where the predicted velocity is higher than 0.42 m/s, the mean velocity is 0.5 m/s for an area of 1.09 m^2, with a flow rate of 0.55 m^3/s and a maximum power of 20.96 W. Such a power is relatively small but should be considered a shallow river with small flows and velocities. Various numerical modeling tools are available to simulate the flow around HK turbines [2].

Keywords: River velocity, Data analysis, Entropy, Model evaluation, Prediction

References

[1] Kirke, Brian. "Hydrokinetic Turbines for Moderate Sized Rivers." Energy for Sustainable Development 58 (October 2020): 182–95. https://doi.org/10.1016/j.esd.2020.08.003.

[2] Gunawan, Budi, Vincent Neary, Josh Mortensen, and Jesse Roberts. "Assessing and Testing Hydrokinetic Turbine Performance and Effects on Open Channel Hydrodynamics: An Irrigation Canal Case Study.," May 1, 2017. https://doi.org/10.2172/1367421.

MATHEMATICAL MODEL FOR THE ANALYSIS OF UNSTEADY FLOW DURING A PRESSURE PIPELINE BREAK USING THE METHOD OF CHARACTERISTICS

GOCE TASESKI [1], NIKOLA KRSTOVSKI [2], …

[1] *Faculty of Civil Engineering Skopje, N. Macedonia,* taseski@gf.ukim.edu.mk
[2] *Faculty of Civil Engineering Skopje, N. Macedonia,* nikolatudence@gmail.com

Abstract

The occurrence of unsteady flow in pressure systems is a very common phenomenon characterized by secondary occurrences of significant flow and pressure oscillations in the pipeline. Such phenomena are usually characterized by the appearance of certain irregularities in the functioning of the pipeline and not infrequently cause defects in the pipeline and even large-scale accidents, especially in parts of the pipeline where a vacuum occurs.

The goal of developing a mathematical model to analyze the occurrence of non-stationary flow is to conduct an analysis of an existing pressure pipeline - specifically, a siphon from an irrigation system in Macedonia. In this system, when a defect occurs in the pipeline, particularly in the section experiencing the highest pressure, the phenomenon of non-stationary flow arises - creating a significant vacuum within the pipeline, leading to a massive breakdown. Specifically, this concerns a steel pipeline with a diameter of D=1640 mm, operating at a maximum working pressure of 8.2 bar in the lowest part of the siphon. When non-stationarity occurs, a substantial negative pressure (vacuum) emerges, resulting in complete destruction of the pipeline over a length of 500 m (see figure 1). It should be noted that air valves are installed on the pipeline at all high points, which fail to cover the need for air to prevent the vacuum when the non-stationary flow occurs.

Figure 1. Pipeline break under pressure - siphon caption heading

When creating the mathematical model for unsteady flow, the basic differential equations were used:

- Dynamic equation – equation of motion and
- Continuity equation

For which the method of characteristics was used for transforming the basic partial differential equations, which are not integrable in closed form, into ordinary differential equations that have closed-form solutions. The basic equations, the continuity equation, and the dynamic equation, through linear combination, yield a system of two partial differential equations, which are transformed into a system of four ordinary differential equations and define straight lines.

In addition to the basic boundary conditions for this pipeline, such as the inlet and outlet channels, air valves, and changes in the thickness of the pipeline, a fundamental condition for a proper and accurate hydraulic model is the choice of the time step for the analysis. This choice determines whether the lines of positive and negative characteristics from the connected pipes will intersect at a single point. In this analysis, the approach of decreasing the time step is used, which in a way forces the characteristic lines to intersect at a single point. It is also important to note that in the section where the pipeline rupture occurs, a boundary condition is applied, such as a sudden valve opening.

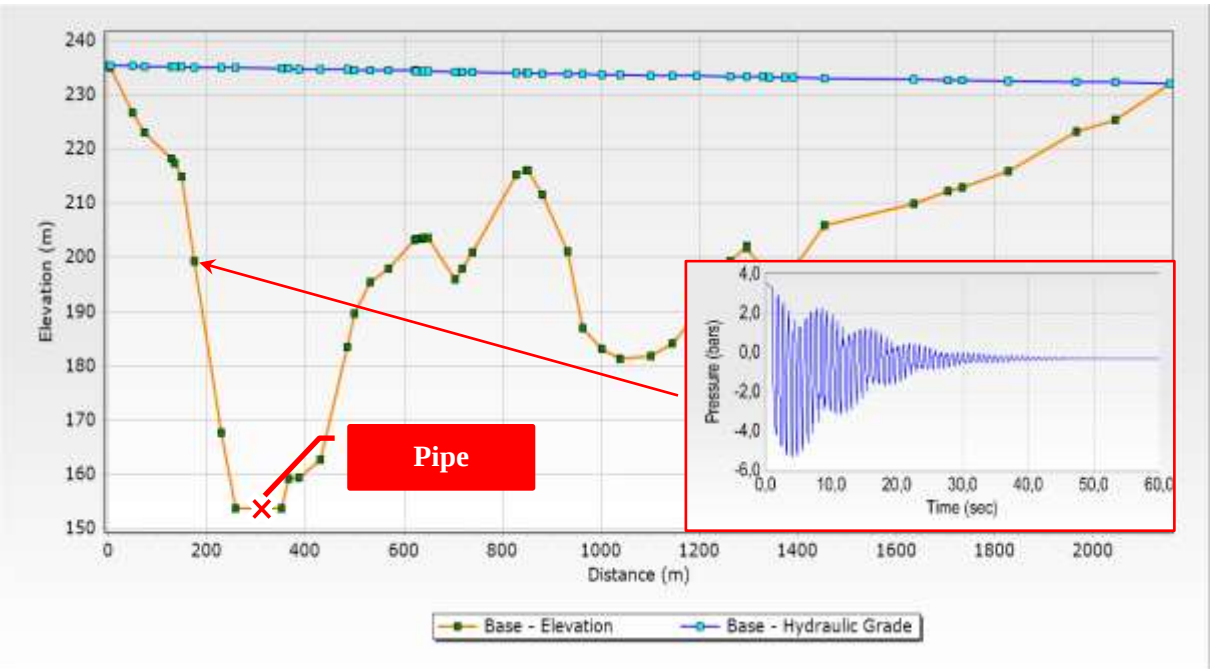


Figure 2. Profile of Syphon Makaria – extract from the hydraulic model with pressure change during pipeline break

According to the results obtained from the mathematical model, it can be concluded that the occurrence of non-stationary flow because of the pipeline breakdown induces a vacuum of such magnitude that cannot be eliminated by the installed air valves. Consequently, the pipeline cannot withstand this negative pressure, leading to its failure. It is understood that during the pipeline's design phase, no one expected such a phenomenon to occur during its operational phase, which itself indicates that the system functioned for 50 years without any issues.

Keywords: method of characteristics, unsteady flow, pressure pipeline, negative pressure

WATER RESOURCES MANAGEMENT AND HYDROLOGY

WATER MANAGEMENT IN ARID REGIONS UNDER CLIMATE CHANGE

SHAMSHODBEK AKMALOV [1,2], TATIANA KALETOVA [1]

[1] *Slovak University of Agriculture in Nitra, Slovakia, tatiana.kaletova@uniag.sk*
[2] *"TIIAME" National Research University, Uzbekistan, shamshodbekjon@mail.ru*

Abstract

Arid regions are distinguished by their dry and hot climate. In these areas, water demand and water scarcity is always very high. Especially in the current climate change condition, this shortage is clearly felt by countries. In addition, arid regions are economically developing countries (mainly due to the agriculture and export of agricultural products) and the population is sharply increasing with comparing to other regions. This, in turn, leads to an even more intense attitude towards water. The main water consumer and waster in the region is agriculture. To rationally organize water management and to properly organize measures to prevent water wastage, it is necessary to analyse current climatic and demographic changes with effective methods and develop plans for the adoption of water management to these changes.

The main objective of the study is to analyse the impact of different climatic and demographic factors on water discharge and water use, in order to obtain important information that will guide water managers in adapting to climate change.

The area of interest is Karakalpakistan and Kharezm located in southwestern part of Uzbekistan. There were analysed a hydrological data of Amudarya River (income and outgoing part in Uzbekistan), meteorological and demographic data of the research area for 40 years. Different statistical tools were used to analyse long-term changes of these data and correlation with each other's. To avoid errors in the research, the water discharge data of the Kyziljar (located in upper stream of river) and Darganata (located lower stream of river) hydrological stations were used. A statistical correlation was made between the discharge, the meteorological data from the Nukus meteorological station and an analysis of the demographic growth.

According to the population statistics, from 1980 to 2020 population of Uzbekistan increased by average 1% each year (1980 y.- 15.8 million inhabitants, 2020 y. – 32.12 million inhabitants). The air temperature of the region increased by 1.33 °C in 40 years, and correspondingly, precipitation decreased by 14.2 mm. The water discharge decreased by 111 m^3/s in the upstream of the river and 269.78 m^3/s in the downstream of the river (Fig.1).

Due to the increasing population and the warming of the climate, the discharge of water and their use is decreasing year by year. This can be explained by the decreasing amount of water, the salinization and desertification of many agricultural lands in the region (Fig. 2).

Precipitation in all cases has a positive weak correlation with water discharge (0.33) and water use indicators (0.35), temperature and population growth have a weak negative correlation with water discharge (-0.12) and water use (-0.27). This shows that the decreasing of precipitation, increase of temperature and the increasing of population lead to a decreasing of water discharge and available water use. The level of weak connectivity means that delaying factor and the impact of human activities like construction of hydrotechnical facilities along the river, is huge and it should be considered in the future action.

Therefore, in this region, where the water shortage is very high, such indicators pose a great threat to water management. Our analysis showed that the situation will become more complicated if the adaptive system of water management is not developed in these regions. In particular, it is necessary to regulate the use of water in agriculture and widely implement the use of water-saving technologies. The results of our research serve as important information for water management specialists and organizations.

Keywords: water, climate change, arid regions, Uzbekistan, hydrology, population

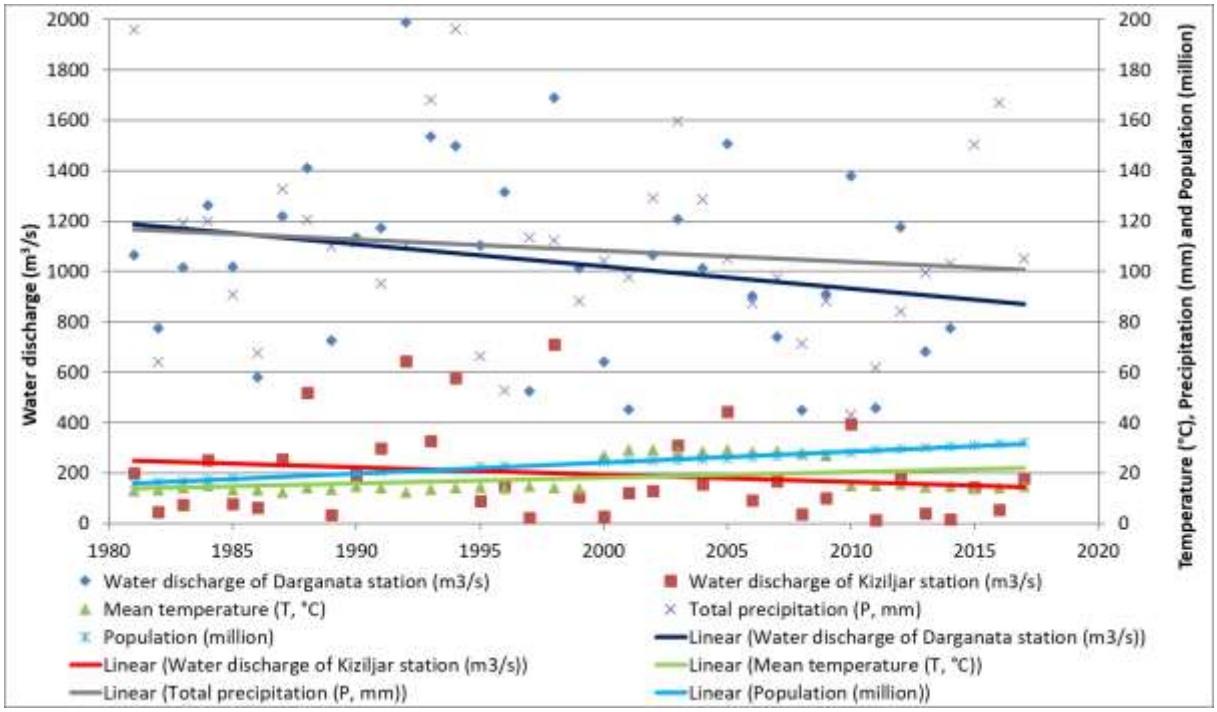


Figure 1. Analyse results of water discharge, population, and climatic factors for Amudarya River.

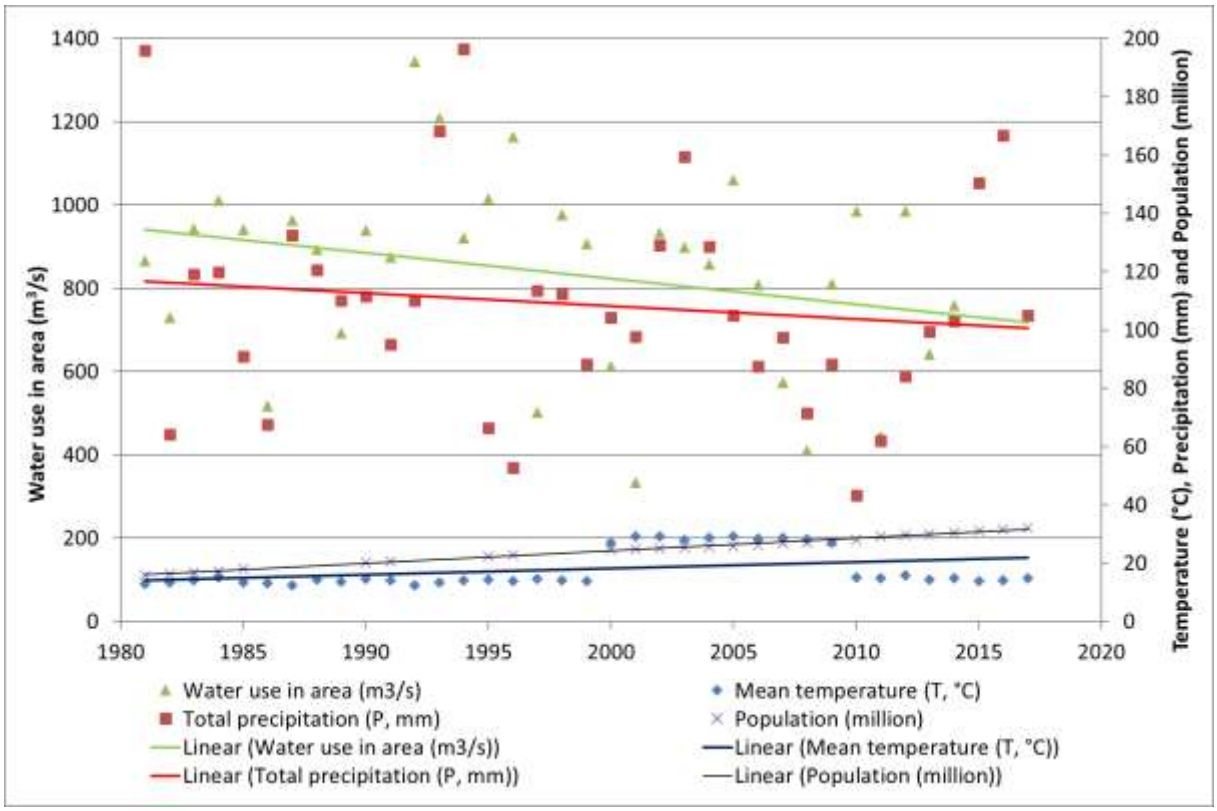


Figure 2. Water use degree and climate factors

PREDICTION OF MONTHLY FLOW BY SUPERVISED LEARNING ENSEMBLE CHAIN MODELS

JADRAN BERBIĆ [1], EVA OCVIRK [2]

[1] *Technical High School Šibenik, Croatia, jberbic@hotmail.com*
[2] *Faculty of Civil Engineering, University of Zagreb, eva.ocvirk@grad.unizg.hr*

Abstract

The objective of the work is twofold: improve modeling procedure of mean monthly flows prediction and find the appropriate way to treat small hydrological dataset, with less than 800 samples. Mean monthly flow is of particular importance for long-term planning in water resources management, therefore, simplified and robust procedure could be of benefit for both practitioners and researchers. The applied methodology generally consists of the following steps: 1. Dataset preparation, inspection and split, 2. Data analysis and treatment, 3. Selection of features, 4. Choice of models, 5. Optimization of model hyperparameters and creation of final model, 6. Evaluation of model. The emphasis of the work is on the 4th and 5th step, while the other steps will be covered briefly. Dataset was split into training, calibration and verification parts in ratios 40, 15 and 45 %. Chosen models are artificial neural network (ANN), support vector machine (SVM), histogram gradient boosting regressor (HGBR) and elastic net (EN). All models are supervised learning models, applied in chain modeling procedure, where 6 successive mean monthly flows are predicted based on 18 features (climatological data and data describing the periodicities of flows) with 16 successive steps – 12 of which are past steps and 6 are future steps corresponding to the months of 6 predicted flows. Totally 288 variables were used as input. Genetic algorithm (GA) has been applied to select optimal model hyperparameters of each model due to the criteria of minimizing scaled root mean squared error. Afterwards, models with optimized hyperparameters were combined into different ensembles in order to maximize performance on calibration part of the data. The analysis was made by using training and calibration parts, while verification part was left unused, in order to avoid leakage of any information to the model and modelers. The work is the continuation of previous research in which the accuracy of ANN and SVM were exhaustively analysed (Berbić et al., 2017) followed by development of hyperparameter optimization procedure by GA and simulated annealing (Berbić et al., 2022). The mean monthly flow from hydrological station Vinalić (Cetina river, Croatia) is predicted based on climatological variables observed at near-by stations (meteorological station Knin – precipitation and temperature, precipitation station Vinalić – precipitation, and climatological sation Sinj – temperature, DHMZ, 2017) and flow periodicities calculated by fast Fourier transformation as proposed for time series forecasting (Abadi et al., 2015). All procedures are developed in Python environment, by using scikit-lean library (Van Rossum and Drake, 2009).

Keywords: ensemble learning, chain models, supervised learning, mean monthly flow, genetic algorithm

References

Berbić J, Ocvirk, E, Gilja G. (2018) Comparison of Supervised Learning Methods for Prediction of Monthly Average Flow, Građevinar 70(8), 643-656

Berbić J, Ocvirk E, Gilja G (2022) Optimization of supervised learning models for modeling of mean monthly flows, Neural Comput & Applic 34, 17877–17904

DHMZ - Croatian Hydrological and Meteorological Service (2017) Hydrological Database, HIS 2000

DHMZ - Croatian Hydrological and Meteorological Service (2017) Relational Meteorological Database

Abadi M, Agarwal A, Barham P, Brevdo E, Chen Z., Citro C., ... & Zheng X. (2015) TensorFlow: Large-scale machine learning on heterogeneous distributed systems, arXiv preprint arXiv:1603.04467

Van Rossum G and Drake FL (2009) Python 3 Reference Manual, Scotts Valley, CA: CreateSpace.

Pedregosa F, Varoquaux G, Gramfort A, Michel V, Thirion B, Grisel O, Blondel M, Prettenhofer PP, Weiss R, Duborg V, Vanderplas J, Passos A, Cournapeau D, Brucher M, Perrot M, Duchesnay É (2011) Scikit-learn: Machine Learning in Python, Journal of machine learning research 12(85), 2825-2830

RELIABILITY OF STANDARD RAIN GAUGE PRECIPITATION MEASUREMENTS IN RELATION TO LYSIMETER OBSERVATIONS

ANDREJ TALL [1], BRANISLAV KANDRA [2], DANA PAVELKOVÁ [1], MILAN GOMBOŠ [1]

[1] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, tall@uh.savba.sk*

Abstract

Reliable precipitation measurement is important for hydrological, climatological and agricultural purposes. A common way to measure precipitation is by using a standard tipping-bucket rain gauge. It is a simple, affordable and relatively reliable method of measurement. However, the shape, size and height of the rain gauge installation tend to be the source of various systematic and random errors. In recent years, many high-precision weighable lysimeters have been put into operation. The construction of modern lysimeters made it possible to achieve an unprecedented accuracy of precipitation measurement. This study compares two methods of measuring precipitation in the conditions of the humid continental climate of the Eastern Slovakian Lowland (Slovakia): measurement using a standard tipping-bucket rain gauge vs. precision weighable lysimeter. The experiment was carried out at the lysimeter station in Petrovce, which is operated by the Institute of Hydrology of the Slovak Academy of Sciences. Lysimeter measurements were chosen as the reference measurement method due to the higher sensitivity of the lysimeter measurement (0.01 mm versus 0.1 mm) and the much larger lysimeter capture area (10,000 cm^2 versus 200 cm^2). The tipping-bucket rain gauge used is not heated, so only liquid precipitation was compared. The comparative experiment lasted 4 years (2019 to 2022) with three winter breaks. The comparison showed that the tipping-bucket rain gauge underestimates the rainfall compared to the lysimeter. Cumulative precipitation for the entire monitored period captured by the rain gauge was 2.8% lower compared to lysimeter measurements. When comparing hourly and daily totals of precipitation and precipitation events, a very high degree of agreement was detected (Fig. 1). A comparison based on precipitation intensity showed a decreasing trend in measurement accuracy with increasing precipitation intensity. The results show a relatively high reliability of precipitation measurements using standard tipping-bucket rain gauges, when measuring liquid rainfall.

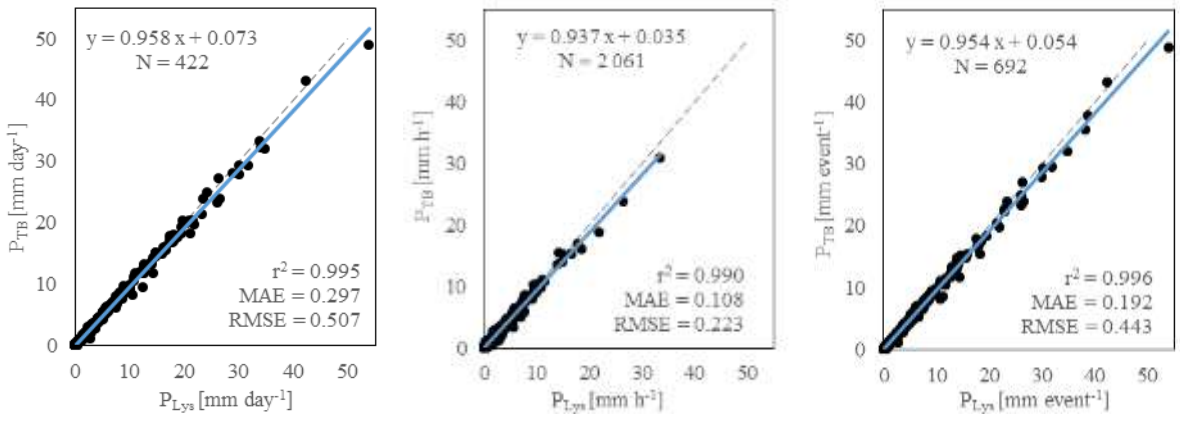


Figure 1. Relationship between precipitation data obtained by tipping-bucket rain gauge (P_{TB}) and lysimeter (P_{lys}) on a daily and hourly basis and on a precipitation event basis (dashed is 1:1 line).

Keywords: precision weighable lysimeter, tipping-bucket rain gauge, precipitation measurement, rainfall intensity

ANALYSIS OF SELECTED SOIL WATER BALANCE MEMBERS OBTAINED BY CALCULATION AND LYSIMETRIC MEASUREMENT

BRANISLAV KANDRA [1], ANDREJ TALL [1], MILAN GOMBOŠ [1] DANA PAVELKOVÁ [1]

[1] *Institute of Hydrology, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava, Slovakia, kandra@uh.savba.sk*

Abstract

Measurements of soil water balance members by modern equipped lysimeters and numerical simulations by mathematical models belong to modern and effective methods of time-space quantification of hydrological processes in the system atmosphere - plant cover – soil unsaturated zone - groundwater. The evaporation from the soil and plants - actual evapotranspiration is a crucial element and energy regulator in this system. The information about the evaporation amount and intensity through plants and soil during the growing season is crucial for agricultural production, water management in the country and the design of adaptation arrangements. Measuring evapotranspiration under natural conditions is a complex process. It can be realized using modern lysimeters. Actual evapotranspiration calculated by numerical simulation on mathematical models needs to be verified via lysimeter measurements.

For the stated reasons, the contribution is focused on the analysis of actual evapotranspiration, precipitation and dew hourly totals as well as water flow totals at the soil unsaturated zone lower boundary and changes in the specified soil volume moisture. The obtained measurements were used for the numerical simulation results verification on the mathematical model.

The methods used were based on the hypothesis that the moisture change dynamics in the soil unsaturated zone result from interactions in the system atmosphere - plant cover - soil unsaturated zone - groundwater. Water balance members were obtained using lysimeter measurements, numerical simulations on the mathematical model HYDRUS-1D in version 4, and expressed via balance equation. The investigated water balance members were measured and calculated during 2017, 2018 and 2020 with hourly and daily time steps.

The results show that evapotranspiration exceeded precipitation totals in all observed periods by 22 % in 2017, 14 % in 2019 and 10 % in 2020. The resulting deficit was supplemented by groundwater and water storage in the soil unsaturated zone. The verification showed that the numerical simulation is inaccurate towards the measured flows at the soil unsaturated zone lower boundary. This inaccuracy was manifested in the form of higher actual evapotranspiration, which was exceeded by 12 % on average. Based on the results, the used model performance is evaluated as satisfactory for the soil water regime analysis in the East Slovak Lowland conditions.

Keywords: lysimetric measurement, soil water regime, actual evapotranspiration, soil unsaturated zone, numerical simulation, soil water balance

THE NUMERICAL MODELLING OF DAM RESERVOIR SILTATION CYCLES: THE CASE STUDY IN ALGERIA

BESSENASSE MOHAMED

University Blida1, Algeria, mbessenasse@yahoo.fr

Abstract

In Algeria, catchment erosion and siltation rates are high enough to significantly reduce the water volumes that can be used for reservoirs. The total capacity of the dams managed by the National Agency for Dams and Water Transfers is estimated to be 6.2 billion cubic meters (Bm3) while the silted volume is estimated at 700 million cubic meters (Mm3), which is about 12%. A numerical model that can simulate the deposition in a reservoir as a function of the hydrologic regime is detailed. Flow propagation and sediment deposition rely on two dimensions shallow water equations coupled to an advection-diffusion equation for suspended sediment transport.
The model was applied to Zardezas reservoir located in Northern Algeria for the period from 1975 to 1986. Because of a lack of some data, the sediment inputs were defined using a simplified way while the water inputs are estimated from the peak flow discharges of the main floods and the daily discharges. The calculated elevation of the reservoir bottom reflects a correct trend although some details cannot be simulated. Therefore, this model can be used for reservoir management or for the design of new reservoirs.

Keywords: Numerical model, flood hydrograph, sediment, dam, Algeria.

A HOLISTIC APPROACH TO THE ASSESSMENT OF E-FLOW UNDER THE CLIMATE CHANGE IMPACT IN DATA - LIMITED RIVER BASIN

GORANA ĆOSIĆ-FLAJSIG[1*], BARBARA KARLEUŠA[2], IVAN VUČKOVIĆ[3], MATJAŽ GLAVAN[4]

[1] Zagreb University of Applied Sciences, Department of Civil Engineering, Croatia, E-mail: gcflajsig@tvz.hr
2 University of Rijeka, Faculty of Civil Engineering, Croatia, barbara.karleusa@uniri.hr
3 Elektroprojekt Consulting Engineers Section of Ecology, Croatia, ivan.vuckovic@elektroprojekt.hr
4 University of Ljubljana Biotechnical Faculty, Department of Agriculture, matjaz.glavan@bf.uni-lj.si
** Corresponding author: gcflajsig@tvz.hr*

Abstract

The obligation to define environmental flow (E-flow) in the European Union Water Framework Directive (WFD) is not explicit, and the implementation of WFD is more focused on water quality. However, the environmental goals achievement is guaranteed by appropriate flow, sediment regime, and hydromorphology. Given the specific climatic, hydrographic, and hydrological conditions and the definition of the E-flow, most EU countries have developed procedures for investigating and determining the E-flow. No methodology has been developed for determining the E-flow in the Republic of Croatia. No legal regulation defines the E-flow downstream of a dam or water intake.

The case study of E-flow assessment under the climate change impact is the transboundary rural Sutla River basin between Croatia and Slovenia, downstream of the dam Vonarje. The "biological minimum" downstream of the dam Vonarje was defined in the 1980s, as a flow of 120 l/s. Using the holistic approach (first without implementing the impact of climate change), the E-flow for the profile on the Sutla River was defined by linking sediment and nutrient pressures, hydrological, hydraulic, morphological, and ecological characteristics based on the research of the Sutla River and its biological communities. The final determined E-flow of 0.68 m³/s is the result of the E-flow assessment based on the developed innovative holistic approach presented in the paper "An Innovative Holistic Approach to an E-flow Assessment Model" (Ćosić-Flajsig et al., 2020). The selection of biological indicator fish species Barbus balcanicus, and accompanying fish species downstream of the dam was important because the entire Sutla River is protected as a NATURA 2000 site. The E-flow obtained by the hydrological method in the vegetation period, which amounts to 0.504 m³/s, had to be increased to 0.68 m³/s to meet the requirements of Barbus balcanicus and enable the normal functioning of the ecosystem. Barbus balcanicus spawns between April and June, and during spawning a water depth greater than 40 cm and a water velocity greater than 49 cm/s are required.

Further research aims to determine the next step, which is the impact of climate change on the holistically assessed E-flow by modeling low flows, sediment, total N, and total P under eight future climate change scenarios, using Indicators of Hydrological Alterations (IHAs) and biological indicators for the Sutla River downstream of the dam. The model is based on an analysis of the river basin pressures with climate change and the occurrence of hydrological extreme impacts, as well as a program of basic and supplementary measures. Past, present, and future scenarios were analyzed with the Soil Water Assessment Tool (SWAT) based on land use, climate and hydrological data, climate change, presence or lack of the reservoir, and municipal wastewater and agriculture measures. In addition to the holistically assessed E-flow for the profile on the Sutla River for the present scenario, the holistically assessed E-flow for future scenarios is proposed by linking hydrological, morphological, and ecological characteristics based on the research of the Sutla River and the composition and abundance of biological quality elements. The presented research contributes to the knowledge and understanding of climate change impacts using long-term predictions of eight future climate change scenarios with six models and six different RCMs at the level of local river basin quantity (river flow) and quality (sediment load, total nitrogen load, and total phosphorus load) states of surface waters. This paper will present detailed research of the proposed methodology for E-flow assessment downstream of the Sutla River dam under the climate change impact, according to average monthly and annual seasonal values for flow, sediment, total N, and total P with IHAs and biological indicators.

Keywords: environmental objectives WFD, environmental flow (E-flow), SWAT, climate change, Sutla River Basin, Indicators of Hydrological Alterations (IHAs), biological indicators, holistic approach

TESTING THE PARAMETERS OF TWO-DIMENSIONAL HORIZONTAL DISPERSION PHENOMENON IN THE COASTAL ZONE

PIOTR ZIMA [1]

[1] Gdansk University of Technology, Faculty of Civil and Environmental Engineering, Poland, piotr.zima@pg.edu.pl

Abstract

Transport of pollutants with flowing waters is one of the most common processes in the natural environment. Pollutants are washed out of catchment areas into watercourses and then migrate with their waters to the seas and oceans. During this transport, they undergo numerous physical, chemical and biological processes and transformations. Chemical and biological processes depend on the conditions prevailing in a given environment. Physical processes (or rather transformations) refer to changes in physical properties related mainly to the state of fragmentation of a given substance.
In general, this process is described by a system of differential equations, including the continuity equation, dynamic equations, pollutant transport equations and equations of state. For the analyzed problem of pollutant migration in the coastal zone, a two-dimensional model is particularly useful because the velocity and mass concentration profile is vertically averaged. In this model, taking into account the dispersion flux leads to appropriate equations, and the dispersion process is described by the dispersion tensor. Due to the transverse isotropy of the dispersion process, the coordinates of this tensor are expressed in terms of local dispersion coefficients along the direction of the velocity and in the direction perpendicular to it. Commonly used methods for determining mass dispersion coefficients refer to a gradient velocity profile, typical for rivers. However, in the coastal zone, the velocity profile changes from gradient to drift when shear stresses on the surface caused by the wind begin to dominate. The drift profile also occurs in estuaries, where there is a difference in the density of fresh and salt water. The paper analyzes the numerical solution of the two-dimensional dispersion equations in the coastal zone for the dispersion coefficients adopted for the gradient and drift velocity profiles. And then it was assessed how it affects the final result.
The research was carried out in the Gulf of Gdańsk. Particularly convenient in terms of the conditions of the two-dimensional model is its part, namely the Bay of Puck. The Bay of Puck is the western branch of the Gulf of Gdańsk in the southern Baltic Sea, separated from the open sea by the Hel Peninsula. It is a shallow bay with an average depth of 3 m, with numerous shoals, no deeper than 1 m. The waters of several agricultural or urban-agricultural streams and rivers flow into the Bay of Puck. The mouth of the largest of them - Gizdepka - was selected for analysis.

Keywords: coastal waters, migration of pollutants in water, two-dimensional dispersion, mass dispersion, dispersion coefficients

PERFORMANCE EVALUATION OF A COMBINED DROUGHT INDEX FOR MULTIVARIATE DROUGHT ASSESSMENT IN MAHARASHTRA, INDIA

HUSSAIN PALAGIRI [1], MANALI PAL [2*]

[1] *Department of Civil Engineering, NIT Warangal, Warangal-506004, Telangana, India*
** E-mail:manalipal000@gmail.com*

Abstract

Drought event is a multivariate phenomenon containing interactive physical linkages of meteorological, hydrological and agricultural droughts. So, an individual index based on single variable cannot capture the complexity and diversity of translational nature of drought. Thus, the primary objective of this study is to focus on evaluating the performance of a Combined Drought Index (CDI) that consists of four hydro-meteorological variables i.e., rainfall, soil moisture, Normalized Difference Vegetation Index (NDVI) and runoff. A vine copula is fitted to these four variables to develop CDI which contains comprehensive information of meteorological (rainfall), hydrological (runoff) and agricultural (soil moisture, NDVI) variables to comprehensively characterize the overall drought. All the four variables are obtained from the European Centre for Medium Range Weather Forecast (ECMWF) Reanalysis data (ERA5 Land). To evaluate its efficiency Indian state of Maharashtra is chosen as the study area and it comes under semi-arid climate of India. The constructed CDI is effective in identifying historical drought in SPH from 1991 to 2020 and is consistent with the four input drought indices. The CDI combines the merit of the rainfall, temperature in capturing the onset of drought and that of the runoff in capturing the end of drought which is of great value for further understanding the drought characteristics and mitigation.

Methodology:
The CDI is developed using a vine copula which has its exclusive structure 1, and have been more practical in hydrological sciences. Before adopting a copula, all the four variables are fitted by four marginal distributions (Table. 1) using the Akaike Information Criteria Goodness of Fit.

Table 1. Marginal distributions used to fit the four hydrometeorological variables

Distribution	PDF	Range
Normal	$\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$	$-\infty < x < \infty$
Lognormal	$\frac{1}{x\sigma_{\ln x}\sqrt{2\pi}}\exp\left(-\frac{(\ln x-\mu_{\ln x})^2}{2\sigma_{lnx}^2}\right)$	$x > 0$
Exponential	$\lambda e^{-\lambda x}$	$x > 0$
Gamma	$\frac{\lambda^{\beta}x^{\beta-1}e^{-\lambda x}}{\Gamma(\beta)}$	$x > 0$

Once the marginal distributions are fitted, three joint copula functions are fitted to the marginal distributions of the four variables as shown in Fig. 1. The individual copula functions used in the vine copula are listed in the Table. 2.

Table 2. Bivariate Archimedean copula functions used to fit joint distributions between the pairs of drought characteristics: d-s, d-p and s-p.

Name of the Copula	Copula Function
Frank Copula	$C(u,v)=\frac{-1}{\theta}\ln\left(1+\frac{\left(e^{-\theta u}-1\right)\left(e^{-\theta v}-1\right)}{e^{-\theta}-1}\right),\theta\neq 0$
Clayton Copula	$C(u,v)=\left[\max\left(0,u^{-\theta}+v^{-\theta}-1\right)\right]^{-1/\theta},\theta\geq 0$
Gumbel Copula	$C(u,v)=e^{\left[(-lnu)^{\theta}+(-lnv)^{\theta}\right]^{\frac{1}{\theta}}},\theta\geq 1$

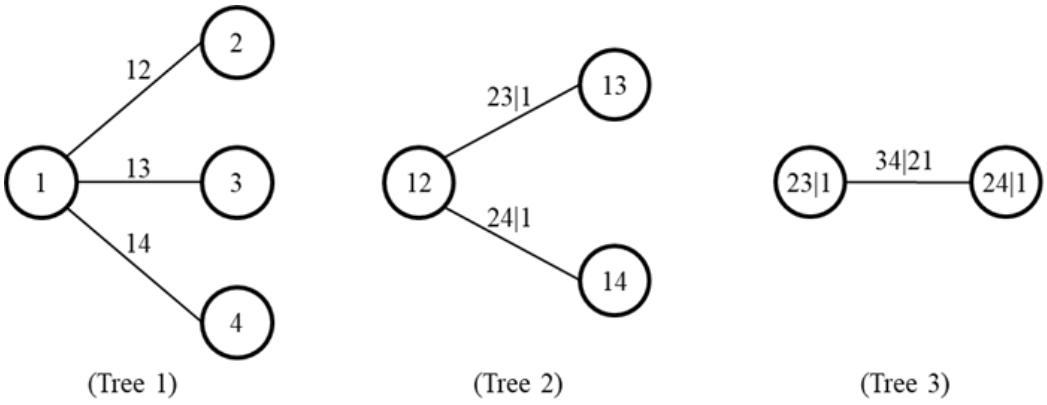


Figure 1. Graphical scheme of four-dimensional vine copula structure with three trees and marginal distributions of four variables: 1) rainfall, 2) soil moisture, 3) NDVI and 4) runoff.

Keywords: Combined Drought Index, Copula, Marginal Distributions, Droughts, Reanalysis Data, Hydrometeorological variables.

IMPACTS OF MAN-MADE STRUCTURES ON FLOOD WATER REGIME OF TOPONIČKA RIVER IN SERBIA

ALEKSANDRA ILIĆ[1], DRAGAN RADIVOJEVIĆ[2], BORKO RADIVOJEVIĆ[3], ILIJA ILIĆ[4]

[1] *Dr., Assistant Professor, Faculty of Civil Engineering and Architecture Niš, Serbia, aleksandra.ilic@gaf.ni.ac.rs*
[2] *Dr., Assistant Professor, Faculty of Civil Engineering and Architecture Niš, Serbia, dragan.radivojevic@gaf.ni.ac.rs*
[3] *MSc, PhD candidate, Faculty of Civil Engineering and Architecture Niš, Serbia, borko.radivojevic@yahoo.com*
[4] *MSc, PhD candidate, Faculty of Civil Engineering and Architecture Niš, Serbia, ilija20ilic@gmail.com*

Abstract:

In June of 2023, Europe was hit by heavy rainfall, causing torrential water streams to overflow from the river bed. Extreme floods also hit Serbia, which caused great damage.
Currently in Serbia, the E-761 highway is under construction which route stretches along the West Morava valley in Western Serbia and crosses several torrential watercourses. One of the watercourses is the Toponička River, which is very specific due to its geomorphological characteristics (Fig. 1). It is also specific in its position in relation to the inhabited and agricultural areas through which it flows.

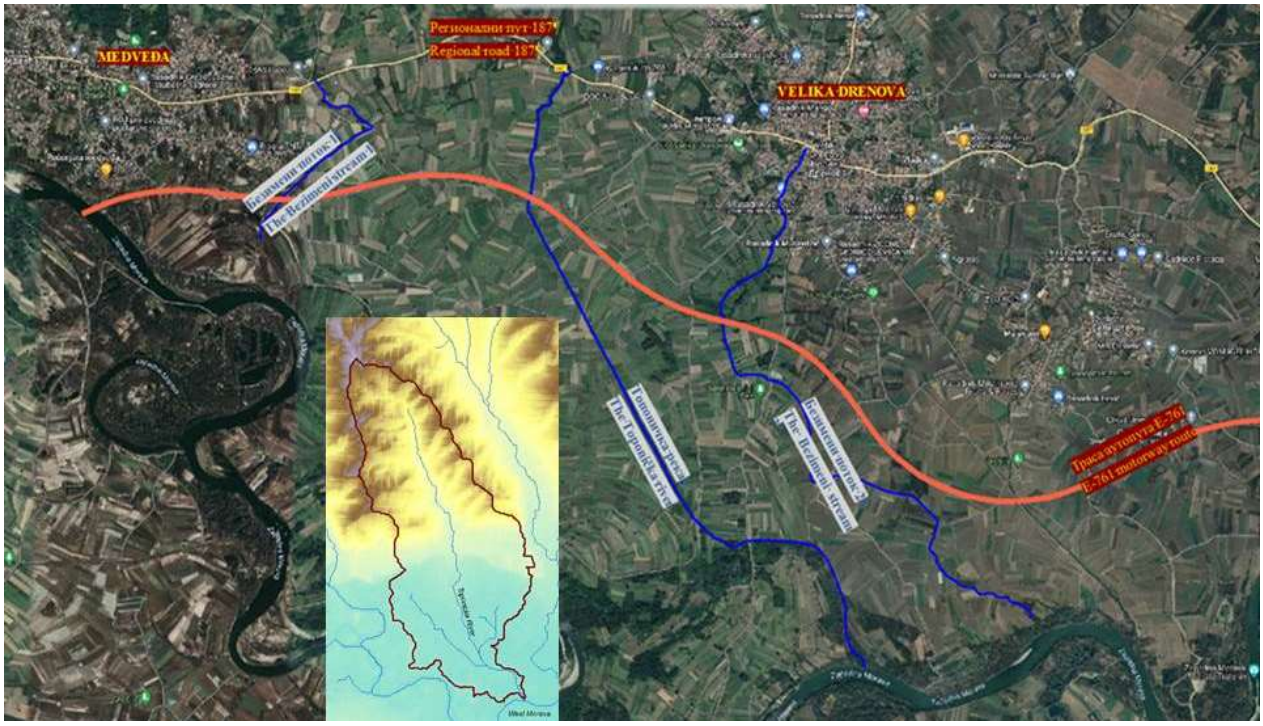


Figure 1. The Toponička River basin according to DEM and orthophoto map

In this paper, the flood flows regime of the Toponička River is analyzed for three approaches. The first approach refers to the delineation of the watershed using a digital terrain model (DEM) and topographic and orthophoto maps (Fig. 1). The second approach takes into account all the sub-basins obtained based on consideration of the water path (Fig. 2). Finally, the third access overlooks the Toponička River basin to the constructed highway E-761 (Fig. 3).
The analyses result in computational flow hydrographs. All hydrological models were conducted using the HEC-HMS software.

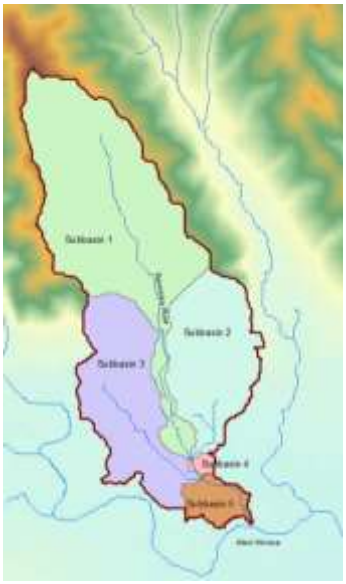


Figure 2. The Toponička River sub basins

Figure 3. The Toponička River sub basins with motorway E-761

Flood hydrographs for all considered sub basins are shown at Figure 4 for 1% probability of occurrence. The results of water balance according to 100 yr. flood hydrograph volumes are presented in Table 1.

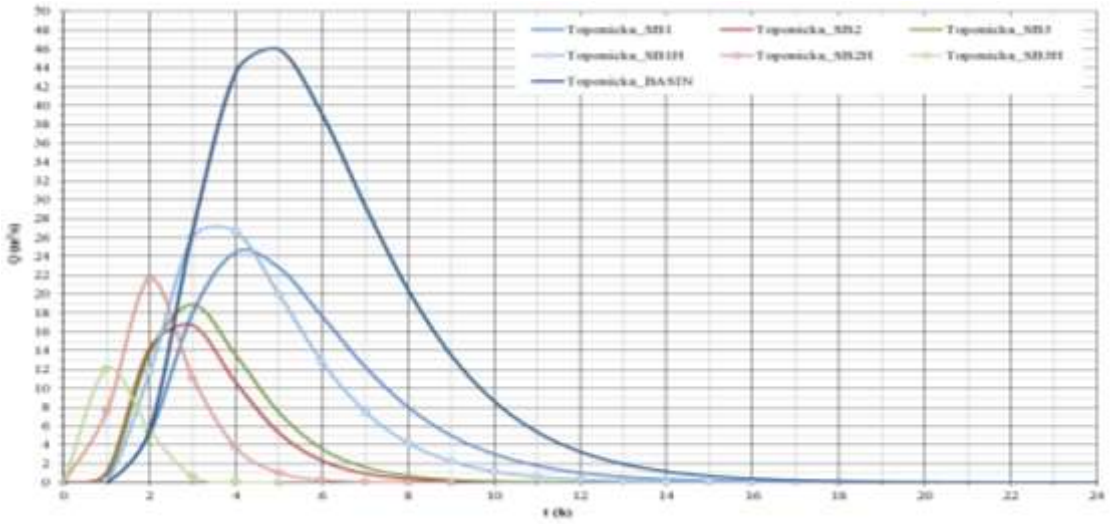


Figure 4. The Toponička River flood hydrographs for 1% probability of occurrence

Table 1. Water balance according to 100 yr. flood hydrograph volumes

	Toponička	SB1	SB2	SB3	SB4	SB5	**SUM**	SB1H	SB2H	SB3H	**SUMH**
$Q_{1\%}$ (100 y)	836,342	434,369	186,362	218,288	5,682	41,486	**886,187**	409,800	163,304	65,595	**638,699**
W(m^3)											

According to presented results it can be concluded that the route of the motorway E-761 presents, conditionally speaking "dam" for runoff from the Toponička river basin and changes its direction that moves laterally (left and right) to accumulate along the length of the structure within whole basin. It is necessary to re-design the surface water drainage concept in the area of the E-761 motorway within the area of the Toponička river basin.

Keywords: heavy rainfall, flood water regime, man-made impacts, hydrograph, HEC-HMS

MAPPING WATER EROSION SUSCEPTIBILITY THROUGH INTEGRATION OF GEOSPATIAL DATA AND MACHINE LEARNING: A CASE STUDY OF THE ISSER BASIN, NORTHERN ALGERIA

HOUSSEYN BOUZERIA [1], HAMZA BOUCHEHED [2], FATMA ZOHRA BAHROUN [3], CHEMSS EDDINE BOUHADEB [4]

[1] *Department of water sciences and environment, university of Blida, Algeria, Bouzeria_housseyn@univ-blida.dz*
[2] *Department of hydraulic, University of Annaba, Algeria, hamzaaoh@gmail.com*
[3] *National high school of hydraulic, Blida, Algeria, f.bahroun@ensh.dz*
[4] *Department of hydraulic, University of Batna, Algeria, chamsouhyd@hotmail.fr*

Abstract

This study aims to investigate the vulnerability to water erosion in the Isser basin, located in northern Algeria, through an integrated approach combining geospatial data and machine learning techniques. Water erosion poses a significant challenge to the sustainability of agricultural lands by reducing their productivity and causing crop losses, biodiversity loss, and water quality degradation through the transport of eroded sediments to watercourses, lakes, and reservoirs in Mediterranean basins, notably in northern Algeria, where it can lead to significant losses of fertile soil and environmental damage.

In this research endeavor, our objective is to accurately map areas prone to water erosion to better understand its spatial distribution and identify factors contributing to its propagation. To achieve this, we amalgamate diverse geographical data, including topographic, hydrological, climatic, and geological data obtained from multiple sources and integrated into a Geographic Information System (GIS) environment. Utilizing advanced machine learning techniques, we aim to develop robust predictive models to estimate the likelihood of water erosion occurrence in the Isser basin. These models were calibrated and validated using historical erosion data as well as data from field observations and satellite imagery.

Ultimately, the findings of this study will furnish critical insights to policymakers and local authorities to devise sustainable water and land resource management strategies aimed at safeguarding agricultural activities against the adverse effects of water erosion. By employing a data-driven approach and cutting-edge technologies, we aspire to contribute to a better understanding of erosion processes and informed decision-making regarding environmental management in the Isser region and beyond.

Keywords: Mapping Erosion, Machine Learning, GIS, Agricultural Lands, Water Quality, Isser Basin, North Algeria.

CONCEPT OF THE WATER MANAGEMENT AND TECHNICAL SOLUTIONS OF SELECTED RESERVOIRS FROM THE GENERAL LAPV THE DYJE AND MORAVA BASIN

ELIŠKA GRMELOVÁ [1*], JAROMÍR ŘÍHA [2], STANISLAV KOTAŠKA [3]

[1*] *PhD student, Brno University of Technology, Veveří 95 Brno 602 00, Czech republic, Eliska.Grmelova@vutbr.cz*
[2] *professor, Brno University of Technology, Veveří 95 Brno 602 00, Czech republic, jaromir.riha@vut.cz*
[3] *assistant, Brno University of Technology, Veveří 95 Brno 602 00, Czech republic, stanislav.kotaska@vut.cz*
**corresponding author*

Abstract

Adaptation to climate is an actual topic, namely for water managers. One of the technical measures is a realization of water reservoirs providing water reserve during the dry periods and helping to attenuate extreme flood events. For the territory of the Czech Republic, the Water Management Plans (WMP) have specified the appropriate localities where territorial protection for future dam construction has been adopted. However, the opinion on the number of protected localities has changed over time. The number of localities was reduced in the updates of WMPs until 2020 when the number was slightly increased.
In Tab. 1 the numbers of protected localities in particular principal river catchments in the Czech Republic are mentioned. Since 2011 the protected localities have been specified within the Master Plan "Localities for Accumulation of Surface Waters" (LASW).

Table 1. The numbers of protected localities

River basin	**WMP 1975**	**WMP 2000**	**LASW 2011**	**LASW 2020**
VLTAVA	145	60	23	28
ELBE	99	34	13	14
OHŘE	46	16	6	9
MORAVA	122	64	20	30
ODER	45	12	3	5
TOTAL	**457**	**186**	**65**	**86**

In the last issue of the Master Plan "Localities for Accumulation of Surface Waters" (LASW) only basic technical and water related data are mentioned for the protected localities. For the practical use, modelling of the climatic changes and the search for adaptation tools, more detailed information about individual dams and reservoirs are needed. To fit these requirements five localities were chosen for more detailed technical solution. The localities are Borovnice, Kuřimské Jestřabí, Vysočany, Brodce, Plaveč and Bělkovice (Fig. 1).

For each locality, the solution consisted in following steps:
- analysis of available documents: information taken from WMP and LASW, engineering geology (geological a hydrogeological maps, database of boreholes), hydrological data, land use, environmental issues and other,
- dam site specification, location of the dam axis,
- basic characteristics of the scheme (dam type and height, reservoir volume, extent of the reservoir area, storage-area-elevation dependence, minimum residual flow),
- hydraulic calculations (bottom outlets, emergency spillway, estimate of hydropower output),
- reservoir water management (storage characteristics, water balance, flood attenuation),
- concept of operation rules for the scheme.

In the paper the procedures described above are demonstrated on the Bělkovice scheme (Fig 2).

Figure 1. Location of selected reservoirs

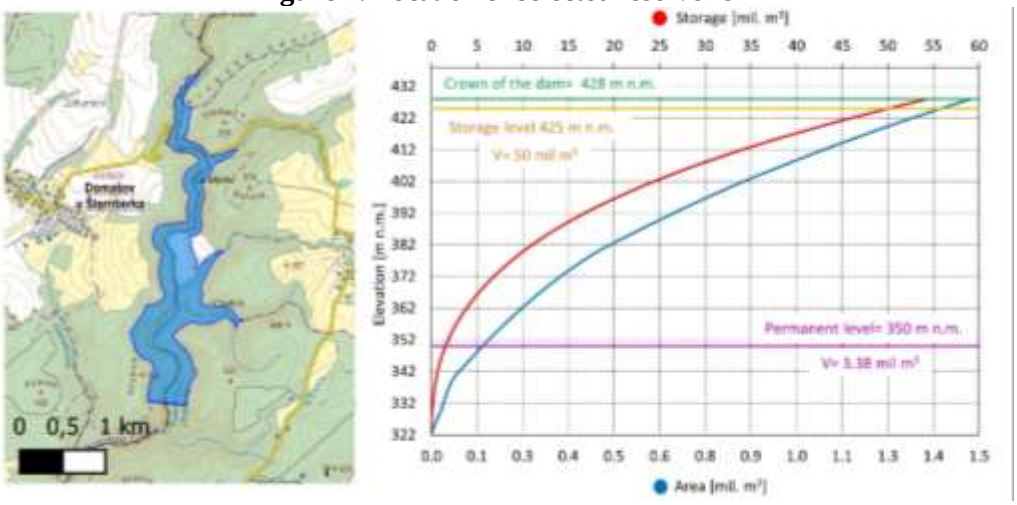


Figure 2. Bělkovice scheme – reservoir area and storage-area-elevation curves

In conclusion the summary of effects of individual schemes is shown in Tab. 2.

Table 2. Basic effects and benefits of reservoirs

Benefits of dams	**Borovnice**	**Kuřimské Jestřabí**	**Vysočany**	**Brodce**	**Plaveč**	**Bělkovice**
Required water supply security [%]	98.50	98.50	98.50	98.50	95.00	98.50
Secured take-off discharge [m^3/s]	0.650	0.400	0.567	0.265	0.200	0.421
Hydropower output [kW]	100	120	187	42	27	35
Transformation of peak flood discharge inflow/outflow						
Q_{100} [m^3/s]	89/78	66/50	78/48	33/23.50	54/50.22	44.70/30.73
Q_{1000} [m^3/s]	171/158	115/96	135/107	66.70/52.7	119/112.1	67.20/57.83
Conflicts						
Flooded buildings [pcs]	23	27	5	29	17	18

The analysis showed that take-off discharge up to 2.5 m^3/s can be withdrawn from all studied reservoirs in total. All reservoirs are considered as potential sources of drinking water. The specified amount would supply drinking water up to for 1.8 million inhabitants in the region.

Keywords: Climate change, protected locality for water storage, water management planning, water reservoir, dam.

This article was elaborated with the support of project FAST-S-24-8513 - „Analysis of the influence of input variables on the results of numerical models used in the safety assessment of water structures“.

PROBLEMS OF HYDROMETRIC APPROACH TO DETERMINE THE THERMAL MINERAL WATER FLOW TO THE BEČVA RIVER IN THE TEPLICE SPA

TOMÁŠ JULÍNEK [1*], JAROMÍR ŘÍHA [2]

[1*] assistant professor, Brno University of Technology, Veveří 95 Brno 602 00, Czech republic, Tomas.julinek@vut.cz
[2] professor, Brno University of Technology, Veveří 95 Brno 602 00, Czech republic, jaromir.riha@vut.cz
*corresponding author

Abstract

The mineral water in the Spa Teplice on Bečva springs into the Bečva river bed out of the hypogenic karst formed by Paleozoic limestones. Recently the focus on the hydrological and hydrogeological conditions of the mineral springs issues from the planning of the Skalička dam whose reservoir is believed to be interconnected with the karstic formation and may influence the regime of mineral waters. One of the related particular problems is to determine the discharge of the rising mineral water which springs into the Bečva river in the vicinity of the Spa Teplice on Bečva. For the estimate of the natural yield of the thermal water several methods were applied. One of them was hydrometric measurements by the classical current meter and measurements using the ADCP (acoustic Doppler current profiler). Several problems arised during the evaluation of measured data.

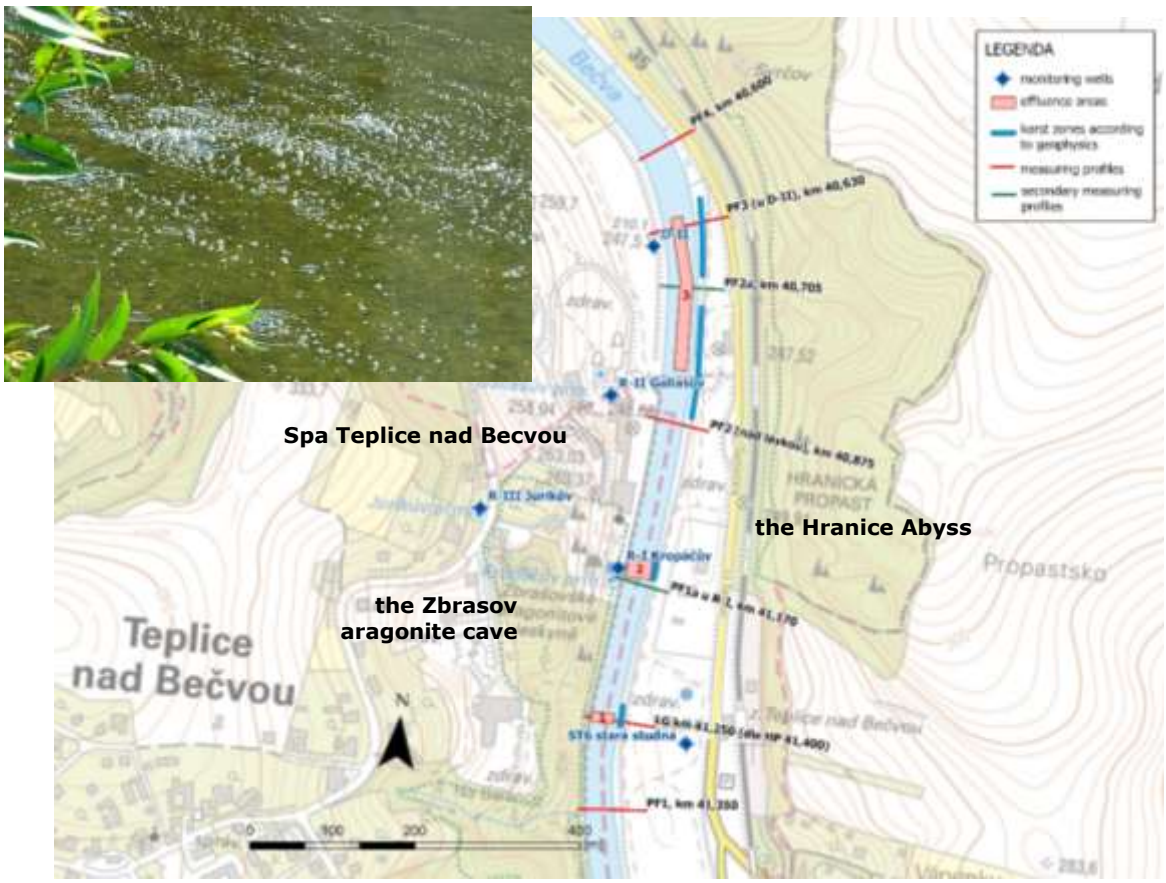


Fig. 1 Location of gauging profiles and example of zone of mineral water springs into the Bečva river

Mineralization of the water is being monitored especially in the intake wells. The springs of mineral water to the Bečva river can be documented visually at number of zones in the river (Fig. 1). Hydrometric measurements were carried out in 4 campaigns. Figure 1 shows location of gauging profiles of hydrometry. There were four main profiles, profile at permanent gauging station run by czech hydrometeorologic institute and two additional profile for other types of measurement.

Figure 2 shows the values obtained in comparison with the average flow recorded at the time of measurement at the Teplice nad Bečvou gauging station (GS). It can be seen that the hydrometric values are systematically 10 to 15% higher than those obtained at the Teplice and Bečvou gauging station.

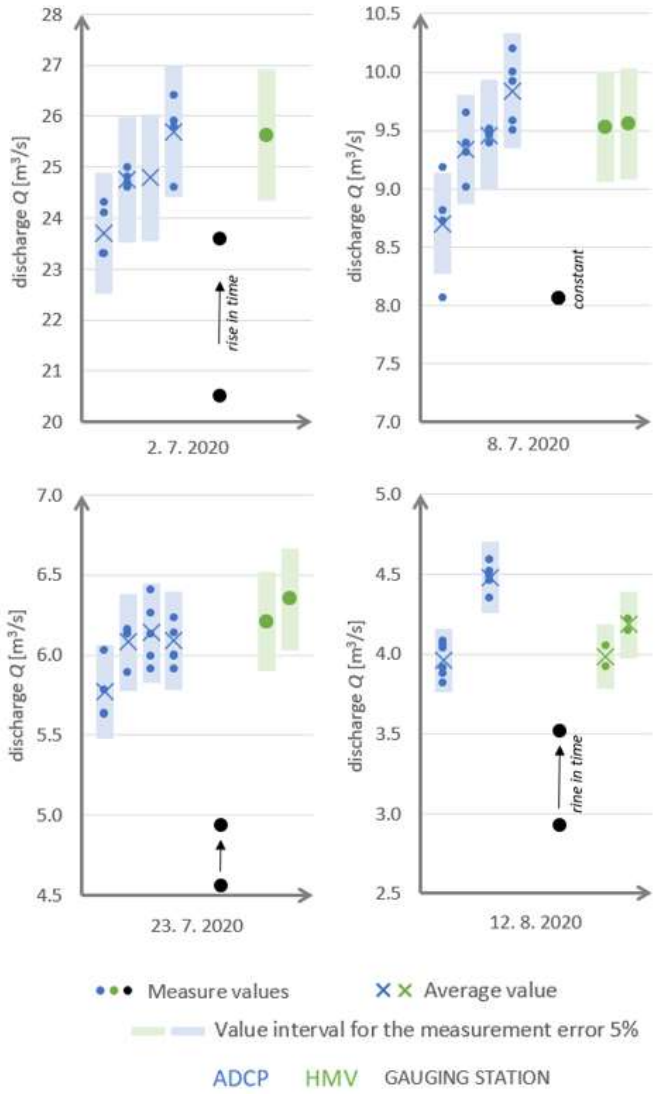


Fig 2. Results of individual flow measurements

The upward flow rate was estimated using hydrometry approach for 80 to 120 l/s. The absolute deviation in the values of the upward flows obtained is around 20 l/s for low and up to 40 l/s for higher flow in the Bečva river.

Keywords: karstic, mineral spring, hydrometry, conductivity, hydraulic gradient.

ESTIMATION OF RECHARGE AND EVAPORATION IN THE NORTH-WESTERN SAHARA AQUIFER SYSTEM (ALGERIA-TUNISIA) USING STABLE ISOTOPE PROFILES IN SOIL WATER, MODELLING AND MANAGEMENT

GUENDOUZ ABDELHAMID

[1]*Blida1 University LPPE Laboratory, B.P.270-Road Souma, 09000-Blida-Algeria*
Email: ah.guendouz@gmail.com

Abstract

The North-Western Sahara Basin (NWSAS) comprises two main aquifers: the deep "Continental Intercalaire" (CI), and the "Complexe Terminal" (CT). With a surface area of approximately 1 000 000 km2, the CI extends across three countries, Algeria, Tunisia and Libya and constitutes one of the largest groundwater systems in the world. This resource is generally considered as being "fossil", i.e. inherited from previous climatic conditions, more humid than at present, with a very limited modern recharge.
For a long time, hydrogeologists and managers of water resources in arid areas have been asking the same question: Do these large reservoirs receive a modern recharge? If yes, at what rate?
The present paper reviews the contribution of the isotopic tools methodology as applied to the groundwaters of these huge aquifers. Water transfers through the unsaturated zone were investigated in order to compute steady-state groundwater recharge rates and evaporative losses.
Many sites have been investigated during the last twenty years: Béni-Abbès, Chott Chergui, Ouargla, El-Oued in Algeria and Tozeur, Dissa in Tunisia within the framework of separate studies. These investigations aimed at estimating evaporation rates based on unsaturated zone stable isotopes profiles. This was implemented making use of the deterministic model developed by Barnes and Allison (1982). The evaporation and recharge rates obtained for a 10 m unsaturated soil profile varied between 1 and 10mm/a. The main objective of the present study is to gather all these data and to examine how they may be interpreted in terms of recharge rate, evaporation losses can help the water managers of the involved countries to develop or refine appropriate models. This should facilitate the implementation of a trans-boundary integrated management of the shared resources.

Keywords: stable isotopes, aquifer, modelling, Evaporation, Recharge, Sahara

MONTE CARLO APPROACH TO LOCAL SCOUR: THE SAVA RIVER BRIDGE, ZAGREB CASE STUDY

MARTINA LACKO [1], KRISTINA POTOČKI [2], NIKOLA ADŽAGA [3], GORDON GILJA [4]

[1] *Water Research Department, Faculty of Civil Engineering University of Zagreb, Croatia, martina.lacko@grad.unizg.hr*
[2] *Water Research Department, Faculty of Civil Engineering University of Zagreb, Croatia, kristina.potocki@grad.unizg.hr*
[3] *Department of Mathematics, Faculty of Civil Engineering University of Zagreb, Croatia, nikola.adzaga@grad.unizg.hr*
[4] *Water Research Department, Faculty of Civil Engineering University of Zagreb, Croatia, gordon.gilja@grad.unizg.hr*

Abstract

The intensity and frequency of extreme flood events can accelerate morphodynamic changes in rivers and expose bridges to a high risk of local scour, which is one of the most common causes of bridge failure. In practice, the prediction of scour depths is subject to considerable uncertainty due to the variability of different influencing factors such as bridge structures, river morphology and flow behavior. In this paper, a framework for estimating local scour around bridges was established by performing a statistical analysis of historical annual maximum discharge in combination with a Monte Carlo simulation. First, different univariate probability distributions of the historical annual maximum discharge were tested with several goodness-of-fit tests to reduce the uncertainties associated with the different factors influencing scour behavior. Subsequently, a Monte Carlo simulation was used to generate a larger data set of annual maxima based on the fitted distribution and its parameters, which is later used as input to a previously developed HEC-RAS model of the study area and an empirical equation to determine the local scour around bridge piers. The research methodology was demonstrated using a case study of a bridge in Zagreb, Croatia, with flow data from the Zagreb gauging station provided by the Croatian Meteorological and Hydrological Service. The aim of this study is to complement the ongoing research of the relationship between climate change indicators, flood wave characteristics and scour development next to the bridges crossing large rivers in Croatia with installed scour countermeasures within the R3PEAT project (Remote Real-time Riprap Protection Erosion AssessmenT on large rivers).

Keywords: flood, bridge, local scour, Monte Carlo, HEC-RAS, R3PEAT

POSSIBILITIES OF WATER REGIME IMPROVEMENT IN THE KLÁTOV BRANCH NATIONAL NATURE RESERVE

ANDREJ ŠOLTÉSZ [1], MARTIN ORFÁNUS [1], DANA BAROKOVÁ [1], JAKUB MYDLA [1]

[1] *Slovak University of Technology in Bratislava, Slovakia, andrej.soltesz@stuba.sk,*

Abstract

In frame of the project 'Status improvement of wetland of Klátov branch National Nature Reserve (NNR)', financed from the Norwegian financial mechanism, was the task of the Department of Hydraulic Engineering as co-researcher partner to find a solution for possible revitalisation of the water regime of the more than 30 km long Klátov branch. The Klátov branch was in the beginning of the 20th century dammed and thus cut off from the surface water source – the Little Danube. It happened after disastrous floods in 1897, and especially in 1899. Since then, the only source for the Klátov branch has become groundwater. This has resulted in the water in the Klátov branch being extremely clean and has a high ecological value. As the groundwater level in the area between the Danube and the Little Danube has dropped significantly in recent years, the water regime of the Klátov branch has also been affected. The paper deals with the hydraulic solution of indirect inflow of surface water from the Little Danube with possible infiltration into the Klátov branch. The basis for the solution was the analysis of hydrological, hydropedological, hydrogeological, morphological and biological characteristics of the area in Klátov branch NNR, which were complemented by own measurements of hydraulic parameters in the flow of the Klátov branch and its tributaries. Considering the proposed technical solution of the recharge of the Klátov branch from the Little Danube by filtration through the "seepage tanks" in the upper section of the Klátov branch, these documents were supplemented by infiltration experiments measuring the intensity of surface water seepage into the bedrock of the Klátov branch bed, on the basis of which the actual system of the process of seepage (seepage tanks, large-scale seepage experiment) of the Little Danube water into the Klátov branch was designed.

Another important basis was the digital terrain model taken from the Basic Database for Geographical Information System (ZBGIS), which was supplemented within the project by data from the detailed digital surveying of the Klátov branch riverbed with the related bathymetry (measurements of water depths in the Klátov branch).

These background materials served as input data for the analysis and forecast of the flow and level regime of both surface water in the Klátov branch and groundwater in the immediate vicinity of the Klátov branch. On the basis of the calibration of the 2-D mathematical model of the water level and flow regime in the Klátov branch, it was possible to develop several scenarios of water recharge to the Klátov branch and related possible morphological modifications of the channel in order to improve the flow velocity regime in order to set the bed sediments in the stream in motion. The proposed solutions are in line with the conclusions of the biological study, which indicated that the revitalisation measures have a high potential for improving the ecological status and that restoring the dynamics of the water regime in the affected area would mean at least approaching the environmental conditions that existed in the Klátov branch before it was cut off from the Little Danube River.

Keywords: Klátov branch, surface water recharge, infiltration experiment, 2-D mathematical modelling, interaction between surface and ground water, revitalisation measures

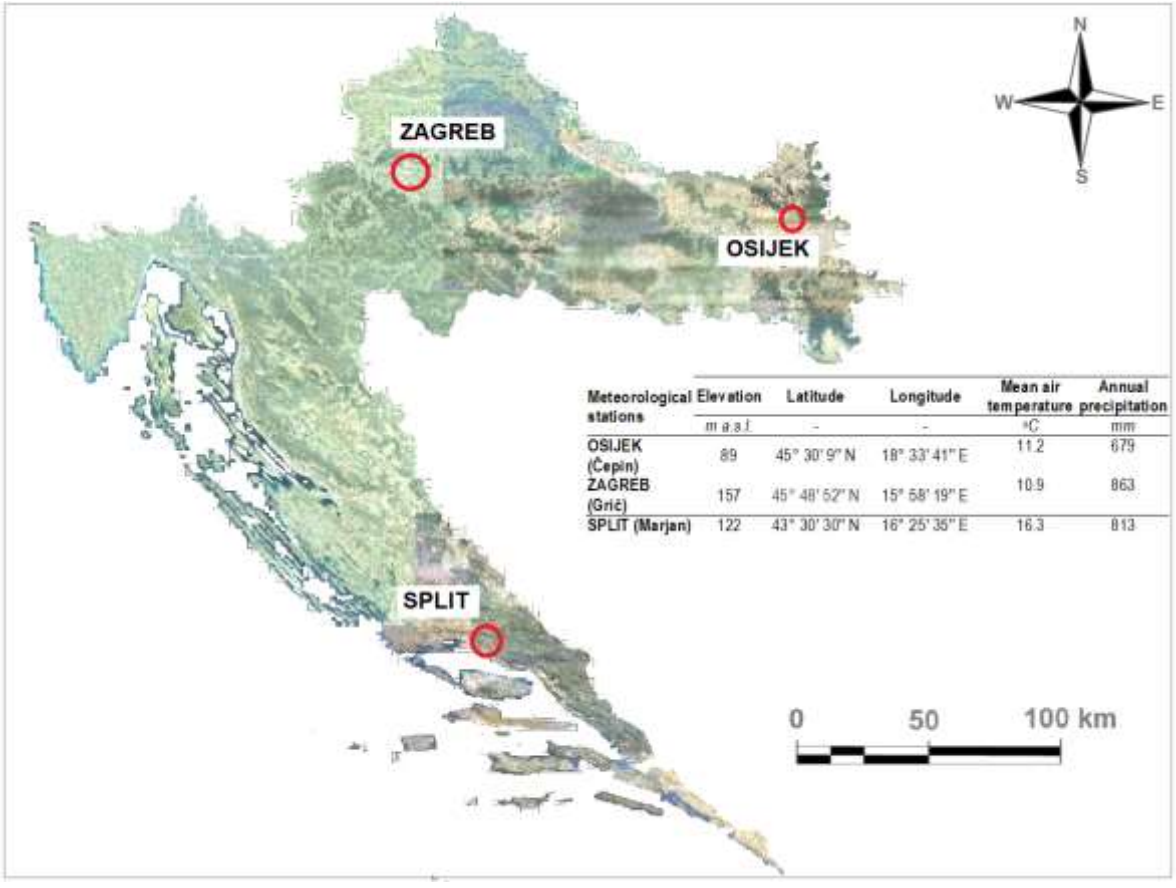
ANALYSIS OF ANNUAL AND SEASONAL PRECIPITATION OF THREE REPRESENTATIVE CROATIAN REGIONS

LIDIJA TADIĆ [1], JOSIP JANJIĆ [2], TAMARA BRLEKOVIĆ[3]

[1] *Faculty of Civil Engineering and Architecture Osijek, Croatia, ltadic@gfos.hr*
[2] *Faculty of Civil Engineering and Architecture Osijek, Croatia, jjanjic@gfos.hr*
[3] *Faculty of Civil Engineering and Architecture Osijek, Croatia, tamaradadic@gfos.hr*

Abstract

Changes in precipitation regime, besides changes in air temperatures, are one of the main climate change impacts on a global scale. They can be recognized on annual and even more seasonal levels causing drought and flood events frequently. This paper focuses on precipitation which is the most important and most common parameter for drought analysis, regardless of the used index for drought calculation. To contribute to the knowledge of drought phenomena in Croatia, the changes in precipitation over a relatively long period between 1951 and 2022 were analyzed. The meteorological stations included in the research were Osijek, Zagreb, and Split, which represented the climate of the entire country. In the Osijek region, there is a typical continental climate, in the Zagreb region there is a continental climate with the influence of maritime climate and in the Split region, there is a Mediterranean climate.
The locations of stations, as well as basic information relevant to the analysis, are shown in Figure 1. In the Osijek, the easternmost station, annual precipitations are the lowest compared to Zagreb and Split, and in Zagreb are the highest. It is 680 mm, in the Zagreb region, mean annual precipitation of the same period is 863 mm and in the Split region is 810 mm.



Meteorological stations	Elevation	Latitude	Longitude	Mean air temperature	Annual precipitation
	m a.s.l.	-	-	°C	mm
OSIJEK (Čepin)	89	45° 30' 9" N	18° 33' 41" E	11.2	679
ZAGREB (Grič)	157	45° 48' 52" N	15° 58' 19" E	10.9	863
SPLIT (Marjan)	122	43° 30' 30" N	16° 25' 35" E	16.3	813

Figure 1. Study area with basic data of meteorological stations, mean air temperature and precipitation sum for the analyzed period

Besides their great geographical differences, previous investigations show some similarities in drought occurrence. Precipitation is tested for homogeneity using the standard normal homogeneity test (SNHT) on an annual and seasonal basis. On an annual basis, there is no inhomogeneity but on the seasonal level there is inhomogeneity only in the precipitation record of the Zagreb station during autumn. The existence of significant temporal trends was tested using the non-parametric Mann–Kendall trend test. It showed negative but not significant trends in the winter and spring months in all three regions. Significant decreasing trend is observed in summer period in Zagreb and Split region. Increasing trend of precipitation is observed in autumn in the Osijek and again in the Zagreb region. On annual basis all three stations have decreasing, but not significant trend. Despite of differences, in geographical features, there are rather similar and even unexpected precipitation regime. Extreme hydrological events such as floods and droughts are very frequent, what requires complex water management system.

Keywords: Mann-Kendal test, precipitation, SNHT, Split, Zagreb, Osijek

WATER CRISIS OF THE PONDS IN KOPAČKI RIT WETLAND

SINIŠA MARIČIĆ [1], ŽELJKO ŠRENG [2]

[1] Faculty of Civil Engineering and Architecture Osijek, Croatia, smaricic@gfos.hr
[2] Faculty of Civil Engineering and Architecture Osijek, Croatia, zsreng@gfos.hr

Abstract

Kopački rit, a protected wetland area where the Drava and Danube rivers converge, is subject to regulatory measures and flood prevention efforts. Human activities in the Danube basin have altered its water dynamics, and climate change impacts are evident. The health of its flora and fauna hinges on its surface water condition.

This study examines hydrological data, particularly water levels, as indicators of Kopački rit's water condition. The water level in its central area, Kopačevo Lake, closely correlates with nearby levels at gauges along the Drava (Osijek) and Danube (Apatin and Aljmaš) rivers. These levels inform about the extent of flooding, indicating habitat variations. Water level analysis reveals significant changes over time, including shorter flood durations and prolonged drought periods. High water events are more pronounced and occur at unusual times. These changes are represented by the annual regime of the characteristic water levels and the duration curve of average daily water levels, for three consecutive periods (30-40 years).

These trends suggest a water crisis, emphasizing the need to preserve wetland values and plan accordingly. Historical considerations of water management interventions underscore the importance of revisiting strategies. Recent data, particularly from 2022, highlighting adverse trends, should prompt reevaluation of risks, vulnerabilities, and adaptation measures to address climate and other chages.

Keywords: Kopački rit, wetland, water level, water crisis

INVESTIGATION OF CHANGES IN THE RAINFALL-RUNOFF MODELING CAUSED BY CLIMATE CHANGE

MITRA TANHAPOUR*[1], PATRIK SLEZIAK[2], KAMILA HLAVCOVA[1], SILVIA KOHNOVA[1], JAN SZOLGAY[1]

1.Department of Land and Water Resources Management, Faculty of Civil Engineering, Slovak University of Technology, Bratislava, Slovakia

2. Institute of Hydrology, Slovak Academy of Sciences, Bratislava, Slovakia

**Corresponding author e-mail: mitra.tanhapour@stuba.sk*

Abstract

In order to secure a sustainable water supply and reduce detrimental effects on ecosystems, it is imperative to quantify the impact of climate change on surface water resources and develop appropriate adaptation methods. This study analyzes the impact of climate change on the streamflow regime of the Hron river basin, located in the central part of Slovakia. In this regard, the downscaled output from two climate scenarios, namely KNMI (Koninklijk Nederlands Meteorologische Instituut) and MPI (Max Planck Institute) regional climate models (RCM), was used as input to the conceptual TUW (Technische Universität Wien) model. Accordingly, we first split the long-term observed data during 1981–2020 into four 10-year periods. Then, the hydrological model was calibrated using observed data during 2011–2020, due to the greater similarity of the climate conditions in this period with the recent climate, and validated in the 1981–2010 period. Thereupon, the streamflow was predicted for future periods (2011–2040, 2041–2070, and 207–1100) and compared with both observed and simulated streamflow in the base period (1981–2010). The results indicated that the hydrological model performed well in both calibration and validation periods based on Nash-Sutcliffe efficiency (NSE) around 0.80. Given the analysis of long-term mean monthly streamflow based on both climate scenarios, the peak flows will mainly happen in March and April during future periods. Furthermore, the trend of streamflow variations has dropped in warm seasons and risen in cold seasons. The results would be helpful in developing sustainable water resource management strategies.

Keywords: RCM models, rainfall-runoff modeling, climate change, Hron River basin

IDENTIFICATION OF FLASH DROUGHT EVENTS IN DANUBIAN LOWLAND USING THE RAPID INTENSIFICATION RATE

EVANGELOS LEIVADIOTIS[1], SILVIA KOHNOVÁ[1]

[1] *Department of Land and Water Resources Management, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, (Radlinskeho 11), Bratislava 81005, Bratislava.*

Abstract

Drought is often characterized as a creeping phenomenon due to the rainfall deficit or a decrease in water shortages in a given period. Its typical slow onset development can pose severe risks to agricultural produce, natural ecosystems, economies and communities. Nevertheless, droughts can manifest rapidly due to extreme atmospheric anomalies coupled with minimal precipitation persisting over a few weeks. Recent studies have highlighted that drought can rapidly take shape under these exceptional atmospheric conditions, leading to "flash droughts" to denote their swift onset. It has become challenging to agree on a definition for flash drought. Nonetheless, the two primary characteristics that define it are the rate of intensification, or "flash", and the water deficit, or "drought". The rapid onset of flash droughts poses a significant threat to the agricultural and environmental sectors, leading to significant crop losses and deterioration of vegetation health, leaving little time for drought preparedness and mitigation measures. In addition to numerous hydrometeorological factors, soil moisture is considered a valuable measure of flash droughts due to its strong correlation with plant development. Soil moisture properties are easily observable and vital aspects of drought events. Advancements in remote sensing methods have facilitated the widespread use of satellite observations, providing regular updates on surface soil moisture changes over large geographic areas. A study in Central Europe revealed that flash droughts impact agriculture, affecting key crop stages. Their rise in occurrence is primarily driven by precipitation deficits, rising maximum temperatures, and alternations in anticyclonic patterns. This study also focuses on Central Europe, especially in Slovakia and specifically in the Danubian Lowland (DL), located in western Slovakia, as this region is one of the most critical regions for agriculture in Slovakia. This study aims to identify the flash drought events characterized by the rate of intensification using soil moisture data retrieved from Advanced SCATterometer (ASCAT) from 2007 to 2019. We define a flash drought event as the decline of soil moisture percentile from above the 40th percentile to the 20th percentile in no more than 21 days (3 weeks). Two critical factors were considered: one refers to the rate of intensification (RI), and the other is the actual soil moisture limitation to be classified as drought. The RI equation computes the average change in soil moisture over consecutive time intervals. It calculates the difference in soil moisture between each pair of consecutive data points $t(i+1)$ and ti, divided by the time interval duration between those points. This process is repeated for all data points, and then the average of those values is taken. The calculation also includes a constraint that specifies that the minimum soil moisture value observed in the dataset must be less than or equal to 20%. The final stage involves applying a threshold to the RI values to pinpoint the most significant events over the years. On this basis, flash droughts over Danubian Lowland during 2007–2019 were identified according to the intensification rate of soil moisture percentile. Finally, the spatiotemporal patterns and the evolutionary process of flash droughts were analyzed.

Keywords: flash drought, ASCAT, soil moisture, rate of intensification

TREND AND CORRELATION ANALYSIS OF GROUNDWATER QUALITY AT THE BARTOLOVEC WELLFIELD IN CROATIA

MARKO ŠRAJBEK [1], IVAN KOVAČ [2], BOJAN ĐURIN [3], GORDON GILJA [1]

[1] *Department of Water Research, Faculty of Civil Engineering, University of Zagreb, Fra Andrije Kačića-Miošića 26, 10000 Zagreb, Croatia, marko.srajbek@grad.unizg.hr, gordon.gilja@grad.unizg.hr*
[2] *Faculty of Geotechnical Engineering, University of Zagreb, Hallerova aleja 7, 42000 Varaždin, Croatia, ivan.kovac@gfv.unizg.hr*
[3] *Department of Civil Engineering, University North, Jurja Križanića 31b, 42000 Varaždin, Croatia, bdjurin@unin.hr*

Abstract

As the quality of life has been improved and the number of people increases on a global scale, the demand for high-quality drinking water is also growing. On the other hand, more intensive economic development and the associated emission of pollutants into the environment are placing increasing pressure on all components of the environment, including aquifers. With this in mind, it is very important to establish a functioning groundwater quality control system that carries out daily analyses so that a timely response can be made in the event of sudden pollution. However, it is equally important to monitor the quality of groundwater over the long term, as such analyses are very effective in revealing changes in trends over specific time intervals. With the aim of preserving groundwater resources, a statistical analysis of the quality of groundwater at the Bartolovec wellfield in Varaždin County in Croatia was carried out in this paper for two periods: 1994-2008 and 2009-2023. The values for five parameters of water quality were analysed: pH value, electrical conductivity, KMnO4 consumption, chloride and nitrate concentration. The time series of the annual averages were formed and the associated trends were analysed. A correlation analysis was carried out by time period and the relationship between same quality parameters at different wells was analysed. The correlation between different quality parameters at the same wells was also analysed. For the all quality parameters for both periods the arithmetic means were calculated and mutually compared and the statistical significance of difference was calculated. Although new methods have been developed and used in water resources management in recent years, the results obtained in this paper still show the importance of conventional statistical methods, the results of which still provide important conclusions.

Keywords: groundwater quality, wellfield, time series, correlation, trend analysis

INTEGRATED WATER RESOURCE MANAGEMENT IN FIJI: A NOVEL APPROACH TO ENHANCING WATER SUPPLY AND MITIGATING FLOOD RISKS

WAYNE AREKI [1], BOJAN ĐURIN [2], ANDREJA ŠANTATIĆ [2*], MARKO ŠRAJBEK [3]

[1] *School of Information Technology, Engineering, Mathematics and Physics, The University of the South Pacific, Laucala Suva, Fiji, wayne.areki@usp.ac.fj*

[2] *Department of Civil Engineering, University North, Jurja Križanića 31b, 42000 Varaždin, Croatia, bdjurin@unin.hr, andsantatic@unin.hr*

[3] *Department of Water Research, Faculty of Civil Engineering, University of Zagreb, Fra Andrije Kačića-Miošića 26, 10000 Zagreb, Croatia, marko.srajbek@grad.unizg.hr*

Abstract

In Fiji, the dual challenges of ensuring reliable water supply and managing flood risks are paramount due to its unique geographical and climatic conditions. This study investigates the current status of water supply demand and flood prevention measures in Fiji, identifying critical gaps and proposing sustainable development strategies tailored to the local context. Through field surveys, GIS mapping, and hydrological modeling, the research quantifies the current and projected water demand across urban and rural regions, juxtaposed against the frequency and severity of flood events over the past two decades. The research reveals a pressing need for an integrated water resource management (IWRM) approach that enhances water infrastructure to meet increasing demand due to population growth and tourism and strengthens resilience against climate-induced extreme weather events. The paper will show a multi-tiered strategy involving adopting advanced water-saving technologies, improved forecasting and early warning systems, community-based adaptation practices, and robust regulatory frameworks. Additionally, the paper explores the potential of green infrastructure and renewable energy sources as a nexus for water supply enhancement and flood mitigation. Recommendations are tailored to various stakeholders, including local governments, international donors, and community organizations, underscoring the need for collaborative efforts in policy implementation and capacity building. The findings aim to contribute to the sustainable development goals (SDGs), particularly ensuring clean water and sanitation (SDG 6) and climate action (SDG 13), offering a blueprint for other Pacific Island nations facing similar challenges.

Keywords: Fiji, water supply, flood prevention, integrated water resource management, sustainable development, climate resilience

EU STRATEGY FOR DANUBE REGION - PROSPERITY THROUGH DIVERSITY

ANDREA VRANOVSKÁ [1], DANA VRABLÍKOVÁ [1]

[1] *Water Research Institute, Slovakia,* andrea.vranovska@vuvh.sk*;* dana.vrablikova@vuvh.sk

The Danube has the most international river basin in the world: it stretches over 2,800 km across Europe. The Danube Basin covers an area of over 800,000 km2. The drainage area of the Danube is also influenced by two major mountain chains: the Alps and the Carpathians. Water management is therefore a central issue to the Danube Region, as water does not recognize borders and its management requires strong coordination and cooperation.

The EU Strategy for the Danube Region (EUSDR) is a macro-regional strategy adopted by the European Commission in December 2010 and endorsed by the European Council in 2011. The Strategy was jointly developed by the Commission, together with the Danube Region countries and stakeholders, in order to address common challenges together. The Strategy seeks to create synergies and coordination between existing policies and initiatives taking place across the Danube Region, it is not about funding but closer cooperation!

The area covered by the Strategy unites nine EU Member States (Austria, Bulgaria, Croatia, the Czech Republic, Germany, Hungary, Romania, the Slovak Republic and Slovenia) and five non-EU countries (Bosnia and Herzegovina, the Republic of Moldova, Montenegro, Serbia and Ukraine), which is home of about 115 million inhabitants.

The scope of Strategy is divided into four major thematic fields (Pillars): connectivity, environment protection, building prosperity and security, reflected in thematic priority areas (fig.1.), jointly coordinated by designated institutions in the EUSDR countries, namely Priority Area Coordinators.

Pillar I. – Connectivity consist of four priority areas: 1A Waterways Mobility, 1B Rail-Road-Air Mobility, 2 Sustainable Energy, 3 Culture and Tourism. Pillar II - Environment Protection is covered by priority areas: 4 Water Quality, 5 Environmental Risks, 6 Biodiversity and Landscapes, Quality of Air and Soils. The third pillar "Building Prosperity" is composed of priority areas 7 Knowledge Society, 8 Competitiveness of Enterprises and 9 People and Skills. The last pillar IV is focused on Security and is built by priority area 10 Institutional Capacity and Cooperation and 11 Security.

Fig. 1 – Structure of EU Strategy for Danube Region - Pillars and Priority Areas (https://danube-region.eu/)

Hungary, together with Slovakia coordinate Priority Area 4 (PA4) "water quality" with the aim to ensure integrated water management towards reaching the good quality of waters in the Danube River Basin. The activities of PA4 are supported by Danube Region Programme.

Decision making body of the Priority Area is the Steering Group, comprised of representatives from all Danube Region countries. The objective of PA4 is reached via implementation of its Action Plan, which was revised in 2020 to align it with the new priorities and challenges of the region and better link the Danube strategy's actions with the new EU priorities, i.e. such as the European Green Deal. The

activities of PA4 , see https://waterquality.danube-region.eu/.
The new Action Plan of PA4 comprise of 7 actions:
Action 1: HAZARDOUS & EMERGING SUBSTANCES: Promote monitoring, prevention and reduction of water pollution deriving from hazardous and emerging substances (EU priority substances and watch list candidates as well as Danube basin specific pollutants candidates and others e.g. micro plastics-plastics, pharmaceuticals, PFOS).
ACTION 2: WASTE WATER: Continue boosting major investments in building, upgrading, maintaining and rehabilitating urban wastewater treatment facilities and promote alternative collection and treatment of wastewater in small rural settlements, including measures to build capacity at the regional and local level across the Danube basin.
ACTION 3: WATER & AGRICULTURE: Promote prevention and reduction of diffuse pollution, promote nutrient retention, smart irrigation and water reuse, foster and develop an active process of dialogue and cooperation between authorities responsible for agriculture and environment to ensure that measures are taken to address diffuse pollution and ensure smart water use
ACTION 4: DRINKING WATER: Promote measures aimed at reducing knowledge deficits related to protecting water resources and safeguarding drinking water supply.
ACTION 5: MIGRATORY FISH: Promote measures to enable fish migration in the Danube River basin
ACTION 6: CLIMATE CHANGE: Promote measures to adapt to climate change impacts in relation to water quality and quantity.
ACTION 7: TOOLS: Enhance cooperation, increase and exchange knowledge and secure financing to water quality measures in the Danube Region.
In 2022, priority areas identified the Danube Strategy Flagships projects or processes, which contribute to the implementation of the EUSDR, have a clear macro regional dimension and a multi-level governance approach. They are of high importance for the Danube Region's economic, social, and territorial cohesion and for improving the quality of life in the Danube Region. In the case of EUSDR PA4 three flagship processes were identified: climate change, migratory fish conservation, and emerging/hazardous substances.
EUSDR PA4 cooperates at developing new project ideas, facilitates project partnerships and supports implementation of projects related to various water management issues. The projects from several financial mechanisms address different issues like coordinating sediment management, preparing a Tisza-Danube integrated action plan to eliminate plastic pollution of rivers; managing and restoring aquatic ecological corridors for migratory fish species; tackling hazardous substances pollution in the Danube River; etc. Apart from projects financed by the Danube Transnational Programme (e.g. JoinTisza, DanubeSediment, DriDanube, Danube Hazard mc3, IDES, SIMONA, MEASURES, Tidy Up, Water Balance, etc.); PA4 supports the implementation of projects financed by other programmes, such as INTERREG Central Europe, Horizon2020, LIFE and CBC programmes (e.g. DEEPWATER-CE, FRAMWAT, MICACC; Danube4all, LIFE Living Rivers, etc.).
By capitalisation of project activities, results and outputs, PA4 seeks synergies and common benefits for Danube region.

Keywords: Danube Strategy, Priority area 4, EUSDR Action Plan, water quality, flagships

BALANCING WATER FLOWS IN THE RYE ISLAND FOR THE PURPOSE OF SUPPLYING WATER TO IRRIGATION PUMPING STATIONS

ANDREJ ŠOLTÉSZ [1], MICHAELA ČERVEŇANSKÁ [1], JAKUB MYDLA [1], DANA BAROKOVÁ [1],

[1] *Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Department of Hydraulic Engineering, Slovakia, andrej.soltesz@stuba.sk, michaela.cervenanska@stuba.sk, dana.barokova@stuba.sk*

Abstract

The Rye Island is an important agricultural area and an important source of quality drinking water in Slovakia. Considering the WEF nexus and consequences of climate change, by implementing appropriately chosen measures, optimal and sustainable conditions for water management can be created, thereby strengthening the competitiveness of agriculture, ensuring food security and reducing the risks resulting from ongoing climate change. The Rye Island channel system, with its damming and dividing structures and pumping stations, can now be considered as multi-purpose. While in the past it was built for the purpose of draining waterlogged soils, especially in the wet spring season and during floods, nowadays an equally important purpose is related to irrigation in the dry growing season and to regulating the water level regime, such as the necessary distribution of water between drainage areas. The paper documents the identification, quantification and optimal use of potential water sources for irrigation purposes, along with their distribution in the necessary quantity through the existing drainage channel system to the irrigation pumping stations. The main result of our work is a proposal for the division (balancing) of water flows (Figure 1) by means of the existing damming and dividing structures on the main skeleton of the drainage system of the Rye Island, ensuring sufficient distribution of water to the pumping stations located in the immediate vicinity of the main skeleton of the drainage channel system.

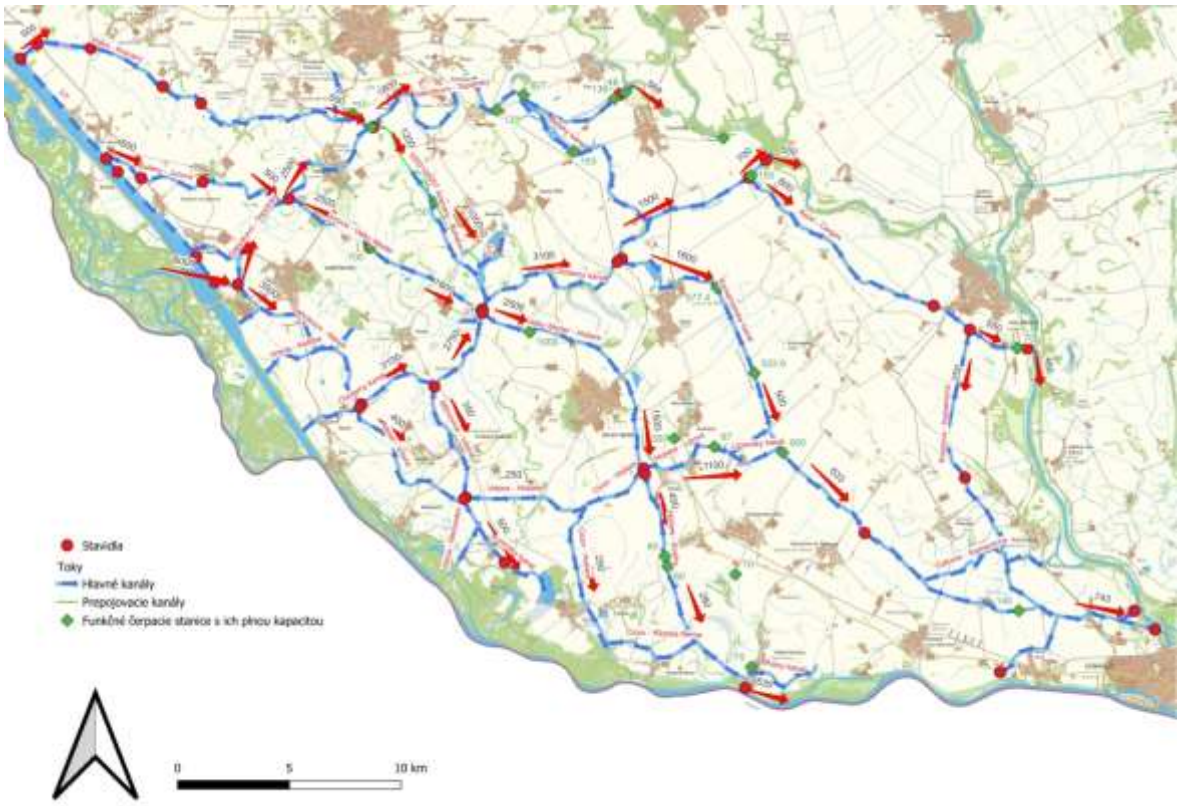


Figure 1. Distribution of water flows in the main skeleton of the Rye Island drainage channel system assuming a total inflow of 9 $m^3.s^{-1}$

To achieve these results, several field measurements were conducted to determine the water level and flow regime, as well as assessing the conditions and basic parameters of the damming and division structures. These measurements were carried out simultaneously with the study of the project documentation of the channel system and archive studies on the drainage channel system conducted by the Water Research Institute in the past.

Keywords: Rye Island, channel system, drainage channels, balancing of water flows, pumping stations, irrigation

WATER SCARCITY MANAGEMENT IN SLOVAKIA – CURRENT STATE

IVANA BAJKOVIĆOVÁ [1], STANISLAV KELČÍK [2]

[1] *Water Research Institute, Slovakia, ivana.bajkovicova@vuvh.sk*
[2] *Water Research Institute, Slovakia, stanislav.kelcik@vuvh.sk*

Abstract

In Slovakia, the issues of available water resources and the coverage of human water needs were treated as a comprehensive water management issue most recently in the document General of Protection and Rational Use of Water, 2002. In the following years, river basin management plans were developed in the spirit of the WFD, which places greater emphasis on maintaining or restoring good water status. The needs and trends in water use appeared in the strategic documents partially, among other sectors, or on a too general level. While water protection belongs to the environmental sector, the water use has mainly an economic and water supply also a social character, which makes this issue cross-cutting.
Since 2020, Slovakia has ranked drought and water scarcity among the significant water management issues related to climate change. The most typical consequence of climate change is a less even distribution of precipitation over time, i.e. greater extremes and shifts of seasons during the year. This encourages not only to better understanding of the trends related to drought.
As part of water scarcity prevention and planning, it is necessary to quantify water needs and possibilities of their coverage in the best possible way. We need to know the available retention capacities or plan new ones. It is necessary to establish priorities in water use. It is also necessary to know the position of the ecological flow among these priorities. A systematic, methodologically uniform approach and a good information system are essential in issuing permits. In geographical areas identified as deficient or vulnerable, it is necessary to plan specific solutions and allocate funds for it.
The poster gives an overview of water scarcity management in Slovakia - current legislation and strategic documents, available databases, methodological approaches, as well as the identified gaps, challenges and possibilities.

Keywords: water scarcity, water resources management, climate change, water allocation, prevention

NEW METHODOLOGY ON E-FLOW DETERMINATION IN SLOVAKIA

IVANA BAJKOVIĆOVÁ [1], MAROŠ KUBALA [2], MAREK ČOMAJ [3]

[1] *Water Research Institute, Slovakia, ivana.bajkovicova@vuvh.sk*
[2] *Water Research Institute, Slovakia, maros.kubala@vuvh.sk*
[3] *Water Research Institute, Slovakia, marek.comaj@vuvh.sk*

Abstract

The requirement for the implementation of e-flow, as described in the EC Guidance Document No. 31 Ecological flows in the implementation of the Water Framework Directive, was in Slovakia defined already in river basin management plans in 2015, through the program of measures for improving the status of surface water bodies. However, so far, other variables have been used in practice, representing minimum residual flows, and the methodology for determining e-flow in the conditions of the Slovak Republic was finalized only in 2023.

The starting point for the new methodology was the ambition to support the objective of maintaining/restoring good ecological status of surface water bodies (defined by WFD) – particularly creating a conditions for survival and reproduction of water related ecosystems, having the necessary amount of water at any time of the year.

Various types of watercourses that occur in the natural conditions of Slovakia (all surface water bodies currently delineated on the territory of the Slovak Republic) were categorized into 5 groups. Each of the categories is represented by an "umbrella" species of fish, as an organism with the most complex demands on the aquatic environment (space, depth, flow velocity, regime). For individual categories, the annual regime of minimum flows was assigned. The set seasonality includes increased requirements in the spawning season.

According to the modified Tennant method, it is appropriate to express the e-flow as a multiple of the long-term average flow Q_a. This multiple should meet the criteria defined with regard to the type of water body and the demands of the umbrella species. The expert team set the requirements (hydraulic criteria) for each of the created categories and carried out testing on 50 profiles of watercourses, which are representative in the territory of the Slovak Republic. The result was a formula for calculating e-flow at any moment in the year, for each of the five categories of watercourses.

Furthermore, the possibilities of additional requirements for e-flow, with regard to location in a protected area or other specifics of the river, were analyzed. The requirements for increasing the e-flow related to the degree of protection were quantified.

The included hydrological analysis described the relationship between the required ecological flows and the available quantity of water in particular catchment areas of Slovakia, also in the context of climate change.

The last part of the methodology consists of recommendations for the implementation of the methodology into water management practice. Among other, it points to the importance of the shape of the river bed in which the e-flow flows – i.e. the need for water to flow in a profile that is as natural as possible (otherwise even a high flow rate will not ensure a good environment for the ecosystem). For eventual exceptions (cases that are allowed, in a certain situation, to abstract the amount of water leading to discharge under the e-flow), the recommendations also include the possibilities of appropriate mitigation.

Keywords: e-flow, ecological flow, ecosystem, water allocation, water need

A PRECIPITATION TREND INVESTIGATION RESEARCH OF HUMENNE, SLOVAKIA

YUNUS ZİYA KAYA [1], MARTİNA ZELENAKOVA [2]

[1] *Civil Engineering Department, Hydraulics Division, Osmaniye Korkut Ata University, Turkey, yzkoku@outlook.com*
[2] *Department of Environmental Engineering, Faculty of Civil Engineering, Technical University of Kosice, Slovakia, martina.zelenakova@tuke.sk*

Abstract

Precipitation is one of the main parameters of the hydrological cycle, and fluctuations in the precipitation amount of the regions directly affect the water management plans of the related catchments. Due to global climate change, these fluctuations and extreme weather conditions are increasing. The negative impacts of the changes on the precipitation amounts must be eliminated. To do this, It is essential to analyze the variations of the precipitation over past years for a specific region. In this study, the authors investigated the trend dependences of Humenne, Slovakia, using a relatively new method, namely the Innovative Şen Trend test. Precipitation trends of the mentioned region were investigated on a monthly, seasonal, and annual basis by applying the Innovative Şen Trend test, Mann-Kendall test, and Linear Regression Line approaches. When the traditional trend investigation methods are generally based on the acceptance or rejection of the null hypothesis, the Innovative Şen Trend method is based on the distribution of the time series. The innovative Şen Trend Test approach is a graphical trend investigation method that gives users the opportunity to evaluate the trends based on their own experiences. The nonparametric Mann-Kendall test was applied to the data set within the 95 percent confidence interval. While any trends were not detected by using the traditional Mann-Kendall method within the given confidence interval, various monthly, seasonal, and annual trends were determined by using the Innovative Şen Trend test. The Innovative Şen Trend test was evaluated based on the three classifications. Those classifications were selected as low, medium, and high classes. This identification helps researchers to understand the extremum conditions for the calculated time scale.

Keywords: Precipitation, Trend, Mann-Kendall, Innovative Şen Test, Climatological Fluctuations

WATER ECONOMY PLANNING ON RIVER SCALE EXTENT BY SIMULATION MODEL

STEVCHO MITOVSKI[1], FROSINA PANOVSKA GEORGIEVSKA[2], LJUPCHO PETKOVSKI[3]

[1] *Associate professor, Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, R.N. Macedonia,* smitovski@gf.ukim.edu.mk

[2] *Teaching assistant, Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, R.N. Macedonia,* fpanovska@gf.ukim.edu.mk

[3] *Professor, Ss. Cyril and Methodius University in Skopje, Faculty of Civil Engineering, R.N. Macedonia,* petkovski@gf.ukim.edu.mk

Abstract

Water management planning is crucial for long-term economic, social and environmental stability in civilized societies. One can only make plans with stored water, i.e. water impounded in reservoirs, formed with construction of dams. The process of long-term water planning and management includes creation of new reservoirs, adding new water users to existing reservoirs, as well as improved management of the existing reservoirs. Such analyses are done for the watershed of river Treska, located in the western part of R.N. Macedonia. With total watershed area of 2068 km^2 and average flow of Q=24,2 m^3/s, currently there are three existing dams with reservoirs – Kozjak, Sv. Petka and Matka – supplying water for power production, as well as flood protection of the city of Skopje. During the wate economy planning process, four new reservoirs are planned – Greshnica, Podvis, Makedonski brod and Kalugjerica - in order to suffice the lack of fresh drinking water for the analysed watershed, as well as water for irrigation of agricultural land for the upcoming 20 years. In order to oversee the new planned scheme for Treska watershed, simulation model is prepared with application of HEC ResSim software. The simulation modelling is carried out on river scale extent, by inclusion of the existing and planned dams with reservoirs. The output results of the simulation model point out that the watershed has enough capacity to suffice the water demands for water supply and irrigation, and in addition it provides increased power production from renewable energy sources, for the next 20 years.

Keywords: wsater economy planning, river scale, water demand, simulation model

SANITARY AND ENVIRONMENTAL ENGINEERING, SUSTAINABLE WATER USE

ANALYSIS OF OCCURENCE AND TRANSPORT OF MICROPLASTIC WASTE IN THE ADRIATIC EEA WITH CROATIAN LEGISLATIVE FRAMEWORK

TONI HOLJEVIĆ [1], DR.SC.DANKO HOLJEVIĆ [2], ELIZABETA KOS [3]

[1] *Hidroprojekt-ing doo,Croatia,tholjevic@hp-ing.hr*
[2] *Croatian waters,Croatia,dholjev@voda.hr*
[3] *Directorate for Water Management and SeaProtection, Croatia,elizabeta.kos@mingor.hr*

Abstract

This paper presents a comprehensive analysis of the occurrence and transport dynamics of microplastic waste in the Adriatic Sea, anchored within a legal framework. Presently, microplastic are ubiquitous across nearly all marine ecosystems, with the heightened production and utilization of synthetic polymers establishing the predicament of MP as a prominent challenge in the current century. Implementing systematic measures is imperative through research concentrated on identifying the sources and movement of plastic (deposition of plastic waste). This approach is essential for effectively delineating preventive measures against its introduction. Additionally, it is crucial to emphasize research focused on modeling the movement (transfer) of plastic waste, enabling the anticipation of situations and the definition of appropriate protective measures. In general, the numerical modeling approach has demonstrated its efficacy as a robust tool for predicting the transport of bodies within aquatic midwater systems. In the realm of hydrodynamics, various studies have extensively explored the behavior of particles such as natural sediment and organic microorganisms in water bodies. However, in the context of investigating the dynamics of plastic particles in aquatic environments, the field of numerical analysis is still in its early stages, with only preliminary efforts undertaken. On February 5, 2021, the Croatian Parliament endorsed the National Development Strategy of the Republic of Croatia until 2030, designating it as the paramount document for strategic planning in the development policies of the Republic of Croatia. Central objective of the adopted National Development Strategy is to advance the sustainable management of the Adriatic Sea, coastal areas, and islands, emphasizing the preservation of marine ecosystems. In terms of legal acquis in the Republic of Croatia, the Directorate for Water Management and Sea Protection (DWMSP) is responsible for safeguarding and overseeing the marine environment and coastal regions, operating within the framework established by the Water Act and Environmental Protection Act.

Key words: microplastic, Adriatic sea, numerical modeling, environmental legislation, sustainable management

HYDRAULIC ANALYSIS AND OPTIMIZATION OF A PART OF THE WATER SUPPLY SYSTEM OF THE BUZET CITY

ELVIS ŽIC [1], PETRA ČERNEKA [2], GORAN VOLF [1]

[1] *Faculty of Civil Engineering Rijeka, Radmile Matejčić 3, 51000 Rijeka, Croatia, elvis.zic@uniri.hr; goran.volf@uniri.hr*
[2] *ZIP KONTIĆ d.o.o., Krizmani 91B, 52424 Novaki Motovunski, Croatia, cerneka.petra@gmail.com*

Abstract

Drinking water supply is an important strategic interest of every country. Therefore, it is necessary to think about potentials and possibilities, and ultimately to provide drinking water for a longer period of time. It is important to educate yourself and use modern sophisticated programs that greatly help in designing and modeling the water supply system. Within this paper, two cases of the layout of the water supply network of the Buzet City have been elaborated. In the first part of the paper, the basic features of the analyzed area are presented, and the relevant amounts of water required are defined. For the purposes of dimensioning, calculations were made for the water reservoir and pumping stations. Hydraulic analysis of the water supply system was performed within WaterCAD V8i (WaterGEMS) and Urbano Hydra software packages. For both cases, two models were observed, the model of gravity inflow of water into the reservoir and the model of water inflow into the reservoir by pumping. In the first case, three variants of gravity water inflow and two variants of water inflow by pumping were considered. The variants differ from each other due to the disposition and altitude of the reservoir and source. In the second case, both models were analyzed, each with one variant. Within hydraulic analyses, changes in physical parameters (water flow, velocity of flow, working pressure ect.) were observed for different types of pipe materials (cast iron, PVC and steel pipes) and different fire load (no fire, with one, two or three fires). Oscillations of the water level in the water chamber due to differently defined water levels in the reservoir were observed. Cases and variants are compared and evaluated with computer programs. The Urbano Hydra program can be used to draw longitudinal and characteristic transverse profiles of certain sections and trenches that will not be shown in the paper.

A part of the Buzet City was chosen for the design and analysis of the water supply system. The water supply system is planned for a final population of 7,082 at the end of the project period (30 years). Given that the number of overnight stays by tourists in Buzet has been increasing over the years, the number of tourists, which is equal to 2000, has also been taken into account. There are several large industrial facilities in the area of Buzeština, so for the purposes of this paper, the water consumption required for two industries was defined. In order to meet the working pressures in the system, two water reservoirs, Reservoir 1 and Reservoir 2, were defined, and water reservoir calculations were made for the gravity inflow of water and the inflow of water into the water reservoir by pumping using pumping stations. At the end, the total volumes of both reservoirs were calculated. For the gravity inflow of water in Water Treatment Plant 1, three variants were performed within the first case of the water supply network. The three variants differ with regard to the disposition and altitude of Reservoir 1. Two variants of the pumping station were made for the first case of the water supply network. The variants differ according to the disposition of the pumping station and the source.

For the purposes of hydraulic analysis of the water supply system, sophisticated software packages and tools for fast data processing and simple display of hydraulic analysis results were used. Two computer programs, WaterCAD V8i (WaterGEMS) and Urbano Hydra, were used to compare the obtained results. Within the computer program WaterCAD V8i, the water supply network itself is defined together with the associated consumers. An analysis was performed for three variants of the gravity flow of water in Reservoir 1 with regard to the disposition and altitude of Reservoir 1. The effects of different pipe materials, oscillation of the water level in the reservoir at different defined levels of water in the reservoir were observed. An analysis of two variants of water pumping in Reservoir 1 with a differently defined structure of the pumping station was performed. The WaterCAD V8i program shows the results of the physical quantities within the system and the overall behavior of the defined water supply system. Within the Urbano Hydra computer program, a hydraulic calculation was carried out, which validated and verified the output data with those obtained through the WaterCAD V8i computer program.

Through this paper, we wanted to show the way to optimize the water supply system through different

scenarios and alternatives, as well as implement additional variants of simultaneous fires or find a more optimal period of time for the pumps to work. In doing so, the mutual relationship between two water bodies can be analyzed, i.e. how one depends on the other and the like. Also, a part of the branched network can be connected into a ring network and in this way conduct a hydraulic analysis of how the water flow and working pressure are distributed in the system. Through the two computer programs presented, it is possible to see the expansion of the water supply system, that is, the possibility of connecting new consumers (residential buildings, campsites, hotels, resorts, industrial plants, hotels etc.) for a certain future period of time. Computer programs offer various options that can be used to model and analyze the observed water supply system in a fast and satisfactory way.

Keywords: Buzet City, water supply system, hydraulic analysis, water reservoir, pump, WaterCAD V8i, Urbano Hydra, water flow, velocity of water, working pressure, cast iron pipes, PVC pipes, steel pipes.

COMPARISON OF OPERATION ON THE WASTEWATER TREATMENT PLANT USING SBR AND MBR TECHNOLOGY

ELVIS ŽIC [1], JOHAN KLARIĆ [2], GORAN VOLF [1]

[1] *Faculty of Civil Engineering Rijeka, Radmile Matejčić 3, 51000 Rijeka, Croatia, elvis.zic@uniri.hr; goran.volf@uniri.hr*
[2] *Komunalac Delnice Ltd., 51300 Delnice, Croatia, jklaric11@gmail.com*

Abstract

Wastewater treatment (WWT) is an indispensable part and the final segment of the entire public drainage system, and SBR and MBR treatment technologies are one of the most common in this industry. Wastewater treatment has been a current issue at the state level for many years, with the aim of protecting water from harmful pollution and meeting legal regulations. Investments are underway in the construction and/or reconstruction of a large number of wastewater treatment plants (WWTP) in the Republic of Croatia. The required degree of purification, depending on the area where it is located, is prescribed by the current legislation, while the choice of purification technology is the final decision of the public water service provider and local and regional self-government units. For the purpose of choosing the optimal WWT procedure, that is WWT technology, the spear is often "broken" and variant solutions are created in which, based on the available input parameters, the application of different WWT technologies is evaluated and compared. In addition to the less common conventional technology, a comparison of SBR and MBR technology is almost always made. As a rule, the optimal technology is selected based on the created variant solution, which ultimately results in the construction of the WWTP with that technology.

The idea for choosing this work topic stems from the desire to show a realistic comparison of two WWT technologies, in this case SBR and MBR technologies, using the example of constructed and functional WWTPs. In order for the comparison to be possible and realistic, it was necessary to find WWTPs of equal size and input load that have been operating for many years, but of course with different technologies.

In this paper, an analysis of the operation of two different technologies installed at WWTP Delnice in the Republic of Croatia (SBR, 6600 ES) and WWTP Siffiano in Italy (MBR, 6000 ES) was performed. On constructed WWTPs that have been in operation for a number of years, an analysis and assessment of the performance of each of the technologies was performed, according to the given criteria that are normally applied to variant solutions for choosing the optimal technology. The goal of the research was a realistic presentation, analysis and evaluation of the entire technological process with a presentation of investment and operating costs obtained from the manager. In the descriptive part, the purification process is divided into mechanical pretreatment, biological purification and treatment of excess sludge. The analysis itself includes the parameter of investment value, operating cost, spatial component, control and process complexity, and the purification effect, which are evaluated differently and lead to the final result. At the end of the paper, the theoretical possibility of technology replacement was also discussed, as well as the related implications on the work results and costs of individual WWTPs. The paper provides a brief analysis of the comparison of these two technologies at the La Center WWTP in the USA.

In order to better understand the work of the technologies themselves, in the introductory part, each of the represented technologies is briefly presented, starting with the historical development, a description of the biological treatment of waste water as an essential part of each technology, certain specificities, and requirements during operation and maintenance that must be respected. For individual WWTPs, their basic characteristics are presented in terms of size, placement in space, microlocation, macrolocation, specificity of the area and climate, history of construction and the beginning of their operation. For each analysis, it is necessary to establish certain criteria that will later be used to evaluate the technologies, and as a starting point for them, the criteria that are used when creating variant solutions, from investment and operational costs, through the spatial component, the complexity of control and processes to the final purification effect. For each of the foreseen criteria, the percentage of their share in the overall assessment is determined, and within some of the criteria, the segments of the individual process in the entire process of WWT that is analyzed.

For the best possible description of the work of a particular technology in practice, that is, in order to be able to carry out an adequate analysis in the central part of the work, a description of the applied technologies was made on these two concrete examples. The WWT system with SBR technology in Delnice City and MBR technology in Siffiano City is divided into mechanical pretreatment, biological treatment and treatment of excess biological sludge. For each of these segments, their work is described in more detail with reference to the requirements and specifics related to the applied technology, and specific data on the costs required for the operation of the plant in the form of energy sources, process management and maintenance. The ultimate goal of each WWTP is to achieve the set and required parameters in the output wastewater, so for both considered plants, the end result of work is shown, that is, the effect of WWT based on analyzes that must be carried out in Croatia and Italy in accordance with legal regulations.
In the final part of the paper, an evaluation of WWT technologies and a comparison according to the given criteria is given, in accordance with the specific data mentioned in the earlier description of the individual segment of work of each of the WWTPs and the installed technology. The ultimate goal of the comparison would be a realistic presentation of the difference in technologies and achieved effects based on concrete data and costs obtained from managers that give a realistic picture of the work, which cannot be adequately presented with variant solutions when choosing the optimal technology.

Keywords: Wastewater treatment plant (WWTP), Sequencing Batch Reactor (SBR), Membrane Bioreactor (MBR), Delnice City, Siffiano City, mechanical pretreatment, biological treatment, treatment of excess sludge, costs, comparison.

PREDICTION OF E. COLI BACTERIA ON DRINKING WATER TREATMENT FACILITY BUTONIGA

GORAN VOLF [1], IVANA SUŠANJ ČULE [1], ELVIS ŽIC [1], SONJA ZORKO [2]

[1] *Faculty of Civil Engineering, Department of Hydraulic engineering, University of Rijeka, Croatia, goran.volf@uniri.hr, isusanj@uniri.hr, elvis.zic@uniri.hr*
[2] *Istarski Vodovod d.o.o. Buzet, Croatia, sonja.zorko@ivb.hr*

Abstract

The microbiological quality of the water is a critical factor influencing the convergence of human, animal, and environmental health. Collaborative endeavours persist in exploring methodologies for the monitoring, prediction, and management of microbiological water quality. However, the escalating pace of human activities, exemplified by urbanization and industrialization, has significantly disrupted environmental equilibrium. Aquatic systems endure most of this disturbance, thereby imperilling the microbiological integrity of water bodies through the influx of untreated domestic wastewater and other anthropogenic discharges.

In order to predict microbiological water quality on the drinking water treatment facility (DWTF) Butoniga, which capture water for treatment processes from a nearby Butoniga reservoir in Istria (Croatia), the prediction of the Escherichia coli (E. coli) bacteria concentrations seven days in advance is performed. Input parameters following temperature, O_2, pH, turbidity, total organic carbon (TOC), $KMnO_4$, UV 254, NH_4, Mn, Al and Fe were used to build a prediction model seven days in advance for E. coli bacteria concentrations.

All data is pre-processed concerning modelling and research goal. For the E. coli bacteria prediction model seven days in advance, the entire span of the measured daily data is used, from 2011 to 2020. Missing data were filled in by usage of cubic spline interpolation.

In this research, the machine learning algorithm M5P for induction of model trees integrated into the WEKA modelling software is used. Predicted (shifted) E. coli bacteria concentrations with a seven-day time step is set as a target (dependant) variable, whereas water temperature, pH, turbidity, $KMnO_4$, NH_4, Mn, Al, Fe, O_2 TOC, UV 254 and E. coli bacteria current concentrations are set as independent variables (descriptors) from which prediction model is build. The above parameters are used because they represent the parts of the system (drinking water treatment facility) on top of which the target variables depend.

To achieve the highest correlation coefficient (R), and the optimal number of equations in the tree default values of parameters for building models in WEKA modelling software were used. The model that was performing most accurately, according to the validation method, was selected as a representative model for prediction purposes.

Obtained model for prediction of the E. coli bacteria seven days in advance, in the form of a model tree, has ten equations from which the abovementioned concentrations of E. coli bacteria seven days in advance can be calculated. Which equation will be used depends on the parameters within the model tree. The model does not have so high correlation coefficient with a value of 0.48 (moderate correlation). Other parameter of model are, Mean absolute error (MAE) of 26.5, Root mean squared error (RMSE) of 57.7, Relative absolute error (RAE) of 69.3 % and Root relative squared error (RRSE) of 73.8 %. The performance of the prediction model is presented in Figure 1. From Figure 1 can be noticed why correlation coefficient is not so high, and that is low prediction of peak values. Model has good prediction of concentrations to 100 CFU/100 ml, while higher values are under forecast. The reason for this is that high values have a high probability expectation.

Regardless of, obtained model through the prediction of E. coli bacteria can help to manage certain drinking water treatment processes depending on the biological quality of raw water in the Butoniga reservoir.

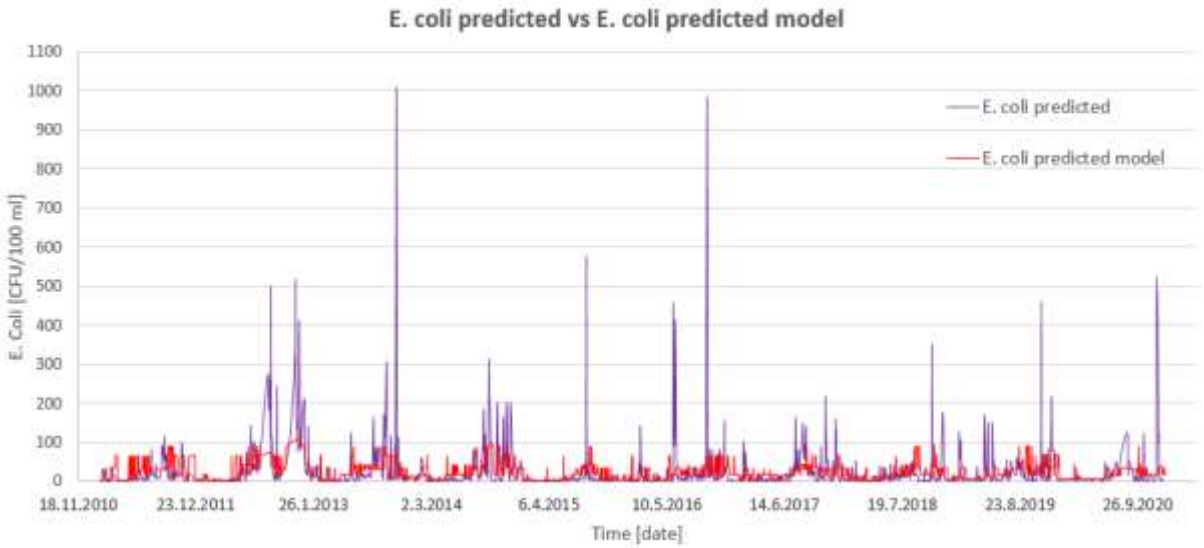


Figure 1. Performace of the prediction model-"shifted" predicted vs. modeled predicted E. coli concentrations seven days in advance.

Future work is focused to obtain more accurate prediction models which can than be used in management purposes.

Keywords: E. coli bacteria, prediction models, machine learning, drinking water treatment facility Butoniga, microbiological water quality

This study received support from several projects. The first project, titled "Sustainable river basin management by implementation of innovative methodologies, approaches, and tools" (uniri-tehnic-18-129), and the second project, titled "Hydrology of water resources and identification of flood and mudflow risk in karst" (uniri-tehnic-18-54), were funded by the University of Rijeka. Additionally, the research also falls under the ZIP UNIRI project line of the University of Rijeka, specifically ZIP-UNIRI-1500-3-22 and ZIP-UNIRI-1500-2-22.

ENERGY CONSUMPTION AND IDLE ENERGY COMPENSATION ON DRINKING WATER TREATMENT FACILITY BUTONIGA

GORAN VOLF [1], DAVID KRAJCAR [2], SONJA ZORKO [2]

[1] *Faculty of Civil Engineering, Department of Hydraulic Engineering, University of Rijeka, Croatia, goran.volf@uniri.hr*
[2] *Istarski Vodovod d.o.o. Buzet, Croatia, sean.cotic@ivb.hr, sonja.zorko@ivb.hr*

Abstract

A prominent challenge confronting the water industry is the integration of sustainability considerations into design methodologies and the mitigation of carbon emissions associated with energy-intensive procedures. Water treatment, an imperative stage for upholding public health standards, constitutes a particularly energy-intensive process.
Drinking water treatment plant Butoniga is one of the main drinking water supply facilities (DWSF) for potable water in Istria, Croatia. Water for treatment process is captured from the Butoniga reservoir, which is a small and relatively shallow reservoir.
The main drinking water treatment process consists of the following units: raw water intake, pre-ozonation, coagulation-flocculation, flotation, rapid filtration, main ozonation, slow sand filter, disinfection, final pH correction, pressure pumping and chlorination.
Water pumping to the water tank/network is carried out through six big pumps with power of 1000 kW, and one small pump with power of 315 kW. The largest consumption of energy on drinking water treatment facility is associated with the pumping operations. On Figure 1 are presented captured and delivered amounts of water from drinking water treatment facility with total energy consumption. It can be seen that the energy consumption on drinking water treatment facility is related to delivered water, i.e. water pumped to water supply system. Also, from Figure 1 can be observed that the operation of the drinking water treatment facility is primarily related to the tourist season. Out of the total annual production and distribution of average 5.000.000 m^3 of water, 3.000.000 m^3 is generated and distributed between June 15 and September 15 (summer month).

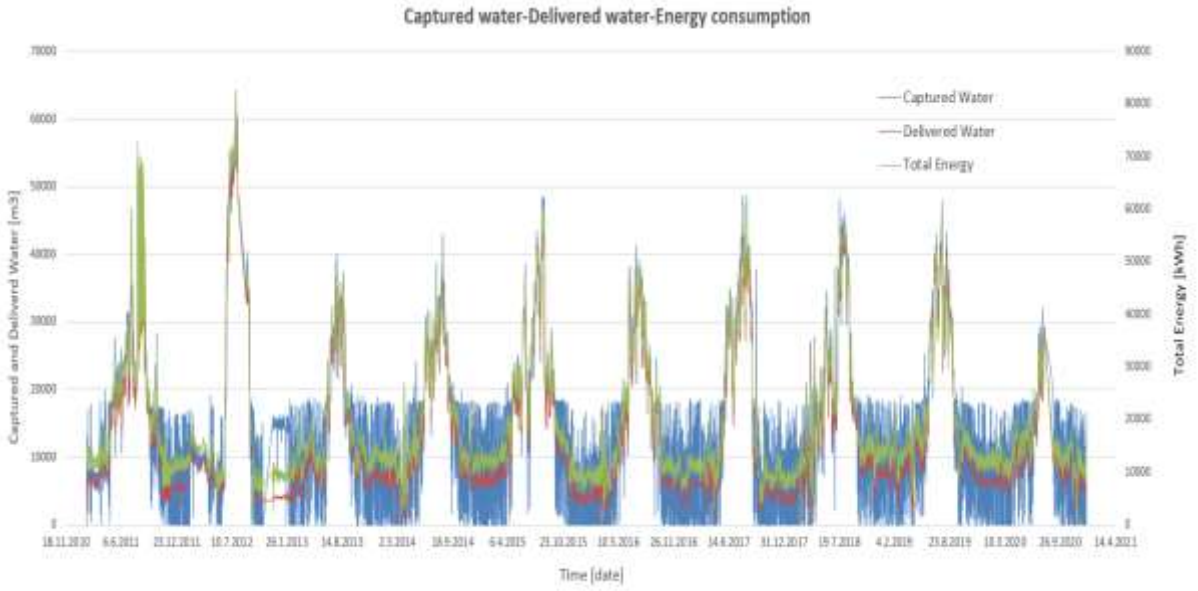


Figure 1. Representation of amounts of captured and delivered water with total energy consumption on Butoniga DWTF in observed period from 2011 to 2020.

Idle energy in pumping water systems refers to the energy consumed by a pump when it's operational but not actively pumping water or when it's running at a capacity higher than necessary to meet the current demand. This can be a source of inefficiency in water distribution systems. By adjusting pump operations to match demand, idle energy compensation improves overall energy efficiency. On drinking

water treatment facility Butoniga, regarding compensation of idle energy, power factor (cos φ) is 0.90 to 0.99.
In this research will be presented energy consumption and idle energy compensation on presented drinking water treatment facility Butoniga.
In summary, managing energy consumption and incorporating idle energy compensation strategies are essential components of sustainable and efficient water pumping systems. These approaches help align energy use with actual demand, optimizing the operation of pumping systems.

Keywords: Drinking water treatment facility Butoniga, reservoir, energy consumption, idle energy compensation

This study received support from several projects. The first project, titled "Sustainable river basin management by implementation of innovative methodologies, approaches, and tools" (uniri-tehnic-18-129), and the second project, titled "Hydrology of water resources and identification of flood and mudflow risk in karst" (uniri-tehnic-18-54), were funded by the University of Rijeka. Additionally, the research was also funded under the project line ZIP UNIRI of the University of Rijeka, for the project ZIP-UNIRI-1500-3-22.

THE EFFECTS OF ULTRASOUND IN OILY WASTEWATER TREATMENT

HANA POSAVCIC [1], IVAN HALKIJEVIC [2], DRAZEN VOUK [3], DOMAGOJ NAKIC [4]

[1] *Faculty of Civil Engineering, University of Zagreb, Croatia, hana.posavcic@grad.unizg.hr*
[2] *Faculty of Civil Engineering, University of Zagreb, Croatia, ivan.halkijevic@grad.unizg.hr*
[3] *Faculty of Civil Engineering, University of Zagreb, Croatia, drazen.vouk@grad.unizg.hr*
[4] *Faculty of Civil Engineering, University of Zagreb, Croatia, domagoj.nakic@grad.unizg.hr*

Abstract

Ultrasonic technology can be used in various branches of industry, but its use in water and wastewater treatment has not been sufficiently researched. The aim of this paper is therefore to explain the basics of ultrasound, its advantages and disadvantages and its application in water and wastewater treatment.
Ultrasound is an acoustic wave generated at high frequencies (above 20 kHz). It is considered an Advanced oxidation process, and has been considered and developed as a potential technology for water and wastewater treatment in the recent decades. When ultrasound is used in water and wastewater treatment, acoustic waves are generated by the vibration of ultrasonic probes or transducers. The zones of higher and lower pressures are created in which microbubbles form and implode.
This paper is divided into two main parts. The first part gives a general overview of ultrasonic technology, including the advantages and disadvantages of this technology and a description of the parameters that influence the process, such as operational and geometrical characteristics. The second part contains an experimental investigation carried out on a laboratory-scale device using a combination of electrochemical (electrocoagulation) and ultrasonic technology to remove mineral oil from oily wastewater. In this part, various operating parameters (number of cycles, flow rate, current density and electrode material) were tested to determine the effects of electrochemistry on mineral oil removal and the contribution of ultrasound to this process. The experimental research showed that the use of both ultrasound and electrocoagulation (sono-EC) with iron electrodes increased the mineral oil removal by 50 % compared to electrocoagulation. When using aluminium electrodes, the removal efficiency of sono-EC is 20 % higher than with electrocoagulation alone. The use of aluminium electrodes is more efficient because the oxidation of aluminium ions is faster than that of iron.

Keywords: cavitation, electrochemistry, intensity, oil; wastewater treatment, ultrasound

ELECTROCHEMICAL REMOVAL OF PESTICIDE ACETAMIPRID

KATARINA LICHT [1], ANTONIJA MATANČEVIĆ [2], DRAŽEN VOUK [3], IVAN HALKIJEVIĆ [4]

[1] University of Zagreb Faculty of Civil Engineering, Croatia, katarina.licht@grad.unizg.hr

2 University of Zagreb Faculty of Civil Engineering, Croatia, amatancevic@student.grad.hr

3 University of Zagreb Faculty of Civil Engineering, Croatia, drazen.vouk@grad.unizg.hr

4 University of Zagreb Faculty of Civil Engineering, Croatia, ivan.halkijevic@grad.unizg.hr

Abstract

Pesticides play an important role in modern agriculture, enhancing crop yield and protecting against pests. However, the indiscriminate use and improper disposal of these chemicals have led to widespread contamination of water bodies, posing potential risks to aquatic ecosystems and human health. Acetamiprid, a neonicotinoid insecticide widely employed in agricultural practices, has garnered attention due to its persistence, toxicity, and potential adverse effects on non-target organisms. Traditional wastewater treatment processes often prove inadequate in efficiently removing pesticides necessitating the exploration of more adequate remediation technologies. Electrochemical methods offer a promising avenue for the degradation and removal of pesticide contaminants from aqueous environments. Through the application of electrical energy, electrochemical processes facilitate the transformation of pollutants via oxidation or reduction, leading to their mineralization or conversion into less harmful by-products. Other mechanisms such as coagulation and precipitation, also, lead to the physical removal of the pollutants.

In this study, the response surface methodology was used to investigate the possibility of electrochemical removal of acetamiprid from water. For statistical experimental design, central composite design was used and three factors were studied – electrode material (Fe, Cu, Al), treatment time (15, 37.5, 60 min) and applied current (4, 9, 14 A). All of the experiments were performed using 5 L of a 10 ppm model acetamiprid solution in a batch reactor. Electrochemical treatment proved to be a viable option with efficiencies over 50%. The generated sludge was analysed and the results indicated that the dominant mechanism of acetamiprid removal is chemical degradation rather than physical removal by formed flocs. Also, a series of experiments was conducted with the addition of hydrogen peroxide in order to investigate the influence of oxidant addition on the efficiency of acetamiprid degradation.

Keywords: neonicotinoid, acetamiprid, electrochemical treatment, wastewater, oxidation

AMMUNITION FACTORY WASTEWATER TREATMENT BY ELECTROCOAGULATION

KATARINA LICHT [1], MARIJA GLAVAŠ [2], IVAN HALKIJEVIĆ [3], DRAŽEN VOUK [4], TOMISLAV BOLANČA [5], ANJA CRNOGAJ [6]

[1] *University of Zagreb Faculty of Civil Engineering, Croatia, katarina.licht@grad.unizg.hr*

[2] *University of Zagreb Faculty of Civil Engineering, Croatia, glavasmari@gmail.com*

[3] *University of Zagreb Faculty of Civil Engineering, Croatia, ivan.halkijevic@grad.unizg.hr*

[4] *University of Zagreb Faculty of Civil Engineering, Croatia, drazen.vouk@grad.unizg.hr*

University of Zagreb Faculty of Chemical Engineering and Technology, Croatia, tbolanca@fkit.unizg.hr

[6] *BO GROUP d.o.o., Croatia, acrnogaj.inzenjering@bp-group.hr*

Abstract

Ammunition manufacturing is characterized by intricate processes and the consequential generation of highly complex and hazardous wastewater. The discharge from ammunition factories typically contains a cocktail of pollutants, including heavy metals, organic compounds, and suspended solids, posing potential ecological risks if left untreated. Conventional treatment methods struggle to efficiently treat the complicated composition of ammunition factory wastewater, often falling short in achieving stringent regulatory standards. In this context, electrocoagulation (EC) emerges as a promising alternative for the remediation of such challenging effluents. EC, a robust electrochemical process, involves the dissolution of sacrificial electrodes to induce coagulation and subsequent removal of contaminants through processes such as precipitation, flocculation, and electroflotation.

This paper presents an investigation into the application of electrocoagulation for the treatment of ammunition factory wastewater characterized by low pH value, high electrical conductivity, high chemical oxygen demand (COD) and total dissolved solids (TDS), as well as high concentrations of iron (Fe), zinc (Zn), copper (Cu) and lead (Pb). Using a simple set-up, two electrode materials, aluminum and iron, were tested, as well as their combinations. The influence of the initial pH value of the solution was, also, investigated. Treatment time varied from 5 to 30 minutes and electric current of 3 A was used in all of the experiments. 50% of COD and almost complete heavy metal removal was achieved in 30 minutes, indicating that electrocoagulation could be a promising technique for the remediation of heavily contaminated wastewaters.

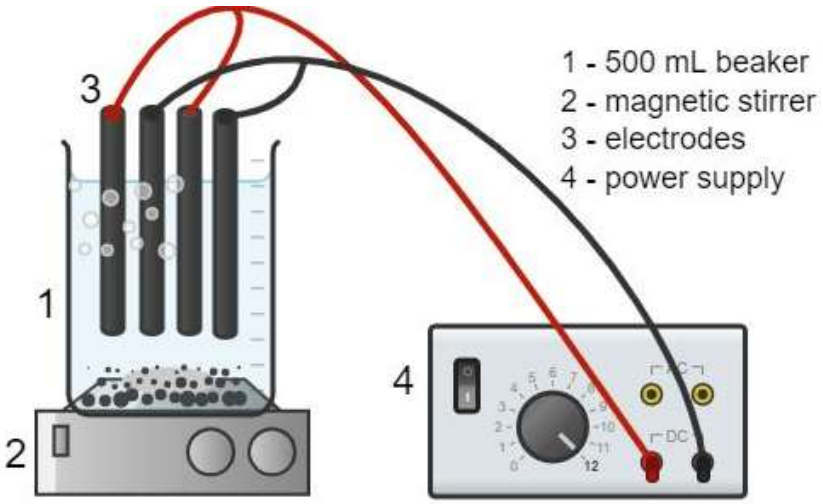


Figure 1. A schematic view of the experimental set-up

Table 1. The initial and final quality parameters of investigated wastewater

	pH	**Conductivity (µS/cm)**	**TDS (mg/L)**	**Salinity (PSU)**	**COD (mg O_2/L)**
Before EC	1.95	7 233	3 616	4.0	2 060
After EC	5.3	1 402	701	0.7	989

Keywords: electrocoagulation, wastewater treatment, COD, heavy metals, ammunition factory wastewater

THE POTENTIAL OF USING RESIDUE FROM SEWAGE SLUDGE GASIFICATION IN AN EXPERIMENTAL PLANT

DOMAGOJ NAKIĆ [1*], HANA POSAVČIĆ [2], KATARINA LICHT [3], DRAŽEN VOUK [4], IVAN HALKIJEVIĆ [5]

[1*] *University of Zagreb Faculty of Civil Engineering, Croatia,* domagoj.nakic@grad.unizg.hr

[2] *University of Zagreb Faculty of Civil Engineering, Croatia,* hana.posavcic@grad.unizg.hr

[3] *University of Zagreb Faculty of Civil Engineering, Croatia,* katarina.licht@grad.unizg.hr

[4] *University of Zagreb Faculty of Civil Engineering, Croatia,* drazen.vouk@grad.unizg.hr

[5] *University of Zagreb Faculty of Civil Engineering, Croatia,* ivan.halkijevic@grad.unizg.hr

[*] *Corresponding author*

Abstract

Sewage sludge (SS) treatment and disposal have become one of the most important and most expensive issues within wastewater treatment cycle. Current requirements for disposal of SS mainly point to the possibility of "using it whenever appropriate", minimizing the adverse effects on the environment at the same time. Croatian company working on the research and development of novel energy production systems has created an innovative gasification system that uses thermal energy to convert organic material into syngas (hydrogen) and carbon black. Almost any organic material can be used as feedstock and so does sewage sludge. Carbon black is the main by-product of the system, and it can be further used based on the principles of circular economy. The derived gasification biochar product is porous and inexpensive, so it has a potential to be used as an adsorbent supplementing traditional commercially activated carbon adsorbent in wastewater treatment. The possibilities of use in this area are multiple, which is shown by concrete results of experimental research on synthetic solutions in the removal of nutrients (phosphate and ammonium), certain heavy metals, but also some pesticides. In a separate part of the research, an examination of the possibility of using SS biochar in the production of building materials was carried out. SS biochar has shown the potential to replace part of the original raw materials: cement in the production of concrete, or clay in the production of brick products. The final goal of the broader research is to examine the possibility of multiple use of SS biochar in wastewater treatment and further use of the same material in the production of innovative building materials and products. This directly closes the cycle of the circular economy, where the by-product of one industry is used first in that same industry, and then finally disposed of in another industry, thereby reducing the need for natural raw materials.

Keywords: sewage sludge, gasification, hydrogen, biochar, adsorbent, construction materials

MATHEMATICAL MODELLING OF THE BATCH REACTOR FOR WATER PH CONTROL

IVAN HALKIJEVIĆ [1], KATARINA LICHT [2], HANA POSAVČIĆ [3], DOMAGOJ NAKIĆ [4],

[1] *University of Zagreb Faculty of Civil Engineering, Croatia,* ivan.halkijevic@grad.unizg.hr

[2] *University of Zagreb Faculty of Civil Engineering, Croatia,* katarina.licht@grad.unizg.hr

[3] *University of Zagreb Faculty of Civil Engineering, Croatia,* hana.posavcic@grad.unizg.hr

[4] *University of Zagreb Faculty of Civil Engineering, Croatia,* domagoj.nakic@grad.unizg.hr

Abstract

The pH value of water is one of the most important parameters when treating wastewater or conditioning drinking water. The desired pH can be achieved chemically by adding acid or alkali, but it can also be achieved by electrolysis of water using a semi-permeable membrane. A semipermeable membrane allows anions or cations to pass through the membrane thus making areas where the pH value is higher or lower. This paper presents the procedure for developing a simple mathematical model for controlling the pH of water in a batch reactor using direct current and a cation exchange membrane. The influential parameters of the model are described, as well as the operating parameters and their values for designing a simple 2D model.

Keywords: pH value, mathematical modeling, water electrolysis,

APPLICATION OF THE AHP METHOD TO THE SELECTION OF SEWAGE SYSTEM TYPE

MARIJA ŠPERAC [1], TATJANA MIJUŠKOVIĆ SVETINOVIĆ [2], SILVIA IVA MILIČEVIĆ [3] …

[1] *Josip Juraj Strossmayer University of Osijek Faculty of Civil Engineering and Architecture Osijek, Croatia, msperac@gfos.hr*

[2] *Josip Juraj Strossmayer University of Osijek Faculty of Civil Engineering and Architecture Osijek, Croatia,* tatjanam@gfos.hr

[3] *Josip Juraj Strossmayer University of Osijek Faculty of Civil Engineering and Architecture Osijek, Croatia, smilicevic3@gmail.com*

Abstract

The sewage system is a very important urban infrastructure that collects, drains and treats wastewater. The choice of the type of sewage system affects the efficiency of drainage and the standard of living of the urban environment. Factors that should be taken into account when choosing the type of sewer are: the area and terrain conditions where the sewer will be built, construction costs, aesthetics, reliability and efficiency of the system, and maintenance methods and costs. Problems related to multi-criteria decision-making are often extremely complex, not only because of the large number of diverse criteria, but also because of their different evaluation and ranking. Due to the large number of available multi-criteria decision-making methods, it is difficult to choose the best one because each method has its own limitations, peculiarities, hypotheses, premises and perspectives and can lead to different results when applied to the same problem. The Analytic Hierarchy Process (AHP) method is a useful tool for handling objectives, multiple and multi-dimensional criteria and measures in the decision-making process. It proved to be well applicable for selecting the type of sewage system. In this paper, the AHP method is applied to the complex sewage system of the town of Županja (town in eastern Slavonia, Croatia), which consists of gravity and vacuum sewage. The selected method, which allows for a hierarchical structure of the problem, included analysis through social (impact during construction, placement in the space, complexity of the system for users, unpleasant smells), economic (investment value, operating costs, complexity of construction) and ecological (impact on the environment and energy consumption) criteria. When determining the most important criterion, the ecological criterion proved to be the most important with a representation of 48%, then social with a representation of 41% and finally economic with a representation of 11%. In the process of choosing the appropriate type of sewerage system in the area of the city of Županja, vacuum sewerage proved to be a more adequate choice. Vacuum sewerage is a modern and advanced technical solution for waste water management that brings a number of advantages. The systems are ideal for use in plain terrain, as well as in cases of high groundwater levels, which is another benefit considering the observed area. This characteristic of vacuum sewerage enables better use of urban space and reduces the need for intensive interventions in the environment during the construction phase. Thanks to the shallow burial depth, the possibility of groundwater infiltration is significantly reduced. Eliminating infiltration and draining only sanitary waste water, vacuum sewerage results in a smaller amount of waste water in the channel and, therefore, a smaller amount of waste water that has to be purified in the purification device. In terms of durability and maintenance, this type of sewer can result in lower operating costs over the life of the system. Also, by implementing such systems, financial savings of approximately 30-40% are achieved. Smaller soil excavations, smaller amount of waste water and reduced need for waste water treatment can reduce harmful effects on the environment and local ecology.

Keywords: multi-criteria decision-making, AHP method, gravity sewerage, vacuum sewerage, Županja (Croatia)

ANTHROPOLOGICAL IMPACT ON SMALL NATURAL WATER RESOURCES ON PAG ISLAND

IVANA SUŠANJ ČULE[1], DANIELA KALAFATOVIC[2], GORAN VOLF[1], PATRIZIA JANKOVIĆ[2], NATAŠA ATANASOVA[3], BARBARA KARLEUŠA[1], NEVENKA OŽANIĆ[1]

[1] *University of Rijeka, Faculty of Civil Engineering, Department of Hydrotehnics and Geotehnics, Republic of Croatia, isusanj@uniri.hr, goran.volf@uniri.hr, barbara.karleusa@uniri.hr, nozanic@uniri.hr*

2 University of Rijeka, Faculty of Biotechnology and Drug Development, Medicinal Chemistry Division, Croatia, daniela.kalafatovic@uniri.hr, patrizia.jankovic@uniri.hr

3 University of Ljubljana, Faculty of Civil and Geodetic Engineering, Institute of Sanitary Engineering, Slovenia, natasa.atanasova@fgg.uni-lj.si

Abstract

Quality, quantity, and availability of water resources, as well as their physicochemical and biological characteristics, are constantly changing because of the impact of natural and human activities [1]. The anthropological impact on water resources is already well defined indicating that urbanisation, industrial and agricultural activities introduce pollutants into water resources, and influence the water balance within the water resource catchments [2]. Natural impact on water resources systems balance can be visible through weather extremes such as droughts and floods [2]. It is impossible to divide anthropological from natural activities' negative impact on water resources systems but the existence of the aforementioned can be determined.

In this paper, the focus is placed on human impact on natural small water resources such as small lakes and ponds, in order to provide the foundation for the development of impact mitigation practices. Naturally formed small lakes or ponds that are located in or near urban areas are usually recognized by the local population and tourists because of their natural beauty and/or biodiversity. They are usually not used for human activities and have specific biotopes and biocenosis, and therefore can be significant for the overall ecosystem. Despite their recognition, the direct or indirect anthropological impact is visible on those small water resources and their catchments and will be described in this paper.

Water bodies of mentioned resources are usually considered public water resources under the Croatian water management and are not characterised as highly protected, vulnerable, or landscape significant areas according to any Croatian or European Union laws and directives. The catchment areas are usually under the jurisdiction of the local authorities and are not recognized in any way in local authority urban plans. Since their importance has not been determined, there is no existing mechanism for their protection, and therefore natural small water resources such as small lakes and ponds are sometimes neglected and can face accelerated degradation. It should be noted that thousands of small lakes and ponds on the Croatian territory are not under protection from anthropological actions, and we can not expect that each of them should be highly protected, but there is a high importance in controlling and maintaining a stable ecosystem with mitigated human impact until they fall under some kind of regulatory protection in the future.

This paper aims to determine the existence of the anthropological impact on three naturally formed ponds located on the island of Pag, Croatia, namely Škuncini stani, Dabovi stani, and Vidasovi stani. These ponds were chosen because of the defined fast growing human impact of tourism, urbanisation, and agricultural activities on the catchment areas and water bodies. To provide insight into the anthropological impact, hydrological analysis and measurement of the water quality properties were performed. The anthropological impact is also shown through the characterisation of the synthetic polymer fragments collected near the water bodies or in the water itself.

The hydrological analysis encompasses a description of the selected water resources' topographic catchments, catchment physical characteristics, hydrogeological properties of the catchments, and analysis of the catchment landcover changes in the last fifty years in order to provide insight into the impact on the natural water balance.

Water quality measurements are carried out by water sampling and water analyses in the Hydrotechnical Laboratory at the Faculty of Civil Engineering in Rijeka. The water quality parameters are measured by the Spectrophotometer - Hach DR 3900. In this paper physical and chemical properties are provided as

follows: pH, Total dissolved solids [ppm], Conductivity [μS/cm], Nitrates [mg/L; NO_3 -N], Ammonium [mg/L; NH_4^+ - N], Chloride [mg/L; Cl^-], Nitrites [mg/L; NO_2^- - N], Total nitrogen [mg/L; TNb], Orthophosphate [mg/L; $PO^3_4{}^-$ P], Total phosphorus TP [mg/L; $PO^3_4{}^-$ P], and Chemical oxygen demand COD [mg/L; O_2], in order to assess overall quality and anthropological impact on the water.
The direct visible negative impact of human activities is provided through synthetic polymer collection in the water or the vicinity of water resources. It is well known that synthetic polymers under atmospheric action degrade, which means that small micro and nano particles are released into the environment and can enter natural water resources [3]. For the purpose of this research, macro plastics are collected, categorized, and analysed using Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) spectroscopy performed on the Cary 630 FTIR spectrometer (Agilent) to determine the types of synthetic polymers. For this purpose transmittance spectra were recorded and typical polymer fingerprints were identified. Moreover, the possible degradation of the collected plastics was assessed.
This investigation determined the anthropological impact on small naturally formed water resources, and the results will be presented within the paper, as well as the hydrological analysis and current water quality state. Moreover, this research will answer the questions about the potential significance of locations, and the need for further observation, protection, and the possibility of revitalization. Furthermore, the obtained results will provide the foundation for the development of protection mechanisms and mitigation of human impact on yet unprotected and vulnerable natural resources.

Keywords: anthropological impact, hydrological research, water quality parameters, synthetic polymer

[1] Khatri, N., & Tyagi, S. (2015). Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Frontiers in life science*, *8*(1), 23-39.

[2] Akhtar, N., Syakir Ishak, M. I., Bhawani, S. A., & Umar, K. (2021). Various natural and anthropogenic factors responsible for water quality degradation: A review. *Water*, *13*(19), 2660.

[3] Zhang, K., Hamidian, A. H., Tubić, A., Zhang, Y., Fang, J. K., Wu, C., & Lam, P. K. (2021). Understanding plastic degradation and microplastic formation in the environment: A review. *Environmental Pollution*, *274*, 116554.

MEASURES TO MITIGATE THE NEGATIVE IMPACT OF RAINFALL RUNOFF IN NON-INFILTRATION AREAS

RÉKA WITTMANOVÁ [1], JAROSLAV HRUDKA [2], ŠTEFAN STANKO[3], MARTIN MELIŠKA[4]

[1] *Slovak University of technology in Bratislava, Faculty of Civil Engineering, Department of Sanitary and Environmental Engineering, Slovakia, reka.wittmanova@stuba.sk*

[2] *Slovak University of technology in Bratislava, Faculty of Civil Engineering, Department of Sanitary and Environmental Engineering, Slovakia, jaroslav.hrudka@stuba.sk*

[3] *Slovak University of technology in Bratislava, Faculty of Civil Engineering, Department of Sanitary and Environmental Engineering, Slovakia, stefan.stanko@stuba.sk*

[4] *Slovak University of technology in Bratislava, Faculty of Civil Engineering, Department of Sanitary and Environmental Engineering, Slovakia, martin.meliska@stuba.sk*

Abstract

Reduction of surface runoff inflow into the sewerage network has been actively discussed for several years. In many countries, approaches have been developed and are now commonly used in practice. These approaches are gradually being applied in Slovakia as well, but we lack a unified methodology adapted to Slovak conditions. Rainwater tanks are considered the most effective in terms of recipient protection, but their construction within an existing network is complicated due to the location of the structure. For the construction of new large-scale buildings, the design and implementation of retention infiltration tanks are approached. In urban center areas and highly urbanized areas, adaptive measures such as infiltration green belts, tree rows with infiltration pits, green roofs, water storage tanks with water recycling, and others are proposed. The aim of the contribution is to propose a system of objects to reduce rainfall runoff into a unified sewerage network and subsequently assess its effectiveness. The contribution focuses on the area defined in the city of Trnava, which does not have suitable soil for the construction of infiltration facilities. The effectiveness of individual measures in the area will be determined using a mathematical model of the sewerage network and three loading scenarios.

Keywords: wastewater, stormwater, runoff, infiltration, climate change, urban areas

WATER TREATMENT IN SLOVAKIA - PAST AND PRESENT

DANKA BARLOKOVÁ, JÁN ILAVSKÝ, ALENA MATIS

Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology, Slovak Republic, danka.barlokova@stuba.sk, jan.ilavsky@stuba.sk,

Abstract

Water treatment represents the necessary step in several cases related to obtain a quality and a safe drinking water. Treatment plants are among technically and technologically advanced constructions that anytime are to treat the ground or surface water to get drinking water complying with the requirements of the Decree of the Ministry of Health of the Slovak Republic no. 91/2023 Coll. which establishes details of drinking water quality, drinking water quality control, monitoring program and risk management in drinking water supply.

In Slovakia, the first water treatment plants (WTPs) were built in the thirties of the last century, which was due to the natural conditions in which Slovakia is located, where groundwater of excellent quality is the dominant source used to supply the population with drinking water. Approximately only 17.8% of the total amount of water supplied to public water supply systems is water obtained from surface sources. From the point of view of the quality of groundwater used for drinking water supply, the content of iron, manganese, ammonium ions, sulfates, nitrates, the content of heavy metals (e.g. arsenic, antimony), etc. are decisive indicators. The content of CO_2, hydrogen sulphide and the microbiological quality of the water are not negligible.

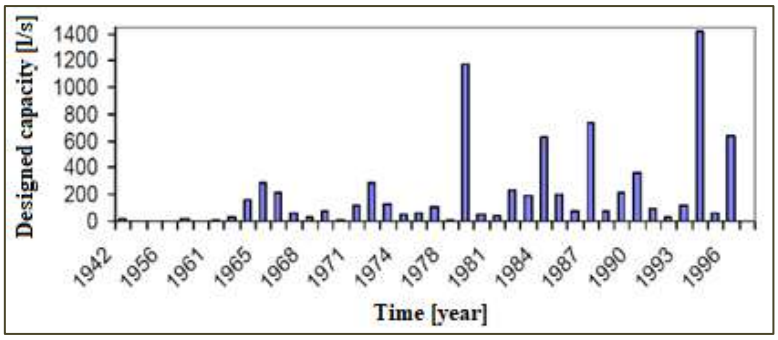


Figure 1. Years in which water treatment plants were put into operation (Source: WRI)

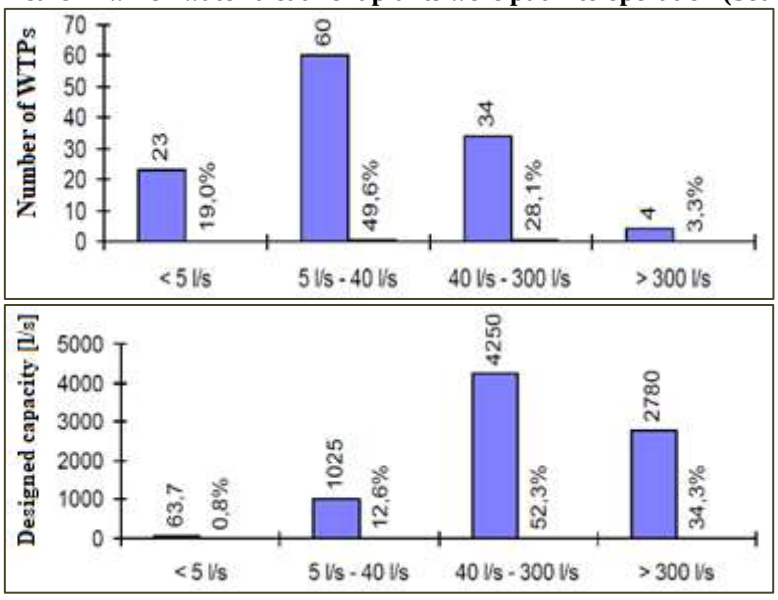


Figure 2. WTPs apportionment between designed capacity and size criterion/categories (Source: WRI)

Important sources of surface water are surface flows in mountain and foothill areas and especially water reservoirs where water treatment plants with a projected capacity of over 200 l/s have been built. In the case of surface waters, it is necessary to remove substances that cause turbidity, coloration, alkalinity, absorbency, microbiological revival, organic pollution (COD, TOC), micropollutants, cyanobacteria and algae are now increasingly coming into focus.
Over the course of several decades, new technologies, materials, and equipment were developed, which led not only to the improvement of the efficiency of the water treatment process, but also to operational and energy savings. And in many cases, the deteriorating quality of the treated water is the cause of inadequate technology. The solution to this problem lies in the modernization and reconstruction of these objects, but the obstacle is often considerable financial resources related to these activities. In recent years, even in Slovakia, modern treatment methods have been put into operation (e.g. membrane processes, adsorption on GAU, flotation, multi-material filtration, advanced oxidation processes, etc.). Currently, they have undergone a complete modernization, e.g. water treatment plants Perlová Dolina, Štrbské Pleso, Demänovská Dolina, Osuské, Borinka, Holíč, Turček, Klenovec, Málinec, Čierny Balog, Jasenie, Pohronský Bukovec, and others. Modernization of UV Rozgrund, UV Hriňová, ÚV Bukovec, UV Stariná, which treat water from water reservoirs, is being prepared. The use of granulated (powdered) activated carbon as a safety screen for organic micropollutants, or when removing the smell of water.
Some modernized water treatment plants will be described in more detail in the presentation.

Keywords: water treatment, groundwater, surface water, water treatment plant technology, drinking water quality.

Preparation of the Manuscript was supported by Project VEGA 1/0666/23 a APVV-22-0610 and I the help of personel of the Water Management Companies who provided the necessary information.

CHANGES OF THERMOCLINE IN TWO DIFFERENT RESERVOIRS FOR DRINKING WATER SUPPLY IN SLOVAKIA

YVETTA VELÍSKOVÁ [1], VALENTÍN SOČUVKA[2], MAREK SOKÁČ [3], MÁRTA KOCZKA BARA [4], SAEID OKHRAVI [5]

[1] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, veliskova@uh.savba.sk*

[2] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, socuvka@uh.savba.sk*

[3] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, sokac@uh.savba.sk*

[4] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, bara@uh.savba.sk*

[5] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, okhravi@uh.savba.sk*

Abstract

Seasonal changes of thermal stratification are common phenomenon in lakes or reservoirs. Thermal stratification means that the water in such water bodies forms certain thermal layers due to solar heating. When a water body stratifies, three different layers typically form (see Fig. 1). Thermocline is a relatively thin part of the metalimnion layer in which temperature decreases rapidly with depth increase. The thermocline has been defined as a layer of water in which the temperature decrease 1° or more along 1 meter of the depth.

Seasonal changes in the intensity of solar radiation and air temperature cause continuous changes in thermal stratification - a change in water temperature causes a change in its density, which makes it move and thermal layers mixing. Such mixing in lakes or reservoirs is extremely important, as it is the event that, for example, causes replenishing dissolved oxygen levels in the deepest waters of such water bodies. This movement causes a change in the stratification of several water quality indicators (chemical stratification) and also the position of the thermocline.

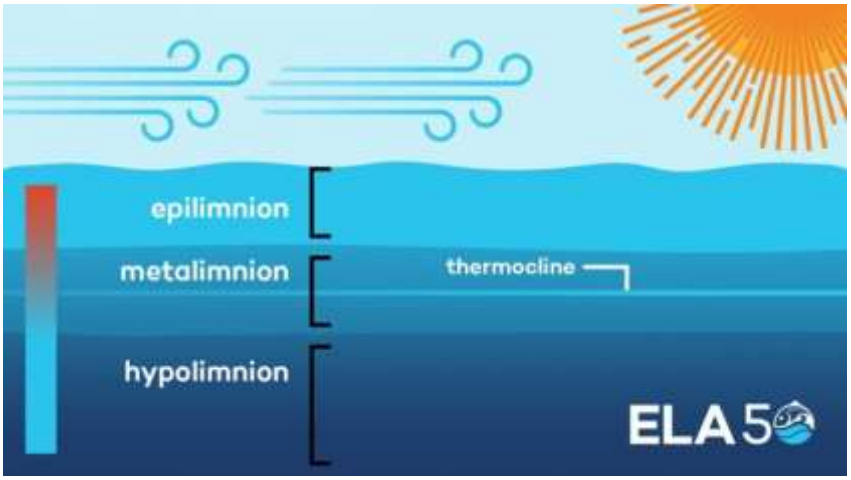


Figure 1. Scheme of stratification in lakes and reservoirs (source:Fafard, 2018) (https://www.iisd.org/ela/blog/lakes-stratify-turn-explain-science-behind-phenomena/)

This paper analyses the seasonal changes of the thermocline position in two water reservoirs in Slovakia: the Rozgrund reservoir and the Turček reservoir. They are relatively close to each other, but have different parameters. The Turček reservoir is younger (1996) and it was built primarily for drinking water supply, but also for flood protection of downstream part of the basin and for ensuring ecological discharges, as well. Total volume of the reservoir is 10,8 mil. m^3, the elevation of the maximum operating level is 775,3 m above sea level, the maximum depth is 60 m. The Rozgrund water reservoir was built in the 18th century as part of a unique water management system in the vicinity of Banská Štiavnica. The original role of the Rozgrund reservoir was the accumulation of water to drive mining machines, from the beginning of the 20th century it was also used as a source of drinking water until the

recent past, and today it is operated as a potential reservoir for supplying the population with drinking water. Its total volume is 0,515 mil. m^3, the elevation of the maximum operating level is 705 m above sea level, the current maximum depth is around 19 m.

As preliminary results show, stratification is formed in both cases. In the summer, its course is almost the same; the thermocline is formed at a depth of about 4-5 m below the water surface (see Fig. 2). In the spring and the autumn season, however, the thermal stratification in these reservoirs is different. It is probably caused both by the different depth of the reservoir and, of course, by the current manipulation. Both of these facts affect the dynamics of the water in them and thus also the mixing of temperature layers.

The study presents measurements over the one year. In the next step, data from next measurement campaigns, as well as the results of numerical simulations, will be analysed to confirm the facts found.

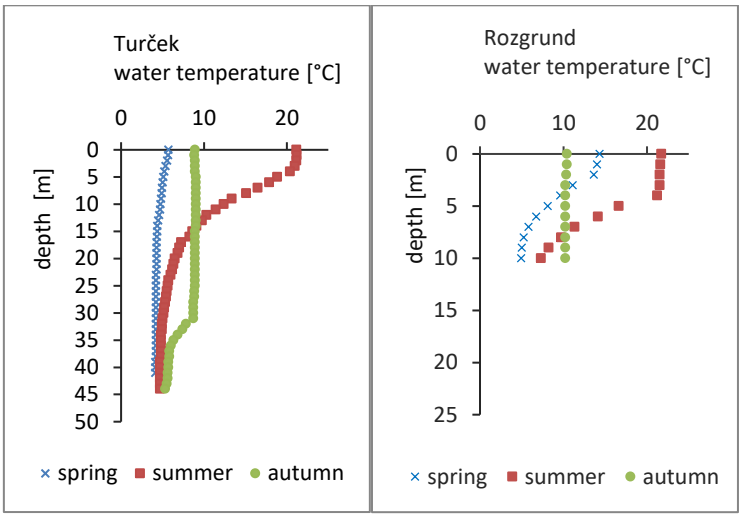


Figure 2. Measured course of water temperature along the water depth in the reservoir (on the right – the Turček reservoir, on the left – the Rozgrund reservoir)

Keywords: temperature, stratification, thermocline, seasonal changes, drinking water supply, the Turček reservoir, the Rozgrund Reservoir

SURFACE RUNOFF AS A POTENTIAL SOURCE OF ENVIRONMENTAL POLLUTION

JAROSLAV HRUDKA[1], ŠTEFAN STANKO, IVONA ŠKULTÉTYOVÁ, RÉKA WITTMANOVÁ, ADAM KOLLÁR

[1] *Slovak University of technology in Bratislava, Faculty of Civil Engineering, Department of Sanitary and Environmental Engineering, Slovakia, jaroslav.hrudka@stuba.sk*

Abstract:

Changing climatic conditions in urbanized areas have a tremendous impact on the quality of life in urbanized areas. Persistent prolonged dry periods, extreme downpours with high runoff or prolonged rainfall are extreme problems for efficient urban water management. Extreme weather changes also result in environmental risks for the seepage or discharge of highly contaminated water from the first flush. These effluents are a potential source of groundwater and surface water pollution in which various types of pollutants are concentrated. Our research focuses on evaluating the water quality of surface runoff with an emphasis on micropollutant concentrations. The analyses are aimed at evaluating the concentrations of heavy metals, microplastics, and other pollutants in surface runoff with respect to receiving water quality and groundwater quality.

GEOTECHNICAL ENGINEERING

STABILITY OF STRUCTURES DURING FLOODS

JOZEF HULLA [1], MARTIN BRČEK [1]

[1] Faculty of Civil Engineering STU in Bratislava, Department of Geotechnics, Slovak Republic, jozef.hulla@stuba.sk, martin.brcek@stuba.sk

Abstract

In 2023, there was likely not a single country in the world untouched by devastating floods. The primary cause was extremely intense rainfall, which in many places led to significant damage and collapses of buildings, including dams and flood protection dikes, triggering numerous landslides. The most severe consequences of the floods were observed in China and Libya. The leading cause was intense rainfall, resulting in water levels rising 5 meters above ground level. Structures were primarily compromised by uplift, flow pressure, and soil erosion.

In the capital of the Slovak Republic, in the historic centre, on the building of the Old Town Hall in Bratislava, a marker from 1850 has been preserved, indicating a flood level approximately 1 meter above ground level at that time. From 1954 to 2023, flood levels in the Danube River showed maximum levels 2 to 3 meters lower.

In the past, protective flood control measures were implemented to ensure that the destructive impacts of floods were practically mitigated in construction sites in Bratislava. On the left bank of the Danube, permanent diaphragm walls were constructed with reinforced and sealed foundations, along with mobile walls positioned at approximately the level of a thousand-year flood.

During the floods of 1954, the protective dikes of the Danube breached in two locations in Hungary. In 1965, breaches occurred at two points in Slovakia, causing damage to over 10,000 homes in the flooded area, which were constructed from unsuitable building materials. The breaches in the protective dikes were attributed to internal erosion in the immediate subsoil. Consequently, critical foundation locations of the protective dikes were sealed with underground walls.

Structures created near unprotected streams are the most vulnerable. To prevent their destruction during floods, they must be constructed with stable materials that meet all stability requirements even under extreme flood conditions. The design includes considering hydrodynamic effects on structures and their foundations and the potential deterioration of soil properties. Stability can be ensured through the use of piles, diaphragm walls, anchors, and artificial improvement of soil properties.

The most significant protective measures include water reservoirs, polders, and flood dikes. They can prevent or significantly reduce the increase in flood levels in human settlement areas.

Keywords: floods, water levels, structures, damages, protective dikes, stability, protection.

MEASURING FILTRATION VELOCITIES IN THE OBSERVATION WELLS OF DAM AND THEIR TIME DEVELOPMENT

JURAJ ŠKVARKA[1], JURAJ CHALMOVSKÝ[2]

[1] *Faculty of Civil Engineering STU in Bratislava, Slovakia, juraj.skvarka@stuba.sk*

[2] *Faculty of Civil Engineering, Brno University of Technology, Czech Republic, chalmovsky.j@fce.vutbr.cz*

Abstract

Special methods for measuring filtration velocities can be used to monitor groundwater flow and seepage flow in dams' bodies and subsoil. In Slovakia, single-well indicator methods are most commonly used to measure water flow velocities. For monitoring vertical water flow in wells, a submerged device is used, which incorporates a dosing unit with pneumatic-hydraulic control of the injection of the indicator and two conductometric sensors positioned below and above the injection point, at a distance of 0.5 m. The indicator is often sodium chloride in powder form or an aqueous solution. The submerged device is connected to a computer converter via a multi-core cable, and then to a portable computer. On the computer screen, concentration curves can be directly monitored, and the time at which maximum concentration occurs (peak time) can be determined.

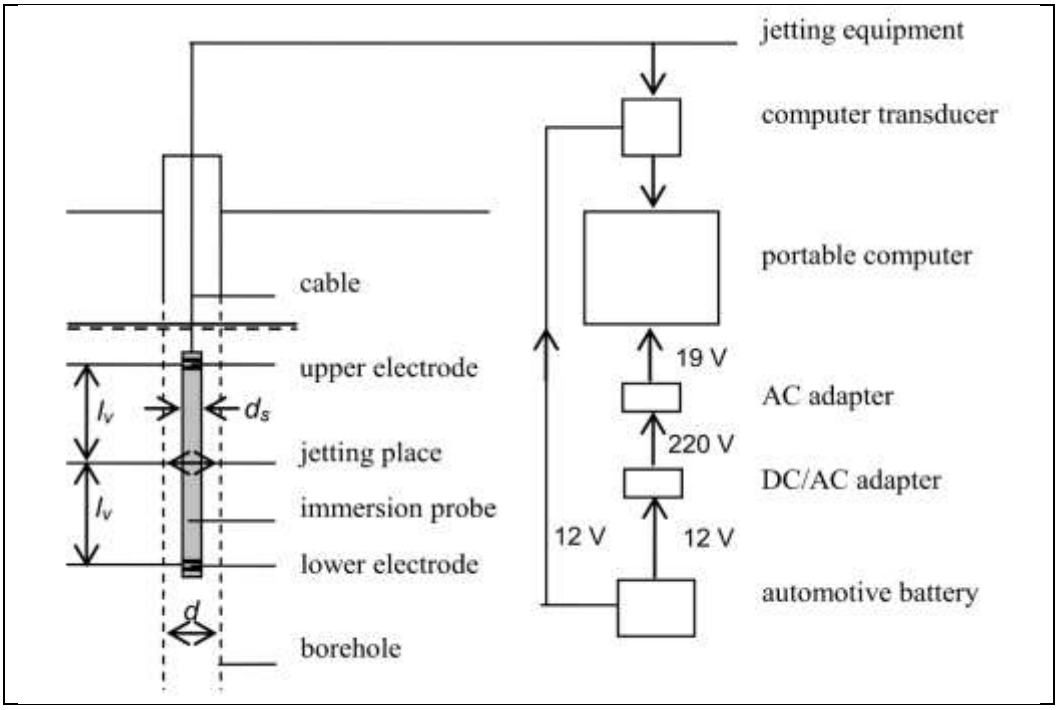


Figure 1. Scheme of the device for measuring vertical water flow in boreholes

This paper focuses on measuring filtration velocities by monitoring the vertical flow of water in a well. The output of the measurement is concentration curves, from which the filtration velocities are then calculated. The paper analyses and compares concentration curves at a specific hydraulic structure at different times under the same loading state, from which the filtration velocities are then derived. The correct interpretation of these measurements has a significant impact on the results of these measurements, which are used to assess the safety of the water structure, mainly from the point of view of filtration stability.

Keywords: groundwater, seepage, vertical water flow, concentration curve, observation well, filtration stability

THE USE OF TERRESTRIAL AND AIRBORNE LASER SCANNING IN THE GEOMETRIZATION OF A 3D NUMERICAL MODEL OF GEOTECHNICAL OBJECTS

MACIEJ BODLAK [1]

[1] *Wrocław University of Science and Technology, Faculty of Civil Engineering, Department of Geotechnics, Hydrotechnics, Underground and Hydraulic Engineering, Poland, maciej.bodlak@pwr.edu.pl*

Abstract

Over time, laser scanning finds new applications in many fields, including not only geodesy, but also civil engineering, due to the simplicity of use and the ease of obtaining results in the form of "point cloud". Point cloud can be the basis for further modeling and 3D visualization of any engineering objects. Moreover, data obtained by laser scanning can be used as a basis for analyzing the deformation process and inventory the scanned objects.

The principle of operation of a terrestrial laser scanner is based on spatial polar measurement, in which the distance is determined based on the time the light beam needs to cover the distance between the emitter-object-receiver. While maintaining the principle of spatial polar measurement, the scanning method differs from total station measurements in the number of measurements (thousands to hundreds of thousands of emitted pulses per second). The scanner uses a pulsating laser beam to scan the object according to a given resolution, i.e. according to a grid with a specific density. The position of each point is recorded in the local system using polar spatial coordinates. The measurement result in the form of a “point cloud” is processed using specialized software, which includes creating cross-sections and planes, trimming and cleaning data from noise, creating files for presentation and converting them to various formats.

In the case of airborne laser scanning, the idea is based on measuring the distance between the measuring equipment on board the plane or helicopter and field points. This method allows the mapping of the terrain surface also in the form of a "point cloud" representing the terrain. As a result of the measurement, we obtain a very accurate surface model. One of the most important advantages of this method in terms of its use in civil engineering is the penetration of the laser through the plant cover. Moreover, the advantage of the method is the ease of downloading measurement results because they are often publicly available on spatial information services. Points with given coordinates are input data to create a digital terrain model (DTM). After building a digital terrain model, the shape of the surface can be presented using a regular grid (GRID) or irregular triangles (TIN).

Geodetic services and scientific institutions are increasingly noticing the advantages of methods of performing measurements, and conducting analyses based on "point clouds" is becoming more and more common. It is reasonable to optimize the use of extensive databases in the form of spatial "point cloud" by searching for new areas of their application. One of them may be to use them as a basis for building numerical models to simulate the behaviour of the rock mass or ground in geoengineering objects.

The procedure for creating a 3D geometry of a numerical model of a underground and overground geotechnical object, using the results of terrestrial and airborne laser scanning will be presented. Methodology for creating the geometry of a numerical model involves the use of FLAC3D - Itasca numerical calculation software, commonly used in issues related to geoengineering.

Keywords: Terrestrial laser scanning, Airborne laser scanning, surveying, geoengineering

CLIMATE CHANGE AND FLOOD RISK MANAGEMENT

IMPACT OF CLIMATE CHANGE ON RAINWATER MANAGEMENT IN THE CITY OF GDAŃSK (POLAND)

MICHAŁ SZYDŁOWSKI [1], KHANSA *GULSHAD* [2], WOJCIECH SZPAKOWSKI [3]

[1] *Gdansk University of Technology, Faculty of Civil and Environmental Engineering, Poland, mszyd@pg.edu.pl*
[2] *Gdansk University of Technology, Doctoral School, Poland, khansa.gulshad@pg.edu.pl*
[3] *Gdańskie Wody (Gdańsk Water company), Poland, w.szpakowski@gdanskiewody.pl*

Abstract

The city of Gdańsk is located in a coastal region where changing climatic conditions increase the frequency of extreme weather events. Consequently, stormwater runoff is rising. Heavy rains and flash floods affect the city's infrastructure and residents. Two extraordinary rainfall events occurred in Gdańsk over the last two decades, on July 9, 2001 and on July 14, 2016 (Fig.1). Observing the increasingly frequent appearance of flash floods in the city, scientific research was carried out on changes in the probability of the occurrence of maximum daily precipitation in Gdańsk. The probability distributions of maximum precipitation for different periods were developed, which showed that the amount of precipitation with the exceedance probability of p=1% increased significantly at the turn of the 21st century (Fig.2). The results, together with information on the increase in flood risk in the city, were presented to the local authorities during thematic conferences, resulting in changes in the management of rainwater by the municipal company Gdańsk Water. Being aware of rising flood hazard, Gdańsk City Hall has also adopted a plan for adapting the city to climate change by 2030. Using blue-green infrastructure is part of the plan. Considering the possibility of implementing the proposed changes in the city, the local authorities decided to involve citizens in the decision-making process. To this end, discussion panels were organized and the Gdańsk Climate Change Forum was launched, attended by both citizens and experts from the scientific community.

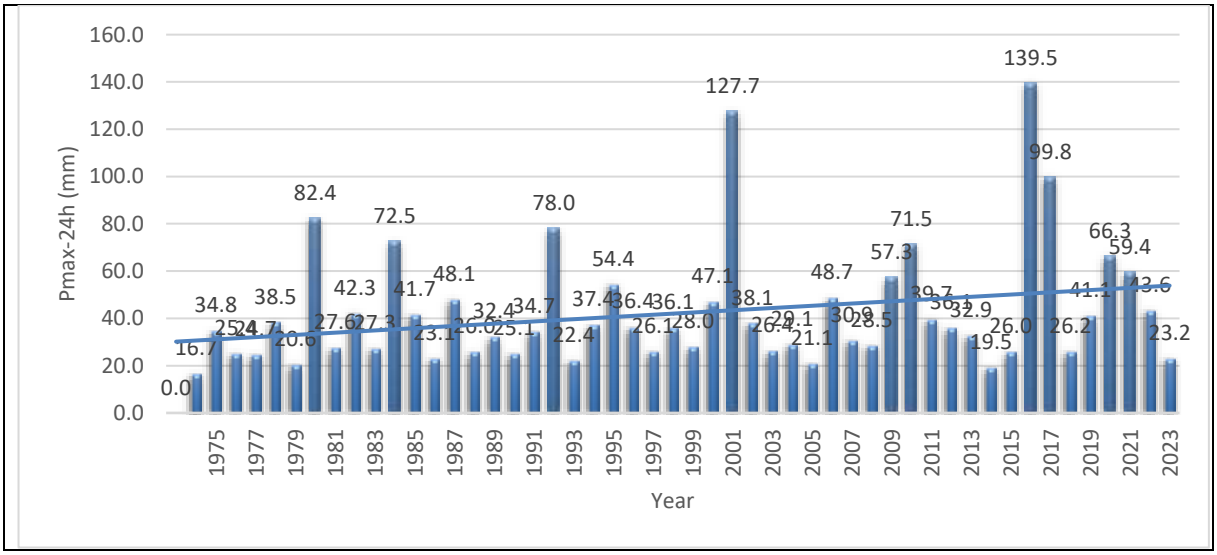


Figure 1. Maximum daily rainfall (Gdańsk Rębiechowo) for the period 1974–2023 with a linear trend line

The climate change, including an increase in extreme precipitation, was confirmed by analyzing changes in the probability of exceeding the maximum daily rainfall. In the 21st century, daily rainfall with a probability of p=1% is approx. 140 mm, up from 92 mm towards the end of the 20th century (Fig.3). Thus, Gdańsk stormwater system design criteria should be revised, what was presented to the local authorities by the researchers.

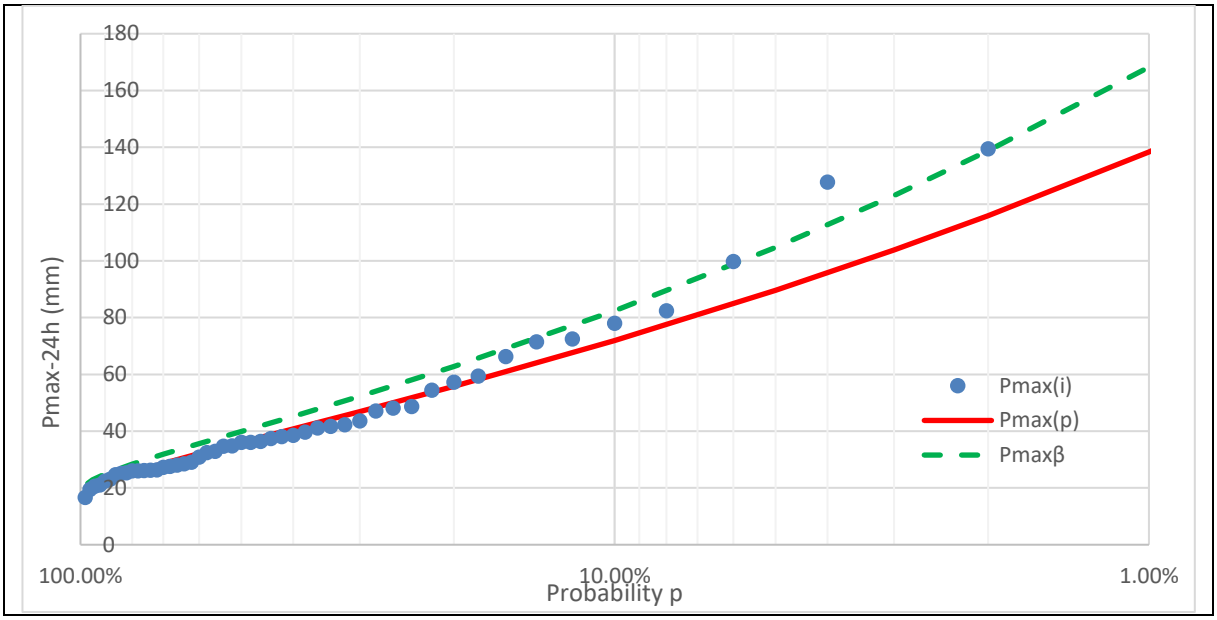


Figure 2. Maximum daily rainfall exceedance probability distribution for period (1974-2023)

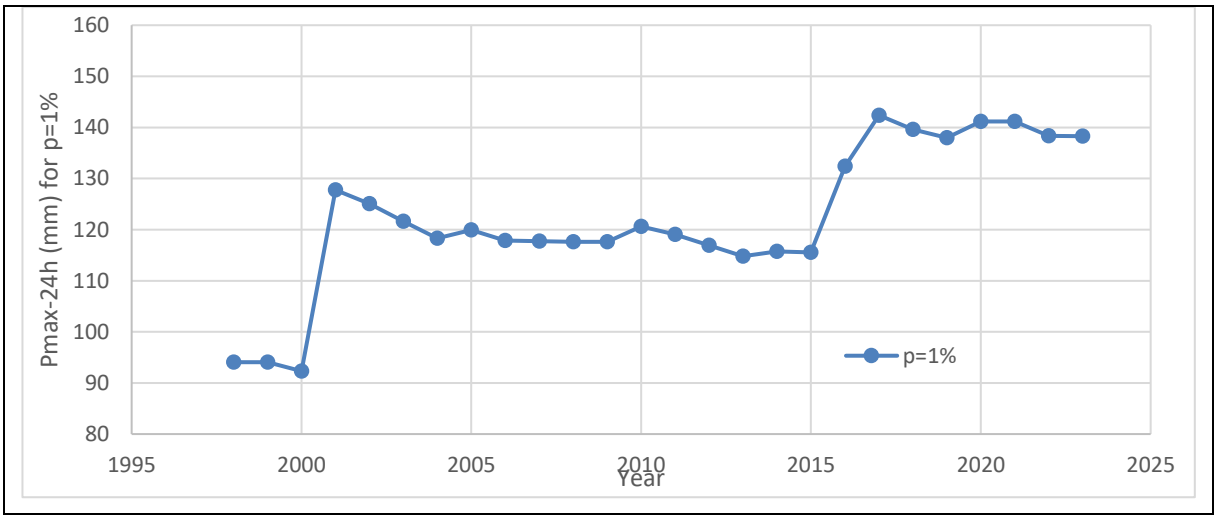


Figure 3. Maximum theoretical daily rainfall with the probability of exceedance of p=1%

Due to the limited capacity of the rainwater drainage system, city authorities began implementing new rainwater management laws in urbanized catchments. A three-stage urban retention system utilising the city's blue-green infrastructure is the new system's principal feature (first-level retention).

It is easier to plan and design retention for new investments, and this is what is also done in Gdańsk, where it is necessary to retain 30 mm of rain in the area of new investment. When the blue-green infrastructure implementation limitations exist or the rainfall is higher than 30 mm, excess flow is channeled to municipal retention ponds, where rainfall can be used as a water resource. Crisis management and rescue activities are used at the third level if reservoirs overflow and flood hazards arise.

The observed increase in pluvial flood risk led city authorities to consider urban floods as inevitable. Adapting to climate change with residents began because of this. The city has provided social platforms for individuals to share experiences and learn about pluvial flood mitigation. A citizens' panel was organized to discuss new strategies of decreasing urban flooding. The Gdańsk Climate Change Forum was created to educate individuals and consult the public on recommended adaption strategies. This is a good example of how citizen science can be developed by engaging citizens in climate change adaptation using expert science.

Keywords: Gdańsk, climate change, starmwater, urban flood, city adaptation, blue-green infrastructure

ANALYSIS OF TWO NORMAL PERIODS IN TERMS OF BASIC HYDROMETEOROLOGICAL ELEMENTS

DANA PAVELKOVÁ[1*], BRANISLAV KANDRA[1], ANDREJ TALL[1],
HELENA HLAVATÁ[2], MILAN GOMBOŠ[1]

1 Institute of Hydrology, Slovak Academy of Sciences, Slovak Republic, E-mail: pavelkova@uh.savba.sk

2 Slovak Hydrometeorological Institute, Regional Office Košice, Slovak Republic

Abstract

Changes in the atmosphere have caused an increase in the frequency of extreme hydrological events. In Slovakia, this is manifested in prolonged rainless periods and a higher frequency of extreme precipitation in terms of intensity and abundance. It is useful to compare the changes in atmospheric elements in two different normal periods for the quantification of climate change in the investigated locality. These normal periods allow the comparison of both atmospheric and hydrometeorological elements in different regions and periods. Representative hydrological and atmospheric elements are, in general, calculated from the normal period. The length of the normal period is at least 30 years. It is a common problem to obtain an uninterrupted series of measurements over 30 years. World Meteorological Organization has specified that for the worldwide comparison of data, three reference normal periods will be used: periods between 1901–1930, 1931–1960 and 1961–1990. WMO recommended that standard 30-years long reference periods should be updated every decade so that they reflect climate change. WMO congress (2021) suggested that new 30-years long standard reference period from 1991to 2020 is set.

The thesis is based on the hypothesis that the planet is warming and thus the frequency of extremes is increasing. The aim of the thesis is to quantify the climatic differences of two consecutive normal periods. The normal periods of 1961–1990 and 1991–2020 are compared. The compared climatic elements were measured at the climatic station SHMÚ Milhostov, which is located in the central part of the East Slovak Lowland. The normal periods were analysed according to precipitation, temperature, evaporation and Palmer drought severity index. Evaporation is characterized in this paper through potential evapotranspiration. It includes the energy balance of the environment and the conditions of water vapor transport to the atmosphere. Palmer's drought severity index, which is used to quantify and compare moisture conditions in areas with different pedological and climatic conditions. It is mainly used in the USA. Its advantage is its versatility. Procedures for calculating potential evapotranspiration, descriptive statistics and trend analysis methods were used for data processing.

Analysis of normal seasons by precipitation, temperature and evaporation identified significant changes in temperatures and associated potential evapotranspiration. There was an increase in the values of these elements on an annual and monthly basis in the period (1991–2020) compared to the period (1991–2020). For the analyses of annual values, significant upward linear trends were identified over the period (1991–2020). In the case of annual rainfall totals, the trends were not significant. Analysis of the normal periods according to the Palmer Drought Severity Index showed that, the normal period of years (1991–2020) is drier compared to the period (1961–1990).

Keywords: normal period, meteorological elements, climate change, Palmer Drought Severity Index

HYDROLOGICAL PROCESSES IN THE WATER UNSATURATED SOIL ENVIRONMENT ON THE EAST SLOVAK LOWLAND IN THE EXTREMELY DRY VEGETATION SEASON OF 2022

MILAN GOMBOŠ[1], ANDREJ TALL[1], BRANISLAV KANDRA[1], DANA PAVELKOVÁ[1]

[1] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, E-mail: gombos@uh.savba.sk*

Abstract

Hydrological processes in the water-unsaturated soil environment are the result of the interaction processes of the unsaturated zone with the surrounding subsystems. Water in the unsaturated zone forms a supply and source of water for the biosphere. This source supplies water to the vegetation cover during the growing season. The water in this source does not have the properties of free water. In order for plants to be able to use it, they must have a developed root system and a suction pressure that is able to overcome the binding of water with the soil. Information on the temporal and spatial distribution and dynamics of moisture in the unsaturated zone of the soil environment is crucial for agricultural production, water management in the country and the design of adaptation measures. In the growing season of 2022, it was possible to see the manifestations and feel the consequences of the lack of water in the unsaturated zone of soils on the territory of Slovakia. In the conditions of the East Slovak Plain, the lack of water manifested itself in the form of soil drought. In the work, the components of the water regime of the soil in the Milhostov area on the East Slovak Lowland during the 2022 vegetation period are quantified and analyzed.

The methodological procedure was divided into two stages. The goal of the first stage was the creation of a database for further analysis. In the second stage, its analysis and interpretation of the results was carried out. The data base was formed by the results of monitoring and numerical simulation on the HYDRUS mathematical model.

As part of the monitoring, the texture of the soil profile was analyzed in layers of 0.1 m to a depth of 1 m, the bulk moisture of the soil samples and the basic hydrophysical characteristics were measured. Volumetric moisture was measured gravimetrically. The results of volumetric moisture measurements were displayed using isolines (isolines, isopleths). From a physical point of view, an isoline is defined as a line along which the selected scalar physical quantity has the same value. The name of the isoline depends on what quantity it shows. Isolines along which there is the same humidity in the soil profile at different times are called chronisopleths. In the form of a chronisopleth, a picture of the time development of moisture in the soil profile is obtained.

To obtain difficult-to-measure characteristics, the method of numerical simulation on the HYDRUS-1D model was used. The mathematical model HYDRUS-1D in version 4 was used to calculate the analyzed members of the balance equation in the evaluated time period. HYDRUS-1D is a one-dimensional model for the simulation of water flow, heat transfer and movement of soluble substances involved in subsequent first-order reactions in variably saturated soils. It is based on the solution of the Richards equation for variably saturated flow and on the advection-dispersion type of equations for the transfer of heat and soluble substances. The flow equation allows for a drop to account for water uptake by plant roots. The chosen hydraulic model of van Genuchten (1980) and was single-pore without hysteresis. For each layer, the basic hydrophysical characteristics of soils were measured in the laboratory and the parameters of the analytical expression of moisture retention curves according to van Genuchten were defined. The input data on groundwater were provided as part of cooperation from the regional office of SHMÚ Košice. The time calculation step of the simulation was set to 1 day. This corresponds to the time scale of all inputs and outputs from the model. The submitted paper presents information from them on evapotranspiration, evapotranspiration deficit and water reserves up to a depth of 1 m. Descriptive statistics and correlation analysis methods were used to describe the investigated parameters and quantify their interrelationships.

Correlation analysis confirmed the significant level of interaction processes between groundwater and water supply in the soil profile. This is due to the fact that groundwater replenishes the water reserves in the root zone of the soil profile up to a certain critical depth. A very low level of actual evapotranspiration ET_a was identified, the total of which for the entire vegetation period was only 3.2%

of ET_0. This was reflected in a high evapotranspiration deficit that almost duplicated ET0. In addition, the expected significant correlations between temperature T and ET_0, ET_D and subsequently GWL were confirmed.

Keywords: unsaturated zone, soil drought, numerical simulation, HYDRUS-1D model

EFFECT EVALUATION OF DIFFERENT ADAPTATION MEASURES APPLIED ON URBAN CATCHMENT

MAREK SOKÁČ [1], YVETTA VELÍSKOVÁ [2], MARTA KOCZKA BARA [3]

[1] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, sokac@uh.savba.sk*

[2] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, veliskova@uh.savba.sk*

[3] *Institute of Hydrology, Slovak Academy of Sciences, Slovakia, bara@uh.savba.sk*

Abstract

The climatic change implies implementation of adaptation measures in the field of urban drainage. Higher rainfall intensities typically requires larger hydraulic / storage capacity of the urban drainage systems in aim to better manage the increased stormwater flows and volume.
This development resulted also in the update of the existing EU legislation in the field of urban drainage, which requires elaboration of the integrated urban wastewater management plans. These plans shall comprise methodology and procedures for achieving the objectives in the field of urban stormwater management, such as a surcharge or flooding as well as minimising the pollution load of untreated water to the local recipients. Such measures could include the adaptation of the existing or the creation of new urban system wastewater collection infrastructure including creation of additional stormwater storage (detention measures). New infrastructure implementation plans should prioritize the implementation of green infrastructure (e.g. and storage ponds, wetlands, semipermeable surfaces, green roofs etc.) designed in order to support biodiversity and water reuse.

Figure 1. Examples of adaptation measures in urban stormwater management

This paper analyses design of various adaptation measures for a part of urban catchment (located in Bratislava) with focus to the legislation, hydraulic and environmental aspects of the urban stormwater management. There were estimated required range and composition of adaptation measures and their effects on the overall urban stormwater management are described with regard to the achievement of the required goals.
As the preliminary results show, the overall approach and design of urban stormwater adaptation measures is very specific and individual depending on local conditions, like the availability of a suitable recipient and its hydraulic capacity, hydrogeological properties of the soil (stormwater infiltration) or

the hydraulic capacity of the urban sewerage system. It is also necessary to emphasize that green measures (green infrastructure) alone cannot eliminate all the negative impacts of climate change and a comprehensive restructuring of the existing urban drainage system is often necessary.

Keywords: urban drainage, stormwater runoff, green infrastructure, climate change, adaptation measures

IMPROVING COASTAL FLOOD ASSESSMENT THROUGH THE USE OF LIDAR DATA - A CASE STUDY OF ROVINJ CITY

NINO KRVAVICA [1], DAMJAN BUJAK [2], GORAN LONČAR [3], MARTA MARIJA BILIĆ [4]

[1] *University of Rijeka, Faculty of Civil Engineering, Croatia, nino.krvavica@uniri.hr*

[2] *University of Zagreb, Faculty of Civil Engineering, Croatia, damjan.bujak@grad.unizg.hr*

[3] *University of Zagreb, Faculty of Civil Engineering, Croatia, goran.loncar@grad.unizg.hr*

[4] *University of Rijeka, Faculty of Civil Engineering, Croatia, marta.marija.bilic@uniri.hr*

Abstract

The paper outlines the findings from numerical simulations of flooding in the city of Rovinj, Croatia. The simulations were carried out under conditions of moderate (RP = 100 years) and high (PP = 5 years) probabilities of elevated sea levels and intense wave action.

The estimation of wave heights in the ocean region and the inundated urban region was performed utilizing the two-dimensional numerical spectral model known as Mike 21/SW. The determination of extreme sea levels relies on a time series of measured sea levels at an hourly resolution spanning from 1990 to 2020. The evaluation process includes the analysis of extreme values within each segment's maximum value, by adjusting the parameters of the general extreme value distribution. In addition, the analysis involves the examination of a series of threshold exceedances and the subsequent fitting of the general Pareto distribution. In order to establish the numerical models, data from the digital elevation model of the State Geodetic Administration were utilized. The integration of elevation data into these wave models involved incorporating two different resolutions: 5 m, known as DGU-5, and 1 m, known as DGU-1. In order to guarantee precise comparisons, a meticulous series of simulations was carried out. The method employed for this purpose included applying identical wave spectra at the open boundaries of the model and utilizing the same extreme sea levels across the board.

The results of the research show that the estimated flooded areas are on average 2% larger for a return period of 100 years, or in other words 8% smaller for a return period of 5 years, in the case of using LiDAR data at a resolution of 1 m (DGU-1) compared to results obtained with elevation data at a resolution of 5 m (DGU-5).

Keywords: coastal flood, mareographic measurements, digital elevation model, SWAN, phase averaged wave numerical model

UNEVEN SHIFTS: HOW CLIMATE CHANGE ALTERS SEASONAL DISCHARGE PATTERNS IN SLOVAK RIVERS

WAEL ALMIKAEEL [1]

[1] *Slovak University of Technology in Bratislava, Department of Hydraulic Engineering, 810 05 Radlinského 11, Bratislava, Slovakia, wael.almikaeel@stuba.sk*

Abstract

This study investigates the impact of climate change on the seasonality of discharge patterns in two distinct Slovak river types: lowland and mountain rivers. Employing STL (Seasonal and Trend decomposition using Loess) decomposition, we analyze seasonal discharge patterns for both river types, focusing on changes that occurred before and after the year 2000.

Our findings reveal significant alterations in seasonal discharge dynamics, highlighting the far-reaching consequences of climate change on river ecosystems. Lowland rivers exhibit substantial shifts in the magnitude of seasonal discharge, accompanied by significant changes in the timing and frequency of peak flows. These transformations underscore the vulnerability of lowland river systems to climatic change, with potential implications for water resource management and ecosystem health.

Conversely, mountain rivers display a distinct response, characterized by a significant decline in discharge volume, primarily during the first half of the year. Peak flow timings in mountain rivers show relatively minor shifts throughout the year. These observations suggest a more complex interplay between climate dynamics and hydrological processes in mountainous regions.

Overall, the study sheds light on the nuanced impacts of climate change on river seasonality, revealing the differential responses of lowland and mountain rivers. These findings hold significant implications for policymakers, resource managers, and researchers endeavoring to mitigate the adverse effects of climate change on freshwater ecosystems and ensure their resilience in the face of future environmental challenges.

Keywords: climate change, seasonality, STL decomposition, lowland river, mountain river

PROCESS OF WASHOUT OF THE GEOTECHNICAL EMBANKMENT DUE TO OVERFLOW OF WATER ABOVE THE CREST BASED ON PHYSICAL TESTS

MIKOŁAJ URBANIAK[1], KRZYSZTOF ZAMIAR [2], STANISŁAW KOSTECKI [3]

[1] *Wroclaw University of Science and Technology, Poland, mikolaj.urbaniak@pwr.edu.pl*

[2] *Wroclaw University of Science and Technology, Poland, krzysztof.zamiar@pwr.edu.pl*

[3] *Wroclaw University of Science and Technology, Poland, stanislaw.kostecki@pwr.edu.pl*

Abstract

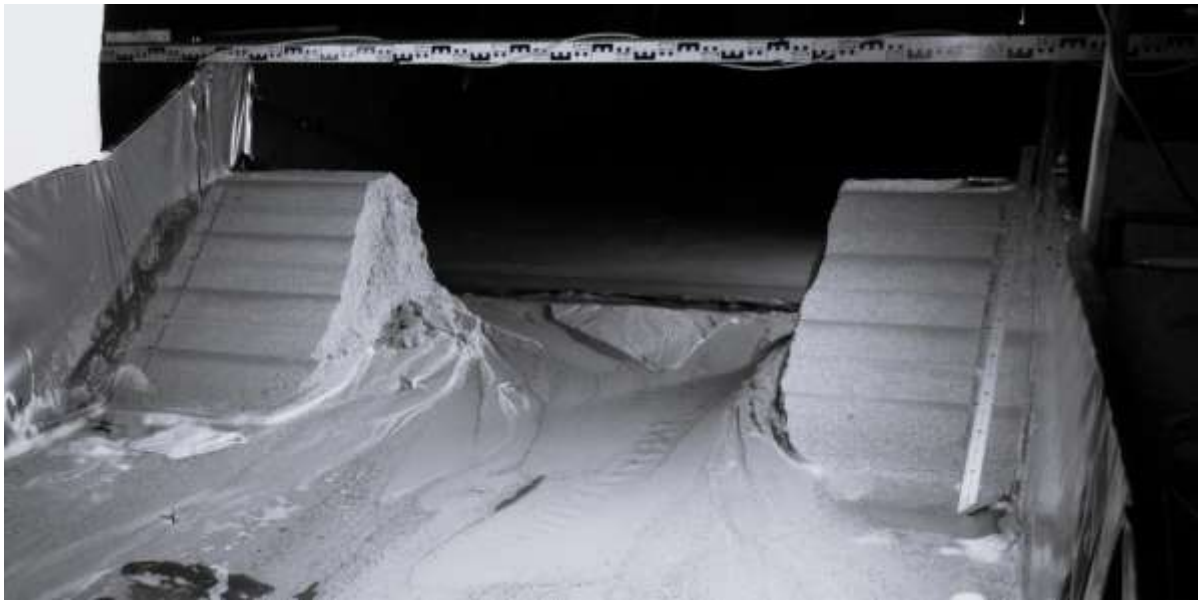


Figure 1. Examined dam during Phase IV - Final breach width

This paper presents model studies on the erosion of a homogeneous geotechnical embankment made of noncohesive soils. Understanding the destruction process of such structures, including earth dams and flood embankments, is crucial to determining the amount and rate of released water. This is necessary to assess the consequences of catastrophe, analyse risk, and develop appropriate crisis management procedures. Despite numerous studies in this area, this process is not fully explored. The presented article discusses the results of physical experiments carried out in the field laboratory of the Wrocław University of Science and Technology for a dam with a height of 0.50 m closing a reservoir with a capacity of 14.4 m3, whose width is significantly greater than the final width of the breach. Figure 2 shows the experimental setup. The scenario analysed assumes that water overflows the crest of the embankment, as it is the most common cause of embankment failure based on databases cataloguing dam disasters. At the same time, for this scenario, the amount of water accumulated in the reservoir is the largest possible, suggesting that such a catastrophe may have the most severe consequences. Based on the results obtained from several experiments, four repeatable phases of erosion evolution were identified and described: (I) the initial phase, (II) the vertical erosion phase, (III) the lateral erosion phase, divided into two cycles, and (IV) the reservoir emptying phase without further propagation of the breach (Figure 1). The water outflow rate of the reservoir was also analysed, allowing the determination of the outflow hydrograph for each trial. The hydrographs showed differences between individual experiments; however, the average erosion rate was similar for all tests. Furthermore, the final width of the breach created each time was between 2.2 and 2.5 H (where H is the height of the embankment), and the volume of eroded soil ranged from 0.52 to 0.59 m3. The article also highlights the methodology for calculating the water outflow hydrograph. The results of laboratory tests were compared with the results of numerical modelling performed in several dedicated programmes.

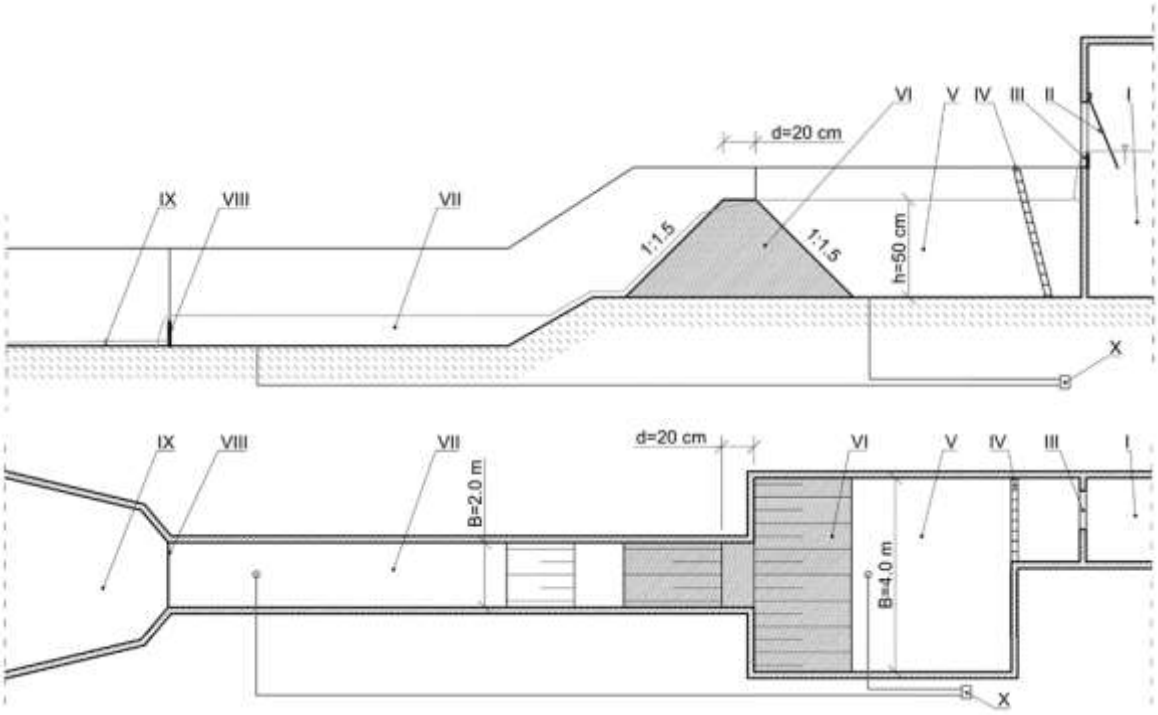


Figure 2. Experimental setup. I – balancing tank, II – check valve (overflow window closing), III – overflow window with Thomson's weir, IV – energy dissipation device, V – upper tank V_{max}=14,4m^3, VI – analysed embankment, VII - downstream channel B=2.0 m, VIII – 2 Thomson's weirs, IX - free discharge channel B>>2.0m, X - hydrostatic pressure sensors.

Keywords: dam safety, flood risk management, overtopping, embankment dam, laboratory tests, breach parameters, breach mechanism

ADVANCING HYDROLOGICAL FORECASTING: MACHINE LEARNING APPROACHES FOR ENHANCED WATER FLOW PREDICTION IN THE BEDNJA RIVER, CROATIA

NAMAL RATHNAYAKE[1], YUKINOBU HOSHINO[2], BOJAN DURIN[3], UPAKA RATHNAYAKE[4], ANDREJA ŠANTATIĆ[3*]

1 Department of Civil Engineering, Faculty of Engineering, The University of Tokyo, 1 Chome-1-1 Yayoi, Bunkyo City, Tokyo 113-8656, Japan. namal@hydra.t.u-tokyo.ac.jp
2 School of Systems Engineering, Kochi University of Technology, 185 Miyanokuchi, Tosayamada, Kami, 782-8502, Kochi, Japan. hoshino.yukinobu@kochi-tech.ac.jp
3 Department of Civil Engineering, University North, Varaždin, 42000, Croatia. bdjurin@unin.hr , andsantatic@unin.hr
4 Department of Civil Engineering and Construction, Faculty of Engineering and Design, Atlantic Technological University, Sligo, F91 YW50, Ireland. upaka.rathnayake@atu.ie

Abstract

The Bednja River in Croatia and its tributaries are essential components of the hydrographic network in the region, impacting the lives and livelihoods of approximately 60,000 people residing there. By accurately forecasting water flow using machine learning models, it is possible to improve early warning systems for floods and flash floods. In this study, we explore the application of machine learning (ML) algorithms to forecast water flow in Bednja using lagged time data from the river flow upstream. Results from the testing phase highlight the performance of the various ML algorithms across different lagged time intervals. For instance, in the case of a one-day lag, the Ensemble (Boost) model shows a Root Mean Squared Error (RMSE) of 2.046 and a Mean Absolute Error (MAE) of 0.867 in the test dataset, along with a high coefficient of determination (R^2) of 0.965. Similarly, in the case of a two-day lag, the Neural Network (Narrow) model demonstrates superior performance with an RMSE of 1.775 and an R^2 of 0.976. Overall, these results underscore the potential of ML algorithms in accurately forecasting water flow in the Bednja River, which is crucial for effective flood management and environmental conservation in the region. Overall, this research highlights the value of integrating advanced ML techniques into hydrological forecasting, paving the way for more effective and sustainable water management practices in the Bednja River basin and beyond.

Keywords: Machine learning, Bednja, floods, lag, water management

ANALYSIS OF FLOOD IN AN URBAN AREA- CASE STUDY: SKOPJE 2016

VIOLETA GJESHOVSKA [1], DENIS JANKULOVSKI [2], BOJAN ILIOSKI[3]

[1] *PhD, Full Professor, University "Ss. Cyril and Methodius", Faculty of Civil Engineering-Skopje, N. Macedonia, violetag@gf.ukim.edu.mk*

[2]*MSc, Civil engineer, Vod – Var Inzenering Skopje, N.Macedonia, denis_jankulovski@hotmail.com*

[3] *MSc, PhD student, University "Ss. Cyril and Methodius", Faculty of Civil Engineering-Skopje, N. Macedonia, bojanilioski@hotmail.com*

Abstract

A flood is a natural disaster and can occur due to the high water level in the rivers and lakes, the spilling of a large amount of water from the riverbeds and the flooding of the surrounding area. Uncontrolled urbanization, inadequate exploitation and management of forest and agricultural land in combination with climate change increase the possibility of more frequent and more intense floods, especially flash floods in urban areas.

The subject of this research is the analysis and determination of the formation process of the flood wave that affected the region of Skopje in the month of August 2016. The reasons for the large peak of the flood wave were investigated through the preparation of a detailed hydrological analysis of the region and the preparation of a 2D hydraulic model for the simulation of the propagation of the flood wave and the definition of flood zones.

By applying the GIS tools ARC Map and QGIS, a digital terrain model (DTM) was prepared and the physical-geographic characteristics of the watershed were determined. An analysis of land use was performed using the CORINE Land Cover 2018 database, analysis of pedological, geological and climatic substrates. With the application of the WINTR 55 software program, hydrological models were created for the generation of surface runoff hydrograms. By applying the HEC-RAS software package, a two-dimensional (2D) hydraulic model was created. The two models, hydrological and hydraulic, are compatible, where the output results from the hydrological model are applied as input data to the hydraulic model. Flooding zones in the Skopje region have been defined through the hydraulic analysis. Calibration and verification of the model was done with the flooded areas recorded in the field (aerial photogrammetry of the flood after 72 hours from the beginning of the flood). The results are presented on maps of maximum depths, maximum velocities and maximum shear stresses in the flood zone.

Keywords: flood, intensive rainfall, GIS, hydrological model, hydraulic model

PROPOSAL OF WATER RETENTION MEASURES IN HODKOVCE VILLAGE

PATRIK NAGY [1], MARIAN DOBRANSKÝ [1], MARTİNA ZELENAKOVA [2]

[1] *Department of Environmental Engineering, Faculty of Civil Engineering, Technical University of Kosice, Slovakia, patrik.nagy@tuke.sk; marian.dobransky.2@tuke.sk; martina.zelenakova@tuke.sk*

Abstract

Paper deals with the proposal of water retention and flood protection above the village of Hodkovce on the Hodkovský stream, which belongs to the Bodva basin. The area of interest is located in the western part of the Košice district.

Keywords: rainwater, weir, hydrology

PROPOSAL OF WATER RETENTION MEASURES IN TURANY NAD ONDAVOU VILLAGE

RASTISLAV FIJKO [1], MARIAN DOBRANSKÝ [1], MARTİNA ZELENAKOVA [2]

[1] *Department of Environmental Engineering, Faculty of Civil Engineering, Technical University of Kosice, Slovakia, rastislav.fijko@tuke.sk; marian.dobransky.2@tuke.sk; martina.zelenakova@tuke.sk*

Abstract

Paper deals with the proposal of water retention measures in the village Turany nad Ondavou. From an urban planning point of view, the measures are designed in such a way that it creates the conditions for the controlled retention of rainwater from the reconstructed area of the parking lot and pedestrian communication or recreation zone, due to which the water will be returned to the water cycle back to nature. A green permeable to semi-permeable paved area will be created in the central part of the village, which will give the space a new dimension and replace the drab asphalt surface with a green "island" in the central part of the village, before the main entrance to the building and the transition between the streets, when it will functionally connect them.

Keywords: rainwater, hydrology

RESEARCH OF THE INFLUENCE OF FLOOD FLOWS ON THE AREA BETWEEN THE ANTOŠOV IRRIGATION CHANNEL AND THE LAMAČSKÝ STREAM

MARTIN ORFÁNUS [1], LEA ČUBANOVÁ [2], JÁN RUMANN [3]

[1] *Faculty of Civil Engineering STU Bratislava, Slovakia, martin.orfanus@stuba.sk*
[2] *Faculty of Civil Engineering STU Bratislava, Slovakia, lea.cubanova@stuba.sk*
[3] *Faculty of Civil Engineering STU Bratislava, Slovakia, jan.rumann@stuba.sk*

Abstract

The aim of the work was to assess the current situation in the area of interest (between the Antošov channel and the Lamačský stream) in terms of flood flows using a 2D mathematical model. As part of the work, 2D flow simulations were made at Q_{100} discharge in the area of interest for the current state and topography measurements, respectively, objects in the location of interest were surveyed as well. The area of interest falls within the basin of the Morava River. The main stream is the Morava River, which flows into the Danube near the Devín Castle. The most important tributary is the Mláka stream, which drains surface water from the Western part of the Carpathians. The following important tributaries flow into the Mláka are the Rakyta, Dúbravčický creek, Vápenický creek and Mariánsky creek. Veľkolúcky creek and Antošov channel (right tributary of the Dúbravčický creek) gradually flow into the Dúbravčický creek. The Lamačský stream and several nameless tributaries flow into the Vápenický creek. The Bystrický creek, the Mástsky creek and several nameless tributaries gradually flow into the Mariánsky creek. The mentioned system creates a characteristic fan-shaped drainage framework of the Western part of the Bratislava territory. The concerned area is limited by the Lamačský stream (approx. rkm 1.5 – rkm 2.8) and the Antošov channel (approx. rkm 1.0 – rkm 2.44). The type of runoff regime of the area is rain-snow. The maximum flows occur in the winter and spring months (March, April) in connection with the melting of snow and in the summer months, when they are conditioned by heavy rains. The minimum flows are mainly in September and October, sometimes also in the summer or winter months. Currently, the river network no longer has a natural character. As a result of frequent floods and waterlogging of the territory, most of the streams have been modified for water management.

Keywords: discharge, measurements, floods, hydrodynamic model, Q_{100}

Ing. Michaela Červeňanská, PhD., Ing. Alexandra Vidová, prof. Ing. Andrej Šoltész, PhD.

18th International Symposium
WATER MANAGEMENT & HYDRAULIC ENGINEERING WHME 2024
10th – 14th September 2024, Štrbské Pleso, Slovakia
BOOK OF ABSTRACTS

Published by the Slovak University of Technology in Bratislava in SPEKTRUM STU Publishing, Bratislava, Vazovova 5, in 2024.

Extent 122 pages, 44 figures, 8 tables, 7.019 author sheets, 7.022 publisher sheets, 1st edition.

ISBN 978-80-227-5423-1

PARTNERS AND SPONSORS

ISBN 978-80-227-5423-1