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CONSIDERING CLIMATE CHANGE PROJECTIONS IN THE ASSESSMENT OF HYDRODYNAMIC LOADS AND SCOUR RISKS ON BRIDGE PIERS – A PILOT CASE AND RESULTS OF THE EU PROJECT RISKADAPT

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ABSTRACT

RISKADAPT (Asset Level Modelling of RISKs in the Face of Climate Induced Extreme Events and ADAPTation) project addresses extreme weather phenomena and their consequences that may severely affect the safety of critical assets. The main project goal is to provide a novel, integrated, modular, interoperable, public, free of charge, customizable, and user-friendly platform to support climate change (CC) induced disaster risk reduction and adaptation regarding critical infrastructure assets in the face of extreme events. This paper discusses the estimation of hydrodynamic loads on the piers and abutments of the Polyfytos Bridge, focusing on discharge rates, water flow velocity fields, and water levels under present and future climate projections.

Keywords: hydrological analysis; hydraulic analysis; climate change projection; scour formation

1. Introduction

Climate change driven by global warming is disrupting the runoff regime in river catchments by increasing temperatures and altering precipitation patterns (IPCC, 2017; Mujere and Eslamian, 2014). To assess these impacts, researchers use meteorological, hydrological, and hydraulic models to determine river discharges and associated risks. In this study, a hydrological model was used to convert precipitation scenarios with different return periods (for current and future climate change projections) into river discharges. The river discharges were then simulated using hydraulic modelling to estimate water flow velocity and water depth and to assess the risk of horseshoe scour formation at the bridge piers of the Polyfytos Bridge (RISKADAPT, 2024).

2. Modelling methods

The hydrological and hydraulic simulations were carried out using the Hydrologic Engineering Centre River Analysis System (HEC-RAS) software, version 6.5, from the US Army Corps of Engineers. HEC-RAS is a proven and frequently used software in water management, hydro-environmental engineering, and research. It was developed originally for hydrodynamic modelling and enables the simulation of one- and two-dimensional (1D and 2D) unsteady flows, sediment and mobile bed transport, water temperature, and water quality. As the full-2D modelling approach in HEC-RAS allows the inclusion of direct precipitation data (i.e., Rain-on-grid) in the hydrodynamic surface flow simulations, it can also be used for hydrological modelling.

In the first phase, hydrological modelling was carried out to estimate the runoff from the selected catchment based on the precipitation provided and the characteristics of the catchment (i.e., topography, land use, and soil type). To calculate extreme discharges, extreme precipitation events of three different return periods, namely 50, 100, and 1,000 years, were considered. For the present climate, global extreme precipitation (GPEX) data (Gründemann et al., 2023; Beck et al., 2019) were used to determine the amount of precipitation within the analyzed catchment. They were provided as gridded layers, each containing precipitation data for a specific return period. Each cell of the individual layer contained information on precipitation duration, ranging from 3 to 240 hours. For future climate projections, we used the EURO-CORDEX data (Jacob et al., 2014), i.e., the results of 48 combinations of different general circulation models (GCM) and regional climate models

(RCM). For each combination, we obtained the results of historical runs (for years 1972-2005) and the Representative Concentration Pathways – RCP 8.5 scenarios (for 2040-2100). Comparing the future climate scenarios with present conditions, some predict a decrease in extreme discharges, while others predict an increase in extreme discharges, with a possible increase of 48%, 46%, and 30% for the events with return periods of 50, 100, and 1,000 years, respectively.

In the second phase, the results of the hydrological modelling were used in the form of hydrographs at the inflow into the Polyphytos Lake. The simulations were carried out for all 12 combinations of flood event return periods and future climate change scenarios, including flood events simulations with mean return periods of 50, 100, and 1,000 years for the present state and three future climate change scenarios.

3. Results

The results of the hydraulic modelling provided time series data for various hydraulic parameters that are important for further analysis, including water depths $d(t)$, water surface elevations $h(t)$, depth-averaged flow velocities $v(t)$ and discharges $Q(t)$ at specific locations. The main objective of the hydraulic modelling was to assess the hydrodynamic loads on the piers and abutments of the Polyfytos Bridge and to generate the necessary input data for further analysis of scour formation that could potentially affect its stability. As the Polyfytos Dam on the Aliakmon River has a height of 112 meters, the water depths in the Polyfytos Lake/reservoir are large, reaching almost 50 meters at the location of the Polyfytos Bridge. Such water depths lead to relatively low flow velocities in the main river channel, even during flood events. At the bridge location, the flow velocities for the Q_{100} remain below 0.5 m/s. Fig. 1 shows water flow velocities for flood events with a return period of 100 years. The present state is compared with the most inconvenient scenario considering the climate change projections, which show the highest increase in discharges. The center line of the bridge is marked by a black line.

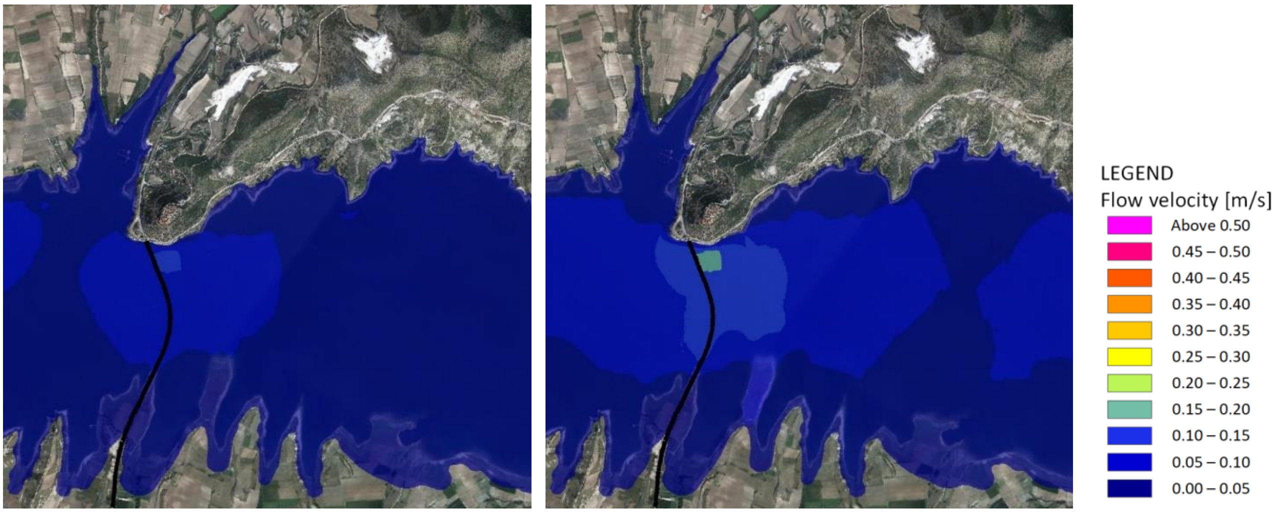

Fig. 1. Maximum depth-averaged water flow velocities for the flood wave Q_{100} (present state – left, the most inconvenient future climate projection - right).

Conclusions

The paper presents the results of the hydrological and hydraulic modelling of the Aliakmon River catchment and the Polyfytos Lake. Various projections of possible future climate changes are considered, focusing on extreme flood events with return periods of 50, 100, and 1,000 years. The hydraulic modelling provided crucial insights into the critical input data, allowing an assessment of the hydrodynamic loads acting on the piers and embankments of the Polyfytos Bridge during these extreme events. The analysis shows that the bridge piers are not significantly susceptible to scour, even during flood events. This conclusion is based on the observation that the water flow velocities around the piers are relatively low, which limits the potential for scour formation.

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