Application of a 2D-Hydrodynamic Model to Assess the Impact of Spring Water Discharge into Lake Pamvotida in Ioannina, Greece.

K. Zachopoulos[1*], D. Papademos[1]
[1] The Goulandris Natural History Museum-Greek Biotope Wetland Centre, 14th km Thessaloniki - Mihaniona, 57001 Thessaloniki-Thermi, Greece
* e-mail: zachopoulosk@ekby.gr

Introduction

According to the study conducted by the Greek Biotope Wetland Centre for the assessment of the minimum water level requirements of Lake Pamvotida, its water level (WL) should be maintained within the specified range of 469.10 - 468.20 m, a.m.s.l. However, the lake is very susceptible to larger reductions in its WL in late summer (below the proposed water level of 468.20 m) due to increased evaporation and over-pumping for irrigation purposes. This study investigates the introduction of freshwater from the Sentenikos and Kalithea Springs into Lake Pamvotida in order to mitigate the decrease in its water level (WL), during the dry season. A 2-D hydrodynamic modelling system was used to evaluate the effects of three scenarios in which the existence and location of the spring discharge inflow are differentiated. WL, temperature (T), dissolved oxygen (DO) and biochemical oxygen demand (BOD) were used for the evaluation of the effect of the scenarios on the lake's condition. The research showed a significant change on the WL fluctuation of the lake, and only minor effects locally dispersed regarding on its temperature, DO and BOD.

Materials and methods

The study area is Lake Pamvotida, which is located in the west part of Greece, in the prefecture of Ioannina. The lake's WL ranges from 468.00 to 469.5 m a.m.s.l., and is regulated by a spillway and its gate. Its mean depth is 5.4 m while its maximum 7.5–8.0 m. The lake is about 22 km^2 in size, with an estimated volume of 118.6 million m^3 of water at its overflow according to the National Lake Monitoring Network.

MIKE 21 Flow Model (FM) was used to simulate the hydrodynamic environment of Pamvotida Lake, including its hydrodynamic (HD) and the ecological (MIKE ECOlab) modules (DHI, 2024a,b). The HD module is based on the numerical solution of the two dimensional shallow water – in depth integrated - Navier Stokes equations. The spatial discretization of the primitive equations is performed using a cell centered finite volume method. MIKE ECO Lab module is able to simulate the spatial distribution of water quality variable concentrations in a 2D domain, based on processes such as: advective transport, biological, physical, and chemical transformation processes as well as settling, resuspension and sediment processes.

Three different scenarios were investigated, for a period of nine years (2013-2021). The base scenario consisted of the hydrodynamic and ecological model of the lake without any spring water inflow. The horizontal discretization of the model was conducted by 3911 triangular elements with side length from 30 to 200 m. Data related to bathymetry of the lake, were acquired from Apostolakis and Papadimos, 2016. Meteorological data retrieved from the open database of National Observatory of Athens (NOA). Solar radiation data were retrieved from the Copernicus Atmosphere Monitoring Service (CAMS) - Atmosphere Data Store (ADS) database. Data related to water inflow into the lake from its torrents and the corresponding outflow data from pumping stations, the spillway and its gate were acquired from the National Lake Monitoring Network.

Two more scenarios (1 and 2) were investigated to assess the effect of the spring water inflow into the lake from two different locations. In Scenario 1, the water inflow is located close to Perama (700 m distance from the spillway) while in Scenario 2, the spring water inflow is located close to Amfithea, 2900 m distance from the spillway (Figure 1a). The temperature of the spring water varies from 12.5-13.5 ^oC, and the discharge ranges from 0.5 to 12.5 m^3/s.

Results and concluding remarks

The model of the Base Scenario was calibrated and validated against monthly data of WL, T, DO and BOD for the period of 2013-2021, with a time step of 5 min. The parameterization of the model after its calibration was kept the same for the models of Scenario 1 and 2.

The scenarios indicated that the seasonal WL fluctuation is substantially affected by the spring water inflow. Both scenarios 1 (Sc1) and 2 (Sc2) have almost the same effect on the WL fluctuation, with an average difference of 0.17 m between them and the Base Scenario. At high WL periods, the WL in Sc1 and Sc2 is slightly elevated (+ 0.05 m) compared to the Base Scenario. Conversely, during low WL periods the WL in Sc1 and Sc2 was found to be greater (+ 0.40 m) compared to the Base Scenario (Figure 1b).

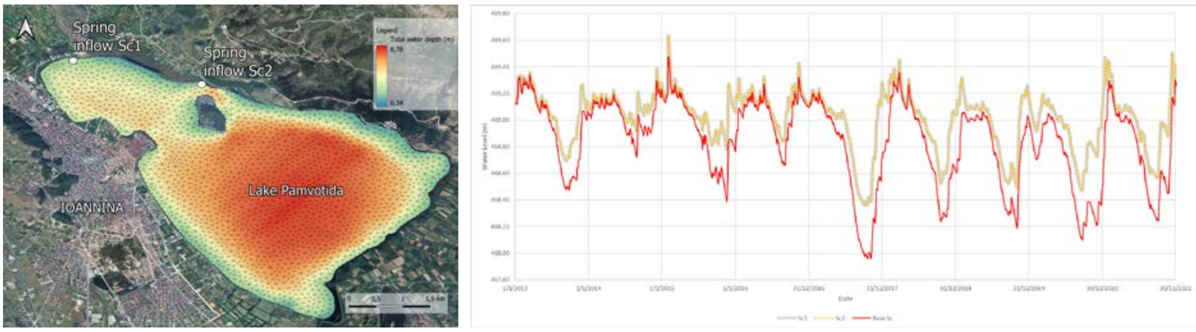

Figure 1. a) The mesh grid and lake bathymetry. White dots indicate the locations of spring water inflow scenarios. b) Water lever fluctuation for the Base Scenario (red), Sc1 (grey) and Sc2 (orange).

Furthermore, the fresh spring water impact on the lake's condition (T, DO and BOD) is limited to the area close to the spring location and has no appreciable effects on the entire lake region (Figure 2). After periods of high discharge, the spring water's dispersion forms a plume that extends 0.26 km^2 in Sc1 and 0.38 km^2 in Sc2 (Figure 2). The plume area in Sc1 is substantially less since the inflow location is close to the lake's spillway and a portion of the intake water runs off.

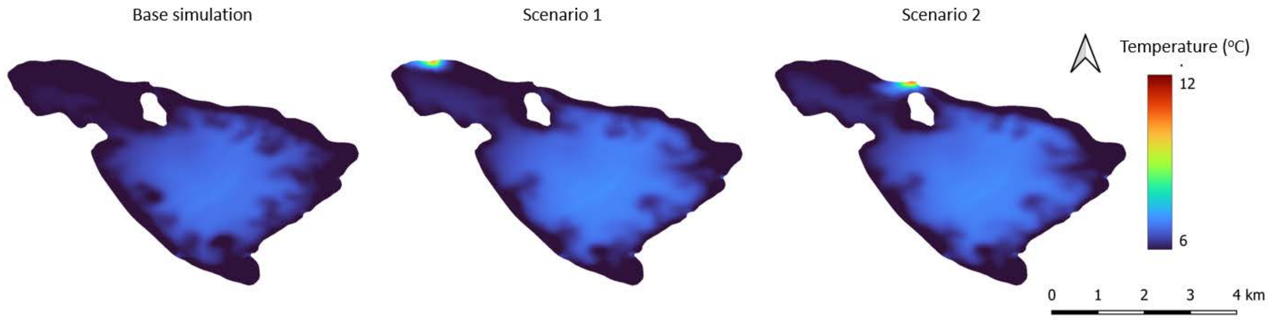

Figure 2. Indicative results simulating the temperature impact of the spring water inflow (12.5 m^3/s on Jan 14, 2021).

Overall, the spring water inflow into the Lake Pamvotida affected significantly the WL fluctuation, especially in low WL periods, keeping the lower WL close to the critical minimum altitude of 468.20 m. The different physiochemical consistence of the spring water did not directly affect the total area of the lake since the impact is limited to the area near to the discharge inflow point.

Acknowledgments: The present study was conducted in the frame of the Greek National Water Monitoring Network, according to the JMD 107168/1444/2021, implemented by The Goulandris Natural History Museum, Greek Biotope/Wetland Centre (EKBY).

References

Apostolakis A, Papadimos D (2016). Isobath curves of Lake Pamvotida [Geospatial Data]. Hellenic Centre for Biotopes-Wetlands (EKBY).

DHI (2024a). MIKE 21 Flow Model FM – Hydrodynamic Module User Guide. Danish Hydraulic Institute, Hørsholm, Denmark. Version 2024.

DHI (2024b). MIKE 21 ECOLAB – Water Quality Module User Guide. Danish Hydraulic Institute, Hørsholm, Denmark.