A BASIC WATER BUDGET MODEL FOR THE PALIĆ LUDAŠ LAKE SYSTEM

Zoltan Horvat [1]
Mirjana Horvat [2]

UDK: 556.552:519.87
DOI: 10.14415/konferencijaGFS2018.042

Summary: *This paper presents a basic water budget model for the Palić Ludaš lake system. The model's domain includes Lake Palić, Lake Ludaš, Lake Omladinsko, the Palić-Ludaš channel, and all the relevant hydraulic structures on the system. All the main water budget elements were taken into account, namely, the discharge from the sewage treatment plant into Lake Palić, precipitation, evaporation and ground water interflow with the lakes. A one year simulation was conducted for 2017. The results were analyzed in order to asses the importance for each component of the water budget, and to predict possible alternative scenarios.*

Keywords: *Numerical model, water budget, Palić Ludaš lake system*

1. INTRODUCTION

The Palić Ludaš lake system is located in northern Bačka, near the town of Subotica in Serbia. The system is composed of three lakes: Lake Palić (total surface area of cca. 590*ha*), Lake Omladinsko (total surface area of cca. 13ha) and Lake Ludaš (total surface area of cca. 358ha). Lake Palić consists of four Sectors (Fig. 1), while the first Sector itself is divided into three Lagoons.

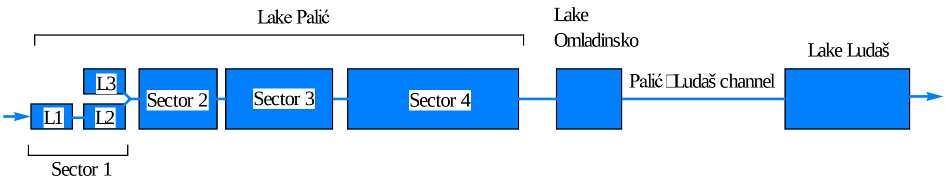

Figure 1. The schematic representation of the modeled system

Culverts of various dimensions and cross-sections are connecting Lagoon 1 (L1) with Lagoon 2 (L2), Lagoon 2 (L2) with both Lagoon 3 (L3) and Sector 2, Sector 2 with Sector 3 and Sector 4 with Lake Omladinsko. A gate and weir allows the water to flow

[1] doc.dr Zoltan Horvat, dipl.inž. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, tel: +381 24 554 300, e-mail: horvatz@gf.uns.ac.rs
[2] doc.dr Mirjana Horvat, dipl.inž. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, tel: +381 24 554 300, e-mail: isicm@gf.uns.ac.rs

from Sector 3 to Sector 4. The water leaves the whole system over a weir at Lake Ludaš. Lake Omladinsko and Lake Ludaš are connected with a 4.5*km* long channel of trapezoidal cross-section. On this channel the most important hydraulic structure is a broad crested weir preceding a 1.41*m* drop in bed elevation. At some areas this channel has a considerable amount of reed in it's bed.
The main source of surface water inflow in the system would be the sewage treatment plant, which releases the treated water into Lagoon 1. Other significant water budget elements are the precipitation and evaporation and the inflow of groundwater.

2. NUMERICAL MODEL

The numerical model is based on a series of storage areas that represent a particular Lagoon, Sector or a Lake of the system. The model computes the change in water elevation in these storage areas by balancing the continuity equation for each of them. These storage areas are connected either by hydraulic structures with defined rating curves or with a channel. In case of channels the St. Venant equations are solved. The precipitation and evaporation is taken into account only for the storage areas, while the groundwater interflow is computed for both the storage areas and channels.
The performed computations are for unsteady flow, due to the varying inflow from the sewage treatment plant and the varying precipitation and evaporation during the year. A stabilization period of three months was adopted (October, November and December of 2016), thus the whole simulation lasted from 1st of October 2016 to 31st of December 2017.

3. INPUT PARAMETERS

The input parameters consisted of a hydrograf that represents the outflow of water from the sewage treatment plant into Lagoon 1 (Fig. 2). Although with some variation during the simulation period, it can be stated that the sewage treatment plant releases the discharge around 0.4m^3/s into Lagoon 1 of Lake Palić. The peaks account for high precipitation on the catchment drained by the sewage system that ultimately brings the water to the sewage treatment plant.

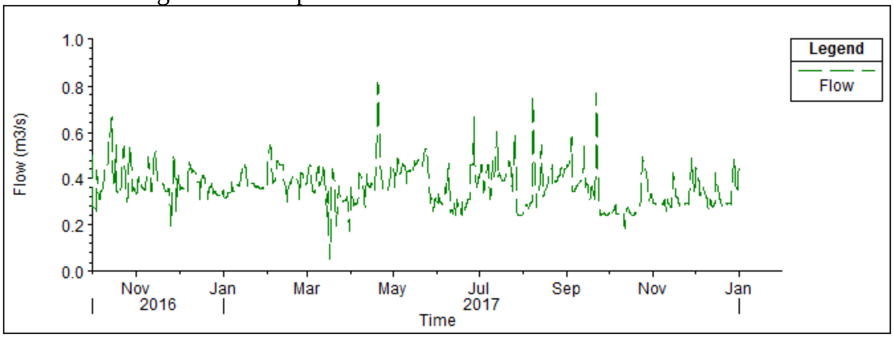

Figure 2. Hydrograph from the sewage treatment plant

The precipitation input data is based on measured values for the simulation period, while the evaporation was computed using measured temperatures and wind speeds in the modeled area. Since the evaporation is not directly measured, one should keep in mind that these computed values can deviate from real ones.
Input data for groundwater was taken as a representative (average) value from historical records. Although, this means that the groundwater elevations are constant during the simulated time period, they represent real (measured) values in the modeled area.

4. RESULTS

Three sets of numerical simulations were produced. The first is based on real data with all the major water budget elements aiming to reproduce field observations, the second endeavors to asses the importance of groundwater interflow by eliminating it from the computation, and the third introduces a hypothetical situation when the water from the sewage treatment plant would bypass the whole lake system.

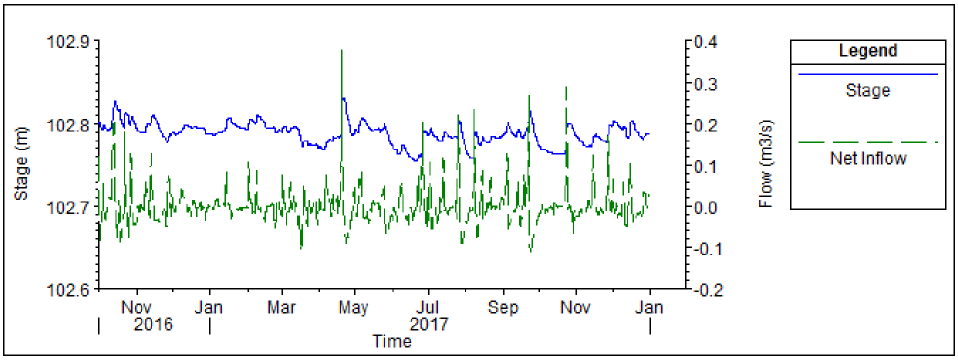

Figure 3. Water surface elevation and net inflow for Sector 3

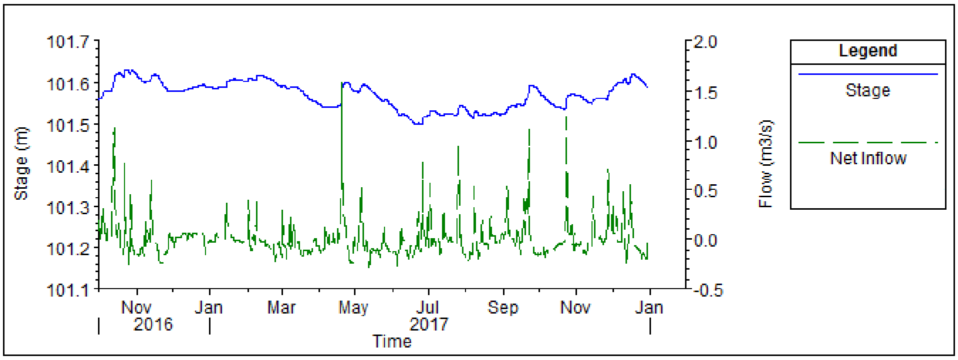

Figure 4. Water surface elevation and net inflow for Sector 4

The first simulation attempts to compute hydraulic parameters of the system during the modeled period, i.e. to reproduce field observations. On Fig. 3 the water surface and net inflow of Sector 3 are depicted. As it can be seen, the water level did not change significantly, and stayed between the values of 102.75 *m* and 102.85 *m*. The levels in Sector 2 and Sector 1 are very similar to those of Sector 3, since the hydraulic structures (culverts) between these parts of the system generate only minor losses in hydraulic head.

Figure 4. presents the water surface elevation and net inflow for Sector 4. Similarly, the water level did not change significantly, and stayed between the values of 101.5*m* and 101.65*m*. The significant difference in water levels between sectors 3 (cca. 102.8*m*) and 4 (101.55*m*) are due to a weir between these two sectors.

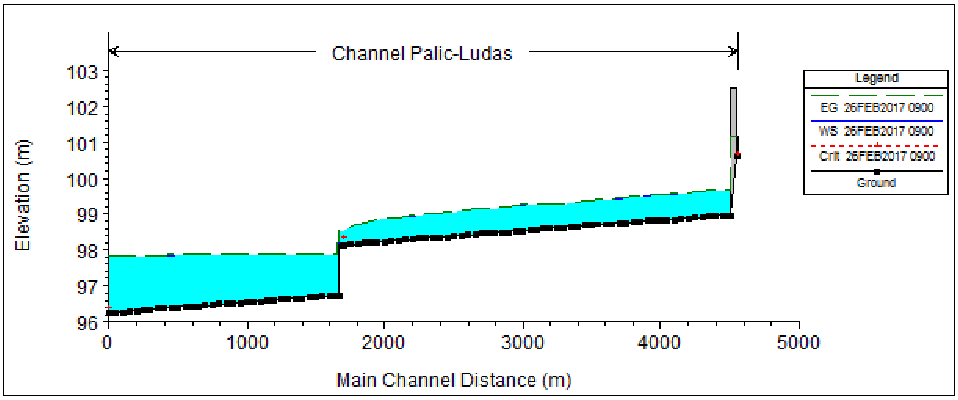

Figure 5. Water surface elevation in the Palić-Ludaš channel

The profile of the Palić-Ludaš channel for 26th of February 2017 is given on Fig. 5. The downstream of the channel (from RKM 0+000 to 1+650) is under the influence of the water surface of Lake Ludaš (backwater effect), while the upstream part (from RKM 1+700 to 4+500) is governed by the broad crested weir and subsequent drop in bed elevation at RKM 1+670. Figure 6. gives the discharge into Lake Ludaš from the Palić-Ludaš channel. Although the inflow into the system (from the sewage treatment plant and groundwater interflow) is approximately uniform during the year, the discharge into Lake Ludaš shows a significant drop in the months of June, July and August. This can be accounted to greater values of evaporation during the summer months in Lake Palić and Lake Omladinsko.

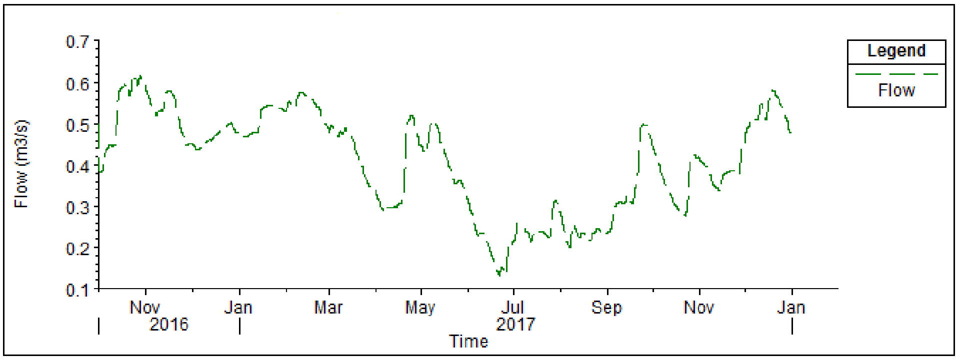

Figure 6. Flow into Lake Ludaš

Finally, Fig. 7. depicts the water surface elevation and net inflow for Lake Ludaš. Unlike Lake Palić and Lake Omladinsko, the simulation shows a noticeable drop of water surface elevation (cca. 10*cm*) during the summer months. This tendency is yet to be confirmed by field observations.

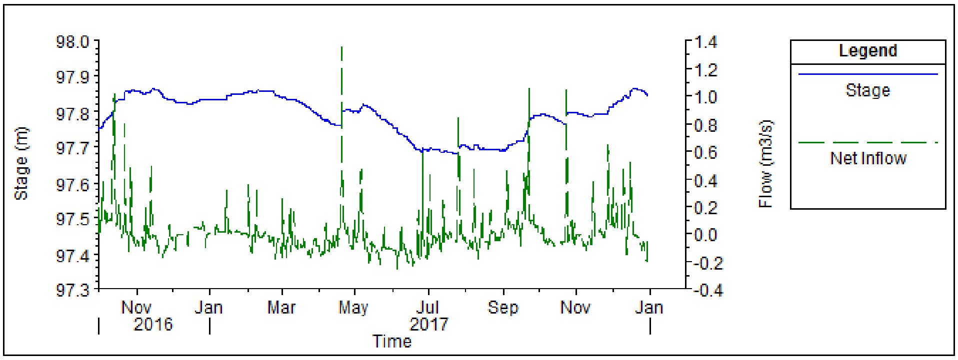

Figure 7. Water surface elevation and net inflow for Lake Ludaš

The second set of numerical simulations aims to asses the influence of groundwater interflow with the modeled system. This was achieved by eliminating the groundwater element from the model and running the simulation with the remaining items of the water budget. The most striking result is shown on Fig. 8. If there would be no flow to the modeled lake system from groundwater, the Palić-Ludaš channel would dry up in the summer months. Since, this phenomena doesn't occur in reality, one can state that the groundwater flow into the system is a significant part of the water budget, and a significant factor in supplying the lakes with water.

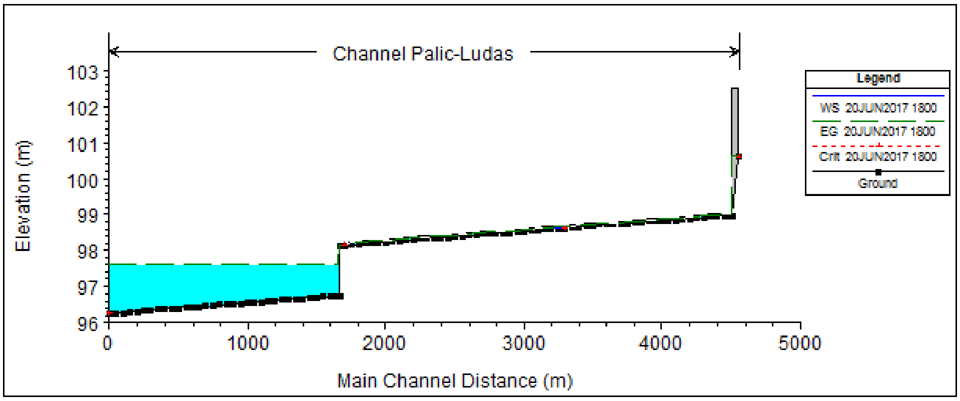

Figure 8. Water surface elevation in the Palić-Ludaš channel with no groundwater interflow with the system

Finally, the third set of computed results depicts a hypothetical situation when the water from the sewage treatment plant is rerouted, and bypasses the modeled lake system completely. Figures 9. and 10. show the water surface elevations and net inflows for both Sector 4 and Lake Ludaš. Without the inflow of water from the sewage treatment plant, there would be a drop of water elevation of cca. 0.2*m* in Sector 4 and 0.45*m* in Lake Ludaš. This would respectively mean a drop of cca. 10% and 25% in these locations.

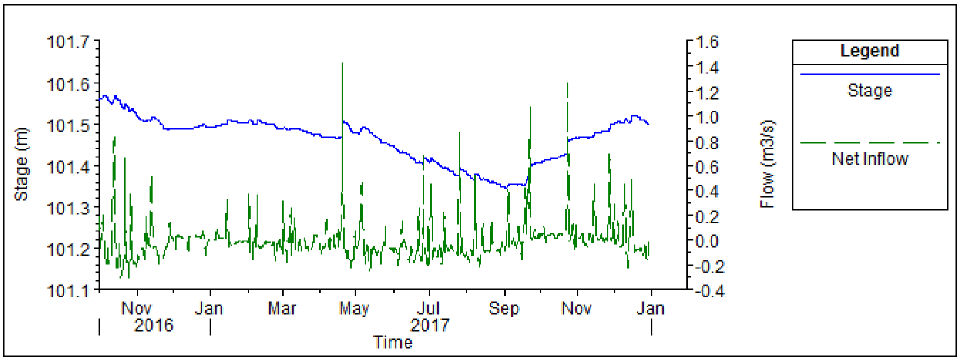

Figure 9. Water surface elevation and net inflow for Sector 4 without inflow from the sewage treatment plant into the system

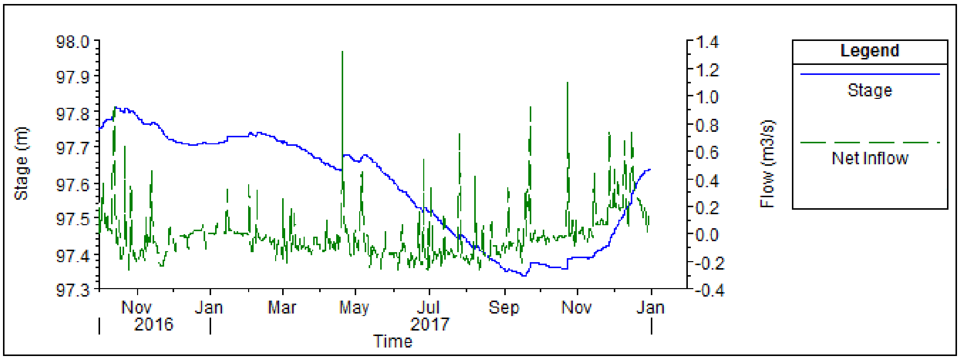

Figure 10. Water surface elevation and net inflow for Lake Ludaš without inflow from the sewage treatment plant into the system

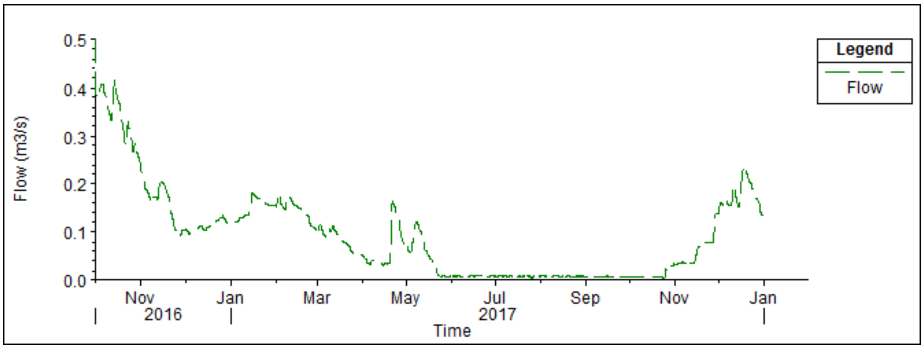

Figure 11. Flow into Lake Ludaš without inflow from the sewage treatment plant into the system

The impact of this hypothetical scenario would be most damaging on Lake Ludaš, since the flow of water in the Palić-Ludaš channel would completely seas in the summer months, as shown on Fig. 11.

5. CONCLUSION

The presented basic water budget model for the Palić Ludaš lake system revealed that the water surface elevations in the modeled lakes do not vary significantly during the year under the current flow regime. Lake Ludaš can face a slight decrease in water surface elevation during the summer months.
Simulations accounting for hypothetical scenarios revealed that the groundwater interflow is a significant element in the water budget of the modeled lake systems. It was

also concluded that the compleat bypass of the sewage treatment plant's discharge would result in significant drops in water surface elevations in Sector 4, and especially in Lake Ludaš.

Acknowledgements
This work was funded by the Ministry of Education and Science of the Republic of Serbia, project number TR 37009.

REFERENCES

[1] Cinkler, R.: *Glavni projekat nasipa ustave i preliva E-539/3-8*, Građevinski zavod pri VTGŠ, Subotica, **1972**.
[2] Rezniček, J.: *Odvodni kanal Palić-Ludaš E-539-5*, Građevinski zavod pri VTGŠ, Subotica, **1971**.
[3] Božić, M.; *Čišćenje i remedijacija mulja iz jezera Palić i Ludaš,* Institut za vodoprivredu "Jaroslav Černi", Beograd, **2010**.
[4] Hovanj, L.: *Pregled promena u slivu Palićkog jezera od kraja XVII veka do danas i istraživanje tih promena – Doktorska disertacija*, Građevinski fakultet Subotica, Subotica, **2008**.

ОСНОВНИ МОДЕЛ БИЛАНСА ВОДЕ ЗА СИСТЕМ ЈЕЗЕРА ПАЛИЋ ЛУДАШ

Резиме: *Овај рад представља основни модел биланса воде за систем језера Палић Лудаш. Домен модела обухвата језеро Палић, Лудаш, Омладинско језеро, канал Палић-Лудаш и све релевантне хидротехничке објекте на систему. Сви релевантни елементи водног биланса су узети у обзир, као што је вода која се испушта у Палић са Постројења за пречишћавање отпадни вода Суботица, падавине, испаравање и интеракција подземне воде са језерима. Спроведена је симулација која обухвата временски период током 2017. године. Добијени резултати су анализирани у циљу процене утицаја појединих елемената водног биланса, као и процене неких алтернативних сценарија.*

Кључне речи: *нумерички модел, водни биланс, систем језера Палић Лудаш*