Extreme Heatwave Scenarios with Impact on Thermal Regime of Dâmbovița River in Bucharest, Romania

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Abstract. The study analyses the qualitative influence of different parameters on Dambovita River water temperature along the 17.5 km length reach of concrete canal passing through Bucharest City, Romania. Air temperature has been increasing during the investigated last 4 decades with detrimental consequences on the river ecosystem. The simplified physical processes taken into account, equations and numerical methods used to develop a deterministic water temperature model are explained. Different scenarios of possible extreme summer heatwaves with influence on river water temperature are defined analysing the available data. A sensitivity analysis is performed for meteorological parameters such as: air temperature, humidity, short wave solar radiation, cloudiness and wind speed to determine their influence on river temperature.

1. Introduction
Water temperature of a river is a very important parameter in stream ecology that affects the health of the aquatic ecosystems and surrounding riverine environment [1, 2]. It’s complex variability in time and space depends on natural and anthropological factors. The natural factors can be classified in: (i) atmospheric conditions (air temperature, solar radiation, precipitation, wind speed, humidity, etc.) (ii) geographical settings (river altitude/latitude, upland and riparian shading by vegetation), (iii) stream characteristics (discharge, streambed geology, morphology, conduction by sediments, hyporheic exchange, groundwater connections etc.). The main anthropological perturbations are due to deforestation, climate change, thermal pollution, controlled flow regime fluctuations, urbanization etc. [1].

Global warming induced by industrialization led to increased air and inland water temperature [3, 4]. The close relationship between air and water temperature is favored by the physical processes taking place in the catchment. Different studies show that in most rivers and lakes across Europe, water temperature has increased by 1-3 °C over the last century [3, 5] and is still expected to rise. Groundwater usually is less affected by climate warming than surface waters [6]. River systems crossing cities are additionally stressed by urbanization and consumption, which affects their...
watershed hydrology and groundwater in terms of quantity / quality and increasing flood risk [7]. Many such rivers were subjected to intensive engineering works over time [8]. In terms of temperature variability, urbanization brings additional stressors on air and water temperature regimes through: hot urban surfaces paved with concrete, asphalt or other impervious materials, artificial riverbeds disconnected from groundwater aquifers, less riverine vegetation, vehicle exhaust gas emissions, air conditioning units etc. All these can cause an urban heat island effect that might increase the air temperature up to 8-10 °C in a city center comparing to adjacent rural regions [9]. Water temperature variation in time follows the same pattern as air, but with a time lag due to its larger thermic inertia. Therefore, surface waters within cities can be thermally impacted above the tolerance of native fauna thus leading to the so-called urban stream syndrome [10]. This process can also affect lakes, their thermal stratification, layer mixing patterns, possibly leading to eutrophication and algal bloom or weed spreading.

Different numerical models are employed to simulate spatial and temporal variability of stream temperatures [1, 2]. They are generally classified into stochastic and deterministic. Stochastic models generally rely on air to water temperature relationships, while deterministic models employ an energy budget approach [1]. For long river reaches, since stream temperature has a low variability along the vertical and in transverse flow direction, a one-dimensional model usually provides sufficient accuracy to estimate it.

This paper addresses the impact of summer heatwaves on water temperature regime of the Dambovita River (first order tributary of Argeș River) stretch that crosses Bucharest city, the capital of Romania. The developed concrete canal emerging from a reservoir is bordered along both banks by high-traffic streets with little riparian vegetation shading. The necessity of the study emerged after aquatic weeds started to invade the canal and reservoir. Also, several episodes of dead fish occurred in the upstream reservoir due to low oxygen concentration in the water, caused by a prolonged high temperature period. Historic records indicate a maximum temperature of 31.5°C recorded on august 10th, 1957 (at the former Conţeşti gauging station) on Dâmbovița River, whereas at Malu Spart gauging station on Argeș River the historical maximum was of 36 °C on July 9th, 1960 [11].

The main objective of present study is to analyse the thermal regime of Dambovita River in Bucharest, during hot summers. The analysis would be useful to mitigate the impact of anthropical factors on water warming up through different methods. In order to achieve that, several secondary objectives are established for this paper:

- to understand the physical processes and necessary mathematical temperature models;
- to set up a 1D hydraulic and temperature numerical model for the case study;
- to process available data and define heatwave modeling scenarios;
- to perform a sensitivity analysis for the weather parameters, to indicate the degree of change in water temperature when each of them is modified. This analysis is necessary since many of the parameters are highly variable in space and time, or difficult to be systematically measured, and their influence in the model has to be understood and quantified in case their variability is estimated or simplified in the temperature model.

2. Site / study area description
Dambovita is a second order tributary of Danube River. It has a length of 286 km, a catchment area of 2,824 km2 and a mean annual flow rate (under natural conditions) upstream Bucharest of 10.6 m3/s. The river crosses from N-W to S-E Bucharest, Romania’s capital city (with a population of about 2 million people and a surface area of about 228 km2).

During 1985-1990 engineering works for the “Complex Management Scheme of the Dâmboviţa River in Bucharest” were developed by the national water authorities in order to protect the city from flooding, to regulate and channelize it and to collect and transport wastewater, runoff and groundwater. In order to achieve all these purposes, the following constructions were built: an upstream accumulation - Morii Reservoir, with a maximum storage capacity of 14.7 million m3), impounded by the 15 m height Ciurel Dam, a reshaped river channel by a trapezoidal concrete canal
and three closed sewage collectors underneath the “clean water” canal (figure 1). Reservoir inflow is from Dambovita and Arges rivers (through the Arges-Roșu canal)

![Figure 1. Plan view of Dâmbovița River through Bucharest City, with the 11 control structures and a typical cross-section profile.](image)

The stretch has 17.5km and is divided into smaller, in series reaches (pools) which are separated by 11 control structures equipped with gated broad-crested weirs (barrages) [8, 12]. The top width varies between 30 and 100 m. Depths can vary between 1.5÷4.5 m, and mean bank slope is of 1.5 along the entire reach for normal pool level (NPL) elevation [12].

Latitude and longitude of the reservoir surface centre are 44°27'18”N and 26°01’39”E, respectively. Mean longitudinal slope of Dâmbovița canal along all pools is about 7 ‰ [12].

Discharge varies from the minimum ecological flow of 3 m3/s, to intermediate values of about 20 m3/s (required for periodic flushing), and up to a maximum of 45 m3/s crossing the pressurised culvert of Unirii Square without flooding the banks.

3. Method
The water quality module withing HEC-RAS 1D [13] software, chosen for this study, is a deterministic-type model [1]. The software includes separate hydraulic and water quality mathematical formulations which are solved sequentially.

3.1. Mathematical model
The hydraulic model solves the Saint - Venant equations for unsteady flows, in order to determine each cross-section water depth \( h(x, t) \) and mean velocity \( V(x, t) \)

\[
\begin{align*}
1 \frac{\partial V}{\partial t} + \frac{\alpha V}{g} \frac{\partial V}{\partial x} + \frac{\partial h}{\partial x} &= S_0 - S_e \\
\rho \frac{\partial V}{\partial x} + V \frac{\partial h}{\partial x} + \frac{\partial h}{\partial t} &= q_l
\end{align*}
\]

(1)

where \( S_0 \) is the channel slope, \( S_e \) - energy slope and \( q_l \) – lateral specific flow and \( \alpha \) - the Coriolis coefficient. Since no tributary or groundwater inflows / withdrawals are considered for the present
study, the lateral specific flow is null.

In case of a steady flow regime, equations (1) simplify to the gradually varied flow from which \( h(x) \) is computed in each cross-section for the specified discharge value (\( Q \)):

\[
\frac{dh}{dx} = \frac{S_0 - \frac{Q^2}{K^2} \left( 1 - \frac{\alpha C^2 R}{gA} \frac{\partial A}{\partial x} \right)}{1 - \frac{\alpha Q^2}{g} \frac{B}{A^3}}
\]  

(2)

in which \( R, B, A \) are hydraulic radius, canal width and cross-section area, respectively.

The upstream water elevation of a control structure is computed by using the weir discharge equation

\[
Q_w = C_d \sqrt{2gBH^3} = CH^{3/2}
\]  

(3)

where \( C_d \) is the non-dimensional discharge coefficient considered a constant 0.4 value to take into account local friction and contraction,

\( H \) – the head over the gate crest,

\( B \) – total width of the gate openings and

\( C \) – the dimensional discharge coefficient that includes the acceleration due to gravity.

The complex processes and factors that influence water temperature variability are depicted in figure 2.

For a constant discharge and cross-section area, in the absence of external inflows/outflows, the one-dimensional heat advection – dispersion equation that describes the thermal behavior of the river in space and time, \( T_w(x, t) \) is given by:

\[
\frac{\partial T_w}{\partial t} = -V \frac{\partial T_w}{\partial x} + D_L \frac{\partial^2 T_w}{\partial x^2} + \frac{H_{\text{total}}}{\rho \cdot c_p \cdot h}
\]  

(4)

where \( T_w \) is the water temperature, \( V \) – mean stream velocity, \( x \) – distance along the stream, \( D_L \) – longitudinal dispersion coefficient, \( \rho \) – water density, \( c_p \) – water’s specific heat, \( h \) – mean water depth in the channel and \( H_{\text{total}} \) – total available thermal energy to be transferred from or to the river channel [2, 14].

Figure 2. Physical processes and factors influencing water temperature
The total heat energy flux, $H_{total}$, considered in the energy balance at the water interface with its natural and/or artificial boundaries depends on the complexity of the model, and includes for the general case the following terms:

$$H_{total} = H_{sw} + H_{lw} + H_l + H_s + H_{bf} + H_{i-o}$$  \hspace{1cm} (5)

where $H_{sw}$ and $H_{lw}$ are the net shortwave and longwave solar radiations respectively, $H_l$ is the net latent heat flux, $H_s$ is the sensible heat flux, $H_{bf}$ is the channel-bed heat transfers and $H_{i-o}$ is the net energy exchange with the groundwater and tributary inflows/outflows. For Dambovita canal study $H_{sw}$ is requested as input data by the HEC-RAS model, $H_{lw}$, $H_l$ and $H_s$ are calculated by the software based on atmospheric and topographic data and last two terms are neglected.

In the absence of calibrated values for the study reach, the longitudinal dispersion coefficient in the pools is calculated by HEC-RAS from the hydraulic parameter results for the discharge value with the [15] formula

$$D_L = 0.011 \frac{V^2 B^2}{h \cdot u}$$  \hspace{1cm} (6)

where $B$, $h$ and $V$ are the average width, depth and mean velocity, whereas the shear velocity, $u^*$ is given by

$$u^* = \sqrt{ghS_e}.$$  \hspace{1cm} (7)

3.2. Numerical model

The river schematic and 1D mesh consists of 105 equally-spaced cross-sections at a mean distance of 200m along the canal. For the steady hydraulic model the necessary boundary conditions are: constant discharge value at the upstream end (Ciurel Dam), uniform flow (slope) at the downstream end of the canal reach and maximum gate openings at the weirs from the 11 control structures.

Comutations are performed starting from the downstream end of the canal for the gradually varied flow under steady flow conditions by using the standard step finite difference method along each elementary computation reach. The hydraulic model has been calibrated on observed water level values by adjusting the overall Manning roughness coefficient in a previous study [8].

The water quality component of HEC-RAS software can simulate temperature variation in space and time for a stream in each cell centre of the same 1D mesh/grid used for the hydraulic computations (figure 3) [2, 16].

![Figure 3. Mesh of the coupled hydraulic-thermal model.](image-url)
The boundary condition for the thermal model consists in water temperature values downstream the Morii Reservoir during the simulation period, whereas the initial conditions consist in water temperature values in each cross-section along the canal at the start-up of simulations.

To compute the total energy flux, a complete meteorological data set is needed. A virtual meteorological station has been set up in Bucharest, defined by longitude, latitude and altitude data. The necessary weather data required by the temperature model include: time series of air temperature, atmospheric pressure, relative humidity, short wave radiation, wind speed and cloudiness.

Shortwave and longwave solar radiations from equation (5) can be computed by the software from input data on cloudiness, site elevation and location, air temperature and humidity. However, user defined data is used as input for the shortwave radiation. The sensible heat and latent heat are computed from input data on atmospheric pressure, air temperature, wind speed and model calculated water temperature and vapour pressure [17].

The advection-dispersion equation in HEC - RAS is solved by the QUICKEST (Quadratic Upstream Interpolation for Convective Kinematics with Estimated Streaming Terms) scheme developed by Leonard together with the ULTIMATE (Universal Limiter) algorithm [18].

4. Data processing and scenario definition

Satellite hourly weather data sets for Bucharest, consisting in air temperature, relative humidity, pressure, wind speed and direction, and cloudiness were obtained from Open Weather – API (https://openweathermap.org/) during a period of 30 years (1990-2020), after the commissioning of the complex development Dâmbovița Canal - Morii Reservoir.

The hourly air temperature variation over studied period (figure 4) shows an increasing multiannual trend with summer heatwaves over 35°C. Of these, three temperature peaks can be identified, reaching 40°C in 2000, 2007 and 2012. An example of annual variation for the hot 2007 year display similar sinusoidal cycles (figure 5) like the others. Calculated mean annual values over a 40 years period show an increasing trend by more than 2 degrees (figure 6).

During summers, the data on atmospheric pressure varies slightly, so a constant average value of 1010 mbar is considered in the model for the scenario (an example for year 2000 in figure 7).

An inverse sinusoidal variation of the daily air temperature and relative humidity can be observed (figure 8). By approximating the two multiple day variations with polynomial functions, heatwave periods of time can be defined.

![Figure 4. Air temperature (hourly) variation over the last 30 years. Three high heatwave periods are emphasized by their peaks of over 40°C.](image-url)
Analysing the multiannual patterns of heatwaves, two simulation periods are considered for defining the scenarios: a one-day and a one-week, both with maximum mid-day values of air temperatures between 35 and 40 °C and minimum night values over 20°C.
Figure 8. Hourly air temperature and relative humidity for the hottest heatwave over the analysed period (July 2000).

The weekly scenario for the air temperature variation replicating the natural heatwave behaviour is shown in figure 9. The hottest day has been selected for the one-day scenario.

Solar radiation has an increasing trend for the first part of the day, followed by a reversed trend in the second part of the day and null values during the night. Summer maximum is usually in July when cloudiness is the lowest. Shortwave diel variation for Bucharest during July has been reproduced according to [19]. Its trend is in phase with the temperature and has an inverse variation with the relative humidity scenario (figure 8, figure 10).

Wind speed is a necessary parameter for latent and sensible heat fluxes estimation. Cloudiness is the fraction of sky covered with clouds and can be varied in HEC-RAS from 10% (clear sky) to 90% (overcast sky) [13]. It is a parameter required to calculate the downwelling longwave radiation. An increase in cloudiness leads to an increased computed longwave radiation along with a decrease in reflected shortwave radiation back into space. Registered wind speed at 10m height of the ground and cloudiness values show a very irregular time variation (figure 11), difficult to be integrated in a modeling scenario. For the sake of simplicity, in defining the extreme one-day heatwave scenario, constant values of 0.1m/s wind speed and of 10% cloudiness were considered.
5. Results and sensitivity analysis
Simulations are performed with the aforementioned boundary and initial conditions for the one-day scenario considered as July 31st, at the ecological flow of 3m$^3$/s.

Longitudinal profile from hydraulic simulation under aforementioned conditions is shown in figure 12. One may observe for the ecological discharge value the Unirii Square culvert is not under pressure.

Figure 13 shows the temperature wave travel along the study reach for the one-day scenario (at 12h and 24h). The variation in time is displayed for a cross-section (at the Sere control structure) at about km. 6.

In the absence of water temperature data to calibrate the thermal model, sensitivity analyses for the following meteorological parameters were performed: atmospheric pressure, air temperature, relative humidity, solar radiation, cloudiness and wind speed.
The base parameter values and their possible variations range during summer heatwaves are: atmospheric pressure = 1010 mbar (950 - 1030 mbar), daily maximum air temperature = 35 °C (30-40°C), daily maximum relative humidity = 65% (48 - 80%), daily maximum solar radiation = 740 W/m² (685 - 805 W/m²), cloudiness = 10% (0 - 90%), wind speed at 10m of ground = 1 m/s (0-10 m/s). By varying one of the parameters at a time and keeping the others at the base value, the influence on water temperature has been investigated at the downstream control structure no. 3 (“Sere”), situated at the exit of Bucharest city.

![Figure 12](image12.png)

**Figure 12.** Longitudinal profile for \( Q_e = 3 \text{ m}^3/\text{s} \) and full gate openings at all control structures

![Figure 13](image13.png)

**Figure 13.** a) Water temperature variation for the one-day scenario: a) in space, along the study reach (at 12h and 24h) and b) in time, at control structure no. 3 (“Sere”).

Different values of atmospheric pressure taken in the aforementioned range show no sensible influence on peak water temperature.

The daily peak air temperature from figure 11 is progressively varied in the range 30 to 40°C to conduct sensitivity analysis. In figure 14 the values on the abscissa represent the daily peak air
temperature, while the values on the vertical axis represent the daily peak water temperature. A one-degree stream temperature increase is obtained if air temperature varies in this range.

![Figure 14. Temperature variation at 12h and 24h of one-day scenario.](image)

A similar procedure of scaling the sinusoidal variation of daily relative air humidity is applied. In figure 15 the values in the abscissa represent the daily minimum relative humidity in the range 20-45%. A very small variation of 0.1 °C is obtained for the considered range of minimum relative air humidity.

![Figure 15. Water temperature variation with minimum relative air humidity.](image)

Shortwave radiation variation pattern from figure 16 has been multiplied with a coefficient ranging from 80-105%. The stream temperature is very sensitive to shortwave radiation, simulation results showing a variation of 1.6°C for the considered range of this parameter.

An increasing trend of peak water temperature with cloudiness can be observed in figure. 17. This trend could be explained by the longwave radiation increase with cloudiness, since fixed data was maintained in the model for the shortwave radiation (and therefore not accounting for its reduction due
to the same parameter). This phenomenon of clouds retaining heat is known as “cloud greenhouse forcing” [20].

Figure 16. Water temperature variation with shortwave radiation.

Figure 17. Water temperature variation with cloudiness.

For wind speed (at 10m from ground) variations between 0 and 10m/s, the computed daily peak stream temperatures decrease by about 0.4 °C (figure 18). However, during summer heatwave conditions, wind speed is usually below 3m/s, corresponding to a decrease in stream temperature of only 0.15 °C. Since stream temperatures are usually measured by data loggers with submersible sensors having accuracies between 0.1-0.4 °C and resolutions of 0.02-0.4 °C [21, 22], this temperature variation can be neglected, since it could not be registered.

Influence of vegetation shading was not considered as the last version of HEC-RAS (5.07) does not yet take this parameter into account.

Results of the sensitivity analysis show the most sensitive parameters are air temperature and solar shortwave radiation. While an important dependence with the first parameter is normal, the second one is characteristic only for shallow depth streams during low flow periods, as it is the ecological flow used in the one day scenario simulations [23]. Also, the third most sensitive parameter to
influence water temperature is cloudiness, which is normal for a stream without riparian vegetation whose water temperature is mainly affected by the aforementioned two parameters.

One of the difficulties in modeling water temperature in streams is that weather conditions may vary over the reach, whereas observations are at fixed locations [23]. Also, the intensity of time variation of the parameters may be important. Therefore, the results of the sensitivity analysis are very useful to gather and prepare data for the model calibration/validation so that accurate prediction of less than 1°C could be obtained for the water temperature.

Figure 18. Water temperature variation with wind speed.

Conclusions
A coupled hydraulic and temperature model has been set up to simulate stream temperature variation along Dambovita River for a defined one-day scenario. The hydraulic model has been calibrated in a previous study.

In the absence of measured water temperature values for calibrating the thermal model, the sensitivity of the model has been analysed by changing the values of atmospheric parameters. This analysis is performed in order to determine which are the most important parameters of the model and the necessary data gathering, accuracy and resolution.

Results show the thermal model is sensitive particularly to shortwave radiation and air temperature parameters, which induce stream temperature variations of over 1°C. Other two important influencing parameters are cloudiness and wind speed, inducing water temperature variations of less than 1°C. Therefore, the first two parameters should be introduced into the model with daily variations, whereas the last two parameters can be introduced as constant values.

The results of this paper will be very useful for further temperature simulations during one-week scenario of heatwaves. Untill the thermal model is calibrated on measured stream temperature values, the results of the sensitivity analysis are capable to show only qualitative variations in time and space.

Simulations show a maximum water temperature of 28.7°C for the given scenario at 2.6km from downstream (Glina) (Fig. 13a). Also, they prove a lag of 4 to 5h between extreme air and extreme water temperatures, which means minimum daily stream temperature is attained between 7:00 and 8:00 in the morning, whereas the maximum value between 18:00-19:00 in the afternoon (Fig. 13b).

The influence of discharge and gate position on water temperature along the Dambovita canal should also be investigated and discharge-temperature variations for each control section developed. This is particularly important when establishing gate operation rules for water management purposes during heatwaves.
References

[1] Caissie D 2006 *Freshwater Biol.* 51(8) 1389
[2] Dugdale S J, Hannah D M, Malcolm I A 2017 *Earth-Sci. Rev.* 175 97
[3] Dokulil M T 2013 *Inland Waters* 4 27
[4] Kedra M, Wiejaczka L 2018 *Sci. Total Environ.* 626 1475
[5] *** 2016 *Water temperature* (Copenhagen: European Environment Agency)
  
  [https://www.eea.europa.eu/data-and-maps/indicators/water-temperature-2/assessment](https://www.eea.europa.eu/data-and-maps/indicators/water-temperature-2/assessment)
[6] Kumar C P 2012 *Water Energy Int.* 69(8) 25
[7] Driscoll M O, Jefferson A, Clinton S M and Manda A K 2010 *Water* 2(3) 605
[8] Gogoașe Nistoran D E, Ionescu C S, Georgescu M and David D Șt 2019 *E3S Web Conf.* 85 06007
[9] Ciocănea A, Dragomirescu A, Tofan B and Toti M 2019 *E3S Web Conf.* 85 07007
[10] Walsh C J, Roy A H, Feminella J W, Cottingham P D, Groffman P M, Morgan R P 2005 *J. N. Am. Benthol. Soc.* 24(3) 706
[11] Cocoș O 2006 *Managementul apei in municipalul București* (București: Ars Docendi) chapter VIII pp 67-103
[12] *** 1993 *Operation Rules for the management of Dambovița River downstream Morii Reservoir* (București: “Romanian Waters” National Administration - Internal Report, in Romanian)
[13] *** 2016 *HEC-RAS, Hydrologic Engineering Centre- River Analysis System, User Manual, Version 5* (Davis: USACE - United States Army Corps of Engineers)
  
  [https://www.hec.usace.army.mil/software/hec-ras/documentation.aspx](https://www.hec.usace.army.mil/software/hec-ras/documentation.aspx)
[14] Abdi R, Endreny T, Novak D 2020 *MethodX* 7 100808
[15] Fischer H B, List E J, Koh R C Y, Imberger J and Brooks N H 2013 *Mixing in inland and coastal waters* (New York: Academic Press)
[16] Jensen M R, Lowney C L 2004 *World Water and Environmental Resources Congress*
  
  [https://doi.org/10.1061/40737(2004)404](https://doi.org/10.1061/40737(2004)404)
[17] Drake J, Bradford A, Joy D 2010 *J. Hydrol.* 389(3-4) 390
[18] Leonard B P 1991 *Comput. Methods Appl. Mech. Eng.* 88 17
[19] Oprea C 2005 *Solar radiation. Theoretical and practical aspects* (In Romanian *Radiația solară. Aspecte teoretice și practice*) (București)
[20] Matuszko D, Weglarczyk S 2014 *Int. J. Climatol.* 34 145
[21] Dunham J, Chandler G, Rieman B and Martin D 2005 *Measuring stream temperature with digital data loggers* (US Dept. of Agriculture)
[22] Briciu A E, Oprea D I, Mihăilă D, Lazurca Andrei L G, Costan Briciu L A, Bistricean P I 2020 *Water Resources Management in Romania* (In: A M Negm et al Springer Water) pp 465-487
[23] Sinokrot, B. A., & Gulliver, J. S. (2000). *Journal of Hydraulic Research, 38*(5), 339–349.
  
  [https://doi.org/10.1080/00221680009498315](https://doi.org/10.1080/00221680009498315)