Modeling the hydrodynamics of a wetland subjected to strong urban and agricultural pressures (Torbiere del Sebino, Italy)

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1. Introduction

Large shallow wetlands like Torbiere del Sebino provide a multitude of ecosystemic services and are an important ecological, social and touristic resource for the area where they are located. A fundamental role played by wetlands is that they also represent a natural solution for the treatment of pollutants, by means of the processes that control contaminant distribution, such as sedimentation, oxidation, disinfection, and stabilization. The expected efficiency of the nutrient removal processes acting in a wetland is related to its flushing time, or residence time, as it describes its waters renewal ability.

The main tools used to reach insights on residence time include hydrodynamic models, lake particle transport models, calculations of residence time and flushing times, isotope-tracer experiments, and drifter experiments.

There is wide consensus on the positive role of connectivity, that is usually associated to a better environmental quality. However, in the presence of a polluted inflow, there are very little studies that discuss the trade-off between connectivity and the worsening of water quality in areas that were originally isolated, considering that the physical separation of some ponds from the incoming contaminants protect them from pollution.

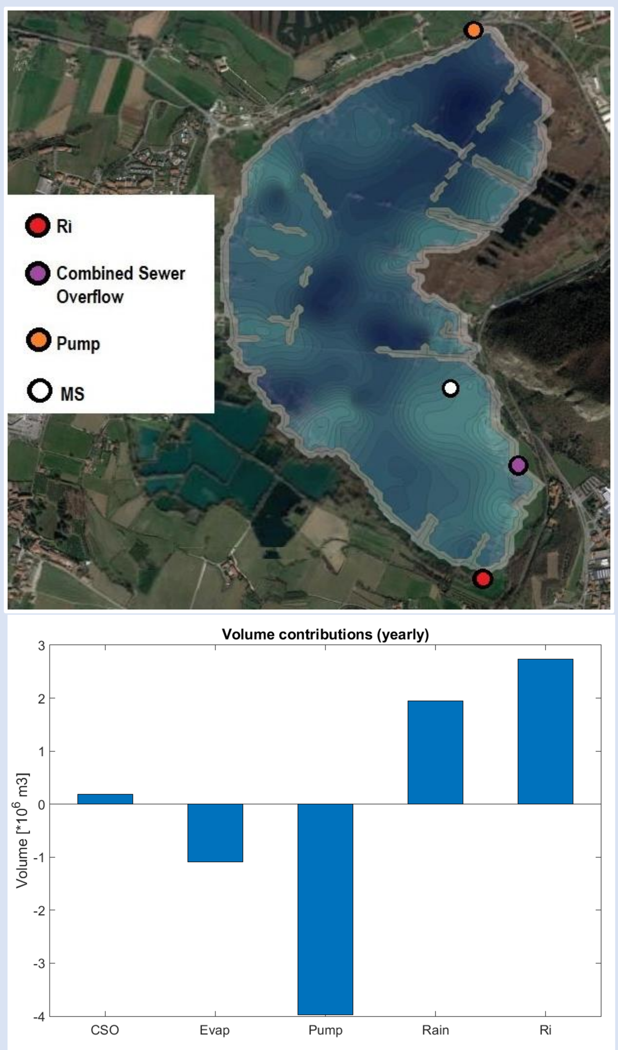
This contribution investigates the variation of Torbiere's residence time after the demolition of the separating banks. We argue that in some cases, a lower level of connectivity might improve the water quality of a basin.

2. Study Area

Torbiere del Sebino is a Natural Reserve located in the Italian subalpine area. The focus of this study is the central area of Torbiere, consisting of 1.6 km^2 of differently communicating tanks, of average depth 1.7 m.

The main affluent, Rì, enters from South after draining a 6km^2 watershed occupied by vineyards, arable lands and urbanized area. A second affluent is the Combined Sewer Overflow draining a 2.7 km^2 watershed and providing a high load of nutrients and total suspended solids. After travelling from South to North, the water of Torbiere is then flushed out through a man-made ditch regulated by a pump.

Torbiere were originally made up of separated ponds, the banks were demolished at the end of last century to promote water circulation. As a result, similar water quality characteristics are now found all over the basin and Torbiere is a eutrophic system with several algal blooms occurring throughout the year.



Top: Bathymetry of the main area of Torbiere. Bottom: Yearly volume contributions of the different terms of the mass balance of Torbiere.

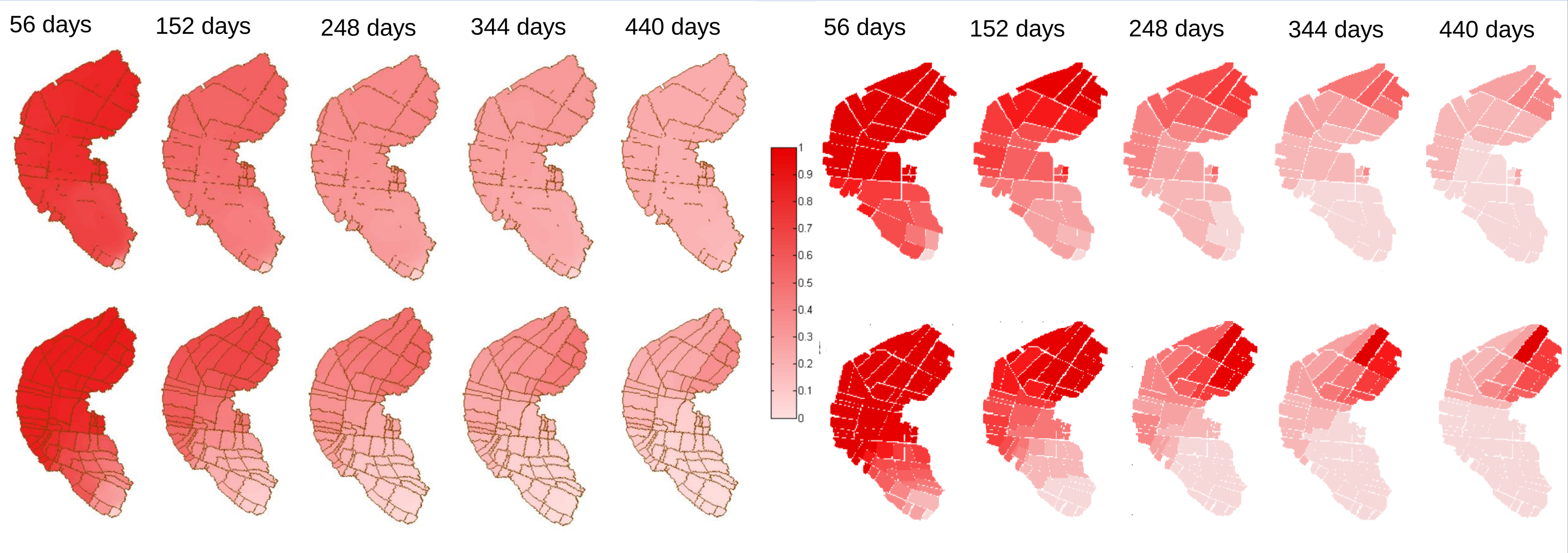
3. DELFT 3D Model and the conceptual 1D model

Torbiere was modelled with the Delft3D-FLOW module and was represented through a fine grid where each cell has a resolution of 5-10m. The banks separating the tanks were represented through thin dams, i.e. infinitely thin walls which prevent flow exchange between two adjacent computational cells. The model was calibrated using field measurements and the data series provided by the monitoring station and was then used to investigate the effects of the wetland morphometry on the water circulation by simulating the fate of a passive tracer initially present in the system. A preliminary estimation of the system's average residence time was obtained through the simulation of 1.3 years long period where an initial conservative tracer concentration, equal to 1 kg/m^3 is set constant all over the domain. The conservative tracer represents the water originally present in the system, that is going to be flushed out.

As an alternative approach, Torbiere was modeled as a non-linear system of n 1D tanks, to simulate mass balance in each pond. The tanks connections reproduce the real connectivity of the ponds through a connectivity matrix, a symmetric nxn square matrix whose $a_{i,j}$ elements are either 1 or 0. The flow between pond i and j is governed by a Chezy-like equation. The renewal time of the wetland is obtained from the distribution of the old water concentration within each tank.

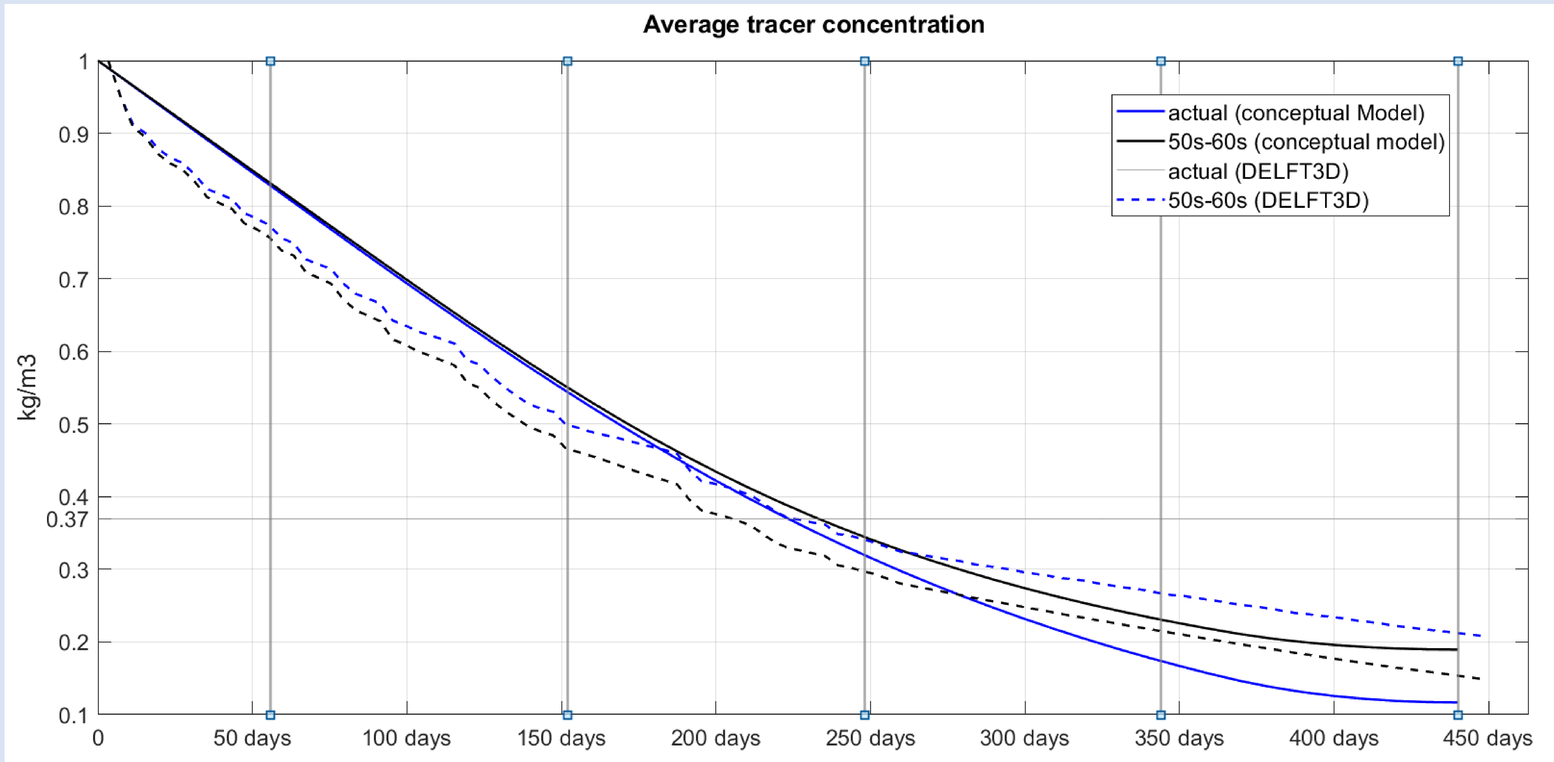
4. Results

For both Delft3D and the conceptual model, two different configurations of Torbiere were chosen: the first one describing the present situation is depicted with a lower number of thin dams (Delft3D) or 34 tanks (conceptual model), the second one, describing the situation in the 50s-60s is schematized with a greater number of thin dams (Delft3D) or 68 tanks. The simulations differ only in the bank configuration, allowing to single out the geometric effect on the residence time



Tracer concentration in the domain at 5 different time steps with the Delft3D simulation (left) and the conceptual model simulation (right). The top row represents the present bank configuration while the bottom row corresponds to the 1950s-1960s bank configuration.

5. Conclusions



Comparison between the average tracer concentration (kg/m^3) within the basin in the present (black) and the 1950s-1960s (blue) configuration computed using the simplified conceptual model (continuous line) and the hydrodynamic model DELFT3D (dashed line).

The overall residence time of Torbiere, e.g. the time required for 63% of the old water to exit the system, is calculated to be 223 days, 20 days larger than the residence time with the 1950s-1960s configuration. Imaging the old water being any pollutant present in the system, a higher residence time means a lower removal efficiency and potentially, a worse water quality. These simulations support the initial idea of a positive role of the banks: keeping the ponds naturally subdivided would lead to a differentiated situation, with some tanks being quickly flushed and some others presenting a higher residence time, but with an overall higher removal efficiency. The present bank configuration, on the other hand, creates a uniform system, with the same old water concentration everywhere that needs more time to be flushed out of the basin.

The results provided by the conceptual model show a similar picture of the water renewal process but with some noticeable differences that will be explored in our future investigations.

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