Geophysical Research Abstracts
Vol. 20, EGU2018-156, 2018
EGU General Assembly 2018

Development and application of an integrated water quality model for a Singapore tropical wetland

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Nee Soon swamp forest is the last vestige of tropical wetland in Singapore. Understanding the hydrological regime of the swamp forest and implications for water quality is critical to guide stakeholders in implementing effective measures to preserve the wetland against anthropogenic impacts. In particular, the potential influx of organic waste from sources like discarded food, historical agricultural plantation, leakages from used water pipes and runoff from surrounding urban catchments can adversely affect the fragile wetland ecosystem. For instance, dissolved oxygen (DO) levels can be reduced below sustainable levels for aquatic flora and fauna due to decomposition of excessive organic waste. Current field measurement data do not indicate a concern with organic pollution in the wetland. However, reviewing the ways in which the wetland responds to elevated organic waste influx and the corresponding impact on DO can help identify potential hotspots, and the impact on the outflow from the catchment which drains into downstream controlled watercourses. An integrated water quality model is therefore developed in this study to investigate spatial and temporal concentrations of DO levels and organic pollution (as quantified by biochemical oxygen demand, BOD) within the catchment's river network under hypothetical, projected scenarios of spiked upstream inflow. The model was developed using MIKE HYDRO (a fully dynamic, one-dimensional modelling package for complex river networks, developed by the Danish Hydraulic Institute) for modelling the study domain, as well as the MIKE ECO Lab numerical laboratory for characterising water quality processes. MIKE HYDRO's NAM model was used to describe rainfall-runoff processes from contributing catchments. Model parameters are calibrated against time series of observed discharges at three measurement stations along the river network. The calibrated model was then used to analyse the impact that a continuous influx of organic waste at an upstream tributary will have on temporal concentrations downstream. The organic waste was assumed to have a BOD of 400 mg/l, typical of untreated domestic sewage, and is modelled by adjusting the boundary conditions at the upstream inflow boundary of the tributary. Over a simulation period of April 2014 to December 2015, the model predicted that this continuous spiked inflow of 400 mg/l BOD will elevate downstream concentrations at the catchment outlet to an average of 12 mg/l, from an assumed nominal baseline BOD of 1 mg/l. Levels of DO were decreased from an initial 5 mg/l to 0.4 mg/l. Under such a scenario, the impact on channels downstream of the swamp forest is expected to be within the current BOD limit for controlled watercourses of 20 mg/l. However, the predicted resulting low DO levels pose concern for ecological well-being. Though a scenario of spiked organic influx at the swamp forest's undeveloped upstream sub-catchments is currently unlikely to occur, the outcomes nevertheless provide insights into how the wetland will behave under conditions of elevated organic pollutant concentrations. Therefore, the results will be beneficial for future planning studies in understanding how the water quality of the catchment will be impacted should urban redevelopment works be considered around the swamp forest.