

EVALUATING FUTURE WATER QUALITY OF URBAN RIVERS IN HA NOI UNDER EFFECT OF URBANIZATION AND CLIMATE CHANGE - THE APPLICATION OF WEAP MODEL FOR CAU BAY RIVER

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Abstract. Every day, up to 750,000 cubic meters of wastewater in Ha Noi metropolitan areas is discharged directly into rivers and lakes, of which only 10 % is treated to the Vietnamese standards. According to the water drainage development master plan for the capital city of Ha Noi until 2030, the government aims at dealing with flood control and improving environmental sanitation for local residents. With respect to the baseline and Master plan implementation scenarios, this study evaluates the future water quality of urban rivers in Ha Noi under the effect of urbanization and climate change using Water Evaluation And Planning tool (WEAP) and take the Cau Bay catchment as the case study. The Cau Bay river is a man-made river system and it has been receiving the untreated wastewater of the Long Bien and Gia Lam districts. The result shows that, without implementation of wastewater treatment plant, the water quality of Cau Bay River will be worse with the DO in dry season is 0.2-1.2 mg/l and BOD is 52.0 - 55.0 mg/l. With the implementation of Master plan, the level of DO and BOD would be 7.1 - 7.3 mg/l and 7.0-13.8 mg/l respectively in the dry season whereas the values are 3.7 - 4.0 mg/l and 36.1 - 41.8 mg/l in the wet season. The degradation of wastewater during the wet season is resulted from the combine- overflow sewage system as designed in the master plan when excess wastewater was discharged directly to the river during storm.

Keywords: urban river water quality, WEAP model, climate change, Ha Noi water drainage development master plan.

Classification numbers: 3.3.3, 3.8.1.

1. INTRODUCTION

The water quality of urban rivers in Ha Noi (Viet Nam) has been the emerging issues of the city's environment for many years. The city urban drainage master plan through 2030 with the vision to 2050 was approved in 2013 aiming at tailoring the drainage planning of Ha Noi within the master plan of construction [1], step by step eliminating urban flooding and increasing the proportion of sewage and wastewater treatment to 90 % in 2030 and 100 % in 2050. Every day,

up to 750,000 cubic meters of wastewater in Ha Noi metropolitan areas is discharged directly into rivers and lake, of which only 10 % is treated to the Vietnamese standards. In addition, 300,000 m³ of wastewater discharged from industrial zones, services and 6,000 m³ from hospitals. The wastewater was discharged from combined sewer system to the southern part of the city and was treated through the pond systems before partially treated and discharged to the Red river. The urban rivers play an important role in draining storm water and receive wastewater has been seriously polluted for many years. Some of these urban rivers are also important water supply sources for the peri-urban areas of Ha Noi for irrigation purpose such as Nhue river and Cau Bay river. Water pollution control for these urban rivers is very important for the city public health as well as prevention of urban flooding.

The Cau Bay river is a man-made river system, it origins from the Kim Quan pond (Viet Hung Ward, Long Bien District of Ha Noi) with the length of 13 km. This river is designed for irrigation of the Bac Hung Hai irrigation system many years ago. Up to now, the river is mainly wastewater channel and drain storm water for the Long Bien urban district and part of Gia Lam rural district. It receives wastewater from residential areas of Long Bien, Gia Lam, and industrial zones Sai Dong. This river is also part of the Bac Hung Hai irrigation system that provides irrigation service for the farmland area of about 110,000 ha. The quality degradation of the Cau Bay river has been seen as the significant factor to affect the water system of the Northern part of Ha Noi and Hung Yen area.

Research shows that an environmental model could assist water resource managers in communicating with stakeholders about different policy options [2]. This study evaluates the future water quality of urban rivers in Ha Noi under the effect of urbanization and climate change using Water Evaluation And Planning tool (WEAP) and take the Cau Bay river catchment as the case study. The study developed two scenarios to assess the future water quality of Cau Bay river with respect to the current Master plan and with the intervention of water quality control.

2. MATERIALS AND METHODS

2.1. Water Evaluation and Planning tool

The WEAP model developed by the Stockholm Environment Institute (SEI) is designed to examine alternative water management strategies based on the principle of water balance accounting, together with demand priorities and supply preferences [3]. WEAP has the friendly interface and help the water planner and scientists to have holistic view on the integrated water management issues. As a forecasting tool, WEAP simulates water demand, supply, flows and storage, and it also includes the generation, treatment and discharge of pollution. The WEAP model focuses on the following issues: Set up of time step, area boundaries and water resource system structure; Water demand, resources, supply and treatment analysis; Scenarios design (involving future policies, costs and techniques); Scenarios evaluation of the water distribution and supply sufficiency.

The WEAP model has been widely applied for the past 10 years in watershed management in the world. The literature study records number of researches using WEAP to simulate water supply and demand for water planning at a regional, local or basin scale [4 - 8]. The WEAP model is also used for policy and decision making in a number of projects [9 - 12].

2.2. Water quality modeling with WEAP for the Cau Bay river

2.2.1 WEAP model development

A scenario analysis on future water quality of the Cau Bay river until 2050 was conducted using WEAP model version 2019.1.1. Firstly, the project area was defined that includes the catchment of Cau Bay river, Red river, Duong river and Bac Hung Hai river. Next, the author input parameters to the model that includes: water sources (drinking water from treatment plants); residential areas; industrial zones, irrigation areas; drainage catchment, residential wastewater treatment plants. Then the author drew link from the water users (transmission links); from drainage catchment to sewer system (infiltration/runoff) and from residential area to wastewater treatment system, the return flow from wastewater treatment plants to Cau Bay river (). .

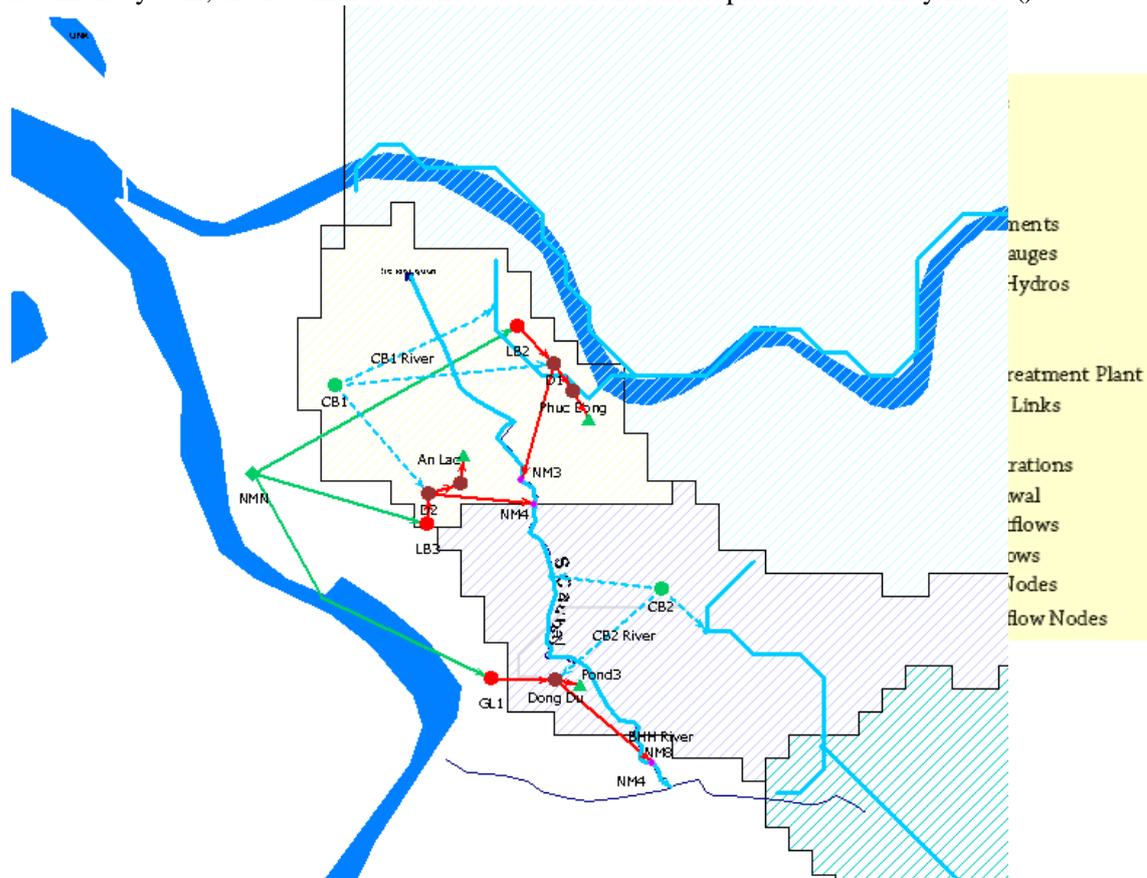


Figure 1. Spatial elements in WEAP that represent interacting model components.

2.2.2. Model validation and calibration

The parameters for WEAP model were then input to the data window with the following databases (**Error! Reference source not found.**)

- Digital elevation model DEM with 15s resolution embed with the WEAP model.
- Daily weather data includes temperatures, precipitation and future weather data was downloaded from Climate Change Knowledge Portal (World Bank).
- Water supply and wastewater discharge from residential areas to Cau Bay river was indicated in Table 1.

Table 1. Input parameters for WEAP model (source: [1]).

No.	Parameters	Unit	Forecast, year			
			Current 2013	2020	2030	2050
I	Urban					
	Population	Thousand persons	2,583.3	4,676.8	6,218.5	7,510.5
	Wastewater discharge	Liter/person/day		180		200
	BOD loading (with septic tank)	g/person/day	20-25	25-30	25-35	
	BOD loading (w/o septic tank)	g/person/day		40-50	50-60	
II	Rural					
	Population	Thousand persons	3,766.7	3,279.2	2,917.0	3,223.0
	Wastewater discharge	Liter/person/day		100		100
III	Total					
	Population	Thousand persons	6,350.0	7,956.0	9,135.5	10,733.5
	Urbanization rate	%	3.09	1.90	1.39	0.68

2.1.2 WEAP model calibration and validation

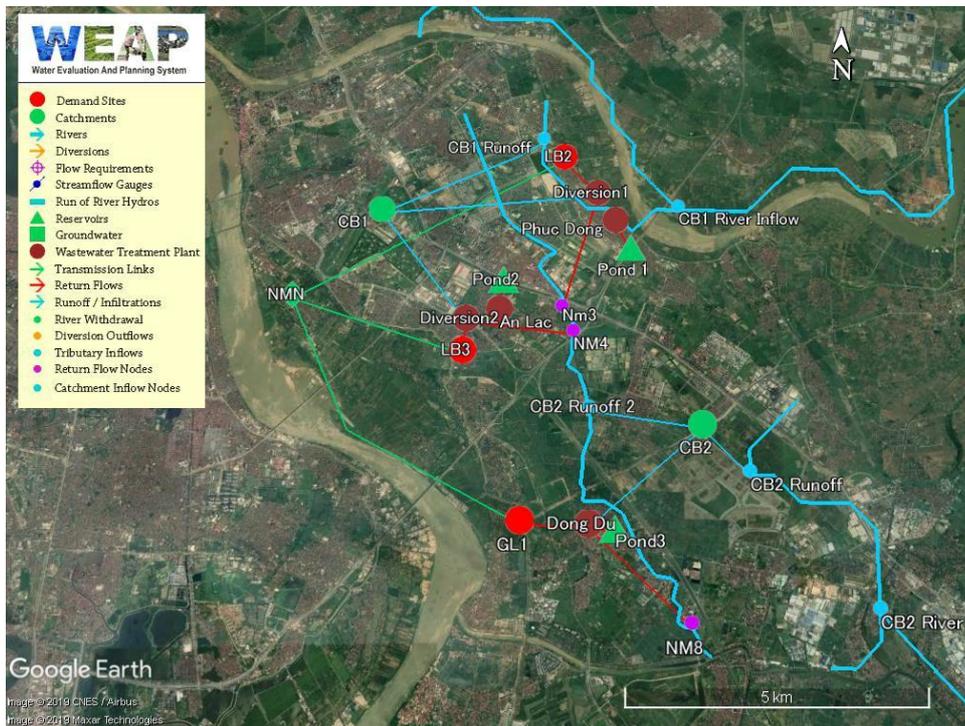


Figure 2. Map of Cau Bay river water sampling points (export to Google Earth).

3. RESULTS AND DISCUSSION

3.1. Analysis of WEAP model results

3.1.1. WEAP calibration and validation

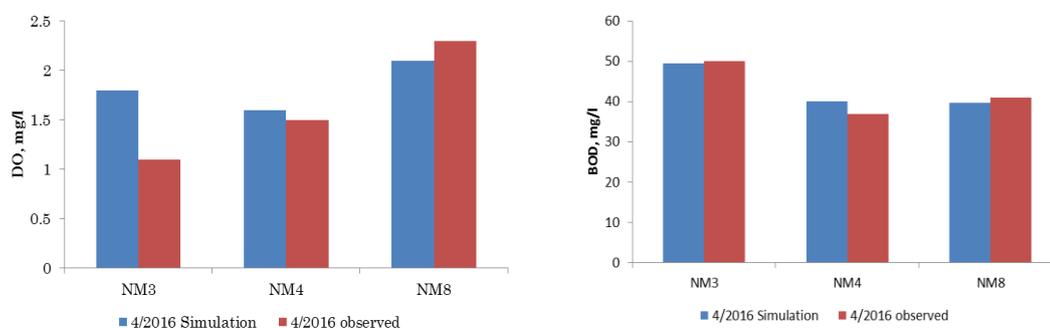


Figure 3. WEAP model calibration and validation result for result for DO and BOD₅ for April 2016.

The model calibration and validation results of water parameters showed a strong agreement between the modelling results and water sample analyzed data as shown in **Error! Reference source not found.**

The results show that DO and BOD₅ concentration in river water in all sampling points exceed the water quality standards for river water type B2 (QCVN 08 – MT:2015/BTNMT). The level of BOD₅ was at 60 mg/l from the upper stream of Cau Bay river through the densely residential areas of Viet Hung, Sai Dong and Da Ton. To the downstream areas, BOD₅ decreased because the decreasing in wastewater discharge and the wastewater was partially diluted with river water. In the rainy season from July to September, the wastewater was diluted with storm water, therefore, BOD₅ concentration decreased to the level that meets the river water quality standards according to QCVN 08 – MT:2015/BTNMT (below 30 mg/l). Regarding the DO concentration, the model results shown that DO level decreased dramatically from the river upstream to the wastewater discharge points. The DO concentration reduces to almost 0 mg/l in the dry season. In rainy season, DO level increase because of mixing with surface runoff, but still do not meet the national standards.

3.1.2 WEAP model simulation for the period 2020-2050

The simulation scenarios were developed for baseline scenario and master plan scenario (Figure 4 and). In baseline scenario, the model simulation results show that if the current wastewater management is not improved, the quality of Cau Bay river will be worse in the future. Specifically, the BOD₅ concentrations are projected to be 1.1 times higher than the current level and 2.2 times higher than the QCVN 08 column B2 in April. Whereas the DO concentration would be 1.1 times higher than current level and 0.8 times lower than the QCVN 08 column B2. For most of the time in the year, the BOD₅ concentration is over 60 mg/l. The DO concentration is also below 1 mg/l at many monitoring locations, even in the rain season.

In the project scenario, with the implementation of Master plan, wastewater treatment plants will be built to collect wastewater from residential areas. There will be 03 treatment plants built in the catchment namely Phuc Dong, An Lac and Dong Du with the capacity of 55,000

m³/day 53,000 m³/day and 45,000 m³/day, respectively. The results show that, in the dry season, the water quality is improved significantly in terms of DO and BOD₅ concentration. The BOD₅ level maintains at below 25 mg/l while DO level is above 6 mg/l.

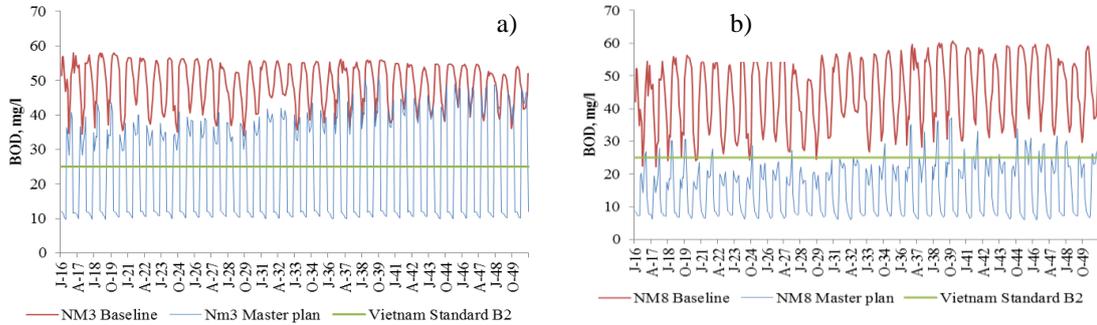


Figure 4. BOD₅ concentration in river water simulation result at upstream (a) and downstream (b) for period of 2016 - 2050.

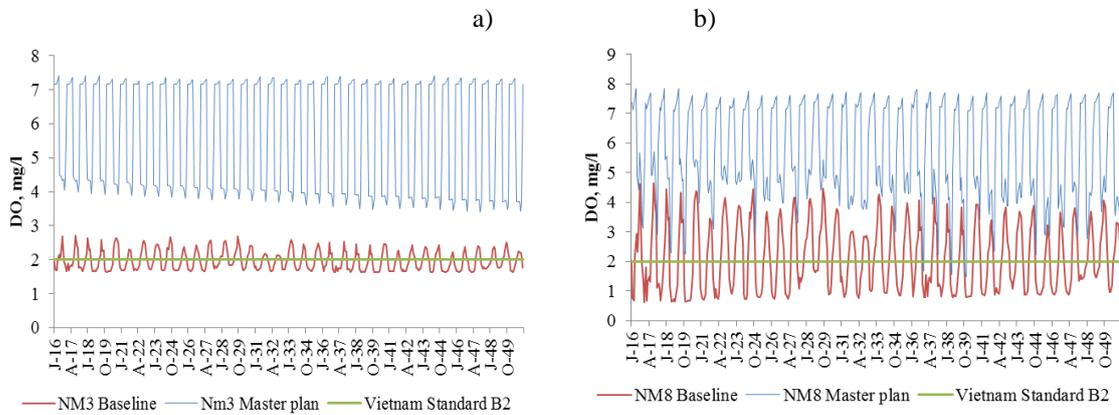


Figure 5. DO concentration in river water simulation result at upstream (a) and downstream (b) for period of 2016 - 2050.

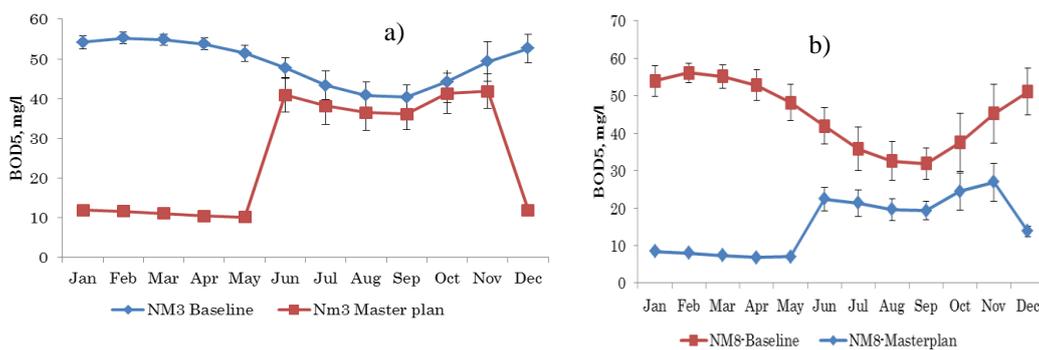


Figure 6. Average monthly BOD₅ concentration with standard deviation value in river water simulation result at upstream (a) and downstream (b) for period of 2016 - 2050.

The river water meets national standard with level B2 in QCVN 08/2015 - BTNMT. However, in the rainy season, with the design of combined sewer and CSO systems, the water quality does not meet standard. The average value of BOD₅ concentration in the dry seasons is 51 - 55 mg/l for baseline while this value is 10 – 12 mg/l for the master plan scenario (**Error! Reference source not found.**). However, the BOD₅ level does not much differ in the rainy season for both scenarios. The increasing level of BOD₅ and decreasing level of DO during rainy season results from the over load of wastewater treatment plant capacity, the proportion of mixed wastewater and storm water is not treated but discharged directly to river through the CSO systems

4. CONCLUSIONS

The evaluation of future water quality of Cau Bay river basin based on different wastewater management scenarios was performed using WEAP. Two scenarios: with and without implementation of Master plan for Ha Noi drainage system were examined. The result shows that, without implementation of wastewater treatment plant, the water quality of the Cau Bay River will be worse with the DO in dry season is 0.2-1.2 mg/l and BOD is 52.0 - 55.0 mg/l. More specifically, the BOD₅ and DO concentrations are projected to be 2.2 times higher and 0.8 times lower than the QCVN 08 column B2 respectively. With the implementation of Master plan, the level of DO and BOD₅ would be 7.1 - 7.3 mg/l and 7.0 - 13.8 mg/l respectively in the dry season whereas the values are 3.7 - 4.0 mg/l and 36.1 - 41.8 mg/l in the wet season. The degradation of the river water during the wet season results from the combine- overflow sewage system (CSO) as designed in the master plan.

The authors suggest that in order to maintain the water quality of Cau Bay river to the level of BOD₅ between 10-20 mg/l and DO between 7-8 mg/l throughout the year, the wastewater discharged should be treated to the QCVN 14:2008/BTNMT column A before pumping back to the river. As indicated in the simulated data, the discharge wastewater to Cau Bay river after treatment would significantly improve the quality of the receiving water body in terms of DO and BOD₅. We also recommend considering the downside of the CSO systems designed in the master plan. It is suggested to discharge the overflow mixed wastewater through CSO systems to the wastewater stabilization pond to prevent the overloading of treatment plant during rainy season.

The application of WEAP model in sound management of urban river system is suggested to evaluate the long term impact of water planning.

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