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Some of water replenishment plans for the inner river system in Hanoi

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Abstract

The inner river system in Hanoi includes Nhue River, To Lich River, Kim Nguu River, Lu River and Set River. Today, they are channels for rainwater and the city's sewage, not be real rivers because they have small slope and cross section, backfilled, with much mud and garbage and therefore, their flow discharge is small. The high pollution of water caused by the amount of waste water from unprocessed trade villages, domestic waste water (above 8 million people), and industrial waste water are discharged directly into the rivers.

In this report, IMECH1D software is used to research and test some of water replenishment plans to clean water, to improve the aquatic environment of the rivers and to ensure the supply of irrigation water for production.

Key Words: Hanoi, river, pollution, water replenishment, Imech 1D.

1. Numerical Modelling

1.1. 1D equations

Hydraulic equations:

$$B\frac{\partial H}{\partial t}+\frac{\partial Q}{\partial x}=q \quad (1)$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left[\beta\frac{Q^2}{A}\right]+gA+\left[\frac{\partial H}{\partial x}+S_f\right]=0 \quad (2)$$

where, x and t denote space and time; A is the area of wet cross-section; B - the width of cross-section; H - water level; Q - discharge; β – is momentum correction factor ($\beta \approx 1$); q is additional (or loss) discharge per unit length; S_f - friction slope (defined by the formula: $S_f = g|Q|Q/C^2R$ with R – hydraulic radius) and C – Chezy coefficient.

Advection - Dispersion equation:

$$\frac{\partial A_t S}{\partial t}+\frac{\partial QS}{\partial x}=\frac{\partial}{\partial x}\left(A_t D\frac{\partial S}{\partial x}\right)+G(S) \quad (3)$$

where S is pollutant concentration; D – diffusion coefficient; $G(S)$ – additional source.

Mass balance equation:

$$F_D(DO)=k_2(DO_s-DO)-k_3.BOD \quad (4)$$

$$F_D(BOD)=-k_3.BOD \quad (5)$$

where k_2 - dissolved oxygen coefficient of the water; k_3 - decomposition coefficient of BOD.

Numerical solving techniques

The finite difference method is used to solve numerically. The Preissman 4-points finite difference scheme is applied for 1D hydraulic

equations (1) and (2), the up-wind scheme for the mass conservation equation (3).

1.2. Research area

The research area consists of Tich Bui river, a part of Day river, To Lich river, Lu river, Set river, Kim Nguu river and Nhue river, limited by Phu Ly station at downstream. The river system consists of 7 rivers and 3 channels with 178 cross sections and 12 junctions.

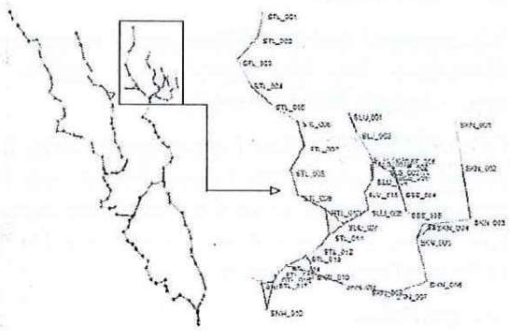

Fig 1: Cross section system of research area.

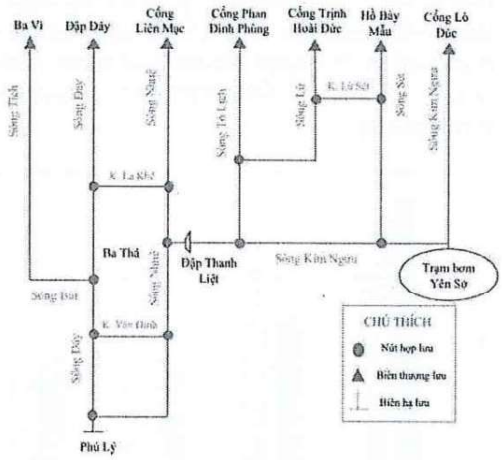

Fig 2: Hydraulic scheme of research area.

Upstream boundary: Dong Mo on Tich river, Day dam on Day river, Lien Mac gate on Nhue river, Phan Dinh Phung gate on To Lich river, Trinh Hoai Duc gate on Lu river, Ba Trieu gate on Set river and Lo Duc gate on Kim Nguu river.

Downstream boundary: Phu Ly station on Day river.

2. Calibration and verification numerical model

2.1. Hydraulic

By using 2014 data for calibration, it is impossible to get the observed data on all cross section, the model parameters are calibrated by using the observed data at some locations only: Ba Tha on Day river, Ha Dong, Dong Quan, Nhat Tuu, Luong Co on Nhue river, ... To evaluate the accuracy between calculated results (Cal.) and the Observed data (Obs.), index Nash-Sutcliffe Efficiency (NSE) is used.

On the basis of the calibration parameters, several calculations using the measured data in 2016 and 2019 are carried out.

Table 1: Calculation times.

Year	Season	Start	End
2014	Rainy	25/8/2014	15/9/2014
2016	Rainy	27/7/2016	11/8/2016
2019	Dry	4/01/2019	15/3/2019

a) Calibration

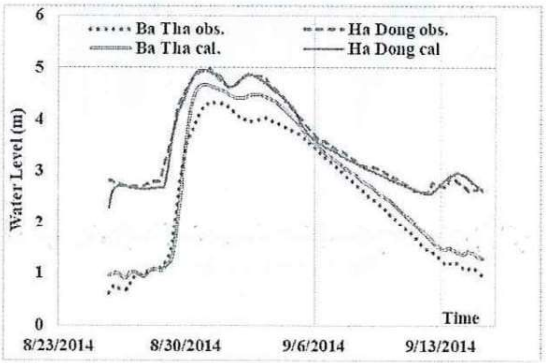

Fig 3: Calculated and measured water levels at Ba Tha station and Ha Dong station in 2014

Table 2: NSE index at some stations in 2014.

Station	Ba Tha	Ha Dong	Dong Quan	Nhat Tuu	Luong Co
NSE	0.95	0.96	0.91	0.87	0.86

The Nash–Sutcliffe efficiency index hit a good accuracy (NSE > 0.85).

b) Verification

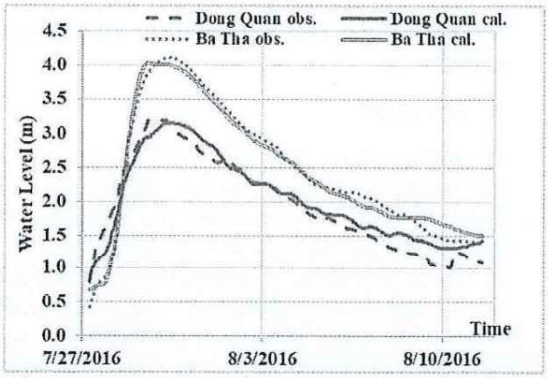

Fig 4: Calculated and measured water levels at Ba Tha station and Dong Quan station in 2016

Table 3: NSE index at some stations in 2016

Station	Ba Tha	Ha Dong	Dong Quan	Nhat Tuu	Luong Co
NSE	0.89	0.88	0.86	0.85	0.85

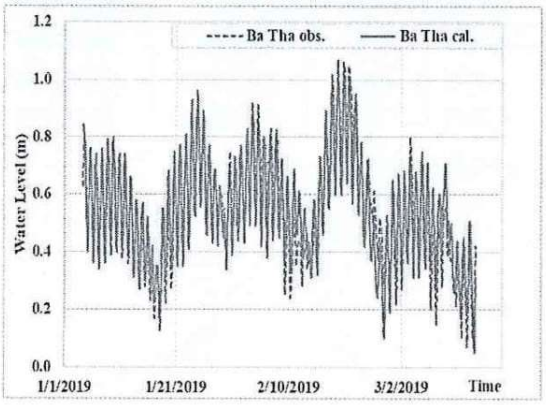

Fig 5: Calculated and measured water levels at Ba Tha station in 2019

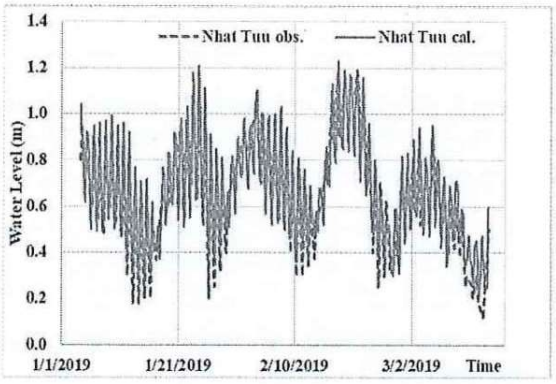

Fig 6: Calculated and measured water levels at Nhat Tuu station in 2019

Table 4: NSE index at some stations in 2019

Station	Ba Tha	Nhat Tuu	Luong Co
NSE	0.81	0.78	0.79

The comparisons between calculated and measured water levels in Figs 4 to 6 and table of NSE index hit a good accuracy, the numerical model are verified and ready to apply to simulate hydrodynamic in the area.

2.2. Water quality

It is estimated that the total amount of wastewater discharged into the Hanoi river system is approximately 850,000 m^3/day.

Due to limited measured water quality data, the average DO and BOD_5 values should only be used in some locations on the Nhue River such as Lien Mac, Phuc La, Cau To and Cu Da to calibration and verification.

a) Calibration

Same with hydraulics, 2014 data is used for calibration. The average Cals. and Obs. data are drawn on one graph with B1, B2 level, which are regulated in "National standard of water surface quality QCVN 08:2008/BTNMT", to accuracy water quality.

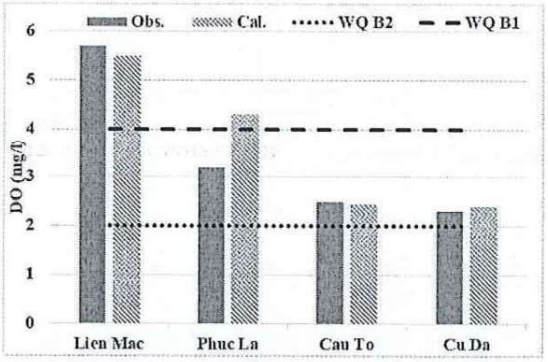

Fig 7: Calculated and measured DO values at some stations on Nhue river in 2014

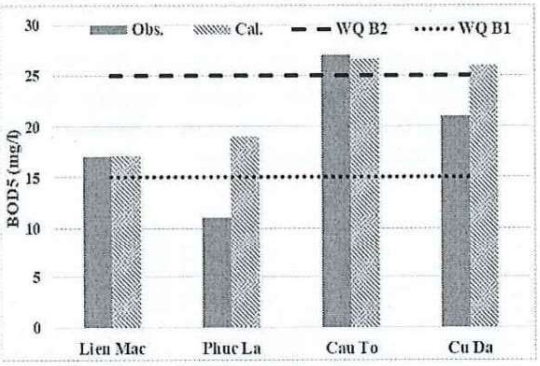

Fig 8: Calculated and measured BOD_5 values at some stations on Nhue river in 2014

Results show that calculated DO values are the same as measured values, and BOD_5 values are acceptable.

b) Verification

Several calculations using the measured data in 2016 and 2019 are carried out.

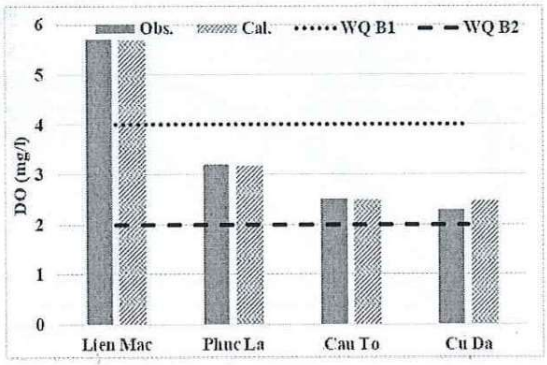

Fig 9: Calculated and measured DO values at some stations on Nhue river in 2016

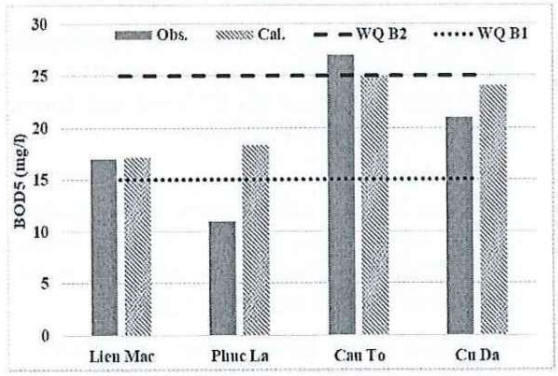

Fig 10: Calculated and measured BOD_5 values at some stations on Nhue river in 2016

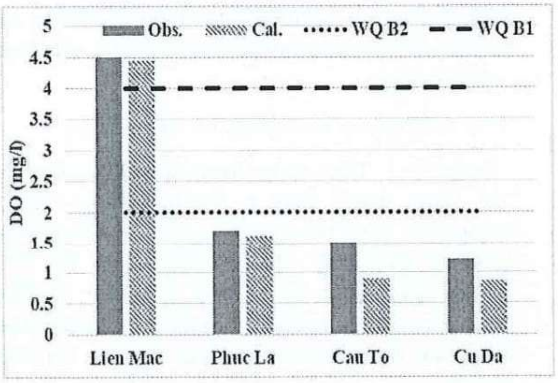

Fig 11: Calculated and measured BOD_5 values at some stations on Nhue river in 2019

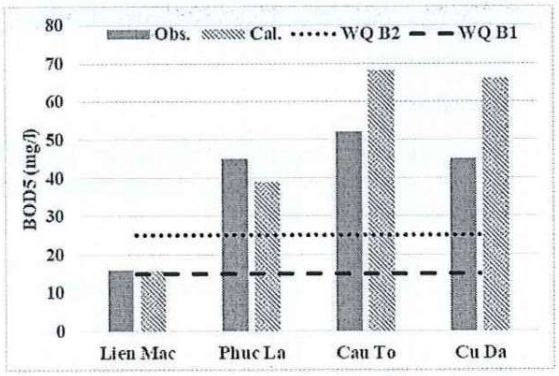

Fig 12: Calculated and measured BOD_5 values at some stations on Nhue river in 2019

The comparisons show that calculated water quality values in rainy season in 2016 are verified rather well because using the calibration parameters of same season in 2014. These parameters are used for dry season in 2019, DO values are good, but BOD_5 values are differences with measured values, explained by the sampling at the measurement points and distribution of waste sources between model and reality. However, overall, all calculated data are consistent in both values and trends with measured data, and ready to apply to simulate hydrodynamic and water quality in the area.

3. Calculation scenarios

In recent years, rivers in Hanoi are gradually becoming polluted, directly affecting the quality of agricultural products, food, environmental landscape, and people's health. Therefore, it is

required to treat pollution, restore river flows and improve the environment, proposed by scientists and managers.

Two calculation scenarios are carried out:

- Scenario 1: Take water from West Lake into the To Lich river with a discharge Q=1.8m^3/s (proposed by Hanoi Sewerage And Drainage Limited Company: Take water from the Red River into West Lake with 156,000 m^3/day, equivalent to 1.8m^3/s for washing West Lake, after that transferring all water flow to To Lich river).
- Scenario 2: Take water from the Red River through Lien Mac gate with a discharge Q=30m^3/s into Nhue river to improve the flow.

3.1. Scenario 1

a) Hydraulic

The comparison water level along the To Lich river between before and after taking water from West lake is shown in Fig 13.

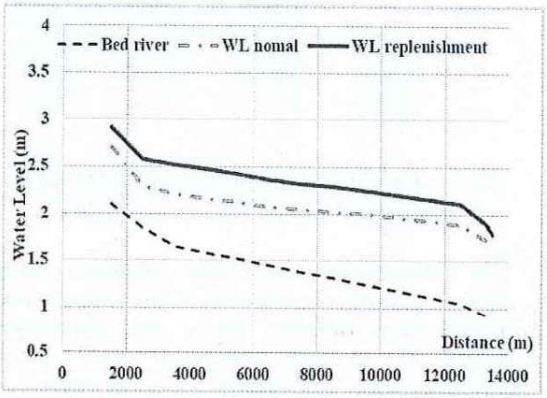

Fig 13: Water level along the To Lich river before and after taking water from West Lake.

After reaching a steady state, water level along the To Lich river increased significantly. The difference in water level is from 20 - 30 cm. The water level difference decreases further downstream.

The velocity also increases significantly. At the cross section STL_001, velocity of flow increased from 0.2 m/s to 0.4 m/s; at the cross section STL_008 (km8.5 from upstream), velocity of flow increased from 0.09 m/s to 0.18 m/s.

b) Water quality

Calculated values are compared with "National standard of water surface quality QCVN 08:2008/BTNMT" to assess pollution levels before and after taking water.

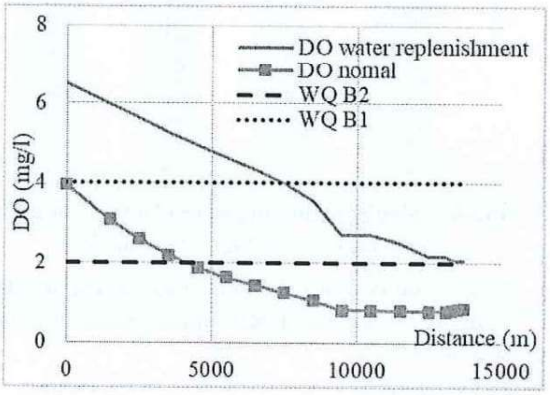

Fig 14: DO values along the To Lich river in scenario 1.

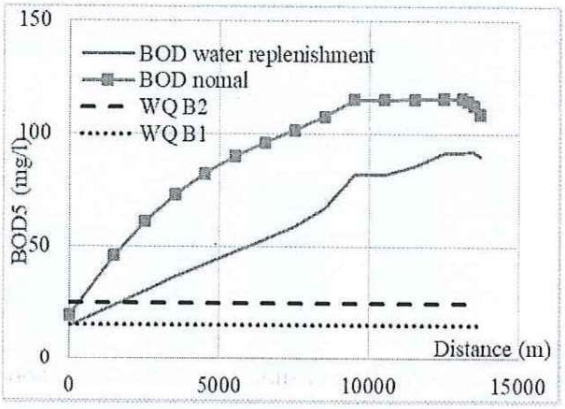

Fig 15: BOD_5 values along the To Lich river in scenario 1

In Fig. 14, DO values increased significantly. From Phan Dinh Phung gate (upstream) to km8, DO values still above the B1 level, and forward to B2 level at Thanh Liet gate.

With BOD_5 values always bigger than B2 level from 1 to 5 times, taking water is no significant effect. BOD_5 values above B1 level because clean water from West Lake, however, quickly forward to B2 level at km2 in Fig. 16.

By scenario 1, taking water contributes to unfreeze the river flow, reduces the BOD_5 values and increases the DO values. But, with only a

discharge Q = 1.8m^3/s into the upstream river, it has no significant effect, the majority of values are still above B2 level.

3.2. Scenario 2

a) Hydraulic

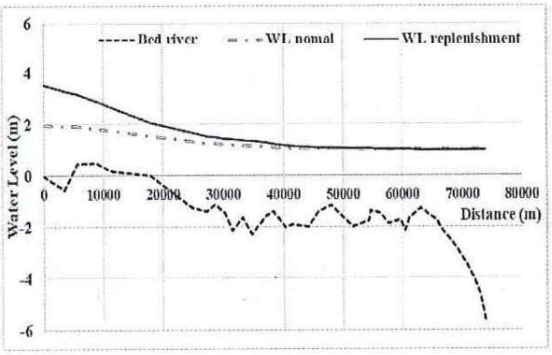

Fig 16: Water level along the Nhue river before and after taking water from Red river.

With a discharge Q=30m^3/s into Nhue river, water level increased significantly. Maximum difference of water level up to 2m at the upstream of the river. Water level at downstream also increased after long time to steady state, sample at wards of Phu Xuyen district, water level increased by 0.8m more than the average of the dry season.

After 60h from the beginning taking water, wards in Thanh Tri, Thanh Oai, Thuong Tin district can take water to canal in field. After 100h, Phu Tuc, Hoang Long, Quang Trung, Son Ha wards in Phu Xuyen district also can start taking water for agricultural production.

b) Water quality

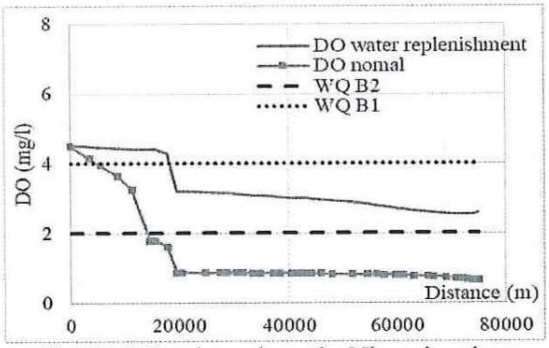

Fig 17: DO values along the Nhue river in scenario 2

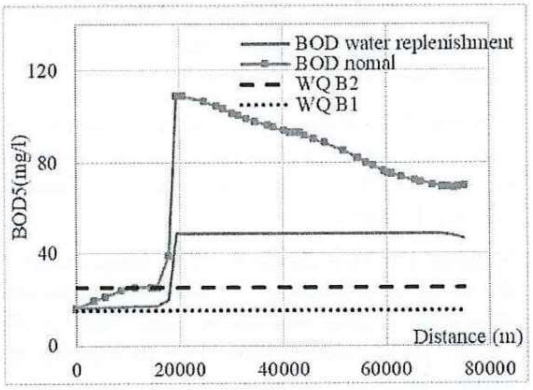

Fig 18: BOD_5 values along the Nhue river in scenario 2

Along the Nhue river, in dry season, DO values are relatively small, BOD_5 values are high. With a discharge Q=30m^3/s into upstream of Nhue river, DO values increased significantly, from 0.5mg/l to above 2.5 mg/l (fig. 17), BOD_5 values decreases significantly and keeping at level ~ 40mg/l from Cau To to downstream of Nhue river.

4. Conclusion

The 1D numerical model for calculating hydrodynamics and water quality has been established for river system in Hanoi. Model is calibrated and verified with the measured data in 2014, 2016 and 2019.

Two calculation scenarios are carried out, their results are shown that: although effective in changing hydraulic and water quality, it is not much, especially on To Lich river. Therefore, it is necessary to study other water replenishment plans as well as combine with other solutions: filter water with probiotics, collect and filter water by factory at downstream, limit discharge directly into the rivers, …

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