A STUDY ON IMPACT OF CLIMATE CHANGE TO SALINITY AT WATER INTAKE POINTS OF SUPPLY WATER FACTORIES AND ADAPTATION SOLUTIONS PROPOSAL

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ABSTRACT

The paper presents a research on impact of climate change to salinity at water intake points of supply water factories and proposes adapting solution. In the research, the change precipitation induced flow as well as the change of discharge of reservoirs flow according to climate change scenarios are calculated by NAM and regulation of reservoirs models. These flows will be upstream boundary data for Mike 11 model to simulate salinity intrusion on the whole system, and sea level rise condition will be the downstream boundary data. After calculating salinity change at water intake points, solutions will be proposed based on simulation results as well as supply water planning under climate change condition.

Keywords: salinization, Sai Gon – Dong Nai River, intake point, climated change.

1. INTRODUCTION

In recent years, salinity of Sai Gon River (SGR) tends dramatically increasing. In addition, lack of water in upstream and salinization in drought season severely happen, as a consequence, those effect directly to supply water of HCMC. Although supply water companies themselves gave many solutions, they still stopped to take raw water because of over salinity and increasing production cost of fresh water. According to Southern Institute of Water Resources Research, April 2016, measure results showed that the salinity usually has reached just over 150 mg/liter at Hoa Phu raw water Pumping station (SGR, Cu Chi Dist.) from the end of January, 2016 to now. Specially, this value was up to 250 mg/liter many times, from 2-3 hours/one time. At Hoa An Bridge point, (intake point of Thu Duc, BOO Thu Duc, Thu Duc 3 supply water factories) tendency increasing of salinity led to many difficulties for operation and production. Supply water of HCMC is described as Figure 1.

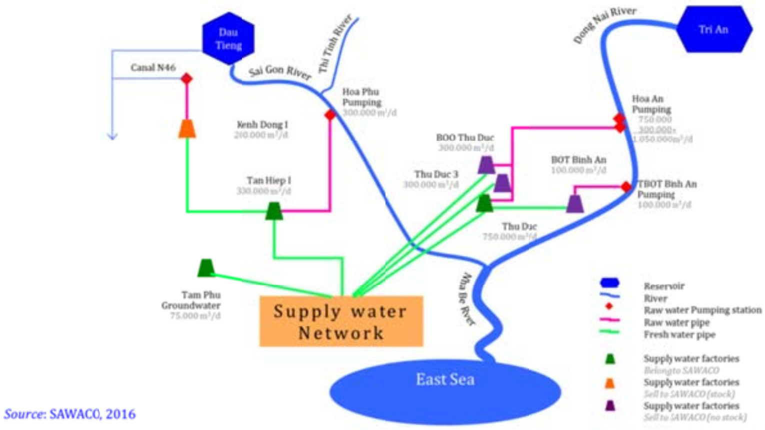


Figure 1. Supply water system of HCMC.

2. METHODOLOGY

2.1. NAM model

The NAM (Nedbor Afstromnings Model) is deterministic, lumped and conceptual rainfall-runoff model that operates by continuously accounting for the moisture content in three different and mutually interrelated storages that represent overland flow, interflow and base flow [1]. In the NAM model, the catchment is represented by five reservoirs, each one representing different physical elements of the catchment and combinating each other by mathematical equations. In present paper, the model has been developed in upstream catchments of Sai Gon – Dong Nai Rivers (SG-DNRs) (includes: Dau Tieng, Tri An, Phuoc Hoa Reservoirs) under climate change.

2.2. Reservoir regulation

Theory of reservoir regulation is based on water balance equation: $\frac{dV}{dt} = Q(t) - q_r(t)$; In which: Q(t) – inflow; $q_r(t)$ – discharge $q_r(t)$; $dV\ /dt$ – Change of reservoir storage. This equation is solved by finite difference method, but in reality, based on trial-and-error method [2]. To be more simplificated, some relation lines need to be built such as: relation between water level and storage Z~V, between water level and discharge Z~q and between water depth and surface area [3 - 5]. This model will be applied to identify discharge after regulation in the context of climate change within this paper.

2.3. MIKE 11 model

MIKE 11 is a package for the simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies developed by Danish Hydraulic Institute, Denmark. It is a dynamic, user-friendly one-dimensional modeling tool for the detailed design, management and operation of both simple and complex river and channel systems [1]. The most commonly applied hydrodynamic model is a flood management tool simulating the unsteady flows in branched and looped river networks and quasi two-dimensional flows in floodplains. In this study, MIKE 11 is used to simulate salinity intrusion on the SG-DNRs system.

3. RESULTS AND DICUSSION

3.1. Study area and mesh

Figure 2. Study area.

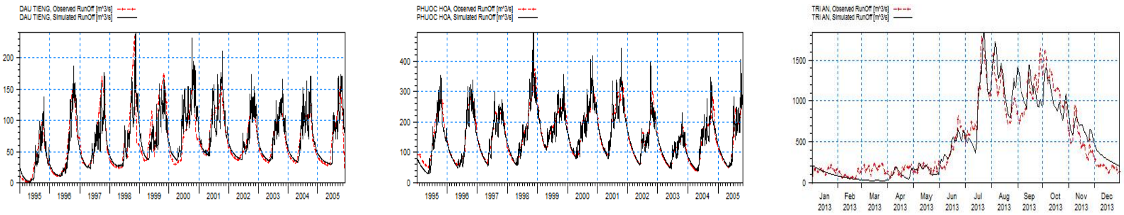
Hydraulic regime of SGR is effected by regulation of three upstream reservoirs as: Tri An reservoir on Dong Nai River (DNR) (Vinh Cuu Dist., Dong Nai Prov.), Dau Tieng reservoir on Sai Gon River (Tay Ninh Prov.) and Phuoc Hoa reservoir on Be River (Phu Giao Dist., Binh Duong Prov.). Consequently, study area will be extended from below the three reservoirs to Dinh Ba, Long Tau, Thi Vai and Soai Rap Estuaries (Figure 2). A mesh applied to Mike 11 (measurement and inheritance) includes: 79 large and small branches, 674 cross sections, 68 distributaries and tributary points. Maximum distance dx on river is 500 – 1000m and 100 – 200 m for minimum dx. To decrease simulation time, the distance is smaller for the small branches and longer for large branches.

3.2. Calibrate and validate hydraulic model

3.2.1. Input data

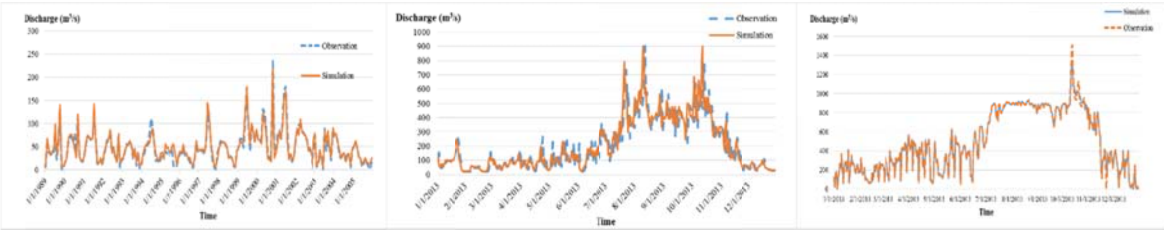
Hydrologic data is used as the boundaries (*source: Institute of Meteology Hydrology Oceanography (IMHOEN) and Environment* and *Southern Regional Hydrometeorological Center (SRHC)* in 2013) as:

(i) 5 upstream boundaries include: water level at Go Dau and Tan An stations, discharge of Phuoc Hoa, Tri An and Dau Tieng reservoir (using NAM and regulation model). Calibration results are described as Figures 3&4 below:



(a) (b) (c)

Figure 3. Plot of calibration at Dau Tieng (a), Phuoc Hoa (b) and Tri An (c) by using NAM model.

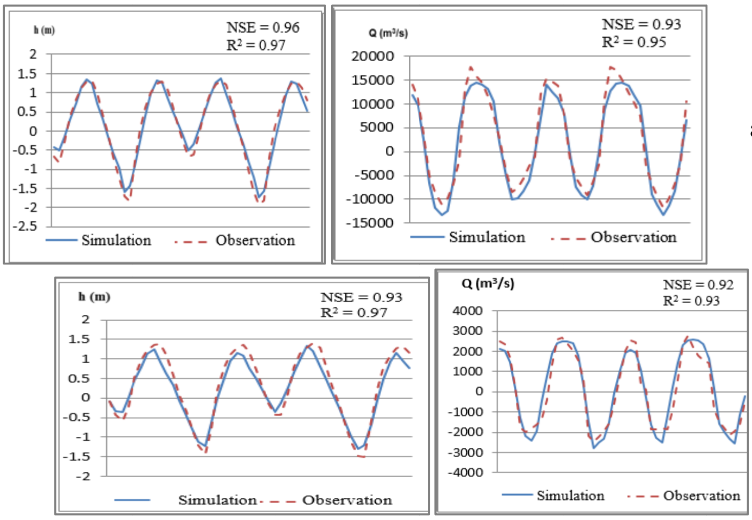


(a) (b) (c)

Figure 4. Plot of calibration at Dau Tieng (a), Phuoc Hoa (b) and Tri An (c) by using regulation model.

(ii) 4 downstream boundaries are water level including: Soai Rap, Dinh Ba, Long Tau and Thi Vai are correlated to Vam Kenh and Vung Tau stations as: Soai Rap and Vung Tau, Long Tau àn Vam Kenh; Dinh Ba and Vam Kenh, Thi Vai and Vam Kenh.

3.2.2. Calibration and validation of hydraulic model



a)

b)

Figure 5. Comparison between observation and simulation of water level and discharge at Phu An (a) and Nha Be (b) stations after calibrating.

(i) Simulation time: from 01/04 0:00 to 30/04/2013 23:00, after that, exporting data within 3 days from 26/4 9:00 to 28/4/2013 20:00 to calibrate; *time step* Δt = 1 minute; *Initial conditions:* initial water level and discharge Q = 0 m^3/s.

(ii) Calibration and validation stations: 10 stations: Phu Cuong, Binh Phuoc, Cat Lai, Hoa An, Phu An, Nha Be, Nga Bay, Cai Mep, Vam Co and Vam Sat from 09:00 26/04 to 20:00 28/4/2013 are used to calibrate and the same for validation from 09:00 25/05 to 08:00 27/5/2013 *(Source: IMHOEN).* Results of the calibration at Phu An and Nha Be station are presented as Figures 5. The results show that simulation data is coincide with observation, NSE và R^2 indexes between observation and simulation are higher than 0.8. Hence, manning coefficient (Table 1) on the whole system (the others will be equal 0.2) will be used for next steps.

Table 1. Manning coefficient on the whole system (SI system) after calibrating.

River	Manning coefficient	River	Manning coefficient
Dong Nai	0.035	Thi Vai	0.022
Sai Gon	0.033	Soai Rap	0.022
Nha be	0.032	Dinh Ba	0.020
Long Tau	0.026	Vam Co Tay	0.028
Dong Tranh	0.021	Vam Co Dong	0.028
Dong Mon	0.020	Vam Sat	0.020
Buong	0.030	Go Gia	0.020
Be	0.033	Ben Luc	0.031
Phu Xuan	0.021	Rach Chiec	0.033

3.3. Calibration and validation of salinity intrusion model

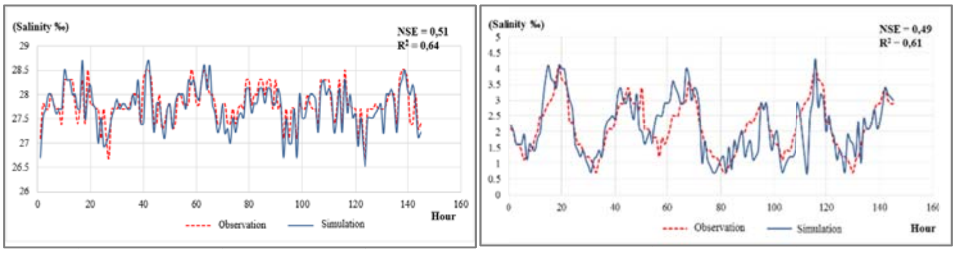


Figure 6. Salinity between simulation and observation at Thi Vai (left) and Cat Lai (right) after calibration.

Salinity data at Cat Lai, Thu Thiem and Nha Be stations are used to calibrate the model from 01:00 24/04/2013 to 23:00 29/04/2013 *(source: SRHC).* To validate, using data at Thi Vai and Cai Lai points from 09:00 19/04/2015 to 9:00 22/4/2015 from measuring of IMHOEN, 2015. Parameter is set up to simulate salinity intrusion on the whole system with some conditions as: *Boundary*: average salinity at 4 estuaries (Soai Rap, Dinh Ba, Long Tau and Thi Vai) within 4 months of drought season from 1-4/2013 approximate 28 - 33 ‰. Upstream and closed boundaries equal 0, the upstream Thi Vai River, dS/dn = 0; *Initial conditions*: based on measure, setting initial salinity for many points near close observation station along the river, decreasing from downstream to upstream, Δt = 30 seconds; *Dispersion coefficient* is set about 5 - 25 m^2/s for most branches, D = 25 m^2/s from Thu Thiem to Sai Gon upstream. After simulating, typical results at Thi Vai and Cat Lai between simulation and observation are described as Figure 6. The figure shows that the result is coincide with observation, NSE và R^2 indexes belong to average and good limits, respectively.

3.5. Research on impact of climate change to salinity at intake points of supply water factories in HCMC

4 PSU: According to the emission scenario A1FI, 4 PSU salinity line will be spread deeply into the upstream site approximate 37 km from the Soai Rap estuary in 2020, (increase 2-3 km higher than the current scenario 2013) and will be a distance 70 km to Tan Hiep factory on SGR. By 2030, that line will still move to upstream site 1 km (compared to 2020) (Figure 8). On DNR, it is about 33.5 km from Hoa An Pumping station (intake point of BOO Thu Duc factory) to downstream site, that means the salinity line move just over 2.5 km higher than current scenario 2013. By 2030, this line will move more 1 km than 2020 scenario which is a distance 32.5 km from the Hoa An regarding to emission scenario A1FI (Figure 7).

1 PSU: According to the emission scenario A1FI, by 2020, 1 PSU line is 17 km from Tan Hiep factoty (moving deeply 1.8 km more than the current scenario 2013). By 2030, this line will keep moving more 0.8 km (compared to 2020 scenario) and will has a distance 16.2 km from the factory (Figure 8). On DNR, it is about 7.3 km from intake point of BOO Thu Duc factory to downstream site, that means the salinity line in 2020 move just over 1.2 km higher than current scenario 2013. By 2030, this line will move more 0.8 km than 2020 scenario equal to a distance of 6.5 km from the Hoa An regarding to emission scenario A1FI (Figure 7).

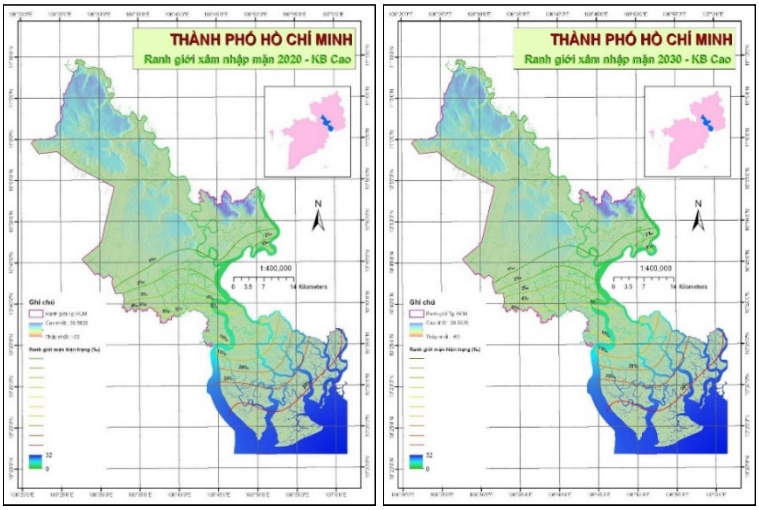


Figure 7. Salinity line by 2020 and 2030 scenarios map at HCMC.

3.5. Propose adaptation solutions

Take water from upstream points: Dau Tieng Reservoir: Increase supply water storage up to 0.99 million m^3/day (approximate 11.5 m^3/s), that will make decrease water level in reservoir down from 0.4 cm to 0.9 cm (According to JICA project); Tri An Reservoir: In the current conditions, most discharge is used for producing electricity, about 475 m^3/s. The amount of water for domestic supply is only about 2.475 million m^3/day (approximate 28.6 m^3/s). Therefore, under climate change, by 2030, electricity required down 6 % to develop supply water priority.

Build raw water reservoir: Raw water reservoir will has storage about 1.35 milion m^3 to response salinization 1 – 3 days in a plan. Long term target of this reservoir is to reserve a storage about 20 million m^3 to response salinization 2 weeks for Tam Hiep factory. Position of plan is described as Figure 8.

Figure 8. Position of plan.

Increase fresh water storage: Build a additional 100,000 m^3 reservoir for Thu Duc factory and a 80,000 m^3 reservoir for Tan Hiep factory (by 2016). In the next period, we need to build more reservoirs for many other factories with minimum water supply capacity from 6 to 7 hours.

Reform Water Tower at HCMC (Water Tower E on Hoang Dieu Street, Dist.4): Increase storage up to 7,200 m^3, estimate storage about 5,040 m^3, still have 2,160 m^3 (30 %) to reserve. Using 3 pumps, operate alternately 2 pumps (1 pump for reserve), Q = 500 m^3/hour, H = 30 m.

4. CONCLUSION

According to the calculation results, most of the Can Gio area will be effected of 4 PSU line and 10 -15 PSU lines also will move deeply to upstream site. As a result, HCMC is facing pressure to supply fresh water, increased exploitation of underground water which changes the water balance in the region, the risk of fresh water shortage for production activities in the area of Nha Be and Can Gio district. Based on the analysis above, there should be a reasonable solution for the water supply sector to adapt to climate change conditions that increasingly complex happen now.

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