Simulation of Water Losses for the 1D Salinity Forecasting Model in Chao Phraya River

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Abstract. *Salinity intrusion is one of a major problem in the Chao Phraya River during dry season. It affects salinity condition for water consumption and other uses. The pumping station of MWA is located at Sumlae station, Pathumthani Province, Thailand, about 80 km from Chao Phraya River mouth. During dry season when the freshwater is low the salinity can be intruded and affected the salinity level at this station. The salinity concentration becomes higher than the safe range for drinking water. The one-dimensional salinity forecasting model has been developed using 1D Mike11 AD model. The model has been setup operationally providing 7 days salinity forecast. When the salinity is forecasted to be higher than accepted range, freshwater will be released from the reservoir to flush the salt water out of the river. Although the overall accuracy is well satisfied, the water losses due to local abstraction along the river is still causing problem to the computed results. Therefore, the model has been setup to simulate the discharge losses into 4 cases; No loss, 40%, 50% and 60%, respectively. The forcing at the upstream river comprised of the release from main reservoirs and gates while at the river mouth, the boundary was adapted using the salinity forecast from HYCOM. The model results have been validated with the results from salinity survey during spring and neap tides in February 2021. The results were found that 60% loss of discharge provide the nearest results compared to the observation from salinogarpher and salinity at gauge station. This is confirmed that there is water loss along the river that need to be included in water flushing plan as well as in the model. The discharge station is recommended to install at Samelae station to measure the exact river discharge that may vary over time. This will improve the accuracy of salinity forecast model as well as the water management for salinity intrusion in Chao Phraya River.*

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1. Introduction

Chao Phraya river is one main river in Thailand. The lower Chao Phraya River connects to the Gulf of Thailand. The previous study by [1] found that the characteristic of the Chao Phraya estuary is well-mixed. During the dry season, the tidal effect reaches up about 60 km from the river mouth to the upstream river [2].

Salinity intrusion is one of the significant problems in the Chao Phraya River during the dry season. It affects salinity conditions for water consumption and other uses. Almost all water supplies for the city water system were produced from the Chao Phraya River, including the city hydrate water system. The pumping station of MWA is located at Samlae station, Pathumthani Province, about 80 km from Chao Phraya River mouth. When the freshwater is low during the dry season, the salinity can be intruded on and affect the salinity level. The salinity concentration becomes higher than the safe range for drinking water. Although the station is located on the area that should be far from the tidal effect, the tidal effect was higher than the salinity of water at Samlae pumping station. The study of salinity variation in Chao Phraya River found that climate change and sea level rise were affected to higher salinity in the Chao Phraya river [3].

To predict the salinity in the Chao Phraya River, Hydro Informatics Institute (HII) develop the salinity forecasting system using 1D Mike11 model. The overall accuracy is well satisfied. However, when the salinity is forecasted to be higher than the accepted range, freshwater will be released from the reservoir to flush the saltwater out of the river. The water losses due to the local activity along the river are still causing the compute results. So, this study aims to find the best percentage of water losses. After finding the best percentage of water losses, that value will be adapted to develop the HII's forecasting system.

2. Methodology

2.1 Study Area

This study focuses on the first 100 km from the Chao Phraya River mouth. The domain of the model was covered from Phra Chulachomklao Fort to Phra Nakhon Si Ayutthaya, Thailand. There are 9 salinity gauge stations in this model domain (Fig. 1).

Fig. 1 Study area and salinity gauge stations

2.2 Salinity Observation

The salinity observation data has been collected from 2 sources. First source is based on the regular monitoring stations from Metropolitan Waterworks Authority (MWA). There are a total 9 stations used in this study which including Samlae station where the water utility intake pumping stations is located, see Fig. 1. Second, to enhance the study of salinity intrusion, the salinity survey has been conducted in February-March 2021 under the collaboration between Hydro-Informatics Institute (HII) and the Faculty of Fisheries, Kasetsart University (KU). The survey covers both spring tide (27 – 28 February 2021) and neap tide (7 - 8 Mar 2021) periods and both survey include the longitudinal salinity profile measurement starting from the river mouth of the Chao Phraya River further upstream for about 100km and the cross-sectional salinity survey at Samlae station [4].

In this study salinity data from the gauging stations and from the survey were used to evaluate the performance of the model. In addition, the data from detailed survey during spring and neap tides was used to explain the characteristic of how the salinity propagates into the river. The discharge measurement at Samlae station was used in this study.

2.3 Model Configuration

The one-dimensional salinity forecasting model has been developed using the 1D Mike11 AD model. The model has been set up operationally, providing 7 days salinity forecast [5]. The salinity model gets the hydrodynamic forcing from the 1D river model (Fig. 2). The forcing at the upstream river comprised of the release from main reservoirs and gates, while at the river mouth, the boundary was adapted using the salinity forecast from the HYCOM global model [6]. The sea level downstream was forced by using 7 days forecast of the total sea level forecast from the storm surge forecasting system [7]. Since there is no water abstraction data and hence no water abstraction input in the model. Therefore, the model will simulate using the full discharge released from the upstream reservoir in which may not reflect the real situation. Therefore in this study there was an attempt to identify the suitable water loss factor to adjust the discharge in the model by comparing several simulations and also compared with the observation. The model was up to compare the effect of salinity intrusion between with and without discharge losses. A total of 4 cases were tested, No loss, 40%, 50% and 60%, respectively. The model was simulated from 1 February 2021 – 7 February 2021.

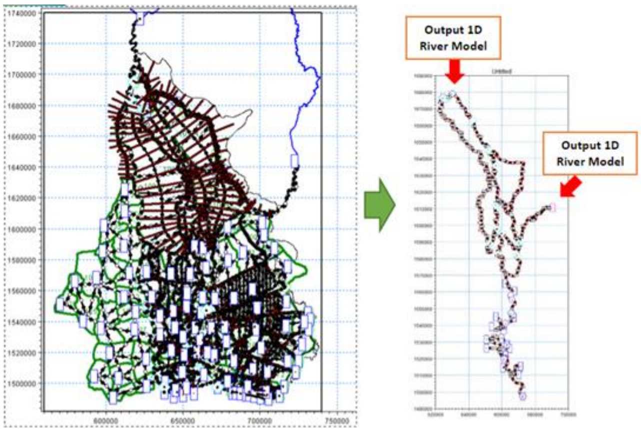

Fig. 2 Illustrate the 1D river model network system and 1D salinity model forcing point input [5].

2.4 Model Evaluation

Three quantitative metrics were used to assess the model skill. Which is Mean Error (ME), Mean Absolute Error (MAE) and Root Mean Square Error (RMSE). Where n is the number of observation data and model, O_i is the i of n observations, Y_i is the i of n model prediction data.

$$ME = \frac{1}{n}\sum_{i=1}^{n} O_i - Y_i \quad (1)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |O_i - Y_i| \quad (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(O_i - Y_i)^2}{n}} \quad (3)$$

3. Results

3.1 Observation Results

The longitudinal salinity profiles in the Chao Phraya River were shown in Fig. 3. The salinity profile during neap tide was found to be slightly higher and propagated further upstream than the salinity during the spring tide period. The salinity at Samlae station was less than 0.25 PSU on 27 February 2021. On the other hand, the salinity values are ranging between 0.5 – 1 PSU on 7 March 2021. The salinity over the depth profile as shown in Fig. 3 illustrates a light stratification of salinity in the water layer around 40 km from the river mouth. After 40 km from the river mouth, the water layer is well-mixed in both the neap and spring tide periods.

The cross-sectional salinity survey was made at the section upstream and downstream of the Samlae station. The salinity as well as the discharge was observed over 24 hours, see Fig. 4. It was found that salinity is at the highest value when the water level at Samlae station has the highest peak. The Fig. also illustrates that the delay time of water level and salinity peak compare with the water level at Phra Chulachomklao Fort is around 7 hrs. It means that the salinity from the river mouth takes 7 hrs to travel to the Samlae pumping station. The highest salinity during the spring tide period is around 0.35 and 1.5 during the neap tide period. Based on these results, it can be concluded that the salinity observed during the neap tide period (0.05-1.40 PSU) is higher than the spring tide (0.04 – 0.32 PSU). Furthermore, the discharge (*Q*) was also measured at the upstream of Samlae station and calculated for the average discharge, see Fig. 5. The average discharge was then compared with the total release from the reservoir upstream of Chao Phraya River and estimated for the losses. It was found that during spring tide, the discharge loss of about 53% was observed and 50% during neap tide.

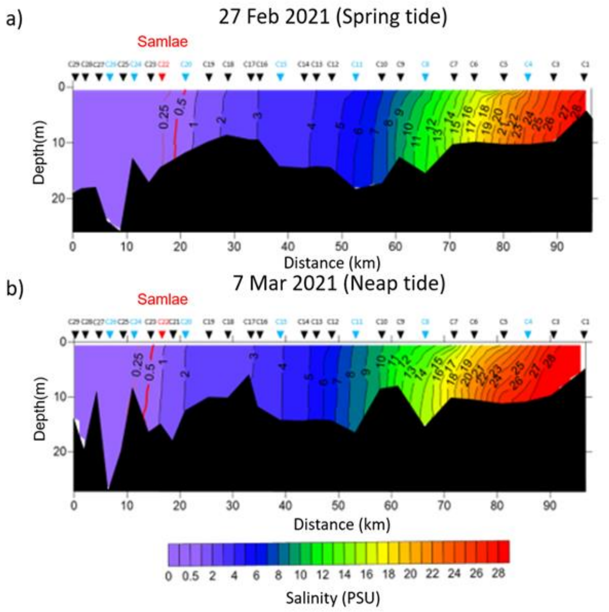

Fig. 3 Longitudinal profiles of salinity in Chao Phraya River. a) The salinity longitudinal profiles on 27 February 2021 (Spring tide). b) The salinity longitudinal profiles on 7 March 2021 (Neap tide) [4]

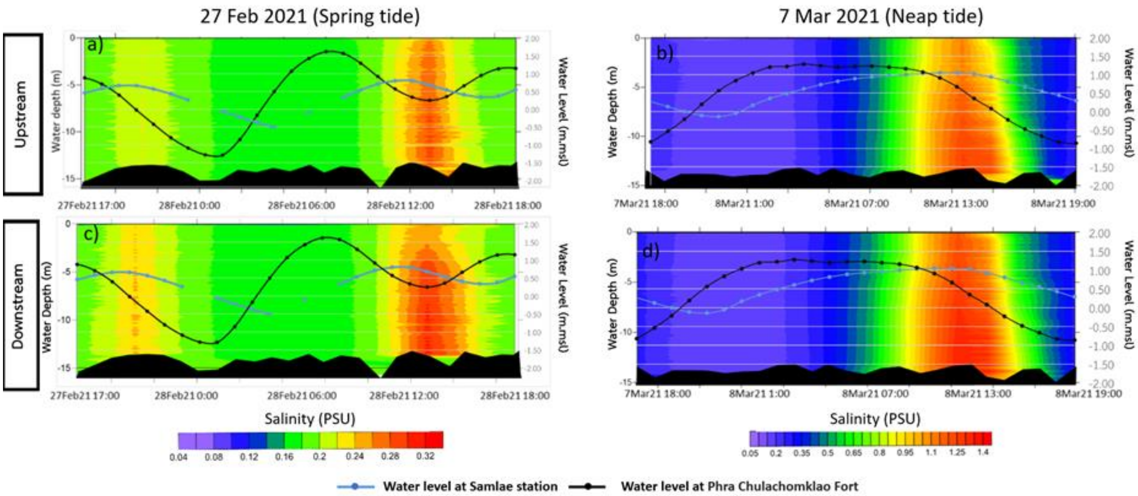

Fig. 4 The cross-section profiles of salinity at Samlae station for different consideration conditions: a) Cross-section of salinity profile at upstream of Samlae pumping station on 27 February 2021 (Spring tide). b) Cross-section of salinity profile at upstream of Samlae pumping station on 7 March 2021 (Neap tide). c) Cross-section of salinity profile at downstream of Samlae pumping station on 27 February 2021 (Spring tide). d) Cross-section of salinity profile at downstream of Samlae pumping station on 7 March 2021 (Neap tide). Blue line is the water level at Samlae station. Black dot line is the water level at Phra Chulachomklao Fort. [4]

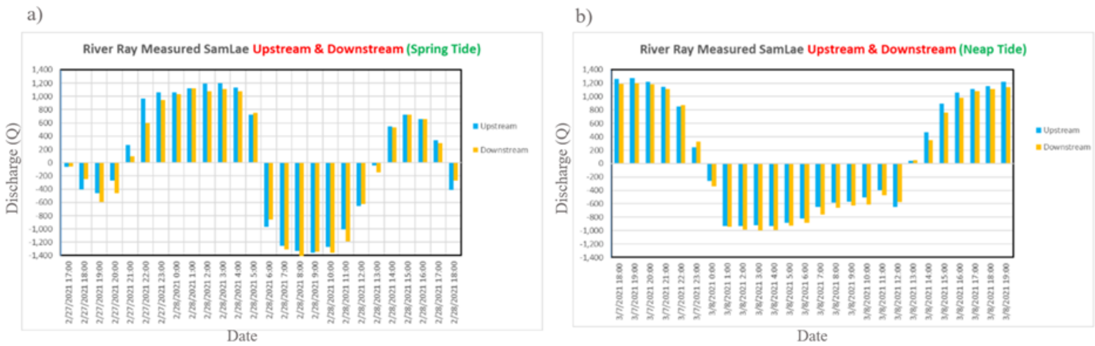

Fig. 5 discharge (Q) measurement from cross-section surveying a) 27-28 February 2021 (Spring tide) b) 7 -8 March 2021 (Neap tide)

3.2 Model simulation results

Fig. 6 to Fig. 9 show the salinity comparison between 4 cases of discharge loss and the observation data at Samlae station. The results from the model simulations (Fig. 6 to Fig. 9) were found that the 60% loss gives the best agreement with observation data. From table 1, The 50% Loss case give the smallest ME and MAE, but the RMSE of 50% Loss is higher than the 60% Loss. Fig.10 shows the linear regression between salinity results from model simulation and observation data at Samlae station. It was found that the best linear regression result and the highest R was found in the case of 60% loss (R = 0.8699). The 50% loss (R = 0.8355), 40% loss (R = 0.7280) and No loss (R = 0.2777) were found the lower trend of R, respectively.

Finally, the 60% discharge loss was interpreted as discharge loss factor in the 1D-salinity intrusion model. The discharge in the model can then be adjusted closest to the real situation where the water abstreaction is taken place and hardly can be measured. The best case for the salinity model simulation in this period is the 60% Loss case.

Scenario	ME (PSU)	MAE (PSU)	RMSE (PSU)
No Loss	0.2835	0.2885	0.4564
40% Loss	0.1686	0.1859	0.3050
50% Loss	0.0709	0.1183	0.1946
60% Loss	-0.0944	0.1269	0.1740

Table 1 Mean Error, Mean Absolute Error and Root Mean Square Error of 4 cases comparison with observation data.

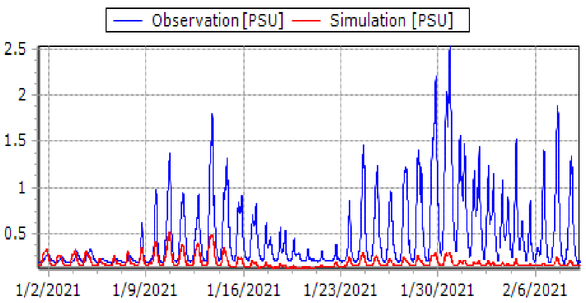

Fig. 6 Comparison between salinity simulation from No Loss case (red line) and observation data (blue line) at Samlae station

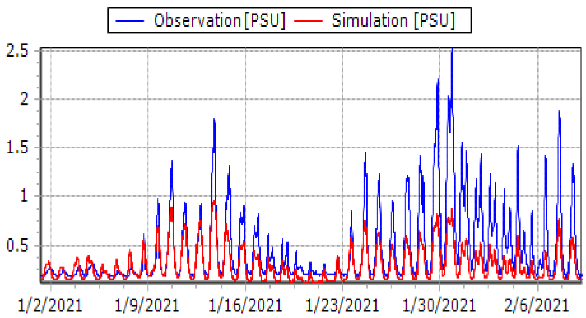

Fig. 7 Comparison between salinity simulation from 40% Loss case (red line) and observation data (blue line) at Samlae station

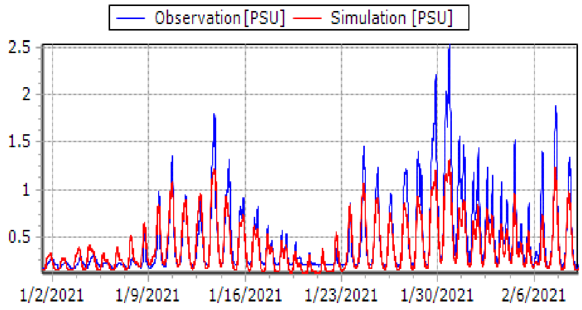

Fig. 8 Comparison between salinity simulation from 50% Loss case (red line) and observation data (blue line) at Samlae station

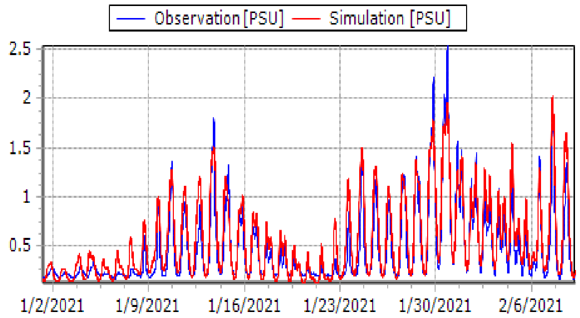

Fig. 9 Comparison between salinity simulation from 60% Loss case (red line) and observation data (blue line) at Samlae station

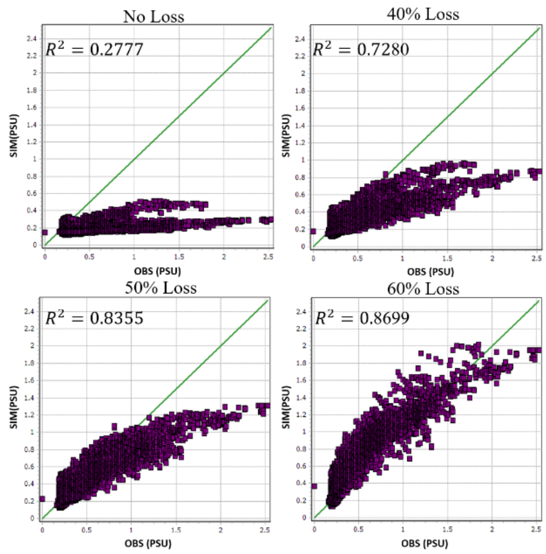

Fig. 10 The 4 graphs show linear regression between salinity results from model simulation and observation data at Samlae station

4. Conclusion

Based on the observed longitudinal salinity profiles of salinity (Fig. 3) in this study, the characteristic of the Chao Phraya estuary is well-mixed both of spring tide period and neap tide period and its effect could propagate more than 80 km further upstream. This is the consequence with the previous studies [1]. This evidence confirmed that the 1D model is efficient for forecasting the salinity intrusion in the Chao Phraya River. However the discharge in the river is still cannot be properly estimated due to lack of water abstraction data. This results in not accurate salinity calculation in the model. The discharge loss factor has been estimated by comparing different simulations and observation. Simulation results from the model were found that the case of 60% discharge loss gives the best results, which in agreement with [4] that found the average discharge loss 52% of total release.

The outcome of this research will be applied to Salinity Intrusion Forecast System in the Chao Phraya for reducing the uncertainty of the prediction.

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Biographies

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