Journal of Coastal Research	SI 50	268 - 272	ICS2007 (Proceedings)	Australia	ISSN 0749.0208

Study on the Effect of Morphology Change on Salinity Distribution in the Dinh An Estuary, Lower Mekong River of Vietnam

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ABSTRACT

NGUYEN, T.V. AND TANAKA, H., 2007. Study on the Effect of Morphology Change on Salinity Distribution in the Dinh An Estuary, Lower Mekong River of Vietnam. Journal of Coastal Research, SI 50 (Proceedings of the 9th International Coastal Symposium), 268 – 273. Gold Coast, Australia, ISSN 0749.0208

Salinity intrusion into estuaries, in general, is mostly affected by river discharge and tidal level. Additionally, the change of salinity can also be attributed to other external forces such as wave height and river mouth morphology. However, there has been very few investigations conducted so far, taking into account these kind of aspects. Therefore, the present paper focused on examining the influence of morphology change on salinity concentration. The question that should be paid attention here is: how is the interaction between morphology change and salinity distribution in the Dinh An estuary, Vietnam? In this research, a three-dimensional model has been used to figure out the effects of morphology change on salinity distribution. The drawn conclusion is that the change of salinity is influenced by not only usual parameters as river discharge and tidal level but also another external force such as changes in the estuarine morphology. Furthermore, river mouth width is found to be directly proportional to the averaged salinity concentration. Therefore, the influence of morphology changes on salinity distribution should not be ignored when simulating salinity.

ADDITIONAL INDEX WORDS: *three-dimensional model, sensitivity analysis*

INTRODUCTION

The Mekong River starts at an elevation of about 5,000m in the Tanghla Shua on the Tibetan Plateau. From this source, the river flows through six countries: China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam. Before flowing out into the South China Sea, the Mekong River is divided into two branches, namely the Mekong (known as Tien River) and the Bassac (known as Hau River). Tran De and Dinh An are the two branches of the Hau River.

The economy of Mekong Delta, which is the major agricultural production area of Vietnam, has quickly responded to the government's "open door" policy and been oriented towards the primary sector. The delta shares 27% to the total GDP of Vietnam, some 40% of agricultural production, and half of rice production in the country as stated by Mekong River Commission (MRC, 2004).

According to MRC (2004), during the dry season saline water from the South China Sea and the Gulf of Thailand moves upstream along the rivers and canals of the Mekong Delta. The salinity intrusion into the Mekong Delta is very complicated. The highest salinity is usually observed in April. Currently, 17700 km^2 of delta lands are affected by saltwater intrusion, posing great difficulties on not only irrigation development but also domestic water supply. Salinity worsens water quality and damages crop-lands. The most severe situations occur during the low flow season when there is insufficient flow to prevent seawater intrusion. Strong tidal waters encroach up to 50-70 km, since the maximum of river discharge is around 15000 m^3/s and its current velocity is about 1.2 m/s. The existing engineering infrastructure will be incapable of coping with salinity intrusion if water abstraction increases in the delta. The affected area may be increased to 22000 km^2, if no preventive measure is taken up. Therefore, salinity intrusion into the Mekong River delta is a problem of great importance for agricultural, aquacultural, and industrial development.

According to LE (2003), tides in the South China Sea are predominantly semi-diurnal with non-uniform amplitude. Each day the tide has two crests and two troughs, and the height of each crest and trough varies from day to day during about 15 day periods.

Salinity intrusion into estuaries in general, is mostly affected by river discharge and tidal level. Furthermore, the change of salinity can also be attributed to other external forces such as wave height, river mouth morphology. There has been a very few investigations, however, studied up to now taking into account these kind of aspects.

The performance of the numerical model has been widely evaluated by appealing to a large series of simple test cases introduced to specific processes and by application of the model to many real case studies all over the world (BLUMBERG, 2002). The purpose of this paper is to evaluate the effect of morphological change on characteristics of salinity intrusion into the Dinh An estuary, Vietnam by using a three-dimensional model.

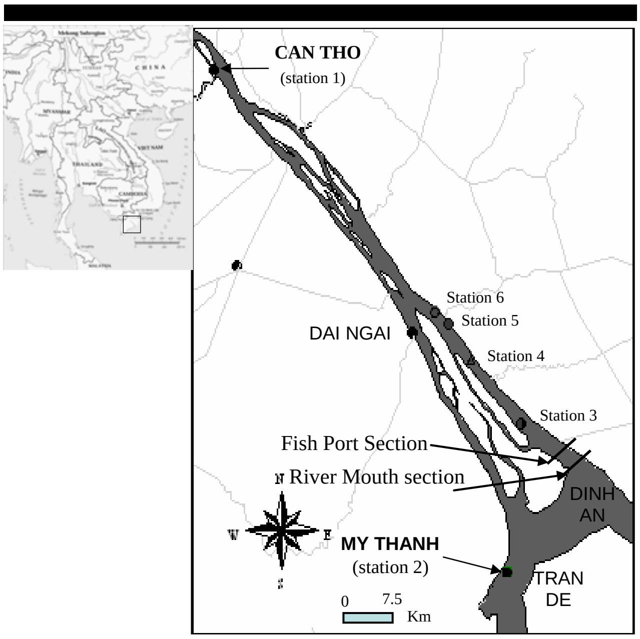

Figure 1. Location map of the Dinh An estuary

Photo 1. Setting up of Compact-CT sensor

STUDY AREA AND DATA INVESTIGATION

The Hau River ($9^0 33'$-10^0 46'N, 105^0 00'- 106^0 42'E) is a part of the Lower Mekong Delta as shown in Figure 1. The total catchment area of the study site is about 490 km^2. The Hau River located in the monsoon tropical semi-equatorial climate zone, and the climatic regime in the Hau River is dominated by the two monsoon seasons: the north-east (dry season, from December to April) and the south-west (rainy season, from May to November) (NGUYEN et al., 2005).

Time variation of salinity

In order to obtain the temporal variation of salinity and temperature, four stations (station 3, 4, 5, and 6, which are 14, 25, 31 and 34 km far from the head of estuary, respectively) were installed along the Dinh An estuary. All of them are imbedded in the navigation buoys in as shown in Photo 1. The equipment used here are compact-CT sensors made by ALEC Electronic Ltd., Japan.

Longitudinal profile of salinity

Water quality parameters were measured by using TPM Chlorotec. By doing so, we are able to obtain to both vertical and longitudinal distribution along the river.

Bathymetry data

Measurement of bathymetry near the river mouth region were carried out by the use of Acoustic Doppler Current Profiler (ADCP) in both longitudinal and cross-sectional transects for two main surveying campaigns, April 2005 and March 2006, respectively.

Beside, tidal level at the river mouth can be measured in My Thanh station (station 2), and the upstream river discharge can be observed in Can Tho station (station 1).

Consequently, a study area as the Dinh An estuary is suitable for studying the influence of morphology change on salinity distribution.

MODEL SET-UP

Hydrodynamic Module

The hydrodynamic module used in the present study, named Estuarine Coastal Ocean Model (ECOM), is a three-dimensional, time-dependent finite difference, developed by BLUMBERG and MELLOR (1987). The model has a long history of successful applications to oceanic, coastal and estuarine waters (BLUMBERG et al., 1999). The model incorporates the MELLOR and YAMADA (1982) with 2.5 level of turbulent closure scheme as modified by GALPERIN et al. (1988) to provide a time and space-dependent parameterisation of vertical turbulent mixing. A system of curvilinear coordinates is used in the horizontal direction, which allows for a smooth and accurate representation of variable shoreline geometry. In the vertical scale, the model uses a transformed coordinate system known as the σ coordinate transformation to permit better representation of bottom topography and flow near the bottom as seen in AHSAN et al. (2005). The mode split technique allows the 2D calculation of the free surface elevation and the velocity transport in barotropic approximation separately from the 3D calculation of velocity and thermodynamics shown in BLUMBERG (1977).

Detailed description on the numerical model can be found elsewhere (BLUMBERG and MELLOR, 1987; BLUMBERG et al., 1999; BLUMBERG, 1977; BLUMBERG, 2002). The model configuration, open boundary conditions and initialisation will be briefly illustrated in the next sections.

Model configuration

The grid system used in the model is an orthogonal curvilinear grid. The computational domain consists of 400x16 segment grids in horizontal plane and 11 equally spaced sigma levels in vertical plane. The internal mode time step, Δt_i=40s and number of time steps between the internal and external modes, Isplit=10. In undertaking the modeling study we have concentrated on determining how river bathymetry effect on salinity based on two main data sets of morphological change in April 2005 and March 2006.

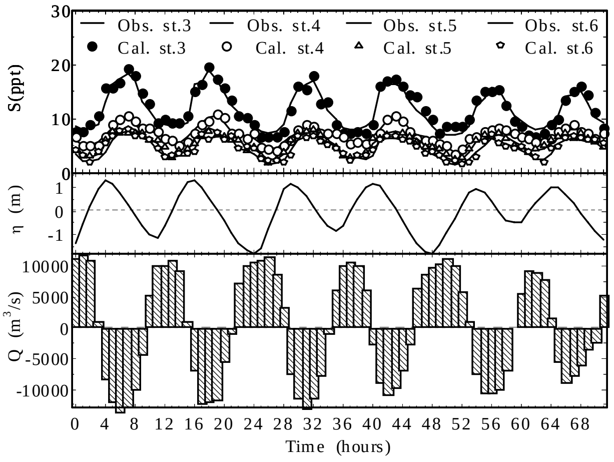

Figure 2. Time variation of salinity on 11, 12 and 13 April 2005 (calibration)

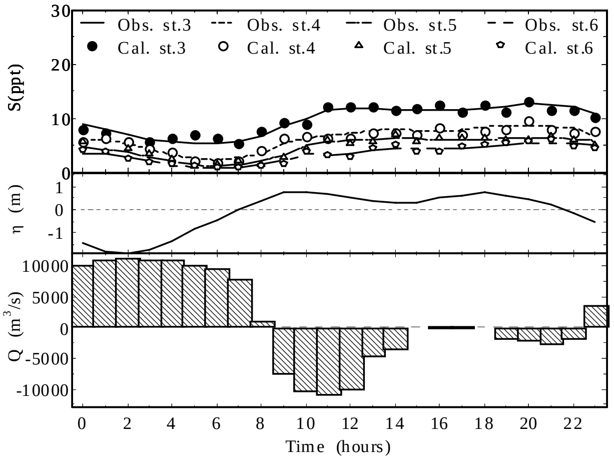

Figure 3. Time variation of salinity on 1 May 2005 (calibration)

Boundary conditions

A description of boundary conditions has been elucidatively introduced in the above mentioned references. In this section, open lateral boundary conditions are presented. Tidal at My Thanh station is given as downstream boundary, whereas river discharge at Can Tho station is used as upstream boundary condition. For salinity at the river mouth, the observed data is input and salinity at Can Tho station setup with zero values. For temperature at both the river mouth and upstream, measured values are used.

RESULTS AND DISCUSSIONS

Time variation of salinity

Figures 2 and 3 reveal the calibrated results of the time variation of salinity on 3 days (11, 12, and 13 April 2005) and 1 day (1 May 2005) at four stations (3, 4, 5, and 6) respectively as seen in Figure 1. It can be seen that the calculated results correspond very well to observed data. Additionally, the variation of salinity is in phase with tidal level. These results also correspond to in-situ data in the Hau River (NGUYEN et al., 2005).

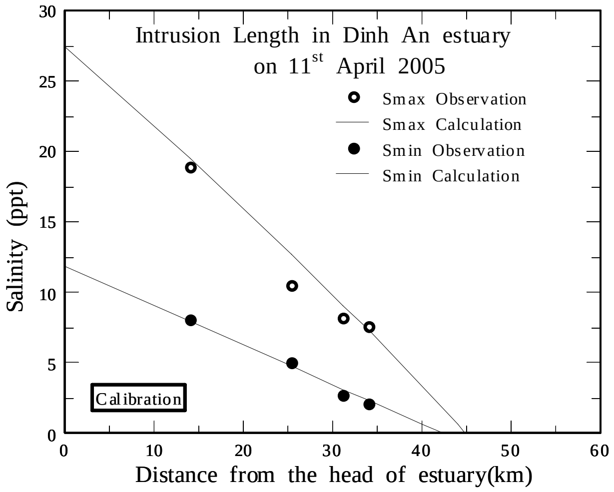

Figure 4. Simulated intrusion length versus observed one (on 11 April 2005)

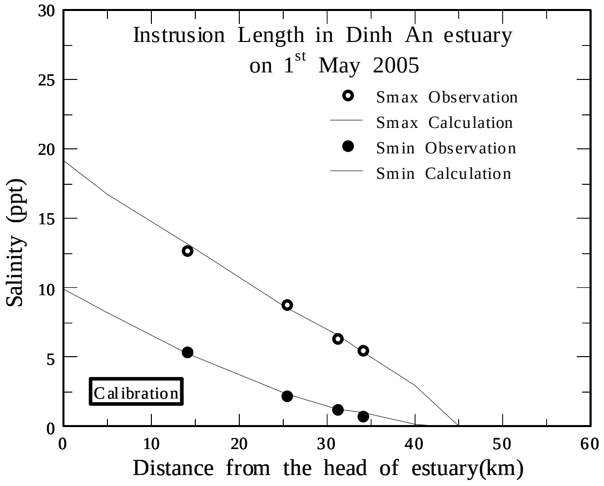

Figure 5. Simulated intrusion length versus observed one (on 1 May 2005)

Salinity intrusion length

The variation of salinity intrusion lengths are shown in Figures 4, 5 corresponding to April 11 and May 1, 2005, respectively.

Even though salinity values were not those at high water slack and low water slack, the intrusion process in the Dinh An estuary can be well reflected. In connection with a practical view point, intrusion length could be considered to be the most important parameter in predicting the intrusion of saltwater further upstream.

Effect of morphology on salinity

Figure 6 shows a distinct difference between two river transects of the Dinh An River Mouth's section and Fish Port's

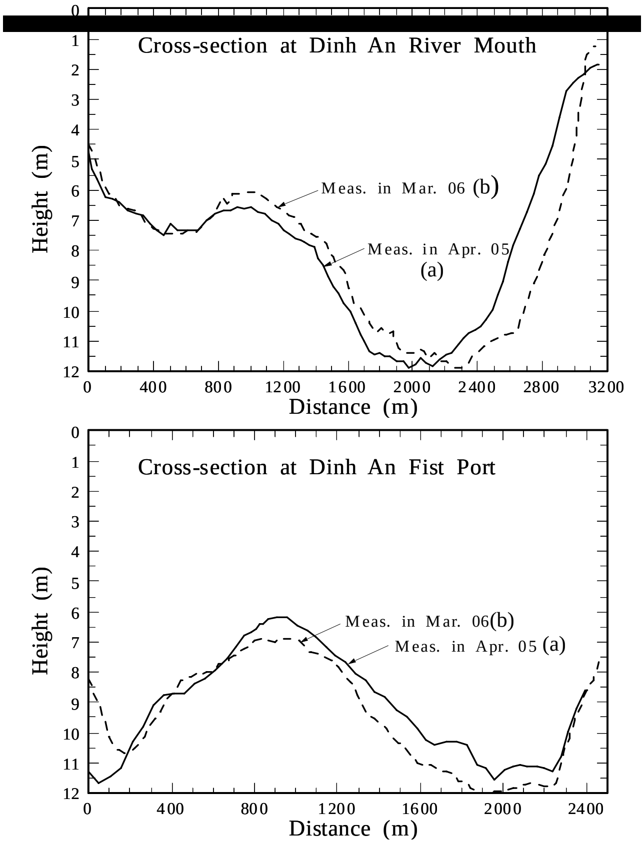

Figure 6. Cross-sectional profiles corresponding to morphology data set of 2005 & 2006

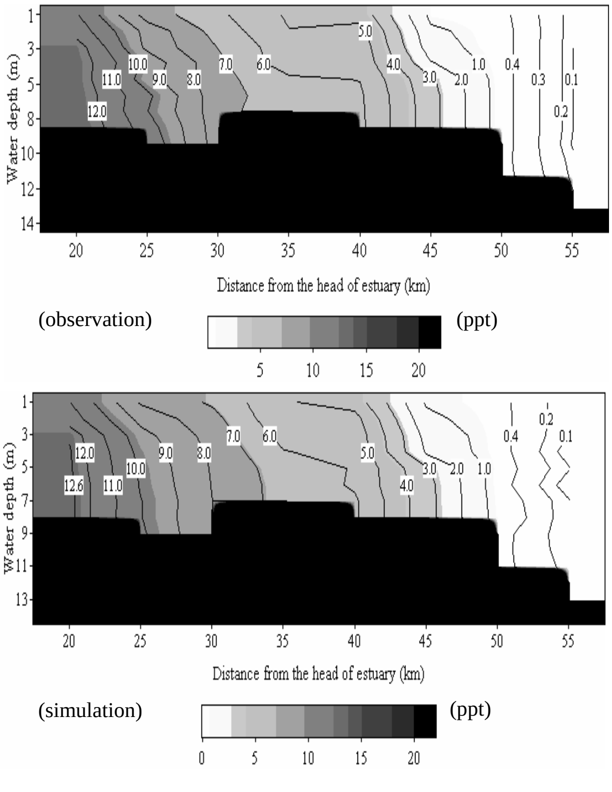

Figure 7. Salinity distribution patterns regarding morphology data on 6 April 2005 (verification)

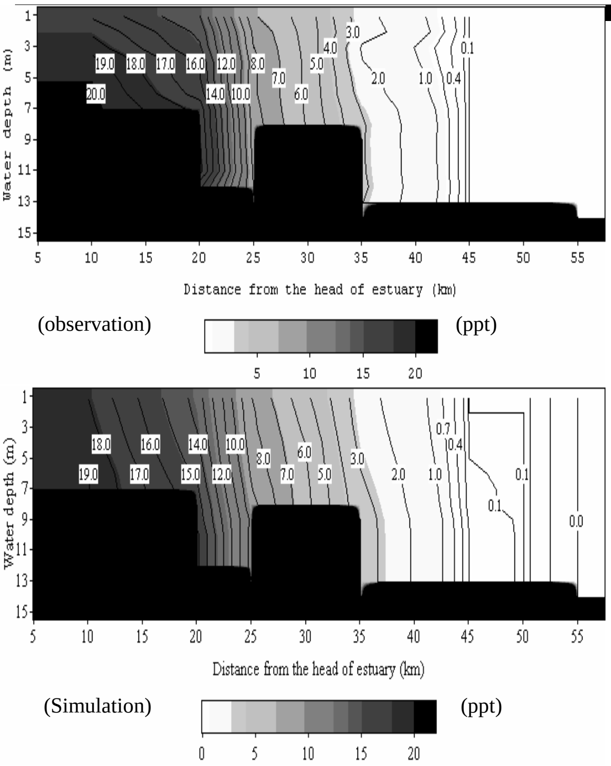

Figure 8. Salinity distribution patterns regarding morphology data on 28 March 2006 (verification)

section, as seen in Figure 1, for 2005 and 2006's measuring data respectively. It can be seen that the latter morphology data is deeper than the former. Therefore, it may affect the salinity distribution. Now, we will assess the effect of morphology change on salinity distribution by taking into account different morphology patterns.

Figure 7 compares the observed and calculated contours of the streamwise vertical salinity along the river on April 6, 2005, whereas similarity of salinity distribution on March 28, 2006 is rendered in Figure 8. In Figures 7 and 8, the horizontal axis indicates the distance from the head of the Dinh An estuary; meanwhile the vertical axis reveals the water depth. These figures clearly depict how the salinity concentration is distributed along the Dinh An estuary from downstream to upstream. It is understandable that the salinity distribution can be well reproduced to represent the real phenomena in an estuary.

Moreover, significant difference in terms of salinity due to the change of morphology has been confirmed by both observation data and simulation results. It clearly appeared that the salinity regime in the Dinh An estuary is well-mixed. From Figures 7 and 8, it can be clearly seen that the salinity distribution on April 6, 2005 is smaller than that on March 28, 2006, although in the measuring period the tidal level of the latter is a little lower than one of the former, whereas river discharge was almost the same. The reason might be caused by significant change of morphology as the above mentioned. Due to the limitation of budget and time, we have just carried out two morphology data sets and that data covered only the area near the coastal region and river mouth.

For more concrete confirmation, hypothetical assumption of morphology data based on the 2005 and 2006's data is utilised to clarify the distinct influence of morphology on salinity

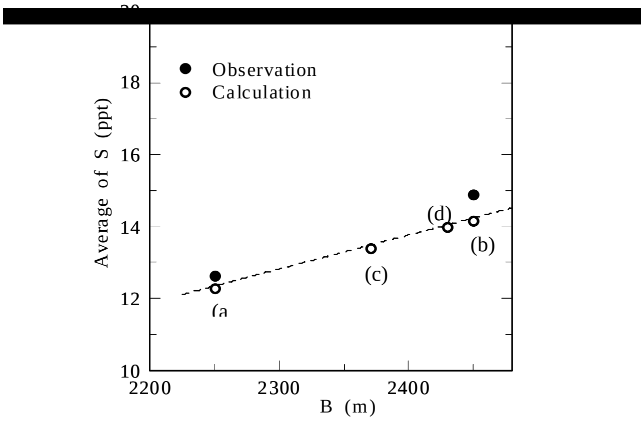

Figure 9. Averaged salinity and river mouth width

Distribution in the Dinh An estuary. The input data of baththymetry nearby river mouth region are changed from (a) to (b) corresponding to Figures 6, whereas the hydrodynamic conditions are kept constant. It means that the initial and boundary conditions are not changed. The explanation of simulation cases regarding to hydrodynamic and morphology conditions are shown in Table 1. The relationship between river mouth width and averaged salinity concentration is drawn to see the extent to which morphology affects the salinity.

Figure 9 represents the relationship between river mouth width and average of salinity. It can be found that the correlation between river mouth width and salinity is directly proportional. Therefore, the influence of morphology change on salinity distribution should not be ignored when simulating salinity.

This study has mainly focused on morphology influences. Other factors affecting salinity intrusion such as wave set-up can be found in NGUYEN et al. (2006a, 2006b).

CONCLUSIONS

The major results of the present study can be summarised as follows:

This paper applied a three-dimensional model to deal with phenomena of salinity distribution in the Dinh An estuary, Vietnam. It can be recognised that the model results are in a good agreement with the measured data. Both calibration and verification processes indicate that the model is able to predict the saltwater intrusion into the river with a reasonable accuracy. Additionally, it can be clearly seen that the salinity regime in the dry season is well-mixed.

Table 1. Sensitivity analysis taking into account the changes of morphology patterns

Items	Case A	Case B
Verification	- Hydrodynamic conditions corresponding to April 6, 2005 - Morphology (a)	- Hydrodynamic conditions corresponding to March 28, 2006; - Morphology (b)
Sensitivity Analysis	---	- Hydrodynamic conditions corresponding to April 6, 2005 - Morphology (b)

Besides, it has been confirmed that the change of salinity is influenced by not only usual parameters as river discharge and tidal level but also by another external force such as morphology change. In addition, river mouth width is directly proportional to the averaged salinity concentration. Therefore, the influence of morphology changes on salinity distribution should not be ignored when simulating salinity.

ACKNOWLEDGEMENT

The authors would like to express their grateful thanks to Prof. Naritaka Kubo for kindly accepting us to use his equipments supported by CREST Project during this field observation. A part of this study was financially supported by a Project on "Development of Risk Management System for the Safety of Water Resources in Monsoon Asia" (RR 2002) from Ministry of Education, Culture, Science, Sports and Technology (MEXT).

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