CHAPTER 1
INTRODUCTION

1.1 Rational/ Problem statement

Knowledge about hydrodynamics of rivers under tidal effects in Thailand is not yetwell understood. The topic has been discussed in several studies by scientists, engineers and government agencies about natural process of river such as salinity intrusion,sedimentation and drainage efficiency. The lower reach of the river is strongly influenced by tides, when interacting with river flows that cause the complicated pattern of process. So, the main factors to control the natural process of the river reach are the upstream flow and tides from the sea.

Water level and river discharge are important factors for river management. Generally, water level and discharge relationship (rating curve)is used to regulate the flow but in case of river under tidal effect it cannot. Because the rating curve of river under tidal effect is not a direct relation, especially when the discharge is difficult to measure.Therefore, many researchers have been trying to find the way for estimating the discharge by using many techniques to solve the problem such as mathematics model, curve analysis and dimensional analysis.

The aims of this research are to investigate the hydrodynamics of rivers and to estimate the discharge in tidal rivers with partially reverse flow, as in the Lower Chao Phraya River, by using the Chen and Chui Method (2002). The Lower Chao Phraya River of Thailand has chosen because it is the main river of the central basin, which is the most important river in the central part of Thailand.

1.2 Literature reviews

Basically, the parameters to be investigated in an open channel are the discharge, the velocity and the time series water level. Many researchers have found the relationship of each parameter by using many tools such as relative curves, equations and mathematic models in an attempt to solve this problem for understanding well in the river process.

Leopold (1993) discusses the downstream change of velocity in rivers. Since a river slope generally decreases in a downstream direction, it is generally supposed that the velocity of flow also decreases downstream. Analysis of some of the large number of velocity measurements made at stream-gaging stations demonstrates that mean velocity generally tends to increase downstream. Although there are many reaches in nearly all rivers where mean velocity decreases downstream, the general tendency for conservation or for downstream increase was found in all data studied. Computations of bed velocity indicate that this parameter also tends to increase downstream. Near the streambed, shear in the vertical profile of velocity (rate of decrease of velocity with depth) tends to decrease downstream. This down valley decrease of shear implies decreasing competence downstream.

Simpson and Bland (2000) proposedmethods for the accurate estimation of net discharge in a tidal channel. Accurate estimates of net residual discharge in tidally affected rivers and estuaries are possible because of recently developed ultrasonic discharge measurement techniques. Previous discharge estimates using conventional mechanical current meters and methods based on stage-discharge relations or water slope measurements often yielded errors that were as great as or greater than the computed residual discharge. Ultrasonic measurement methods consist of: (1) the use of ultrasonic instruments for the measurement of a representative "index" velocity used for in situestimation of mean water velocity, and (2) the use of the acoustic Doppler current discharge measurement system to calibrate the index velocity measurement data. Methods used to calibrate (rate) the index velocity to the channel velocity measured using the Acoustic Doppler Current Profiler are the most critical factors affecting the accuracy of net discharge estimation. The index velocity first must be related to mean channel velocity and then used to calculate instantaneous channel discharge. Finally, the discharge has been low-pass filtered to remove the effects of the tides.

Discharge measurement data were collected during three time periods. Two sets of data were collected during a spring tide and one set during a neap tide. The relative magnitude of instrumental errors, acoustic Doppler discharge measurement errors, and calibration errors were evaluated. Calibration error was found to be the most significant source of error in estimating net discharge. Using a comprehensive calibration method, net discharge estimates developed from the three sets of calibration data differed by less than an average of 4 m^3/s, or less than 0.5% of a typical peak tidal discharge rate of 750 m^3/s.

Weesakul and Thammasittirong (2000) studied operational flood forecasting forthe Chao Phraya River Delta. This study applied the AIT River Network Model (river model and flood plain model) to forecast floods. The input data at the upstream boundary is the daily discharge at the Chao Phraya Dam while the downstream boundary is tidal level at Fort Chula. At the upstream boundary, the non-dimensional shape of unique flood hydrograph was formulated and proposed. The three empirical formulae of forecasting peak discharge, time base and dimensionless shape of hydrograph were derived. Good agreement between observed and forecasted water level were obtained with the error of 10% or 0.3 m. For the downstream boundary, the conventional harmonic analysis was applied. The optimum length of tidal record and number of tidal constituents were found to 30 days with 4 constituents which provide the least root mean square at the error 20% or 0.2-0.3 m. Then the model was applied to forecast the daily maximum water levels of 1980, 1983 and 1995 flood with one month in advance. The result shows the acceptable agreement between the observed and forecasted water levels with the average errors of about 0.2 m in the river and 0.15 m in the flood plain.

Chen and Chiu (2002) described an efficient method of discharge measurement in tidal streams.The efficient method is based on the regularity of water flow in an open channel, which is maintained by nature at a constant ratio of mean to maximum velocities at a channel section. This ratio is a function of a parameter of a probability distribution that is equivalent to velocity distribution in the physical space. The maximum velocity can be determined by measuring velocities from a single vertical axis, that to remain invariant with time. Whereas the mean velocity in a section can be determined by estimating the product of the maximum velocity multiplied by the ratio. The cross sectional area of an open channel can be determined by the relation between gage height and area. Thus, the discharge in an open channel may be estimated as the product of mean velocity multiplied by the cross sectional area. The available data of the Tanshui River downstream reach of which is in an estuarine area is used to illustrate the accuracy and reliability of the method

Chiu et al. (2002) discusses maximum velocity and regularities in open-channel flow. The maximum velocity in a channel section often occurs below the water surface. Its location is linked to the ratio of the mean and maximum velocities, velocity distribution parameter, location of mean velocity, energy and momentum coefficients, and probability density function underpinning a velocity distribution equation derived by applying the probability and entropy concepts. The mean value of the ratio of the mean and maximum velocities at a given channel section is stable and constant, and invariant with time and discharge. Its relationship with the others in turn leads to formation of a network of related constants that represent regularities in open-channel flows and can be used to ease discharge measurements and other tasks in hydraulic engineering. Under the probability concept, the ratio of mean and maximum velocities being constant means that the probability distribution underpinning the velocity distribution and other related variables is resilient, and that the same probability distribution is governing various phenomena observable at a channel section and explains the regularities in open-channel flows.

Vongvisessomjai and Srivihok (2003) studied the interaction between tide and salinity barriers. Presently, there is a number of salinity barrier utilizations and this kind of structure has become more common in estuarine areas. However, the construction of a barrier at the river mouth or inside the river results in the amplification of tide due to the creation of a standing tide at the barrier. This standing tide creates two major problems, namely, the overspill of salinewater during high water and bank erosion during low water along the tidal reach downstream of the barrier. In the study, the analytical model was developed to determine theriver hydraulic behaviors which affects by tide, river flow and barrier structure of the Bang Pakong River, Thailand. The analytical model of tide and river flow of the Chao Phraya River was adopted and adjusted to determine the tide characteristics modified by river flow. Moreover, the analytical model of tide and salinity barrier would then be developed by cooperating of the analytical model of tide and river flow interaction together with tidal flow co-oscillating tide theory. It was found that the analytical model of theChao Phraya River which is suitable for high freshwater discharge underestimates damping modulus and friction slope which requires adjustment for low freshwater discharge of the Bang Pakong River. The analytical model of tide and salinity barrier can be finally used to predict the water level downstream of the barrier. The model overestimated the water level fluctuation during the unsteady flow from upstream which may be because of the assumption of steady flow condition in the model development due to limited data available after the construction.

Chen and Chui (2004) proposed a fast method of flood discharge estimation. The greatest advantage of the proposed method is its application to the estimation of flood discharge that cannot be measured by conventional methods. It has as its basis the regularity of open-channel flows, that nature maintains a constant ratio of mean to maximum velocities at a given channel section by adjusting the velocity distribution and the channel geometry. The maximum velocity at a given section can be determined easily over a single vertical profile, which tends to remain invariant with time and discharge, and can be converted to the mean velocity of the entire cross-section by multying by the constant ratio. Therefore, the mean velocity is a common multiple of maximum velocity and the mean/maximum velocity ratio.

The channel cross-sectional area can be determined from the gauge height, the water depth at the y-axis or the product of the channel width multiplied by the water depth at the y-axis. Then the most commonly used method, i.e. the velocity–area method, which determines discharge as the product of the cross-sectional area multiplied by mean velocity, is applied to estimate the flood discharge. Only a few velocity measurements on the y-axis are necessary to estimate flood discharge. Moreover the location of the y-axis will not vary with time and water stage. Once the relationship of mean and maximum velocities is established, the flood estimation can be determined efficiently. This method avoids exposure to hazardous environments and sharply reduces the measurement time and cost. The method can be applied in both high and low flows in rivers. Available laboratory flume and stream-flow data are used to illustrate accuracy and reliability, and results show that this method can quickly and accurately estimate flood discharges.

Muste et al. (2004) proposed practical aspects of ADCP data used for the quantification of mean river flow characteristics. Acoustic Doppler Current Profiler (ADCP) measurements have gained considerable popularity because of their ability to efficiently measure discharges from boats moving across river transects(Figure 1.1). The accuracy of the estimated discharges is relatively good compared with the existing measurement alternatives. The study presents several methods for enhancing the significance of the ADCP velocity distribution profiles collected from moving boats and proposes complementary software to further process and visualize the ADCP data for better support of hydraulic investigation requirements. The studyfirst analyzes the assumptions and error sources involved in the measurement process. The appearance of the velocity profiles collected with ADCP operated from moving vessels and post-processing algorithms for data conditioning and smoothing were tested and evaluated next. The relevance of data collected from moving vessels along transects for description of the mean velocity profiles is inferred by comparison with data obtained with the same ADCP system and settings, collected from fixed locations along the transect route. Velocities enhanced using the optimum tested post-processing algorithms are used to further determine depth-averaged velocities, velocity components in river coordinates, and river discharge estimates.

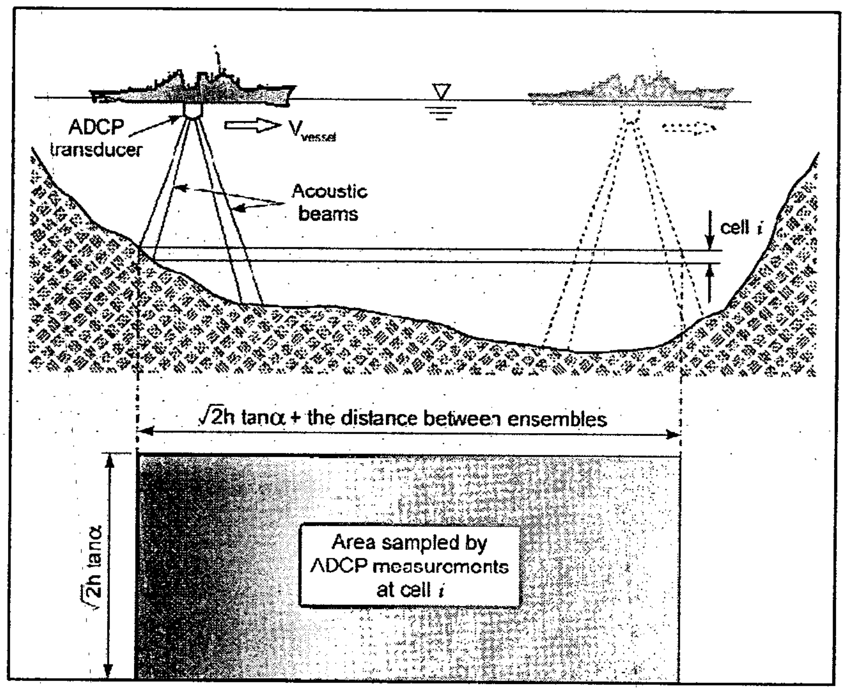

Figure.1.1ADCP measurement (Muste et al, 2004).

Maghrebi and Rahimpour (2005) studied a model for estimatingdimensionless isovel contours in open channels. The power law and the logarithmic law were used in the model to simulate the normalized isovel contour in rectangular channels. Velocity profile was applied to simulate the model by single-point measurement at cross section in uniform. The kinetic energy and momentum correction factor, and ratio of maximum to mean velocity are also calculated from isovel patterns. Calibration and validation of the model were done by comparing the obtained results and field measurements.

Lu et al. (2006) studied the application of a portable measuring system with an Acoustic Doppler Current Profiler to discharge observations in steep rivers. Obtaining discharge measurements during high flows is very difficult in steep rivers (slopes greater than about 0.1%) because of the highly unstable free surfaces and bed elevations. In this study, a portable flow measuring system with an acoustic velocity meter was developed. The proposed system has been proved to be better than existing systems for streamflow measurements in steep rivers. Field data collected by conventional velocimeters were analyzed, and compared with the flow measurements using the portable system with an ADP (Acoustic Doppler Profiler) or ADCP (Acoustic Doppler Current Profiler). In general, the method was applicable to higher flows where the measuring verticals were reasonably stable.

Maghrebi and Ball (2006) proposed a new method for estimation of discharge.A new technique for drawing isovel patterns in an open or closed channel was presented. It is assumed that the velocity at each arbitrary point in the conduit is affected by the hydraulic characteristics of the boundary. While any velocity profile can be applied to the model, a power-law formula is used here. In addition to the isovels patterns, the energy and momentum correction factors α and β, the ratio of mean to maximum velocity (V/u_{max}), and the position of the maximum velocity are calculated. To examine the results obtained, the model was applied to a pipe with a circular cross section. A comparison between the profiles of the proposed model and the available power-law profile indicated that the two profiles were coincident with each other over the majority of the cross section. Furthermore, the predicted isovels were compared with velocity measurements in the main flow direction obtained along the centerline and lateral direction of a rectangular flume. The estimated discharge, based on measured points on the upper half of the flow depth away from the boundaries was within ±7% of the measured and much better in comparison to the prediction of one- and two-point methods. The prediction of the depth-averaged velocity values for the River Severn in the United Kingdom shows a good agreement with the measured data and the best analytical results obtained by the depth-averaged Navier-Stokes equations.

Vongvisessomjai and Chatanantavet(2006) presentedan analytical model of the interaction of the tide and river flow.Hydrodynamic characteristics of a river resulting from interaction of tide and river flow areimportant since problems regarding flood, salinity intrusion, water quality and sedimentation are ubiquitous. The lower reach of the river strongly influenced by tides from the sea, when interacting with river flows, results in a complicated pattern which is simplified to its interaction with four main constituents of tides obtained from harmonic analysis. An analytical model was developed for simulating the hydrodynamic processes in estuarine waters, with the emphasis being given to the interaction between tides and river flows. The perturbation method is used to derive the analytical solution, in which the estuarine flow is separated into steady and unsteady components. Thus the analytical solutions derived consist of two distinct parts; one represents the influence of river flows and the other represents the influence of tides. The application of the model to a case study, the Chao Phraya river, which requires a time series of discharges and loadings at the river mouth to model water quality in the Gulf of Thailand, showed that the model can simulate the hydrodynamic features of tide and river flow interaction especially in the rainy season when the river discharge is high. Data of tidal discharges are scarce because of high cost of measurement especially in the lower reach of the river strongly influenced by tides from the sea. From this study of the relation between tidal discharges and tides, the analytical model can correctly compute tidal discharges from tides. The results of tides and tidal flow can subsequently be used to calculate eddy viscosity and dispersion coefficient for describing salinity.

Liu et al. (2007)describedthe modeling of the influence of river discharge on salt intrusion andresidual circulation in the Danshuei River Estuary, Taiwan. A 3-D, time-dependent, baroclinic, hydrodynamic and salinity model was implemented and applied to the Danshuei River estuarine system and the adjacent coastal sea in Taiwan. The model forcing functions consist of tidal elevations along the open boundaries and freshwater inflows from the main stream and major tributaries in the Danshuei River estuarine system. The bottom friction coefficient was adjusted to achieve model calibration and verification in modelsimulations of barotropic and baroclinic flows. The turbulent diffusivities were ascertained through comparison of simulated salinity time series with observations. The model simulation results are in qualitative agreement with the available field data. The validated model was then used to investigate the influence of freshwater discharge on residual current and salinity intrusion under different freshwater inflow condition in the Danshuei River estuarine system. The model results reveal that the characteristic two-layered estuarine circulation prevails most of the time at the Kuan-Du station near the river mouth. Comparing the estuarine circulation under low- and mean flow conditions, the circulation strengthens during low-flow period and its strength decreases at moderate river discharge. The river discharge is a dominating factor affecting the salinity intrusion in the estuarine system. A correlation between the distance of salt intrusion and freshwater discharge has been established allowing prediction of salt intrusion for different inflow conditions.

Lee and Cheong (2009) developed the regression equations for water discharge estimation in tidally affected rivers. The different stage heightsare considered to derive the rating curve while the index velocity is considered to derive the rating curve and mean velocity equation. The results of discharges from these equationsare compared with the measured discharge collected in the Samrangjin station where tidal current effects are dominant. A robust minimum covariance determinant method, one of the nonlinear multi-regression methods, is applied to derive regression equations for the rating curve and mean velocity equation using 39 measurements collected at Samrangjin gauging station. The new rating curves allow superior in predicting discharge more precisely in tidally affected river as compared to existing equation. The discharge estimated using the mean velocity from the index velocity is in best agreement with the measured discharge data.

Manoj and Unnikrishnan (2009) investigated the tidal circulation and salinity distribution in the Mandoviand Zuari Estuary of India. This estuary is characterized mixed by tides with semidiurnal and heavy fresh water influx during the wet season. A hybrid network numerical model 1D and 2D were used for upstream and downstream boundaries, respectively. The model reproduced observed tides accurately during the dry and wet seasons. The model could reproduce the longitudinal distribution of salinity well during the dry season and the simulation of salinity distribution was seasonably well in wet season. That simulate over M_2 tidal period for varying river discharges, which show a small fresh water influx can affect the longitudinal distribution of salinity to a great extent in estuaries.

Maghrebi and Givehchi(2010)examined the discharge estimation in a tidal river with partial reverse flow at theOhta Estuary in Japan by using an Acoustic Doppler Current Profile (ADCP) to measure the velocity profiles at different verticals.Due to the fluctuations of the measure velocities, vertical and horizontal grouping of the measured points were used to estimate the discharges instead of a single point of measurement. The measured points were selected from the regions with the corresponding high values of isovelsin the range of -0.5 >u/V>0.5, where u/V is dimensionless of streamwise velocity at a point in a channel section at a mean cross-section velocity. Then, the results were compared with Maghrebi's Model (2006)(Figure 1.2) and found that the minimum errors are associated with the horizontal groupings (Figure 1.3).

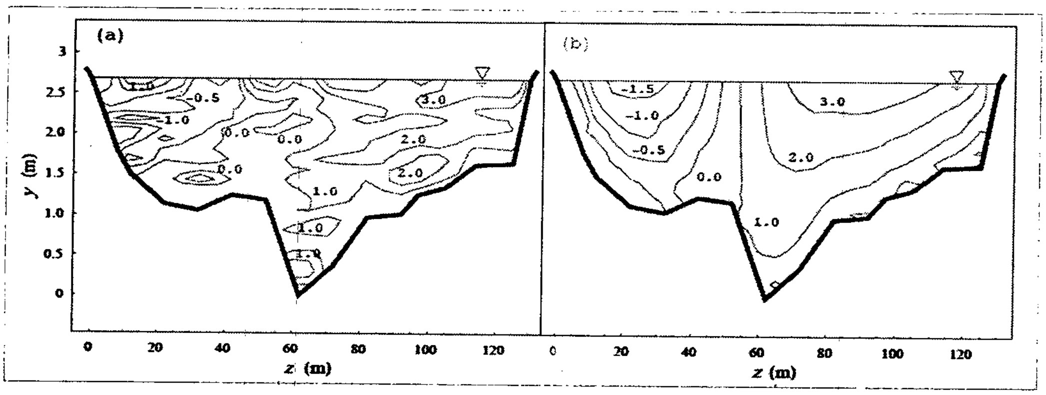

Figure 1.2 Isovel contours at the observation section based on (a) field data; (b) Maghrebi's model(2006)

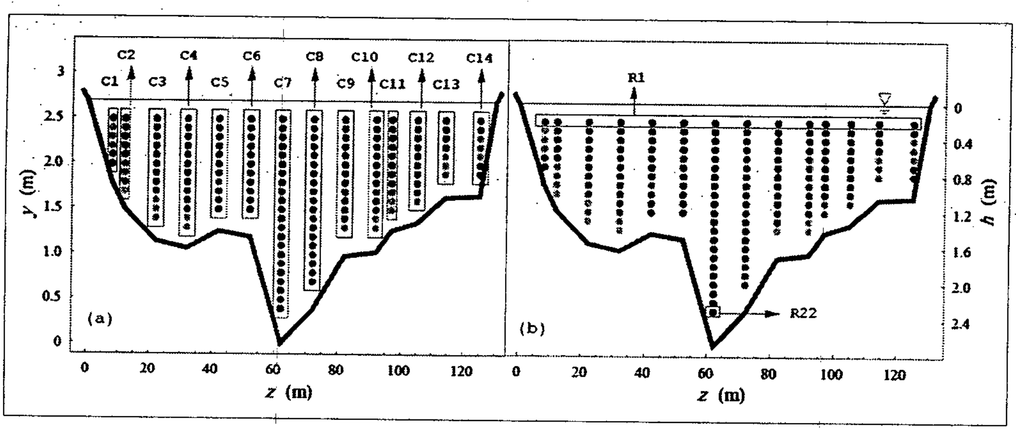

Figure 1.3 Areas for calculation of the error of average discharge estimation: (a) vertical groups; (b) horizontal groups

Choi et al. (2011) studiedthe effect of the tidal boundary condition at a river mouth. This study discusses the limitations of downstream boundary conditionsin previous studies and presents new boundary conditions with procedures for development and appropriateness. It is difficult to collect the observed data on the Han River mouth because of complex flow characteristics and restrictions by the military. Therefore, the tidal data of

Incheon Harbor and the data of water level of cardinal points, which is defined in the "Basic Plan for River Maintenance in the Han River", have been applied in the previous studies without consideration of spatial patterns of study areas. However, if the boundary condition is applied without consideration of spatial pattern, the complexity of flow characteristics in real condition cannot be considered. New boundary condition has been presented with several literature review and field investigation and validated by numerical modeling. As a result of this study, it is proved that the location of downstream affects the result of modeling and the proper location and condition of downstream boundary have been presented. And it is suggested that the boundary condition of numerical study should be decided in consideration of field investigation, spatial pattern of study area and the characteristics of study.

Dias et al. (2011) presented the comparative analysis of the rating curves and the ADP estimatesof instantaneous water discharge through estuaries in two contrasting Brazilian rivers. This work quantifies, using ADP and rating curve techniques, the instantaneous outflows at estuarine interfaces: higher to middle estuary and middle to lower estuary, in two medium-sized watersheds (72,000 and 66,000 km^2 of area, respectively), the Jaguaribe and Contas Rivers located in the northeastern (semi-arid) and eastern (tropical humid) Brazilian coasts, respectively. Results from ADP showed that the net water balances show the Contas River as a net water exporter, whereas the Jaguaribe River Estuary is a net water importer. At the Jaguaribe Estuary, water retention during flood tide contributes to 58% of the total volume transferred during the ebb tide from the middle to lower estuary. However, 42% of the total water volume (452 m^3/s) that entered during flood tide is retained in the middle estuary. In the Contas River, 90% of the total water is retained during the flood tide contributing to the volume transported in the ebb tide from the middle to the lower estuary. Outflows obtained with the rating curve method for the Contas and Jaguaribe Rivers were uniform through time due to river flow normalization by dams in both basins. Estimated outflows with this method are about 65% (Contas) and 95% (Jaguaribe) lower compared to outflows obtained with ADP. This suggests that the outflows obtained with the rating curve method underestimate the net water balance in both systems, particularly in the Jaguaribe River under a semi-arid climate. This underestimation was somewhat decreased due to wetter conditions in the Contas River Basin.

1.3 Research objectives

1.3.1 To investigate the hydrodynamic behavior of the Lower Chao Phraya River.

1.3.2 To test the applicability of the Chen and Chui Method (2002) for estimating the discharge in the Lower Chao Phraya River.

1.4 Scope of this research work

This research investigates the hydrodynamics of the Lower Chao Phraya River, which is a tidal reach with reverse flow. The field data was taken by using the Acoustic Droppler Current Profile (ADCP) in the wet season (June to October 2012). The drainage discharge was estimated using the Chen and Chui Method (2002). The important hydraulic data we are determined and analyzed to obtain their relationship-less terms. Accuracy and reliability of the proposed equation are discussed.