Characteristics of Flooding in the Mekong Delta Area and the Regulating Role of the Great Lake

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This paper is a compact presentation of our understanding about the flood characteristics and related issues in the Mekong Delta. It is revealed that hydrological conditions in the Mekong Delta are such that any intervention has implications throughout the whole area. Particularly, the attenuation of the Mekong flood by the Greta Lake is enormously significant.

Key Words: *The Mekong Delta, flood, the Great Lake, MIKE11, river network*

1. Introduction

Mekong river is the longest river in South Asia and the twelfth longest in the world. The Mekong river basin covers a catchment of approximately 795,000km^2, and produces a total runoff of 475,000 million m^3 annually. As the economies of this region develops at high growth rate in recent years, the Mekong faces complicated problems not only in water quantity and quality, but also in ways of usage. The issue of sustainable management and development of the Mekong to meet not only the economic needs but also the social, cultural and environmental has become one of the top priorities.

Originating from China, the Mekong with its tributaries drain regions in six counties: China, Burma, Lao PDR, Thailand, Cambodia and Vietnam. The southern part of the Mekong river basin, downstream of the Burma-Lao PDR- Thailand border, is defined as the Lower Mekong Basin. The Mekong Delta is the area of the flood plains downstream of Kratie, Cambodia, and covers 49,520 km^2. Most of the Delta is situated within the border of Vietnam. The Delta's rich resources are of vital importance to Vietnam, they account for some 40% of agricultural production in the country, including 50% of the rice. Rice and fisheries products contribute significantly to export earnings and account for about 27% of Gross Domestic Product.

Based on literature review, data collection and field survey over the past two years, Some characteristics of the Mekong Delta area is outlined and discussed in this paper, and the role of the Great Lake in regulating flood water level in the Mekong Delta is analyzed with the river simulation system, MIKE 11 which was developed by Danish Hydraulic Institute. The paper is aimed at presenting concisely an updated view on the characteristics of the Mekong Delta water system, and trying to identify problems involved with developing and managing water resources in the Delta. It is also intended to serve as a way of information sharing, to inform people concerned with the Mekong of what information and data are available from the River and Environmental Engineering Lab. (REEL), Univ. of Tokyo.

2. Delta flood characteristics

After passing through Phnom Penh, at the confluence of the Mekong River, and the Tonle Sap River, the Mekong bifurcates, forming two distinct rivers, the Mekong and Bassac, which discharge into the South China Sea through nine estuaries. Annually, during the flood season, mainstream water levels rise and flood waters enter canals or flow over embankments flooding large areas of the Mekong Delta. Figure 1 shows an example of the range of flood levels in the Lower Mekong Basin in Cambodia and Vietnam. Although the figure is based on rather old data, they still demonstrate the complex situation of the Mekong Delta. As can be seen from the figure that the Plain of Reeds and Long Xuyen are two large flooded areas. The elevation in the flooded area varies from 0.5m to 3m with 60% of the area under 1.0m elevation. Flood water enters the Plain of Reeds mainly from area across the Cambodia-Vietnam border(75-80%), and due to the canal system used for irrigation and drainage. Recently, flooding has increased in the Plain of Reeds, especially from the canals adjoining the border. It was reported that the overflow of the 1961 flood was 3,000 m^3/s. However, the figure has risen to 10,000m^3/s in the 1996 flood. Flood water in the Plain of Reeds drains out in 3 directions: 34% flows westward into Mekong River, 25% southward into Mekong River, and 41% eastward into the two Vaicos. The population growth of the Plain of Reeds is quite high, so that a large number of people are affected by flooding in the rainy season. With annual flooding, the problem of population distribution and protection from flooding is a big issue in development planning for the Plain of Reeds.

Flood water enters the Long Xuyen quadrangle in two ways; (1) via the flooded area of Cambodia crossing seven bridges along the road from Chau Doc to Tinh Bien(62-65%), (2) via canals adjoining the Bassac River(35-38%).

A predominant feature of the Delta is the interaction between the Mekong River and the Great Lake(Tonle Sap) in Cambodia. During the flood season, the Mekong water level rises faster than the Tonle Sap, and feeds water into the lake. When the Mekong water level goes down from September, the Great Lake releases water into the Mekong-both the stored Mekong flood water and the yield of its own catchment area. Another important feature of the Delta water regime is the tidal fluctuations of the surrounding seas. The tide of the South China Sea is predominantly semidiurnal with an amplitude of some 2.5-3.0m. The tide of the Gulf of Thailand, however, is mostly of the diurnal type, while its amplitude is only some 0.4-1.2m The tides of the South China sea have a significant influence on the river and canal water levels in the coastal zone and also on inundation depths in the area along the main Mekong branches. In the flooded areas, infrastructure is basically nonexistent, and the annual loss of human life, private and public properties are very high. For example, 1994 flood took the lives of 407 people, and 1997 flood claimed another 1997 victims and incurred damages of VND 700 billion.

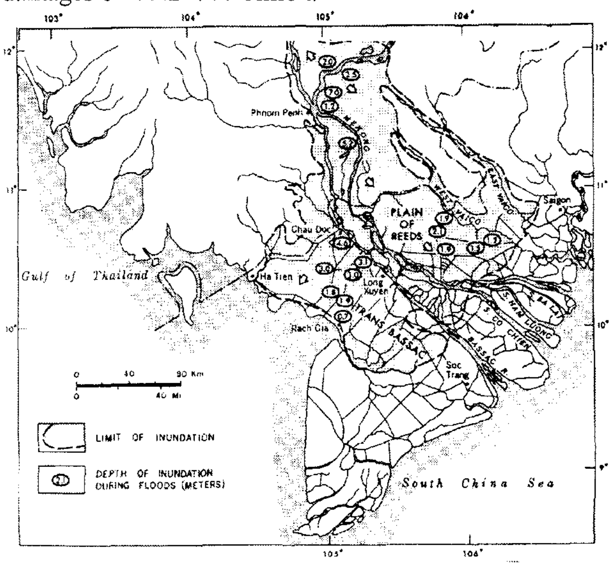

Fig.1 Flood inundation in the Mekong Delta

In the Mekong Delta, flooding also brings some benefits. Annually, an estimated nine to thirteen million tons of sediments are deposited by floods in the Mekong Delta, especially in the strips of land along the Mekong and Bassac. This land is extremely productive for rice, upland crops, and fruit crops. The flood offers a flushing to push away the acidic soil elements, and to reduce the rat population. Flooding also provides suitable conditions for fresh water fish development. Annually, approximately 35 million fish hatching are taken from flood water. Furthermore, the flood water is indispensable for irrigation. In view of the flood benefits, people in the Delta has adopted the Winter-Spring and Summer-Autumn cropping practice, that is to adapt to flood conditions by shifting the cropping seasons. This practice has contributed to the increase of rice production in the Mekong Delta. To develop rural areas in the Mekong Delta in the way of modernization, flood control is of paramount importance. However, since the Mekong Delta is a hydrological entity. Any intervention in the regime of the river influences the entire region. Analyses have been made to evaluate flood control alternatives, such as the "Outline of Flood Control Planning for the Mekong Delta" completed by the Sub-Institute of Water Resources Planning and management, Vietnam. In principle, flood control should be carried out in a comprehensive manner to take advantage of flood benefits, and minimize environmental impacts. Therefore, complete flood control that is to construct embankments and floodways in the border areas, and a dyke system along the Mekong and Bassac, although allow for modernization and infrastructure development in the Delta, will stop rich sediment deposition, damage natural fish resources, and destroy the double cropping practice. In addition, full flood control in Vietnam would cause a significant rise in water levels in Cambodia. One favorable alternative is to protect heavily populated areas and infrastructure from flooding, while to live with flood in deep flooded areas(depth over 1m) by adapting to flood conditions in order to make use of sediment deposition in enriching soils and preserve fish resources. Another aspect of flooding which should be dealt with is the simultaneous happening of flood and high tide. In 1994, flood and spring tide occurred at the same time, caused most of the Delta area inundated with at least the water depth of 0.5m. As shown in Table 1 that the flood peak at TanChau which is near Phnom Penh in 1994 was lower than the peaks of the other years, but the flood peak at the downstream station CanTho in 1994 was higher than that of the other years due to the effect of the tide.

Table 1. Maximum water stage above the South China Sea at TanChau and CanTho

Year of flood	Peak at TanChau	Peak at CanTho
1961	5.28 (m)	2.09 (m)
1966	5.27	2.09
1978	4.94	2.06
1984	4.97	2.06
1991	4.80	1.98
1994	4.67	2.16

Given the fact that the flood control planning of the Mekong Delta should consider its relationship with social-economic planning, and the interaction between structural measures taken upstream and downstream, and various competing factors, an urgent task is to build up a comprehensive modeling system by which various alternatives can be assessed in an integrated manner. To achieve this goal, updated topographic, cross-sectional and land-use database should be established and made available to public. In this way, various research groups around the world may able to contribute their knowledge and know-how to the development of the Mekong Delta.

3. The Great Lake -Tonle Sap-Mekong system

The Great Lake is the largest freshwater lake in Southeast Asia. The lake covers an area of 2500km^2 in the dry season with an average depth of less than 2m, and 13000km^2 in the wet season with a maximum depth of 8-10m. The Great Lake is connected to the Mekong River at Phnom Penh via the Tonle Sap River. The Great Lake and Tonle Sap River system is one of the most important economic and natural resource of Cambodia, and one of the world's most unique. The Tonle Sap-Great Lake system naturally regulates the Mekong flood approximately 20% every year. The Mekong floods at Phnom Penh during some four months (June-September) vary between 150 and 300×10^9 m^3, of which the reverse flow to the Lake is between 35 and 65×10^9 m^3. The Tonle Sap-Great Lake system has been playing so far the greatest role of the Mekong flood regulation.

The lake is surrounded by dense and semi-dense forests, which is called floating forest by the local residents. The nature of the forest varies from a continuous cover of big trees to an open cover of shrubs. During the wet season, the forest is flooded, but the trees are not submerged according to the interview with local residents. This indicates a problem when applying the remote sensing technique to detect the lake surface area. A commonly used approach to detect the water edge is based on surface roughness because different roughness will give different reflection to microwave. However, in the Great Lake, this approach may lead to a wrong reading since the flooded surface area is shaded by the floating forest. At present, more than 10 million land mines are still not removed in Cambodia, so that field survey could be pretty risky. Given this condition, it is preferable to use the remote sensing method to monitor any change in this region. Thus, it presents a research task to Japanese engineers as to how to develop an improved method which takes the forest shading into consideration.

According to the studies by Carbonnel, the total sediment deposition in the Great Lake is 4.7×10^6/year, this would produce a bed aggradation of around 0.3 to 0.5mm/year. The study by M.Imre Csara, FAO Fish Expert in 1990 indicated that the deposition in the bed of Great Lake was occurring at a rate of 4cm/year due mainly to the intensive deforestation. Although this figure may be overstated since the lake would disappear with this rate in 10 years, it may be reckoned as a warning signal. In Cambodia the current deforestation rate is estimated at 2500km^2, or 1.4% of the total land. According to Schmid, the forest in the northern part of the lake has already degraded into a secondary forest.

As with all major rivers in humid tropical regions of Asia, the Mekong river has very high rate of sediment transport, principally suspended sediment in its lower reach. A better understanding of the characteristics of these sediments and their transport mechanisms in the complex Mekong-Tonle Sap-Great Lake system is of vital importance for planning purposes. Based on the review of available documentation, it can be stated that suspended sediment transport rates in the lower Mekong river are increasing slightly. At Snoc Trou which is near the mouth of the Great Lake, there has been aggradation of the bed, which is caused by: The discharge of sediment-laden flood water coming from the Mekong creates a delta due to the sharp decrease in velocity and turbulence, and the Stung Sen tributary, one of the most import contributing rivers in the catchment of the Great Lake, discharges also at this location. Because Stung Sen transports coarser sediments than those of the flood flows in Tonle Sap, the corresponding deposits are not easily eroded by Tonle Sap flood flow.

Considering the deforestation-induced bed rise in the Lake and sediment deposits at the lake entrance, it can be expected that the flood regulation capacity of the Great Lake would be seriously reduced. It should be pointed out that the sampling stations for sediment in Cambodia and Vietnam are very sparsely distributed in comparison with the conditions in Thailand, as shown in Figure 2.

Fig.2 Sampling stations for sediment in the Delta

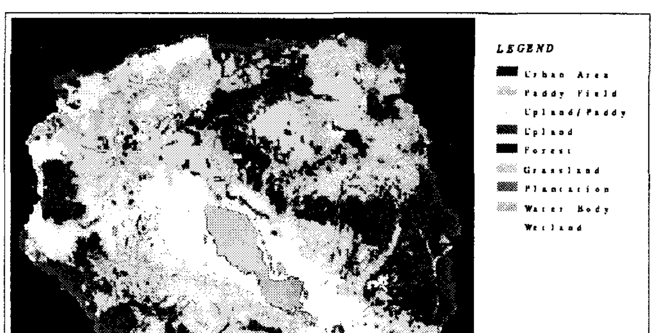

Fig.3 Land-use map on the watershed of the Great Lake

Figure 3 shows the land-use pattern on the watershed of the Great Lake. The source data is obtained from the "Global Map" database, which covers all over the world with a ground resolution of 1km × 1km, and contains fundamental data such as land-use, elevation, drainage systems/river basin and administrative boundaries. As can be observed, the urban area in the catchment of Great Lake is virtually non-existent currently. Forest and grassland share more than 50% of the drainage area. With the digital elevation data, the river network on the watershed of Great Lake is generated by GIS Arc/Info system as shown in Figure 4.

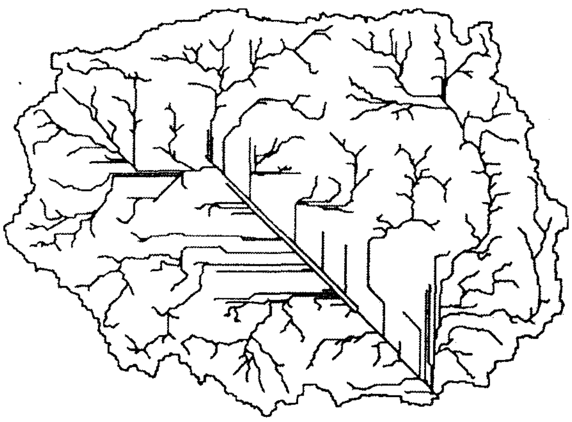

Fig.4 Generated stream network around the Great Lake

Then, a distributed hydrologic model is applied to assess the water balance on the watershed of the Great Lake. In the model, the catchment area is divided into 42-sub-catchments. The area of sub-catchment ranges from 531km^2 to 4709km^2. Each sub-catchment is further divided into a number of flow intervals along the flow path. Within each flow interval, there are several river segments. A hillslope element is then assumed to correspond to a river segment, so that a flow interval can be simply represented by a series of hillslope elements. The number of hillslope elements depends on the number of streams within the same flow path. The model consists of three modules: (1) spatial distribution module, (2) hillslope module, and (3) river routing module. The spatial distribution module deals with catchment spatial variations such as topography, land use, soil properties, and meteorological conditions. The hydrologic processes that occur in the hillslope elements such as interception, evapotranspiration, ground water flow are described by the physically-based formulations. The from river routing module employs the kinematic wave method. For model details, readers are refer to reference 10. The simulated annual water balance for 1992 is summarized in Table 2.

Table 2. Annual water balance (1992)

Components	In mm	In %
Runoff	314.0	22.5
Evaporation	1081.2	77.3
Change of storage	2.5	0.2

As can be seen from the table, the runoff from the drainage area of the Great Lake is $26.5 \times 10^9 m^3$, and it is in close agreement with recorded data.

4. The river reach from Phnom Penh to the sea

The length of the river stretch from Phnom Penh to the sea is about 325km, both the Mekong and Bassac are alluvial. The water surface slope amounts to 2 to 5 cm per kilometer under flood conditions. Along this reach, the Mekong river is constrained by roads. Exchange of water with the flood plains and Bassac river is, therefore, concentrated at some interlinking canals. The major link between the Mekong and Basaac is the Vam nao river, capable of conveying more than 10,000m^3/s. In Cambodia, a road on the right bank of the Bassac river is present having some culverts through which water exchanges take place between the flood plains and the Bassac river. On the left bank there is no dike so that the Bassac river water has free access to the flood plains between the Mekong and Bassac rivers. The flood plain between the Mekong and Bassac rivers in the Vietnamese part is small compared with the ones in the Cambodia part of the Delta, because in the Vietnamese part both the Mekong and the Bassac are well constrained by embankments, which are hardly ever overtopped. The flood plains on the southwest side of the Bassac river are constrained by the Bassac river, the road Phnom Penh-Takeo-Chau Doc, the Gulf of Thailand and the sea. It covers large areas of the Cambodia and Vietnamese Delta. Exchange of flood water with the Bassac river takes places at locations about 30, 46, and 85km downstream of Phnom Penh, and via a number of irrigation canals in the Vietnamese delta having open connections with the Bassac river. In the Cambodia part, the flood water of the Bassac flows mainly via the Prek Ampel and the Chau Doc river, back towards the Bassac and the Long Xuyen Quadrangle in Vietnam. Near the city of Takeo the Takeo river enters the flood plain. The flood plain is intersected by a number of roads, creating some local storage areas. In the reach from Phnom Penh to the sea, channel cross-sectional data and flood plain configuration at more than 40 locations has been collected and processed in accordance with MIKE 11 system. A typical simulation-ready cross-section with storage area is shown as below:

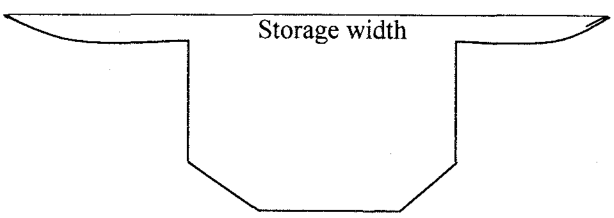

Fig.5 Typical cross-section used in the simulation

Those data are collected by Dr. Ca, and now available from REEL upon request.

5. River network simulation

The Mekong Delta water system consists of main branches, the dense canal network and flood plains. Facing the complexity of the problem and the lack of necessary data, the present numerical study focuses its attention on the main branches from Phnom Penh to the sea. The simulated river system is schematized in Figure 6. As can be seen that the tributaries in the Plain of Reeds and Long Xuyen are not modeled in the present study, however, the storage effect of flood plains are considered in the model. The widths of these branches vary from one kilometer at the upstream parts to a few kilometers at the river mouths. The average depths are about 6-7m. The numerical simulation is performed with the MIKE 11 system. The model is calibrated for April, 1988 at several stations by adjusting the value of Manning roughness and lateral flows. The recorded discharge at Phnom Penh is used as upstream boundary condition, and for downstream boundaries at river mouths, observed water level are used. The figure 7, 8 show the comparison of daily maximum water level between computed and observed at Tanchou and Chau Doc station. In view of the omission of many canals and the uncertainty of data accuracy, the simulated results may be considered to be preliminary but qualitatively acceptable.

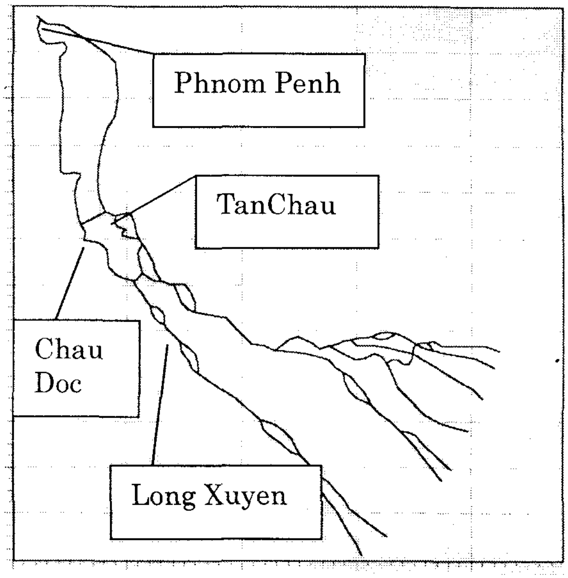

Fig.6 Schematic of main branches from Phnom Penh to the sea

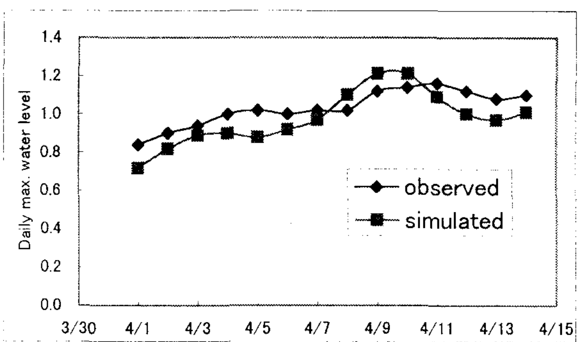

Fig.7 Comparison of maximum water level at TanChou

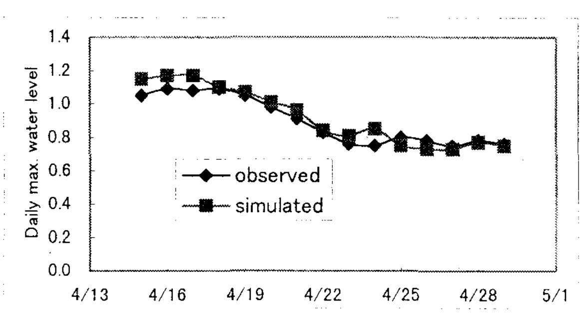

Fig.8 Comparison of maximum water level at ChauDoc

Then, the MIKE 11 is applied to study the impact of reduction of the Great Lake flood regulation capability on downstream flood magnitude. According to the Lower Mekong Hydrological Yearbook issued by the Mekong River Commission, the historical maximum discharge at Stung Treng, upstream of Phnom Penhn was 66000m^3/s. As mentioned in previous section, currently the Great Lake regulates approximately 20% of the Mekong flood water. Assuming different reduction rates of the flood regulation capability by the Great Lake, the response of water level at downstream station to the different scenarios are simulated. The Figure shows that at Long Xuyan, the water level rises in a nearly linear way as the lake's regulation capacity decreases. For extreme case when the lake stops functioning completely, the water level would rise as much as 1m. A similar situation has occurred last year in Yangtze River, China. Along the middle reach, there situates the Dongting Lake which has been playing very important role in diverting flood water from Yangtze River. Due to intensive land reclamation, the storage of the Dongting Lake has reduced by 40% over the past several decades. Downstream of the junction between Yangtze River and the Dongting Lake, the water level at Chenglingji station in 1998 flood was about 1.5-2.0m higher than that in a similar big flood occurred in 1954. The 1998 flood took the lives of 1320, and seriously affected the country's economy. 1998 flood in Yangtze River is a good lesson for people in the Delta to learn in order to prevent similar disaster form happening in the Mekong Delta.

Fig.9 The regulating effect of the Great Lake

6. Conclusion

The conclusions can be made as following:

1. Floods in the Mekong Delta are dependant on features of the whole region such as the regulation effect of the Great Lake, and the tidal regime. It is very unique in the sense that the socia-economical development in the Delta is so heavily constrained by water resources management.
2. The importance of the Great Lake in regulating the Mekong flood is analyzed with a numerical model. It is shown that the reduction of the lake's regulation capacity, which could be caused by on-going deforestation, may lead to very serious consequence.
3. The land-use data on the watershed of the Great Lake is classified, the river network around the lake is

generated with the GIS Arc/Info system. Preliminary water balance analysis in the catchment of the Great Lake is carried out subsequently. They are necessary steps toward comprehensive study on the watershed of the Great Lake. Besides, a problem in applying the remote sensing technique to monitor the change of the lake surface area is pointed out.

Finally, it should be mentioned that the complex and unique nature of the Mekong Delta requires more and hard study for its full understanding. As the Mekong River Basin has increasingly become a focus of regional development, the detailed apprehension of key issues to sustainable development is needed in order to integrate water resources management into economical and social development processes.

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