

Morphological Characteristics and Development of the Estuary Area of Lam River, Vietnam

Hai Nguyen Tien

Abstract—On the basis of the structure of alluvial sediments explained by echo sounding data and remote sensing images, the following results can be given: The estuary of Lam river from Ben Thuy Bridge (original word: Bến Thủy) to Cua Hoi (original word: Cửa Hội) is divided into three channels (location is calculated according to the river bank on the Nghe An Province, original word: Nghệ An): i) channel I (from Ben Thuy Bridge to Hung Hoa, original word: Hưng Hòa) is the branching river; ii) channel II (from Hung Hoa to Nghi Thai, original word: Nghi Thái) is a channel develops in a meandering direction with a concave side toward Ha Tinh Province (Hà Tĩnh); iii) channel III (from Nghi Thai to Cua Hoi) is a channel develops in a meandering direction with a concave side toward Nghe An province. This estuary area is formed in the period from after the sea level dropped below 0m (current water level) to the present: i) Channel II developed moving towards Ha Tinh Province; ii) Channel III developed moving towards Nghe An Province; iii) In channel I, a second river branch is formed because the flow of river cuts through the Hong Lam- Hong Nhat mudflat (original word: Hồng Lam -Hồng Nhất), at the same time creating an island. Morphological characteristics of the estuary area of Lam River are the main result of erosion and deposition activities corresponding to two water levels: the water level is about 2 m lower than the current water level and the current water level. Characteristics of the sediment layers on the riverbed in the estuary can be used to determine the sea levels in Late Holocene to the present.

Keywords—Lam River, development, Cua Hoi, river morphology.

I. INTRODUCTION

THE area where the river flows into the sea belongs to the coastal zone, which is strongly influenced by the interaction between lithosphere, atmosphere and hydrosphere. Under such conditions, the morphology and changes of the estuary are strongly caused by erosion and sediment accumulation. These activities take place depends mainly on many factors, of which sea level is the main factor

Lam River (another name is Ca River) is the largest river in Bac Trung Bo (original word: Bắc Trung Bộ) area of Vietnam with a length of 512 km [6]. This river originates in the Truong Son Mountains in the West, where the height is over 2,000 m. Lam River flows in the Northwest - Southeast direction from upstream to Duc Tung commune (Duc Tho district, Ha Tinh Province) (original word: Đức Thọ, Hà Tĩnh), here it integrates with the La River [6]. The channel from Duc Tung commune (original word: Đức Tùng) to Cua Hoi area, the river turns Southwest – Northeast and flows into the East Sea. The study area is the channel from Ben Thuy Bridge to Cua Hoi area (see Fig.1A).

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Lam River has an average annual water volume of 21.90 km³ (corresponding to an annual water flow of 688 m³/s), an annual flow module of 53.8 l/s.km² [7]. The river flow regime depends on the season: the rainy season (usually causing floods) mainly from June to November, accounting for about 74-80% of the annual flow). The turbidity of the Lam River water is up to 900-1,200 NTU [7].

The dynamic regime of the sea where the Lam River flows is influenced by the monsoon regime. The wave height here is 1.5 – 3 m and often accompanied by sea level rise of 1 - 1.5 m [7]. The tides in this area are irregular semi-diurnal regimes with magnitudes of 2.0 - 2.5 m. Salt water encroaches deeply and affects Trang market in dry season (original word: Chợ Trang). The length from Trang Market to Cua Hoi area is 32 km.

In the sea of Nghe An Province and Quang Binh Province (original word: Quảng Bình), the coastal currents in the Winter are Northwest - Southeast with a speed of 1.1 - 1.4 m/s, while in the summer, these currents are Southeast - Northwest and the speed is 0.8- 0.9 m/s [6]. Especially in this area, the expression of modern tectonic is quite strong, in which, the speed of subsidence in Nghi Loc Basin (original word: Nghi Lộc) at Early Holocene is about 0.058 mm/year and 5.75 mm/year at Late Holocene [1].

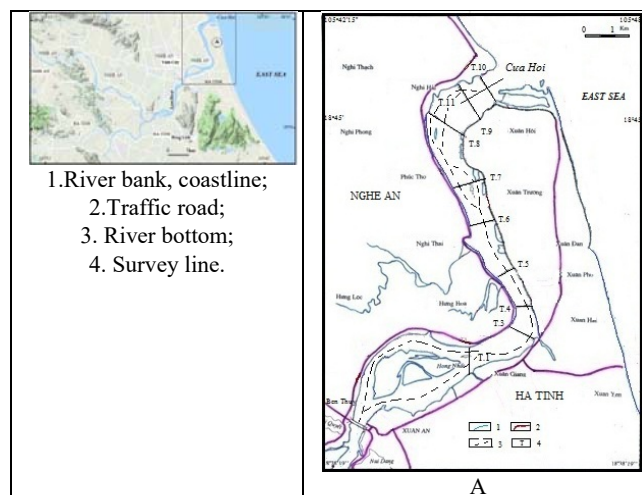


Fig.1 Scheme showing Lam River and the Study Area (A)

To the present, there have been some studies on the estuary area of Lam River, that is the study of Hung H. M et al., 1991 [2] (estuarine morphology), Son P. Q, 2002 [4] and Hai N. Tand Duong D. C, 2010 [1] (shoreline erosion and changes in

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estuaries and adjacent coastline) etc. Many issues about this river have not been paid attention, especially why the river has two branches in the estuary area and river-bed sediment activity.

Among the contents that need to be further researched in the estuary area of Lam River, the development of estuaries and riverbeds is of high scientific and practical value. The results of the paper may contribute to elucidating the fluctuations of sea level in Late Holocene – Present and orientation for proposing solutions to alleviate riverbank erosion.

II. MATERIAL AND METHODS

The characteristics of the alluvial ground (structure, development direction, material composition etc.) are the result of interactions between river flow dynamics and river levels and

river morphology. Such as, on the map, the development of the alluvial flats along the riverbank over time creates layers of sediment. These sediments are distributed in the band form, arc and annular shape (at convex side) according to composition, color etc. (Fig.2).

On the vertical section, the accumulating sediment layers are overlapping with each other over time. This structure is shown quite clearly on the section of echo sounding equipment: small fine materials (mud, clay) have light - colored signals, while hard materials have bold signals (Fig.3).

Morphological characteristics of the river, especially the structure of alluvial flats of the river are clearly shown on the remote sensing image and in the field (Fig.1B).

On the basis of the characteristics of the river morphology and the structure of the mudflats, it is possible to explain the development process and changes of the river in certain times.

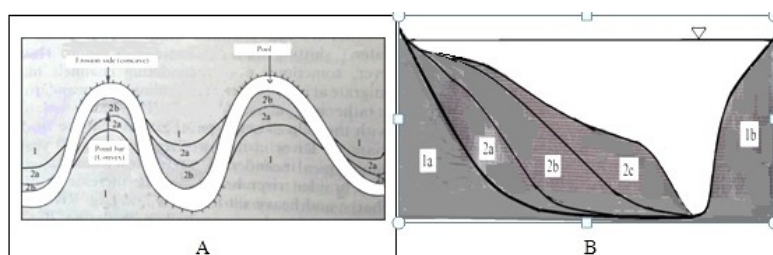


Fig. 2. Scheme showing meandering channel and erosion - accretion activity [5] (A) Meandering channel; (B) Cross-section of meandering channel; 1. River-side; 1a. convex side; 1b. concave side; 2a, 2b. The layers of sediment over time

Materials and data used in the article are the survey materials by the author in August 2008, April 2014, June 2019 and inherit some documents of other authors. The Remote sensing image used is image of Google Maps.

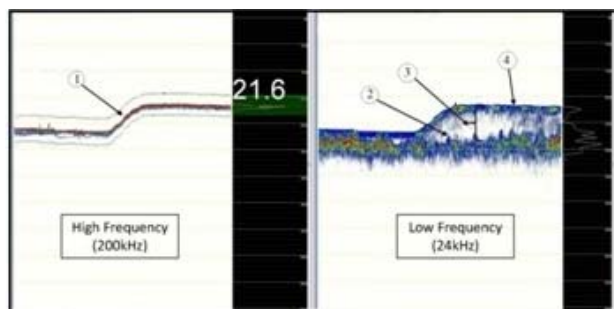


Fig. 3 Scheme showing echo sounding data [8]. (1) Precision determination of the floor from the high frequency acoustic; (2) Hard floor; (3) Soft mud layer; (4) First return of the acoustic signal

III. RESULTS

A. Morphology of River and Bottom Characteristics

Lam River from Ben Thuy bridge to Cua Hoi areas an S – shaped meandering channel with a length of 21,820 m and a width of the river from 500 to 2,200 m (Fig.1A).

According to the recorded echo sounding data (10 lines cross the river and 2 lines along the river), it shows: The depth of the river bed ranges from 5 m to 12m, in which the deepest places are lines T.5, T.6 and T.9.

Along the river, in some sections there are two bottoms (Fig. 1A). That is the channel near Ben Thuy bridge, the channel in Xuan Truong commune (Ha Tinh Province, original word: Xuân Trường) and the channel in Nghi Giang commune (Nghe An Province, original figures: Nghi Giang).

The cross-section of channel is mainly in a V-shaped deflection, but in the Cua Hoi area, the cross-section of channel has a balanced U-shape (Fig.4H). Below are some typical river cross-sections.

B. Cross Section of Channel

Section T.1: The width of channel is 1,250 m, the river has two branches, but merges at the beginning and the end. The main branch of Nghe An Province is a meandering channel with a bottom depth of over 8m, while the second branch is a straight channel in Ha Tinh Province with a depth of about 5 – 6 m (Fig.4A).

Section T.2: (position: near Section T.1) similar to Section T.1, but the signal is not clear.

Section T.3: The width of channel is 799 m and the maximum depth of about 8 m. The river's cross-section has a V-shaped profile, which deflects to Ha Tinh Province (Fig.4B). On the riverbed on the left side (Nghe An Province), the sedimentation activity is quite strong with two layers of sediments up to 4 m thick, while the bottom on the Ha Tinh right side Ha Tinh Province, is strongly eroded.

Section T.4: The width of channel is 782 m and the maximum depth of about 12 – 13 m. The river's cross-sectional shape and

the activity of accretion and erosion is similar to that in section 3 (Fig.4C).

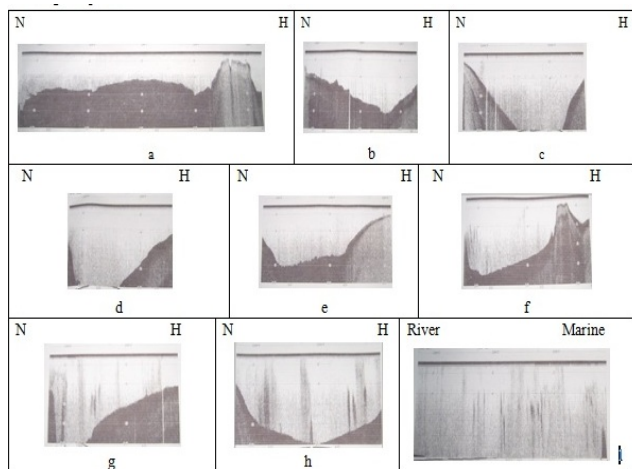


Fig. 4. Scheme showing echo sounding data of cross-section of Lam River
 (Length of the survey line: see Fig. 5)

Section T.5: The width of channel is 816 m and the maximum depth of about 10 -12 m. The river's cross-section has a V-shaped profile, which deflects to Nghe An Province (Fig.4D). On the riverbed on the Ha Tinh Province, the sedimentation activity is quite strong with two layers of sediments up to 3.8 m thick, while the erosion was strong in the side of Nghe An province.

Section T.6 and T.7: The width of channel is 820 m and 870 m (Fig.4E and Fig. 4F). Cross-sectional of the channel has an unbalanced U-shape the depth of the bottom is about 6 m and 9 m activity of erosion is not strong Northern side and accretion of sediments occurs in the South side.

Section T.8: The width of channel is 1,100 m and the bottom depth is 11 m. The V-section deflects to the left side. The features of this section are similar to that of section T.9.

Section T.9: The width of channel is 885 m. Cross-sectional of the channel has a V-shape that deflects to left side (on Nghe An Province) and forms a depression about 12 m of the deep (Fig.4G) etc. River side on Ha Tinh Province has a small slope on which the deposition has created two layers of sediment with a total thickness of about 4 m).

Section T.10: The width of channel is 850m (Fig.4H). River cross-section of channel has a symmetrical U-shape with a maximum depth is about 10 m. On this terrain, there is no accretion of sediments.

Addition to the above cross-section of river, the Section T.11 (the section along the river) in Cua Hoi area (Fig.1A and 4I) shows that here, the riverbed has a raised ridge about 40 m and is higher than the bottom of channel about 4 m.

IV. DISCUSSION

On the basis of the above results can indicate that:

At the estuary area of the Lam River, the morphological characteristics of the river and the river bed, the width and depth of the river are different at different channel.

Two layers of sediment on the convex riverbed of the channel formed in two successive phases, corresponding to two different water levels. These two water levels correspond to two sea levels at the same time where the second water level is the current water level.

Hong Lam-Hong Nhat Island (near Ben Thuy Bridge, Fig.2) is essentially a riverbank alluvial ground and it was formed in the time before the second river branch appeared.

From the above statement, the following assessment can be made:

The Lam River (from Ben Thuy bridge to Cua Hoi area) can be divided into three channels (coordinates are calculated according to landmarks on the river bank of Nghe An province).

+ Channel branching (I), from Ben Thuy bridge to Hung Hoa commune, Nghe An province (18°6'29.14 N/105°7'49.195 E): length 7.364 m, width 526-2.200m, depth of the bottom: 8-9 m,

+ Channel meandering II, from Hung Hoa commune to Nghi Thai commune, Nghe An Province (18°7'12.752N/105°7'49.710 E): length 6,570 m, width 520-600m, depth of the bottom 8-12m, meandering coefficient 1.25. The cross-section of river has a V-shape with a convex side in Nghe An Province and concave side in Ha Tinh province.

+ Channel meandering III, from Nghi Thai to Cua Hoi area: length 7,364 m, width 600-1,200 m, depth of the bottom: 9-11.5 m, meandering coefficient 1.1. The cross-section of river in V-shape, changed to U-shape and reduced bottom depth at Cua Hoi area, convex side in Ha Tinh Province and concave side in Nghe An Province.

According to the authors [3], the sea level was at an altitude of 4 - 5m at about 5,000 years ago and 3m at about 3,500 years ago (higher than current water level). After this time, the sea level fell below the present sea level. Also according to these authors [3], the sea level was about 2 m lower than the current sea level about 2,000 years ago. So, two layers of sediment on the riverbed (at the convex sides) were formed corresponding to this sea level and present sea level. The sedimentation rate is about 1.3mm/year if the time when the river water level drops below the current water level is 3,000 years until now. This sedimentation rate is acceptable.

Along with the time existing above water levels, the Hong Lam - Hong Nhat mudflats were formed and developed. Then, due to the fluctuations here, river branch two was formed and cut through the Hong Lam - Hong Nhat mudflats. The change in the channel I can be due to the subsidence of the Nghi Loc Basin or the flood water of the river too strong during sea level rise. Fig. 6 shows the change of the Lam River the change of the river from about 4,500 - 5,000 years ago to the present and Fig. 5 shows the variation in river cross-section during this period.

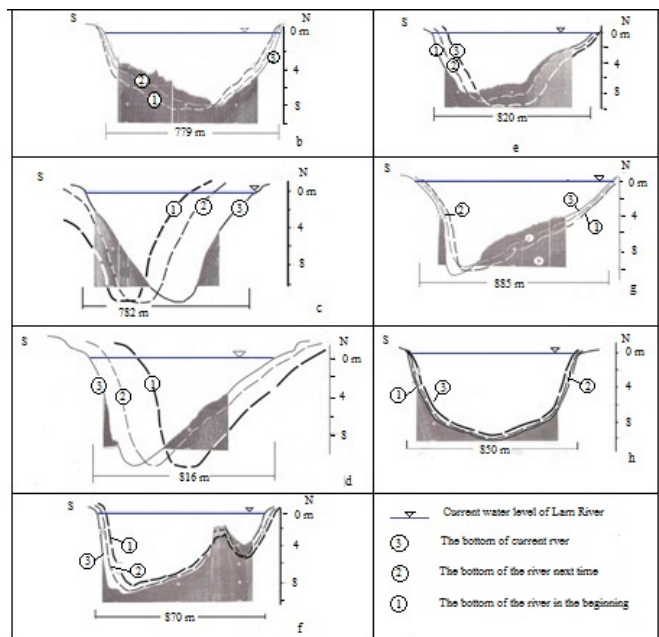


Fig. 5 Scheme showing the change of the river bottom over time: 1. River bottom over 3,000 years ago; 2. River bottom 3,000 years ago; 3. River bottom today. River cross sections: line T.3 (b), line T.4 (c), line T.5 (d), line T.6 (e), line T.7 (f), line T.9 and line T.10 (h)

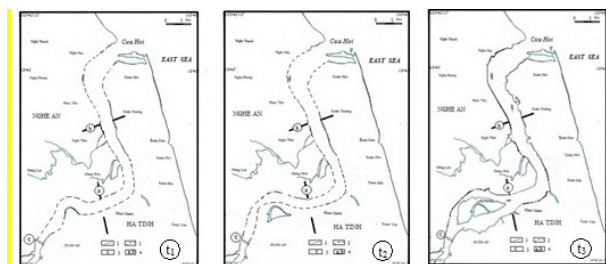


Fig. 6 Scheme showing process of morphological change of Lam River over time from t_1 to t_3

V. CONCLUSION

Lam River from Ben Thuy Bridge to Cua Hoi area is an S-shaped meandering (meandering coefficient of 1.45). Cross-section of river has an unbalanced V-shape with a depth from 8 m to 12 m. Particularly at the end of the river (Cua Hoi area), cross-section of channel is quite balanced and there is a decrease in depth with raised ridge 4 m above the bottom.

The present river morphology and river bed cross-section are the result of river development in the period from the time sea level receded from the current continent up to now. During this period, the riverbeds at the convex sides were deposited with two layers of sediments with the maximum total thickness of 4m corresponding to two different water levels. And in the channel from Ben Thuy Bridge to Hung Hoa commune, there was a process of water passing through the coastal mudflats to create a second branch about 6 km long.

ACKNOWLEDGMENT

The authors would like to thank the Project: code NVCC24.03/20-20 that has supported to complete this article.

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