The equilibrium stages of headland-bay beaches in the coastal provinces of Vietnam

Dang Van To[1]

Abstract: The study presents the application of parabolic model using MEPBAY package to estimate the equilibrium stages of the headland-bay beaches in Binh Thuan and Ninh Thuan provinces. The model results showed that the present shorelines in Phan Thiet, Binh Thuan are not under equilibrium stages. As for Binh Thuan, the shoreline changes with and without structures in Phan Thiet and Hon Rom beaches were predicted. Phan Thiet beach is a dynamic equilibrium; Hon Rom beach is a static equilibrium. As for Ninh Thuan, Phan Rang beach is not an equilibrium beach. If the jetty in the downdrift of Phan Rang beach were constructed, the beach would be stabilized.

Key words: Headland-bay beaches, parabolic model, MEPBAY, Binh Thuan, Ninh Thuan, Vietnam.

1. Introduction

Binh Thuan and Ninh Thuan, formerly called Thuan Hai, are two among many coastal provinces in the central southern Vietnam which are being developed rapidly for non-smoking industries such as hotels and tourism. Binh Thuan is surrounded by Lam Dong and Ninh Thuan in the north, East Sea (Biển Đông) in the east, Dong Nai in the west and Vung Tau in the south (Figure 1). Comparatively, the north and the south of Ninh Thuan are Phu Yen and Binh Thuan; the west and the east of Ninh Thuan are Lam Dong and East Sea (Figure 2). The physical conditions of Binh Thuan and Ninh Thuan are relatively similar. They have two seasons, high temperatures, short and small rivers, many large sand-dunes, strong winds and long stretches of sandy beaches.

Figure 1. Location of Binh Thuan

Figure 2. Location of Ninh Thuan

Binh Thuan has six main river mouths (Long Huong, Phan Ri, Phu Hai, Thuong Chanh, Tan Hai and Lagi) and many headlands (La Gan, Mui Nho, Mui Rom, Mui Ne, Mui Ke Ga) along 190km coastline. Binh Thuan has constructed many coastal works to develop the local fishery industry and ensure the navigation safety through the river mouths. Also, these structures aim at controlling the beach erosion and stabilizing the estuaries (e.g. seawalls in Ham Tien, breakwaters in Ca Ty and Lagi). Recently, Binh Thuan has developed its tourist industry. Many luxury resorts and highly standardized hotels have been being erected along the coastline (e.g. Novotel hotel, Swiss and Russian villages) [1].

[1] University of Natural Sciences, Ho Chi Minh City, Vietnam; E-mail: dangvanto@hcmuns.edu.vn

All of these have rapidly influenced the beach responses in Ham Tien, Doi Duong, Phan Thiet. The successes of breakwater/jetty to stabilize the river mouths in Phan Thiet and Lagi have caused the severe erosion in the downdrift of the jetty and the siltation in the Lagi estuary. The beach recess in Ham Tien-Mui Ne which is controlled by the seawall has shifted the erosion spots to somewhere further down drift of the shore (e.g. Phu Hai or Doi Duong).

The situation in Ninh Thuan is similar to Binh Thuan. Many coastal works have been constructed to develop the local fishery industry and maintain the navigation safety through river mouths such as two jetties in Song Ca, sea dikes in Ca Na and hotels along Ninh Chu beach.

Without adequate data, to evaluate the equilibrium stages requested by the local authority for long-term shoreline changes and infrastructure planning along the sandy beaches in Binh Thuan and Ninh Thuan are challenging tasks. However, the satellite images provided by open sources of WebGIS (e.g. GoogleEarth®) can be used preliminarily to estimate the long-term shoreline changes of the headland bay beaches in these coastal provinces.

In this paper, the physical conditions of hydro-meteorological and geomorphologic conditions in Binh Thuan are introduced. The study then describes the theoretical background of the parabolic model for evaluating shoreline changes. The computational results of shoreline-equilibrium stages along Binh Thuan and Ninh Thuan beaches with and without structures are discussed.

2. Physical Conditions in Phan Thiet-Binh Thuan

2.1 Hydro-Meteorology Conditions

Since the physical conditions in Binh Thuan and Ninh Thuan are quite similar. It would be consequently appropriate to briefly describe the natural conditions in Phan Thiet, Binh Thuan.

Phan Thiet has rainy and drying seasons. As for winds, the 16-year statistical data from 1978-1994 for the average frequencies, wind speeds and wind directions are shown in Table 1. From V-X the wind speeds are calm around 2.4-3.4m/s and in W/SW directions. From XI-IV the wind speeds are gusty about 4.7-5.7m/s and in E/NE directions [4].

Table 1 Average Frequency, Wind Speed and Wind Direction in Phan Thiet (1978-1994)

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Freq/yr(%)	47.9	49.7	43.6	29.6	16.6	50.6	54.0	64.5	41.1	16.4	29.9	37.5
Speed(m/s)	5.2	5.5	4.9	4.7	2.4	3.4	2.9	3.0	3.1	3.1	5.7	5.1
Direction	E/NE	E/NE	E/NE	E/S	W/S	W/SW	W/SW	W/SW	W/SW	W/E	E/NE	E/NE

As for storms, Table 2 shows the 85-year statistical data from 1911-1995 for the number of storm hitting the Phan Thiet coast. The total numbers of storm over 85 years are 23 and the most stormy seasons are X-XII. Very few and rare storms occur in other months.

Table 2 Average Storm Number and Frequency in Phan Thiet (1911-1995)

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Storm No.	0	0	1	1	1	0	0	0	1	7	8	4	23
%	0	0	4.3	4.3	0	0	0	0	4.3	30.5	34.9	17.4	100

The average wave height in Phan Thiet is about 0.25-1.0m in the swell seasons and 0.5-3.0m in the storm seasons. As for tides, one month data from 26/05/81-26/06/81 shows tides as semi-diurnal tides of 2m range (Figure 3).

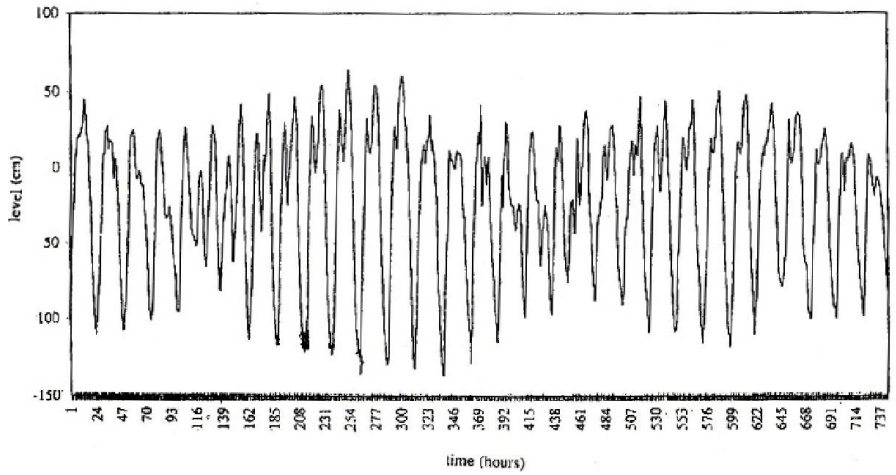

Figure 3. Tidal Elevations in Phan Thiet - Binh Thuan

2.2 Morphological Conditions

The coastal sediments have closely correlations to the river sediments. In Binh Thuan, the rivers are steep and short. The river sediment are transported and deposited in river mouths. Without human's interferences, the river mouths change their courses to the south and lagoons can be formed. Recently, the sand pumping and filter for construction purposes in the rivers have been over explored. This causes the re-orientation of the river and the unpredictable erosion of the river and unbalance of the coastal sediment budget. In Binh Thuan, the coastal sands are blown off by winds. As ebb tides, the beach exposes and very quickly becomes dry. Under strong winds along the coasts, coastal sands can migrate inland and form sandy dunes.

3. Methodology

3.1 Theoretical Background

There are several models to fit the field and laboratory data for the headland-bay curved shorelines: spiral model, tan-hyperbolic model and parabolic model. Once the upcoast point is fixed, the equilibrium curved shoreline can be predicted. Among these models, the parabolic model replied on the physical interpretations is preferred ([2],[3],[6]).

Silvester and Hsu [7], Hsu and Evans [5] used 27 data from the field surveys and experimental studies for headland-bay shorelines to develop a parabolic model as follows:

$$\frac{R}{R_0} = C_0 + C_1\left(\frac{\beta}{\theta}\right) + C_2\left(\frac{\beta}{\theta}\right)^2 \quad (1)$$

where two basic parameters in Eq. (1) are the wave angle β (dominant wave direction) and the control line R_o. The wave angle β is the reference angle defined by the wave direction and control line *Ro* (Figure 4). The control line connects the diffraction point (upcoast fixed point) and the downcoast fixed point along the relatively straight coastline. From this diffraction point, the ray of radius R can be drawn by varying θ with respect to β and R to produce a curved shoreline. The correlation coefficients C_o, C_1 and C_2 are determined by curve fitting from the field and laboratory data as the wave angle β changes (Figure 4).

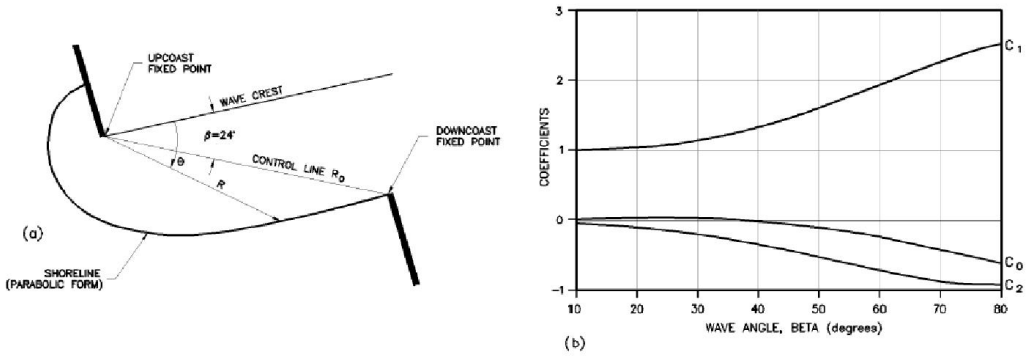

Figure 4. Parabolic model and correlation coefficients

The selection of upcoast and downcoast control points should be done carefully based on the images, bathymetry, geo-morphological conditions in the study area. For the downcoast control point, the selection is simple. However, for the upcoast control point, the diffraction point is not always obvious for selection. The reason is that sometimes the upcoast control point is submerged in the water instead of the apparent tip of the coastal structures. Once, the wave direction β and the control line R_o are determined, the equilibrium shoreline would be determined.

3.2 MEPBAY package

The educational package, MEPBAY version 1.0, was developed by Vargas, Hsu, Klein and Raabe using the Hsu and Evans' parabolic model (Figure 5). Prior to have the package, the shoreline equilibrium had been determined manually. As one intends to investigate the upcoast control points by trial and error, the investigation is quite time consuming. With MEPBAY, the model can be easily changed and the shoreline equilibrium can be rapidly estimated.

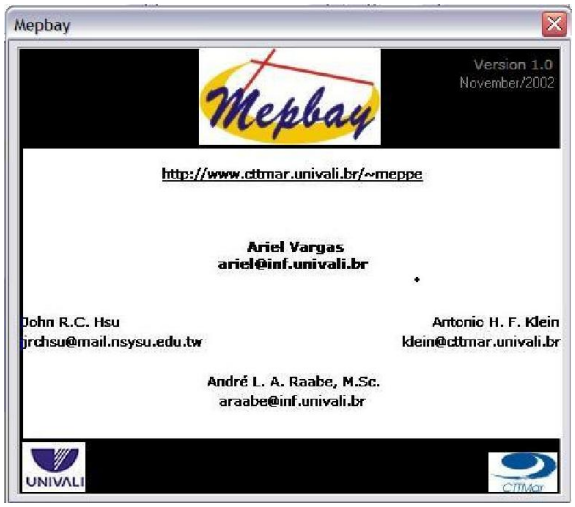

Figure 5. The group of MEPBAY developer

For adopting the MEPBAY model, following procedures are required:

- Load images

- Determine the beach orientation with respect to the wave direction
- Determine the upcoast control point, downcoast control point, an end point along the tangent to the beach
- Activate MEPBAY and estimate the curved shoreline by changing R and θ.

The MEPBAY interface and applied example are given in Figure 6.

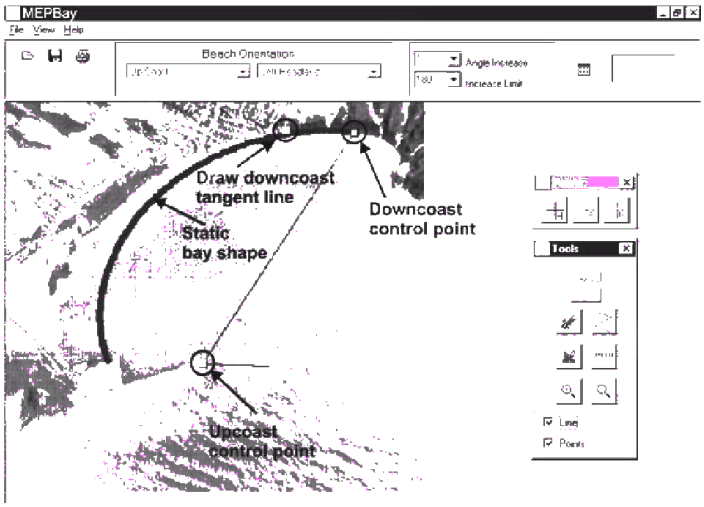

Figure 6. The interface of MEPBAY

4. Model Results

The parabolic model was applied to the headland-bay beaches along the Binh Thuan and Ninh Thuan provinces in order to estimate the equilibrium stage of the bay-shape shorelines.

4.1 Shoreline equilibrium stages in Binh Thuan

Two typical areas which are similar to the pocket beaches in Binh Thuan were selected for estimating the shoreline equilibrium stages: Phan Thiet beach (Mui Ke Ga – Mui Ne), Hon Rom beach (Mui Ne – Hon Rom).

Figure 7. Predicted shoreline for Phan Thiet bay

Figure 7 shows two estimated shorelines using the parabolic model for Phan Thiet beach from Mui Ke Ga to Mui Ne. In this figure, there are one actual upcoast control point and one virtual control point. The virtual control point is an imaginary tip of the structure which aims at stabilizing the existing shoreline. The dominant wave angle is β=41-46^o and the control line is R=20-25km. Two predicted shorelines have the same curvatures to the existing shoreline. From the fishery port to the Mui Ke Ga, the predicted shorelines match the

existing shoreline quite well. However, from the fishery port to Mui Ne, the predicted shorelines recess behind the existing shoreline. Over long period, the present shoreline tends to recede to the static equilibrium shoreline. From Figure 7, the artificial structure may not improve the threat of shoreline erosion.

Figure 8. Predicted Shoreline from Ong Dia to Mui Ne

Figure 8 and Figure 9 show the estimated shorelines from Mui Ong Dia to Mui Ne and from Mui Ke Ga to Phan Thiet fishery port. Two figures are drawn with actual control points and imaginary control points correspondingly. The existing shoreline is a dynamic equilibrium beach and tends to erode. If the imaginary coastal works were done for the beach from Mui Ke Ga to the fishery port and for the beach from Mui Ong Dia to Mui Ne, these beaches would be controlled properply without erosion.

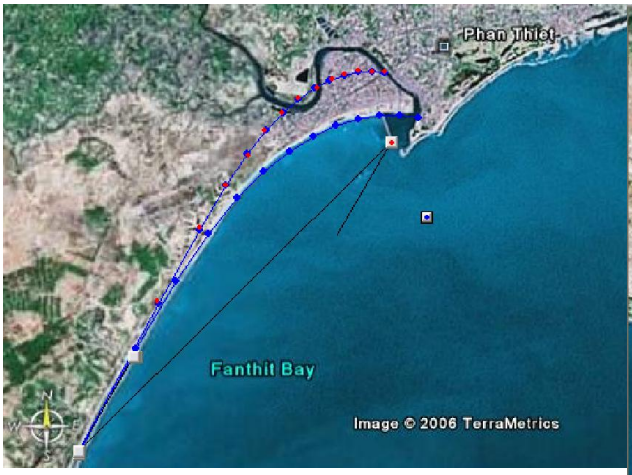

Figure 9. Predicted Shoreline from Mui Ke Ga to Fishery Port

Figure 10. Shoreline From Mui Ne to Hon Rom

Figure 10 show the predicted shoreline compared to the present shoreline for Hon Rom beach. There are two upcoast control points in Figure 10. If only one control was used, the predicted shoreline would be unequilibrium. However, there is another diffraction point in the left side of Hon Rom; by combination, the integrated shoreline shows the equilibrium stage of the present shoreline in Hon Rom. Thus, Hon Rom is a static equilibrium beach.

Detail discussions about various situations of the present shoreline compared to predicted shorelines in Figure 8, 9, 10 are presented in the author's study [2].

4.2 Shoreline equilibrium stages in Ninh Thuan

The study area of Ninh Thuan is the bay-shaped beach in Phan Rang, Ninh Thuan. From the satellite image, there are two jetties to stabilize the Song Ca river mouth. The right (north) jetty (about 800m) in the updrift is shorter than the left (south) jetty (about 1000m) in the down drift. From the image, the alongshore sediment transport flows from the right (updrift) to left (down drift) directions which obviously follows the general current system in Ninh Thuan and Binh Thuan. The sand bypass due to the short length of the north jetty is also can be seen (Figure 11).

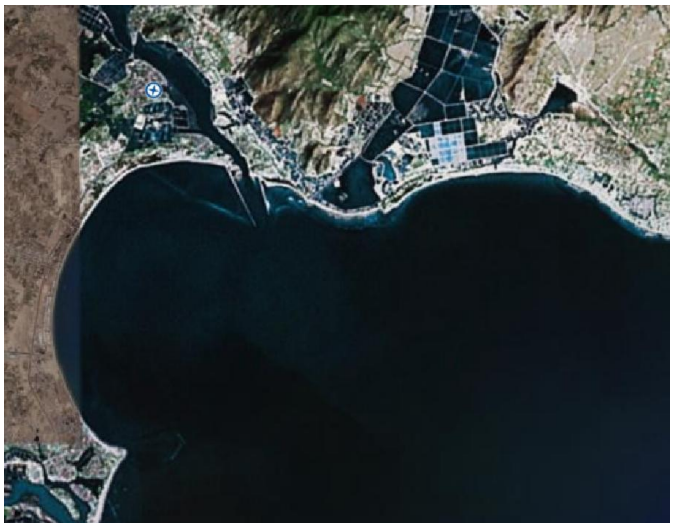

Figure 11. The Study Area in Ninh Thuan

Figure 12 shows the predicted shorelines with and without the presence of structure in the updrift of Phan Rang bay-beach. Without the structure, the predicted shoreline is retreated landward about 1000m. With the structure, the shoreline is shifted about 800m to the present existing shoreline. However, the predicted shoreline is still about 200m landward of the present shoreline. Although the jetty has worked effectively to reduce the tendency of shoreline recess, the risk for shoreline erosion still exists. The shoreline retreat may also be anticipated by the interception of alongshore sediment from the right jetty.

Figure 12. Predicted Shoreline in the Updrift of Ninh Thuan Beach

Figure 13 shows the predicted shorelines with and without the presence of imaginary structure in the downdrift of the Phan Rang bay-beach. Without the structure, the predicted shoreline is retreated landward about 800m. With the 1000m- long structure, the predicted shoreline well matches the present shoreline.

As a result, the existing Phan Rang bay-beach is a dynmaic and unequilibrium shoreline. Over long period, the shoreline in Ninh Thuan tends to retreat not only in the updrift but also in the down drift of the beach. If a jetty of the same length of the right jetty were constructed in the downcoast, the beach would have the equilibrium stage.

5. Conclusions

The headland-bay beaches in Binh Thuan and Ninh Thuan were stuided. Some results can be given as follows

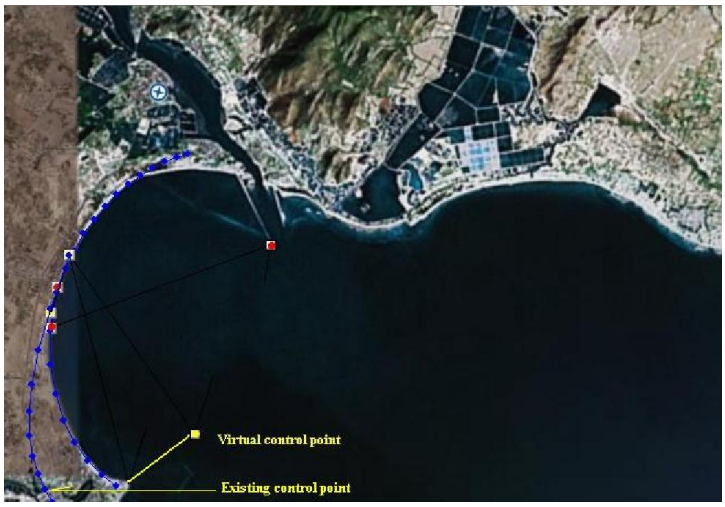

Figure 13. Predicted Shoreline in the Downdrift of Ninh Thuan Beach

- The shorelines in Binh Thuan and Ninh Thuan are not static equilibrium. Over long period, they would retreate landward.
- For Binh Thuan, regionally from Mui Ke Ga to Mui Ne, the tendency of shoreline erosion exists. Despite the availability of the structure, the erosion control is not effectively improved.
- Locally, from Mui Ke Ga to the fishery port, the beach would recede. With the imaginary coastal work, the beach would be stabilized.
- From Mui Ong Dia to Mui Ne, the existing shoreline would retreat. With the imaginary coastal work, the curved beach would be stabilized.
- For Mui Ne to Hon Rom, the curved beach is predicted as a static equilibrium beach. No further coastal work is required
- For Ninh Thuan, the model shows the tendency of shoreline erosion in Phan Rang bay-beach.
- For the upcoast of Phan Rang beach, without the jetty, the beach erosion is obvious. With the present jetty, the erosion control of the beach is improved.
- For the down coast of Phan Rang beach, the beach tends to erode. Phan Rang beach would be stabilized if the jetty in the downdrift were constructed.

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