CHAPTER 1

INTRODUCTION

This thesis has three objectives. The first objective is to assess the accuracy of the tide table produced by the Hydrographic Department, Royal Thai Navy in Thailand at Pattani, by comparing the published tables of high and low tide times and relative levels with data obtained from a study based on direct measurements over two 25-hour periods one week apart in May and June 1996.

The second objective is to produce effective graphical displays of the successive high and low tide relative levels at Pattani for the year 1996, using the published maritime tables for that year. For comparative purposes the data for the same year at Songkhla, 100 km West of Pattani, are displayed using the same method.

The third objective is to investigate, using simple statistical time series models, the nature of the series of high and low tide relative levels at the Pattani and Songkhla locations, again using the published maritime tables. Although the tables are themselves produced by a mathematical model, this model is quite complicated, so it is of interest to investigate the extent to which a simpler model can provide a good fit to the data. This approach is similar to a method known as 'reverse engineering'.

This thesis is thus largely an exercise in statistical data analysis. It describes the nature of the variation in low and high tide levels at two locations 100 km apart toward the southern part of the Gulf of Thailand, and attempts to develop a relatively simple model to account for this variation, using empirical data produced routinely by the Hydrographic Department, Royal Thai Navy.

1. Tides

1.1 Tide-generating Forces

For centuries efforts have been directed toward understanding the physics and hydrodynamics of the tides in the sea (Middlehurst, 1979: 383). Tides are bulges of water caused directly or indirectly by the gravitational pull of the sun and the moon the earth and its waters. The gravitational attraction of the sun or the moon varies directly with its mass and inversely with the square of its distance from the earth. The sun has about 27 million times the mass of the moon, but the moon is 387 times closer to the earth. As a result, lunar gravitational effects are more pronounced; lunar tides being approximately twice as great as solar tides (Ingmanson and Wallace, 1994:208).

Acting opposite to the gravitational force is the centrifugal force of rotation. At the centers of the earth and the moon, the centrifugal force exactly balances the gravitational force, but these two forces do not cancel each other everywhere on the surface of the two bodies. On the side of the earth toward the moon, the moon's gravitational attraction is greater than its centrifugal repulsion; the converse is true on the opposite side of the earth. The differences in these forces are small but they are enough to move the water and are termed tidal forces. These tidal forces cause water bulges on the side facing the moon and corresponding bulges of the same size appear on the opposite side.

1.2 The Tidal Day

While the earth turns upon its axis, the moon is moving in approximately the same direction along its orbit about the earth. After twenty-four hours the earth point which was initially directly under the moon is displaced and the earth must turn for an additional fifty minutes, about 12°, to bring the starting point on earth back into the initial position (under the moon). Therefore, a tidal day (*or lunar day*) is not twenty-four hours long but twenty-four hours and fifty minutes. This difference also explains why corresponding tides arrive at any location about one hour later each day (Duxbury and Duxbury, 1994: 266). This relationship is shown in Figure 1.

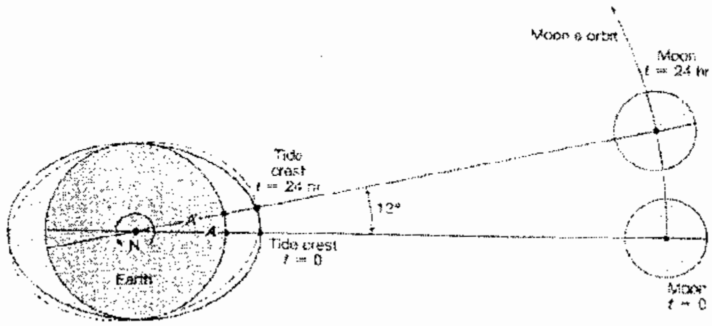

Figure 1: A tidal day.

Point A requires twenty-four hours to complete one earth rotation. During this time the moon moves 12°east along its orbit, carrying with it the tide crest. To move from A to A ′requires an additional fifty minutes to complete a tidal day.

Source: Duxbury and Duxbury, 1994: 266.

1.3 Spring Tides and Neap Tides

Relative to the earth, the moon's orbit requires close to 29 1/2 days. During this period the sun, the earth and the moon move in and out of phase with each other. At the new moon, the moon and sun are on the same side of the earth so that the high tides or bulges independently produced by each coincide. Tides of maximum height and depression, or tides with the greatest range between high water and low water, are thus produced. These tides are known as spring tides. Neap tides are the times of smallest variation between high and low tides. These occur when the earth, sun and moon align at right angles during the first and last quarters of the moon. The tides follow a cycle of changing tidal amplitude, with spring tides occurring approximately every two weeks and a period of neap tides occurring in between (Duxbury and Duxbury, 1994: 267). See Figure 2.

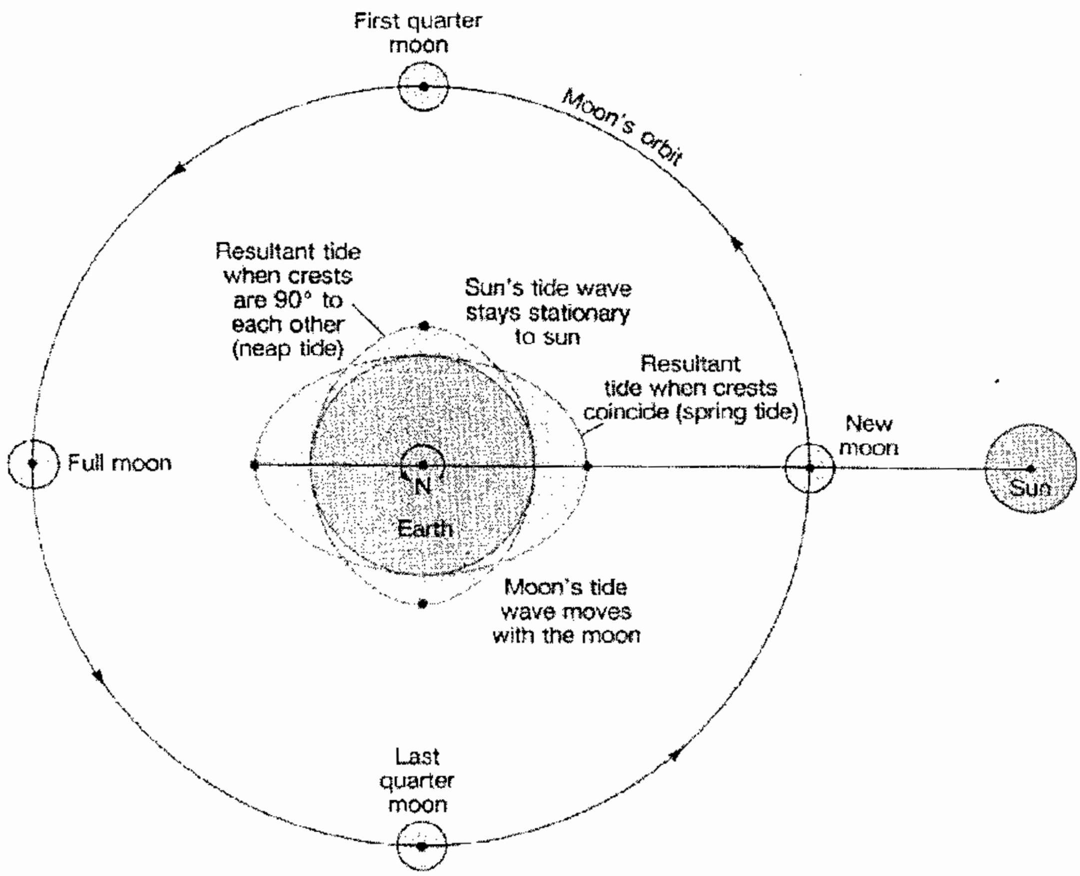

Figure 2: Spring tides and Neap tides.

Spring tides result from the alignment of the earth, sun and moon. During the moon's first and last quarters, neap tides are produced.

Source: Duxbury and Duxbury, 1994: 267.

1.4 Tidal Patterns

Measurements of tidal movements around the world show us that the tides behave differently in different places. Factors affecting this behavior include the depth, size, and shape of the ocean basins (Thurman, 1994: 263). The tides on the earth are classified as follows.

The *diurnal tide* is characterised by a single high and low water each lunar day. This occurs when the moon stands north or south of the equator resulting in high waters for both the southern and northern hemispheres. These tides are common in the Gulf of Mexico and along the coast of Southeast Asia. Such tides have a tidal period of approximately 24 hours (Thurman, 1994: 263).

The *semidiurnal tide* has two high and two low waters each lunar day, and the heights of successive high waters and successive low waters are approximately the same. Since tides vary at any location, due to the spring neap-tide sequence, successive high tides and successive low tides can never be exactly the same at any location. Semidiurnal tides are common along the Atlantic coast of the United States.

The *mixed tide* may have characteristics of both diurnal and semidiurnal tides. The diurnal inequality and the heights of the successive high tides and/or low tides will have significantly different heights. Mixed tides usually have a tidal period of 12 hours 25 min, which is a semidiurnal characteristic, but will also possess diurnal periods for a few days of each tidal month (Thurman, 1994: 263-264). Figure 3 gives an example of each tidal pattern.

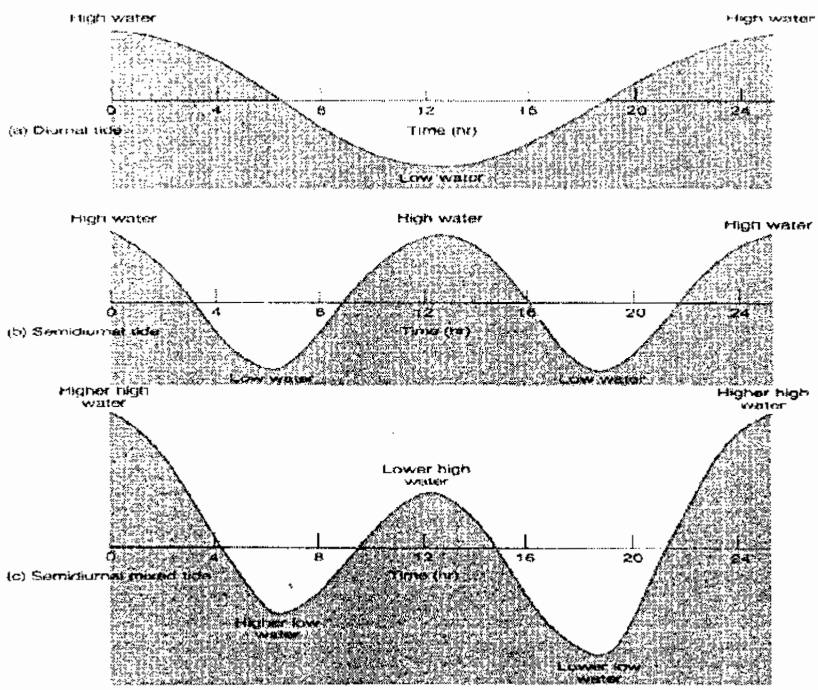

Figure 3: The three basic types of tides.

The three basic types of tides: (a) a once-daily diurnal tide, (b) a twice-daily semidiurnal tide, and (c) a mixed semidiurnal tide with diurnal inequality.

Source: Thurman, 1994: 263.

1.5 Tide Levels

Tidal measurements taken over many years are used to calculate the average (or mean) tide levels. Averaging all water levels over many years gives the local mean tide level. Averages are also calculated for the high water and low-water levels. For mixed tides, mean higher high water, mean lower high water, mean higher low water and mean lower low water are calculated (Duxbury and Duxbury, 1994: 263).

1.6 Tidal Currents

Currents are associated with the rising and falling of the tide in coastal waters. These tidal currents may be extremely swift and dangerous as they move the water into a region on the flood tide and remove it on the ebb. When the tide turns or changes from an ebb to a flood (or vice versa) there is a period of slack water during which the tidal currents slow and then reverse. Knowledge of tidal currents is important for shipping, especially in bays and estuaries. Slack water may be the only time that a vessel can safely navigate a narrow channel with swiftly moving tidal currents (Duxbury and Duxbury, 1994: 264).

1.7 Tidal Range

The tidal range is the difference in height between consecutive high and low water (Thurman, 1994: 252). The tidal range varies with basin configuration. In small areas such as lakes, the tidal range is very small. In large enclosed areas, such as the Baltic or Mediterranean seas, the tidal range is also moderate. The tidal range is not the same over a whole ocean basin; it varies from the coast to the centers of oceans. The largest tidal ranges occur at the edges of the largest ocean basins (Garrison, 1994: 179).

2. Background and Rationale

2.1 Gulf of Thailand

There are three types of tides in the Gulf of Thailand, the diurnal, the semidiurnal and the mixed type. There is a marked difference in the characteristics of tides at each locality in the Thai waters. The tide at Bangkok Bar is a mixed type, Laem Sing is a regular diurnal, Songkhla is a semidiurnal with inequality and Phuket is a regular semidiurnal. At Songkhla, the two high waters are almost equal in height but the two lows, are unequal in height. The lower is therefore designated "the lower low water" and the higher "the higher low water." The tidal range is about 0.5 meters (Brans, et al., 1995: 15).

The tides in the Gulf of Thailand vary, due to the landlocked nature of the Gulf, from pure semidiurnal to pure diurnal as one moves from the south to the middle of the Gulf. At Pattani the tide is close to pure semidiurnal, whereas at Nakorn Si Thammarat, 300 km northwest, it is a mixture of semidiurnal and diurnal, and at Ko Lak, a further 400 km north by northwest, the tides are purely diurnal.

2.2 Pattani Bay

Pattani Bay is situated at the Southern end of the Gulf of Thailand, between the latitudes 6° 53′ N and 6° 57′ N and longitudes 101° 14′ E and 101° 21′ E. Pattani Bay covers a total area of approximately 74 square kilometers. The north of the Bay is bounded by a sand spit, which has built up over the years due to wind and water currents. Today it has formed a peninsula 16 km in length, which extends from the mainland in an east-west direction. The Bay mouth opens up into the Gulf of Thailand at the western end of the Bay. The peninsula is called "Laem Pho" or "Laem Tachi". The water around the shore of Pattani Bay is very shallow. Many rivers flow into the Bay along the coast, but there are only two main ones. Pattani River flows into the sea at the mouth of the Bay, and Yaring or Yamoo River flows into the bottom of Pattani Bay at Amphur Yaring. The mixing of the freshwater and saltwater in the Bay has produced brackish water, muddy areas and mangrove forests, notably along the inside edges and at the end of the peninsula. The circulation of the water from the combination of currents, and the mangroves are important factors in the ecological balance of the Bay. The Bay provides a sanctuary for a variety of birds and marine lives in the area, many of which would not survive without it. This balance of nature makes Pattani Bay a fertile source of life in the South of Thailand.

2.3 Songkhla

Songkhla is an eastern province in southern Thailand covering some 7,150 square kilometers. The provincial capital, also called Songkhla, is 950 km south of Bangkok. Indian, Persian formerly knew Songkhla as Singha-la (a lion) and Arabian merchants since the small offshore Cat and Rat islands had a somewhat leonine appearance from the sea. Once a medieval pirate stronghold, Songkhla is a historic, albeit sleepy gulf town with a thriving fishing community and the fine Samila Beach facing the Cat and Rat islands is an important attraction for locals.

Songkhla has a population of about 80,000. The dwellings are scattered over sixteen communities. Four of these communities (Bon Wah, Soi Ku Boo, Sam Yek Sam Rong and Gao Seng) are situated along the banks of the river Sam Rong. New communities like Bon Ga Wa are settling down at a rapid rate. The residents of these areas depend on the river for water supply and transport. Songkhla's main industries are the rubber plantations between Songkhla and Hat Yai, and the shrimp farms on the Satin Phra peninsula. There is hardly any tourism in Songkhla, foreigners coming to Songkhla are mostly employees of the oil/gas platforms some 150 kilometers offshore.

Songkhla is located at longitude 100° E and latitude 7° N. At Samila point the headland, which generally is aligned NNW, narrows a width of around 1500 m to a further low-lying projection less than one-third of its width. A reef of rocks extends seaward from Samila, which forms a natural barrier to the movement of beach material from south to north. Northward from the point a sandy beach curves round to end at the approach channel breakwater. Two kilometers from the coastline lies Ko Nu (Rat Island). Further north other small islands and reef and rock outcrops occur generally between the 5 and 10 kilometer contour. This latter contour meanders some

5 kilometers from the shore. Consequently, the seabed is gently sloping at a gradient between 1:400 and 1:5000 (Brans, et al., 1995: 17-18). Figure 4 shows the location of Pattani and Songkhla provinces.

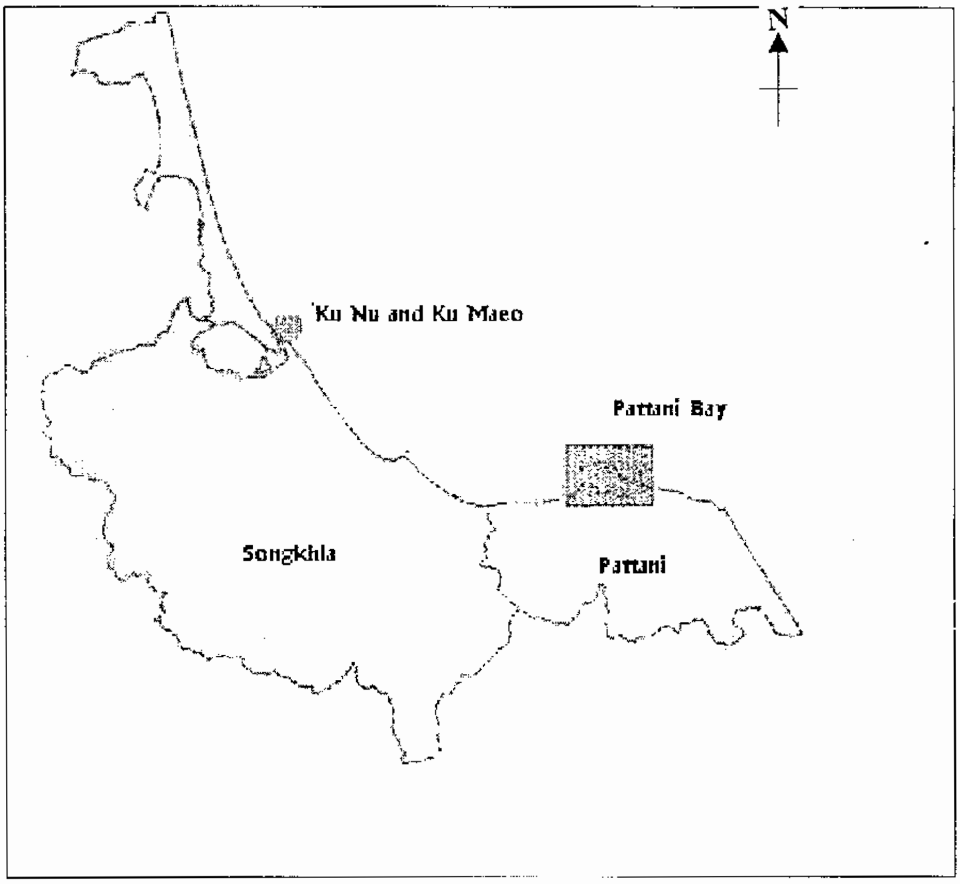

Figure 4: Map showing the approximate lacations of Pattani and Songkhla provinces.

2.4 Tide Table

Most of tidal sea-level records originate from the coasts of the continents and from islands. Available measurements taken in the open sea are insufficient to permit understanding of the tidal processes in that region, which constitutes the greater part of the surface of the world's oceans.

The data from tide tables have benefits for a wide range of occupations. Shrimp farmers use the tables to determine the best times, i.e. high tides, to pump the water from the seas into their farms. Fisherman uses the tables to navigate through shallow waterways.

Data from the tide tables are obtained by predictions of the times and heights of high and low waters at various stations using computer modelling. The predictions are based on calculations made according to the "harmonic method" (Darwin, 1898: 199). It is necessary to assess the accuracy of these data for the benefit of the general community. To understand the processes of the tides it is necessary to provide easier interpretation and understanding of the data, especially over a long period of time, by effectively graphing the tide table data.

Various methods will be employed to find the best way to graph the data. The mathematical modelling used to calculate the tide data is complicated. It is thus of interest to develop a simplified method, which explains the tide movements without losing too much accuracy.