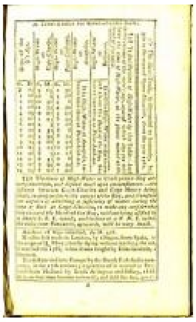
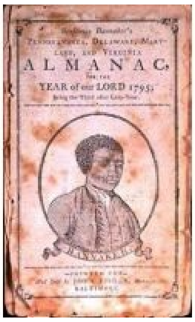
Tide Prediction in Colonial America





Although tidal ranges in America are, in general, less than in Europe, they have still had an impact on history. Many harbours were only accessible with high tide, introducing a lunar influence on the maritime economy. However, misjudgement of tide levels also played a crucial role in several historical events, even hilarious ones as you can read about here when Bruce Parker describes the tide situation at the time of the Boston Tea Party.

In 1776, the same year that the American colonies declared their independence from Great Britain, Pierre Simon the Marquis de Laplace published a paper that first described how the oceans respond dynamically to the Newtonian tide-producing forces caused by the changing gravitational effects of the moon and sun.[1] Laplace's mathematical equations demonstrated that tidal energy is found only at specific frequencies, and he proposed that by calculating the energy at these tidal frequencies one can accurately predict the tide. It would take almost a century before Laplace's idea would be used by Sir William Thompson (in Britain in 1867) and William Ferrel (at the US Coast and Geodetic Survey in 1874) to develop the harmonic method of tide prediction. Both Thompson and Ferrel invented analogue tide-prediction machines based on their harmonic methods. These large finely crafted brass machines represented the energy at the most important tidal frequencies using dozens of gears and pulleys.

Before this, tide predictions had to be produced using observed correlations between the tides and the motions of the moon, sun and Earth. There were several quite sophisticated versions of the non-harmonic method, such as those invented by Richard and George Holden[2] in Liverpool (UK) and John William Lubbock[3] in London (UK) (which included spring-neap, apogee-perigee, and lunar declination effects). However, most tide-prediction products were based on what was referred to as the 'vulgar establishment' (also called the establishment of the port; high water full and change; tide hour; and lunitidal interval). At a particular harbour, the time interval between the moon's transit overhead and the following high tide would be measured on the day of new moon and then used to predict the time of high water for all the days of the month by adding 48 minutes for each day after new moon.

In colonial America, most people obtained their tide predictions from one of the many annually published almanacs, which mainly used the vulgar establishment as the primary method of tide prediction. These almanacs also included additional information including the times of sunrise and sunset, moonrise and moonset, dates and times of eclipses, the dates of religious holidays, and advice on when farmers should plant their seed and make their hay. Almanacs such as Benjamin Franklin's *Poor Richard's Almanack* (1732-1757) were the best-selling books after the Bible.

Most colonists came to the New World with an appreciation of tides and tidal currents. They were used to greater tidal ranges (exception at the Bay of Fundy with its 50-foot tidal range), but the tidal ranges that American colonists had to deal with were still large enough to be of concern. English and French mariners had been familiar with 20- to 40-foot tide ranges, the Dutch with 15-foot tidal ranges, and the Spanish with 8- to 12-foot ranges along their Atlantic Coast. Along the Atlantic Coast of what would become the USA, the average spring tidal range was over 20 feet only near Eastport (MN, USA) and less in major harbours: 11 feet in Boston, 5 to 8 feet in New York, 6 feet in Philadelphia, 6 feet in Charleston, and only 1 foot in Baltimore (but 3 feet at the entrance to Chesapeake Bay).

The most frequent use of tide and tidal current information was for safe navigation. Ships could only enter or leave most harbours near times of high water. Countless paintings in Europe and America were called 'Waiting For the Tide', showing large vessels in a harbour, presumably ready to leave as soon as the tide was high enough. Customs officials were typically called 'tide waiters' because the ships they boarded did not arrive until high tide. In addition, a strong flood or ebb current could keep a ship from leaving or entering a harbour when there was not enough wind to buck that current, the five-knot currents in the rocky Hell Gate of the East River in New York Harbor being the most dramatic example.

There were other reasons for needing accurate predictions of the times of high water or low water, or maximum flood or maximum ebb. Shell fishermen who went out onto mudflats revealed at low tide to dig up oysters or scallops had to know when the sea would come rushing back. There were also hundreds of gristmills and sawmills powered by the tide. One tide mill in Glen Cove, Long Island (NY, USA), provided the lumber for the building boom in New York City in the 1660s, and another ground the wheat and corn that went into the biscuits eaten by generations of sailors.[4] In the Carolinas, tidal irrigation was important to successful rice farming (the tidal signal reaching into the fresh water sections of many rivers). The business cycle for these mills and rice plantations were dependent on tide predictions.

During the American Revolution, there were important events whose outcomes depended on knowledge of the tide. In June 1772, the British schooner *Gaspee* (carrying eight cannons) had been sailing around Narragansett Bay enforcing a strongly disliked British trade regulation, when she was enticed to chase after the American packet boat *Hannah*. Near the time of high tide, the *Hannah* led the unknowing *Gaspee* into shallow water, trapping the Gaspee behind a bar when the tide began to ebb. A "man passed along the main street [of Providence (RI, USA)], beating a drum and informing the inhabitants of the fact that the *Gaspee* was aground on Namquid Point and [according to the tide prediction] would not float until 3 o'clock the next morning and inviting persons who felt a disposition to go and destroy that troublesome vessel to repair in that event to Mr James Sabin's house."[5] This was written by a man who was in one of the eight long boats that were rowed down the river to the *Gaspee*, which had partly rolled on her side as the tide reached low water. The colonists captured the British and set the *Gaspee* on fire.

Colonial knowledge of the tide also became troublesome for HMS *Cancaeux*, another British ship lured into shallow water at high tide by a Yankee pilot. She was sailing to Portsmouth (NH, USA) to reinforce Fort William and Mary, where a large store of ammunition was defended by only six English soldiers. Since this enticement into shallow water behind a shoal took place after a spring high tide, the following high tides were lower, trapping the *Cancaeux* behind the shoal for days. This gave Paul Revere time to ride to Portsmouth and warn the colonists, on 13th December 1774. The colonists then stormed the fort and took the ammunition before the *Cancaeux* could arrive. The weapons and ammunitions taken from the fort eventually found their way to Americans who fought in the Battle of Bunker Hill.[6]

Paul Revere's more famous ride took place four months later and this time the tidal current played an important role. On the night of 18th April 1775 the British army crossed the Charles River in Boston on their way to Lexington, where they expected to capture John Hancock and John Adams and to seize the weapon stores in Concord.

Revere also crossed the Charles River during his horseback ride to Lexington. However, Revere crossed the river at the most favourable time with respect to tidal current, going diagonally upstream while there was a flood current, while the British troops crossed at an unfavourable time for them, going diagonally downstream against the flood current. Revere arrived at Lexington before the British.[7]

Even the American colonists did not always pay attention to tide predictions. This made the famous Boston Tea Party not go quite as planned on the night of 16th December 1773. The colonists probably did not realise that their assault on three British East India Company ships at Griffin's Wharf was going to take place during a perigean spring low tide, one of the lowest tides in the year.[8] The depth of the water next to the *Dartmouth*, *Beaver* and *Eleanour* was only two feet. Although tied to the wharf, they were actually aground. During the Boston Tea Party, the Americans broke open 342 casks and threw 45 tons of tea over the sides of the ships. The tea rested on the bottom and quickly rose above the water surface. Immense piles of tea began growing around the ships. Some of the piles of tea were so high that they rose above the sides of the ships and even fell back into the ships.

When the tide rose, the piles of tea rose with it, most of it floating on the water, the current moving it toward the shores. According to one account: "Early on the morning of the 17th, a long windrow of tea, 'about as big as you ever saw hay,' was seen extending from the wharves down to the castle. A party of volunteers soon turned out in boats and stirred it up in the 'pot' pretty effectually." [9] During the following weeks, tea washed up on the shores around Boston, some of it still in dry piles floating above the water, so that colonists had to beat it with oars to make it unusable.

After American independence, almanacs continued to be very popular. In addition to tide predictions, they included other material unique to the author, for example, the humorous writing of Benjamin Franklin in *Poor Richard's Almanack*. Another popular almanac was *Benjamin Banneker's Pennsylvania, Delaware, Maryland, and Virginia Almanack*, written from 1792 to 1797 by a free African American in Baltimore. Banneker was a self-educated scientist, astronomer and inventor, who carried out his own astronomical calculations. He used his almanac to make his readers aware of the evils of slavery. In case his readers might not read his essays, Banneker put interesting facts next to the tables in the almanac. Next to the tide table for Chesapeake Bay, he wrote: "The Slave-Trade, so disgraceful to humanity, began in the reign of Queen Elizabeth, about the year 1567." Below the tide table, he wrote "Needles first made in London, by a Negro, from Spain, in the reign of Q. Mary; but he dying without teaching the art, it was lost till 1566, when it was taught by Elias Grorose, a German." [10]

Banneker's tide table for Chesapeake Bay had five columns. The first column listed the values for the age of the moon, which is the number of days after new moon. The other columns gave the times of high water for Cape Charles, Point Lookout, Annapolis and Baltimore. To the right of the table, Banneker instructed: "To find the time of High-Water by this Table - Look in the column of the moon's age, against which day you will have the time of High-Water, at the places named at the head of the table." Methods like this would be used in the USA for almost another century, until the US Coast and Geodetic Survey began publishing tide tables with daily predictions based on Ferrel's harmonic method.

Footnotes

1. Simon, P., the Marquis de Laplace, 1776. Recherches sur plusieurs points du system du monde. *Mémoires de l'Académie Royale des Sciences*, vol. 89, pp. 177-264.

2. Woodworth, P.L., 2002. Three Georges and one Richard Holden: the Liverpool tide table makers. *Transactions of the Historic Society of Lancashire and Cheshire*, vol. 151, pp. 19-51.

3. Cartwright, D.E., 1999. *Tides, A Scientific History*. Cambridge University Press; pp. 91-2.

4. Bleyer, B., 2007. The daily grind. *Newsday*. www.newsday.com

5. Staples, W.R., 1845. *The Documentary History of the Destruction of the Gaspee, Compiled for the Providence Journal*. Providence: Knowles, Vose & Anthony.

6. Fischer, D.H., 1995. *Paul Revere's Ride*. Oxford University Press.

7. Ibid; see also: Olson, D.W., Doescher, R.L., 1992. Astronomical computing: Paul Revere's midnight ride. *Sky and Telescope*, vol. 83, pp. 437-40.

8. Olson, D.W., Doescher, R.L., 1993. Astronomical computing: the Boston Tea Party. *Sky and Telescope*, vol. 86, no. 6, pp. 83-6.

9. Drake, F.S., 1884. *Tea Leaves: Being a Collection of Letters and Documents Relating To the Shipment of Tea to the American Colonies In the Year 1773, By the East India Tea Company*. Boston: A.O. Crane; quote from p. LXXVII.

10. Banneker, B., 1792. *Benjamin Banneker's Pennsylvania, Delaware, Maryland, and Virginia Almanack, for the Year of Our Lord 1792*. Baltimore: William Goddard and James Angell. [From the Library of Congress Rare Books and Special Collections Division, Washington, DC, Digital ID: rbcmisc ody0214.]