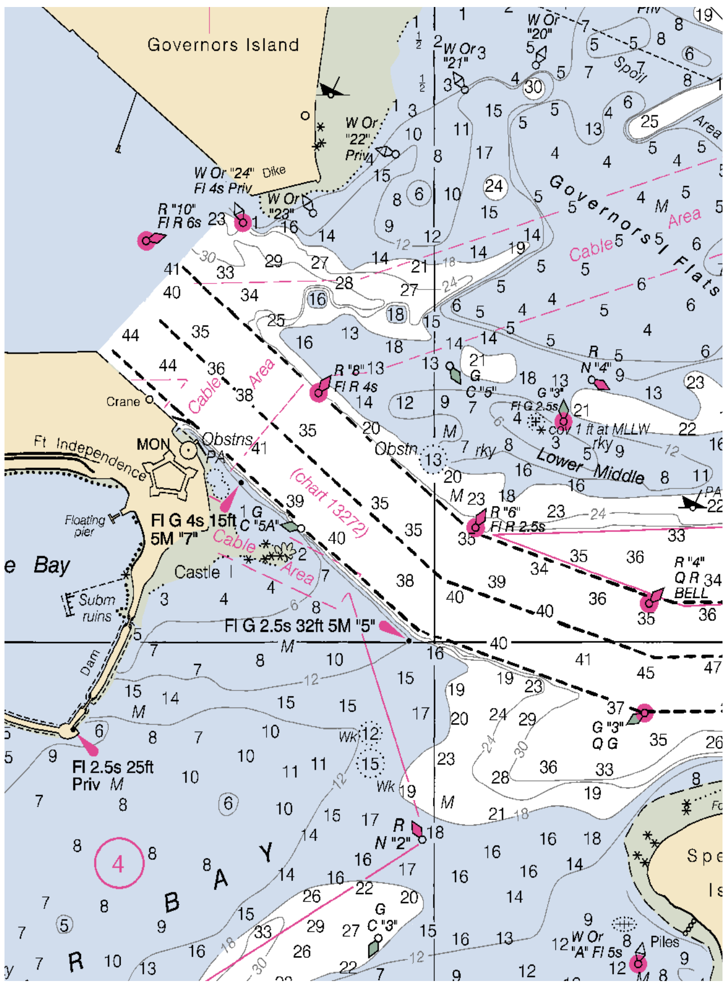
**Chart Basics**

Charts help you to find your way, avoid danger, and get back home on time. Whenever you are in charge of a vessel on unfamiliar waters, it is prudent to carry up-to-date charts of the area in which you will be operating; whenever you go beyond the Yellow Flag boundary, you should have your chart at the ready for quick reference.

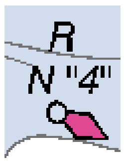
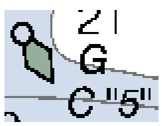
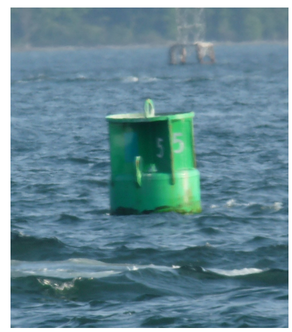
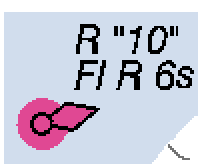
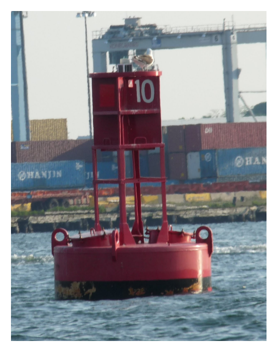
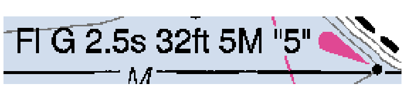
Below is a detail of the entrance to the inner harbor. The tan color represents land, the blue and white are for shallow and deep water respectively, and the green area is the intertidal zone - dry at low tide, submerged at high water. All the numbers in the water are depths (in this case, in feet) at low tide (mean lower low water to be precise). The numbers are supplemented by contours which give a more detailed picture of the seafloor.

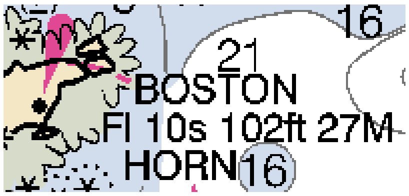



Charts display a lot of information in a relatively small space, and to do so rely on a vast array of symbols and abbreviations, all of which can be found on Chart No. 1. We will go over a few of the most common.

-Aids to Navigation

There are two main types of Aids to Navigation maintained by the Coast Guard: buoys and beacons. The former category includes conical **nuns**, square-topped **cans**, and tower buoys, which can have bells, gongs, whistles, and lights. Beacons are solid structures built on land or on the seabed. See if you can find the symbols below on the chart above!

| | | |
|---|---|---|
|  | This is the chart symbol for a red ( R ) nun ( N ) with the number 4 on it ("4") |  |
|  | This is the symbol for a green ( G ) can ( C ) with the number 5 on it ("5") |  |
|  | This is a red ( R ) tower buoy (not marked N or C) with the number 10 on it ("10"). It also has a flashing ( Fl ) red ( R ) light every 6 seconds ( 6s ).<br>(The red circle indicates that it is lighted and is present on green lighted buoys also.) |  |
|  | This is a green beacon with a daymark on it bearing the number 5. It flashes (Fl) every 2.5 seconds, is 32 ft above the water, and is visible for 5 nautical miles. |  |

| | | |
|---|---|---|
|   | This is Boston Light (not on above chart). It has a white (by default) light which flashes (Fl) every 10 seconds (10s) at a height of 102 ft above the water and is visible for 27 nautical miles. It also has a horn. |  |

You will notice that all the odd-numbered markers are green, while the even-numbered ones are red. As a general rule, you should keep red markers to starboard when returning to harbor (Red Right Returning), but this can be confusing when the channel is between two harbors! It is therefore advisable to consult a chart before following any aid to navigation. You should never tie your boat to any aid to navigation except in an emergency.

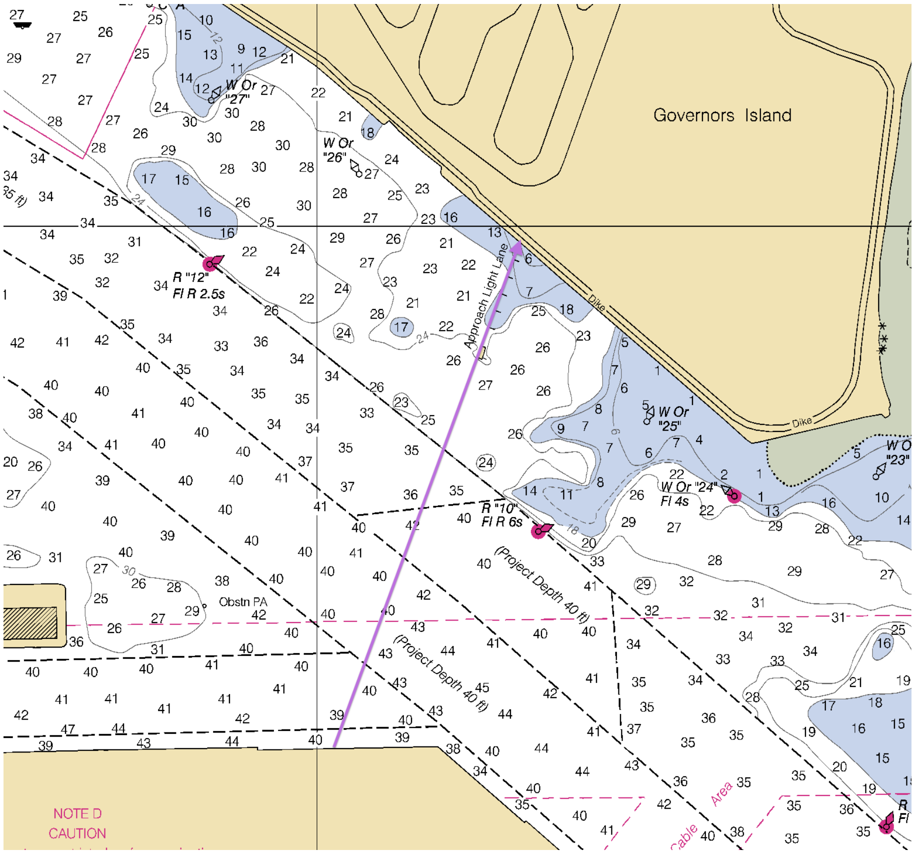
**Where Am I going? Where Am I Now?**
**Plotting a course and Lines of Position**

Now that you can interpret the chart, you must learn how to plan a trip using it. This is done simply by drawing a series of straight lines on the chart. This set of lines represents your ideal path through the water, and should not pass over or close to any dangers marked on the chart. Where available, your course should allow you to make use of aids to navigation such as those listed above. Once you have a course plotted, you will endeavour to follow it, while steering to avoid other vessels and in accordance with wind conditions.

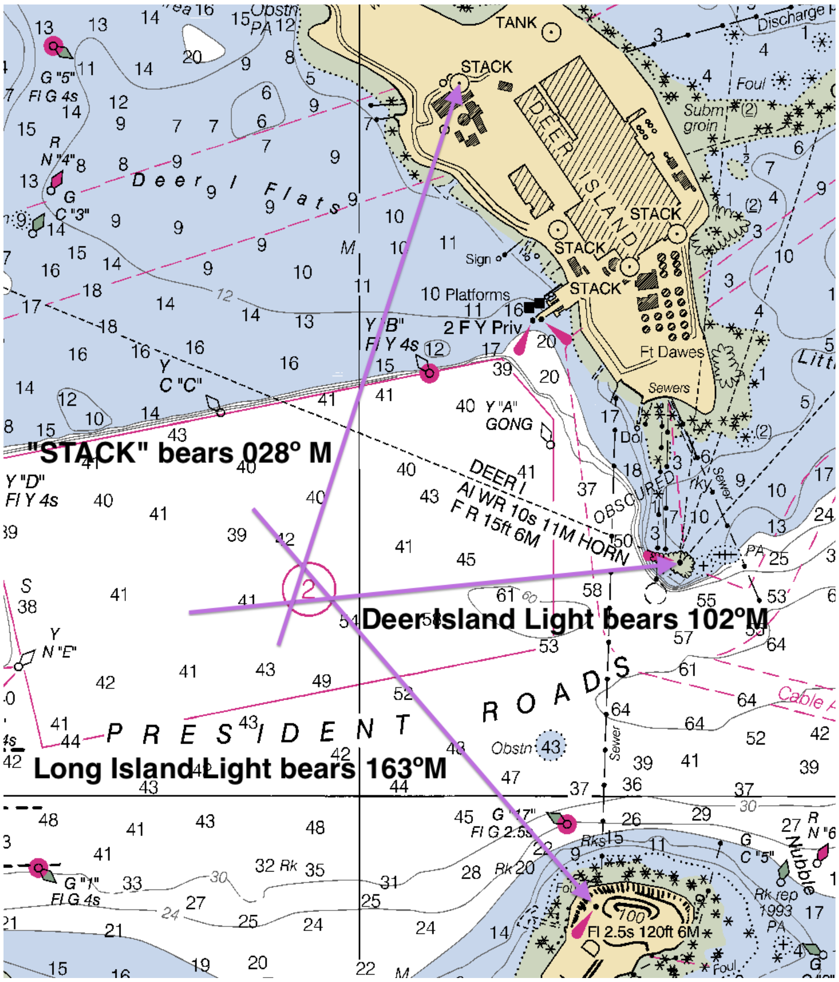
Various methods can be used to ensure that you follow your plotted course, ranging from simple line-of-sight observation up to celestial and satellite navigation. Inside the harbor, there are plenty of visual aids to make navigation relatively easy.

One of the easiest ways of determining your location in the harbor is simply to get close to a buoy, read the number on it, and locate it on the chart. This does require a vague notion of your position, as there are multiple buoys with the same markings in the harbor, but it will take you from a vague estimation to a pinpoint location. Buoys are also useful when describing your location to somebody else.

Perhaps the most important concept to grasp is the Line of Position, or LOP. This is a line that you know yourself to be on. An example of an LOP would be the Yellow Flag Boundary: as you cross it, you are perfectly in line with the airport pier. If you extend the pier across the harbor, you must be somewhere on that line, represented by a purple arrow below.




If you can get two accurate LOPs, the point where they intersect is your position. However, there are not many piers available for navigational use outside of the inner harbor, so you must use a compass instead. Specifically, you will use a hand-bearing compass. You point the compass at a known object marked on the chart and read off the number on the compass card. This is called a bearing, and is where the expression “to get one’s bearings” comes from. By plotting this bearing on the chart as a line, you create an LOP. Once you have two intersecting LOPs, you have a good idea of your location. It is advisable to create a third LOP to check your accuracy. Once you have three intersecting LOPs, you have a **three-point fix**. The smaller the triangle at the intersection, the more accurate the fix. The most accurate fixes will use objects which are equal parts of a circle apart from each other, so the best three point fix will use objects which are 60º (or 240º) apart. The closer the lines run to parallel, the less accurate the fix. Bearings should also be taken in quick succession for accurate results.




This chart has a three-point fix plotted on it. The navigator first identified three landmarks on the chart, then found them by observing the shoreline, took a bearing on each of them, and transferred that bearing to the chart using a Chart Protractor.

### Danger Bearings

Another navigation technique that uses lines of position is the danger bearing. A danger bearing is a line drawn on a chart that separates you from a hazard to navigation, and which passes through a charted landmark. As you approach the line, your bearing on the landmark will approach your danger bearing. Danger bearings are especially useful when sailing in areas with unmarked dangers and few aids to navigation.

## Tides & Currents

Boston Harbor experiences about a ten-foot tidal difference every six hours, and because of the vertical change in sea level, there's a lot of water pouring into and out of the harbor! When navigating in tidal waters, you must take into account both the height of the tide (vertical) and the current (horizontal flow) associated with it.

Fortunately there are many resources available to mariners which provide information on tides and currents. Tide tables will tell you when high and low tides will occur on a given date, as well as their height above the depths shown on your chart. For example, if high tide is 8.8 ft and the depth on the chart at my position is 21 ft, at high tide I will be in 29.8 ft of water. If low tide is -1.0 ft, at low tide I will be in 20 ft of water.

Tide Table - Deer Island - May 24th through 27th, 2013

| | | HIGH | | | | LOW | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AM | hgt | PM | hgt | AM | hgt | PM | hgt | sunrise | sunset |
| Friday | 24 | 11:08 | 10.08 ft | 11:21 | 11.58 ft | 4:56 | -1.11 ft | 5:10 | -0.35 ft | 5:14 | 8:07 |
| Saturday | 25 | 12:00 PM | 10.31 ft | | | 5:47 | -1.55 ft | 6:01 | -0.55 ft | 5:13 | 8:08 |
| Sunday | 26 | 12:13 | 11.83 ft | 12:53 | 10.44 ft | 6:39 | -1.79 ft | 6:53 | -0.63 ft | 5:12 | 8:09 |
| Monday | 27 | 1:05 | 11.89 ft | 1:47 | 10.45 ft | 7:30 | -1.83 ft | 7:46 | -0.58 ft | 5:12 | 8:10 |

This table only provides the height of the water at four times per day. If you want to know the height of the tide at 2:00 PM on Saturday May 25th, you need to do some basic calculations to get a good estimate. The height of the tide can be represented by a sine wave, but if you don't carry around a graphing calculator or slide rule, here's a simple trick you can use to estimate the height of the tide.

The Rule of Twelfths goes like this: one twelfth of the tide comes or goes in the first hour, two twelfths in the second hour, three twelfths in the third hour, three in the fourth, two in the fifth, and one in the sixth. Since high tide was two hours before 2:00 PM, we need to find three twelfths (one for the first hour, two for the second) of the 10.8 ft tidal difference. One twelfth of 10.8 is .9, .9x3 is 2.7, so we subtract 2.7 ft from the height at 12:00 PM (10.31 ft) for a height of 7.6 ft above charted depth.

This sort of precision is not required for everyday navigation, since you will always be giving yourself a significant buffer zone between your keel (Rhodes 19 is 3'3"deep, j/22 is 3'11", don’t go into less than 8’ of water on purpose) and the bottom. It will usually suffice to know high and low tide times and heights, and to know that half way between these times, half of the water will have come or gone. Make a conservative estimate based on this knowledge and navigate accordingly.

Currents are a direct consequence of the rise and fall of the tide, and therefore flow in a similar pattern. If only 1/12th of the water leaves during the first hour after high tide, but 3/12ths leave during the third hour, then it stands to reason that the tide will be much stronger during the third hour. In fact, peak ebb (the fastest current flowing out of the harbor) is about 3.5 hours after high tide. Similarly, peak flood (fastest current into the harbor) is about 3.5 hours after low tide.

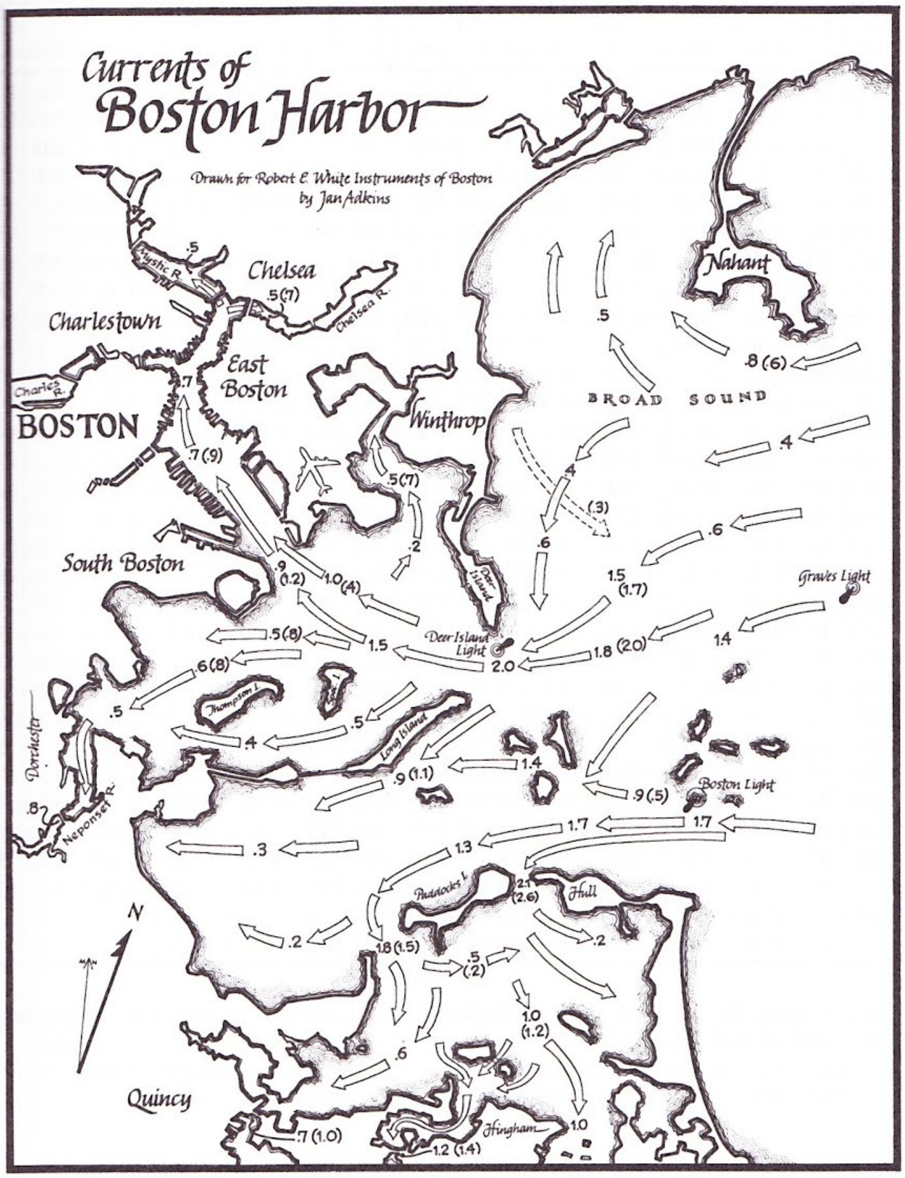
The final piece of this puzzle is figuring out where all the water is going. In a simple harbor, the answer is either “in” or “out”, but in a harbor complicated by islands and peninsulas, a visual aid such as this one can be useful.

## Boston Harbor Currents

This diagram shows the direction of the Flood Currents in Boston Harbor at the Maximum* Flood velocity, generally 3.5 hours after Low Water at Boston.

The Ebb Currents flow in precisely the opposite direction (note one exception, shown by dotted arrow east of Winthrop), and reach these maximum velocities about 4 hours after High Water at Boston.

The velocities of the Ebb Currents are about the same as those of the Flood Currents. Where the Ebb Current differs by .2 kts., the velocity of the Ebb is shown in parentheses.




*The Velocities shown on this Current Diagram are the **maximums** normally encountered each month at Full Moon and at New Moon. At other times the velocities will be lower. As a rule of thumb, the velocities shown are those found on days when High Water at Boston is 11.0' to 11.5' (see Boston High Water Tables pp. 38-43). When the height of High Water is 10.5', subtract 10% from the velocities shown; at 10.0', subtract 20%; at 9.0', 30%; at 8.0', 40%; below 7.5', 50%.

**Speed - Distance - Time**

A vital part of sailing farther from Courageous is being able to get back before sunset, and in order to do that you must be able to accurately (or at least conservatively) estimate how long it will take to get back. This will depend on three major factors: Your distance from Courageous, Wind (speed and direction), and Current (speed and direction). A Rhodes 19 has a top speed of about 6 knots; a j/22 about 7. It therefore stands to reason that 1 hour before sunset, under no circumstances should you be more than 6 or 7 miles from Courageous. If the tide is ebbing, you must account for that also: a 1-knot tide turns that 6 or 7 miles into 5 or 6. Will you have to beat upwind for any part of your trip back? Beating takes about twice as long as sailing in a straight line on a reach. Beating into an opposing current will be exceptionally slow. To top it all off, you may not have enough wind to go at your maximum speed! Where you go and when you decide to head back will be dictated by wind and tide.

Let's start with the basics, and forgive me if you didn't want to revisit middle school pre-algebra: Speed, Distance, and Time. Since one knot of boatspeed equals one nautical mile per hour, it takes a boat moving at one knot one hour to go one mile. But how do we do more complicated calculations? With the following three formulae (which are really all the same one, rearranged): Speed equals Distance divided by Time. Time=Distance/Speed. D=S•T. Let's try a few exciting problems:

1.) How far can a boat making 4 knots go in 2 hours?

I need to solve for Distance, because the question is asking "how far". Therefore I use the last formula, D=S•T. I know the other two variables, S=4 knots and T=2 hours. D=4•2, D=8 Nautical Miles. Simple, right?

2.) How fast am I going if I go 3 nautical miles in half an hour?

This time, I need to solve for Speed, since the question asks "how fast". I use the first formula, S=D/T. I know D=3 nm and T=.5 hr, so S=3/.5; S=6 knots.

Now let's look at some complicating factors: Beating and Current. As I mentioned above, a boat beating into the wind will take longer to reach its destination than one reaching. If your destination lies directly upwind, only ~.7 (cos45) of your boatspeed is going towards that destination. The rest is lost in your movement from side to side. Therefore you must multiply your boatspeed by .7 if you are beating to a destination directly upwind.

Current is simple - if you are going against the current, you subtract it from your boatspeed. If you are going with the current, you add it. If you are going across it at an angle, you'll need to do some trigonometry, but thankfully that doesn't happen too often around here.

Let’s try a couple more example problems:

3.) You are beating towards Courageous (which lies directly upwind). You are 2 nautical miles away and going at 3 knots. How long will it take you to get back?

Since the question wants us to solve for time, we use the form T=D/S. We have the distance already (2 nautical miles), but we need to find our speed towards Courageous, or Velocity Made Good (VMG). To find VMG, simply multiply the speed by the cosine of the average angle at which your destination bears relative to your course (in this case 45º, a good average close-hauled angle, gives a cosine of ~.7; use .7 when in doubt). 3•.7=2.1, so your final equation should be T=2 nm/2.1 kts, T=.95 hours.

4.) You are beating towards Courageous (which lies directly upwind). You are 3 nautical miles away and going at 4 knots against a .6-knot tide. How long will it take you to get back?

This question is similar to the last one, but with current added. We use the same form T=D/S since we are still solving for time, and we still need to figure out VMG. 4 knots • .7 gives us 2.8 knots; from this we subtract the current of .6 knots for a VMG of 2.2 knots. T=3 nm/2.2 kts, so T=1.36 hours.

A trip back to Courageous from Lovell Island might take one hour with a strong following wind and a flooding tide, but with an ebbing tide and light wind it could take five. This is why these calculations are important.