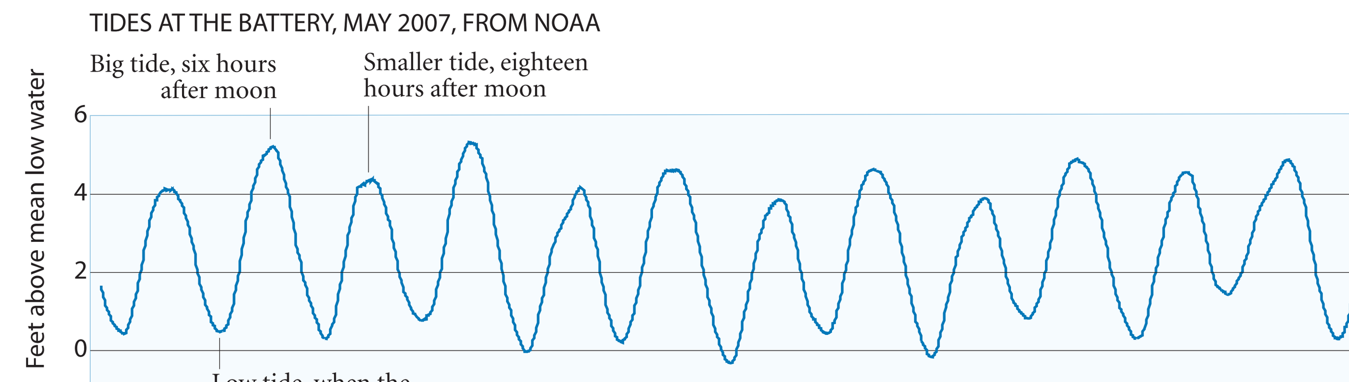
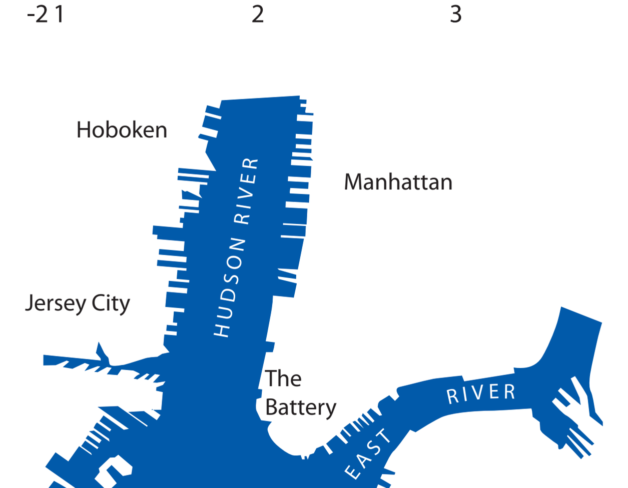
TIDES IN THE HUDSON

The Hudson River has tides and tidal currents, and in fact the tidal currents dominate its flow, and the tidal cycle accounts for much of its variation in height. This has interesting consequences. The tides make the Hudson a reversing river, in which pollution can move upstream as well as downstream; a complex river, which can be flowing upstream at its mouth and downstream in the middle; and in part, but only in part, a salt river, containing seawater as well as fresh.

TIDES AT THE BATTERY, MAY 2007, FROM NOAA





The Battery is the southwest corner of Manhattan Island, at the mouth of the Hudson, where, or near where, the Dutch and English had at various times a battery of canons.

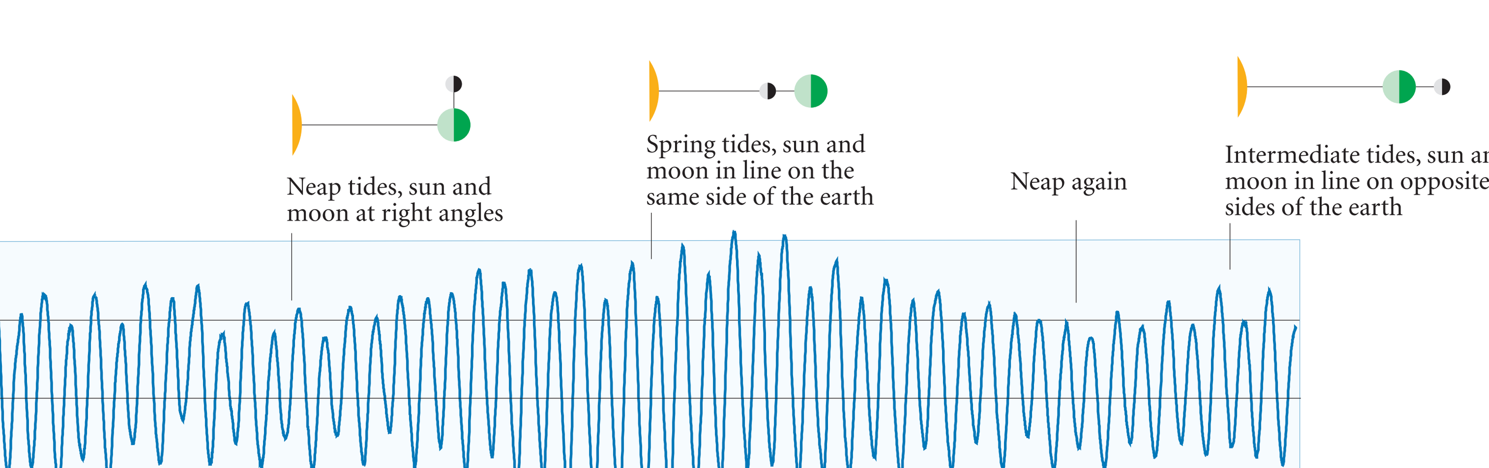
At the mouth of the Hudson the tides are ordinary ocean tides, though modified by being in an enclosed bay. They are caused by the pull of the moon and the sun on the water in the open ocean; they go up and down about twice a day, with high water coming about 6 hrs and 18 hrs after the moon is at its highest; and they have a regular but complicated shape that results from superimposing roughly 65 simpler tidal waves. The total tide range was about 4 feet during the first week in May. This is larger than the range in the ocean outside the bay, and is again a result of the tide being modified by the bay.

While twice-a-day tides with a range of four feet are common in our part of the world, they are not the only kinds of tides. Some places -- Louisiana for example -- have only one tide a day. Some places, mostly in enclosed bays, can have tidal ranges of 20, or even 40 feet. And in the centers of most oceans are quiet spots, the amphidromic points, where there are no tides at all.

(Cautionary note: tides are perhaps the single most badly explained subject in elementary science. The culprit is the little picture of the earth with one bulge under the moon and another opposite it. It is a good picture -- Newton used it -- but only for a non-rotating earth covered with water 15 miles deep. On such a world there are two tidal bulges, one of which stays right under the moon, and both of which travel from east to west. On our world there are many bulges, not just two, and they are usually at right angles to the moon rather than under it. The bulges do not travel from east to west, but instead rotate in circles around the amphidromic points.)

THE MONTHLY TIDE CYCLE

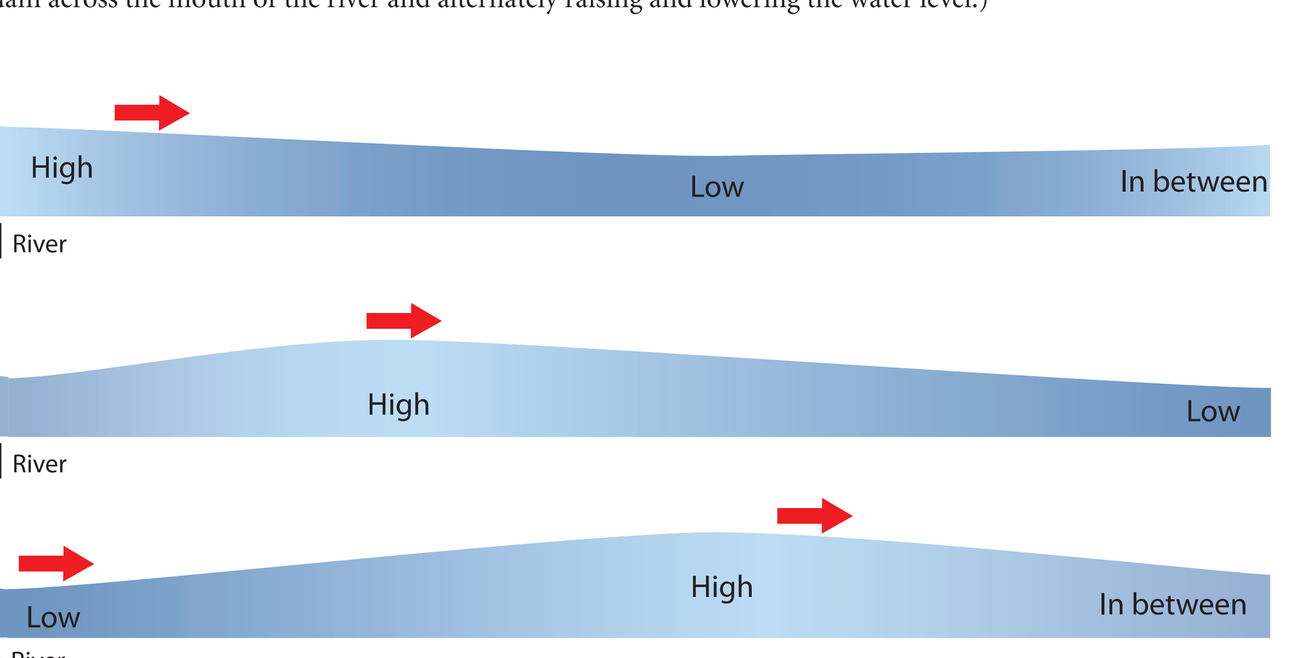
TIDES AT THE BATTERY, MAY 2007, FROM NOAA



The tide producing force depends on the position of the sun and the moon. It is greatest when they are in line on the same side of the earth; less when they are in line on opposite sides; and least when they pull at right angles to each other. This generates a monthly pattern of big and little tides, with the biggest over six feet and the smallest under three feet. As with the daily tides, it is a complex pattern because many different tidal waves are involved: note for example that the highest high tides were on different days than the lowest low ones.

TIDES IN AN ESTUARY

The tides in the Hudson come from the rising and falling of the water at the mouth of the river, and not the direct action of the moon. (Because it runs north and south the tidal forces pull the water across the river, not up and down it, and so can't make tides.) The rising and falling in the ocean generates a wave which travels up the river, in the direction of the red arrow. (If we had no moon we could still generate tidal waves by putting a dam across the mouth of the river and alternately raising and lowering the water level.)



High tide at the mouth of the river; a wave begins to travel upstream

The wave moves upstream; meanwhile the tide is falling (blue arrow) at the mouth.

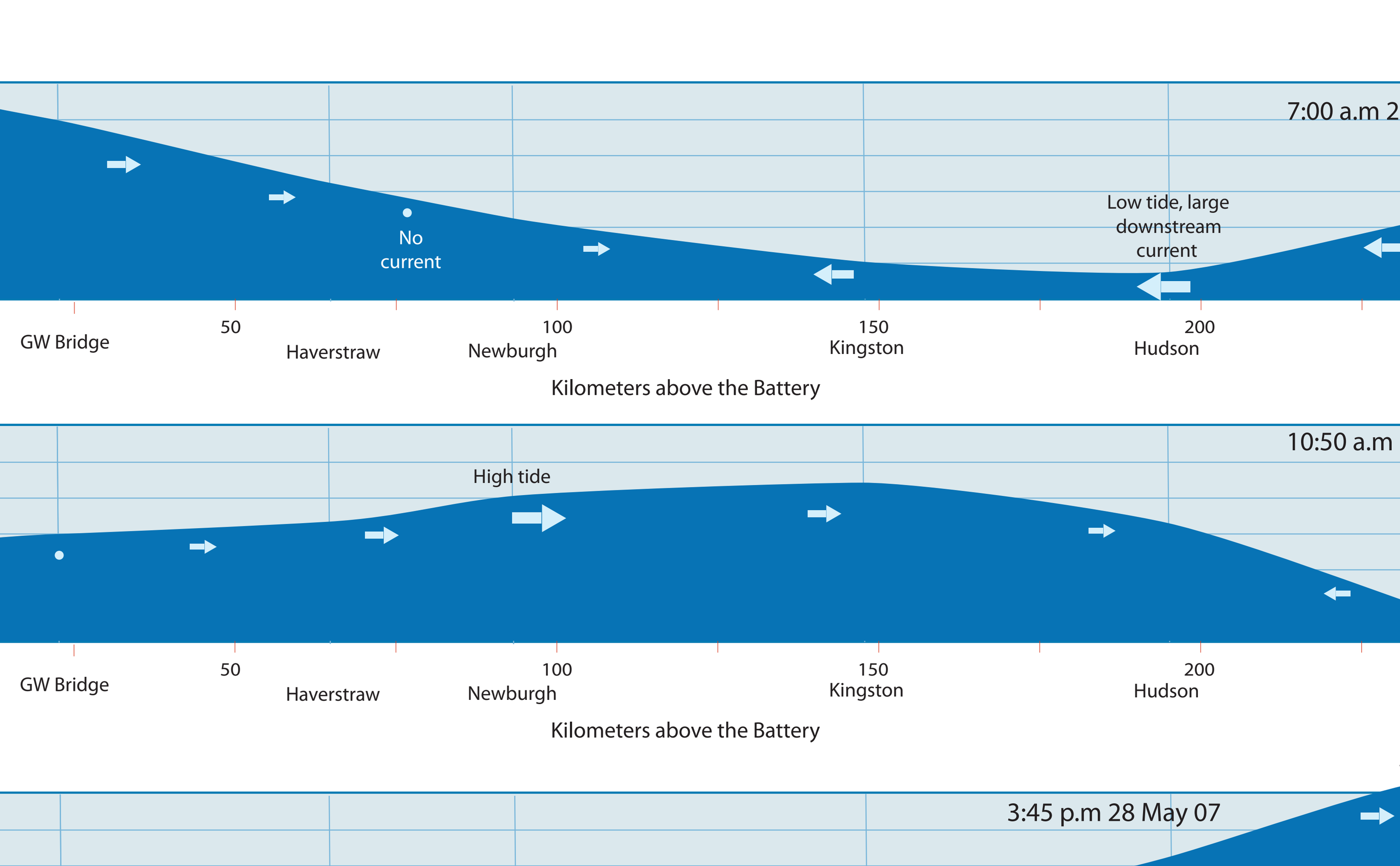
The wave has moved upstream; it is low tide at the mouth and the low part of the wave also begins to move upstream.

The wave reaches the top; the low tide has moved upstream and the tide is now rising at the mouth.

An estuary is a long, narrow, bay of the ocean, and a tide is a long wave moving up it. The speed of the tidal wave, in miles per hour, is roughly 4 times the square root of the depth in feet. If, for example, the high tide moves 100 miles upstream in 6 hours, for a speed of about 16 miles an hour, the average depth must then be $(16/4)^2$, or 16 feet.

The movement of a wave is different from the movement of the water in the wave. The wave moves in one direction at a uniform speed, which can be quite fast. The water in the wave moves back and forth, upstream with the crest and downstream with the trough. Its speed is always much slower than the speed of the wave.

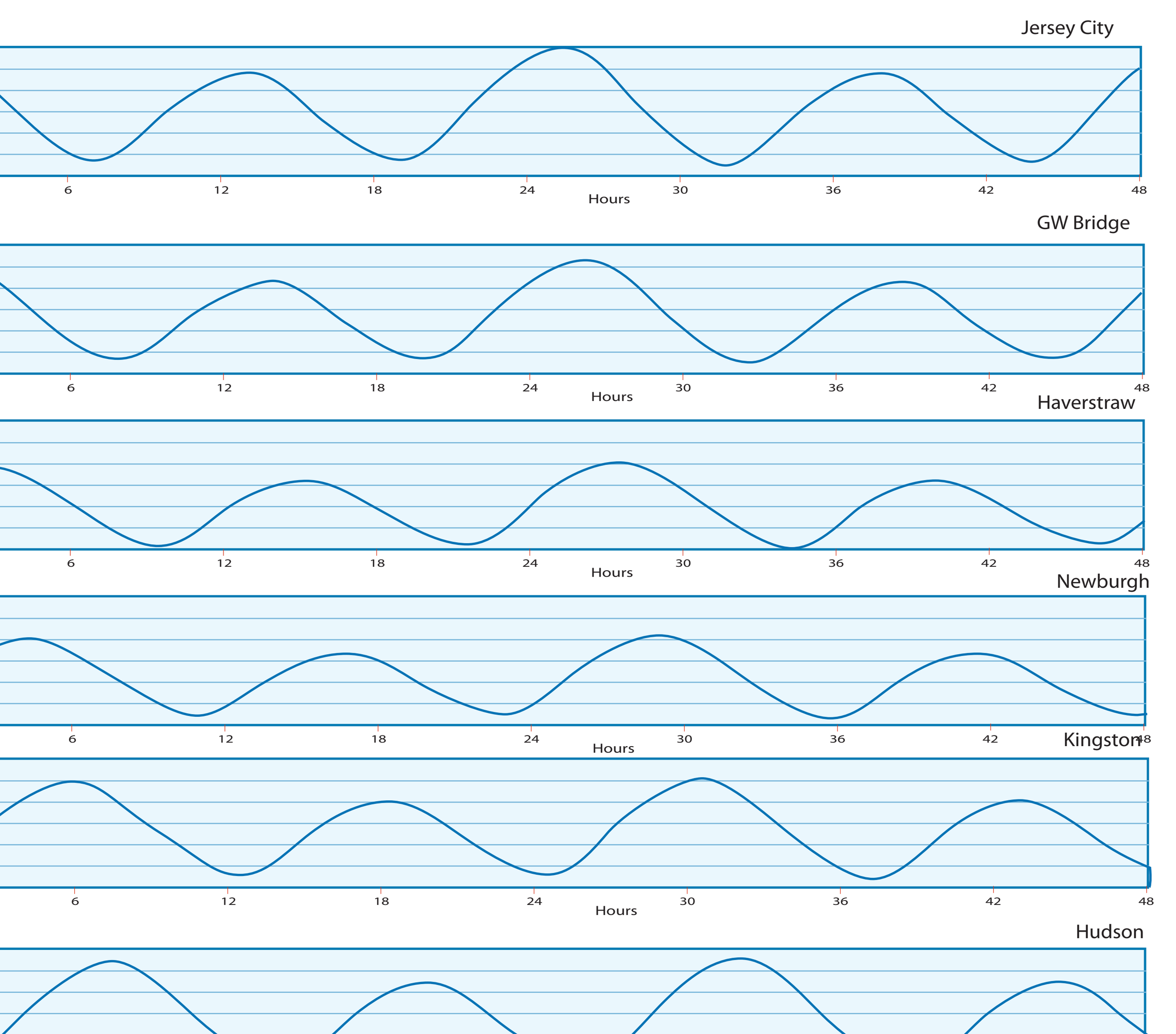
PROGRESSION OF THE TIDAL CREST UP THE HUDSON



Here is a similar diagram for the Hudson River. The tide moves 235 kilometers in 8.75 hrs, or about 26 kilometers per hour or 16 miles per hour.

The wave changes its shape as it moves upstream, somewhat like a wave moving up a beach. In the upper river tides rise fast and fall slowly.

TIDAL CURVES AT DIFFERENT PLACES ALONG THE HUDSON



Seven tidal curves for the Hudson Estuary, from Jersey City (the mouth of the river), to Albany. Note the delay in high tide as you move up the river, and that the tides are small in the middle but large at the top and bottom. For a version of this graph tied to a map see *Tide in the Hudson I, 2 pages.*

TIDES AND CURRENTS

A peculiar feature of tides, evident on several of the maps, is that the current continues to run upstream after the tide starts to fall. This seems odd: how, after all, can the river level fall when water is still running - up it?

One way to understand this is by watching a wave approach a floating object.

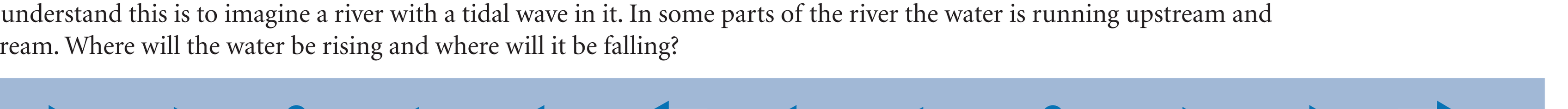
As the wave encounters the object the object begins to move forward and upward).

It continues forward while it is on the back side of the wave but is now moving downward as well.

The object only begins to move backward toward its original place when it is in the trough of the wave.

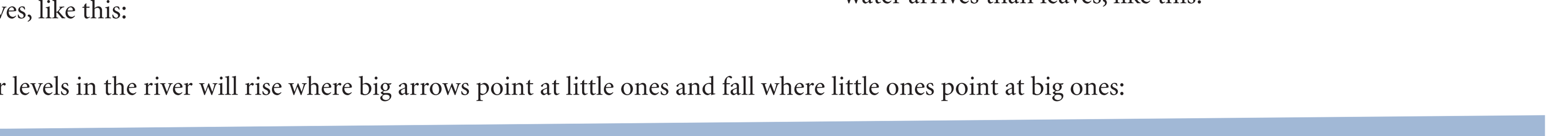
Thus the direction an object (and hence the current it is in) moves doesn't tell us whether it is on the rising or the falling part of the wave. In panels 2 and 3 the object is moving to the right, but in panel 2 the object is on the rising part of the wave, and on panel 3 the falling part.

Another way to understand this is to imagine a river with a tidal wave in it. In some parts of the river the water is running upstream and in some downstream. Where will the water be rising and where will it be falling?



The water will be rising in places where more water arrives than leaves, like this: arriving leaving or this: leaving arriving and falling in places where more water arrives than leaves, like this: leaving arriving

And so the water levels in the river will rise where big arrows point at little ones and fall where little ones point at big ones:



And the tide must be full in the middle and low on the ends: