NOTE ON THE MODIFICATION OF MEAN SEA LEVEL UNDER THE ACTION OF CURRENTS.

by

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1. On the coasts of the ocean, the mean water-level is subject to variations due to meteorological causes such as wind, barometric pressure etc; when the predominating effect is in the same direction during the course of the year, the mean level of the sea is modified and the level obtained by the usual processes, such as the mean of hourly tide readings, mean of high and low waters etc., does not coincide with the water-level called "mean sea level"; one only obtains a *local* mean level, the difference between which and the above water-level may sometimes be several decimeters.

The result is that if one determines the local mean levels at two different ports in the same district and connects the two levels obtained by terrestrial levelling, one does not necessarily find the same quantity for the two places.

2. The existence of *currents*, and particularly of tidal streams, in the neighbourhood of the coasts also exerts an influence capable of modifying the position of the mean sea level.

If in fact the currents are not rectilinear, they give rise to a centrifugal force which results sometimes in dispersing the coastal waters (Fig. 1), sometimes in concentrating them (Fig. 2).

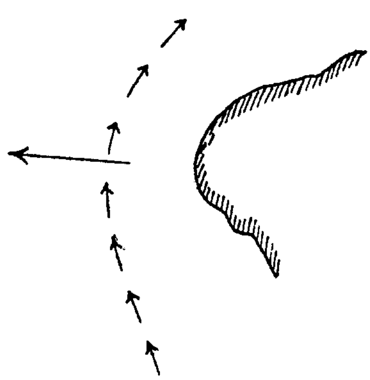

FIG. 1

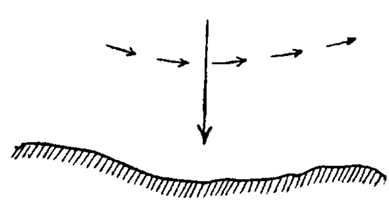

FIG. 2

This action may be of prime importance, and affect a whole region in the case of strong currents.

We propose here to show by an example, that of the North-West point of Cotentin (English Channel), the order of magnitude of these changes of level.

3. The tide observed in the little port of Goury, situated at the point of la Hague on the South shore of the Channel, presents a remarkable peculiarity which has several times been commented upon (1).

In this port, the movement of water above mean level is not equal to its movement below it; the increase in amplitude of the tide which is found from day to day in the course of the lunation does not bear equally upon high water and low water; while the level of high water rises 0.30 metres, the level of low water falls 0.45 metres; in other words, the tidal diagram (Fig. 3) is not symmetrical about *N*, the mean sea level, and one finds a certain "unité de hauteur" (unit of amplitude) for the high waters (2.97 m.) and a

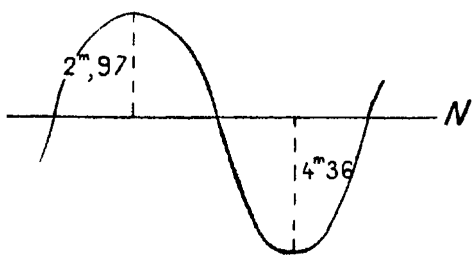

Fig. 3

different "unité" for the low waters (4.36 m.).

Daussy attributed this phenomenon to modifications in the shape of the tidal wave on its arrival at the point of Cotentin. (2)

Actually, it is a question of a purely hydraulic phenomenon due to the action of currents.

4. In the vicinity of the point of la Hague, the tidal streams, which effect the exchange of the waters between the region of the Channel Islands and the Eastern part of the Channel, do not flow in a rectilinear direction but swing round the point of la Hague; the resulting centrifugal force lowers the waters near the French coast (Fig. 4) and the phenomenon occurs during both flood and ebb.

It is well known, on the other hand, that the currents off the coast are nil at half-tide and attain their maximum value at high and low water; this results in the effect of the lowering of level being at its greatest at the moment of high and low water; so much so that if we consider the tidal diagram (*a*) (Fig. 5), theoretically symmetrical about the mean level *N*, we find it lowered both at high and low water and assuming the position (*b*).

(1) Rollet de l'Isle, Observation, étude et prédiction des Marées, 1905, page 172.
(2) Daussy. Mémoire sur les Marées, Connaissance des Temps, Année 1838, page 64.

For the same reasons the mean water-level, instead of remaining at N, is lowered to N'; and this displacement varies according to the strength of the currents, *i. e.* according to the age of the moon.

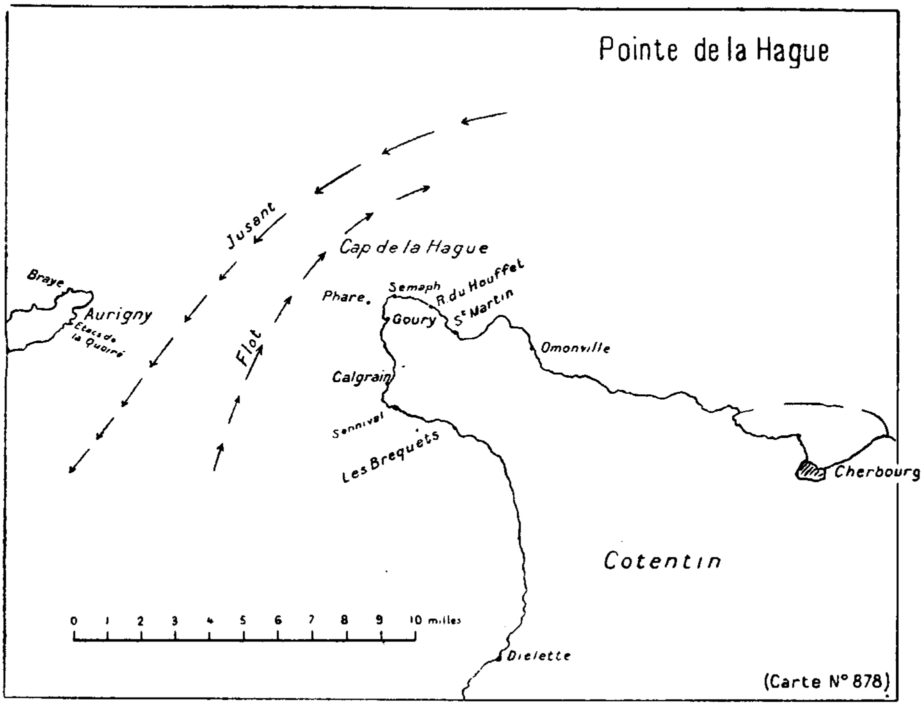

FIG. 4

The order of magnitude of this phenomenon may be evaluated very roughly in the following way.

Any molecule of water M off the point of la Hague (Fig. 6) is submitted to the resultant of two principal forces: one, its weight mg; the other: the centrifugal force $\frac{mV^2}{r}$, V being the speed of the current and r the radius ol its course.

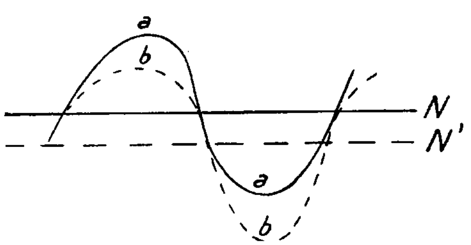

FIG. 5

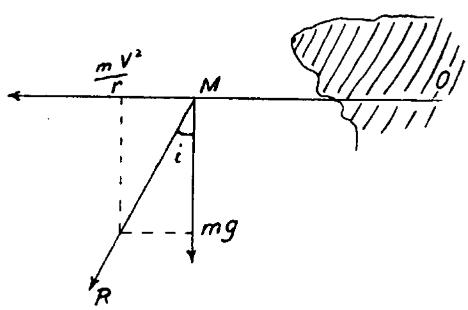

FIG. 6

The surface of the water at the point M is normal to the resultant R, and thus assumes a slope whose value i is equal to $\frac{V^2}{gr}$.

In the case where the velocity V is equal to 4 knots and $r = 8$ kilometres, we thus have

$$i = \left(\frac{4 \times 1852}{60 \times 60}\right)^2 \times \frac{1}{9.81 \times 8000} = \frac{1}{20,000} \text{ nearly.}$$

If we assume as an approximation that the slope i represents the mean inclination of the sea between the region where the water-level is not modified and the coast, there results a change of level near the coast equal to $h = Di$ where D denotes the radius of the inclined region.

$$\text{For } D = 16 \text{ kilometres we get}$$
$$h = 0.80 \text{ metres.}$$

This is the approximate order of magnitude of the amount of change of level.

We shall see that this order of magnitude is in reasonable agreement with the truth.

5. The work of the 1921-1922 hydrographic mission in the vicinity of the point of la Hague produced the results shown in the following table.

The heights are reckoned above the zero of the *Service du Nivellement général* of France, and are referred to a tide of coefficient 100 (mean equinoctial springs).

TABLE

SHOWING THE HEIGHT OF HIGH AND LOW WATER AND THE LOWERING OF THE MEAN LEVEL AT THE N. E. POINT OF COTENTIN FOR A TIDE OF COEFFICIENT 100.

Serial Nº	*PORT.*	*Distance from Cherbourg.*	*Tides of coefficient 100.*		
			HW	LW	Mean $\frac{HW+LW}{2}$
			m	m	m
1	Cherbourg	0 kil.	+2,90	—2,74	+0,08
2	Omonville	30	+2,62	—2,91	—0,14
3	Anse Saint-Martin	37	+2,50	—3,02	—0,26
4	Roches du Houffet	40	+2,36	—3,21	—0,42
5	Sémaphore de la Hague	44	+2,32	—3,66	—0,67
6	Phare de la Hague	46	+2,24	—4,30	—1,03
7	Goury	47	+2,98	—4,32	—0,67
8	Anse de Calgrain	54	+3,40	—4,38	—0,49
9	Anse de Sennival	56	+3,80	—4,55	—0,37
10	Les Brequets	58	+4,00	—4,60	—0,30
11	Dielette	86	+4,63	—4,28	+0,17
12	Alderney (Port de Braye)	76	+3,07	—2,94	+0,06
13	dº (Etac de la Quoiré)	82	+4,00	—3,84	+0,08

In the above table we have included the ports of Dielette and Alderney, although these positions are not connected by topographical levelling with the general level net of France. To determine the position of the zero of this levelling with respect to the tide gauges of these ports, the following method was used : by means of simultaneous tidal observations taken both at the port in question and at Cherbourg, the curve was drawn (Fig. 7) which shows the relationship between the height of high and low waters at the two places; and it was assumed that the zero position of the general levelling at the port in question corresponded with the zero of Cherbourg.

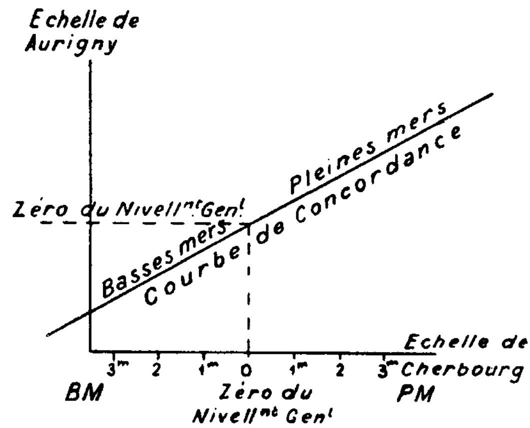

FIG. 7

6. In the last column of the table will be noticed the difference in value at the ports in question between the mean level and the zero of the general levelling of France, *i. e.* mean sea level.

It will be seen that the changes in level due to the currents affect the whole district round the point of la Hague; they extend as far as Dielette, Cherbourg and Alderney; at the same time there is at these places not a lowering but a raising of the level, due to the fact that the general direction of the current results in making the water flow towards the coast instead of dispersing it.

Presumably a similar influence of currents on the mean level exists to a certain extent at all the Channel ports; one would be justified in assuming so at the point of Finistère and in the Brest region if the very accurate work of the *Service du Nivellement général* had not shown the coincidence of mean sea level at Brest with mean sea level at Marseilles and hence with the mean surface of the seas.

7. The foregoing results show the importance, for accurately determining the position of the mean sea level, of disentangling oneself from the influence of the coastal currents. Instead of striking a general average of the heights of the tide indiscriminately for every day of the year, it may be preferable to use the days of neap tides when the tidal streams are weak.

In countries where the semi-diurnal tide is preponderant, if it is proposed to work rapidly, it would be well to determine the mean level by drawing the curve of high and low waters of the port in question either as a function of the tidal coefficient from the French Annuals (Fig. 8) or as a function of the heights of corresponding high and low waters observed at a standard port, where the mean sea level is exactly known (Fig. 9).

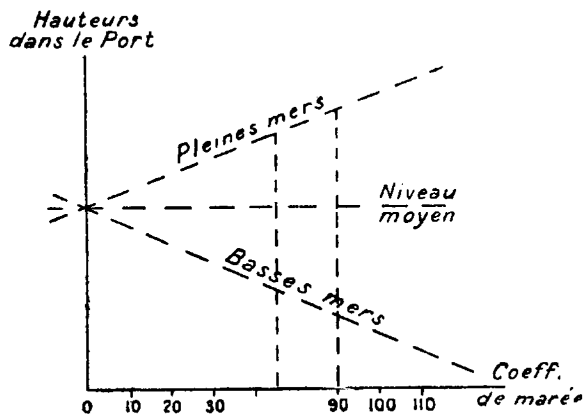

FIG. 8

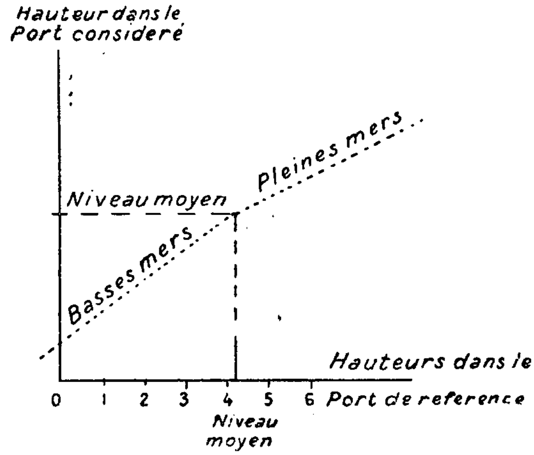

FIG. 9

8. To conclude, we would stress the importance, for accurate determination of the mean sea level, of choosing observation stations in regions removed as far as possible from the influence of sea currents.

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