XI. *Researches on the Tides.—Fourteenth Series.*
On the Results of continued Tide Observations at several places on the British Coasts.

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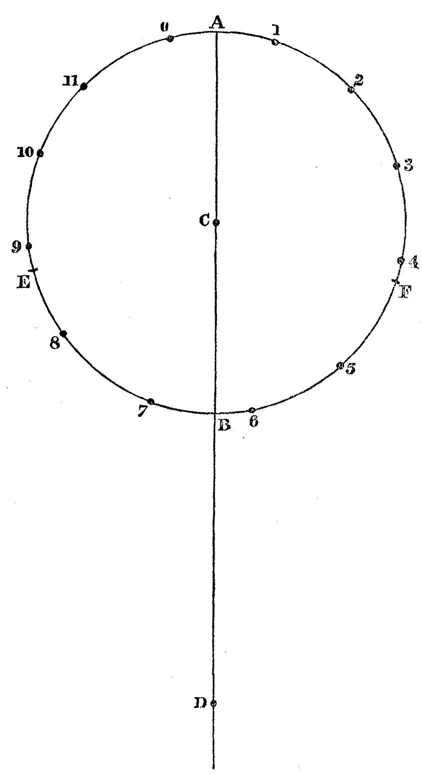
Tide observations made at several different parts of the British and the neighbouring shores, and in some instances continued for a considerable period, have been discussed by Mr. D. Ross of the Hydrographer's Office, with great labour and perseverance; and as the results which his labours afford may be of use to mariners, I offer to the Royal Society a brief statement of these results.

The discussions at present referred to relate to the height of high water, and the variations which this height undergoes in proceeding from springs to neaps and from neaps to springs. It is found, by examining the observations at 120 places and throwing the heights into curves, that the curve is very nearly of the same form at all these places. Hence the semimensual series of heights at any place affords a rule for the series of heights at all other places where the difference of spring height and neap height is the same. For instance, Portsmouth, where the difference of spring height and neap height is 2 feet 8 inches, is a rule for Cork, Waterford, Inverness, Bantry, Boucout on the French coast, and other places.



And the Tables of the height of high water at one of these places suffice for all the others, a constant being of course added or subtracted according to the position of the zero-point from which the heights at each place are measured.

The series of heights of high water for a semilunation also agrees very exactly, as to the form of the curve, with the equilibrium theory. The following construction gives this curve.

With centre C and radius CA (half the difference of the height at spring and neaps), describe a circle; and in AC produced take CD to CA as 12 to 5. Divide the circumference of the circle into twelve hours, representing the twelve hours of moon's transit; and join D with each of these divisions. The lines thus drawn to the hours will give the heights of high water for each hour of the moon's transit; a constant quantity being, as before stated, added or subtracted in order to refer the height to the proper zero.

According to the theory, the 0^h or 12^h hour-points would be at A; the ratio of DC to AC would be that of the lunar to the solar tide; and the distances of the hour-points from D would be the heights of high water above mean water. But all these properties are, in the actual cases, modified in a manner which must be noticed.

The tides in these discussions are not referred to the transit of the moon *immediately* preceding, but to some earlier transit, namely, the second, third, fourth or fifth preceding transit; it being found that in this way the accordance with the theory becomes more exact. Thus in the British Channel the tides are referred to the *third* preceding transit; and this extends also to Ireland and to the west coast of England and Scotland. On the east coast of England, in the northern parts, as at Shields, Sunderland, Scarborough and Hull, the *fourth* preceding transit is used; at Harwich, Sheerness and London, the *fifth* (see Table B). But this reference to an earlier transit does not make the highest tide correspond exactly with the hour of transit 0^h or 12^h: and it is found, in the cases which have been included in the present examination, that a displacement of the 0^h point about fifteen minutes from A will best make the theoretical and the observed curves agree with each other.

The ratio of DC to AC is, as has been said, 12 to 5; and this, according to the theory, would be the ratio of the lunar to the solar tide. If this were the case, the spring tide measured above mean water would be 17, and the total spring tide above spring tide low water would be 34. The neap tide in this case would be 7 above mean water, and therefore 24 above spring tide low water. Hence the difference of springs and neaps would be to the height of neaps above low water springs as 10 to 24, a ratio constant for all places.

But in fact, this ratio of the excess of springs to the total height of neaps above low water springs is different at different places: and the observations now under consideration show in some measure the law of this difference. The ratio is smaller when the tide is smaller. This appears from the observations at different places, as arranged by Mr. Ross in the annexed Table A. We have there the following results, taking the means of groups of places according to the amount of tide.

Number of places.	Mean neap tide above spring low water.	Mean excess of spring high water above neap.	Ratio.
	ft. in.	ft. in.	
37	9 3	2 5	38 : 10
40	12 0	3 8	33 : 10
39	17 10	5 9	31 : 10
4	27 0	9 8	28 : 10

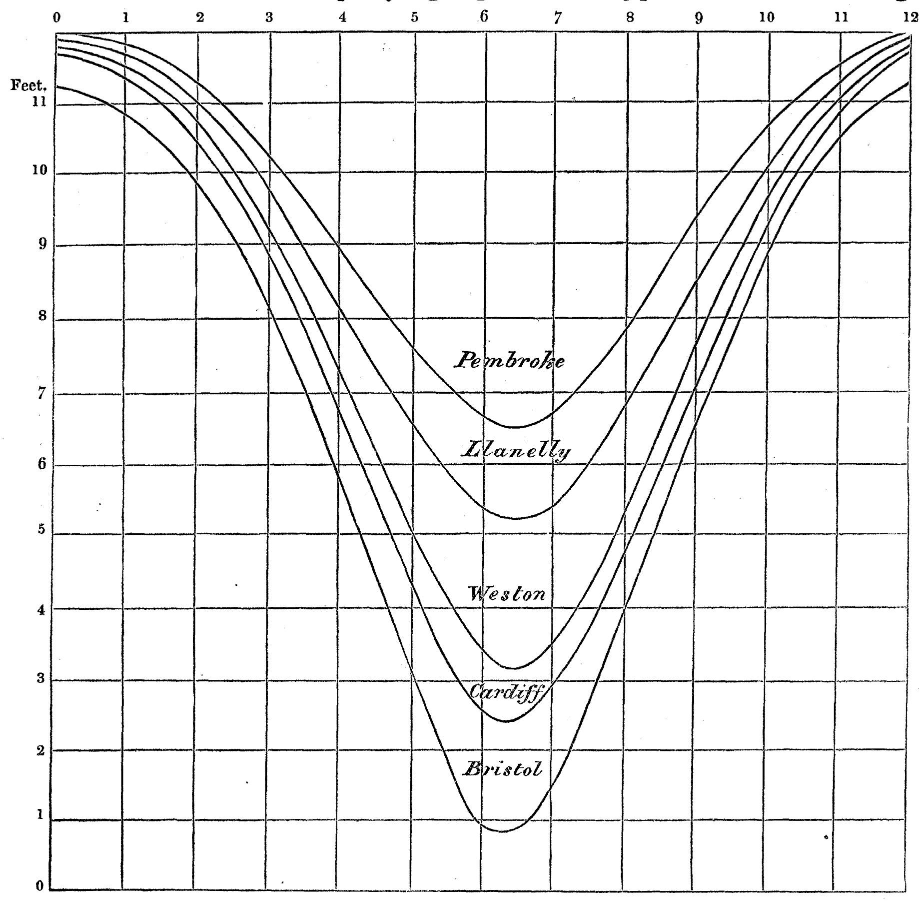
Where it appears that the actual ratio approaches to the theoretical ratio in proportion as the amount of tide increases.

If the ratio just spoken of were constant, we should be able to find the height of mean water by knowing the excess of springs above neaps: the excess being 10, the mean water would be 7 below the neap high water. But it appears that in general the mean water is lower than this: and the excess of springs being 10, the mean water is from 14 to 19 below neap high water at various points on the coast of Great Britain and France.

In consequence of the law of the high waters, given alike by the theory and by the observations, the spring high waters are above the mean high water for a longer period than the neaps are below it. For it is evident that if DE and DF be each equal to DC, the heights are greater than the mean DC through the arc EAF, which is greater than a semicircle. And it is evident that the excess of AE above a quadrant will be an arc of which the sine is $\frac{\frac{1}{2}EC}{DC}$ or $\frac{5}{24}$; or 12° nearly. Hence the two portions of the semicircle will be, in time, $3^h\ 24^m$ and $2^h\ 38^m$; and the tides will be above the mean during $6^h\ 48^m$ of lunar transit, and below the mean during $5^h\ 12^m$; and this is found to be very nearly the case at all the places examined; thus confirming the identity of the rule of different places one with another, and with the construction given above.

Additional Note on the Tides of the Bristol Channel.

Mr. Ross has traced the modification which the semimensual inequality of heights undergoes in ascending the Bristol Channel from Pembroke to Bristol. This modification is shown in the accompanying figure. It appears from the diagram which



Mr. Ross has drawn from the observations, that the difference of springs and neaps increases gradually from Pembroke to Llanelly, Weston, Cardiff, and finally Bristol, the difference being 5 ft. 6 in. at the first place, and 10 ft. 6 in. at the last; and the curve which represents the change from day to day being at all the places of the same form, namely, of the form described in the preceding paper.

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Trinity College, Cambridge,
Nov. 3, 1849.

TABLE A.—Results of Tide Observations arranged according to the amount of excess of Springs above Neaps.

TABLE B.—Places along the same coasts arranged in the order of their "Establishment."

TABLE A.

Number of observations from which curves were formed.		"Establishment" of the port. h m	Mean spring rise above mean low water spring. ft. in.	Mean neap rise above mean low water spring. ft. in.	Excess of spring over neap. ft. in.	
128	Ardrishaig	12 0	9 2	8 7	0 7	
704	Lowestoft	9 57	6 6	5 4	1 2	
673	Belfast	10 43	9 5	8 1	1 4	Third preceding transit.
375	Greenock	12 8	9 9	8 2	1 7	Third preceding transit.
107	Ayr Harbour	12 10	8 9	7 2	1 7	
418	Harwich	0 6	11 6	9 9	1 9	Fifth preceding transit.
595	Donaghadee	11 13	11 3	9 5	1 10	
218	Crookhaven	4 9	9 10	8 0	1 10	
190	Baltimore	4 23	10 2	8 3	1 11	
144	Courtmacsherry	4 36	10 8	8 7	2 1	
233	Skull	4 2	9 8	7 7	2 1	
1,059	Kingstown	11 10	11 0	8 10	2 2	Third preceding transit.
209	Castletown	4 14	9 10	7 7	2 3	
351	Peterhead	0 34	10 9	8 6	2 3	
130	Bantry Harbour	3 47	10 2	7 8	2 6	
90	Arcachon, France	4 37	11 8	9 2	2 6	
77	Boucout, France	3 39	8 8	6 1	2 7	
123	Dunmore	5 27	12 3	9 8	2 7	
4,230	Portsmouth	11 41	12 8	10 0	2 8	Third preceding transit.
373	Cork	5 1	11 9	9 1	2 8	Third preceding transit.
51	Castletownsend	4 21	10 9	8 1	2 8	
299	Waterford	6 6	13 5	10 9	2 8	
193	Inverness	12 18	12 2	9 6	2 8	
171	Kinsale	4 43	11 7	8 9	2 10	
522	Sligo	6 0	8 8	5 9	2 11	Third preceding transit.
377	Sheephaven	5 25	11 11	9 0	2 11	
1,383	Ramsgate	11 41	15 6	12 7	2 11	
124	Bordeaux, France	6 50	14 1	11 2	2 11	
4,233	Sheerness	0 37	16 1	13 1	3 0	Fifth preceding transit.
105	Loch Inver	6 41	13 11	10 11	3 0	
69	East Looe	5 26	16 2	13 2	3 0	
446	Inishbofin	5 5	12 10	9 9	3 1	
76	Omonville, France	7 29	15 6	12 5	3 1	
692	Westport	4 57	12 8	9 6	3 2	
92	Peel, Isle of Man	11 8	16 3	13 1	3 2	
103	Caernarvon	9 33	13 9	10 7	3 2	
156	Port Navallo, France	3 42	12 11	9 9	3 2	
183	Tobermorey	5 36	12 10	9 7	3 3	
79	Ramsay, Isle of Man	11 12	19 3	16 0	3 3	
125	Royan, France	3 38	13 3	10 0	3 3	
86	St. Surin, France	4 11	14 3	11 0	3 3	
277	Roundstone	4 28	13 6	10 2	3 4	
117	Goodick Pier	6 56	11 7	8 3	3 4	
937	Dundee	2 32	14 7	11 3	3 4	
125	Patiras, France	5 10	15 6	12 2	3 4	
13,400	London	1 59	19 6	16 1	3 5	Fifth preceding transit.
705	Sunderland	3 22	14 5	11 0	3 5	Fourth preceding transit.
541	Holyhead	10 11	16 0	12 7	3 5	Third preceding transit.
236	Foynes Island, Shannon	5 35	15 5	12 0	3 5	
356	Scarborough	4 11	15 10	12 5	3 5	Fourth preceding transit.
821	Hartlepool	3 28	15 0	11 7	3 5	Fourth preceding transit.
688	Granton Pier	2 20	16 0	12 7	3 5	
	North Shields	3 30	13 8	10 3	3 5	Fourth preceding transit.
148	Socoa, France	3 19	12 3	8 10	3 5	
159	Dunkirk, France	12 8	16 10	13 5	3 5	
2,820	Devonport	5 43	15 5	11 11	3 6	Fourth preceding transit.
2,823	Leith	2 17	16 4	12 9	3 7	Fourth preceding transit.
299	Barfleur, France	8 51	17 0	13 5	3 7	
155	Concarneau, France	3 12	13 1	9 6	3 7	
154	Port Louis, France	3 11	13 1	9 5	3 8	

Table A. (Continued.)

Number of observations from which curves were formed.		"Establishment" of the port.	Mean spring rise above mean low water spring.	Mean neap rise above mean low water spring.	Excess of spring over neap.	
		h m	ft. in.	ft. in.	ft. in.	
104	Cordouan Lighthouse, France	3 37	13 10	10 2	3 8	
437	Thurso	8 27	13 3	9 6	3 9	Third preceding transit.
134	Melville, France	9 36	21 1	17 4	3 9	
107	La Hougue, France	8 42	18 5	14 7	3 10	
66	Aberystwyth	7 31	13 5	9 7	3 10	
684	Galway	4 35	14 10	10 11	3 11	Third preceding transit.
164	Belleisle, France	3 18	14 3	10 4	3 11	
147	Calais, France	11 49	19 6	15 7	3 11	
121	Ile d'Yeu	3 6	14 2	10 2	4 0	
125	Pwllheli	7 46	13 8	9 8	4 0	
1,207	Great Grimsby	5 36	19 2	15 1	4 1	
153	Limerick, Shannon	6 20	16 10	12 8	4 2	
194	Tarbert Island, Shannon	4 57	14 6	10 4	4 2	
259	Cherbourg, France	7 49	16 11	12 9	4 2	
134	Havre, France	9 51	22 1	17 11	4 2	
2,116	Dover	11 12	18 8	14 5	4 3	Third preceding transit.
170	Aix Island, France	3 20	16 11	12 8	4 3	
174	St. Nazaire, France	3 40	15 2	10 11	4 3	
154	Beagh Castle, Shannon	5 49	17 6	13 2	4 4	
157	Mellon, Shannon	6 1	18 3	13 10	4 5	
115	Port en Bessin, France	8 57	19 11	15 6	4 5	
703	Hull	6 29	20 10	16 4	4 6	Fourth preceding transit.
118	Alderney	6 46	17 4	12 10	4 6	
258	Douglas, Isle of Man	11 12	20 8	16 1	4 7	
156	Noirmoutier Island, France	3 2	15 11	11 4	4 7	
129	Goury, France	7 6	21 11	17 3	4 8	
153	Cape Grisnez, France	11 27	21 6	16 9	4 9	
223	Tarn Point	11 22	23 1	18 1	5 0	
213	Whitehaven	11 14	23 3	18 2	5 1	
138	Beaumaris	10 32	21 5	16 4	5 1	
132	Fécamp, France	10 44	23 3	18 1	5 2	
513	Brest, France	3 47	19 1	13 10	5 3	Third preceding transit.
62	Honfleur, France	9 29	23 4	18 1	5 3	
13,400	Liverpool	11 16	25 7	20 3	5 4	Third preceding transit.
135	Boulogne, France	11 25	24 10	19 5	5 5	
74	Sein Island, France	3 21	17 6	12 1	5 5	
4,236	Pembroke	6 12	21 0	15 6	5 6	Third preceding transit.
74	Ushant	3 32	19 4	13 9	5 7	
143	Pontasval, France	4 26	22 4	16 8	5 8	
305	Roscoff, France	4 46	23 1	17 4	5 9	
175	Poulton-le-Sands	11 26	27 3	21 6	5 9	
149	Ploumarach, France	5 15	24 3	18 5	5 10	
176	Abervrach, France	4 14	21 9	15 10	5 11	
184	Morlaix Roads, France	4 53	23 9	17 10	5 11	
122	St. Ives	4 44	21 0	15 1	5 11	
72	Ilfracombe	5 42	27 4	21 4	6 0	
221	Dieppe	11 6	27 0	20 8	6 4	
303	Fleetwood	11 12	26 3	19 8	6 7	
292	Port des Enfans, France	5 17	25 5	18 10	6 7	
117	Cayeux, France	11 5	27 6	20 11	6 7	
391	Brehat, France	5 51	31 2	23 7	7 7	
81	Lezardrieux, France	5 54	30 3	22 2	8 i	
119	Jersey	6 15	29 9	21 5	8 4	
370	Weston-super-Mare	6 54	37 3	28 9	8 6	Third preceding transit.
129	Ecrehou	6 32	30 11	22 5	8 6	
139	Erqui	5 59	33 3	24 5	8 10	
153	St. Malo, France	6 5	35 0	25 10	9 2	
277	Chausey, France	6 9	35 2	25 10	9 4	
294	Granville, France	6 13	37 1	27 2	9 11	
138	Portishead	7 11	41 4	31 1	10 3	

TABLE B.

	Establishment. h m
From the Land's End to Ramsgate.	
East Looe	5 26
Devonport (4th transit?)	5 43
Portsmouth (3rd transit)	11 41
Dover (3)	11 12
Ramsgate	11 41
From the Land's End up St. George's Channel round the North of Scotland to London.	
St. Ives	4 44
Ilfracombe	5 42
Weston-super-Mare (3)	6 54
Portishead	7 11
Pembroke (3)	6 12
Goodick Pier	6 56
Aberystwyth	7 31
Pwllheli	7 46
Caernarvon	9 33
Holyhead	10 11
Beaumaris	10 32
Liverpool (3)	11 16
Fleetwood	11 12
Tarn Point	11 22
Poulton-le-Sands	11 26
Peel, Isle of Man	11 8
Douglas, Isle of Man	11 12
Ramsay, Isle of Man	11 12
Whitehaven	11 14
Ayr	12 10
Greenock (3)	12 8
Thurso (3)	8 27
Inverness	12 18
Peterhead	0 34
Dundee	2 32
Granton (4)	2 20
Leith	2 17
North Shields (4)	3 30

	Establishment. h m
Sunderland (4)	3 22
Hartlepool	3 28
Scarborough (4)	4 11
Hull (4)	6 29
Great Grimsby	5 36
Lowestoft	9 57
Harwich (5)	0 6
Sheerness (5)	0 37
London (5)	1 59
From Bantry Bay up St. George's Channel round the North of Ireland to the Shannon.	
Bantry Harbour	3 47
Castletown (Berehaven)	4 14
Skull	4 2
Crookhaven	4 9
Baltimore	4 23
Castletownsend	4 21
Courtmacsherry	4 36
Kinsale	4 43
Cork (3)	5 1
Dunmore	5 27
Waterford	6 6
Kingstown (3)	11 10
Donaghadee	11 13
Belfast (3)	10 43
Sheephaven	5 25
Sligo (3)	6 0
Westport	4 57
Inishbofin	5 5
Roundstone	4 28
Galway (3)	4 35
Tarbert, Shannon	4 57
Foynes Island, Shannon	5 35
Beagh Castle, Shannon	5 49
Mallon, Shannon	6 1
Limerick, Shannon	6 20

	Establishment. h m
From Arcachon in the Bay of Biscay to Dunkirk.	
Arcachon	4 37
Bordeaux	6 50
St. Surin	4 11
Royan	3 38
Cordouan	3 27
Ile d'Aix	3 20
Ile d'Yeu	3 6
Noirmoutier Island	3 2
St. Nazaire	3 40
Belleisle	3 18
Port Louis	3 11
Concarneau	3 12
Brest (3)	3 47
Ushant	3 32
Morlaix Roads	4 53
Brehat	5 51
Erqui	5 59
St. Malo	6 5
Granville	6 13
Chausey	6 9
Jersey	6 15
Ecrehou	6 32
Alderney	6 46
Cherbourg	7 49
Barfleur	8 51
La Hougue	8 42
Honfleur	9 29
Havre	9 51
Fécamp	10 44
Dieppe	11 6
Cayeux	11 5
Boulogne	11 25
Cape Grisnez	11 27
Calais	11 49
Dunkirk	12 8

For the places not otherwise marked in these Tables, the tides were referred to the transit immediately preceding, as giving sufficient exactness for general maritime purposes: but observations received at the Admiralty since the above laws were discovered, have been referred to the third, fourth, or fifth preceding transit, according to their place in Table B.

The Devonport tides discussed some years ago, apart from those of neighbouring places, appeared to give the greatest exactness with the *fourth* preceding transit, which has accordingly been used in the Admiralty Tables. There can be no doubt at present that the *third* preceding transit is more correct for this port; but the labour of recalculating new Tables would be great, and the difference of the result would never be more than one minute in the time and one inch in the height.