No. 227

THE TIDES

IN

KINGSTON HARBOUR,

AND

THE KINGSTON TIME SERVICE.

QC
987
.J25
W34
1894/1897

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THE TIDES IN KINGSTON HARBOUR.

In Weather Reports Nos. 179 and 191, the results of the registration were roughly discussed, and it was shown that the observations could not properly deal with the Diurnal tides. In consequence a self-registering Tide-gauge was recommended, and constructed; but it had the defect usual to all such instruments, namely, that although it worked well in a general way, yet it was liable to "stick" or "jam" to an extent beyond the driving power of the clock.

The method of registration was then altered; instead of observing during every hour between 6 a.m. and 5 p.m. the boatmen were instructed to observe every second hour throughout the 24 hours on certain days. These days were selected before-hand as those on which the Semi-diurnal tides, and the Diurnal tides, would be most clearly marked; or they were those days when the Moon's Declination was 0°, or when it was at its maximum, North or South.

By means of these observations which were continued between February and June, 1897, the two kinds of Tides were clearly distinguished, and their dependence on the Moon's Declination as clearly established.

It thus became possible to pick out of the registers between Jan. 1894 and Jan. 1897 all the observations which referred to the day-time High and Low water of the Semi-diurnal tides; and also the day-time High or Low water of the Diurnal tides.

It will be noticed that the day-time High and Low water of the Semi-diurnal tides will also give the Range, or difference between High and Low, and also the Mean sea-level, for each day in question. But in the case of the Diurnal tides no such Range has been observed, and it is necessary to take the yearly means of High and Low in order to obtain the yearly Range.

In consequence the Semi-diurnal tides during 1894, 1895, 1896, and half of 1897, were first reduced, and the results are here given. It is hardly necessary to say that the present reduction for 1894 supersedes that given in W. R, No. 179.

In the following Tables for the Semi-diurnal Tides the first column gives the date of the Moon's Transit across the meridian, the second column states whether that Transit is Upper or Lower, and the third column gives the Kingston mean time of Transit. This is found by merely adding 10 min. to the corresponding Transit at Greenwich as given in the Nautical Almanac. The fourth and fifth columns give the Moon's Parallax, and the direction of the Moon's motion in Declination, North or South. All these columns apply to the time when the Moon's Decl. is 0°.

The sixth and seventh columns give the date and observed time of High water next following the Moon's Transit. If that particular High water has not been observed, the High water before and after, and all the corresponding data in the preceding columns, have been used instead.

The eighth column gives the computed time of High water. This is found by adding

11hr. 28min.

to the time of the Moon's Transit, by subtracting or adding 8 min. according as the Moon's motion in Decl. is North or South, and by applying the following Annual and Semi-mensual Inequalities.

ANNUAL INEQUALITY (Semi-diurnal tides).

			Min.	Diff.				Min.	Diff.
January	1	...	− 60	7	July	1	...	+ 112	28
	11	...	− 67	12		11	...	+ 140	4
	21	...	− 79	9		21	...	+ 144	48
February	1	...	− 88	6	August	1	...	+ 96	70
	11	...	− 94	3		11	...	+ 26	54
	21	...	− 91	19		21	...	− 28	10
March	1	...	− 72	20	September	1	...	− 38	7
	11	...	− 52	21		11	...	− 31	19
	21	...	− 31	9		21	...	− 12	21
April	1	...	− 22	2	October	1	...	+ 9	24
	11	...	− 20	5		11	...	+ 33	23
	21	...	− 25	20		21	...	+ 56	17
May	1	...	− 45	11	November	1	...	+ 73	7
	11	...	− 56	3		11	...	+ 80	6
	21	...	− 53	51		21	...	+ 74	37
June	1	...	− 2	48	December	1	...	+ 37	49
	11	...	+ 46	40		11	...	− 12	32
	21	...	+ 86	26		21	...	− 44	16

SEMI-MENSUAL INEQUALITY (Semi-diurnal tides).

Hour of Moon's transit a.m. or p.m.

hr.	min.			Min.	Diff.
0	0	...	...	+ 2	10
0	48	...	...	− 8	11
1	36	...	...	− 19	9
2	24	...	...	− 28	7
3	12	...	...	− 35	3
4	0	...	...	− 38	1
4	48	...	...	− 37	12
5	36	...	...	− 25	22
6	24	...	...	− 3	20
7	12	...	...	+ 17	17
8	0	...	...	+ 34	10
8	48	...	...	+ 44	1
9	36	...	...	+ 45	10
10	24	...	...	+ 35	16
11	12	...	...	+ 19	17
12	0	...	...	+ 2	

The ninth column gives the difference betwen the Observed and the Computed times of High water.

The tenth and eleventh columns give the observed scale reading of High and Low water; the twelfth gives the mean of these two readings, or the mean sea-level for that day.

The thirteenth column gives the mean sea-level computed according to the following formula:—

$$\text{Mean sea-level} = \overset{\text{in.}}{21.3} + \overset{\text{in.}}{0.84} \left\{ (T) - 78^\circ.6 \right\}$$

where 21.3 in the scale reading for a mean sea-level corresponding to a mean temperature of (T) of 78°.6, and where (T) is half the sum of the mean temperature of the air for any month in question and for the preceding month; whence we get the following table:—

(T)			Mean sea-level.
			in.
73°	...	...	16.6
74	...	...	17.4
75	...	...	18.3
76	...	...	19.1
77	...	...	20.0
78	...	...	20.8
79	...	...	21.6
80	...	...	22.5
81	...	...	23.3
82	...	...	24.2

The values of (T) for each month are given in the last column.

The fourteenth column gives the difference between Mean water as observed and computed.

The fifteenth column gives the observed Range or difference between HW and LW. The sixteenth gives the computed Range, as affected by the variation of the Moon's Parallax, and by a small Semi-mensual Inequality.

Let $p = \frac{Parallax - 57'}{57'}$, then the factor for Parallax is $(1 + 3\,p)$; and taking the mean Range to be 2.9in., we have,

Parallax.		Factor.		Range.
′				in.
53	...	0.79	...	2.3
54	...	0.84	...	2.4
55	...	0.90	...	2.6
56	...	0.95	...	2.8
57	...	1.00	...	2.9
58	...	1.05	...	3.0
59	...	1 10	...	3.2
60	...	1.16	...	3.4
61	...	1.21	...	3.5

Hour of Moon's Transit, a.m. or p.m.	Semi-mensual Inequality.
hr.	in
0	+ 0 2
1	+ 0.4
2	+ 0.4
3	+ 0.3
4	+ 0 2
5	0.0
6	+ 0.1
7	+ 0.3
8	+ 0.4
9	+ 0.4
10	+ 0.3
11	0.0
12	+ 0 2

The seventeenth column gives the difference between the observed and the computed values of the Range.

And as already stated the last column gives the values of (T). They were found from the following table :—

KINGSTON :—MEAN MONTHLY TEMPERATURES.

Month.	1893.	1894.	1895.	1896.	1897.
	°	°	°	°	°
January	...	74.3	74.5	75 0	75.4
February	...	73.5	74.7	76.8	77.2
March	...	73.9	75.2	76.9	77.5
April	...	76.9	78.2	76.8	79.7
May	...	78.8	80.5	79.3	80.8
June	...	80.6	81.4	83.3	82.5
July	...	79.9	81.5	82.0	...
August	...	80.7	80.8	81.7	...
September	...	81.1	81.0	81.6	...
October	...	77.9	80.1	81.0	...
November	...	78.0	77.7	79 4	...
December	75.0	74.7	76.0	78.2	...
Means	...	77.5	78.5	79.3	...

And finally the Mean Monthly Temperatures were found from the formula

$$T = \frac{M + m}{2} - 1^\circ.5$$
$$- 0.43 \quad (R - 17)$$
$$- 0.11 \quad (H - 78)$$
$$- 0\ 12 \quad (C - 5.5)$$

where

M = Mean Monthly Max.
m = " " Min.
R = " " Range
H = " " Humidity
C = " " Cloud (in tenths).

1894. Semi-diurnal tides observed when Moon's Declination = 0°.

Moon's Decl. = 0°					Following High Water.				Heights.					Range.			
Date.	Tr.	Time of Transit.	Par.	Motion.	Date.	Time Observed.	Time Computed.	O—C	HW	LW	Mean water O	Mean water C	O—C	O	C	O—C	(T).
		hr. min.	'			hr. min.	hr. min.	min.	in.	in.	in.	in.	in.	in.	in.	in.	°
Jan. 13	L	4 45 a.m.	56	N	13	1 30 p.m.	2 19 p.m.	— 49	26	22	24.0	18.0	+ 6.0	4	2.8	+ 1.2	74.6
25	U	3 28 "	58	S	25	1 30 "	1 5 "	+ 25	24	20	22.0	18.0	+ 4.0	4	3.3	+ 0.7	"
26	U	4 13 "	58	S	26	2 0 "	1 48 "	+ 12	24	21	22.5	18.0	+ 4.5	3	3 2	— 0.2	"
Feb. 9	L	2 45 "	56	N	9	Noon	0 2 "	— 2	23	18	20.5	17.4	+ 3.1	5	3.1	+ 1.9	73.9
10	L	3 28 "	57	N	10	0 30 p.m.	0 39 "	— 9	23	18	20.5	17.4	+ 3.1	5	3.2	+ 1.8	"
22	U	2 2 "	58	S	22	11 30 a.m.	11 42 a.m.	— 12	23	16	19.5	17.4	+ 2.1	7	3.4	+ 3 6	"
Mar. 8	L	0 42 "	56	N	8	Noon	10 56 "	+ 64	21	17	19.0	17.2	+ 1.8	4	3.2	+ 0 8	73.7
9	L	1 26 "	57	N	9	11 30 a.m.	11 33 "	— 3	21	18	19.5	17.2	+ 2.3	3	3.3	— 0.3	"
20	U	11 52 p.m.	58	S	21	11 0 "	10 57 "	+ 3	19	13	16.0	17.2	— 1.2	6	3.2	+ 2.8	"
22	U	0 37 a.m.	58	S	22	10 30 "	11 37 "	— 67	18	15	16.5	17.2	— 0.7	3	3.3	— 0.3	"
Apr. 4	L	11 20 p.m.	57	N	5	10 30 "	10 34 "	— 4	18	13	15.5	18.6	— 3.1	5	3.0	+ 2.0	75.4
17	U	10 31 "	58	S	18	10 0 "	10 17 "	— 17	18	16	17.0	18.6	— 1 6	2	2.9	— 0.9	"
May 1	L	9 11 "	57	N	2	8 30 "	8 30 "	0	21	19	20.0	20.6	— 0.6	2	2.5	— 0 5	77.8
2	L	9 55 "	57	N	3	8 0 "	9 11 "	— 71	21	17	19.0	20.6	— 1.6	4	2.6	+ 1.4	"
14	U	8 29 "	57	S	15	8 0 "	7 49 "	+ 11	21	18	19.5	20.6	— 1.1	3	2.5	+ 0.5	"
15	U	9 13 "	57	S	16	8 0 "	8 38 "	— 38	20	18	19.0	20.6	— 1.6	2	2.5	— 0.5	"
29	L	7 46 "	57	N	30	7 0 "	7 22 "	— 22	22	18	20.0	20.6	— 0.6	4	2.5	+ 1.5	"
June 11	L	6 50 a.m.	57	S	11	7 30 p.m.	7 19 p.m.	+ 11	22	19	20 5	22 3	— 1.8	3	2.6	+ 0.4	79.7
26	U	6 2 "	56	N	26	6 30 "	6 47 "	— 17	24	20	22.0	22.3	— 0.3	4	2.7	+ 1.3	"
July 9	L	5 32 "	58	S	9	7 0 "	6 57 "	+ 3	23	21	22.0	22.7	— 0.7	2	2.9	— 0.9	80.2
23	U	4 1 "	55	N	23	5 0 "	4 57 "	+ 3	22	20	21 0	22.7	— 1.7	2	2.8	— 0.8	"
Aug. 5	L	3 24 "	59	S	No	observations	...	...	...	...	...	...	...	...	...	...	...
20	U	2 41 "	56	N	20	2 30 p.m.	1 8 "	+ 82	25	23	24.0	22.7	+ 1.3	2	3.1	— 1.1	80.3
Sept. 1	L	1 12 "	60	S	1	Noon	11 57 a.m.	+ 3	22	20	21.0	23.2	— 2.2	2	3.8	— 1.8	80.9
16	U	0 40 "	56	N	No	observations	.	...	...	..	...	...	...	...	..	..	...
28	L	11 48 p.m.	59	S	29	Noon	11 32 "	+ 28	21	17	19.0	23.2	— 4.2	4	3 4	+ 0.6	"
Oct. 12	U	10 36 "	56	N	13	11 30 a.m.	11 2 "	+ 28	21	18	19.5	22.1	— 2.6	3	2.7	+ 0.3	79.5
25	L	9 40 "	59	S	26	11 0 "	11 4 "	— 4	21	19	20 0	22 1	— 2.1	2	2.9	— 0.9	"
26	L	10 26 "	58	S	27	11 30 "	11 41 "	— 11	20	17	18.5	22.1	— 3.6	3	2.8	+ 0.2	"
Nov. 8	U	8 30 "	56	N	9	...	...	...	19	19	19.0	20.8	— 1.8	0	2.4	— 2 4	78.0
21	L	7 37 "	58	S	22	9 0 "	8 52 "	+ 8	23	21	22.0	20.8	+ 1.2	2	2.6	— 0.6	"
22	L	8 23 "	58	S	23	10 0 "	9 48 "	+ 12	23	21	22.0	20 8	+ 1.2	2	2.6	— 0.6	"
Dec. 6	U	7 4 "	55	N	7	...	...	...	22	21	21.5	19.5	+ 2.0	1	2.3	— 1 3	76.4
19	L	6 22 "	58	S	20	...	...	...	21	19	20.0	19.5	+ 0.5	2	2.8	— 0.8	"
Means	...	...	...	..	...	...	...	—2	21.6	18.5	20.1	20.1	0 0	3.1	2.9	+ 0.2	77.1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

		hr.	min.	
June 11.	Time of HW taken from LW at	1	30	p.m.
" 26.	" " " "	0	30	"
July 9.	" " " "	1	0	"

Nov. 9. No tide.
Dec. 7. Tide small: HW apparently about 1 p.m. instead of 6 a.m. and p.m.
" 20. Tide small and irregular: HW about 9 hr. 30 min. a.m.

1895. SEMI DIURNAL TIDES OBSERVED WHEN MOON'S DECLINATION = 0°.

Moon's Decl. = 0°.					Following High Water.				Heights.					Range.			
Date.	Tr	Time of Transit.	Par.	Motion.	Date.	Time Observed.	Time Computed.	O—C	HW	LW	Mean water O	Mean water C	O—C	O	C	O—C	(T)
		hr. min.	′			hr. min.	hr. min.	min.	in.	in.	in.	in.	in.	in.	in.	in.	°
Jan. 3	L	5 19 a.m.	55	N	3	...	...	...	19	19	19.0	18.0	+ 1.0	0	2.6	— 2.6	74.6
15	U	3 52 "	60	S	15	3 0 p.m.	1 38 p.m.	+ 82	17	14	15.5	18.0	— 2.5	3	3.6	— 0.6	"
16	U	4 40 "	59	S	No observations		...	...	...	...	...	...	...	...	...	...	...
30	L	3 18 "	54	S	30	2 0 p.m.	0 47 "	+ 73	18	16	17.0	18.0	— 1.0	2	2.7	— 0.7	"
31	L	3 58 "	55	N	31	1 0 "	1 13 "	— 13	19	18	18.5	18.0	+ 0.5	1	2.8	— 1.8	"
Feb. 12	U	2 29 "	60	S	12	0 30 "	0 3 "	+ 27	17	16	16.5	18.0	— 1.5	1	3.8	— 2.8	"
26	L	1 18 "	54	N	26	1 0 "	11 2 a.m.	+ 118	18	15	16.5	18.0	— 1.5	3	2.8	+ 0.2	"
27	L	1 58 "	55	N	No observations		...	...	...	...	...	...	...	...	...	...	...
Mar. 11	U	0 13 "	61	S	11	0 30 p.m.	10 55 "	+ 95	24	21	22.5	18.3	+ 4.2	3	3.7	— 0.7	75.0
12	U	1 4 "	60	S	12	10 0 a.m.	11 38 "	— 98	23	21	22.0	18.3	+ 3.7	2	3.8	— 1.8	"
25	L	11 56 p.m.	55	N	26	Noon	10 51 "	+ 69	20.6	17.4	19.0	18.3	+ 0.7	3.2	2.8	+ 0.4	"
April 7	U	10 50 "	60	S	8	...	...	...	22.8	19.2	21.0	19.7	+ 1.3	3.6	3.4	+ 0.2	76.7
21	L	9 54 "	55	N	22	...	...	...	22.2	20.8	21.5	19.7	+ 1.8	1.4	2.3	— 0.9	"
22	L	10 34 "	55	N	23	...	...	...	22.2	20.0	21.1	19.7	+ 1.4	2.2	2.5	— 0.3	"
May 4	U	8 43 "	59	S	No observations		...	...	...	...	...	...	...	...	...	...	...
5	U	9 31 "	59	S	6	...	...	...	24.[illegible]	21.8	22.9	22.0	+ 0.9	2.2	2.9	— 0.7	79.4
18	L	7 49 "	55	N	No observations		...	...	...	...	...	...	...	...	...	...	...
19	L	8 29 "	55	N	20	...	...	...	23.8	20.4	22.1	22.0	+ 0.1	3.4	2.2	+ 1.2	"
June 1	L	7 4 a.m.	59	S	1	8 30 p.m.	6 52 p.m.	+ 98	24.0	21.0	22.5	23.3	— 0.8	3.0	2.9	+ 0.1	81.0
2	L	7 51 "	59	S	No observations		...	...	...	...	...	...	...	...	...	...	...
15	U	6 4 "	54	N	15	9 30 p.m.	6 13 "	+ 197	25.0	22.2	23.6	23.3	+ 0.3	2.8	2.3	+ 0.5	"
16	U	6 44 "	55	N	No observations		...	...	...	...	...	...	...	...	...	...	...
28	U	5 26 p.m.	59	S	29	6 0 a.m.	6 21 a.m.	— 21	25.8	23.0	24.4	23.3	+ 1.1	2.8	3.2	— 0.4	"
July 13	U	4 40 a.m.	54	N	13	7 0 p.m.	5 44 p.m.	+ 76	27.6	26.0	26.8	23.7	+ 3.1	1.6	2.5	— 0.9	81.4
26	L	3 44 "	60	S	26	5 0 "	4 44 "	+ 16	31.8	26.2	29.0	23.7	+ 5.3	5.6	3.6	+ 2.0	"
Aug. 9	U	2 39 "	54	N	9	...	...	...	26.0	25.6	25.8	23.5	+ 2.3	0.4	2.7	— 2.3	81.2
22	L	1 33 "	61	S	22	2 0 "	0 21 "	+ 99	28.0	24.4	26.2	23.5	+ 2.7	3.6	3.9	— 0.3	"
23	L	2 23 "	61	S	23	3 0 "	1 2 "	+ 118	29.6	25.0	27.3	23.5	+ 3.8	4.6	3.9	+ 0.7	"
Sept. 5	U	0 39 "	54	N	5	10 30 a.m.	11 18 a.m.	— 48	23.4	22.2	22.8	23.2	— 0.4	1.2	2.7	— 1.5	80.9
6	U	1 18 "	54	N	6	2 0 p.m.	11 49 "	+ 131	24.8	22.6	23.7	23.2	+ 0.5	2.2	2.7	0.5	"
19	L	0 8 "	61	S	19	0 30 "	11 26 "	+ 34	25.8	23.0	24.4	23.2	+ 1.2	2.8	3.7	— 0.9	"
Oct. 2	U	11 17 p.m.	54	N	3	10 30 a.m.	11 5 "	— 35	23.0	20.8	21.9	23.0	— 1.1	2.2	2.5	— 0.3	80.6
15	L	9 54 "	61	S	16	Noon	10 54 "	+ 66	23.2	19.4	21.3	23.0	— 1.7	3.8	3.2	+ 0.6	"
16	L	10 45 "	61	S	17	1 0 p.m.	11 33 "	+ 87	24.6	18.8	21.7	23.0	— 1.3	5.8	3.5	+ 2.3	"
29	U	9 15 "	54	N	30	Noon	10 28 "	+ 92	19.6	17.0	18.3	23.0	— 4.7	2.6	2.0	+ 0.6	"
Nov. 12	L	8 35 "	60	S	13	10 30 a.m.	10 12 "	+ 18	23.0	19.6	21.3	21.6	— 0.3	3.4	3.0	+ 0.4	78.9
26	U	7 31 a.m.	54	N	26	...	...	...	23.6	22.4	23.0	21.6	+ 1.4	1.2	2.0	— 0.8	"
Dec. 9	L	6 31 p.m.	59	S	10	7 30 a.m.	6 5 "	+ 85	20.8	19.8	20.3	19.8	+ 0.5	1.0	3.0	— 2.0	76.8
23	U	5 46 "	54	N	24	...	...	...	18.2	17.2	17.7	19.8	— 2.1	1.0	2.3	— 1.3	"
Means	..	...	...	...	...	...	...	+ 57	23.0	20.5	21.7	21.1	+ 0.6	2.5	3.0	— 0.5	78.4

Jan. 3. No tide.
Apr. 8. Water 22.8 from 6 a.m. to 11 a.m. and then gradually to 19.2 at 5 p.m.
22. " 22.2 " " 10 " " " 20.8 " 4 "
23. Time of HW uncertain.
May 6. Water 24.0 from 6 a.m. to 10 " " " 21.8 " 5 "
20. Water falling from 23.8 at 6 a.m. to 20.4 at 5 p.m.
June 1. HW taken from LW at 2.30 p.m.
15. " " " 3.0 "
Aug. 9. Time of HW uncertain.
Nov. 26. " " "
Dec. 23. " " "

1896. SEMI-DIURNAL TIDES OBSERVED WHEN MOON'S DECLINATION = 0°.

Moon's Decl. = 0°.					Following High Water.				Heights.					Range.			
Date.	Tr.	Time of Transit.	Par.	Motion.	Date.	Time Observed.	Time Computed.	O—C	HW	LW	Mean water O	Mean water C	O—C	O	C	O—C	(T)
		hr. min.	′			hr. min.	hr. min.	min.	in.	in.	in.	in.	in.	in.	in.	in.	°
Jan. 6	U	4 53 a.m.	59	S	6	2 30 p.m.	2 48 p.m.	— 18	20.6	19.6	20.1	18.7	+ 1.4	1.0	3.2	— 2.2	75.5
20	L	4 2 "	54	N	20	2 0 "	1 26 "	+ 34	19.0	17.2	18.1	18.7	— 0 6	1.8	2.6	— 0.8	"
Feb. 2	U	2 46 "	61	S	No	observations	...	...	...	...	...	...	...	...	...	...	...
3	U	3 36 "	60	S	3	1 0 p.m.	1 7 "	— 7	18.8	15.4	17.1	19.0	— 1.9	3 4	3.6	— 0 2	75.9
16	L	2 0 "	54	N	No	observations	...	...	...	...	...	...	...	...	...	...	...
17	L	2 38 "	54	N	17	10 0 a.m.	11 56 a.m.	— 116	22.4	18.2	20.3	19.0	+ 1.3	4.2	2.7	+ 1.5	"
29	U	0 31 "	61	S	29	11 30 "	10 48 "	+ 42	22.4	19.2	20 8	19.0	+ 1.8	3.2	3.8	— 0 6	"
Mar. 2	U	2 15 "	61	S	2	..	...	...	23.4	19.6	21.5	19.8	+ 1.7	3.8	3.9	— 0.1	76.8
13	L	11 59 p.m.	54	N	14	10 30 "	10 33 "	— 3	19.8	17.8	18.8	19.8	— 1.0	2.0	2.6	— 0.6	"
15	L	0 38 a.m.	54	N	No	observations	...	...	...	...	...	...	...	...	...	...	...
27	U	11 6 p.m.	61	S	28	10 0 a.m.	10 37 "	— 37	21.8	19.2	20.5	19 8	+ 0.7	2 6	3.5	— 0.9	"
28	U	11 58 "	61	S	No	observations	...	...	...	...	...	...	...	...	...	...	...
April 10	L	10 38 "	54	N	11	9 30 a.m.	10 8 "	— 38	21.4	19.6	20.5	19.8	+ 0 7	1.8	2.3	— 0.5	"
24	U	9 44 "	61	S	25	9 30 "	9 32 "	— 2	22.8	20.6	21.7	19.8	+ 1.9	2.2	3.2	— 1.0	"
May 7	L	8 36 "	54	N	8	7 30 "	7 46 "	— 16	22.6	20.6	21.6	20.8	+ 0.8	2.0	2.0	0.0	78.0
21	U	7 36 "	60	S	22	6 30 "	6 44 "	— 14	24.0	20.0	22.0	20.8	+ 1.2	4.0	3.0	+ 1.0	"
June 4	U	6 53 a.m.	54	N	4	6 30 p.m.	6 35 p.m.	— 5	22.8	19.6	21.2	23.6	— 2.4	3.2	2.1	+ 1.1	81.3
18	L	5 57 "	59	S	18	5 0 "	6 32 "	— 92	26 6	20.6	23.6	23.6	0.0	6.0	3.1	+ 2.9	"
July 1	U	4 49 "	54	N	1	6 0 "	5 24 "	+ 36	26 8	24.4	25.6	24.7	+ 0.9	2.4	2.4	0.0	82.6
2	U	5 28 "	54	N	2	7 0 "	6 16 "	+ 44	26.6	24.4	25.5	24 7	+ 0.8	2.2	2.4	— 0.2	"
15	L	3 55 "	59	S	15	5 0 "	5 15 "	— 15	28.4	25.6	27.0	24.7	+ 2.3	2.8	3.4	— 0.6	"
16	L	4 43 "	59	S	16	4 0 "	6 4 "	— 124	...	...	...	...	...	...	...	...	...
29	U	3 24 "	54	N	29	5 0 "	3 58 "	+ 62	26.6	24.8	25.7	24.7	+ 1.0	1.8	2.7	— 0.9	"
Aug. 11	L	1 48 "	60	S	11	Noon	1 29 "	— 89	24.0	19.8	21.9	24.0	— 2.1	4.2	3.8	+ 0 4	81.8
12	L	2 38 "	60	S	12	Noon	2 5 "	— 125	24.8	19.2	22.0	24.0	— 2.0	5.6	3.7	+ 1.9	"
25	U	1 21 "	54	N	25	10 0 a.m.	11 54 a.m.	— 114	22.4	20.2	21 3	24.0	— 2.7	2.2	2.8	— 0.6	"
Sept. 8	L	0 26 "	61	S	8	11 0 "	11 26 "	— 26	26 4	19 6	23.0	23.8	— 0.8	6.8	3.8	+ 3.0	81.6
20	U	11 20 p.m.	54	N	21	10 0 "	10 42 "	— 42	24.6	22.0	23 3	23.8	— 0.5	2.6	2.5	+ 0.1	"
21	U	Midnight	54	N	22	10 0 "	11 10 "	— 70	26 2	23.6	24.9	23.8	+ 1.1	2 6	2.6	0.0	"
Oct. 4	L	10 11 p.m.	61	S	5	10 0 "	10 41 "	— 41	29 6	24 2	26.9	23 6	+ 3.3	5.4	3.2	+ 2.2	81.3
5	L	11 2 "	61	S	6	10 30 "	11 19 "	— 49	31.6	24.4	28 0	23.6	+ 4.4	7.2	3.5	+ 3.7	"
18	U	9 59 "	54	N	19	10 0 "	10 20 "	— 20	26.4	22.6	24.5	23.6	+ 0.9	3.8	2.1	+ 1 7	"
Nov. 1	L	8 48 "	60	S	2	10 0 "	10 21 "	— 21	27.8	22.4	25.1	22 7	+ 2.4	5.4	3.0	+ 2 4	80.2
13	U	7 18 "	55	N	14	10 0 "	8 16 "	+ 104	24.8	21.6	23.2	22 7	+ 0.5	3.2	2.3	+ 0.9	"
15	U	8 38 "	54	N	16	10 0 "	9 58 "	+ 2	26.6	22.8	24.7	22.7	+ 2 0	3.8	2.0	+ 1.8	"
28	L	6 40 "	59	S	No	observations	...	...	...	...	...	...	...	...	...	...	...
29	L	7 28 "	59	S	30	7 0 a.m.	8 8 "	— 68	28.6	24.2	26.4	22.7	+ 3.7	4 4	2.9	+ 1.5	"
Dec. 12	L	6 15 a.m.	55	N	12	...	...	...	23.8	21.4	22.6	21.5	+ 1.1	2.4	2.4	0.0	78.8
26	L	5 25 p.m.	59	S	No	observations	...	...	...	...	...	...	...	...	...	...	...
Means	...	...	...	...	...	...	...	— 27	24.5	21.1	22.8	22.1	+ 0.7	3.4	2.9	+ 0 5	79.5

Mar. 2. Water falling from 23.4 at 6 a.m. to 19.6 at 5 p.m.
June 4. Time of HW taken from LW at 0 hr. 30 min. p.m.
18. " " " " 11 0 a.m.
July 1. " " " " noon.
16. " " " " 11 0 a.m. At 3 p.m. the water suddenly rose 9in. and remained remarkably high for 2 or 3 days.
Dec. 12. Tide irregular.
25, 26, 27. No observations.

1897. Semi-diurnal tides observed when Moon's declination = 0°

Moon's Decl. = 0°					Following High Water.				Heights.					Range.			
Date.	Tr.	Time of Transit.	Par.	Motion.	Date.	Time Observed.	Time Computed.	O—C	HW	LW	Mean water O	Mean water C	O—C	O	C	O—C	(T)
		hr. min.	′			hr. min.	hr. min.	min.	in.	in.	in.	in.	in.	in.	in.	in.	°
Jan. 8	L	4 9 a.m.	55	N	8	1 0 p.m.	1 46 p.m.	— 46	17.4	16.2	16.8	19.8	— 3.0	1.2	2.8	— 1.0	76.8
9	L	4 50 "	55	N	9	1 0 "	2 27 "	— 87	16.8	15.8	16.3	19.8	— 3.5	1.0	2.6	— 1.6	"
22	U	2 59 "	59	S	No	observation.	...	...	...	...	...	...	...	...	...	...	...
Feb. 4	L	2 2 "	55	N	No	observation.	...	...	...	...	...	...	...	...	...	...	...
19	U	1 40 "	60	S	19	Noon	11 25 a.m.	+ 35	20.2	15.8	18.0	19.1	— 1.1	4.4	3.8	+ 0.6	76.3
Mar. 4	L	0 39 "	55	N	4	10 30 a.m	10 47 "	— 17	21.4	18.1	19.7	20.3	— 0.6	3 3	2.9	+ 0.4	77.4
17	U	11 28 p.m.	60	S	18	11 0 "	10 38 "	+ 22	21.8	19.8	20 8	20.3	+ 0.5	2.0	3.5	— 1.5	"
30	L	10 38 "	55	N	31	10 0 "	10 5 "	— 5	21.6	21.2	21.4	20.3	+ 1.1	0.4	2.5	— 2.1	"
April 13	U	9 14 "	59	S	14	9 0 "	9 14 "	— 14	21.6	19.4	20.5	21.3	— 0.8	2.2	2.8	— 0.6	78.6
26	L	8 37 "	55	N	27	10 0 "	8 4 "	+ 116	18.6	17.8	18.2	21.3	— 3.1	0.8	2.2	1.4	"
May 11	U	7 52 "	59	S	12	8 0 "	7 3 "	+ 57	18.0	16 8	17.4	22.7	— 5.3	1.2	2.8	— 1.6	80.2
24	U	6 56 a.m.	55	N	24	...	...	...	14.8	13.8	14.3	22.7	— 8.4	1.0	2.3	— 1.3	"
June 7	U	5 47 p.m.	58	S	8	6 0 "	5 30 "	+ 30	17.4	16.2	16 8	23.8	— 7.0	1.2	2.9	— 1.7	81.6
20	L	5 13 "	56	N	21	3 0 "	5 24 "	— 144	19.2	16.8	18.0	23.8	— 5.8	2.4	2.8	— 0.4	"
Observations discontinued.																	
Means	...	...	...	...	...	...	...	— 5	19.1	17.3	18.2	21 3	— 3 1	1.8	2.8	— 1.0	78.6

Feb. 4. No obs. on 4th or 5th.
May 24. Diurnal tide. Low water at 1 p.m. and High water at preceding and following midnights.
At Montego Bay the water was also remarkably low during May and June.

RESULTS FOR SEMI-DIURNAL TIDES.

With regard to the observed and computed times of High water, as the observed time is always liable to an error of at least half an hour, the mean difference between observation and computation, namely 47 minutes, is fairly satisfactory. But during 1895 the difference (O—C) was positive, while it was negative in the other years; and in consequence of such long continued fluctuations above or below the mean the observations would have to be continued for many years before the tidal constants could be ascertained with accuracy. The mean Establishment was taken to be 11hrs. 28min.; and the above 95 differences, (O—C), indicate that it should be increased by 4 min.; but in consequence of those fluctuations, it would be useless to recompute at present.

The mean Establishment being 11 hr. 32 min., by adding 2 min., the Semi- mensual Inequality at New or Full Moon when the Hour of Transit is 0 hr. 0 min., we get 11 hr. 34 min. as the Vulgar Establishment.

There is apparently no Inequality depending on U and L.

With regard to the observed Heights of HW, LW, and Mean water, the long continued fluctuations above or below the mean are most remarkable; in 1894 between Mar. 20th and Nov. 8th the difference (O—C) was negative with a single exception; in 1895 from June 28th to Aug. 23rd, and in 1896 from Sept. 21st to Dec 12th, the difference (O—C) was largely positive; while in 1897 from Jan. 8th to June 20th the difference was largely negative with two exceptions. The average height of Mean water was taken to be 21.3 inches corresponding to (T) = 78°.6, and the 109 differences, (O—C), confirm this height.

The connection between (T) and the height of Mean water is very curious: it is best shown by first taking monthly means of Mean water for each year, and then for the average of the three or four years, and by comparing them with the results of computation.

Month.	1894.		1895.		1896.		1897.		Average.	
	O.	C.	O.	C.	O.	C.	O.	C.	O.	C.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	22.8	18.0	17.5	18.0	19.1	18.7	16.6	19.8	19.0	18.6
February	20 2	17.4	16.5	18.0	19.4	19.0	18.0	19.1	18.5	18.4
March	17.8	17.2	21.2	18.3	20.3	19.8	20.6	20.3	20.0	18.9
April	16.2	18.6	21.2	19.7	21.1	19.8	19.4	21.3	19.5	19.8
May	19.5	20.6	22.5	22.0	21.8	20.8	15.8	22.7	19.9	21.5
June	21 2	22.3	23.5	23.3	22.4	23.6	17.4	23.8	21.1	23.2
July	21.5	22.7	27.9	23.7	23.9	24.7	...	...	24.4	23.7
August	24.0	22.7	26 4	23.5	21.7	24.0	...	...	24.0	23.4
September	20.0	23.2	23.6	23.2	23.7	23.8	...	...	22.4	23.4
October	19.3	22.1	20.8	23.0	26.5	23.6	...	...	22.2	22.9
November	21.0	20.8	22.2	21.6	24.8	22 7	...	...	22.7	21.7
December	20.8	19.5	19.0	19.8	22.6	21.5	...	...	20.8	20.3
Means	20.4	20.4	21.9	21.2	22 3	21.8	...	...	21.2	21.3

The mean values of (T) for February and July are 75°.2 and 81°.4, respectively; and for this change of 6°.2 of temperature, the mean sea-level changes 5.2 inches; or according to the formula, for every degree of (T), the mean sea-level changes 0.84 inch.

These large changes of level apparently indicate that the changes of temperature are carried deep down below the surface of the sea presumably by the incessant action of the waves. We know that changes of temperature penetrate the ground to a small depth; the following table gives the temperature 6 feet below the surface of the ground from 5 years' observation at the Cinchona Plantation, or Hill Gardens, as it is now called.

Month.	Temp. 6 ft. below the surface of the ground.
January	60°.3
February	59.6
March	59.3
April	59.2
May	59.3
June	60.0
July	61.3
August	62.3
September	62.4
October	61.9
November	61.6
December	61.2
Mean	60.7

There is therefore a change of temp. of 3°.2 six feet below the surface of the ground, corresponding to a change of air temp. of 6°.4 at the surface; and assuming the change to decrease uniformly with the depth, the change vanishes at 12 feet below the surface.

Now the co-efficient of volumetric expansion of salt water is 0.05 for 180° F.; and assuming, as before, that the change decreases uniformly with the depth, it may be shown that we must go down to a depth of 500 feet before we can get such a volume of water that by its expansion its level will be raised 0.84 inch for every degree of (T) at the surface.

This was not to have been expected; but I can account for the change of level with (T) in no other way.

The mean difference, (O—C), without regard to sign, is 2.0 inches; to this extent therefore the mean sea level is continually liable to variation from unknown causes. The Range, or variation due to the action of the Sun and Moon, is 2.9 inches, or rather 2.84 inches from the 109 observations; so that the variation due to unknown causes is almost as large as the Range.

The Range does not vary with the month; it was the disturbing effect of the Diurnal tides which caused the Range to gradually decrease from Jan. and Feb. to Aug. and Sept. 1894 (W. R. No. 179, p. 7), and which rendered these further investigations necessary.

The mean sea-level then adopted was 19.5 inches on the scale of the Tide-gauge; but this was similarly disturbed by the Diurnal tides; and as already stated, 21.3 inches on the scale, corresponding to (T) = 78°.6, is nearer the true value.

Now there is a Bench-mark on a pillar* near the Tide-gauge on the same level as the zero of the scale; and when the Tide-gauge reads 21.3 inches, the surface of the water is 53.0 inches below the zero of the scale; consequently the Bench mark is 53.0 inches above the Mean sea-level. This mark will be useful in the course of years.

Diurnal Tides.

In the following Tables for the Diurnal Tides the columns require no further explanation excepting indeed that containing the computed times of High water.

High water is now found by adding 12 hr. 56 min. to the time of the Moon's transit; and by applying the following Annual and Semi-mensual Inequalities.

Annual Inequality. (Diurnal tides.)

			min.	Diff.					min.	Diff.
January	1	...	— 70	6	July	1	...	+	38	34
	11	...	— 76	8		11	...	+	72	10
	21	...	— 68	12		21	...	+	82	10
February	1	...	— 56	8	August	1	...	+	72	14
	11	...	— 48	0		11	...	+	58	10
	21	...	— 48	28		21	...	+	48	6
March	1	...	— 76	18	September	1	...	+	54	10
	11	...	— 94	2		11	...	+	64	0
	21	...	— 96	58		21	...	+	64	30
April	1	...	— 38	64	October	1	...	+	34	36
	11	...	+ 26	24		11	...	—	2	14
	21	...	+ 50	6		21	...	—	16	8
May	1	...	+ 56	10	November	1	...	—	8	14
	11	...	+ 46	14		11	...	+	6	8
	21	...	+ 32	16		21	...	—	2	16
June	1	...	+ 16	18	December	1	...	—	18	20
	11	...	— 2	0		11	...	—	38	20
	21	...	— 2			21	...	—	58	

Semi-mensual Inequality. (Diurnal tides.)

Hour of Moon's transit a.m. or p.m.

hr.	min.				min.	Diff.
0	0	...	...	—	7	12
0	48	...	...	—	19	8
1	36	...	...	—	27	6
2	24	...	...	—	33	0
3	12	...	...	—	33	6
4	0	...	...	—	27	27
4	48	...	...		0	34
5	36	...	...	+	34	12
6	24	...	...	+	46	4
7	12	..	...	+	50	2
8	0	...	..	+	48	9
8	48	...	...	+	39	10
9	36	...	...	+	29	11
10	24	...	...	+	18	12
11	12	...	...	+	6	13
12	0	...	...	—	7	

* Of the gate-way leading to the beach south of the Custom-house.

1894. DIURNAL TIDES OBSERVED WHEN MOON'S DECL. = MAX. N OR S.

Moon's Decl. = Max. N or S.					Following High Water.				Heights.		Notes.
Date.		Tr.	Time of Transit.	Decl.	Date.	Time Observed.	Time Computed.	O—C	HW	LW	
			hr. min.	°		hr. min.	hr. min.	min.	in.	in.	
Jan.	3	L	9 40 pm.	26 S	4	9 0 am.	9 54 am.	− 54	25	...	
	4	"	10 30 "	28 "	5	10 0 "	10 32 "	− 32	26	...	
	5	"	11 22 "	" "	6	10 30 "	11 12 "	− 42	25	...	
	17	U	8 28 "	25 N	18	8 0 "	8 52 "	− 52	31	...	
	18	"	9 32 "	28 "	19	8 30 "	9 47 "	− 77	30	...	
	19	"	10 39 "	" "	20	10 0 "	10 43 "	− 43	34	...	
	30	L	7 36 "	25 S	31	6 0 "	8 24 "	− 144	28	...	
	31	"	8 25 "	27 "	1	7 0 "	9 3 "	− 123	28	...	
Feb.	1	"	9 16 "	28 "	2	8 0 "	9 45 "	− 105	27	...	
	15	U	8 22 "	" N	16	7 0 "	9 18 "	− 138	27	...	
	16	"	9 27 "	" "	17	8 30 "	10 4 "	− 94	29	...	
	28	L	7 9 "	" S	1	7 0 "	7 42 "	− 42	25	...	
March	1	"	8 0 "	" "	2	7 30 "	8 28 "	− 58	23	...	
	15	U	7 16 "	" N	16	7 0 "	7 27 "	− 27	26	...	
	16	"	8 19 "	27 "	17	7 0 "	8 28 "	− 88	25	...	
	27	L	5 0 "	28 S	28	1 30 "	5 3 "	− 213	...	12	LW. at 3.30 p.m. 27th.
May	21	"	1 34 "	" "	22	1 30 "	2 35 "	− 65	...	14	" " 3.30 " 21st.
June	4	U	0 41 "	" N	5	2 0 "	1 29 "	+ 31	...	14	" " 4.0 " 4th.
	5	"	1 48 "	" "	6	3 0 "	2 26 "	+ 34	...	15	" " 5.0 " 5th.
	18	L	0 21 "	" S	19	1 30 "	1 8 "	+ 22	...	17	" " 3.30 " 18th.
	19	"	1 13 "	" "	20	2 0 "	1 44 "	+ 16	...	17	" " 4.0 " 19th.
July	2	U	11 26 am.	" N	3	1 30 "	1 3 "	+ 27	...	18	" " 3.30 " 2nd.
	14	L	9 25 "	27 S	15	0 30 "	0 5 "	+ 25	...	20	" " 2.30 " 14th.
	16	"	11 9 "	28 "	17	1 0 "	1 26 "	− 26	...	19	" " 3.0 " 16th.
	28	U	8 1 "	26 N	29	0 0 "	11 0 pm.	+ 60	...	18	" " 2.0 " 28th.
	30	"	10 11 "	28 "	31	1 30 "	0 38 am.	+ 52	...	18	" " 3.30 " 30th.
Aug.	11	L	8 12 "	" S	11	11 0 pm.	10 54 pm.	+ 6	...	19	" " 1.0 " 11th.
	13	"	9 55 "	27 "	13	11 30 "	0 16 am.	− 46	...	20	" " 1.30 " 13th.
	25	U	6 51 "	28 N	25	10 0 "	9 27 pm.	+ 33	...	17	" " Noon 25th
Sep.	22	U	5 45 "	29 "	22	8 0 "	8 16 "	− 16	...	15	" " 10.0 a.m. 22nd.
Oct.	18	"	2 38 "	26 "	18	2 30 "	2 52 "	− 22	25	...	
	19	"	3 39 "	28 "	19	4 0 "	3 52 "	+ 8	24	...	
	31	L	1 44 "	26 S	31	2 30 "	2 4 "	+ 26	20	...	
Nov.	15	U	1 28 "	28 N	15	2 30 "	2 0 "	+ 30	24	...	
	16	"	2 32 "	29 "	16	3 30 "	2 57 "	+ 33	24	...	
	17	"	3 36 "	27 "	17	4 0 "	4 3 "	− 3	24	...	
	28	L	0 27 "	" S	28	1 30 "	0 57 "	+ 33	23		
	29	"	1 21 "	28 "	29	3 0 "	1 35 "	+ 85	22	...	
	30	"	2 14 "	" "	30	2 30 "	2 21 "	+ 9	25	...	
Dec.	13	U	0 14 "	" N	13	1 0 "	0 17 "	+ 43	22	...	
	14	"	1 20 "	" "	14	1 30 "	1 5 "	+ 25	23	...	
	15	"	2 25 "	26 "	15	3 0 "	2 2 "	+ 58	25	...	
	27	L	0 7 "	28 S	27	1 0 "	11 51 am.	+ 69	20	...	
	28	"	0 59 "	27 "	28	0 30 "	0 28 pm.	+ 2	20	...	
Means		...	...	...	...	...	...	− 18	25.2	16.9	

1895. DIURNAL TIDES OBSERVED WHEN MOON'S DECL. = MAX. N. or S.

Moon's Decl. = Max. N. or S.				Following High Water.				Heights.		Notes.
Date.	Tr.	Time of Transit.	Decl.	Date.	Time Observed.	Time Computed.	O—C	HW	LW	
		hr. min.	°		hr. min.	hr. min.	min.	in.	in.	
Jan. 8	U	9 51 p.m.	28 N	9	10 30 a.m.	9 56 a.m.	+ 34	22	...	
9	"	10 56 "	" "	10	Noon	10 49 "	+ 71	23	...	
21	L	9 9 "	" S	22	11 30 a.m.	9 31 "	+ 119	18	...	
23	"	10 54 "	" "	24	1 30 p.m.	10 56 "	+ 154	19	...	
Feb. 6	U	9 39 "	" N	7	11 30 a.m.	10 12 "	+ 78	24	...	
17	L	7 5 "	" S	18	11 30 "	8 3 "	+ 207	19	...	
18	"	7 58 "	29 "	19	11 0 "	8 54 "	+ 126	20	...	
19	"	8 50 "	28 "	20	11 30 "	9 37 "	+ 113	20	...	
March 6	U	8 26 "	27 N	7	9 30 "	8 40 "	+ 50	25	...	
18	L	6 44 "	29 S	19	9 30 "	6 53 "	+ 157	24.6	...	
Apr. 1	U	5 15 "	" N	2	7 0 "	5 50 "	+ 110	25.2	...	
2	"	6 16 "	28 "	3	7 30 "	7 26 "	+ 4	27.6	...	
3	"	7 16 "	25 "	4	8 0 "	8 36 "	− 36	25.8	...	
15	L	5 28 "	28 S	16	7 0 "	7 29 "	− 29	22.6	...	
July 5	"	10 57 a.m.	" "	6	1 30 "	0 57 "	+ 33	...	22.8	LW at 3.30 p.m. 5th.
6	"	11 52 "	" "	7	2 0 "	1 41 "	+ 19	...	22.8	" " 4.0 " 6th.
19	U	9 27 "	" N	20	1 0 "	0 12 "	+ 48	...	21.6	" " 3.0 " 19th.
Aug. 16	"	8 11 "	" "	16	11 30 p.m.	10 46 p.m.	+ 44	...	22.8	" " 1.30 " 16th.
17	"	9 14 "	27 "	18	1 0 a.m.	11 36 "	+ 84	...	22.8	" " 3.0 " 17th.
28	L	6 47 "	28 S	28	11 0 p.m.	9 23 "	+ 97	...	20.6	" " 1.0 " 28th.
29	L	7 42 "	" "	29	11 0 "	10 19 "	+ 41	...	21.4	" " 1.0 " 29th.
Sept. 12	U	5 59 "	29 N	12	8 30 p.m.	8 39 "	− 9	...	19.6	" " 10.30 a.m. 12th.
13	"	6 59 "	28 "	13	9 30 "	9 48 "	− 18	...	19.2	" " 11.30 " 13th.
25	L	5 35 "	" S	25	8 0 "	7 57 "	+ 3	...	17.6	" " 10.0 " 25th.
26	"	6 25 "	27 "	26	10 30 "	8 56 "	+ 94	...	19.0	" " 0.30 p.m. 26th.
Nov. 18	"	1 4 "	" "	18	2 0 "	1 39 "	+ 21	23.0	..	
Dec. 3	U	0 38 "	28 N	3	1 0 "	0 55 "	+ 5	24.0	..	
4	"	1 37 "	" "	4	1 0 "	1 42 "	− 42	23.4	...	
15	L	11 48 p.m.	" S	16	0 30 "	11 58 a.m.	+ 32	24.2	...	
17	"	0 47 a.m.	" "	17	0 30 "	0 34 p.m.	− 4	24.8	...	
18	"	1 43 "	26 "	18	2 30 "	1 20 "	+ 70	24.4	...	
29	U	10 23 p.m.	27 N	30	10 30 a.m.	10 29 a.m.	+ 1	25.6	...	
30	"	11 23 "	28 "	31	11 0 "	11 13 "	− 13	25.2	...	
Means	...	...	...	...	...	...	+ 50	23.2	20.9	

1896. DIURNAL TIDES OBSERVED WHEN MOON'S DECL. = MAX. N or S.

Moon's Decl. = Max. N. or S.					Following High Water.				Heights.		Notes.
Date.		Tr.	Time of Transit.	Decl.	Date.	Time Observed.	Time Computed.	O—C	HW	LW	
			hr. min.	°		hr. min.	hr. min.	min.	in.		
Jan.	12	L	10 36 p.m.	28 S	13	11 0 a.m.	10 32 a m.	+ 28	24.4	...	
	13	"	11 33 "	27 "	14	0 30 p.m.	11 33 "	+ 57	20.2	...	
	27	U	10 5 "	28 N	28	10 30 a.m.	10 23 "	+ 7	25.6	...	
Feb.	9	L	9 27 "	" S	10	10 0 "	10 2 "	− 2	22.8	...	
	23	U	7 47 "	" N	24	8 0 "	8 37 "	− 37	21.8	...	
	24	"	8 46 "	27 "	25	11 0 "	9 25 "	+ 95	23.2	...	
April	[illegible]	L	5 14 "	28 S	4	7 0 "	6 2 "	+ 58	20.6	...	hr. min.
June	11	U	9 16 "	" N	12	0 0 "	0 59 "	− 59	...	16.4	LW at 2 0 p.m. 11th.
	24	L	11 25 a.m.	" S	24	11 30 p.m.	0 34 "	− 64	...	18.6	" " 1 30 " 24th.
	25	"	0 26 p.m.	27 "	26	0 0 a.m.	1 24 "	− 84	...	19.0	" " 2 0 " 25th.
July	8	U	10 4 a.m.	28 N	9	0 0 "	0 25 "	− 25	...	19.8	" " 2 0 " 8th.
	9	"	11 2 "	" "	9	11 30 p.m.	1 9 "	− 99	...	19.4	" " 1 30 " 9th.
	10	"	11 59 "	26 "	11	1 0 a.m.	1 54 "	− 54	...	21.2	" " 3 0 " 10th.
	21	L	9 15 "	28 S	22	1 0 "	0 6 "	+ 54	...	22.4	" " 3 0 " 21st.
	22	"	10 14 "	" "	23	1 0 "	0 51 "	+ 9	...	21.4	" " 3 0 " 22nd.
Aug.	5	U	8 47 "	" N	5	11 0 p.m.	11 28 p.m.	− 28	...	19.6	" " 1 0 " 5th.
	6	"	9 45 "	27 "	6	11 0 "	0 14 a.m.	− 74	...	18.2	" " 1 0 " 6th.
	18	L	8 8 "	28 S	18	9 30 "	10 43 p.m.	− 73	...	15.8	" " 11 30 a.m. 18th.
	19	"	9 6 "	27 "	19	10 0 "	11 26 "	− 86	...	16.0	" " noon 19th.
Sept.	1	U	6 35 "	28 N	1	7 30 "	9 11 "	− 101	...	19.6	" " 9 30 a.m. 1st.
	2	"	7 30 "	" "	2	9 0 "	10 10 "	− 70	...	17.8	" " 11 0 " 2nd.
	3	"	8 27 "	26 "	3	9 30 "	10 59 "	− 89	...	17.6	" " 11 30 " 3rd.
Oct.	25	"	2 23 "	27 "	26	3 0 "	2 33 "	+ 27	26.8	...	
	26	"	3 15 "	28 "	27	4 0 "	3 26 "	+ 34	28.2	...	
	27	"	4 9 "	27 "	28	4 0 "	4 32 "	− 32	29.2	...	
Nov.	7	L	1 32 "	" S	7	1 0 "	2 1 "	− 61	30.0	...	
	23	U	2 5 "	" N	23	1 0 "	2 26 "	− 86	26.8	...	
	24	"	2 58 "	26 "	24	2 0 "	3 14 "	− 74	25.6	...	
Dec.	18	"	11 5 p.m.	27 "	19	Noon	11 15 a.m.	+ 45	25.6	...	
	21	"	0 53 a.m.	26 "	21	1 0 p.m.	0 32 p.m.	+ 28	28.4	...	
Means		...	...	...	...	...	...	− 25	25.2	18.8	

1897. DIURNAL TIDES OBSERVED WHEN MOON'S DECL. = MAX. N or S.

Moon's Decl. = Max. N. or S.					Following High Water.				Heights.		
Date.		Tr.	Time of Transit.	Decl.	Date.	Time Observed.	Time Computed.	O—C	HW	LW	
			hr. min.	°		hr. min.	hr. min.	min.	in.	in.	
Jan.	1	L	10 59 p.m.	27 S	2	11 0 a.m.	10 54 a.m.	+ 6	26.0	.	
	15	U	9 48 "	" N	16	10 0 "	10 0 "	0	22.0	.	
	28	L	8 46 "	" S	29	10 0 "	9 21 "	+ 39	21.6	.	
	29	"	9 48 "	" "	30	10 0 "	10 13 "	− 13	22.8	.	
Feb.	24	"	6 41 "	" "	25	6 0 "	7 29 "	− 89	18.6	14.5	LW 8 hrs. after HW.
Mar.	10	U	5 27 "	" N	11	7 0 "	5 18 "	+ 102	20.6	17.8	" 17 " "
	23	L	4 33 "	26 S	24	6 0 "	3 56 "	+ 124	22.4	19.0	" 16 " "
April	7	U	4 12 "	27 N	8	4 30 "	4 49 "	− 19	20.6	15.6	" 17½ " "
	19	L	2 17 "	25 S	20	4 0 "	3 25 "	+ 35	22.0	17.3	" 15 " "
May	4	U	2 7 "	27 N	5	5 0 "	3 26 "	+ 94	16.7	14.0	" 12 " "
	17	L	1 1 "	26 S	18	4 30 "	2 11 "	+ 139	19.0	13.2	" 15 " "
	31	U	0 4 "	" N	1	0 0 "	1 11 "	− 71	17.8	12.8	" 17 " "
June	13	L	10 39 a.m.	25 S	14	0 0 "	11 48 "	+ 12	21.4	13.5	" 17 " "
	27	U	9 59 "	26 N	28	0 0 "	11 40 "	+ 20	21.6	15.6	" 16 " "
Means		...	...	...	...	...	...	+ 27	20.9	15.3	LW 15.0 hrs. after HW.

RESULTS FOR DIURNAL TIDES.

In the case of the Semidiurnal tides the average difference between the observed and computed times of High water was 47 minutes; in the case of the Diurnal tides this difference is increased to 55 minutes. For the latter tides the mean Establishment was taken to be 12 hrs. 56 min.; and the above 121 differences, (O—C), indicate that it should be increased by 4 min. as in the case of the former tides.

The mean Establishment being 13 hrs. 0 min., by subtracting 7 min., the Semi-mensual Inequality at New or Full Moon when the Hour of Transit is 0 hr. 0 min., we get 12 hrs. 53 min. as the Vulgar Establishment.

With regard to the observed Heights of HW and LW, by taking means we get the following Table:—

Year.	HW.	(T)	LW	(T)
	in.	°	in.	°
1894 ...	25.2	76.0	16.9	79.0
1895 ...	23.2	76.1	20.9	81.2
1896 ...	25.2	78.1	18.8	81.8
Means ...	24.5	76.7	18.9	80.7

We thus have a scale reading of 24.5 in. for HW corresponding to a temp. (T) of 76°.7, and a scale reading of 18.9 in. for LW corresponding to a temp. (T) of 80°.7 Reducing both to a temp. (T) of 78°.6 by subtracting

$$\text{in. } 0.84 \left\{ (T) - 78^\circ.6 \right\},$$

HW becomes 25.3 in. and LW becomes 17.1 in.

Hence the Range of the Diurnal tides is 8.2 in.; and the scale reading for Mean sea-level is 21.2 in. for (T) = 78°.6.

Now for the Semidiurnal tides the scale reading for Mean sea-level was found to be 21.3 in. for (T) = 78°.6; and this close agreement between the Diurnal and Semidiurnal tides is very satisfactory.

The last result we shall mention is that HW occurs 10 hrs. 0 min. after LW; and it was by means of this interval that the times of HW were obtained from the times of LW observed in the Diurnal tides for 1894, 5, and 6.

There now remains for future consideration the large fluctuation of sea-level referred to above. More observations are required; and I have recommended that daily observations should be taken about the time of mean tide. In this way the trouble of observing, registering, and reducing is very small; and at the same time we get accurate results for groups of days, such as months, or periods of fluctuation above or below the mean. These simpler observations were commenced July 12th this year and will be published in due course.

MAXWELL HALL.

Dec. 31st, 1897.

THE KINGSTON TIME SERVICE, 1897.

The Time Service was established in 1896 to ascertain the errors and rates of marine chronometers sent to the Transit-room for that purpose, and to supply the public offices and institutions in Kingston with Time as may be required.

The Transit-room in the Parade Gardens, Kingston, is in latitude 17° 58′ 8″.7 north, and in longitude 5 hrs. 7 min. 10.41 sec. west of Greenwich, according to a survey which connected the Transit-room with Captain Green's station at the lower end of King Street.

The building is of brickwork with wooden floor, and roof covered with "Tilestoneite" roofing material. It comprises two small wings connected by a central portion in which stands the transit instrument, over which there is a movable roof, consisting of light wooden canvass covered shutters, operated by rods from below. The structure is well suited to its purpose, its only defect being a want of roof ventilation which, especially during the summer months, renders it excessively warm. This can be remedied at a small cost.

The instruments are, a Transit-instrument., a Sidereal clock, and a Mean time chronometer; the two former were brought to Kingston from the Kempshot Observatory; the last was purchased from Messrs. J. H. Milke Bros. for £20.

The Transit-instrument has an aperture of 3 inches; it may easily be reversed; and it is provided with a very delicate hanging level. It was made by Messrs T. Cooke & Sons of York, and cost £66 in England.

The clock is provided with a mercurial compensating pendulum and a dead-beat escapement.

By watching the transit of stars across the wires in the field of view of the Transit instrument, the error of the Sidereal clock may be ascertained with all possible accuracy; and then the error of the Mean time chronometer, or of any other marine chronometer, may be ascertained by comparison with the clock, and by reduction from sidereal to mean time.

As soon as the Transit room had been completed, the instruments were put in their places and adjusted; this was done Jan. 28th and 29th; and Mr. John D'Aeth, of the Public Works Department, entered on his duties as my assistant. On March 14th the survey was made by Mr. D'Aeth and myself connecting the Transit-room with Captain Green's Station. And on March 18th a notice was published in the Jamaica Gazette to the effect that the Time Service was in operation.

The Transit-instrument is mounted on a solid concrete pedestal which has proved firm and stable during the year 1897 according to the constancy shown in the following Table of instrumental errors.

The flooring of the building is constructed so that it is entirely clear of the pedestal of the Transit-instrument and of the Sidereal clock.

Let a'' be the error of azimuth, or the deviation of the plane of collimation to the East of the South horizontal point, measured in seconds of arc; and let $a = \frac{a''}{15}$, or the same error expressed in seconds of time.

Let b'' be the error of level, or the elevation of the West pivot above the East pivot; and as before let $b = \frac{b''}{15}$.

Let c'' be the error of collimation, or the displacement of the mean wire to the East of the plane of collimation when the illumination is West; and let $c = \frac{c''}{15}$.

Then the following table gives the values of a, b and c, obtained by reversing during the transit of a polar star, and reading the level at the same time.

1897		a	b	c
		sec.	sec.	sec.
March	13 ...	— 0.9	— 0.4	+ 0.1
April	24 ...	— 0.2	— 0.6	— 0.4
April	28 ...	— 0.2	...	+ 0.1
July	23 ...	— 0.7	— 0.8	+ 0.1
November	22 ...	— 0.4	— 0.2	— 0.4
Mean	...	— 0.5	— 0.5	— 0 1

The following were the equatoreal reductions of the five wires to the mean wire* :—

I.	+ 23.29
II.	+ 11.56
III.	+ 0.00
IV.	— 11.75
V.	— 23.10

Their order is for the Upper transit, illumination west.

The following are the Errors and Rates of the Mean time chronometer :—

* But from only 2 observations.

MEAN TIME CHRONOMETER: ERROR AND RATE.

1897.		Hour.	Error.		Rate.	Notes.
			sec.		sec.	
January	31	4 p.m.	106	slow	2.0	The rate is the daily rate gaining.
February	5	6 "	96	"	1.7	
	15	7 "	79	"	1.6	
	21	8 "	69.5	"	1.6	
March	2	7 "	56	"	1.5	
	6	7 "	50	"	1.4	
	17	8 "	33.7	"	1.4	
	29	9 "	17.5	"	1.0	Mean rate, 1.27, Jan. 31 to May 28.
April	3	11 "	12.7	"	0.8	
	11	9 "	6.2	"	1.1	
	16	9 "	0.9	"	1.2	
	22	7 "	6.2	fast	1.7	
	28	11 "	16.6	"	1.2	
May	7	7 "	27.7	"	0.1	Rate irregular.
	13	9 "	28.4	"	1.0	
	19	7 "	34.4	"	0.9	
	28	10 "	42.5	"		
June	10	8 "	43.4	"	0.0	Chron. ran down and was reset.
	25	9 "	42.6	"	0.1	
July	3	8 "	43.1	"	0.1	
	10	9 "	43.9	"	0.5	Mean rate, 0.25, June 10 to July 31.
	17	9 "	47.2	"	0.7	
	23	12 "	51.6	"	0.6	
	31	10 "	56.0	"		
August	6	9 "	20.5	"	0.0	Chron. ran down and was reset.
	13	9 "	20.7	"	0.3	
	20	9 "	23.1	"	0.6	
	28	9 "	27.8	"	0.3	
September	6	9 "	30.2	"	0.6	Mean rate, 0.61, Aug. 6 to Nov. 14.
	15	7 "	35.3	"	0.8	
	21	6 "	40.2	"	0.9	
October	5	0 "	52.5	"	0.8	
	11	7 "	57.6	"	1.3	
	22	8 "	72.2	"	0.7	
	30	10 "	77.9	"	0.1	Rate irregular.
November	8	9 "	78.9	"	0.5	
	14	8 "	81.7	"		
November	22	9 "	29.4	"	0.2	?
	27	5 "	30.2	"	0.3	
December	6	8 "	32.6	"	0.7	Mean rate, 0.34, Nov. 22 to Dec. 30.
	11	6 "	36.1	"	0.5	
	17	8 "	39.0	"	0.3	
	30	5 "	42.2	"		

From the above Table it will be seen that the Mean time Chronometer went fairly well during the year if we make allowance for the fact that its rate greatly changes should it run down at any time. This occurred twice during the year, and on each occasion it took a month or more for the Chron. to recover its normal rate.

Its mean daily rate between January 31 and December 30 was 0.76 gaining; and the mean change of daily rate between the several dates of determination was about 0.3.; so that in deducting at any time the Kingston Mean Time from the Chron by applying Error and Rate we would always be liable to an average error of about 2 seconds

This is more than sufficiently accurate for the Kingston clocks.

During the year 1897 only four chronometers were sent to the Transit-room to have their Errors and Rates accurately taken; it is to be presumed that more will be sent when the service is more generally known.

MAXWELL HALL, Govt. Meteorologist.

March 17th, 1898.