Thesis 1891

A Determination of the Discharge of the Connecticut River, at South Deerfield Mass

Clement March.

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Part I

Measurements made with the Ellis Sub-surface Floats.

The base line was laid out upon the west bank of the Connecticut river, at a point some eight hundred feet below the highway bridge, which crosses the river between Deerfield and Sunderland. The base line was two hundred and fifty feet in length, and was divided into sections of fifty feet each. A second line was laid out on the east bank of the river, but, owing to obstacles such as trees, etc, it was found impossible to make this line parallel to the original one. Its length varied but slightly, however, from the original line, and, like that one, it was divided into five sections, the ends of which were marked by range poles. The ranges were numbered from 0-0 to 5-5, the former being farthest up-stream.

The stage of water was obtained by means of readings on a five foot gauge, placed on one of the western piers of the bridge above mentioned; and readings were taken three times, daily.

The Cross Sections

On the diagram of Ellis float measurements, page 69, are shown cross-sections of the river at each range. The data from which these sections were plotted, are to be found on pages 4 to 11 incl, in the "Table of Soundings".

The first column contains the numbers of the stations, which were intended to be approximately equi-distant from each other.

The second column is made up of angles which were found as follows:

The boat containing the sounding party is kept, as nearly as possible, on Range (say) 0-0, by means of signals from the transitman at 0; and, the instant the sounding is taken, the angle of the boat from station 250, is taken by means of the transit at that station.

The base of the triangle being two hundred and fifty feet, it follows that, the distance

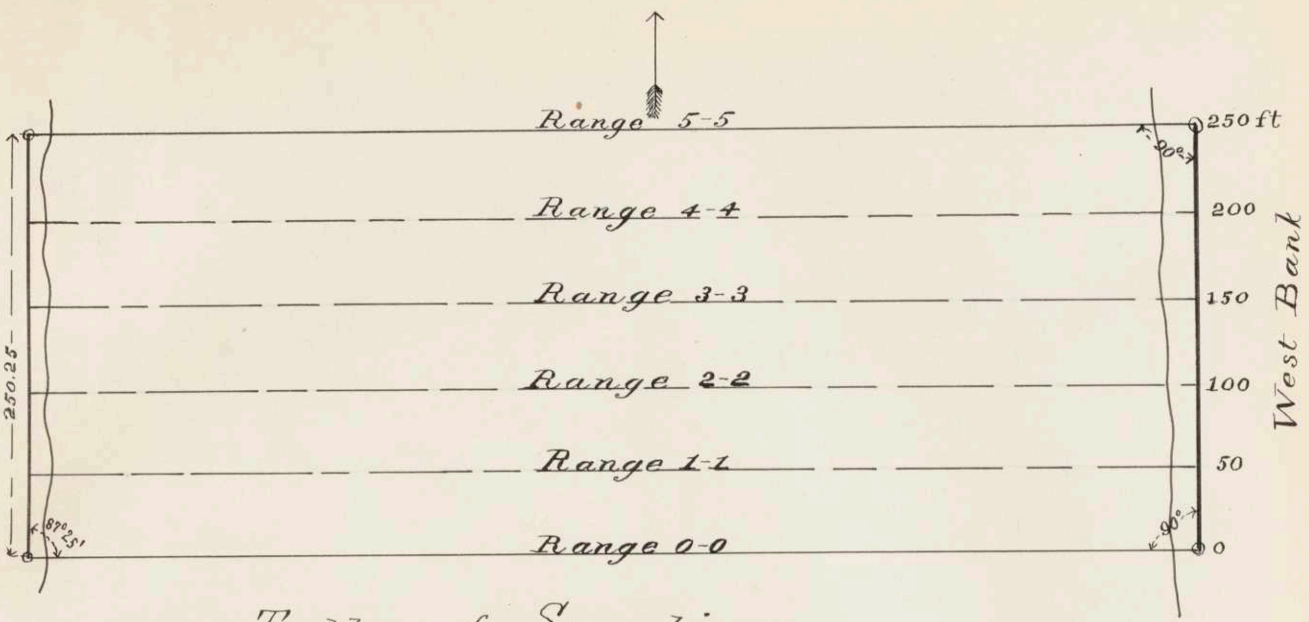


Table of Soundings

Range 0-0

Sta.	Angle at Base Transit at Pt 250	Nat Tang.	Calc. Dist	Sounding Gauge at 3.10	Adjst'd Sounding at -0.56	Remarks
0 W. Base				+8.6		On river Bank
1	Base of Triangle = 250 ft.			+7.5		water's edge.
2				+4.4		
3				+2.3		Gauge
4			19	0.0	-3.7	June 16 9. a.m. 3.10
5			21.2	1.6	-2.1	1 P.M 3.10 6 P.M. 3.05
5a	—	—	25.3	—	0.0	
6	6°-37'	0.11606	29.0	5.6	1.9	June 17 9. a.m 2.8
7	6°-09'	0.10775	26.9	5.0	1.3	1. P.M 2.5 4 .. 2.45.
8	6°-47'	0.11895	29.7	5.8	2.1	
9	9-39'	0.17004	42.5	8.0	4.3	
10	20°-00'	0.36397	91.0	7.8	4.1	
11	21°-50'	0.40065	100.2	7.9	4.2	

Range 0-0

Sta.	Angle from Base. Transit at 250	Nat Tang.	Calc. Dist.	Sounding Gauge at 3.70	Adj'std Sndg Gauge at -0.56	Remarks
12	25°-47'	0.48306	120.8	9.7	6.0	
13	36°-15'	0.73323	183.3	10.5	6.8	
14	50°-55'	1.23123	307.8	9.0	5.3	
15	59°-08'	1.67309	418.3	7.6	3.9	
16	65°-22'	2.18084	545.2	9.0	5.3	
17	64°-57'	2.13963	534.8	9.3	5.6	
18	67°-44'	2.44230	610.6	10.9	7.2	
19	70°-00'	2.74748	686.9	11.3	7.6	
20	71°-22'	2.96573	741.4	10.1	6.4	
21	72°-07'	3.09914	774.8	7.0	3.3	
22	72°-30'	3.17159	792.9	5.0	1.3	
23	72°-35'	3.18775	796.9	4.1	0.4	
23.a	—	—	798.4	—	0.0	waters edge
24	72°-54'	3.25055	812.6	0.0	-3.7	on river Bank
25 E. Side.	73°-04'	3.28452	821.1	+3.8		

Base of Triangle = 250 ft.

Range 1-1

Sta.	Angle at Base Transit at 250	Nat. Tang.	Calc. Dist.	Sounding Gauge at 3.10	Adj'st'd Sounding at -0.56	Remarks.
1 E. side	76°-17'	4.09699	819.4			On River Bank
2	76°-8'	4.05092	810.2	0.0	-3.7	Waters edge
2a	—	—	799.8		0.0	
3	75°-54'	3.98117	796.2	5.0	1.3	
4	75°-55'	3.98607	797.2	5.0	1.3	
5	75°-41'	3.91839	783.7	6.8	3.1	
6	75°-24'	3.83906	767.8	9.2	5.5	
7	75°-13'	3.78931	757.9	10.7	7.0	
8	74°-49'	3.68485	737.0	11.0	7.3	
9	73°-32'	3.38317	676.6	11.3	7.6	
10	71°-10'	2.93189	586.4	10.3	6.6	
11	69°-50'	2.72281	544.6	8.8	5.1	Base of triangle
12	67°-12'	2.37891	476.0	7.7	4.0	= 200 ft.
13	63°-20'	1.99116	398.2	7.8	4.1	
14	57°-19'	1.55866	311.7	8.8	5.1	
15	49°-51'	1.18544	237.1	10.1	6.4	
16	38°-39'	0.79972	159.9	11.1	7.4	
17	32°-28'	0.63625	127.2	10.1	6.4	
18	23°-10'	0.42791	85.6	7.4	3.7	
19	13°35'	0.24162	48.3	7.9	4.2	

Range 1-1

Sta	Angle Transit at 250	Nat Tang.	Calc. Dist.	Sounding Gauge at 3.10	Adj'st'd at -0.56	Remarks.
20	9°-01'	0.15868	31.7	6.3	2.6	
20a			25.1	—	0.0	
21	7°-00'	0.12278	24.6	3.5	-.26	
22	4°-45'	0.08309	16.6	0.0	-3.7	Waters edge
23	4°-12'	0.07344	14.7			On river Bank.
24 West Bank						

Range 2-2

Sta.	Angle Transit at 250	Nat. Tang	Calc. Dist.	Sounding Gauge at 3.05	Adj'st'd Sounding at -0.56	Remarks
0 West bank	6°-10'	0.10805	16.2			On river Bank.
2	8-05	0.14202	21.3	0.0	-3.6	Waters edge.
2.a	—	—	27.7	—	0.0	
3	11-30	0.20345	30.5	5.2	1.6	
4	15-50	0.28360	42.5	6.5	2.9	
5	23-34	0.43620	65.4	6.8	3.2	
6	33-28	0.66105	99.2	8.5	4.9	
7	34-20	0.68301	102.5	9.0	5.4	Base of triangle = 150 ft.
8	41-51	0.89567	134.4	10.9	7.3	
9	53-40	1.35968	204.0	11.9	8.3	
10	61-51	1.86891	280.3	9.8	6.2	
11	68-00	2.47509	371.3	8.0	4.4	
12	73-28	3.36875	505.3	8.3	4.7	
13	73-55	3.46837	520.2	9.4	5.8	

Range 2-2

Sta.	Angle Transit at 250	Nat Tang.	Calc. Dist.	Sounding Gauge at 3.05	Adj'st'd Sounding at -0.56	Remarks.
14	75°-42'	3.92316	588.5	10.8	7.2	
15	77-00	4.33148	649.7	12.4	8.8	
16	77-46	4.61219	691.8	10.9	7.3	
17	78-24	4.87162	730.7	11.9	8.3	Base of triangle
18	78-45	5.02734	754.1	10.0	6.4	= 150 ft
19	79-03	5.16863	775.3	6.5	2.9	
20	79-08	5.20925	781.4	5.0	1.4	
20a	—	—	786.0	—	0.0	
21	79-21	5.31778	797.7	0.0	-3.6	Waters Edge
22 E side						River Bank.

Range 3-3

Sta.	Angle Transit at 0	Nat. Tang.	Calc. Dist.	Sounding Gauge at 3.05	Adj'st'd Sounding at -0.56	Remarks.
1 East Bank	79°-34'	5.43077	814.6	+1.8	-5.4	On river Bank
2	79-25	5.35206	802.8	0.0	-3.6	Waters Edge.
2a	—	—	794.4	—	0.0	
3	79-16	5.27553	791.3	4.9	1.3	
4	79-13	5.25048	787.6	5.8	2.2	
5	79-04	5.17671	776.5	8.0	4.4	
6	78-46	5.03499	755.2	11.4	7.8	Base of triangle
7	78-11	4.77978	717.0	11.0	7.4	= 150 ft.
8	77-51	4.64480	696.7	11.1	7.5	

Range 3-3

Sta.	Angle Transit at 0	Nat. Tang.	Calc. Dist.	Sounding Gauge at 3.05	Adj'st'd Sounding at -0.56	Remarks
9	76°-40'	4.21933	632.9	11.9	8.3	
10	74-28	3.59775	539.7	8.9	5.3	
11	70-28	2.81870	422.8	7.5	3.9	Base of triangle
12	63-40	2.02039	303.1	8.9	5.3	= 150 ft.
13	58-40	1.64256	246.4	10.2	6.6	
14	45-44	1.02593	153.9	11.0	7.4	
15	29-57	0.57619	86.4	7.6	4.0	
16	17-40	0.31850	47.8	6.1	2.5	
17	10-25	0.18384	27.6	4.0	.4	
17a	—	—	26.8	—	0.0	
18 West Side	7-30	0.13165	19.7	0.0	-3.6	Waters Edge.

Range 4-4

Sta.	Angle Transit at 0	Nat. Tang.	Calc. Dist.	Sounding Gauge at 2.80	Adj'st'd Sounding at -0.56	Remarks
West 1 Bank		—	—	—	—	River Bank
2	6°-10'	0.10805	21.6	0.0	-3.4	Waters Edge.
2a	—	—	28.6	—	0.0	
3	9-45	0.17183	34.4	6.2	2.8	Base of triangle
4	13-37	0.24223	48.4	5.5	2.1	= 200 ft.
5	20-42	0.37787	75.6	6.0	2.6	
6	26-44	0.50368	100.7	8.7	5.3	
7	32-54	0.64693	129.4	9.8	6.4	

Range 4-4

Sta.	Angle Transit at 0	Nat. Tang.	Calc. Dist.	Sounding Gauge at 2.80	Adj'st'd Sounding at -0.56	Remarks
8	42°-17'	0.90940	181.9	10.6	7.2	
9	53-56	1.37302	274.6	9.0	5.6	
10	58-59	1.66318	332.6	7.8	4.4	
11	65-19	2.17582	435.2	6.9	3.5	
12	70-09	2.77002	554.0	8.9	5.5	Base of triangle
13	70-52	2.88240	576.5	10.0	6.6	= 200 ft.
14	72-51	3.24049	648.1	11.2	7.8	
15	74-17	3.55364	710.7	10.6	7.2	
16	75-13	3.78931	757.9	10.0	6.6	
17	75-30	3.86671	773.3	8.1	4.7	
18	75-44	3.93271	786.5	5.4	2.0	
18a	—	—	791.9	—	0.0	
19	75-59	4.00582	801.2	0.0	-3.4	waters edge
East 20 Side	76-10	4.06107	812.2	+5.0	-8.4	On River Bank

Range 5-5

Sta.	Angle Transit at 0	Nat. Tang.	Calc. Dist.	Sounding Gauge at 2.75	Adj'st'd Sounding at -0.56	Remarks
East 0 Bank	72°-51'	3.24049	810.1	+2.0	-5.3	On River Bank,
1	72-41	3.20734	801.8	0.0	-3.3	waters edge
1.a	—	—	795.8	—	0.0	
2	72-32	3.17804	794.5	4.0	0.7	
3	72-13	3.11775	779.4	6.9	3.6	

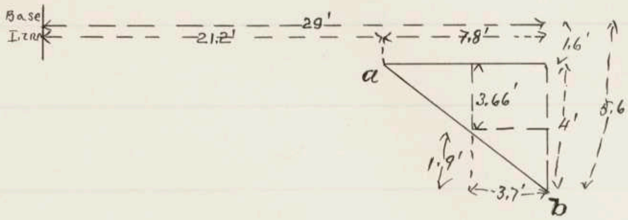
Range 5-5

Sta.	Angle Transit at 0	Nat. Tang.	Calc. Dist.	Sounding Gauge at 2.75	Adj'st'd Gauge at -0.56	Remarks.
4	71°-57'	3.06837	767.1	9.0	5.7	
5	71-17	2.95155	737.9	10.9	7.6	
6	70-30	2.82391	706.0	10.7	7.4	
7	69-49	2.72036	680.1	11.4	8.1	
8	68-57	2.58484	646.2	11.0	7.7	
9	66-02	2.24956	562.4	9.6	6.3	Base of triangle
10	63-20	1.99116	497.8	7.7	4.4	= 250 ft.
11	58-37	1.63934	409.8	6.8	3.5	
12	50-50	1.22758	366.9	8.2	4.9	
13	44-35	0.98356	246.4	9.5	6.2	
14	36-47	0.74764	186.9	10.4	7.1	
15	28-12	0.53620	134.0	10.1	6.8	
16	24-35	0.45748	114.4	9.4	6.1	
17	17-14	0.31019	77.5	7.0	3.7	
18	12-25	0.22017	55.0	5.1	1.8	
19	7-50	0.13758	34.4	5.0	1.7	
19a	—	—	31.7	—	0.0	
20	6-04	0.10628	26.6	0.0	+3.3	Waters Edge
21	3-42	0.06467	16.2	+5.0	—	On River Bank
22 West Bank	1-42	0.02968	7.4	+6.0	—	" " "

out from the base line, of the boat, is the product of the base and the natural tangent of the angle found as mentioned. By this method, we find the numbers which make up the fourth column.

The fifth column contains the soundings as actually taken, some being taken at a different stage of water from others. They must all be reduced to a common stage, which is here taken as -0.56; that being the lowest stage of the water during the period in which the measurements were taken. The method of reduction is extremely simple; thus, on page 4, Range 0-0. the gauge stood at 3.10; the reduced gauge reading is -0.56; therefore, the results in the sixth column are obtained by subtracting 3.66 from each number in the fifth column.

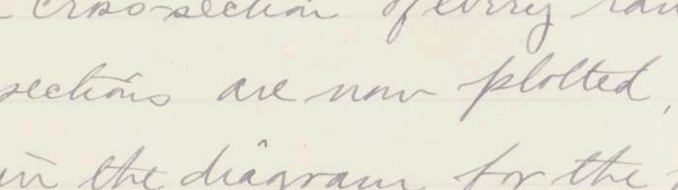
It is important for us to know the distance out from the base line, of the water's edge at a reduced sounding. This may be found in the following manner, a figure being shown to illustrate it.



We start with the gauge reading 3.10. The distance out from the base line to the point "a", is 21.2 feet, and, to the point "b" is 29 feet; the depth of water at "a" is 1.6 feet; and at "b", 5.6 feet. Now when the gauge reading is -0.56, the level of the water is 3.66 feet below the former level. Therefore, under the new condition, the depth of water at "b" is 1.9 feet. We assume the bank to have a continuous slope from "a" to "b". To find the position of the water's edge under the new conditions of things, we see that

1.9 : 4 :: 7.8 : X ∴ X = 3.7 feet; and, therefore, the distance out, of the water's edge, from the base line under a reduced gauge reading, is 25.3 feet. We proceed in this manner for each range, finding the position of the water's edge at each end under a reduced water level. This gives us complete data for a cross-section of every range. These cross-sections are now plotted, and are shown in the diagram for the float measurements on page 68.

We next wish to get an average cross-section, and the principle upon which this is accomplished, may be seen from the following figure:



We suppose, a, b, c, d, e, & f, to be the depths of points at a distant x (any distance), from the west bank, at different ranges. The bottom of the river at that distance out from the base line has, then, the shape of the broken line; the straight line representing the surface of the river. The average depth of water at

Calculation of Depths for Average Section

Distance out from West Bank	40	50	60	70	80	90	100	110	120	130
	3.8	4.3	4.2	4.2	4.1	4.1	4.2	5.0	5.9	6.1
	3.4	4.2	4.0	3.9	4.0	4.0	4.7	5.2	5.7	6.2
	3.4	4.2	4.0	3.9	4.0	4.0	4.7	5.2	5.7	6.2
	2.6	3.0	3.1	3.5	3.8	4.2	4.7	5.3	6.0	6.4
	2.6	3.0	3.1	3.5	3.8	4.2	4.7	5.3	6.0	6.4
	2.5	2.6	3.0	3.4	3.1	4.2	5.0	5.7	6.1	6.5
	2.5	2.6	3.0	3.4	3.1	4.2	5.0	5.7	6.1	6.5
	1.7	2.1	2.3	2.5	3.8	4.5	5.3	5.9	6.4	7.0
	1.7	2.1	2.3	2.5	3.8	4.5	5.3	5.9	6.4	7.0
	1.8	1.8	2.2	3.1	3.9	4.5	5.2	5.8	6.3	6.7
	26.0	29.9	31.2	33.9	37.4	42.4	48.8	55.0	60.6	65.0
Mean Depth	2.6	2.99	3.12	3.39	3.74	4.24	4.88	5.50	6.06	6.50
Distance out from West Bank	140	150	160	170	180	190	200	210	220	230
	6.3	6.3	6.5	6.6	6.8	6.7	6.6	6.5	6.4	6.2
	6.6	6.7	6.9	7.0	7.1	7.0	6.9	6.7	6.6	6.4
	6.6	6.7	6.9	7.0	7.1	7.0	6.9	6.7	6.6	6.4
	6.7	7.1	7.4	7.3	7.2	7.1	7.0	6.8	6.6	6.5
	6.7	7.1	7.4	7.3	7.2	7.1	7.0	6.8	6.6	6.5
	6.8	7.2	7.4	7.3	7.2	7.1	6.9	6.9	6.8	6.7
	6.8	7.2	7.4	7.3	7.2	7.1	6.9	6.9	6.8	6.7
	7.4	7.5	7.7	7.8	7.9	8.1	8.3	8.1	7.9	7.5
	7.4	7.5	7.7	7.8	7.9	8.1	8.3	8.1	7.9	7.5
	6.8	6.9	6.9	7.0	7.1	7.1	6.9	6.9	6.6	6.5
	68.1	70.2	72.2	72.4	72.7	72.4	71.7	70.4	68.8	66.9
Mean Depth	6.81	7.02	7.22	7.24	7.27	7.24	7.17	7.04	6.88	6.69
Distance out from West Bank	240	250	260	270	280	290	300	310	320	330
	6.1	6.0	5.9	5.8	5.6	5.5	5.4	5.3	5.1	5.0
	6.2	6.0	5.8	5.7	5.5	5.3	5.1	4.9	4.7	4.5
	6.2	6.0	5.8	5.7	5.5	5.3	5.1	4.9	4.7	4.5
	6.3	6.1	5.9	5.7	5.6	5.4	5.2	5.0	4.9	4.8
	6.3	6.1	5.9	5.7	5.6	5.4	5.2	5.0	4.9	4.8
	6.7	6.5	6.3	6.1	5.9	5.6	5.4	5.2	5.1	5.0
	6.7	6.5	6.3	6.1	5.9	5.6	5.4	5.2	5.1	5.0
	7.3	7.0	6.7	6.5	6.2	6.0	5.8	5.6	5.4	5.2
	7.3	7.0	6.7	6.5	6.2	6.0	5.8	5.6	5.4	5.2
	6.3	6.1	6.0	5.8	5.7	5.5	5.4	5.2	5.0	4.9
	65.4	63.3	61.3	59.6	57.7	55.6	53.8	51.9	50.3	48.9
Mean Depth	6.54	6.33	6.13	5.96	5.77	5.56	5.38	5.19	5.03	4.89

Calculation of Depths for Average Cross-Section

Distance out from West Bank	340	350	360	370	380	390	400	410	420	430
	4,9	4,8	4,6	4,5	4,4	4,3	4,1	4,0	3,9	4,1
	4,4	4,6	4,6	4,5	4,4	4,3	4,1	4,1	3,9	4,1
	4,4	4,6	4,6	4,5	4,4	4,3	4,1	4,1	3,9	4,1
	4,7	4,3	4,6	4,4	4,4	4,4	4,1	4,1	4,1	4,5
	4,7	4,3	4,6	4,4	4,4	4,4	4,1	4,1	4,1	4,5
	4,9	4,8	4,5	4,4	4,3	4,2	4,5	4,5	4,5	4,0
	4,9	4,8	4,5	4,4	4,3	4,2	4,5	4,5	4,5	4,0
	5,0	4,8	4,2	4,1	4,0	3,9	3,8	3,7	3,7	3,6
	5,0	4,8	4,2	4,1	4,0	3,9	3,8	3,7	3,7	3,6
	4,7	4,5	4,4	4,2	4,0	3,8	3,7	3,5	3,6	3,7
	47,6	46,3	44,8	43,5	42,6	41,7	40,8	40,3	39,9	40,2
Mean Depth	4,76	4,63	4,48	4,35	4,26	4,17	4,08	4,03	3,99	4,02

Distance out from West Bank	440	450	460	470	480	490	500	510	520	530
	4,2	4,4	4,5	4,7	4,8	5,0	5,1	5,2	5,5	5,4
	4,6	4,6	4,6	4,6	4,7	4,7	4,8	5,1	6,0	5,8
	4,6	4,6	4,6	4,6	4,7	4,7	4,8	5,1	6,0	5,8
	4,1	4,2	4,4	4,5	4,6	4,7	4,7	5,0	5,2	5,1
	4,1	4,2	4,4	4,5	4,6	4,7	4,7	5,0	5,2	5,1
	4,1	4,0	4,0	4,1	4,3	4,5	4,6	4,8	5,1	4,9
	4,1	4,0	4,0	4,1	4,3	4,5	4,6	4,8	5,1	4,9
	3,6	3,8	3,9	4,0	4,1	4,2	4,4	4,6	4,9	4,7
	3,6	3,8	3,9	4,0	4,1	4,2	4,4	4,6	4,9	4,7
	3,8	3,9	4,0	4,1	4,2	4,3	4,5	4,7	5,4	5,1
	40,8	41,5	42,3	43,2	44,4	45,5	46,6	48,9	53,3	51,5
Mean Depth	4,08	4,15	4,23	4,32	4,44	4,55	4,66	4,89	5,33	5,15

Distance out from West Bank	540	550	560	570	580	590	600	610	620	630
	5,5	5,5	5,8	6,0	6,3	6,6	6,9	7,2	7,2	7,3
	6,2	5,4	5,7	6,1	6,4	6,7	6,8	7,2	7,0	7,1
	6,2	5,4	5,7	6,1	6,4	6,7	6,8	7,2	7,0	7,1
	5,3	5,3	5,8	6,3	6,6	6,8	7,0	6,9	7,3	7,5
	5,3	5,3	5,8	6,3	6,6	6,8	7,0	6,9	7,3	7,5
	5,2	5,6	6,0	6,3	6,7	6,9	7,2	7,6	7,9	8,2
	5,2	5,6	6,0	6,3	6,7	6,9	7,2	7,6	7,9	8,2
	5,0	6,4	6,6	6,8	7,0	7,2	7,5	7,8	8,0	8,3
	5,0	6,4	6,6	6,8	7,0	7,2	7,5	7,8	8,0	8,3
	5,6	6,1	6,2	6,4	6,6	6,8	6,9	7,1	7,3	7,4
	54,5	57,0	60,2	63,4	66,3	66,6	70,8	73,3	74,9	76,9
Mean Depth	5,45	5,70	6,02	6,34	6,63	6,66	7,08	7,33	7,49	7,69

Calculation of Depths for Average Cross Section

Distance out from West Bank	640	650	660	670	680	690	700	710	720	730
	7,4	7.4	7,5	7.5	7,6	7,5	7,3	7,1	6,9	6,6
	7,2	7,3	7,4	7,5	7,5	7,4	7,3	7,2	7,1	7,0
	7,2	7,3	7,4	7,5	7,5	7,4	7,3	7,2	7,1	7,0
	7,7	7,8	7,7	7,6	7,6	7,4	7,5	7,4	7,4	7,3
	7,7	7,8	7,7	7,6	7,6	7,4	7,5	7,4	7,4	7,3
	8,2	8,1	8,0	7,9	7,7	7,5	7,6	7,4	7,5	7,6
	8,2	8,1	8,0	7,9	7,7	7,5	7,6	7,4	7,5	7,6
	8,6	8,8	8,4	8,1	7,7	7,6	7,5	7,8	8,0	8,3
	8,5	8,8	8,4	8,1	7,7	7,6	7,5	7,8	8,0	8,3
	7,6	7,7	7,9	8,0	8,1	7,8	7,6	7,4	7,5	7,5
	78,2	79,1	78,4	77,7	76,7	75,1	74,7	74,1	74,4	74,5
Mean Depth	7,82	7,91	7,84	7,77	7,67	7,51	7,47	7,41	7,44	7,45

Distance out from West Bank	740	750	760	770	780					
	6,4	5,6	4,7	3,7	2,8					
	6,8	6,7	5,4	3,7	3,2					
	6,8	6,7	5,4	3,7	3,2					
	7,3	6,7	6,4	5,1	3,7					
	7,3	6,7	6,4	5,1	3,7					
	7,5	7,1	6,8	5,2	3,8					
	7,5	7,1	6,8	5,2	3,8					
	7,6	7,8	7,0	5,4	1,8					
	7,6	7,8	7,0	5,4	1,8					
	7,5	6,5	6,2	5,2	3,6					
	72,3	68,7	62,1	47,7	31,4					
Mean Depth	7,23	6,87	6,21	4,77	3,14					

Distance out from West Base Line				West or Right	East or Left					
to Water's Edge				25,3	798,4					
				25,1	799,8					
				25,1	799,8					
				27,7	786,0					
				27,7	786,0					
				26,8	794,4					
				26,8	794,4					
				28,6	791,9					
				28,6	791,9					
				31,7	795,8					
				273,4	7938,4					
Mean. Distance out.				27,34	793.84					

the particular distance out x, will then be $\frac{25}{200}(a+2b+2c+2d+2e+f)$, the length of base line being 200 feet, and the length of a section being $2 \times 25 = 50$ feet. This principle is used on pages 15 to 17, in the calculation of the depths for the average cross-section; the distances apart being ten feet.

The same principle is used to find the average distance out, of the waters edge, from the base line. This is calculated on page 17. In this case the vertical lines represent distances out from the base line and, the broken line represents the water's edge along the entire course.

On page 69, is shown the average cross section, in which the ordinates represent the depths of water, while, the abscissae represent the distances out from the west base line.

The Float Measurements.

On pages 20 to 25, are given tables for the position of the Ellis floats. An explanation of them will now be given.

The first column contains the number of the series; and, the second, the number of the float in that series.

In the third column are to be found the angles at the lower transit, when the float is crossing the upper transit line. This last line is Range 0-0, while the lower transit is stationed at the point 250, on Range 5-5.

The fourth column is made up of the natural tangents of angles shown in the third column; and, column V is found by multiplying the results in the third column by the length of base, 250 ft.

The sixth column contains the angles at the upper transit, when the float is crossing Range 5-5, the lower transit

Table for Position of Fillis Floats

Series	No. of Float	Angle to Float at Upper Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Angle to Float at Lower Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Mean Dist. out.	Remarks
1	1	8°-40'	.15243	38.1	10°-58'	.19378	48.4	43.2	
	2	8-25	.14796	37.0	not taken	~	—	37.0	
	3	7-48	.13698	34.2	9-06	.16017	40.0	37.1	
2	1	13°-36'	.24193	60.5	30°-11'	.57774	144.4	102.5	
	2	13-0	.23087	57.7	28-1	.53208	133.0	95.3	
	3	13-37	.24223	60.6	28-53	.55165	137.9	99.3	
									Gauge
3	1	26°-8'	.49012	122.7	34°-22'	.68386	171.0	146.8	8.30 A.M. -0.56'
	2	26-2	.48845	122.1	32-12	.62973	157.4	139.8	1. P.M -0.58'
	3	26-15	.49315	123.3	30-52	.59770	149.4	136.3	6. P.M - -0.52'
	4	26-24	.49640	124.1	32-58	.64858	162.1	143.1	Mean for Day - - 0.56
	5	26-11	.49170	122.9	31-38	.61601	154.0	138.5	
	6	26-25	.49677	124.2	30-35	.59101	147.8	136.0	
4	1	34°-42'	.69243	173.1	43°-42'	.95562	238.9	206.0	
	2	34-45	.69372	173.4	43-55	.96288	240.7	207.1	
	3	34-42	.69243	173.1	45-31	1.01820	254.3	213.8	

Table for Position of Fillis Floats

Series	No. of Float	Angle to Float at Upper Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Angle to Float at Lower Line	Nat. Tang.	Dist. out from Transit Line on River Line	Mean Dist. out	Remarks
4	4	34°-35'	,68942	172,4	46°-46'	1,06365	265,9	219,1	
	5	34-25	,68514	171,3	43-45	,95729	239,3	205.3	
	6	34-44	,69329	173,3	47-29	1,09067	272,7	223.0	
	7	32-33	,63830	159,6	22-24	,41217	103,0	131,3	
	8	34-47	,69459	173,6	46-12	1,04279	260,7	217.1	
5	1	45°-00'	1,00000	250	52°-00'	1,27994	319,9	285,6	
	3	44-46	.99189	247,9	56°-45	1,52525	381,3	314,6	
	4	44-46	,99189	247,9	56-29	1,50988	377,4	312,6	
	5	44-52	,99536	248,8	55-46	1,46962	367,4	308,6	
	6	43-55	,96288	240,7	57-30	1,56969	392,4	316,6	
	7	45-16	1,00935	252,3	53-55	1,37218	343,0	297,9	
6	1	55°-56'	1,47885	369,7	64°-03'	2,05485	513,7	441,7	
	2	56-05	1,48722	371,8	62-50	1,94858	487,1	429,5	
	3	56-06	1,48816	372,0	63-12	1,97966	494,9	433,4	
	4	56-05	1,48722	371,8	63-07	1,97253	493,1	432,5	
	5	55-58	1,48070	370,2	63-05	1,96969	492,4	431.3	

Table for Position of Ellis Floats

Series	No. of Float	Angle to Float at Upper Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Angle to Float at Lower Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Mean Dist. Out	Remarks
7	1	72°-28'	3,16517	791,3	72°-10'	3,10842	777,1	784.2	
	2	72-26	3,15877	789,7	72-02	3,08379	770,9	780.3	
8	1	72°-05'	3,09298	773,2	71°47'	3.03854	759,6	766,0	
	2	72-00	3,07769	769,4	72-05	3,09298	773,2	771,3	
	3	71-59	3,07464	766,2	71-43	3,02667	756,6	761,4	
	4	71-52	3,05349	763,4	71-47	3,03854	759,6	761,5	
9	1	70°-32'	2,82914	707,3	70°-22'	2,80316	700,8	704,1	
	2	70-39	2,84758	711,9	70-41	2,85289	713,2	712,5	
	3	70-38	2,84494	711,2	70-36	2,83965	709,9	710,6	
	4	70-41	2,85289	713,2	70-50	2,87700	719,3	716,2	
	5	70-35	2,83702	709,2	70-37	2,84229	710,6	709,9	
	6	70-40	2,83439	712,6	70-22	2,80316	700,8	706,7	
	7	70-34	2,85623	708,6	70-29	2,82130	705,3	706,9	
	8	70-32	2,82914	706,0	70-14	2,78269	695,7	700,9	
	9	70-33	2,83176	707,9	70-20	2,79802	699,5	703,7	
	10	70-33	2,83176	707,9	70-20	2,79802	699,5	703.7	

Table for Position of Ellis Floats

Series	No. of Float	Angle to Float at Upper Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Angle to Float at Lower Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Mean Dist. out.	Remarks.
10	1	68°-20'	2,51715	629,3	68°-16'	2,50864	627,2	628,2	
	2	68-20	2,51715	629,3	68-13	2,50229	625,6	627,5	
	3	68-28	2,53432	633,6	68-40	2,56046	640,1	636,8	
	4	68-26	2,53001	632,5	68-01	2,47716	619,3	625,9	
	5	68-26	2,53001	632,5	68-19	2,51502	628,7	630,6	
	6	68-25	2,52786	631,9	68-27	2,53217	633,0	632,4	
	7	68-25	2,52786	631,9	68-39	2,55827	639,6	635,8	
	8	68-22	2,52142	630.4	68-01	2,47716	619,3	624,8	
	9	68-35	2,54952	637.4	67-50	2,45451	613.6	625,5	
	10	68-16	2,50864	627,2	68-21	2,51929	629,8	628,5	
11	1	64°-23'	2,08560	521,4	65°-01'	2,14614	526,5	524,9	
	2	64-21	2,08250	520,6	65-08	2,15760	539,4	530,0	
	3	64-24	2,08716	521,8	64-49	2,12671	531,7	526,8	
	4	64-22	2,08405	521,0	65-08	2,15760	539,9	530,2	
	5	64-18	2,07785	519,5	64-58	2,14123	535.3	527,4	
	6	64-20	2,08094	520,2	65-08	2,15760	539,4	529,8	

Table for Position of Ellis Floats

Series	No. of Float	Angle to Float at Upper Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Angle to Float at Lower Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Mean Dist. out.	Remarks
12	1	56°-15'	1,49661	374,2	57°-01'	1,54085	385,2	359,7	
	3	56-11	1,49284	373,2	57-14	1,55368	388,4	381,8	
	4	56-13	1,49472	373,7	56-29	1,50988	377,5	375,6	
	5	56-30	1,51684	377,7	58-06	1,60657	401,6	389,6	
	6	56-24	1,50512	376,3	56-03	1,48536	371,3	373,8	
13	1	59°-36'	1,70446	426,1	60°-48'	1,78929	447,3	436,7	
	2	59-34	1,70219	425,5	60-09	1,74257	435,6	430,6	
	3	60-00	1,73205	433,0	61-15	1,82276	455,7	444,8	
	4	59-51	1,72163	430,4	60-21	1,75625	439,2	434,8	
14	1	62°-26'	1,91534	478,9	63°-06'	1,97111	492,8	485,8	
	2	62-33	1,92508	481,3	63-10	1,97681	494,2	487,8	
	3	62-28	1,91826	479,6	63-20	1,99116	497,8	488,7	
	4	62-38	1,93195	483,0	63-15	1,98396	496,0	489,5	
15	1	52°-06'	1,28456	321,0	52°01'	1,28071	320,2	320,7	
	2	51-55	1,27611	319,0	51-50	1,27230	318,0	318,5	

Table for Position of Fillis Floats

Series	No. of Float	Angle to Float at Upper Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Angle to Float at Lower Line	Nat. Tang.	Dist. out from Transit Line on River Bank	Mean Dist. out.	Remarks
15	3	52°-06'	1,28450	321,0	×	×	×	321,0	
	4	51-53	1,27458	318,6	52-06	1,28456	321,0	319,8	
	5	51-44	1,26774	316,9	51-15	1,24597	311,5	314.2	
	6	51-55	1,27611	319,0	51-51	1,27306	318.3	318,7	

line.

The seventh and eighth columns are found from the sixth column, in the same manner that the fourth and fifth columns, were found from the third.

The ninth column is found by averaging the results of the fifth and eighth columns.

Table of Velocities

On pages 27 to 32, are given tables as designated above. The first two columns explain themselves. The third column contains the depths of the centres of the sub-surface floats below the surface of the water.

The fourth column is made up of distances passed over. These are not strictly correct, as, the path pursued by a float was not parallel to the base line; but, the variation was slight, and for our purpose amounted to nothing.

Table of Velocities at Points in Cross Section

Series	No. of Float	Depth of Centre of Float	Dist passed over	Time Interval	vel. in f.p.s	mean Dist. Out.	mean for Series	Area of Curve in Sq.in.	Actual Area, Sq. Ft.	Length of Base of Curve	mean Vel in vertical f.p.s
			ft	min. sec.							
1	1	0,4'	250	3-18,2	1,26	43,2					
	2	1,0		4-13,5	.99	37,0	39,1	2,855	2,284	2,55	0,895
	3	1,5		4-50	.86	37,1					
2	1	0,4	250	2-49	1,48	102,5					
	2	1,0		3-13,7	1,29	95,3	99,0	7,17	5,736	4,85	1,183
	3	1,5		3-16	1,27	99,3					
3	1	2,0	250	2-22,2	1,77	146,8					
	2	3,0		2-37	1,59	139,8					
	3	4,0		2-33	1,63	136,3					
	4	0,4		2-24	1,74	143,1	140,0	13,50	10,79	6,80	1,587
	5	1,0		2-25	1,72	138,5					
	6	5,0		2-43	1,53	136,0					
4	1	0,4	250	2-26,2	1,71	206,0					
	2	1,0		2-11	1,91	207,1					
	3	5,0		2-54	1,44	213,8					
	4	2,0		2-27	1,70	219,1					

Table of Velocities at Points in Cross Section

Series	No. of Float	Depth of Centre	Dist. passed over	Time	Vel. in f.p.s	Mean Dist. out.	Mean for Series	Area of Curve in Sq. In	Actual Area in Sq Ft.	Length of Base of Curve	Mean Vel. in vertical f.p.s.
			ft.	min. sec							
4	5	4,0	250	2-32	1,64	205,3					
	6	3,0		2-32	1,64	223,0	202,6	14,055	11,24	7,10	1,586
	7	Surf		4-45	,88	131,3					
	8	6,0		3-00	1,39	217,1					
5	1	3	250	2-04	2,02	285,6					
	2	5		2-38	1,58	314,6					
	3	2		2-5,8	1,99	312,6	305,9	12,36	9,888	5,30	1,866
	4	4		2-30	1,67	308,6					
	5	0,4		2-7,4	1,96	316,6					
	6	1		2-3	2,03	297,9					
6	1	0,4	250	2-32	1,64	441,7					
	2	1		2-33	1,63	429,5					
	3	2		2-45	1,51	433,4	433,7	7,415	5,932	4,05	1,467
	4	3		3-05	1,35	432,5					
	5	3		2-52	1,45	431,3					

Table of Velocities at Points in Cross Section

Series	No. of Float	Depth of Centre	Dist. passed over	Time	Vel. in f.p.s	Mean Dist. out	Mean for Series	Area of Curve in Sq. In.	Area in Sq. Ft.	Length of Base of Curve	Mean Vel. in Vertical f.p.s.
7	1	0,4	250	3-46	1,11	784,2	782,0	3,06	2,448	2,70	0,988
	2	1		4-24	,95	780,3					
8	1	0,4	250	3-46	1,11	766,0					
	2	1		3-50	1,09	771.3	765,0	5,855	4,684	5,52	0,850
	3	2		4-01	1,04	761,4					
	4	3		4-37	,90	761,5					
9	1	2	250	2-09	1,94	704,1					
	2	3		×	×	712,5					
	3	0,4		2-07	1,97	710,6					
	4	3		2-12	1,90	716,2					
	5	1		1-57	2,14	709,9	707,6	17,175	13,74	7,40	1,859
	6	4		2-10	1,92	706,7					
	7	5		2-07	1,97	706,9					
	8	6		2-25	1,72	700,9					
	9	7		4-17	,97	703,7					
	10	6		2-26	1,71	783,7					

Table of Velocities at Points in Cross-Section

Series	No. of Float	Depth of Centre	Dist. passed over	Time	Vel. in f.p.s	Mean Dist. out.	Mean for Series	Area of Curve in Sq. In.	Actual Area in Sq. Ft.	Length of Base of Curve	Mean Vel. in Vertical f.p.s
10	1	7	250	3-20	1,25	628,2					
	2	6		×	×	627,5					
	3	5		2-39	1,57	636,8					
	4	6		2-22	1,76	625,9					
	5	4		2-14	1,86	630,6	629,4	17,075	13,66	7,70	1,774
	6	3		2-01	2,07	632,4					
	7	2		2-03	2,03	635,8					
	8	1		1-58	2,12	624,8					
	9	0,4		2-13	1,88	625,5					
	10	3		2-09	1,94	628,5					
11	1	0,4	250	2-40	1,56	524,9					
	2	3		2-57	1,41	530,0					
	3	1		2-27	1,70	526,8					
	4	2		2-34	1,62	530,2	527,8	8,90	7,12	5,30	1,344
	5	1		2-50	1,47	527,4					
	6	4		3-52	1,08	529,8					

Table of Velocities at Points in Cross Section

Series	No. of Float	Depth of Centre	Dist. passed over	Time	Vel. in f.p.s	Mean Dist. Out.	Mean for Series	Area of Curve in Sq.In.	Actual Area in Sq.Ft.	Length of Base of Curve	Mean Vel. in Vertical f.p.s.
12	1	1	250	2-42	1,54	359,7					
	3	2		3-00	1,39	381,8					
	4	3		3-16	1,27	375,6	380,0	7,135	5,70	4,75	1,342
	5	2		2-52	1,45	389,6					
	6	0,4		2-45	1,52	373,8					
13	1	2	250	2-56	1,42	436,7					
	2	0,4		2-39	1,57	430,6	436,6	6,435	5,148	4,07	1,263
	3	3		3-51	1,08	444,8					
	4	1		2-44	1,52	434,8					
14	1	3	250	3-26	1,21	485,8					
	2	1		2-46	1,51	487,8					
	3	0,4		2-30	1,67	488,7	487,9	7,385	5,908	4,52	1,308
	4	2		3-05	1,35	489,5					
15	1	0,4	250	2-12	1,89	320,7					
	2	2		2-15	1,85	318,5	318,8	9,94	7,952	5,025	1,583
	3	1		2-22	1,76	321,0					

Table of Velocities at Points in Cross-Section

Series	No. of Float	Depth of Centre	Dist. passed over	Time	Vel. in f.p.s	Mean Dist. out.	Mean for Series	Area of Curve in Sq. In.	Actual Area in Sq. Ft	Length of Base of Curve	Mean Vel. in Vertical f.p.s.
15	4	3	250	2-36	1.60	319.8					
	5	1		2-20	1.78	314.2					
	6	4		3-14	1.29	318.7					

The fifth column shows the time taken by the floats in passing over the distance between the upper and lower ranges, and is determined by stop-watch.

The sixth column is obtained by dividing the results in the fourth column, by those in the fifth.

The results in the seventh column were determined on pages 20 to 25, and, are repeated for convenience only.

The Velocity Curves.

From the results of the third and sixth columns, the velocity curves on pages, 67 & 68 of the diagrams, are plotted. They are numbered from I to XV. In these, the ordinates represent velocities in feet per second; and, the abscissae mark the depths of water. The points are plotted and connected by straight lines. A curve is then drawn in such position, that, the sums of the vertical deviations of the points on either side of the curve, from the curve, are equal. This curve is continued until it meets the lines which represent the surface of the river, and the bottom of the stream. The broken lines are then continued to these points thus found. The area of this figure is then determined by use of a planimeter, and the results are shown in the ninth column.

The tenth column is obtained by multiplying the results of the preceding column by ·8. This is necessary on account of the use of different scales for the ordinates and the abscissae in the curves shown on pages 67 & 68 of the diagram for float measurements.

The results in the column headed, "Length of Base of Curve", are obtained by measurement of the bases of the curves mentioned above; and, the results in the last column are found by dividing each number in the tenth column by the corresponding number in the eleventh.

The results of the eighth and twelfth columns are now plotted, as shown by the small circles in the Diagram of Ellis' Float Measurements. A curve is then drawn in such position that the sums of the vertical deviations, from the curve, of points on either side of the curve, shall be equal.

Calculation of Q.

We have now an average cross-section, and a velocity curve covering points in the entire width of the stream. We now proceed to calculate the discharge of the stream, and for this purpose, the tables on pages 36 and 37 are given.

The first column contains the number of the sections shown in the Diagram for Float Measurements, page 69. The sections are made of such length, that,

Calculation of Q from Diagram of Ellis Floats

Section No.	Area Sq. In	Actual Area Sq. Ft	V in f.p.s.	Q in c.f.p.s.	Remarks	
1	0,23	18,4	0,66	12,14		
2	0,735	58,8	0,93	54,68		
3	0,84	67,2	1,13	75,94		
4	2,425	194,0	1,32	256,08		
5	3,355	268,4	1,47	394,55		
6	3,62	289,6	1,59	460,46		
7	3,435	274,8	1,67	458,92		
8	3,06	244,8	1,73	423,50		
9	2,69	215,2	1,735	373,37		
10	2,365	189,2	1,63	308,40		
11	2,11	168,8	1.39	234,63		
12	2,06	164,8	1,31	215,89		
13	2,12	169,6	1,30	220,48		
14	2,35	188,0	1,33	250,04		
15	2,775	222,0	1,425	316,35		
16	3,245	259,6	1,62	420,55		
17	3,735	298,8	1,78	531.86		
18	3,905	312,4	1,86	581,06		
19	1,88	150,4	1,85	278,24		

Calculation of Q from Diagram for Ellis Floats

Section No.	Area Sq. In	Actual Area Sq. Ft	V in f.p.s	Q in c.f.p.s	Remarks	
20	1,85	148,0	1,80	266,40		
21	1,85	148,0	1,66	245,68		
22	1,70	136,0	1,39	189,04		
23	1,195	95.6	0,93	88,91		
24	0,325	26,0	0,70	18,20		

Total Discharge

= 6675.37 c.f.p.s

the portion of the velocity curve intercepted between dotted lines projected vertically through the extreme ends of the sections, shall be straight, or, nearly so.

The second column represents the area of the sections on the diagram, in square inches, as determined by the use of a planimeter. In using the planimeter, enough readings were taken to secure two readings which agree within two-one-hundredths of an inch

The third column contains the actual areas of the sections in square feet. The scales of abscissae and ordinates on the diagram are different, and the readings obtained by planimeter must, therefore, be modified. In this case the scale of readings in square inches to areas in square feet, is one to eighty. The results in the third column are obtained, therefore, by multiplying each number in the second column by eighty.

The fourth column is that of velocities in feet per second. These are found by projecting the middle ordinate of each section on the diagram, vertically, until it meets the velocity curve. The intercept on this line, between the velocity curve and the base line, represents the mean velocity, in the section under consideration, in feet per second.

The product of the area of each section by the velocity corresponding to the middle ordinate of that section, gives the discharge for that section; and, this is placed in the fifth column. The sum of the numbers in this column is, therefore, the discharge in cubic feet per second for the entire stream, and, as stated on page 37, is 6675.37 c.f.p.s

Part II

Measurements made with Current Meters.

Data.

The entire set of meter measurements was made on Range 250-200, i.e; at the lower end of the transit line. They were begun on June 18, 1890, and were completed on June 23rd. During that period, the river fell from 1.9 by gauge at 9. a.m. on June 18th, to -0.48 at 6 P.M on June 23rd. The lowest stage of water at any time, during the stay of the party at Deerfield, was -.56, on June 26th, and the measurements are, for the sake of simplicity, reduced to that stage of water.

On pages 44 and 45 is a table of measurements for the Stiley Meter.

Column I contains the numbers of the stations and requires no explanation.

Column II, is that of the distances out from the west bank of the river. Where more than one measurement was taken at a station, the mean distance out is placed in the column.

Column III is a column of depths as actually measured with the meter; while, the fourth column is one of corrected depths to be used in plotting the cross-section of the river. The results of the third column could be used, but, as we already have a very large number of points calculated from the Float Measurements, in which the gauge-reading is -.56, we can, by reducing the results in the third column to those in the fourth, obtain additional points at a stage greater .56; and, thus obtain a very accurate cross-section. This fourth column is, therefore, obtained by reducing the depths in the third column from their respective gauge-readings to -.56

Column V is the time expressed in seconds, and represents the period required for a vertical integration at that particular station. The time was determined by stop watch. Where more than one integration was taken, the mean, only, is placed in the table.

The sixth column contains the number of revolutions during each integration, and is read directly from the meter.

Column VII is a column of velocities, expressed in feet per second; this is obtained from diagrams of meters which have been prepared, and are in use in the Civil Engineering Department of the Institute:
On the diagrams, the ordinates represent the number of revolutions per second, and the abscissae, the velocities in feet per second; the horizontal and vertical projections, respectively, meeting on the curve.

The eighth column contains, among other things, the gauge-readings read from a gauge five feet long, placed on one of the western piers of the highway bridge between Deerfield and Sunderland.

Table of Measurements with the Fteley Meter

I Sta. No.	II Dist. out from West Bank	III Depth by Meter	IV Reduced Depth	V Time in Sec.	VI No. of Rev	VII Velocity in F. P. S	VIII Remarks.
							Gauge at
1	37	4.6	2,14	160	197	1,04	1.9 9 A.m. 1,7 4 P.m
2	60	5.0	2.64	187	372	1.63	
3	88	6.3	4.04	356	766	1.76	
4	159.5 162.0 161.0	9.3	7.44	439	1044	1.94	1.3 9 A m. 1.1 5.P. m
5	455 447 451	6.1	4.24	226	531	1.92	
6	782.5 783.5 783	4.4	2.64	165	212	1.08	
7	764 771 770	7.1	5.44	228	318	1.17	
8	717	9.2	7.54	190	506	2.17	0.70 8 a m 0.60 5 P. m
9	260.5 260.7 260.6	7.4	6.14	349	868	2.03	
10	623.5 626.1 624.8	8.9	7.64	338	835	2.02	Column IV contains
11	55	3.2	1.94	209	78	1.42	depths reduced to
12	88	6.1	4.84	427	157	1.41	gauge reading -.56
13	128.8 126.9 128	8.1	6.94	565	274	1.80	Velocities in f.p.s
14	239.6 240.0 239.8	7.6	6.44	536	305	2.08	are obtained from Diagram
15	368.1 369.0 368.5	5.2	4.04	340	171	1.86	of the Fteley Meter.
16	776 780 778	3.9	3.24	237	56	0.97	0.1 9. a. m. -0.3 2. P. m.
17	737.5 734.3 735.9	8.4	7.84	512	239	1.74	
18	693.7 695 694.4	8.3	7.84	278	142	1.89	
19	623.9	8.3	7.94	308	158	1.90	

Table of Measurements with the Fteley Meter

I Sta No.	II Dist. out from West Bank	III Depth by Meter	IV Reduced Depth.	V Time in Sec.	VI No. of Rev.	VII Velocity in F.P.S	VIII Remarks
							Gauge at
20	499.2 498.6 498.9	4.9	4.64	223	91	1,53	
	203.9 202.6						-.0.44 9.A.M
37	203,3	7,3	7,21	534	1140	1,75	-0.48 6.P.M.
38	777,9	3,6	3,51	479	455	0,81	
39	743.6	7,3	7,21	819	1402	1,42	
40	698.2	7,6	7,51	521	1219	1,92	
41	653.0	8,1	8.01	581	1340	1,86	
42	547.3	5,9	5,81	390	760	1,60	
43	439,8	3,8	3,72	262	469	1,47	
44	332,6	4,7	4.62	330	6.27	1,56	
45	254.7 256.5 255.6	6,2	6.12	450	1019	1,87	
46	155,0	7,5	7,42	551	1107	1,65	
47	93,5	5,5	5,42	402	557	1,16	
48	60.4 60.9 60,6	2,5	2,42	166	165	0,85	

Table of Measurements with the Ellis Meter

I Sta No.	II Dist. out from West Bank	III Depth by Meter	IV Reduced Depth.	V Time in Sec.	VI No. of Rev	VII Velocity in F. P. S	VIII Remarks
							Gauge at. -0.44 9 a.m -0.48 6 p.m
21	776.3	3.7	3.58	229	48	0.88	
22	761.9 761.1 761.5	6.1	4.98	429	111	1.04	
23	718.6 719.3 719.0	7.2	7.08	508	249	1.81	
24	686.9 686.2 686.5	7.0	6.88	499	269	1.98	
25	641.8 643.4 642.6	7.8	7.68	551	286	1.91	Column IV contains
26	595.7 595.2 595.5	7.2	7.08	515	240	1.74	depths reduced
27	548.6	5.7	5.59	393	176	1.68	to gauge reading
28	490.3	4.4	4.29	297	113	1.45	-.56
29	433.0 432.7 432.9	3.6	3.49	218	88	1.53	
30	387.7	3.7	3.59	240	96	1.57	Velocities in
31	313.9 314.7 314.3	5.0	3.99	335	147	1.64	feet per second
32	245.4 246.0 245.7	6.4	6.3	448	226	1.86	are obtained from
33	50.5	2.1	2.0	127	31	0.98	Diagrams of the
34	84.5 83.4 84.9	4.6	4.5	282	76	1.08	Ellis Meter.
35	139.4	7.2	7.1	496	224	1.69	
36	202.9 203.9 203.4	7.0	6.9	493	233	1.75	

Page 46 contains a similar table for the measurement by use of the Ellis meter, and requires no explanation. On page 48 will be found a series of soundings taken on range 5-5 (or 250-250) on June 17th. The transit station being at 0, it follows that the base of the triangle to be calculated is 250 ft; and, therefore, the column of calculated distances is obtained from the column of natural tangents by dividing each number in the latter column by 4. The reduction of gauge-readings is precisely like those previously made.

Cross Section of River at Range 5-5

The data for plotting this cross section are to be found on pages 10&11 of the float measurements, and pages 48 of the meter measurements. The cross-section as plotted, is to be found in the diagram for meter measurements on page ..., As stated in the diagram, the ordinates represent depths in feet, and the abscissae represent distances out from the West bank

Range 5-5. Additional Soundings used in Cross Section of River in Diagram for Meter Measurements

Sta. No. from E. Bank	Angle from Base. Transit at 0+0	Nat Tang	Calc. Dist.	Sounding Gauge at 2.45	Reduced Sounding Gauge at -.56	Remarks
1	72° 40'	3.20406	801.0	0.0	×	
2	72° 27'	3.16197	790.5	3.8	0.79	
3	72° 02'	3.08379	770.9	7.9	4.89	
4	71° 32'	2.99447	748.6	9.9	6.89	
5	70° 58'	2.89873	724.7	10.2	7.19	
6	69° 01'	2.60736	651.8	11.0	7.99	
7	66° 57'	2.35015	587.5	10.2	7.19	
8	63° 32'	2.00862	500.2	7.6	4.59	Base of triangle 250 ft
9	60° 05'	1.73788	434.5	6.7	3.69	
10	50° 58'	1.23343	308.4	8.0	4.99	
11	41° 20'	0.87955	219.9	9.6	6.59	
12	36° 48'	0.74810	187.0	9.9	6.89	
13	18° 18'	0.33072	82.7	7.4	4.39	
14	11° 51'	0.20982	52.5	4.9	1.89	
15	9° 06'	0.16017	40.0	4.9	1.89	
16 West side	5° 40'	0.9923	24.8	0.0	×	

of the river. The gauge-reading is −.56

For convenience and reference points plotted from different set of measurements are marked differently, and in this manner:

o A small circle, thus, designates point obtained by the first set of soundings.

◠ A half circle placed thus, designates points determined from the second set of soundings.

c Points marked thus, were obtained from use of the Fteley Meter, and

ↄ Points designated thus, were found by use of the Ellis Meter.

Where the points occur in groups, they are "weighted"; i.e: the curve is passed through a point, such that the sums of the vertical deviations on either side of the curve are equal.

The Velocity Curves.

The velocities in column VII on pages 44 to 46 are used to plot the curves shown in the diagram for meter measurements on page 70.

The points, marked with circles, are projected vertically from their distances out, which are represented by the abscissae; and, the ordinates measured from the base line represent velocities in feet per second. The points are grouped in nearly all cases, and the sums of the vertical deviations on either side of the curve are, in all cases, equal.

Calculation of Q

Tables showing the calculation of Q are given on pages 53 to 56 and an explanation of them will now be given.

The first column contains the numbers of the sections shown on the diagram of meter measurements, page 70. The sections are made of such length, that, the portion of the velocity curve, intercepted between the dotted lines projected vertically through the extreme ends of the section, shall be straight, or nearly so.

The second column represents the area of the sections on the diagram in square inches, as determined by use of a planimeter. In using the planimeter, enough measurements were taken to secure two readings within two one-hundredths of a square inch of each other.

The third column contains the actual area of the sections in square feet. The scales of abscissae and ordinates on the diagram are not the same, and, therefore, the reading obtained by planimeter must be modified. In this case, the scale of readings in square inches, to actual areas in square feet is one to eighty. The results in the third column are obtained, therefore, by multiplying each number in the second column by eighty.

The fourth column contains velocities in cubic feet per second. These velocities are obtained by projecting the middle ordinate of each section, vertically, until it meets the velocity curve. The intercept on this line, between the velocity curve and the base line, is the mean velocity for the section.

The fifth column is obtained by multiplying the area of each section, in square feet, by the mean velocity of that section. This gives the discharge, Q, for the section. The sum of the numbers in this column will be the discharge for the entire cross-section.

Calculation of Q by means of Diagram for Fteley Meter

I Section Number	II Area Sq. In	III Actual Area Sq. Ft	IV V in f.p.s	V Q in c.f.p.s	VI	VII Remarks
1	0.18	14.4	0.62	8.93		
2	0.51	40.8	0.75	30.60		
3	0.80	64.0	0.94	60.16		
4	1.25	100.0	1.13	113.0		
5	3.19	255.2	1.37	348.62	Stage of water for this	
6	3.66	292.8	1.63	477.26	cross section used	
7	3.45	276.0	1.79	494.04	is – 0.56	
8	3.175	254.0	1.83	464.82	The correction is made	
9	2.865	229.2	1.78	407.98	on Pages 59 & 60	
10	2.40	192.0	1.65	316.80		
11	2.065	165.2	1.53	252.76		
12	1.755	140.4	1.48	207.79		
13	1.915	153.2	1.47	225.20		
14	2.16	172.8	1.49	257.47		
15	2.60	208.0	1.54	320.32		
16	3.12	249.6	1.64	409.34		
17	3.62	289.6	1.76	509.70		
18	3.905	312.4	1.88	587.31		
19	4.00	320.0	1.94	620.80		

Calculation of Q by means of Diagram for Fteley Meter

I Section Number	II Area Sq. in.	III Actual Area Sq. Ft	IV V in f.p.s	V Q in c.f.p.s	VI Remarks	
20	3.67	293.6	1.72	504.99		
21	1.665	133.2	1.30	173.16		
22	1.185	94.8	0.95	90.06		
23	0.35	28.0	0.70	19.20		

Total Area = 4259.2 sq ft.

" Q = 7000.31 c.f.p.s

Calculation of Q by means of Diagram for Ellis Meter

I Section Number	II Area Sq. in.	III Actual Area Sq. Ft.	IV Velocity f.p.s	V Q c.f.p.s	VI Remarks
1	.18	14.4	0.75	10.80	
2	.51	40.8	0.87	35.50	
3	.80	64.0	1.05	67.20	
4	1.25	100.0	1.24	124.00	
5	3.19	255.2	1.47	375.14	Stage of water for
6	3.66	292.8	1.71	500.69	cross-section used
7	3.45	276.0	1.83	505.08	is -0.56
8	3.175	254.0	1.84	467.36	The Correction is made
9	2.865	229.2	1.77	405.68	on Page .
10	2.40	192.0	1.66	318.72	
11	2.065	165.2	1.55	256.06	
12	1.755	140.4	1.49	209.20	
13	1.915	153.2	1.47	225.20	
14	2.16	172.8	1.49	257.47	
15	2.60	208.0	1.56	324.48	
16	3.12	249.6	1.67	416.83	
17	3.62	289.6	1.82	527.07	
18	3.905	312.4	1.96	612.30	
19	4.00	320.0	1.98	633.60	

Calculation of Q by means of Diagram for Ellis Meter

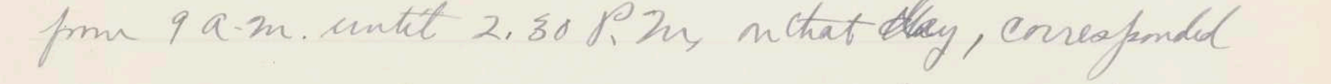
I Section Num.	II Area Sq. In	III Actual Area Sq Ft	IV V in f.p.s	V Q in c.f.p.s	VI Remarks
20	3.67	293.6	1.77	519.67	
21	1.665	133.2	1.26	167.63	
22	1.185	94.8	0.94	89.11	
23	0.35	28.0	0.78	21.84	

Total Area = 4259.2 sq ft.
" Q = 7070.63 c.f.p.s

These results are not strictly accurate, and a correction must be added to them; since, they were calculated upon the assumption that the stage of water, at the time the meter measurements were made, was -0.56 ft. This assumption is not correct. The following table shows the stages of water at short intervals during the day (June 23rd) the meter measurements were made:

Gauge	9. a. m.	-0.44
	11. a. m	-0.45
	1. P. m	-0.46
	3. P. m	-0.47
	6 P. m	-0.48

We may therefore make the statement, without appreciable error, that the mean water level from 9 a.m. until 2.30 P.M, on that day, corresponded to a gauge-reading of -0.45; while that from 2.30 to 6. P.M, corresponded to a reading of -0.47. We now proceed as follows, drawing the figure, first:



The line AB represents the surface of the water when the gauge-reading is -0.56. When the reading is -.45;

the surface of the water may be represented by the line CD at a distance .11 ft above AB. Now the additional discharge due to this increased depth of water may be correctly ascertained by multiplying the area of each small section cross-hatched, by the velocity corresponding to the middle ordinate of that section, — the velocity is obtained from the Diagram of Meter-measurements, — and taking the sum of the results thus obtained. If now this additional discharge be added to the quantity obtained on page 56. the final sum will be the true discharge of the river as determined by the use of the Ellis Meter. Similarly, the true discharge by use of the Fteley Meter may be found.

The following table shows the additional discharge of each section, due to an increase in the water level. The numbers of the sections, and the velocities are taken directly from the Diagram for Meter measurements and are identical with columns. I and IV on pages 53 to 56 inclusive.

Calculation of Additional Discharge due to Increase of Water Level

Ellis Meter					Fteley Meter				
Section Number	Area Sq Ft	V f.p.s	Q c.f.p.s	Remarks	Section Number	Area Sq Ft.	V f.p.s	Q c.f.p.s	Remarks
1	1.32	0.75	0.92		1	1.08	0.62	0.67	
2	2.20	0.87	1.91		2	1.80	0.75	1.35	
3	2.20	1.05	2.31	Stage of water	3	1.80	0.94	1.69	Stage of water
4	4.40	1.24	5.45	9 a.m to 2.30 P.M.	4	3.60	1.13	4.07	2.30 to 6. P.M.
5	4.40	1.47	6.46	-.45	5	3.60	1.37	4.93	-0.47
6	4.40	1.71	7.52	Stage of water	6	3.60	1.63	5.87	Stage of water
7	4.40	1.83	8.05	on diagram	7	3.60	1.79	6.44	on diagram
8	4.40	1.84	8.10	of meter meas-	8	3.60	1.83	6.58	of meter meas-
9	4.40	1.77	7.78	urements	9	3.60	1.78	6.41	urements
10	4.40	1.66	7.30	-.56	10	3.60	1.65	5.94	-0.56
11	4.40	1.55	6.82	Difference	11	3.60	1.53	5.51	Difference
12	4.40	1.49	6.55	equals .11 ft	12	3.60	1.48	5.33	= .09 ft.
13	4.40	1.47	6.46		13	3.60	1.47	5.29	
14	4.40	1.49	6.55		14	3.60	1.49	5.36	
15	4.40	1.56	6.86		15	3.60	1.54	5.54	
16	4.40	1.67	7.35		16	3.60	1.64	5.90	
17	4.40	1.82	8.00		17	3.60	1.76	6.33	
18	4.40	1.96	8.62		18	3.60	1.88	6.77	
19	4.40	1.98	8.71		19	3.60	1.94	6.98	

Calculation of Additional Discharge due to Increase of Water Level

Ellis Meter

Section Number	Area Sq. ft	V f.p.s	Q c.f.p.s	Remarks
20	4.40	1.77	7.78	
21	2.20	1.26	2.77	
22	2.20	0.94	2.07	
23	1.76	0.78	1.37	
	Total Q =		135.71	

Fteley Meter

Section Number	Area Sq. Ft	V f.p.s	Q c.f.p.s	Remarks
20	3.60	1.72	6.18	
21	1.80	1.30	2.34	
22	1.80	0.95	1.71	
23	1.44	0.70	1.01	
	Total Q =		108.28	

The column of areas is made up, by finding the product of the ordinate (which is the increase in water-level shown in the column of Remarks), and the length of the section (which is determined by scale from the cross-section of the river shown on the Diagram for Meter Measurements).

The numbers in the column headed Q, are of course the product of the corresponding Areas and velocities, and are easily found.

On page 54 the discharge of the river as determined by use of the Fteley Meter is found to be 7000.31 c.f.p.s., the gauge-reading being -0.56. For a gauge-reading 0.47, we have just calculated an increase of 108.20 c.f.p.s. The total discharge is therefore 7108.51 cubic feet per second.

Similarly, by reference to pages 55 and 56, we find the total discharge of the river, as found by measurements with the Ellis Meter, to be 7206.34 cubic feet per second.

Part III

Estimation of the Probable Discharge at Holyoke Mass.

Calculation of the Discharge at Holyoke Mass.

We now wish to calculate the discharge of the river at Holyoke Mass., a place about thirty miles distant, by the river course, below South Deerfield. It is first necessary to obtain, by some means, the additional drainage area between Deerfield and Holyoke, and, from that, to calculate the discharge due to this additional drainage area.

From the maps published by the State Topographical Survey, we find the drainage area, mentioned above, to be 375 square miles in extent. In order to obtain the discharge due to this area, we shall use a method, to be given presently, which involves the assumption that the relation of the drainage area between Deerfield and Holyoke, to the total drainage area at Deerfield, is the same as that of the discharge at those places. This assumption we know is not true for a reason which will now be given.

The area between Holyoke and Deerfield is made up of foot hills, meadows, and very few ponds. Mill River is the only stream of any consequence, which discharges into the Connecticut River between the places mentioned. Above Deerfield we find a different country, from a topographical point of view. The mountains are high, the slopes of the hills, steep, and the country more rocky. Snow on the western slopes of the White Mountains melts in the spring, and the water descends the slopes to form the Ammonoosuc and other rivers. These in turn flow into the Connecticut and form the largest portion of its discharge. In Northern Massachusetts, the Deerfield and Miller's Rivers flow into the Connecticut, and as these streams are either, of much larger size than the Mill River, it is fair to claim, that the discharge due to the drainage area between Holyoke and Deerfield, does not bear the same ratio to the total discharge at Deerfield, as that of the respective drainage areas. We will use the method, however, with the following results.

From the portion of the Tenth Census Reports devoted to water-power, we find the drainage area at Holyoke to be 8006 square miles. Subtracting 375 square miles from that number, we obtain 7631 square miles, as the total drainage area at Deerfield Massachusetts. The average discharge of the Connecticut River at Deerfield, as calculated from both float and meter measurements is found to be almost exactly 7000 cubic feet per second. Dividing the latter number by the former, ~~and~~ we have .92 cubic feet per second per square mile of drainage area. For the reason mentioned upon a previous page, this amount is too large, and we must, in some way, modify it.

From a study of the topographical maps of Massachusetts we learn that the drainage basin of the Sudbury River, in the eastern part of the state, is very similar to that between Holyoke and Deerfield. Furthermore, a study and comparison, of the curves of flow of the Sudbury and Connecticut rivers reveals the fact that, when the discharge of the latter is 0.92 cubic feet per second per square mile of drainage area, that of the former is 0.75 cubic feet per second per square mile. We shall therefore assume this last number as correct for that portion of Massachusetts adjacent to Holyoke and Deerfield. We then find the discharge to be 281 cubic feet per second, this being the product of .75 c. f. p. s. p. sq. mi. and 375 sq. mi. Adding this number to the discharge at Deerfield we obtain 7288, or 7300, cubic feet per second as the true discharge at Holyoke Mass.