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(10)

A PROPOSED WATER POWER PLANT FOR THE UNIVERSITY OF MISSOURI.

by

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A THESIS

Presented for the

DEGREE OF BACHELOR OF SCIENCE

In Civil Engineering.

University of Missouri

Department of Engineering

1909.

INDEX.

GENERAL DESCRIPTION.

Hydro-Electric Power Development is fast becoming one of the largest branches of engineering. Much attention is being paid to it in all good engineering schools. But it is impossible to get much out of the study unless a plant is available for experimental work for the students. Cornell University has such a plant for this use. The engineering of this plant, the water wheels, the electrical equipment, etc. were supplied by various large manufacturing companies at practically cost price.

Now that the University of Missouri is giving special courses in hydraulic engineering, it is very essential that she have such a plant at her services. The object of this thesis is to investigate a project that will supply this need. It can hardly be expected that the project will be a success financially, tho it should pay enough in order that it will not become a burden to the University.

On the Hinkson Creek is the only place where a plant could be built within easy reach of the University. About a mile due south of Academic Hall there is a narrow place in the valley, and it is proposed to build the dam and power house at that point.

In the investigation of the project the following points are to be considered:

Drainage Area.

Reservoir Site.

Design of Dam.

Design of Spillway.

General Details.

Power Developed.

Approximate Cost.

Conclusions.

DRAINAGE AREA.

A map of the drainage area is shown on Plate I. The red line is the divide. There are approximately sixty-one square miles in the drainage area. This map was copied from an atlas of Boone County. From this drainage the runoff can be figured approximately by using the ratio of runoff to rainfall as determined by Messrs. Hunter and Phillips in their thesis 1909, "Rainfall and Runoff Data of Hinkson and Grindstone Creeks." The following are the Percentages of Run-off ~~results~~ they obtained:—

		Hinkson Creek.	Grindstone Creek.
1908	October	5.12 %	7.78 %
"	November	9.08 %	10.45 %
"	December	16.75 %	11.51 %
1909	January	36.90 %	42.20 %
"	February	88.95 %	52.7 %
"	March	48.15 %	13.55 %
"	April.	33.96 %	14.56 %

RESERVOIR SITE.

The survey of the reservoir site was made with the transit and stadia. The object of this survey was, first, to obtain the high water line; second, to get the capacity of the reservoir.

There are two things that limit the height of the dam, and therefore the high water line: first, there is a low place in the hills just south of the dam; and second, the water must not flood so much land that the expense of the site become so great as to make the project too expensive.

Plate 2 shows a map of the site as plotted from this survey. As shown by the map, the valley is closed in by rock bluffs almost all the way. The lowest point in the low place south of the dam is at an elevation of 628 feet, sea level datum. Therefore, the top of the spillway can be built to an elevation of about 624 feet, and allow for a five foot ~~rise in the reservoir.~~ overflow. This can be taken care of by building a levee about five feet high across the low place for a distance of about 300 feet. The red line on the map shows the water ~~line where~~ contour when the water is just at the top of the spillway.

The capacity of the reservoir is found by measuring the area of the contours, dividing the sum of each two successive contours by two, and

multiplying the result by the distance between. In this project the only essential capacity is that between the upper contours as this only is available for power purposes.

The areas were measured with a planimeter. The following are the results:

Area of 624 foot contour = 11,160,000 sq. ft.

Area of 620 foot contour = 8,172,000 sq. ft.

Area of 610 foot contour = 2,502,000 sq. ft.

Capacity between 624 and 620 foot contour = 38,664,000 cu.ft.

Capacity between 620 and 610 foot contour = 53,370,000 cu.ft.

Total ------- 92,034,000 cu.ft.

The water will flood Quarry Road, and this road, therefore, must be abandoned. But the Ashland Gravel Road will not be damaged.

DESIGN OF THE DAM.

A dam of standard dimensions for various heights was found in Wegmann. The height of the dam is 50 feet from foundation as shown by Plate 3 and the remaining dimensions were determined from this standard form, giving width at base equal to 33 feet, and width at top equal to 5 feet. This height of dam is 3 feet above high water mark, and 8 feet above top of spillway.

Drills had been sunk in ~~close~~ the vicinity of this site to a depth of 10 feet, and a gravel bottom was found. So the foundation or piers upon which the dam rests are to extend down a distance of 20 feet on the up-stream side, and 14 feet on the down-stream side, or until solid rock is encountered. The purpose of these piers is not only to insure a firm foundation, but also to guard against any water seeping under the dam and thus undermining it. As these piers or foundations are constructed under the spillway as well as under the dam proper, the entire structure may be said to rest upon a solid rock foundation.

The total length of main portion of dam is 390 feet ~~with~~ including the length of spillway 200 feet. The dam is constructed of cyclopean concrete with a mixture of 1:2½:5 and containing 15,660 cubic yards. There also being 8,632 cubic yards of concrete in the spillway, makes a total of 24,295 cubic yards, and costs $4.00 per cubic yard, or a total of $97,180.

DESIGN OF THE SPILLWAY.

The form of spillway to be used is known as the Plattsburg type. From "Water Supply Paper No. 200 of the U.S. Geological Survey" a form was found from which this spillway was designed.

As shown by the dimensions in Plate 4 the height equals 30 feet from creek bed with a slope on the upper face of 4 to 1, and a radius of crest equal to 3 feet. With this slope and curve, the overflow water will not leave the crest, but clings closely to the surface of the spillway. Built upon each end of the spillway is a wall 5 feet high and one foot thick which prevents the water from spilling over and undermining the dam.

The length of spillway was determined by the formula:

$$L = \frac{Q}{C H^{3/2}}$$

where Q is the quantity of discharge in cubic feet per second, C is the coefficient 3.52 taken from table in Water Supply Paper No. 200, and H. is the head, 5 feet.

In order to find the value of Q, discharge curves for Grindstone and Hinkson Creeks as ascertained by Hunter and Phillips were used. As these curves were made from data with reading of the guage equal to 5 feet, they had to be continued until a head of 10 feet was reached. Therefore multiplying value of mean velocity by

by value of sectional area, gives an approximate value of Q for a guage height of 10 feet. The Q for Kinkson Creek equals 5000 cubic feet per second, and for Grindstone Creek equals 2500 cubic feet, making a total 7500 cubic feet of water per second as the probable maximum flow over the spillway.

The spillway is constructed of cyclopean concrete, proportional parts 1:2½:5. Rip-rap was built on the lower edge of the spillway, forming a toe to insure against any washing under the foundation. And under the apron of the spillway which is 75 feet long, rip-rap was laid to a depth of 4½ feet. This gives a firm foundation and insures against any undermining which might be caused by seepage water. This design was modeled after the Granite Reef dam of the Salt River Project, U.S. Reclamation Service.

POWER DEVELOPED.

From the data collected the quantity of water available for power may be found in two ways:

(1) By taking the mean of the daily rainfall for the last ten years as shown by Plates 12 to 22, and multiplying by the runoff factor;

(2) By using the runoff from October 10,1908 to May 1, 1909 as found by Messrs. Hunter and Phillips in their thesis on "Rainfall and Runoff Data of Hinkson and Grindstone Creeks" and figuring the power on that basis.

The second method was chosen because of its simplicity and because of comparison with rainfall for the last ten years shown on Plates 12 to 22, it is seen that during the period from October 10, 1908 to May 1, 1909, the rainfall is just about what may be expected one year after another. Plate 12 shows the daily runoff. These data were obtained by taking the sum of the runoffs from the station at the Ashland Gravel Road Bridge on the Hinkson Creek and a similar one on the Grindstone Creek on the Ashland Gravel Road. This runoff is plotted on Plate 11.

From the bed of the creek to the top of the spillway is 30 feet. Therefore, allowing a 6 foot loss in draft tube, tail race, etc. the plant has a total available

head of 24 feet. Since the discharge is very small at times, the storage must be drawn upon for a good portion of the time. It is proposed to draw the level of the reservoir down 14 feet. Hence, the average head at the powerhouse will be 17 feet.

The next thing to be determined is the maximum quantity of water available in cubic feet per second. This is first figured on a 24 hour per day basis then converted into a 10 hour per day basis. By comparing the areas between the 21 cubic-feet-second line and the discharge curve, and the available storage area, all on Plate 11, it is seen that 21 cubic feet per second for 24 hours per day, or 50 cubic feet per second for ten hours per day can be used the first semester, September 15 to February 1. In a similar way, it is found that 50 cubic feet per second for 24 hours per day or 120 cubic feet per second for 10 hours per day can be used during the second semester, February 1 to June 1.

It is proposed to keep the power constant. Hence as the head decreases the quantity of water used must be increased.

$$H\,P = C\,\frac{QYH}{550}$$

Power Developed first semester $= .60\ \dfrac{50 \times 62.5 \times 17}{550} = 40$ H.P.

Power Developed second semester $= .70 \times \dfrac{120 \times 62.5 \times 17}{550} = 160$ H.P.

Hence if power is to remain constant and H and Q vary here, $QH = Constant$. The curve of this equation is a parabola. Two such curves were plotted , one on Plate 6 for the first semester, and one on Plate 7, for the second. With these curves, when the head is known, the Q required can be picked directly off the curve.

The power is worth $90.00 per horse power per year, 10 hour days.

Income first semester = 90 x 5/12 x 40 = $1,500.00

Income second semester = 90 x 5/12 x 160 = 6,000.00

Total ------ $7,500.00

GENERAL DETAILS.

The power house is to be built of concrete and constructed at the north end of the dam. It is 20 feet wide, being just large enough to contain the turbines and generators. The up-stream face of the dam forms the outer wall of the power house.

The turbines are designed for a head ranging from 24 to 10 feet and are of the ordinary low head reaction type. Two of these turbines are to be used with an auxiliary one which may be put into operation during low water. Cost of the turbine is $8.00 per horse power.

Between the power house and the spillway are two 6 x 8 foot sluice gates which may be raised and lowered during high water. These gates are to be hand operated, built in the dam and when opened will cause the silt and mud to be scoured away.

In the hills south of the dam site is a low ridge where the water would overflow from the reservoir during high water stage. The elevation of this ridge is at contour 628 and the high water level is at contour 629. So an earth embankment will here be built, 300 feet long and 5 feet high. The width of base is 30 feet and width of top is 10 feet. About 1200 cubic yards of earth will be required to make this fill, and at a cost

of 22 cents per cubic yard makes a total cost of $265.00

Approximate Cost of the Project.

Dam and Spillway, $4.00 per cu. yd. ---------	$ 97,180.00
Power House, $7.00 per cu. yd. ---------------	375.00
Turbines, $8.00 per horse power. -------------	1,280.00
Gates, $300.00 each. ------------------------	600.00
Earth fill, 22 cents per cu. yd. ------------	265.00
Property, $100.00 per Acre -----------------	26,000.00
Total -----------	$ 125,700.00

CONCLUSION.

The cost of the project is $125,000, and the income $7,500 per year. This is 6 % on the investment, which shows that the project is not a success financially. But since the plant is for educational purposes it can be made possible by special donations of appropriations.

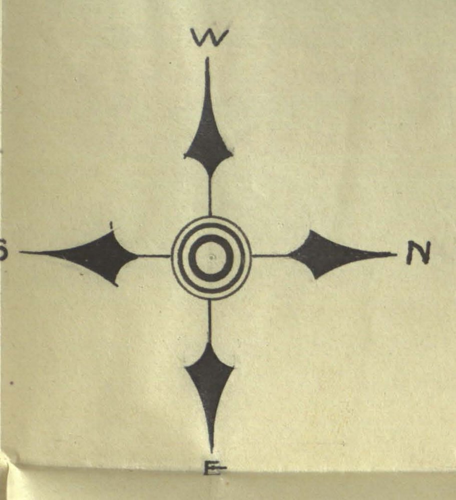
BIBLIOGRAPHY.

River Discharge by Hoyt and ~~Given~~ Grover.

Water Supply Paper No. 200.

Design and Construction of Masonry Dams.
Wegmann.

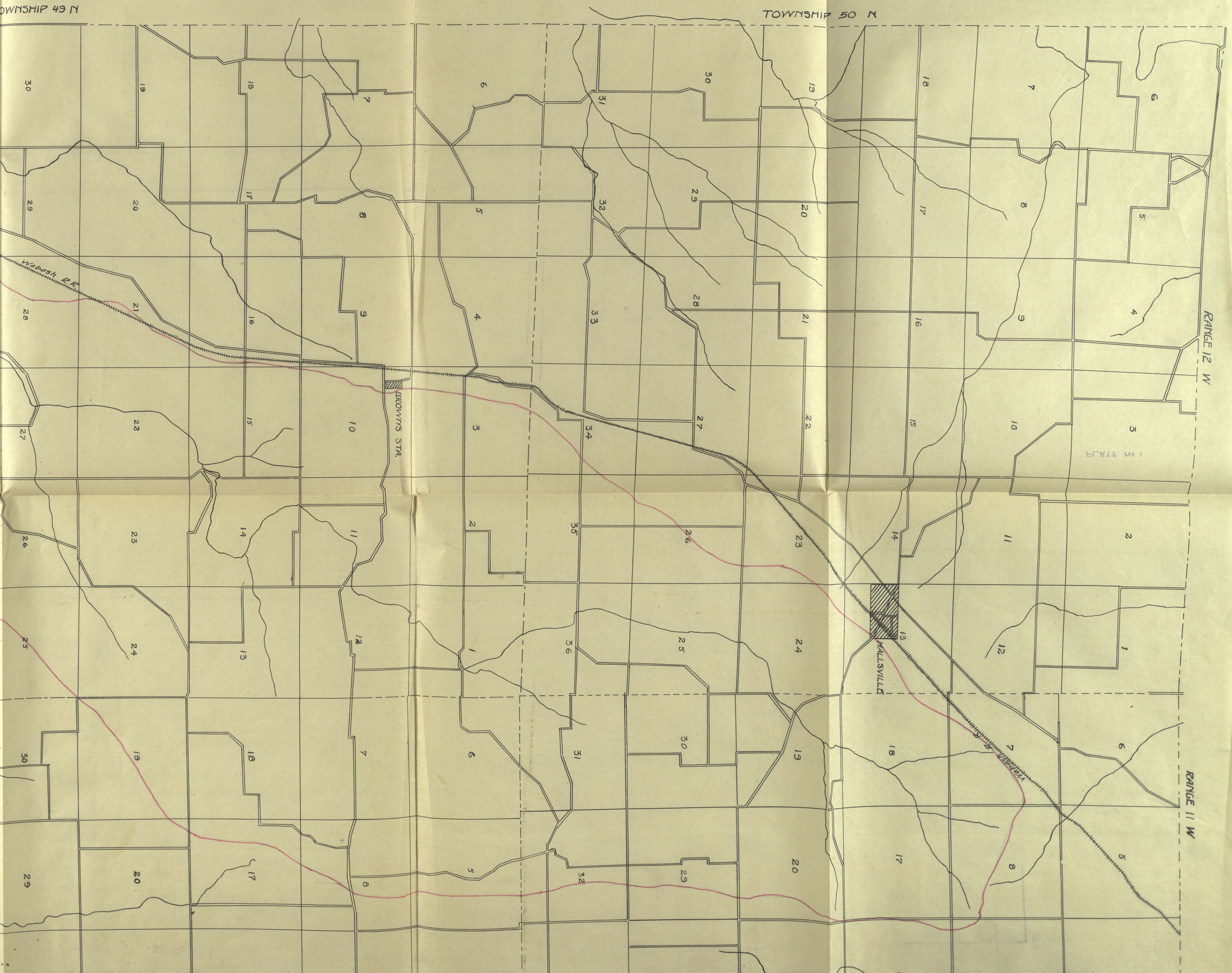

W
S
N
E
TOWNSHIP 48 N
TOWNSHIP 49 N
COLUMBIA
Grindstone Creek
Hinkston Creek
Hominy Branch
Wabash R.R.



MAP
SHOWING DRAINAGE
OF
HINKSON CREEK

Scale 2" = 1 Mile

Drainage Area = 61 Sq. Miles.




MAP
OF
RESERVOIR SITE
ON
HINKSON CREEK
Scale 1" = 300'
QUARRY ROAD
HINKSON CREEK
GRINDSTONE CREEK
ASHLAND GRAVEL ROAD
Dam Site
Fill
N
S
E
W
PLATE No 2

PLATE No 3

SECTION
OF
DAM
Scale 1" = 10'

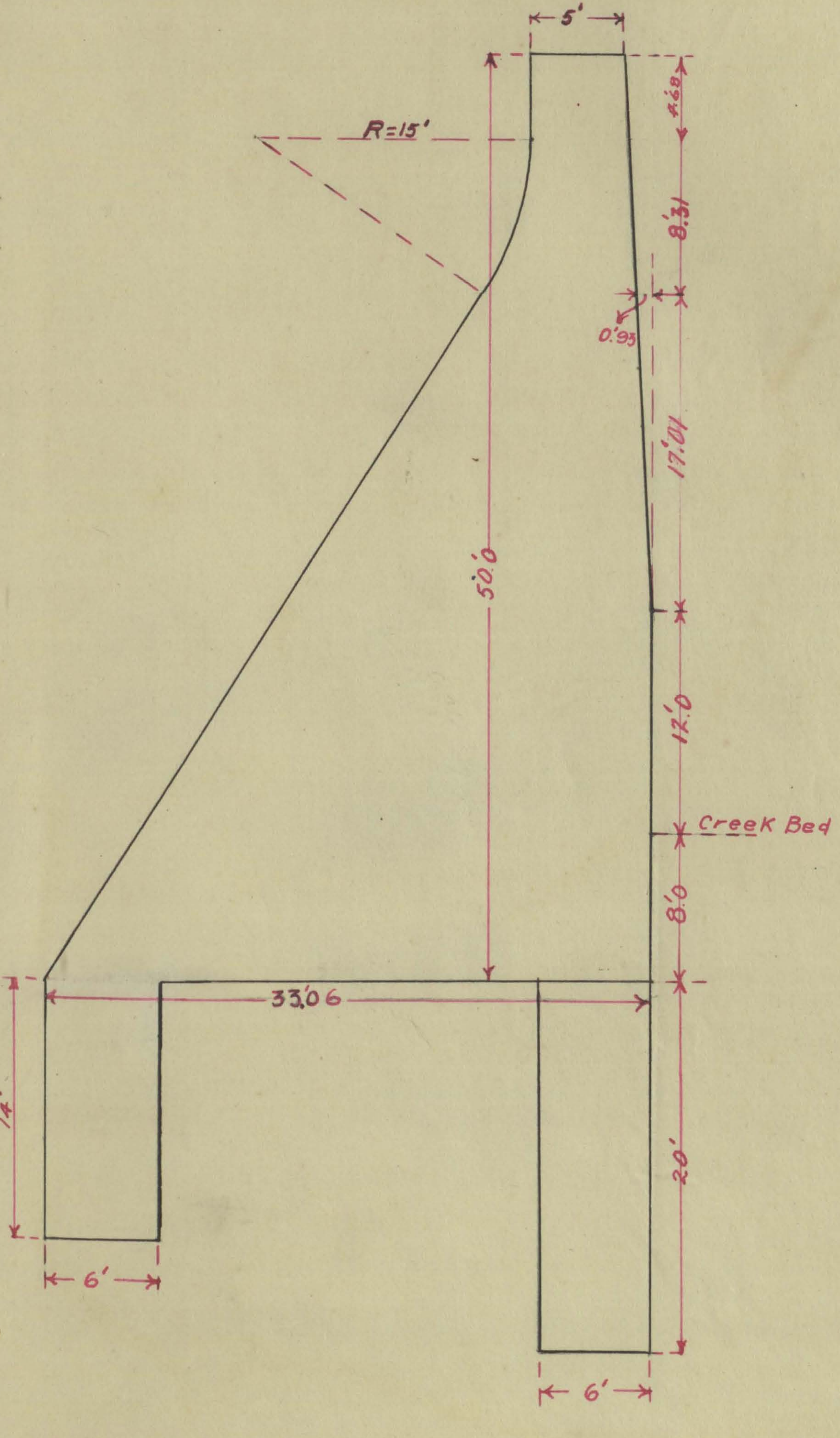


PLATE № 4

SECTION OF SPILLWAY

Scale 1"=20'

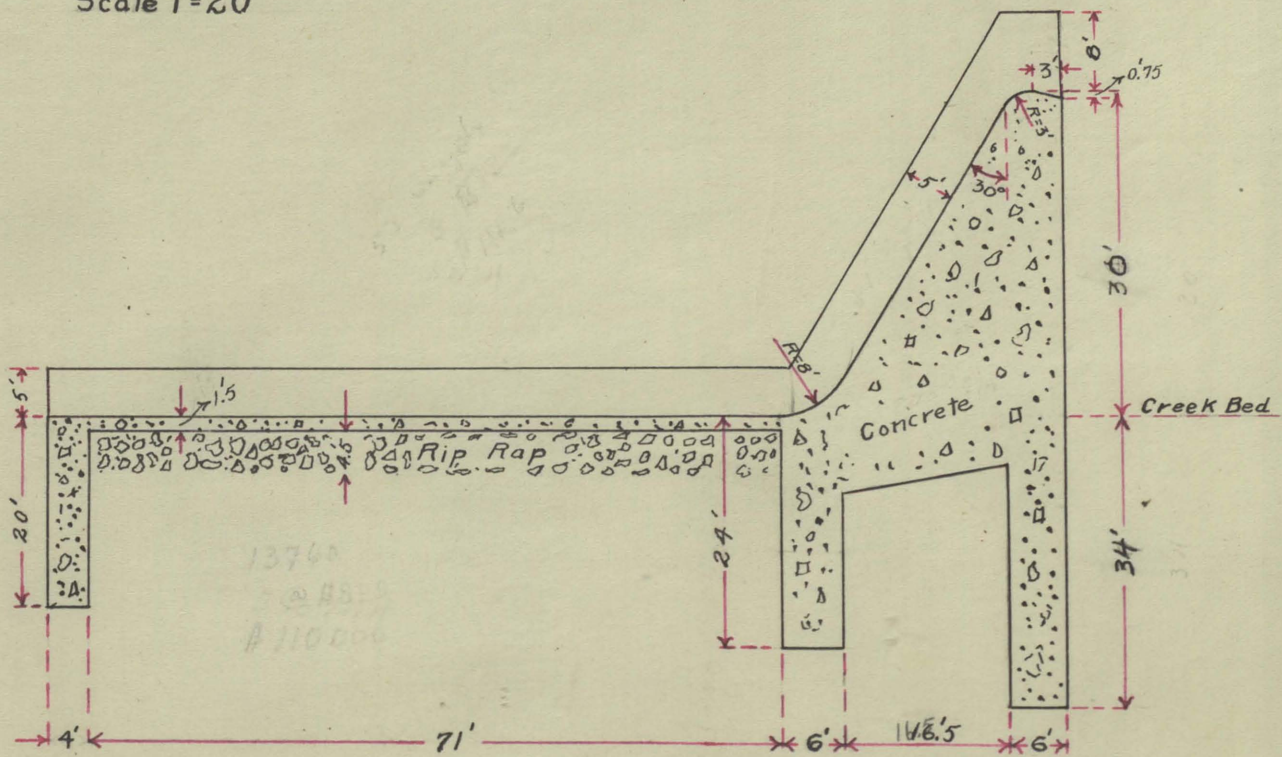
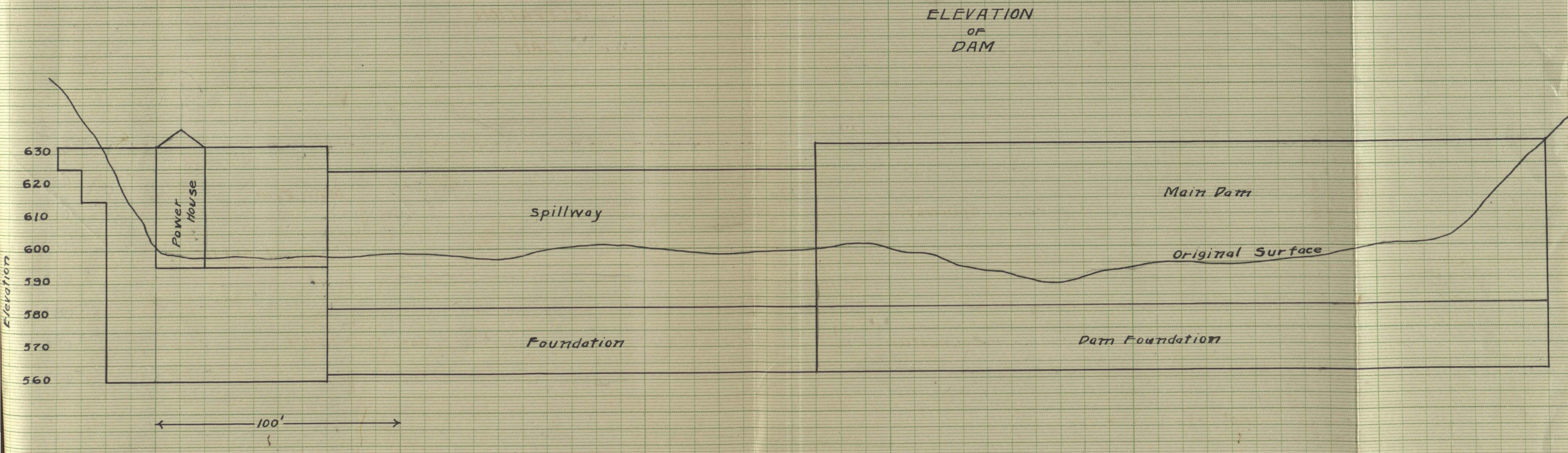


PLATE No 5



ELEVATION
OF
DAM
630
620
610
600
590
580
570
560
Elevation
Power House
Spillway
Foundation
Main Dam
Original Surface
Dam Foundation
100'

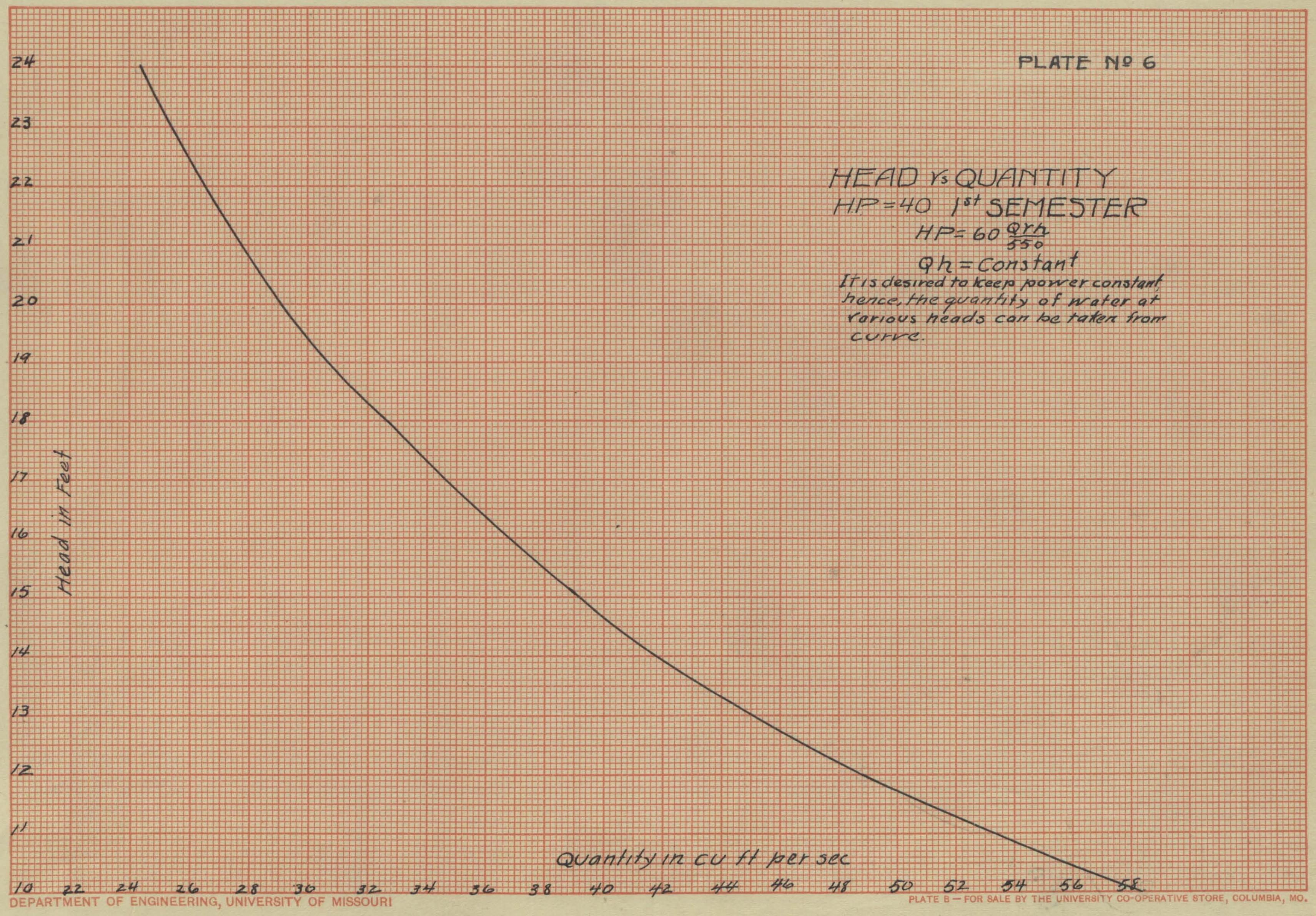


PLATE № 6
HEAD vs QUANTITY
HP=40 1st SEMESTER
HP= 60 Qrh/550
Qh = Constant
It is desired to keep power constant hence, the quantity of water at various heads can be taken from curve.
Head in Feet
Quantity in cu ft per sec
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
DEPARTMENT OF ENGINEERING, UNIVERSITY OF MISSOURI
PLATE B — FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

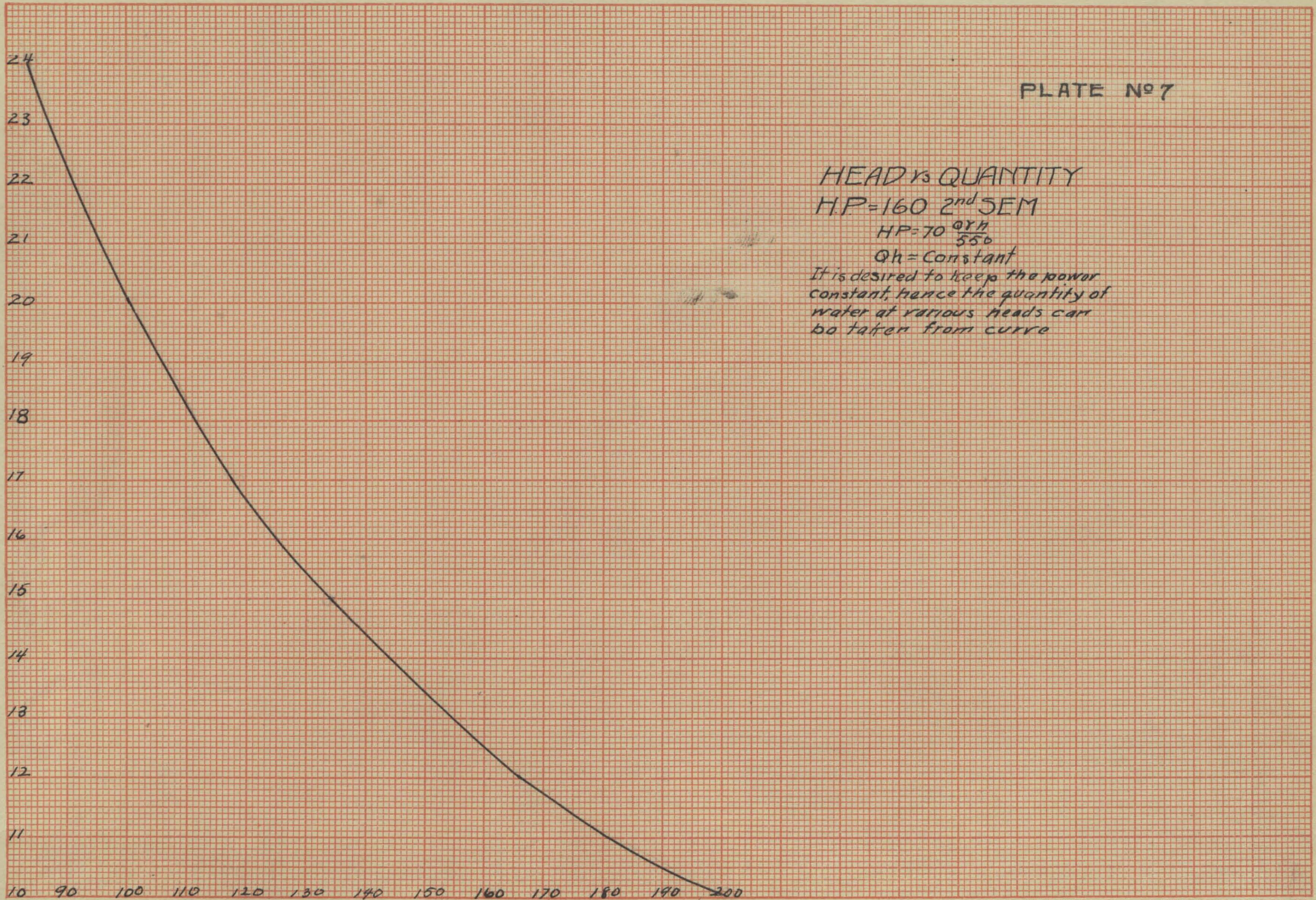


PLATE No 7
HEAD vs QUANTITY
H.P.=160 2nd SEM
HP=70 Qwh/550
Qh = Constant
It is desired to keep the power constant, hence the quantity of water at various heads can be taken from curve
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
90
100
110
120
130
140
150
160
170
180
190
200

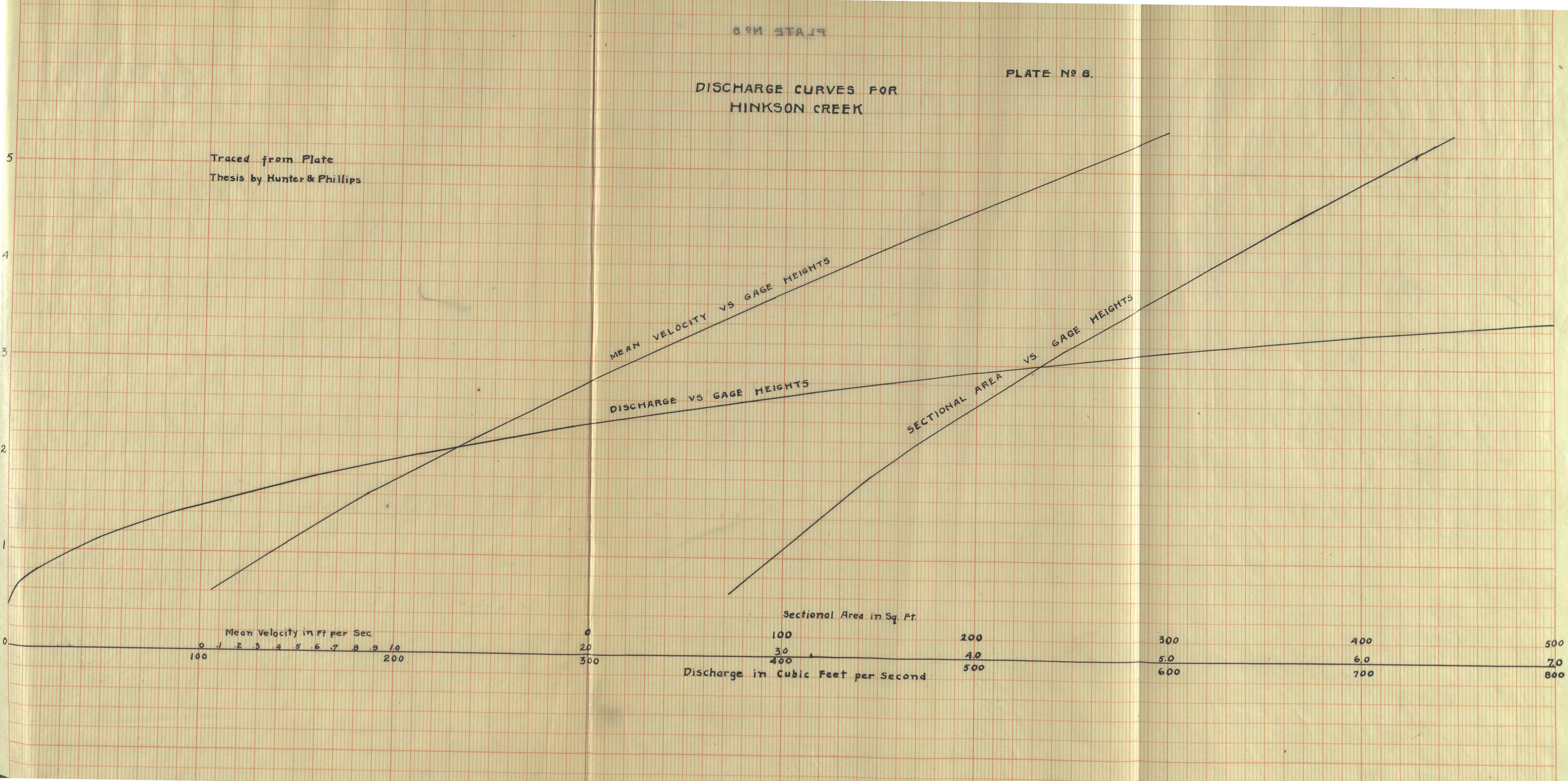


PLATE No 8.
DISCHARGE CURVES FOR
HINKSON CREEK
Traced from Plate
Thesis by Hunter & Phillips
MEAN VELOCITY VS GAGE HEIGHTS
DISCHARGE VS GAGE HEIGHTS
SECTIONAL AREA VS GAGE HEIGHTS
Sectional Area in Sq. Ft.
Mean Velocity in Ft per Sec.
Discharge in Cubic Feet per Second
0
1
2
3
4
5
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
100
200
0
100
200
300
400
500
2.0
3.0
4.0
5.0
6.0
7.0
300
400
500
600
700
800

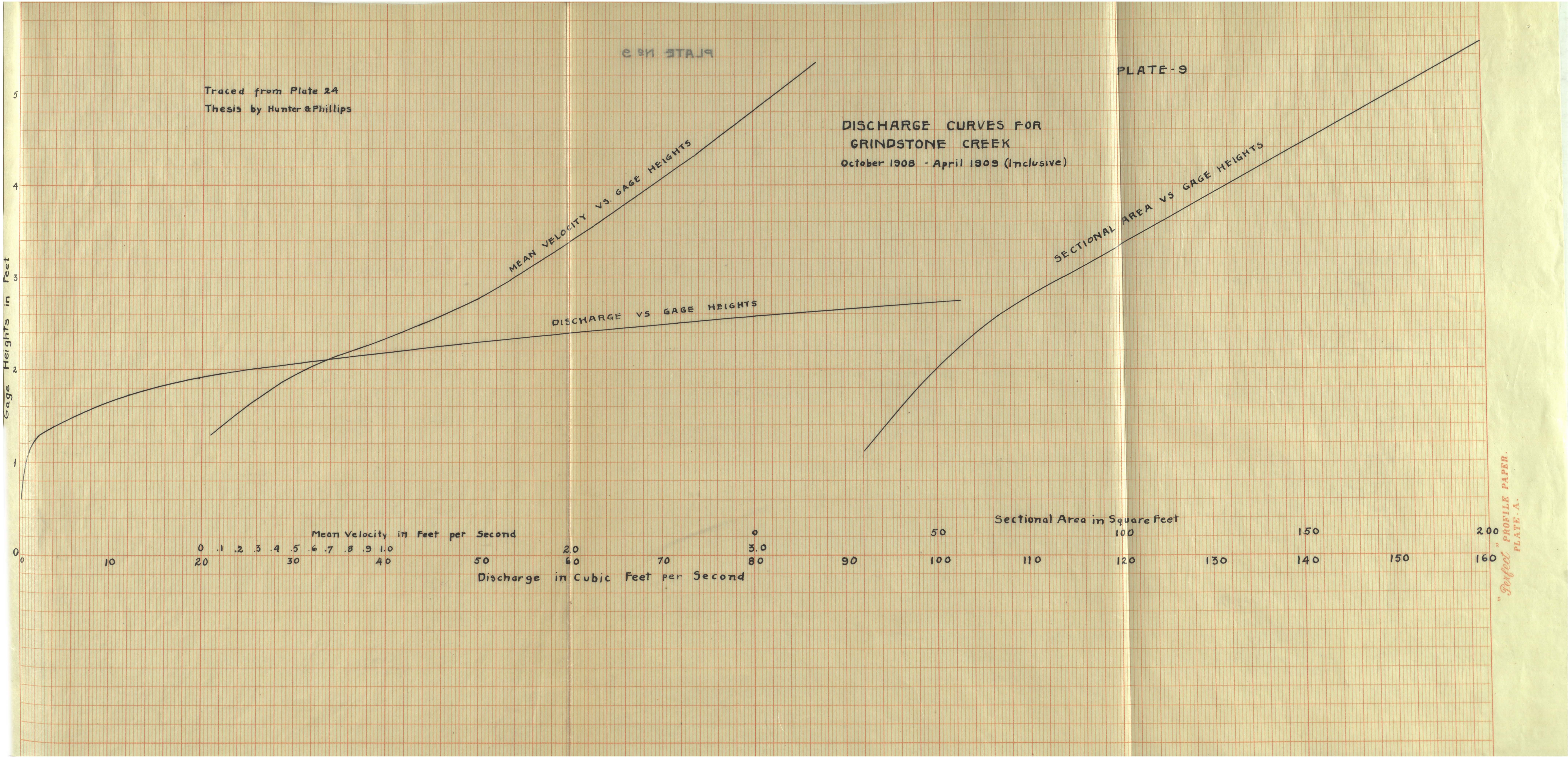


PLATE - 9
Traced from Plate 24
Thesis by Hunter & Phillips
DISCHARGE CURVES FOR
GRINDSTONE CREEK
October 1908 - April 1909 (Inclusive)
MEAN VELOCITY VS. GAGE HEIGHTS
DISCHARGE VS GAGE HEIGHTS
SECTIONAL AREA VS GAGE HEIGHTS
Gage Heights in Feet
0
1
2
3
4
5
Mean Velocity in Feet per Second
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
2.0
3.0
Sectional Area in Square Feet
0
50
100
150
200
Discharge in Cubic Feet per Second
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
"Perfect" PROFILE PAPER.
PLATE. A.

DAILY DISCHARGE AT DAM SITE
OCT 10, 1908 – MAY 1, 1909

PLATE Nº 10

	October	November	December	January	February	March	April
1		3.1	54.4	34.4	42.6	19.6	10.4
2		13.0	14.2	23.6	40.0	17.6	10.2
3		8.2	10.4	15.2	78.6	17.0	9.2
4		7.2	12.6	14.5	118.8	15.6	7.0
5		7.1	12.6	14.5	357.0	15.2	5.6
6		6.5	12.2	10.8	66.4	13.8	18.6
7		6.3	11.3	8.2	68.0	14.0	15.4
8		6.8	10.5	5.5	55.2	14.0	12.2
9		6.9	10.5	5.5	137.8	187.7	10.2
10	4.0	5.9	8.8	5.5	75.6	81.5	7.9
11	4.0	4.9	9.8	5.5	32.0	48.8	8.2
12	3.3	4.8	10.4	5.4	41.8	35.1	71.6
13	2.7	4.8	8.7	4.3	54.2	25.5	78.4
14	2.5	4.8	9.4	4.3	1232.0	20.8	43.7
15	2.3	4.8	7.4	4.2	93.4	18.1	24.0
16	1.6	4.8	7.4	4.2	88.2	17.0	15.2
17	1.5	4.8	7.4	4.1	89.1	15.0	13.0
18	2.1	4.8	5.8	3.5	104.8	14.0	10.5
19	2.2	4.8	5.6	2.8	305.8	11.9	166.4
20	2.3	4.8	5.1	8.8	128.2	10.8	132.8
21	2.5	4.8	5.0	26.0	130.8	9.8	752.0
22	2.3	4.8	4.9	24.8	95.8	9.8	213.0
23	1.8	25.2	4.9	27.2	378.6	10.6	48.6
24	5.2	64.6	4.9	23.4	128.0	11.8	41.8
25	13.8	120.0	4.9	17.8	57.7	15.8	24.0
26	14.5	58.6	4.8	12.4	40.4	18.9	18.6
27	4.8	23.2	4.8	49.6	32.7	23.0	17.1
28	4.7	14.4	4.8	942.0	24.0	11.7	12.8
29	4.5	92.4	4.8	160.0		10.5	10.2
30	4.5	104.4	4.8	97.0		10.0	18.0
31	4.3		57.2	57.2		9.9	
Total	91.4	631.0	340.2	1674.1	4209.2	754.8	1710.4

PLATE Nº 11

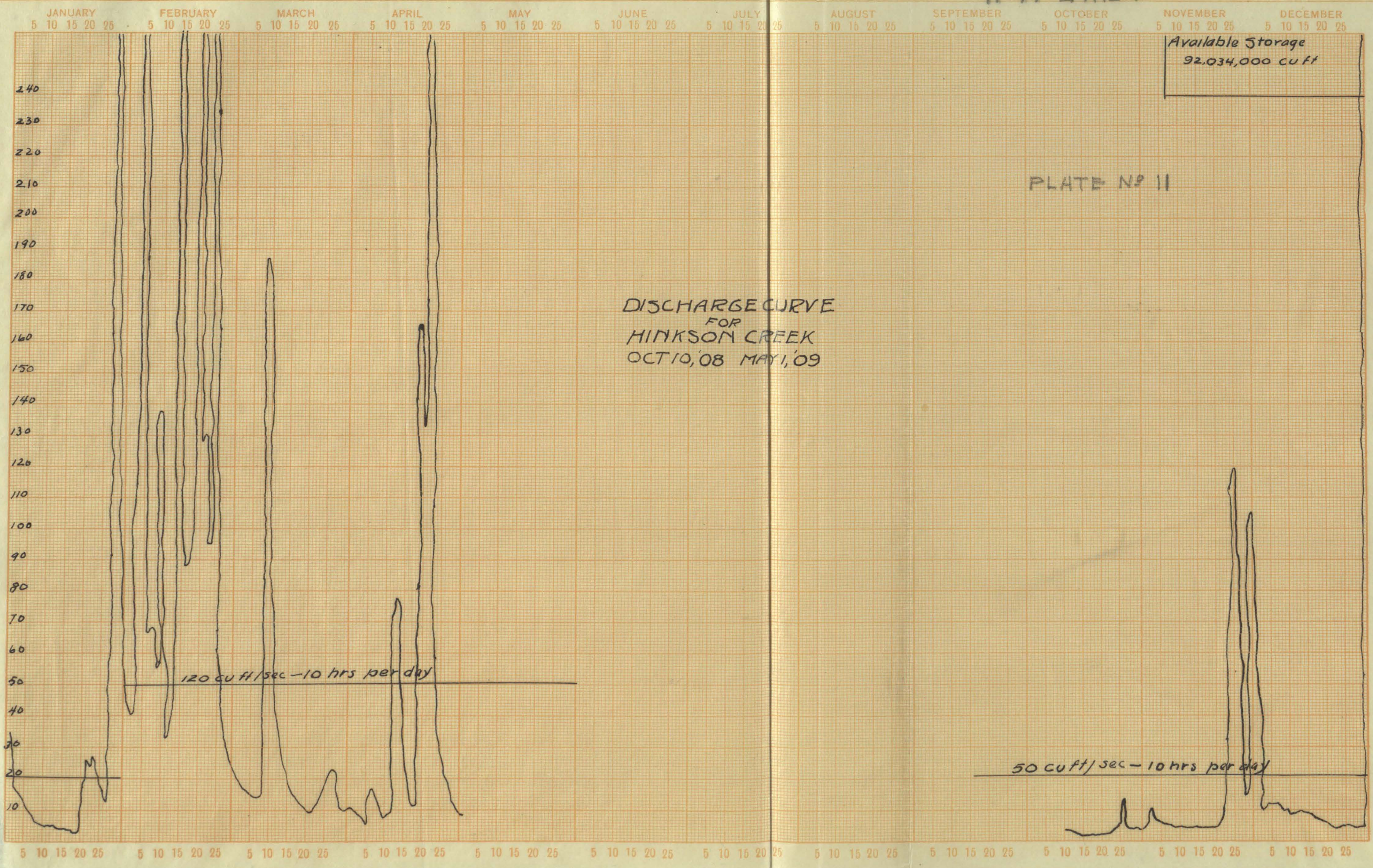

DISCHARGE CURVE
FOR
HINKSON CREEK
OCT 10, '08 MAY 1, '09
Available Storage
92.034,000 cu ft
120 cu ft/sec – 10 hrs per day
50 cu ft/sec – 10 hrs per day
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

PLATE No 12

Station: Columbia, Mo.

Data Daily Precipitation

~~190~~ 1898	January	February	March	April	May	June	July	August	September	October	November	December
1	0	0	0	T	1.06	.66	0	0	T	.03	0	.01
2	0	.02	T	.02	0	0	0	.05	0	T	0	0
3	0	0	0	.01	.37	0	0	.25	0	0	T	.03
4	0	T	0	.67	.25	1.05	0	0	.20	0	0	.02
5	0	0	0	0	.05	T	0	0	T	0	.54	0
6	0	0	0	0	.11	0	.07	0	1.08	0	0	T
7	0	0	0	0	0	1.02	.20	T	0	T	0	0
8	0	0	0	.07	0	.02	.28	0	0	0	.28	0
9	.66	1.01	0	0	.16	.16	0	0	0	.35	.29	0
10	0	0	.57	0	.25	T	0	0	0	.32	.10	0
11	.65	.08	.97	0	.02	.48	0	0	T	.02	0	0
12	.49	0	.34	.02	.09	.26	0	0	.60	0	0	.32
13	0	0	.06	.95	.13	0	0	.05	.49	0	.02	0
14	.16	0	0	.01	.41	0	0	0	0	0	0	0
15	.05	T	.17	0	1.40	3.18	0	0	.40	0	0	0
16	0	0	0	0	1.14	.55	0	.01	.01	.31	0	T
17	0	.08	0	T	T	0	.11	.08	.54	.60	0	T
18	0	.01	.74	.29	.35	0	0	T	0	.06	0	.09
19	.03	.64	.01	.01	.67	0	0	0	0	.11	0	.52
20	.50	T	T	0	T	0	2.21	0	0	.04	0	.01
21	T	T	.24	.10	.48	0	.25	0	1.60	.03	.97	T
22	.53	0	1.03	.20	0	.01	.01	0	.08	T	T	.52
23	.05	0	0	T	0	0	0	T	0	0	0	0
24	T	0	0	0	0	T	0	.03	0	T	0	0
25	.25	0	0	.04	0	.06	.70	0	0	.74	.02	T
26	T	0	.08	0	0	1.55	.21	0	0	0	.04	0
27	0	0	.14	0	.19	.02	0	0	.42	0	0	0
28	0	T	0	T	.03	0	.17	0	0	0	.02	0
29	T		0	0	1.23	0	.35	0	0	0	.01	0
30	T		.06	.37	0	0	.04	0	.01	0	T	0
31	0		0		0		T	0		0		0
Sums	3.37	1.84	4.41	2.76	8.39	9.02	4.60	0.47	5.43	2.61	2.29	1.52
MEANS												

P+H '09

PLATE Nº 13

Station: Columbia, Mo

Data Daily Precipitation

~~190~~ 1899	January	February	March	April	May.	June	July.	August	September	October	November	December
1	0	0	0	0	0	.90	0	0	0	0	0	0
2	0	T	0	.06	.11	0	.41	0	0	0	T	0
3	0	.03	0	.51	.10	0	.02	0	0	0	0	.06
4	.27	T	.35	.05	0	.15	.46	0	0	0	0	.04
5	0	0	T	0	T	0	0	.28	0	0	0	0
6	.05	.04	T	.11	.10	.09	.28	.43	0	0	0	0
7	0	0	0	T	.05	.67	.41	.21	.02	0	.09	0
8	.03	T	0	T	.04	.52	0	.20	.01	0	.02	0
9	0	0	0	0	.06	.54	0	.33	0	0	0	.23
10	0	.28	0	0	.81	0	0	.03	.96	.04	0	.25
11	0	.10	.37	0	0	0	0	0	0	T	0	.52
12	0	0	0	0	T	0	0	0	0	0	0	.10
13	.02	0	0	0	0	0	0.	1.32	0	0	T	.18
14	0	0	.61	0	0	.19	.07	T	0	0	.04	.30
15	0	0	.01	T	0	.28	.95	0	0	0	0	T
16	0	0	0	0	0	0	.13	0	0	.77	0	0
17	T	.01	.34	0	.33	0	0	0	2.42	0	.37	0
18	T	0	.45	.12	0	0	0	0	.02	0	0	.11
19	0	0	0	0	.12	0	0	0	0	.02	0	.02
20	0	0	0	.01	.90	0	0	T	0	0	.30	0
21	0	.06	0	.26	.60	0	T	0	0	0	.24	0
22	0	0	T	1.16	0	0	0	.36	.10	0	.16	.01
23	.17	.20	0	.06	0	0	0	0	0	0	T	.03
24	0	0	0	.06	0	.04	T	.03	0	0	0	.20
25	0	1.45	0	0	0	1.55	T	0	0	T	0	.07
26	T	.02	.02	0	.04	T	0	T	0	.72	0	T
27	0	0	.16	.14	.04	.02	0	.02	0	.88	0	.16
28	.10	0	.14	0	.27	0	0	0	.02	.30	0	0
29	0		0	0	.15	0	T	0	0	0	0	0
30	.07		.26	.07	.10	0	T	0	0	0	0	0
31	0		T		1.07		1.02	0		0		.01
SUMS	~~1.89~~	2.19	2.71	2.61	4.89	4.95	3.75	3.21	3.55	2.73	1.22	2.29
MEANS	0.71											

R.R. 09

PLATE No 14

Station: Columbia, Mo.

Data Daily Precipitation

1900	January	February	March	April	May	June	July	August	September	October	November	December
1	T	0	0	T	0	.15	.19	0	.29	0	T	0
2	0	0	0	0	.31	0	0	0	.51	0	0	0
3	0	.03	0	0	0	0	0	0	.15	0	0	0
4	0	.16	T	0	T	0	.07	0	0	0	0	T
5	01	T	.97	0	0	0	.11	0	0	0	0	0
6	.04	0	.18	0	.02	.08	0	0	0	0	0	.16
7	.02	.12	0	0	.16	1.19	0	0	0	2.03	0	.07
8	T	.38	0	T	0	0	.29	0	0	0	0	0
9	.03	0	0	0	0	0	0	0	0	0	0	0
10	.01	0	0	.81	0	.10	.11	0	0	0	.01	0
11	0	0	0	.40	0	0	0	0	T	0	.01	0
12	.03	.03	0	.03	0	T	T	T	0	0	0	0
13	0	.18	0	0	0	1.13	0	.40	0	0	0	0
14	0	.04	0	0	0	0	0	0	T	0	0	0
15	0	.01	.01	.33	.31	0	.14	T	0	0	0	0
16	.01	.01	.01	.30	.17	0	.03	0	T	0	.32	T
17	1.27	0	0	.14	.16	.16	.50	0	0	0	0	T
18	.01	0	0	0	.21	0	0	T	.10	0	.02	0
19	.03	0	.17	0	.02	0	T	T	.42	0	.23	0
20	0	.07	0	0	0	0	.35	0	0	0	.27	0
21	0	.74	0	.53	0	.05	0	.14	0	.89	T	0
22	0	.01	0	.06	.01	.23	0	.12	0	.22	T	.01
23	0	.29	.09	.28	.02	.94	T	.35	T	T	.32	.01
24	0	0	.03	T	.36	.64	.75	.09	.17	0	.06	.05
25	0	T	.05	.14	0	.09	.40	2.79	0	0	T	T
26	0	T	0	0	0	0	0	.10	.08	0	0	0
27	0	.86	0	0	0	T	0	.06	.36	T	0	.03
28	0	.93	T	0	T	.01	0	0	.91	2.90	0	T
29	0		0	T	T	0	T	0	.15	.38	0	0
30	0		T	0	T	.25	0	0	0	.28	0	0
31	0		0		0		0	T		1.03		.05
SUMS	1.46	3.76	1.51	3.02	1.75	5.02	2.94	4.05	3.14	7.73	1.24	0.38
MEANS												

P.H. '09

Station: Columbia, Mo.

Data Daily Precipitation.

1901	January.	February.	March.	April.	May.	June.	July.	August.	September	October.	November.	December
1	0	T	0	.17	0	0	T	0	0	0	0	.02
2	0	.26	0	.23	0	0	T	0	0	0	0	T
3	0	.94	0	T	0	.06	.27	0	0	0	.11	0
4	0	T	T	0	T	T	0	1.22	0	0	0	T
5	0	0	T	.48	T	T	0	T	0	T	0	.10
6	T	0	0	.03	T	.40	0	0	0	.01	0	0
7	0	.01	0	0	.03	0	0	0	0	0	0	.09
8	T	.26	0	0	.08	.22	0	0	T	.32	T	.68
9	1.97	T	.58	0	0	0	0	.12	T	.01	T	0
10	T	0	1.41	0	0	.19	0	.22	.04	0	0	0
11	.01	.11	0	T	T	0	0	T	.64	.01	.10	0
12	T	0	T	.12	0	.12	0	0	0	.65	0	T
13	0	0	T	.83	0	0	T	0	0	T	0	.97
14	0	0	.03	.03	0	0	0	.04	T	0	0	0
15	0	0	T	0	T	0	0	0	0	0	0	0
16	0	0	0	.23	T	0	.07	0	.10	T	0	.10
17	0	0	0	.26	T	0	1.36	.05	.14	0	0	T
18	.04	0	0	T	0	0	0	.02	0	0	0	.26
19	0	0	.69	0	.19	T	0	T	.21	0	0	0
20	0	T	.04	0	T	.22	0	T	T	0	0	0
21	0	.10	T	0	.05	T	0	0	0	0	.01	0
22	0	T	0	0	0	0	T	T	0	0	.58	0
23	.01	T	.21	T	T	0	0	T	0	0	T	0
24	0	0	.02	0	T	0	0	0	0	0	0	T
25	T	0	0	0	T	0	0	T	.21	0	0	.05
26	.29	0	0	0	0	0	T	0	T	.07	0	0
27	0	0	0	0	0	.02	.10	0	0	0	0	0
28	0	.11	0	0	0	0	.09	0	0	0	0	.02
29	T		.24	0	0	0	.30	0	.03	.06	0	0
30	0		.03	0	0	0	.55	0	0	0	0	0
31	0		0		0		0	0		.03		0
SUMS	2.32	1.79	3.25	2.38	0.35	1.23	2.74	1.67	1.37	1.16	0.80	2.29
MEANS												

PTH '09

PLATE № 16

Station: Columbia, Mo.

Data Daily Precipitation

1902	January	February	March.	April	May.	June.	July.	August.	September.	October.	November.	December.
1	0	.14	.02	0	0	2.91	2.30	0	0	0	T	0
2	0	T	.01	0	.04	0	0	0	0	.04	.07	.54
3	0	0	0	.62	0	T	0	.18	0	.69	0	.01
4	0	T	0	0	T	.38	0	0	0	.38	.44	T
5	0	.07	0	T	.17	T	0	.02	0	.13	.48	0
6	0	T	0	T	.85	.01	0	0	1.03	0	0	.07
7	0	0	.15	0	0	.02	.64	0	0	0	0	.01
8	0	0	.02	0	0	.33	0	T	.12	0	T	0
9	0	0	0	0	0	0	.70	0	.02	0	0	0
10	0	T	.03	0	0	0	0	1.01	0	0	T	.07
11	0	.08	.45	T	0	0	0	0	.22	0	T	.24
12	0	0	1.22	0	0	0	0	0	.01	.42	0	.15
13	0	0	0	0	0	0	0	0	0	0	.35	.02
14	0	T	0	T	T	T	0	0	0	0	.54	.42
15	0	0	.12	0	.19	.18	T	.11	0	0	0	.30
16	0	T	0	T	0	0	0	T	0	0	.08	T
17	0	T	T	T	0	T	0	0	.35	.84	0	0
18	0	0	0	T	0	.01	.06	3.15	.04	0	0	0
19	0	0	0	0	T	.02	3.25	.25	0	0	0	T
20	.30	0	.04	0	.01	.79	T	0	T	0	0	.30
21	.04	0	.14	0	T	0	0	T	.02	0	0	.02
22	0	0	0	.09	1.25	0	T	.16	.12	0	0	T
23	0	0	0	.0	.29	T	0	T	.12	0	0	0
24	T	0	T	.27	.79	.12	T	0	.32	0	.70	0
25	.55	0	T	1.09	.31	0	0	.24	T	T	0	0
26	T	.01	.37	T	.15	.12	T	.58	0	0	T	T
27	0	.41	0	.01	0	.18	.04	.80	.01	T	T	0
28	T	.19	T	.37	0	.87	T	0	0	.01	.19	.05
29	1.5		.44	.14	0	.62	0	0	0	.01	.04	T
30	T		.57	.83	T	T	0	0	.22	.01	0	0
31	T		0		.28		.67	.14		T		0
SUMS - -	1.04	.90	3.58	3.42	4.33	6.56	7.66	6.64	2.60	2.52	2.89	2.20
MEANS												

PTK 09

PLATE Nº 17

Station: Columbia, Mo.

Data Daily Precipitation

1903	January	February	March	April	May	June	July	August	September	October	November	December
1	0	T	0	0	0	.08	0	.05	0	0	.01	.01
2	.74	T	0	0	0	.20	T	.10	0	T	0	0
3	.02	1.78	.04	1.39	0	.06	.18	0	0	T	T	0
4	.07	T	.09	0	0	.09	.02	0	0	.01	.07	T
5	T	0	.19	0	.28	.06	0	.01	.10	0	T	0
6	0	0	.09	0	T	0	0	.65	0	.08	0	0
7	T	.02	1.60	.03	.01	0	0	.01	0	2.06	0	0
8	0	.01	T	0	0	T	0	.24	.11	0	0	T
9	0	0	T	0	T	.13	0	0	.15	0	0	.03
10	.03	.03	.14	.32	T	0	0	0	1.56	0	0	.11
11	.16	.09	T	.23	.33	0	.80	.07	0	0	.39	.01
12	0	0	0	T	.04	0	.01	.58	0	T	0	.38
13	0	T	0	.01	.23	0	0	.91	.80	T	0	0
14	0	.10	0	.06	.01	0	.01	0	1.00	.06	0	0
15	0	.49	T	T	0	0	0	0	.77	.06	0	0
16	.01	T	.44	.01	0	.01	.13	T	0	T	.10	0
17	T	0	0	0	.09	0	.03	0	0	0	0	0
18	0	T	T	.02	.03	0	.62	0	0	0	0	0
19	0	T	.49	.98	.13	.58	0	T	0	0	0	.22
20	.01	0	.20	.70	T	0	0	0	0	0	0	0
21	0	0	0	0	.37	.01	.53	0	0	0	0	0
22	0	0	0	0	0	.33	T	0	0	0	0	0
23	.68	0	.04	0	.05	0	.01	0	0	0	0	.03
24	.06	0	.04	.02	.04	0	0	T	0	0	.05	.08
25	0	0	0	0	1.96	.02	0	.24	0	0	.09	T
26	T	.08	0	0	T	.57	0	.88	.69	0	0	0
27	12	06	.06	0	.06	.02	0	.47	.02	0	0	0
28	T	T	.04	0	0	0	0	.88	0	0	0	0
29	T		0	.14	.24	0	.02	T	.02	0	T	0
30	0		0	.75	.28	0	0	0	.02	.13	T	0
31	0		0		1.11		T	0		.01		0
SUMS	1.90	2.66	3.46	4.66	5.26	2.16	2.36	5.09	5.24	2.41	0.71	0.87
MEANS												

P+H 09

PLATE No 18

Station: Columbia, Mo.

Data Daily Precipitation

1904	January	February	March.	April.	May	June	July.	August.	September	October	November	December
1	.03	T	0	0	0	0	0	.01	0	1.23	0	0
2	.17	0	0	0	0	T	0	0	.30	0	0	0
3	0	0	T	0	0	.73	0	0	0	0	0	T
4	.06	0	0	0	.49	1.73	.60	T	0	0	0	0
5	0	0	.13	.38	.05	0	.23	0	0	0	0	T
6	0	0	.12	.01	.88	0	.04	0	0	0	0	0
7	0	.25	0	.32	.06	0	.05	0	0	0	0	0
8	0	T	0	1.14	.33	0	.46	0	0	.05	0	0
9	T	T	0	T	T	0	0	T	0	0	.17	.05
10	.19	T	.06	0	0.	0	.59	.33	0	.01	.11	0
11	T	0	0	0	0	0	.25	0	0	0	0	.32
12	.25	0	0	0	0	0	0	0	0	0	0	.01
13	.01	0	.16	0	.32	0	0	.01	.40	0	0	T
14	0	0	T	0	0	.01	0	.02	.04	0	0	0
15	0	0	0	0	0	.81	0	0	0	0	0	0
16	0	T	T	0	.78	0	0	.92	0	0	0	.23
17	0	.60	.31	0	.01	T	0	0	0	0	0	.19
18	0	.03	0	0	.01	.58	T	.72	.13	0	0	.06
19	0	0	0	T	0	T	0	3.08	4.25	T	0	0
20	.42	.01	.01	.87	0	.38	0	.01	.36	0	0	0
21	.44	.12	.01	0	0	.24	0	.02	0	.07	0	0
22	T	0	.81	T	.04	0	T	.87	0	0	0	0
23	T	0	0	.50	.45	0	T	0	0	0	0	T
24	0	0	1.27	2.50	0	0	0	0	.31	0	0	.01
25	.40	.0	.05	1.52	T	.66	0	.09	0	0	0	.02
26	.03	0	0	.01	.83	.19	.18	0	0	0	0	.45
27	0	0	0	0	0	.22	T	0	0	0	0	.58
28	T	0	0	0	T	.01	0	0	0	0	0	.04
29	0	T	T	0	1.13	0	0	.07	0	0	0	0
30	.01		.11	0	.01	T	0	.01	0	0	0	0
31	.08		.65	0	0		.02	.01		0	0	0
SUMS	2.09	1.01	3.69	7.35	5.39	5.56	2.42	6.17	5.79	1.36	0.28	1.96
MEANS												

P+M 09

PLATE Nº 19

Station: Columbia, Mo.

Data Daily Precipitation

1905.	January.	February	March.	April	May.	June.	July.	August	September.	October.	November.	December.
1	T	.04	0	0	0	0	.08	0	0	.08	0	.04
2	.16	0	0	.05	0	0	1.50	.85	.06	0	T	0
3	0	.26	0	.02	0	0	.01	1.07	0	0	0	0
4	0	.10	0	0	.35	0	.07	0	0	0	.49	0
5	0	.54	0	T	.34	0	T	0	.06	0	.29	0
6	.02	0	T	0	.10	0	.46	.19	.54	0	T	0
7	.05	0	.01	0	0	0	.20	0	.07	0	0	0
8	.16	.56	.07	0	.20	0	0	0	0	0	0	0
9	0	0	0	.04	.23	0	.31	0	1.12	.06	0	0
10	.32	0	0	.22	0	.10	.80	0	.12	.02	0	0
11	1.13	.10	0	0	1.46	0	.19	0	0	0	0	0
12	0	.04	0	0	0	0	0	0	.01	0	0	0
13	0	0	0	0	.89	0	0	.13	0	0	0	0
14	T	.05	0	0	0	0	0	.89	.24	.56	0	0
15	0	0	0	.02	.41	0	0	0	1.20	0	0	0
16	0	.09	T	0	.27	0	0	.06	5.98	1.49	0	0
17	0	0	.25	0	0	0	0	0	.40	1.72	0	0
18	.09	0	.24	0	0	T	0	1.12	1.73	.60	.13	0
19	0	.02	.01	0	0	.61	0	.10	0	.06	.11	0
20	0	0	T	.15	0	.57	.23	0	0	0	0	.38
21	0	0	0	0	0	0	0	0	0	0	0	T
22	0	0	0	0	T	0	0	2.44	0	0	0	T
23	0	0	.19	.01	0	0	0	T	0	.31	.27	T
24	.04	.11	0	.49	0	0	0	0	0	.67	0	0
25	0	0	T	.61	.17	0	0	0	0	.07	0	0
26	0	0	0	.14	0	.06	.10	0	0	0	0	0
27	0	0	.03	.16	0	0	.10	.06	0	T	.11	.02
28	T	0	.11	.74	.03	0	0	0	0	.04	0	.52
29	T		.01	0	.08	1.15	0	0	0	.04	T	0
30	T		0	0	T	1.34	T	0	.01	.61	0	0
31	0		0		0		0	0		T		.03
SUMS	1.97	1.91	0.92	2.65	4.53	3.83	4.05	6.91	11.54	6.33	1.40	0.99
MEANS												

Pr M'09

PLATE № 20.

Station: Columbia, Mo.

Data Daily Precipitation

1906	January.	February	March.	April	May.	June	July	August	September	October	November	December
1	0	0	0	0	.18	0	.10	T	.04	0	0	.12
2	1.05	0	.21	0	.01	0	.24	0	.36	0	0	.03
3	1.15	0	.02	.01	0	T	.02	0	0	.01	0	0
4	0	.10	T	.21	0	.04	T	0	T	0	0	09
5	0	0	0	.32	T	0	0	.76	0	.01	0	.15
6	0	T	.25	0	0	0	0	.55	0	0	0	0
7	.02	0	.02	.01	0	1.23	0	.65	.32	0	T	0
8	0	0	T	.21	0	.14	T	0	.75	0	0	0
9	0	0	0	0	0	0	T	.14	0	0	0	.16
10	.05	0	.15	0	0	0	0	0	T	0	0	.01
11	.03	0	.12	0	0	0	0	.14	T	0	0	0
12	0	0	.03	01	T	0	T	T	T	0	0	0
13	0	.59	.10	.81	0	0	.03	0	0	0	.16	0
14	0	.02	.05	T	0	.02	0	0	0	0	.27	.22
15	.10	0	T	0	T	0	.08	0	0	.04	0	0
16	0	0	.04	0	0	0	0	0	0	.01	.29	0
17	0	.07	0	0	0	.14	0	0	0	T	0	0
18	0	0	.50	0	.63	.14	0	T	0	0	0	0
19	0	0	.30	0	0	.02	.09	T	T	0	.45	0
20	0	.81	0	0	0	.04	.01	0	0	T	.53	.05
21	.10	0	0	0	0	0	0	.01	48	0	.48	0
22	.44	0	0	0	.18	T	.70	0	0	0	0	0
23	0	.54	.52	.06	.18	.76	0	0	0	.33	0	0
24	0	T	0	0	.03	.78	0	T	0	0	0	T
25	0	0	.01	0	.20	0	0	.67	0	0	.01	0
26	0	.43	.51	0	.02	0	0	.02	0	0	0	.01
27	0	0	.0	.24	T	0	0	0	0	T	0	.01
28	0	0	0	0	0	0	.06	0	2.23	0	0	0
29	0		0	0	0	.72	0	0	.62	0	.07	.25
30	0		0	.08	.68	.18	0	0	0	T	.67	.50
31	0		0		.62		0	0		0		0
SUMS	3.94	2.56	2.83	1.96	2.73	4.21	1.33	2.94	4.80	0.40	2.93	1.60
MEANS												

P.Y.H. '09

Station: Columbia, Mo.

Data Daily Precipitation

1907	January	February	March	April	May	June.	July.	August	September	October.	November	December
1	.01	0	.31	0	0	.01	.23	.28	0	.10	.09	0
2	.05	0	0	0	0	0	0	0	.09	T	0	0
3	.06	.10	0	.38	.46	.01	0	0	0	.89	0	0
4	0	.11	0	.03	0	0	0	.04	0	0	0	0
5	0	.04	0	0	.40	0	0	.25	0	0	0	0
6	0	.02	T	.31	.21	.01	0	T	0	0	0	0
7	.05	0	0	.27	.01	.55	0	0	0	T	0	T
8	T	0	0	.01	.25	0	0	.56	0	0	0	0
9	0	0	.63	0	0	.54	.01	0	T	0	0	T
10	0	0	.01	0	0	0	T	0	0	0	T	0
11	.03	0	.23	.13	0	.24	.08	0	0	0	T	0
12	0	0	.41	0	0	.01	0	0	0	0	0	0
13	.02	0	.09	0	.01	0	0	.01	0	0	0	.18
14	.20	0	0	0	2.22	1.59	1.35	.05	0	0	0	.11
15	1.00	0	0	.05	0	0	1.26	.08	0	.13	0	0
16	1.55	0	0	T	0	0	.13	.56	0	0	0	0
17	.06	0	0	0	.01	0	.11	.05	0	0	0	.08
18	1.20	0	0	.15	T	0	.31	.01	0	0	0	0
19	1.03	0	0	0	.40	.24	0	1.18	0	0	0	0
20	0	.13	0	0	T	.01	0	.14	.33	0	1.10	0
21	0	0	0	0	0	.13	0	.0	0	0	0	0
22	0	0	0	.24	0	.39	0	T	0	0	0	.58
23	0	.16	T	.48	0	.02	0	T	0	0	0	.31
24	T	0	0	T	0	T	0	0	0	0	0	0
25	0	0	0	.01	0	.94	.06	0	0	.27	T	0
26	.02	.01	.05	0	T	0	.17	0	.26	.63	0	0
27	.05	0	.30	0	0	T	.02	.27	.13	0	0	0
28	0	T	.95	0	T	0	1.41	0	0	0	0	0
29	0		.01	1.76	T	.07	0	0	.08	.04	0	0
30	.08		0	.03	.05	.10	0	0	.04	.10	0	0
31	.24		0		.03		.29	0		0		0
SUMS	5.65	0.57	2.99	3.85	4.05	5.04	5.49	3.48	1.01	2.16	1.19	1.26
MEANS												

P.H.H. '09

PLATE Nº 22.

Station: Columbia, Mo.

Data Daily Precipitation

1908	January	February	March	April	May	June	July	August	September	October	November	December
1	0	.05	0	T	0	T	.01	0	.04	0	1.09	0
2	0	0	0	0	0	.37	.06	0	0	0	.01	0
3	.27	0	T	0	.37	1.72	0	0	0	0	0	T
4	0	.36	.44	.64	.54	0	0	0	.10	0	0	.32
5	0	.25	0	T	.87	.37	0	.18	0	0	0	0
6	0	0	0	.01	.02	.01	.53	1.30	0	.01	0	0
7	0	0	.10	.66	0	.13	0	.36	0	T	0	0
8	0	0	.74	.67	0	.59	0	0	0	0	0	0
9	0	0	0	T	0	0	0	0	0	0	.20	0
10	0	T	0	.05	0	0	0	0	0	0	.01	0
11	.30	.15	.05	0	.01	0	0	.08	0	0	T	0
12	.28	.31	0	0	0	.28	0	.12	0	0	0	0
13	0	.20	0	0	.51	.63	0	0	0	0	T	0
14	0	.92	0	.53	.04	.01	T	0	0	0	.07	0
15	T	.16	0	.90	0	0	0	0	0	0	0	0
16	0	0	0	0	0	.01	.01	0	T	0	0	0
17	0	0	0	.14	.75	.02	.36	0	0	0	0	T
18	0	1.04	.09	0	.05	0	0	0	0	0	0	0
19	0	.07	0	0	0	.24	0	.36	0	0	0	0
20	0	0	0	0	0	0	.37	0	0	.02	0	0
21	0	0	0	0	.75	0	0	0	0	0	0	0
22	0	0	0	T	0	0	0	0	.62	T	.58	0
23	0	0	0	.32	.24	1.14	0	0	.06	.20	.62	0
24	T	.47	0	.12	0	0	1.55	.31	0	.63	.02	0
25	0	.04	0	T	.66	0	0	0	0	T	.50	0
26	0	.04	0	.22	0	0	0	T	1.73	.04	0	0
27	0	0	.06	T	.29	0	.08	0	.42	.01	.02	0
28	0	0	0	0	1.03	.08	0	2.03	.02	0	.06	0
29	0	0	0	0	.04	.92	0	0	0	0	.62	.91
30	0		.31	T	0	0	0	0	0	0	0	0
31	.28		0		0		T	0		0		0
SUMS	1.13	4.06	1.79	4.26	6.17	6.52	2.97	4.74	2.99	.91	3.80	1.23
MEANS												

P+K '09

PLATE Nº 23

Station: Columbia, Mo.

Data Daily Precipitation

1909	January	February	March	April	May	June	July	August	September	October	November	December
1	0	0	0	.03								
2	T	0	0	.01								
3	0	0	0	0								
4	.03	T	0	0								
5	0	.21	0	.01								
6	0	.09	0	.60								
7	0	0	.20	0								
8	0	.34	.75	0								
9	.03	T	.04	0								
10	.18	T	0	0								
11	.51	0	0	0								
12	0	.34	.03	.91								
13	0	.40	0	0								
14	0	.49	0	.01								
15	0	.54	T	0								
16	T	.07	0	0								
17	0	0	0	.03								
18	0	.13	.13	.48								
19	T	T	T	.25								
20	T	0	T	.68								
21	0	0	0	.07								
22	0	.24	0	0								
23	0	0	.08	0								
24	0	.02	.44	0								
25	.04	0	T	0								
26	0	0	0	0								
27	0	0	0	0								
28	1.16	0	0	.02								
29	.53		0	.25								
30	0		0	T								
31	0		0									
SUMS	2.48	2.87	1.67	3.35								
MEANS												

P+M 09