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CHARLES D. WALCOTT, DIRECTOR

PHYSICAL CHARACTERISTICS OF KERN RIVER, CALIFORNIA

BY

FRANK H OLMSTED

AND

RECONNAISSANCE OF YUBA RIVER, CALIFORNIA

BY

MARSDEN MANSON

WASHINGTON

GOVERNMENT PRINTING OFFICE

1901

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., March 6, 1901.

SIR: I have the honor to transmit herewith two manuscripts for publication together in the series of papers upon water supply and irrigation.

The first manuscript is by Mr. Frank H. Olmsted, a civil engineer of southern California, and relates to the physical characteristics of the catchment area of Kern River, California. In this paper the author describes the drainage basin and estimates the amount of water coming from it and the power available from a complete utilization of the various portions of the stream. He also discusses the utilization of this power in pumping for irrigation.

The ultimate development of a considerable portion of the arid region depends not only upon complete storage and control of the streams, but upon the largest possible use of the power which may be generated in the upper or steeper portions of the channel and transmitted electrically out upon the plains, to be used in bringing to the surface the moisture which has sunk below the reach of the roots of the plants. By this means the area of cultivation can be greatly extended; and, as shown by Mr. Olmsted, the cost of pumping this water and applying it to the soil may, under favorable conditions, be less than that of obtaining a supply by gravity.

In earlier pamphlets of this series of Water-Supply Papers the utilization of wind power for this purpose has been discussed, the efficiency of the windmill has been described, and the advantages due to the small cost and independent construction of each mill have been shown. Where, however, it is practicable to obtain electric power at small cost, pumping plants operated by electricity can be widely distributed and may have certain advantages over the windmill. It is therefore important, in any discussion of the method of utilizing the water resources, to bring to public attention the possible developments along this line.

The second manuscript presented herewith has been prepared by Dr. Marsden Manson, and relates to Yuba River, a tributary of the Sacramento. Dr. Manson discusses the physical conditions and storage possibilities of this stream, bringing out particularly the importance of preserving the forest cover on the upper catchment basin, and, if possible, increasing this by artificial means; and shows by estimates the possible increase of available water through complete afforestation of the area. The relation of forests to river flow is believed to be of great importance, and is a matter upon which precise data are needed. It is hoped that as the systematic river measurements continue it will be possible to state more and more definitely the precise relation which the forest cover bears to the behavior of the stream.

The protection of the forests by the creation of reservations and the conservation of the waters through reservoirs constructed within these various reservations are of such vital importance to the utilization of the arid lands of the West, both by direct irrigation and by the creation of power for pumping water, that all matters pertaining to these subjects have interest to the citizens of the country as the great landowners.

It is for these reasons that these manuscripts are presented as contributions to a larger knowledge of the subject.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

PHYSICAL CHARACTERISTICS OF KERN RIVER, CALIFORNIA, WITH SPECIAL REFERENCE TO ELECTRIC POWER DEVELOPMENT.

By Frank H. Olmsted.

INTRODUCTION.

The development of southern California has been retarded by three factors which are still operative: (1) Distance from the world's markets and commercial centers; (2) shortage of water; (3) lack of cheap fuel and power. Volumes might be written in regard to the relation which the development of water in southern California bears to the progress of the people, but broadly stated it may be said that the real development of this section will be defined and limited by the amount of water available for irrigation from San Diego to Santa Barbara and from San Pedro to the desert on the east. Regarding cheap fuel and power, neither Los Angeles, the commercial center of this section, nor any other place in southern California has had it, and even now, when it is reasonable to suppose that the local oil industry is at its best, the price of oil is approaching $1 a barrel of 42 gallons; or, expressed differently, the cost of oil as fuel is equal to bituminous coal at $4 a ton. During the last five years Los Angeles has had an industrial awakening corresponding to this decrease in the cost of fuel from $7 or $8 a ton to $4 a ton.

During the first year of its advent in the Los Angeles market the cost of oil ranged between $0.40 and $1 a barrel. Most of the users of coal at that time found it economical to change their grates to oil burners, but since 1896 the tendency of the oil market has been upward, until now the cost of oil is $0.75 to $1 a barrel. At $1.50 a barrel oil as fuel is no cheaper than Gallup coal at $7 a ton, except that usually the oil feeder is arranged so as not to require an attendant, thus saving the wages of a stoker. In carload lots, the cost of Wellington bituminous coals is about $1 a ton more than the Eastern lignites; and, limited as the output has been, at present it virtually controls the Los Angeles market. During at least half of the year the demand in Los Angeles is so near the greatest available supply that outside orders for coal are not sought. The oil supply has contributed to the industrial advancement of southern California, and there are many reasons for believing that with cheap electric power

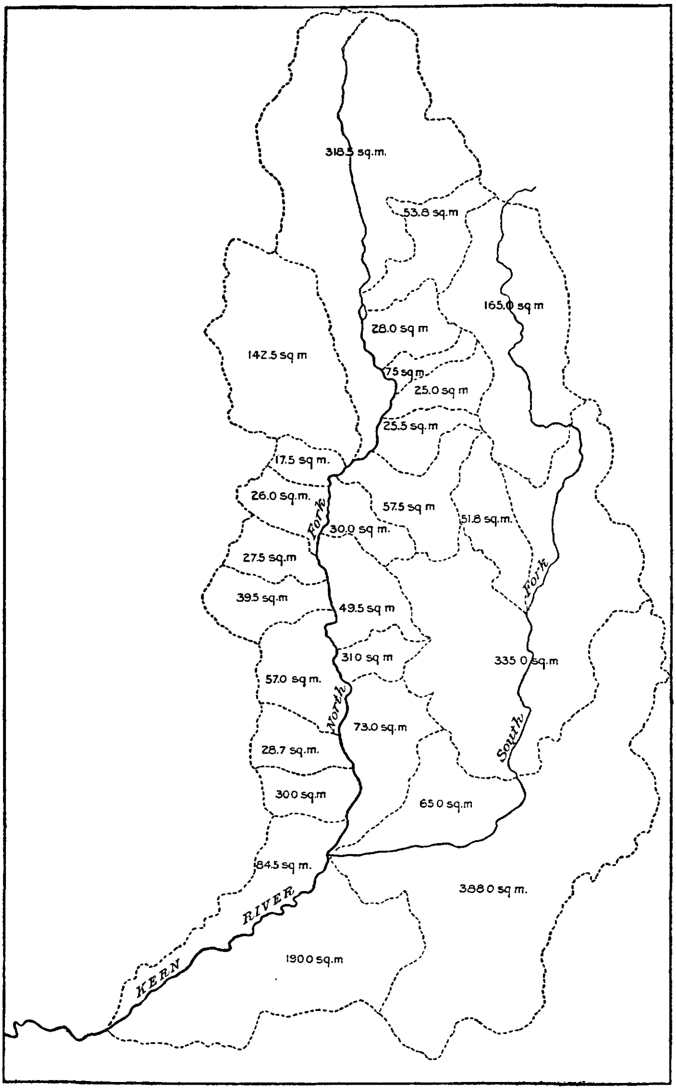


FIG. 1.—Map showing minor drainage basins of upper Kern River.

the manufactures and industries of southern California in general, and of the city of Los Angeles in particular, would quickly respond, and that their growth would be upon a safer foundation and a broader basis. The future outlook does not, however, warrant the hope for much better fuel rates, even with the construction of the

Salt Lake Railroad assured; but there is good reason to expect cheaper power, and if this expectation is realized, the greater part of the power must come from Kern River.

PHYSICAL FEATURES.

Kern River rises on the western slope of the Sierra Nevada, the greatest mountain range in the United States. For a distance of 100 miles the average elevation of this crest line is more than 11,000 feet above the sea, and so great is the run-off that within the first 15 miles of its course the river receives 80 per cent of its total summer flow at the mouth of its canyon 100 miles away. The drainage area of the stream above the latter point is 2,349.3 square miles. Fig. 1 is a map showing the distribution of this drainage area, the minor drainage basins being outlined and their respective areas given. The following tables give the names and the respective areas of these minor drainage basins:

Areas of minor drainage basins of North Fork of Kern River.

	Square miles.
Headwaters	318.5
Whitney Creek	53.8
Small Creek	28.0
Ninemile Creek	7.5
Menache Creek	25.0
Trout Meadow Creek	25.5
Harris Creek	57.5
Tibbetts Creek	30.0
Brush Creek	49.5
Salmon Creek	31.0
Corral and other creeks	75.0
Little Kern River	142.5
Needles Creek	17.5
Clark Creek	26.0
Jackson Creek	27.5
Wade Creek	39.5
Tobias and other creeks	57.0
Bull Run Creek	28.7
Tilly Creek	30.0
Total to junction of South Fork	1,070.0

Areas of minor drainage basins of South Fork of Kern River.

	Square miles.
Headwaters	165.0
Fish Creek	51.8
Middle tributaries	335.0
Lower tributaries from north	65.0
Lower tributaries from south	388.0
Total to junction with North Fork	1,004.8

Drainage areas of Kern River.

	Square miles.
North Fork	1,070.0
South Fork	1,004.8
Tributaries from north side after junction	84.5
Tributaries from south side after junction	190.0
Total	2,349.3

The length of Kern River from King River summit, on its main fork, to the mouth of the canyon above Bakersfield is 118 miles. The channel is in granite, and, with the exception of a few drops in the lower reaches of the stream, the grades are fairly uniform. In

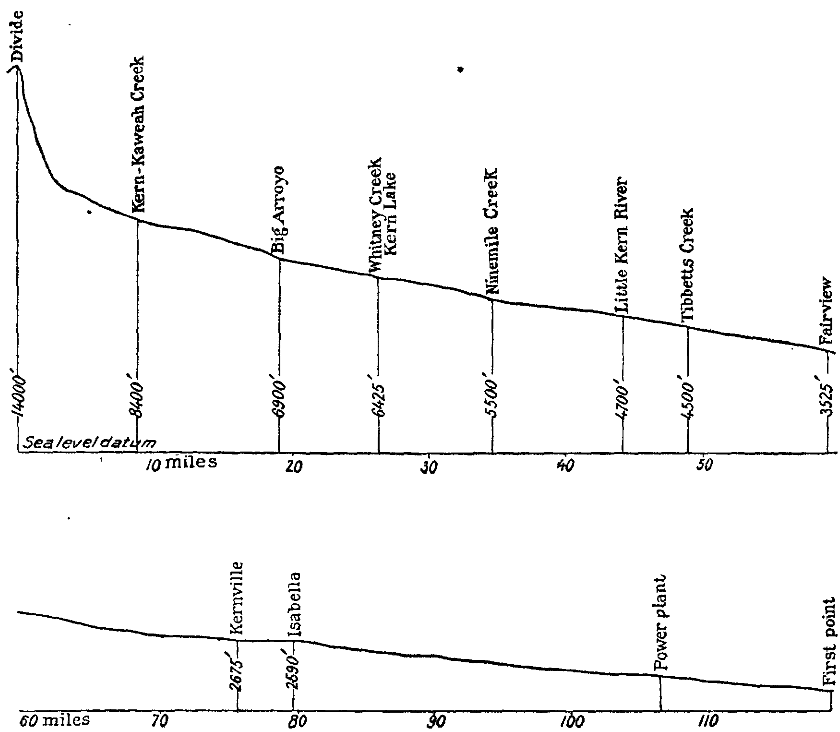


FIG. 2.—Profile of Kern River.

the 62 miles above Kernville the stream falls 5,600 feet, and in the 48 miles below Kernville it falls about 2,100 feet. A view of the river near Kernville is shown in Pl. I, and a profile of the stream in fig. 2. Fig. 3 is a view of a mountain valley in the basin of the river.

The South Fork of the stream, which rises just south of Cirque Peak, is 83 miles long to its junction with the North (or main) Fork at Isabella. The main range of the Sierra Nevada drops off rapidly just south of Cirque Peak, which may account in a large measure for the comparatively small flow of the South Fork. This branch of Kern River possesses one decided advantage over the other branch,

VIEW OF KERN RIVER NEAR KERNVILLE.

and over most California streams, in that it has a succession of particularly fine reservoir sites along a channel otherwise distinguished by reaches of rapid descent. A profile of the South Fork is shown in fig. 4.

The entire flow of Kern River is utilized for irrigation in the

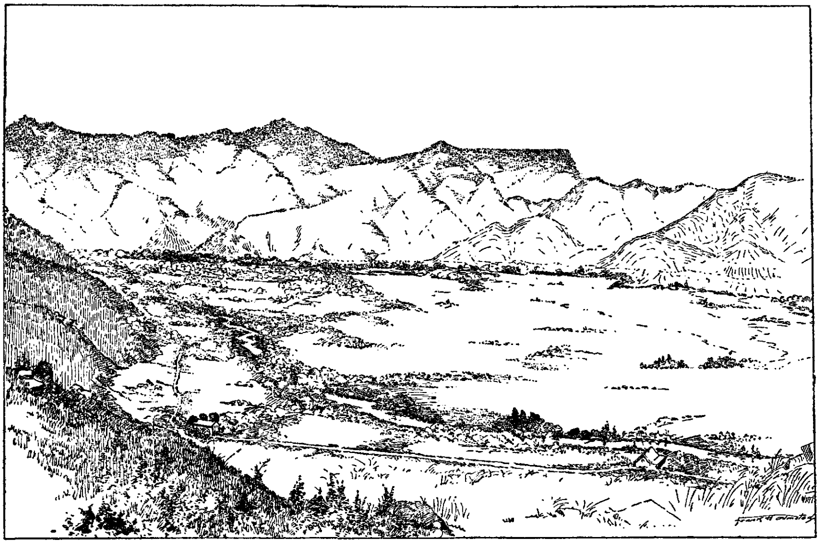


FIG. 3.—View of mountain valley in Kern River Basin.

southern end of San Joaquin Valley, and were it not for the great evaporation losses from the Buena Vista Lake reservoir the system could be called effective. The power of the stream, which, with one small exception, is available in large units, wastes itself upon the marbled bowlders and granite bed rock of the canyon, and suggests

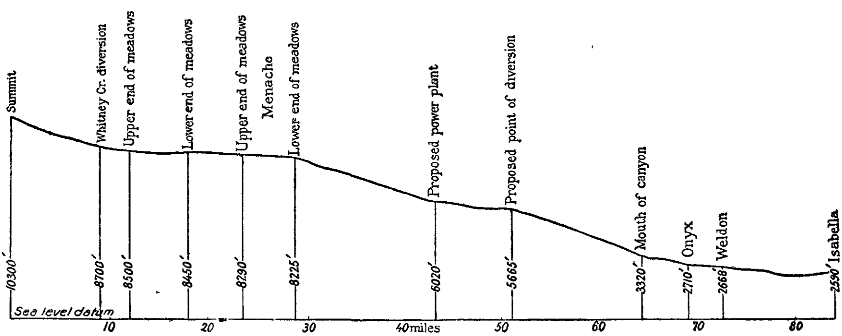


FIG. 4.—Profile of South Fork of Kern River.

an encouraging field for immediate investigation. The need of power in the agricultural valleys of California was never so apparent as now, after a series of dry years, when the ordinary flow of the streams has diminished to the extent of eliminating much hitherto valuable land, which of course precludes further development along gravity lines. Power applied to the pumping of water from the gravel beds which underlie most of the California streams where they debouch from their canyons at once solves the difficulty; and where the water plane is not far below the surface this method of irrigation

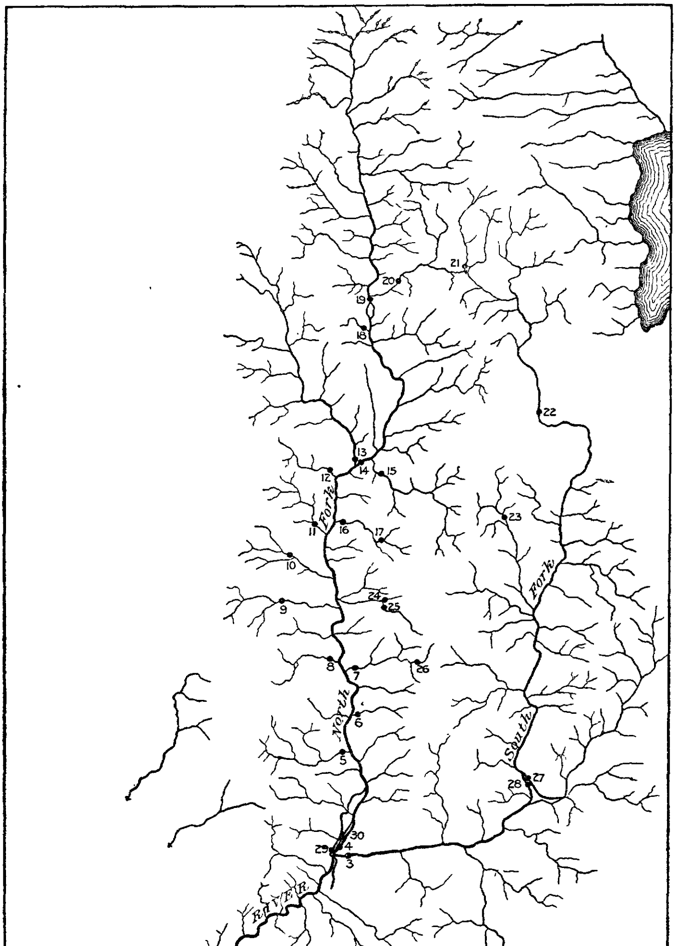


FIG. 5.—Map showing points of stream measurements.

is in many ways more convenient and perhaps not more expensive than the ordinary canal.

VOLUME.

From daily measurements continued through a series of years the run-off of Kern River Basin is well established, though the precipita-

VIEW OF GAGING STATION ON NORTH FORK OF KERN RIVER.

tion and the local discharges in the watershed are still in question. Mr. Henry Hawgood, Mem. Inst. of C. E., who has made a careful study of the physical conditions existing in the watershed of Kern River, more particularly in that of the North Fork, has estimated the annual precipitation for the North Fork above Isabella at 25.4 inches, with a run-off of 12.5 inches. This would give a mean annual flow of the North Fork of 982 second-feet. Mr. Hawgood estimates the rainfall of the entire basin at 23 inches, and the mean run-off at 7.8 inches. On this last assumption the mean discharge of Kern River at its mouth would be 1,350 second-feet. As a fact, however, for the last five years (1895–1899)—a period of exceptional drought in the basin—the stream has had a mean annual discharge at First Point of Measurement, near Bakersfield (see map, Pl. III), of 864 second-feet, or 64 per cent of the normal assumed by Mr. Hawgood.

In June, 1900, stream measurements made by the writer above Kern Lake, about 90 miles above First Point of Measurement, showed that, when considered with measurements made at the latter place and making a time allowance for the distance between, the discharge of the upper part of the stream was 99 per cent of that of the lower part. The loss in volume in the passage of 939 second-feet of water (the amount flowing in the river just above Kern Lake on June 27, 1900) from Kern Lake to Bakersfield can not be stated accurately, but in the lower reaches of the stream, from Isabella to Bakersfield, where the conditions are similar, the loss when the flow was 1,333 second-feet was determined by the writer to be 3.21 second-feet to the mile. On this basis, on June 27, 1900, the flow of the North Fork just above Kern Lake was equal to 83 per cent of the flow of Kern River at First Point of Measurement. Fig. 5 is a map showing the points where stream measurements were made, and the following table gives the dates of the measurements and the discharge in second-feet, the numbers in the table corresponding to the numbers on the map.

Discharge measurements of Kern River and tributaries at points shown on map (fig. 5).

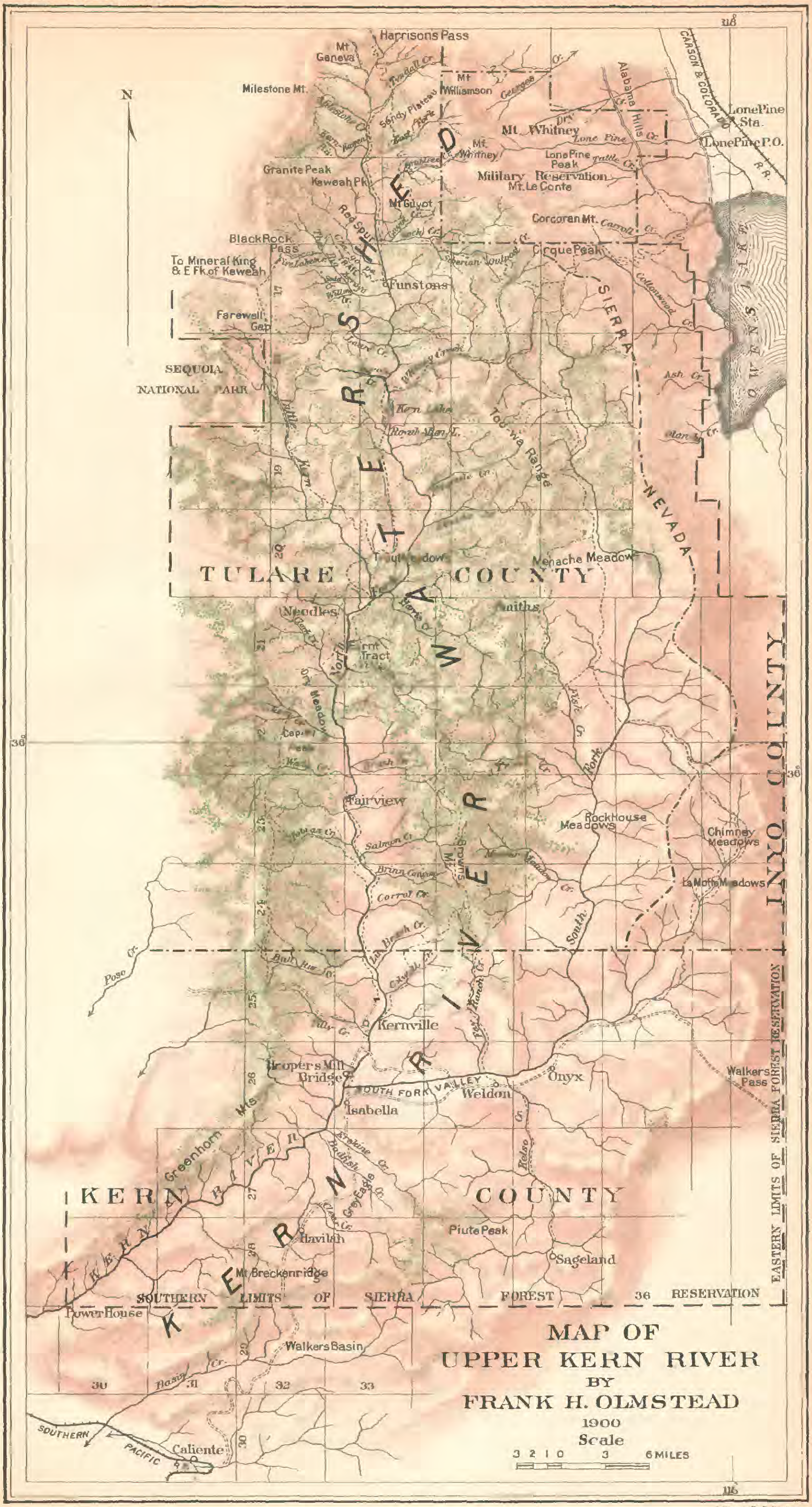
Location.	Date.	Discharge.	Location.	Date.	Discharge.
	1900.	Sec.-ft.		1900.	Sec.-ft.
1	(First Point of Measurement.)		16	June 25	2.87
			17	June 29	1.80
2	June 19	1.31	18	June 25	4.87
3	June 20	14.18	19	June 27	939.60
4	do	1,333.17	20	do	39.11
5	June 21	2.30	21	do	4.72
6	June 22	0.32	22	June 28	3.67
7	do	3.45	23	June 29	Dry.
8	do	2.92	24	do	1.04
9	June 23	5.07	25	do	8.22
10	do	5.74	26	June 30	4.05
11	do	5.19	27	July 2	2.38
12	June 24	4.26	28	do	11.05
13	do	81.00	29	July 3	1.96
14	June 25	1,154.90	30	do	7.31
15	do	8.45			

Since September, 1893, the Kern County Land Company has made careful daily measurements of the flow of Kern River at First Point of Measurement. At Rio Bravo ranch, in sec. 11, T. 29 S., R. 29 E., M. D. M., 8¼ miles above First Point of Measurement, the flow of the river has been measured for many years by the State engineer of California. It is estimated by Mr. James, chief engineer of the Kern County Land Company, that there is a loss of 50 second-feet between these gaging stations. The accompanying tables give the monthly discharge of the river at Rio Bravo ranch for the years 1878–1884, inclusive, and at First Point of Measurement for the years 1893–1900, inclusive. On page 22 is a comparative table of the estimated daily discharge of the river during 1900 at First Point of Measurement and just below Tobias Creek, which is 17 miles above the mouth of the South Fork of Kern River and about 2 miles above the mouth of Salmon Creek, and enters the North Fork from the east.

On pages 22 and 23 is a table of miscellaneous discharge measurements of Kern River and its tributaries, and on the latter page are tables of rainfall at three places in Kern River Basin.

Estimated monthly discharge of Kern River at Rio Bravo ranch.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1878.						
November			400	23,802	0.19	0.17
December			350	21,521	.17	.15
1879.						
January	686	389	462	28,407	.23	.20
February	745	466	591	32,823	.26	.25
March	659	510	552	33,941	.28	.24
April	1,054	661	764	45,461	.37	.33
May	1,231	680	927	56,999	.46	.40
June	1,190	812	971	57,778	.47	.42
July	865	386	535	32,895	.26	.23
August	387	168	266	16,356	.13	.11
September	174	146	171	10,176	.08	.07
October	210	145	182	11,191	.09	.08
Season	1,231	145	514	371,350	2.99	.22
November	325	184	261	15,531	.12	.11
December	650	280	356	21,890	.17	.15
1880.						
January	410	315	354	21,767	.17	.15
February	380	315	370	21,282	.17	.16
March	385	349	389	23,919	.20	.17
April	3,320	395	1,557	92,648	.73	.66
May	3,560	1,615	2,659	163,496	1.31	1.14
June	4,070	2,740	3,317	197,376	1.58	1.42
July	3,140	1,550	2,196	135,027	1.08	.94
August	1,500	840	1,060	65,177	.52	.45
September	846	710	767	45,640	.37	.33
October	794	722	758	46,608	.37	.32
Season	4,070	184	1,169	850,361	6.79	.50


MAP OF
UPPER KERN RIVER
BY
FRANK H. OLMSTEAD
1900
Scale
3 2 1 0 3 6 MILES
TULARE COUNTY
KERN COUNTY
INYO COUNTY
KERN RIVER
KERN
SIERRA NEVADA
SEQUOIA NATIONAL PARK
SOUTHERN LIMITS OF SIERRA FOREST 36 RESERVATION
EASTERN LIMITS OF SIERRA FOREST RESERVATION
Harrisons Pass
Mt Geneva
Milestone Mt.
Mt Williamson
Mt. Whitney
Lone Pine Peak
Military Reservation
Mt. Le Conte
Granite Peak
Kaweah Pk
Mt Guyot
Corcoran Mt.
Black Rock Pass
Cirque Peak
To Mineral King & E Fk. of Kaweah
Funstons
Farewell Gap
Lone Pine Sta.
Lone Pine P.O.
CARSON & COLORADO R.R.
OWENS LAKE
Tou-wa Range
Menache Meadow
Needles
Smiths
Fairview
Rock House Meadows
Chimney Meadows
La Motte Meadows
Kernville
Bridge
Isabella
SOUTH FORK VALLEY
Weldon
Onyx
Walkers Pass
Greenhorn Mts
Havilah
Piute Peak
Sageland
Mt Breckenridge
Power House
Walkers Basin
Caliente
SOUTHERN PACIFIC
Poso Cr.
South Fork
N
118
36°

Estimated monthly discharge of Kern River at Rio Bravo ranch—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1880.						
November	830	695	767	45,640	0.37	0.33
December	1,480	790	1,063	65,361	.52	.45
1881.						
January	1,640	950	1,078	66,284	.52	.46
February	2,970	1,430	1,073	98,471	.79	.76
March	2,100	1,400	1,570	96,535	.77	.67
April	2,612	2,100	2,288	136,145	1.09	.98
May	2,710	2,060	2,362	145,110	1.16	1.01
June	2,390	1,475	1,890	112,462	.90	.81
July	1,520	710	1,126	69,235	.55	.48
August	1,200	420	627	38,552	.31	.27
September	420	320	361	21,481	.17	.15
October	360	310	333	20,475	.16	.14
Season	2,970	310	1,263	915,751	7.31	.54
November	360	300	337	20,053	.16	.14
December	410	320	350	21,521	.17	.15
1882.						
January	380	310	335	20,598	.16	.14
February	510	360	395	21,937	.18	.17
March	1,260	440	600	36,893	.30	.26
April	1,670	920	1,174	69,858	.56	.50
May	2,000	1,420	1,670	102,684	.82	.71
June	1,990	900	1,306	77,712	.62	.56
July	1,110	450	726	44,640	.36	.31
August	....	....	330	*a* 20,291	.16	.14
September	....	....	330	*a* 19,636	.16	.14
October	....	....	330	*a* 20,291	.16	.14
Season	2,000	300	655	476,114	3.81	.28
November	....	....	280	*a* 16,661	.13	.12
December	....	....	280	*a* 17,217	.14	.12
1883.						
January	....	....	280	*a* 17,217	.14	.12
February	....	....	350	*a* 19,438	.16	.15
March	....	....	700	*a* 43,041	.35	.30
April	....	....	1,170	*a* 69,620	.56	.50
May	....	....	1,410	*a* 86,698	.69	.60
June	....	....	1,170	*a* 69,620	.56	.50
July	....	....	940	*a* 57,798	.46	.40
August	....	....	470	*a* 28,899	.23	.20
September	....	....	350	*a* 20,826	.17	.15
October	....	....	280	*a* 17,217	.14	.12
Season	....	....	638	464,252	3.73	.27
November	....	....	200	*a* 11,901	.10	.09
December	....	....	200	*a* 12,298	.10	.09
1884.						
January	....	....	350	*a* 21,521	.17	.15
February	....	....	470	*a* 27,034	.22	.20
March	....	....	940	*a* 57,798	.46	.40
April	....	....	1,980	*a* 117,818	.89	.80
May	....	....	5,860	*a* 360,317	2.90	2.50
June	....	....	9,380	*a* 558,148	4.46	4.00
July	....	....	5,860	*a* 360,317	2.90	2.50
August	....	....	2,350	*a* 144,496	1.15	1.00
September	....	....	940	*a* 55,934	.45	.40
October	....	....	470	*a* 28,899	.23	.20
Season	....	....	2,422	*a* 1,756,481	14.03	1.03

a Estimated from fragmentary records by State engineer.

Estimated monthly discharge of Kern River at First Point of Measurement.

[Drainage area used in previous reports, 2,345 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1893.						
October	554	517	534	32,861	0.26	0.23
November	559	467	518	30,827	.24	.22
December	590	430	516	31,757	.25	.22
1894.						
January	741	562	661	40,644	.32	.28
February	1,114	604	717	39,817	.32	.30
March	1,443	762	1,001	61,541	.65	.43
April	1,892	1,209	1,495	88,952	.71	.64
May	2,208	1,228	1,607	98,798	.79	.69
June	1,719	871	1,085	64,557	.51	.46
July	1,051	400	700	43,036	.34	.30
August	549	256	335	20,565	.16	.14
September	382	172	248	14,756	.12	.11
October	363	224	279	17,178	.14	.12
November	268	230	244	14,500	.11	.10
December	805	234	470	28,908	.23	.20
The year	2,208	172	737	533,252	4.40	.31
1895.						
January	1,616	473	809	49,762	.40	.34
February	4,762	675	1,252	69,536	.55	.53
March	3,004	987	1,374	84,437	.67	.59
April	3,897	1,911	2,724	162,076	1.29	1.16
May	5,384	3,100	4,369	268,608	2.14	1.86
June	3,721	2,174	2,906	172,919	1.37	1.24
July	2,063	867	1,482	91,113	.73	.63
August	1,073	354	629	38,665	1.31	.27
September	676	290	344	20,469	.17	.15
October	612	276	327	20,106	.16	.14
November	436	308	346	20,588	.17	.15
December	447	368	403	24,779	.20	.17
The year	5,384	276	1,413	1,023,058	8.16	.60
1896.						
January	3,101	377	747	45,931	.37	.32
February	798	559	617	35,489	.28	.26
March	2,089	652	951	58,475	.47	.41
April	1,263	766	972	57,838	.46	.41
May	3,370	934	1,401	86,144	.69	.60
June	3,611	1,244	2,456	146,142	1.17	1.05
July	2,210	741	1,316	82,762	.66	.57
August	741	353	486	29,883	.24	.21
September	473	234	304	18,089	.14	.13
October	425	223	267	16,417	.13	.11
November	416	288	355	21,124	.17	.15
December	426	313	347	21,336	.17	.15
The year	3,611	223	854	619,630	4.95	.36
1897.						
January	832	305	373	22,935	.18	.16
February	2,306	516	809	44,930	.36	.35
March	2,044	688	923	56,753	.45	.39
April	4,410	1,094	2,914	173,395	1.38	1.24
May	5,342	4,054	4,580	281,613	2.25	1.95
June	4,352	1,289	2,309	137,395	1.09	.98
July	1,536	644	1,006	61,857	.49	.43
August	671	338	469	28,838	.23	.20
September	363	260	295	17,554	.14	.13
October	441	278	340	20,906	.17	.15
November	477	289	355	21,124	.17	.15
December	1,023	327	422	25,948	.21	.18
The year	5,342	260	1,234	893,248	7.12	.53

Estimated monthly discharge of Kern River at First Point of Measurement—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	400	311	363	22,320	0.17	0.15
February	923	316	434	24,103	.20	.19
March	485	304	388	23,857	.20	.17
April	1,342	371	710	42,247	.33	.30
May	980	560	735	45,193	.36	.31
June	686	394	551	32,786	.26	.23
July	416	127	244	15,003	.12	.10
August	142	86	120	7,378	.06	.05
September	294	80	116	6,902	.06	.05
October	232	127	160	9,838	.08	.07
November	188	136	166	9,877	.08	.07
December	314	147	199	12,236	.09	.08
The year	1,342	80	348	251,743	2.01	.15
1899.						
January	361	182	263	16,172	.13	.11
February	365	258	302	16,772	.14	.13
March	4,932	247	590	36,278	.29	.25
April	1,167	593	893	53,138	.43	.38
May	1,302	576	835	51,342	.41	.36
June	2,230	809	1,331	79,200	.63	.57
July	894	229	489	30,057	.24	.21
August	240	99	156	9,592	.08	.07
September	117	89	105	6,257	.05	.04
October	229	86	160	9,838	.08	.07
November	385	183	221	13,151	.10	.09
December	781	182	277	17,032	1.36	1.18
The year	4,932	86	468	338,829	3.94	.29
1900.						
January	1,048	266	362	22,259	.17	.15
February	329	238	280	15,550	.12	.12
March	502	307	413	25,394	.21	.18
April	592	387	472	28,086	.22	.20
May	1,969	449	1,111	68,312	.54	.47
June	1,878	841	1,283	76,344	.61	.55
July	850	202	392	24,103	.20	.17
August	217	101	144	8,854	.07	.06
September	270	106	166	9,878	.08	.07
October	186	137	160	9,838	.08	.07
November	1,339	161	349	20,767	.17	.15
December	445	288	373	22,934	.18	.16
The year	1,969	101	459	332,319	2.65	.20

Thirteen-year mean of the discharge of Kern River, as compiled from the foregoing records of the State engineering department and the United States Geological Survey.

Season and year.	Discharge.	
	Sec.-ft.	*Acre-feet.*
1878–1879	514	371,350
1879–1880	1,169	850,361
1880–1881	1,263	915,751
1881–1882	655	476,114
1882–1883	638	464,252
1883–1884	2,422	1,756,481
1894	737	533,252
1895	1,413	1,023,058
1896	854	619,630
1897	1,234	893,248
1898	348	251,743
1899	468	338,829
1900	459	332,319
Thirteen-year mean	936	678,953

Estimated daily discharge of Kern River for 1900.

Day.	July.		August.		September.		October.	
	First Point of Measurement.	Just below Tobias Creek.	First Point of Measurement.	Just below Tobias Creek.	First Point of Measurement.	Just below Tobias Creek.	First Point of Measurement.	Just below Tobias Creek.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1			209.08	334.00	108.31	212.80	144.95	204.32
2			190.64	338.00	115.71	310.40	142.44	205.20
3			188.25	306.20	131.89	308.00	141.92	208.16
4			193.78	252.90	147.24	274.28	147.92	204.12
5			195.49	244.38	190.01	256.00	146.64	202.80
6			188.78	234.82	159.17	253.20	154.68	202.80
7			178.86	230.62	156.86	246.40	164.04	202.40
8			169.11	230.00	241.22	244.00	164.77	200.80
9			178.32	228.66	221.09	244.00	157.39	201.20
10			171.89	228.66	212.66	234.82	153.45	202.14
11			159.38	226.14	188.13	232.06	153.30	201.80
12			161.24	226.50	175.33	232.58	151.08	201.66
13			157.67	226.00	174.77	230.44	152.02	202.00
14			149.18	224.34	170.70	222.60	156.04	201.20
15			140.79	222.34	170.66	220.30	158.50	201.20
16			130.41	222.34	165.97	220.00	156.19	200.40
17			122.57	213.30	157.06	213.76		
18			116.84	205.80	155.60	214.90		
19			116.75	201.50	151.98	211.14		
20			120.21	198.44	146.16	210.84		
21	274.25	352.58	120.16	195.36	138.63	211.00		
22	269.00	344.80	120.38	194.30	139.29	206.58		
23	274.43	340.30	121.81	192.90	142.05	206.60		
24	282.59	336.20	114.32	195.64	144.14	207.32		
25	250.55	327.72	110.85	195.00	139.79	208.90		
26	229.73	318.50	109.43	193.40	141.31	208.40		
27	224.64	308.18	110.70	194.08	153.44	207.54		
28	216.80	208.20	107.63	186.00	155.78	205.86		
29	212.69	291.34	102.99	187.20	151.31	205.32		
30	219.59	285.40	106.31	181.00	147.22	207.10		
31	222.49	282.06	103.18	178.40				
Mean			144.10	222.00	166.45	228.91		

Miscellaneous discharge measurements of Kern River and its tributaries.

Date.	Stream.	Locality.	Hydrographer.	Elevation.	Discharge.
1898.				*Feet.*	*Sec.-ft.*
July 10	North Fork of Kern River.	"A" channel, above junction with South Fork.	F. H. Olmsted		17.00
Do	do	"B" channel	do		199.00
Do	do	"C" channel	do		107.00
Do	do	"D" channel	do		8.00
Do	South Fork of Kern River.	700 feet above junction with North Fork.	do		13.00
July	North Fork of Kern River.	At mouth	do		330.00
Do	South Fork of Kern River.	At engineers' old camp.	do		18.00
Do	do	Sec. 6, T. 22 S., R. 36 E	do		10.00
Do	do	Menache Meadows	do		5.30
Aug. 29	Kern River	First Point of Measurement.	do		115.60
1899.					
Sept. 2	do	do	do		99.22
1900.					
June 19	Basin Creek	Rankin's ranch, Walkers Basin.	do		1.32
June 20	South Fork of Kern River.	700 feet above junction.	do		14.18
Do	North Fork of Kern River.	Hooper's mill bridge	do		1,333.17
June 21	Bull Run Creek	Near mouth	do		2.30
June 22	Tobias Creek	do	do		2.92
Do	Ant Creek	At mouth	do	3,200	.18
Do	Salmon Creek	do	do		3.45
Do	Corral Creek	Near mouth	do		.32
June 23	South Needles Creek	At Needles Peak	do	4,550	5.82

Miscellaneous discharge measurements of Kern River and its tributaries—Cont'd.

Date.	Stream.	Locality.	Hydrographer.	Elevation.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
June 23	Clark Creek	Dry Meadows	F. H. Olmsted		5.19
Do	Jackson Creek	do	do		5.74
Do	Wade Creek	do	do		5.07
June 24	North Needles Creek	At Needles Peak	do		4.26
Do	Little Kern River	At junction with Kern River.	do		81.00
June 25	Tibbetts Creek	1 mile above mouth	do		2.87
Do	Harris Creek	At mouth	do		8.45
Do	Onemile Creek	1 mile below Kern Lake.	do		4.87
Do	North Fork of Kern River.	3,000 feet above junction with Little Kern River.	do		1,154.90
Do	Whitney Creek	At tunnel in divide	do		4.72
June 27	do	At lava bridge	do		39.11
Do	Creek south of Bald Mountain.		do	6,560	17.64
Do	North Fork of Kern River.	800 feet above Kern Lake.	do		939.60
June 28	South Fork of Kern River.	Menache Meadows	do		3.67
June 29	Tibbetts Creek	At 8,300 feet elevation	do		1.80
Do	North Fork of Brush Creek.	At 5,800 feet elevation	do		1.04
Do	Brush Creek	Above North Fork	do	5,600	8.22
June 30	North Fork of Kern River.	At new gaging station 4,000 feet above junction with South Fork.	do		825.25
Do	Salmon Creek	At Horse Meadows	do	7,700	4.05
July 2	South Fork of Kern River.	T. 25 S., R. 35 E	do	2,920	11.05
Do	Powers ditch	Near head	do		2.38
July 3	Neils ditch	Isabella	do		1.96
Do	Hooper's mill ditch	At gaging station on Kern River.	do		7.31

Precipitation in Kern River Basin.

DAUNT.

[Observer, Mountain Home sawmill.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1895–96					11.91	0.83	5.13	11.01	1.30	2.70	0.65	0.50
1896–97	0.00	0.60	0.40	1.95								

KERNVILLE.

[Observer, Stephen Barton, Isabella.]

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1895–96					3.52	0.00	1.54	0.86	0.00	0.20	2.25	0.05	
1896–97	0.00	1.15	0.41	0.85	3.40	3.60	2.57	0.10	0.00	0.00	0.00	0.00	12.08
1897–98	0.15	0.38	0.00	1.28	0.58	0.99	0.58	T.	0.54	0.00	0.00	0.00	4.50
1898–99	0.04	0.00	0.00	0.33	1.95	0.19	1.89	0.28	0.25	0.45	0.00	0.00	5.38
1899–00	0.00	0.78	0.85	0.73	0.80	0.53	0.58	0.52	0.90	0.00	0.00	0.00	5.69
1900–01	0.79	0.10	5.09	0.00									

MOUNT BRECKENRIDGE.

[Observer, G. Otterman.]

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
1896–97			2.20	4.30	2.00	4.67	7.72	0.00	0.40	0.10	0.00	0.00
1897–98	0.00	0.00										
1898–99					1.67	0.94						

The rain gage at Daunt is at the Mountain Home sawmill, near the divide between Kern and Kaweah rivers, and at an elevation of 6,600 feet. Kernville is at an elevation of 2,600 feet, and Mount Breckenridge at an elevation of 6,750 feet.

From the diagram (fig. 6) showing synchronous discharge and temperature observations at First Point of Measurement for the months of April, May, and June, 1897—the particular season of the year when the factor of snow enters prominently into the regimen of the river—we gather, by connecting the peak points of flow and temperature, that ordinarily it requires about forty-seven hours for the stream waters to pass from the snow line, about 100 miles up the river, to

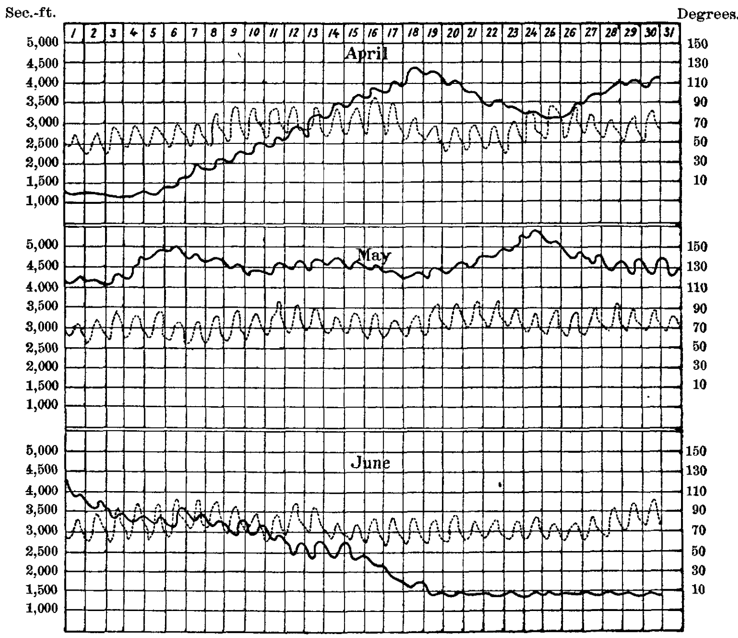


FIG. 6.—Diagram showing synchronous discharge and temperature observations at First Point of Measurement. Dotted lines are temperature curves; heavy lines are discharge curves.

First Point of Measurement. Under ordinary circumstances the melting of snow below the 7,000-foot contour would accompany a low gage, and the mean velocity would of course be relatively slow compared with a larger stream. The run-off of the heavy snows would start certainly not lower than the 8,500-foot contour, and invariably would be accompanied by a general breaking up of winter in the higher mountains, resulting in a high gage throughout the entire stream; from which we may infer that there is no marked difference in the time required for the passage of snow water between points as much as 30 miles apart to the canyon mouth. When the spring rise begins the mean velocity of the stream waters from the snow line, 60 miles up, to First Point of Measurement must be about 1.90 feet per second. When the snow line reaches the 8,500-foot contour, 100 miles upstream, the flood velocity is approximately 3.1 feet per second. This 1.2-foot-per-second play in velocity between high and low snow water gage in the stream represents the only data available for estimating, even crudely, the velocity-slope relations during the remainder of the year.

POWER POSSIBILITIES.

Elevations and distances have been and still are to a certain extent assumptions, and were it not that the data in some form is in demand, it certainly would be desirable to possess more basic information of Kern River Basin before undertaking to even outline the power possibilities of the stream. The flood period of the year is May and June; the minimum flow occurs in September and October. During extremely dry years the flow at First Point of Measurement drops to 80 second-feet, with a probable mean for the month in which this occurs of, say, 100 second-feet.

In the reach between First Point of Measurement and Isabella the stream has been affected by losses from evaporation and seepage and by increment in flow due to the South Fork, Clear Creek, and other small tributaries. The net result of these plus and minus factors is estimated to be a loss between these points of 122 second-feet. Calling this loss 120 second-feet, and taking the minimum flow at First Point of Measurement (80 second-feet), we have, as the least flow of the river at the latter place, 200 second-feet. Between Isabella and First Point of Measurement the fall is about 1,900 feet, giving more than 42,000 theoretical horsepower. At Isabella the mean flow for the full year 1899 was 588 second-feet, for 1898 it was 469 second-feet, and for 1897 it was 1,353 second-feet. Below Isabella the topography on the right bank is not unfavorable for the construction of a large canal, but the immense bowlders which cover the southern and western sides of the Greenhorn Mountains, and which are constantly in transit down the slopes, are not an economical factor in canal construction.

Of the total flow of Kern River at First Point of Measurement 80 per cent passes Funstons on the North Fork, or a point of equal elevation (7,050 feet) on the South Fork, which would be about midway between the lower end of Menache Meadows and the mouth of Fish Creek. The theoretical power possibilities of the stream below these places would be, then, about 500,000 horsepower, which, for a watershed of 2,349.3 square miles in an arid region, evidences the remarkable advantages of the stream, so far as grades and discharge are concerned, for electrical-power development.

The Kern River Company, which has been engaged for the last four years in securing rights of way (now approved by the Department of the Interior), and in arranging preliminaries incident to the construction of so large a plant, has as yet accomplished nothing in the way of actual building. A plan of the reservoir site of the company is shown in fig. 7. The diversion works of their power canal will be in

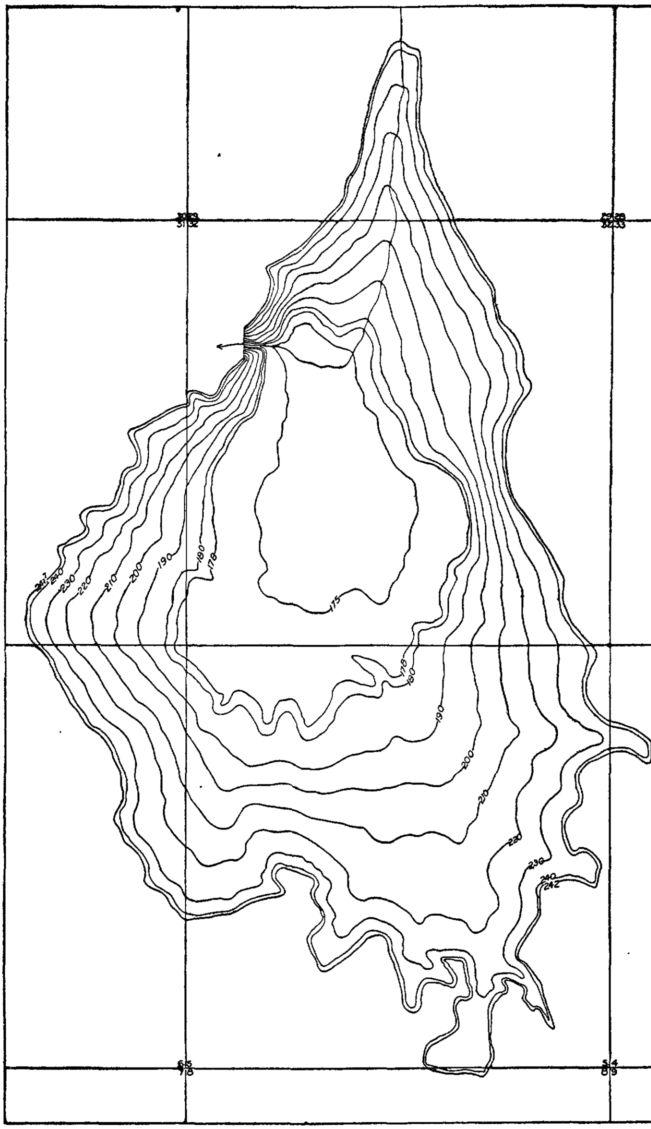


FIG. 7.—Plan of reservoir site of Kern River Company. Area, 1,121 acres; storage capacity, 42,000 acre-feet; height of dam, 72 feet.

the lower end of the town of Kernville, where the river forks. The West Fork is to be deepened so that during low stages this branch will gather all of the water of the river, and a low training wall, over which floods of the river will pass, will be built. The head gate will be 3,600 feet distant, on bed rock, and of solid masonry. The standard cross section of the canal for the first 10 miles is 25 feet wide at bottom, 7.5 feet depth of water, and on a grade of 1.058 feet to the mile. At a distance of 4½ miles from the head gate the only considerable structure on the line is encountered—the bridge over Kern River. After passing that point the cross section of the canal is reduced and the grades are increased accordingly.

The plans of the company are based upon a minimum flow of Kern River past their diversion works of 400 second-feet. This, considering the storage proposed on Salmon Creek, which is described further on, is a conservative estimate for any ordinary series of years, but could not have been maintained in 1899–1900, although in nine out of ten years it easily could be increased to 500 second-feet. The plans are based on an available head at the wheels of 230 feet during extreme high water, with an additional head of 40 feet when the river is at its minimum stage. Mr. H. Hawgood, the chief engineer of the Kern River Company, has designed, as a generating unit, a water wheel of 1,500 horsepower; with an alternator of 1,030 kilowatts capacity. There are to be nine of these units—eight for daily service and one to be held in reserve. For the additional 40-foot head possible during low water, there will be a 750-horsepower wheel and one 550-kilowatt alternator. On this basis, at no time would there be supplied to the wheels less than 11,200 horsepower. The impulse type of wheel would give an efficiency of 80 per cent, the alternators an efficiency of 95 per cent, and the step-up transformers an efficiency of 98 per cent, thus delivering to the line 8,342 horsepower. Assuming 5 per cent average loss in transmission (a larger allowance than the 80-mile carriage of the Southern California Power Company's current indicates is necessary), there would be delivered at the Los Angeles power house 7,825 horsepower, and with 98 per cent efficiency in the step-down transformers there would be 5,720 kilowatts for daily distribution in the city. This delivery could be increased 50 per cent for an hour to take care of the maximum load, which occurs between the hours of 5 and 6 p. m. Speaking conservatively, and having in mind the ruling rates elsewhere on the Coast, this 7,668 horsepower should command 1⅓ cents per horsepower per hour. During the irrigating season of 1900 the municipality of Los Angeles paid 2.2 cents per horsepower per hour for power registered between the hours of 11 p. m. and 5 p. m., and 4.4 cents per horsepower per hour for power registered between the hours of 5 p. m. and 11 p. m. In large plants working eighteen hours a day, and with good bituminous coal at $4 a ton, the cost of 1 horsepower per year would be $85, and in small plants, where the attendance factor is relatively greater, the cost would be $150. At the rate of 1⅓ cents the cost of a horsepower per year of three hundred and thirteen working days is $75. At this rate the gross annual revenue of the plant would be $768,000.

The company's estimate of the cost of construction of the plant and lines for the transmission of the current to Los Angeles is, approximately, $1,333,000. Using direct-connected motor and centrifugal pumps, with 30 feet depth of wheel pit and 20 feet additional lift, and assuming the duty of water to be 8 acres per miners' inch, 1.42 horsepower would irrigate 100 acres at the rate of, say, $2.50 per acre per annum. This would be on the basis of a 50-foot lift and a rate of 2 cents per horsepower per hour for the current. The efficiency of pumping plants ranges from 20 to 68 per cent—frequently plants are condemned solely because of a lack of skillful assembling of the units.

Electric motive power possesses many advantages over either steam or gasoline plants for pumping water, and in actual cost of service it may be questioned whether it is not to be compared with many well-managed canal systems of the State. The Kern Land Company has twenty-five pumping plants in operation near Bakersfield, each delivering from 1,400 to 2,000 gallons a minute. These plants each consist of four wells in a line, sunk to a depth of 80 to 130 feet through strata of alluvial loam, clay, and water-bearing sand. The wells are cased with galvanized iron, 13 inches in diameter, No. 16 gage, perforated with vertical slits opened one-sixteenth of an inch. It was the practice of Mr. Lewis A. Hicks, the engineer in charge of this work, to land the casing in clay, and to perforate for all sand below a depth of 30 feet. Surface water was generally encountered at about 15 feet. In each plant the four wells are 6 feet apart on centers, and by experiment it was found that the flow from the four was generally a little more than double that from one. The total lift for most of these plants was about 35 feet.

After many experiments to determine the pump best suited to these conditions, a centrifugal pump, connected directly to the motor and working on a vertical rod, all thoroughly bolted to steel framework, was found to give the greatest efficiency and the least trouble in operation—one attendant looks after ten plants, and there have been months when the plants were in operation 98 per cent of the time. The farmers under the Kern Land Company's water supply are taxed 75 cents per acre-foot for irrigating water from these electrically driven pumping plants, and as the land requires 2 acre-feet annual irrigation the expense is $1.50 per acre per year. It is not probable that the rate of 1½ cents per horsepower per hour could be maintained in Antelope Valley or farther south in San Fernando Valley for irregular demand, but there is no good reason why a 2-cent rate could not be maintained by any of the Kern River companies.

The 68 per cent efficiency obtained in many of the Kern Land Company's plants deserves more than passing notice. In electrically driven pumping plants 55 per cent efficiency (reckoned from the meter consumption to the foot-pounds raised) is very good, but when this is raised to 68 per cent, the method employed to obtain this result merits a detailed description. The following is quoted from one of Mr. Hicks's reports:

The pumps are of the Pit type, provided with 10-inch outlet, automatic balance, heavy shaft, and runners of special curvature adapted to the speed and height of lift, and a delivery of 5 to 6 cubic feet per second. The bearings are provided with sight-feed oil cups, and the feed on the upper bearing is upward against the water with which the stuffing-gland chamber is filled. The chamber is provided with a gage glass to enable the attendant to note any leak through the packing. The pump is bolted to cast-iron pedestal set on a wooden base, and the steel angles which support the motor are attached to the same pedestal. The assembling of the pumps and frame was accomplished in the shops, and the completed unit was hauled to its destination and lowered into place on the floor of the pit, only requiring to be guyed to a perpendicular position in the anchor frame to be ready to receive the motor. The adjustment of the thrust of the pump can be altered so as to carry the entire weight of the motor and shafting or such portion of it as may be desirable. It has been found preferable to separate them with 100 to 200 pounds down thrust, as there is a tendency to bow out the shaft between bearings if it is thrown into compression with resulting vibration. The motor is provided with adjusting screws, so that its position in vertical or horizontal planes can be easily changed with a hand wrench. The pump, motor, and frame constitute a self-contained unit, so that any settlement of foundation does not

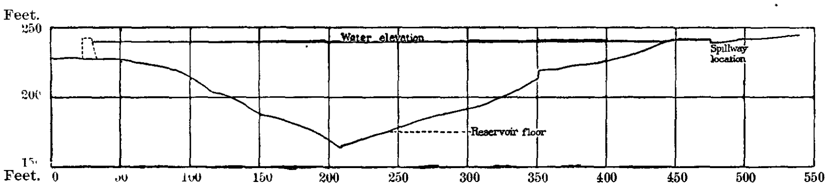


FIG. 8.—Cross section of proposed dam site of Kern River Company on Salmon Creek.

alter the relative position of either machine, and can be quickly rectified, should it occur, by guying the frame back to a vertical position. The motors used for this installation are the ordinary type of 30-horsepower inductive motor, equipped with special end shields to adapt them for vertical use. The oiling is accomplished by means of centrifugal force, which is utilized to lift the oil from the inside periphery of a revolving cup to the top of the bearings, whence it returns to the oil cups through oil grooves along the shaft. The motors are wound for a potential of 550 volts, and as the transformers at these points can be connected up to 605 volts, the effective heating overload is greatly reduced.

The Kern River Company's transmission line from the power station at the mouth of Clear Creek to Los Angeles would be 105 miles long, map measurement, and 108 miles when the vertical departures are considered. The line begins at an elevation of 2,450 feet, and its southern terminal at Los Angeles is 350 feet above the sea. A number of mountain ranges would be crossed, but a large proportion of the line would be over good ground, and it is believed that the highest elevation reached (6,500 feet, at Tehachapi) will offer no serious obstacles to a daily inspection of the pole line.

A reservoir on Salmon Creek, a tributary of Kern River, is planned by the Kern River Company for the storage of 47,000 acre-feet of water. About 20,000 acres can be made tributary to this intake, and it is hoped that with this catchment basin and the precipitation from an elevation of 7,700 feet on this divide the reservoir will supplement the flow of Kern River to 400 second-feet during the particular season of any year when the normal flow is below that figure. Fig. 8 is a cross section of the dam site on Salmon Creek. It is in a

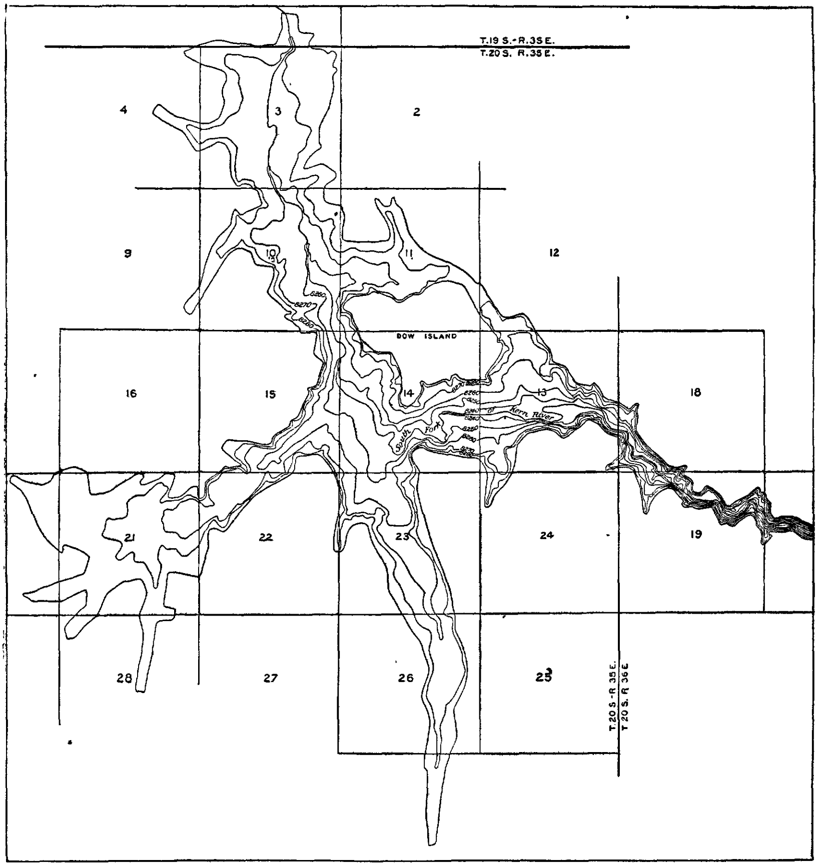


FIG. 9.—Plan of reservoir site of Kern-Rand Electric Power Company. Area, 3,562 acres; storage capacity, 63,722 acre-feet; height of dam, 65 feet above stream bed.

granite canyon, with clean bed rock on bottom and sides. The width at the bottom is 125 feet between walls; the top width at the 75-foot level would be 390 feet. A rock-fill dam is estimated to require 26,000 cubic yards of material and to cost $80,000.[1]

The utilization of the higher reaches of Kern River for power purposes will certainly be accomplished in time, but for the present,

[1] Reservoirs for Irrigation, Water Power, and Domestic Water Supply, by J. D. Schuyler.

and with the disinclination of electrical engineers to recommend the transmission of power to distances greater than 100 miles, it is doubtful whether the market outside of Los Angeles will warrant the outlay; and the latter city is so far away from the upper river as

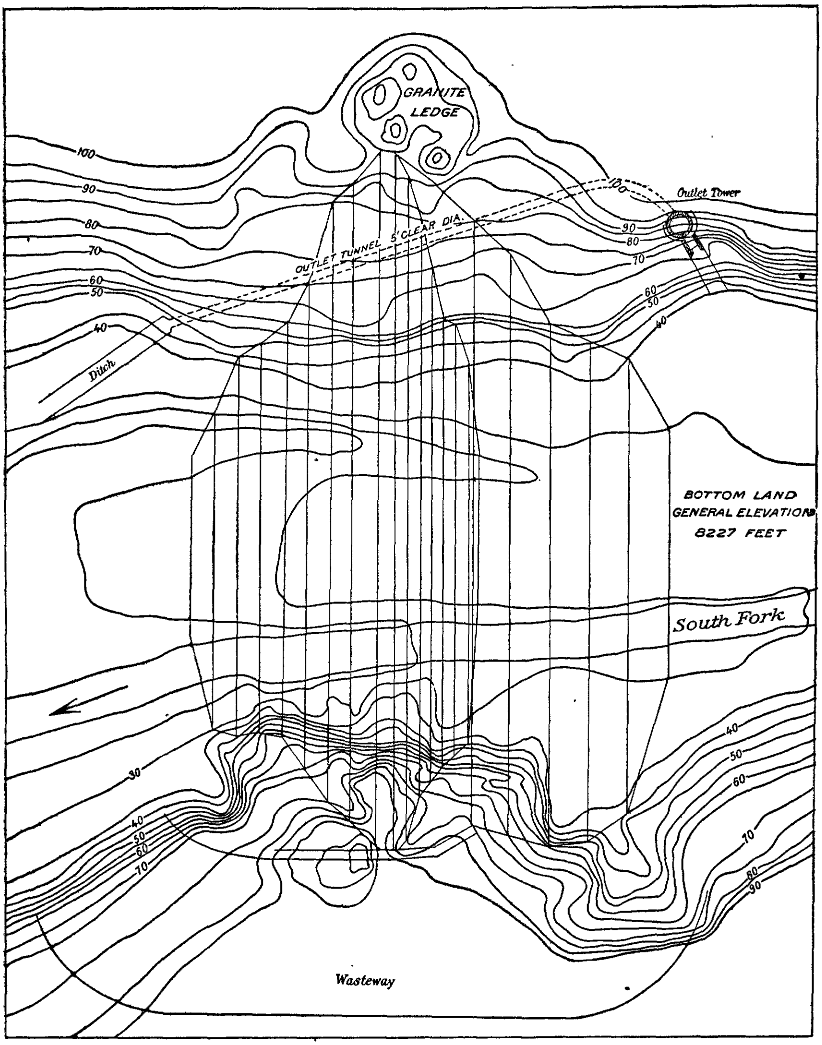


FIG. 10.—Plan of dam site of Kern-Rand Electric Power Company.

to preclude, for the present at least, supplying it with power from that source.

The Kern-Rand Electric Power Company, of Los Angeles, purposes to construct a rock-fill dam on the South Fork of Kern River, at Menache Meadows, and an initial power station near the upper end of South Fork Valley, about 35 miles farther down the stream. At some recent geological time Menache Meadows must have been an immense mountain lake. A dam 65 feet high would throw the water back 6 miles from the canyon mouth, in two arms 6 miles apart. A dam of that height would store 63,700 acre-feet of water at a mean depth of 18 feet. There is no question that in an ordinary year the drainage area tributary to the South Fork and above the Meadows (165 square miles) would furnish ample storage water for this reservoir, although it is probable that in a season like that of 1899–1900 there would be a shortage. There is no reliable data for determining the minimum precipitation in Menache Meadows, for generally the snows lie so deep over the mountains surrounding the basin as to make it impenetrable during at least the colder half of the year.

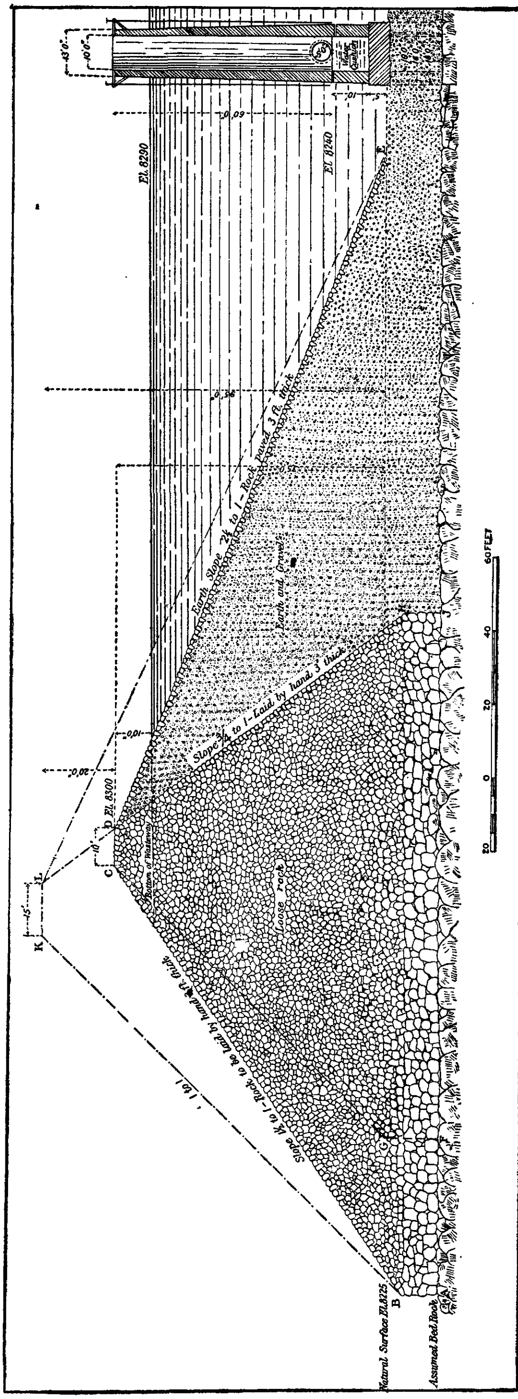


FIG. 11.—Sectional elevation of dam proposed by the Kern-Rand Electric Power Company. For dam 75 feet high above bed rock, build on lines *F*, *G*, *C*, *D*, and *E*. If it is desired to increase capacity of reservoir in future, build on lines *A*, *B*, *C*, *D*, and *E*. Dam built on lines *B*, *K*, *L*, and *E* would nearly treble the capacity of the reservoir.

Capacity of Menache Meadows reservoir site.

Height above base of dam.	Surface area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
10	22	110
20	146	954
30	812	4,563
40	1,865	18,827
50	2,599	40,732
60	3,254	69,885
70	3,814	105,236
80	4,420	146,419
100	5,830	248,852

Fig. 9 is a plan of the reservoir site of the Kern-Rand Electric Power Company in Menache Meadows, fig. 10 is a plan of the dam site, and figs. 11, 12, and 13 are details of the dam proposed. The material at the dam site is apparently hard granite, overlain with earth, sand, and gravel. The dam site is at an elevation of 8,200 feet above the sea, and consequently snow and frost prevail there during the winter months. There is no wagon road to the dam site, and the cost of making one would add very materially to the cost of the dam. The drainage area tributary to this reservoir being all above an elevation of 8,200 feet, naturally has the greater part of its precipitation in the form of snow. This makes the run-off an uncertain quantity, and leaves the proper height for the dam a difficult question to decide.

Taking all of these considerations into account, the engineers of the company were led to select a loose rock-fill dam faced with earth as the most economical and serviceable for the locality. On account of the possible action of frost, flatter slopes were given the rock faces than are absolutely necessary to make the dam heavy enough to resist the water pressure. So far as possible, the material found in the immediate vicinity of the dam will be used in its construction, and the outlet, gates, and connections have been designed so that all of their parts can easily be transported on mules over a steep mountain trail. The crest of the dam was fixed at 65 feet above the natural surface of the ground at the dam site. This height can, however, be increased to 95 feet, if it is found that a larger reservoir capacity could be supplied, at a proportionate increase in cost. It is proposed to excavate all of the rock required in the construction of the dam on the north side, forming a suitable wasteway in the solid rock, capable of discharging a stream of water 100 feet wide and 9 feet deep at a velocity of 6 feet per second—a volume of 5,400 cubic feet per second. As each foot rise of water over the bottom of the wasteway represents about 5,000 acre-feet, 9 feet rise of water in the wasteway would increase the volume in the reservoir to 45,000 acre-feet. This, in addition to the water running through the wasteway and outlet, would make more than 50,000 acre-feet, which, if it all came in twenty-four hours, would represent a run-off of about 5½ inches. It is believed that a wasteway of this size would make the dam absolutely safe against any possibility of the water ever flowing over the top. The capacity of the reservoir with a dam 65 feet high, as now

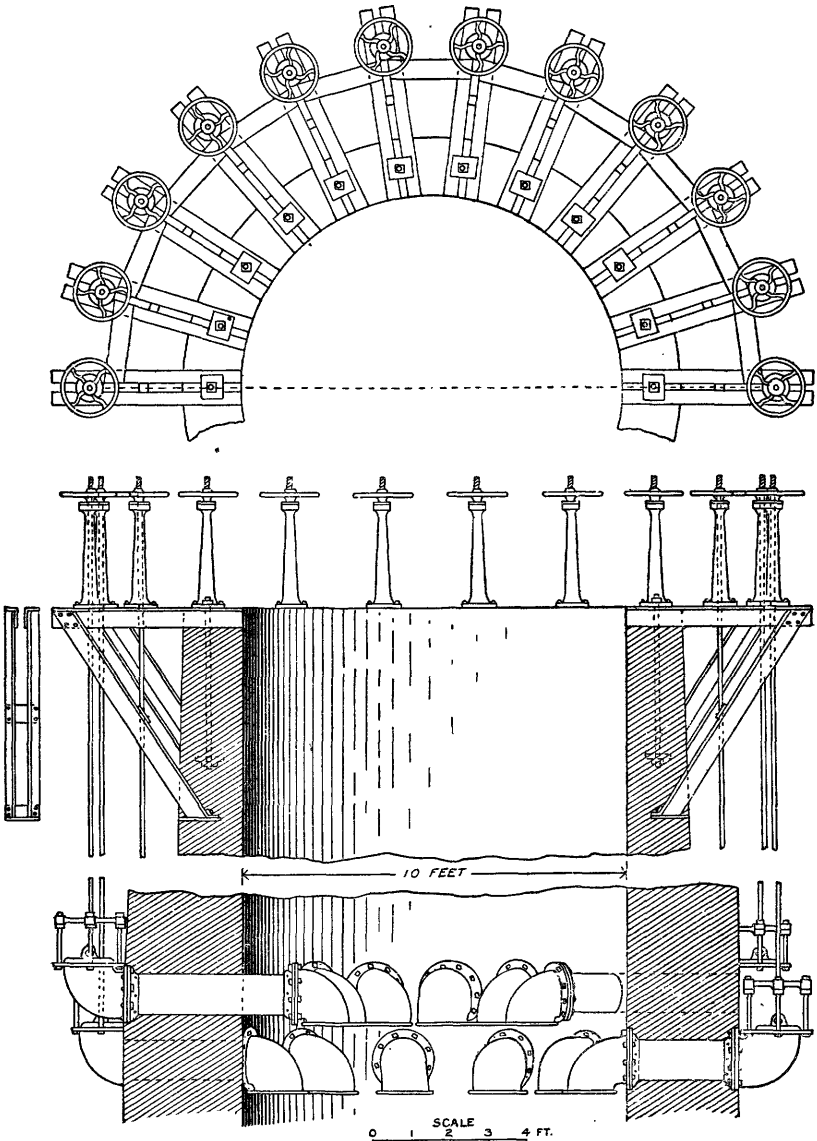


FIG. 12.—Vertical section of tower for dam proposed by Kern-Rand Electric Power Company, showing arrangement of gates.

proposed, would be 63,700 acre-feet; and if the dam were raised hereafter to a height of 85 feet the capacity of the reservoir would be nearly trebled.

It is proposed to take the water from the reservoir by means of a tunnel through the solid rock on the south side of the dam. The masonry or concrete tower (see figs. 11, 12, and 13) is designed as an inlet to this tunnel and to accommodate the placing of the gates in

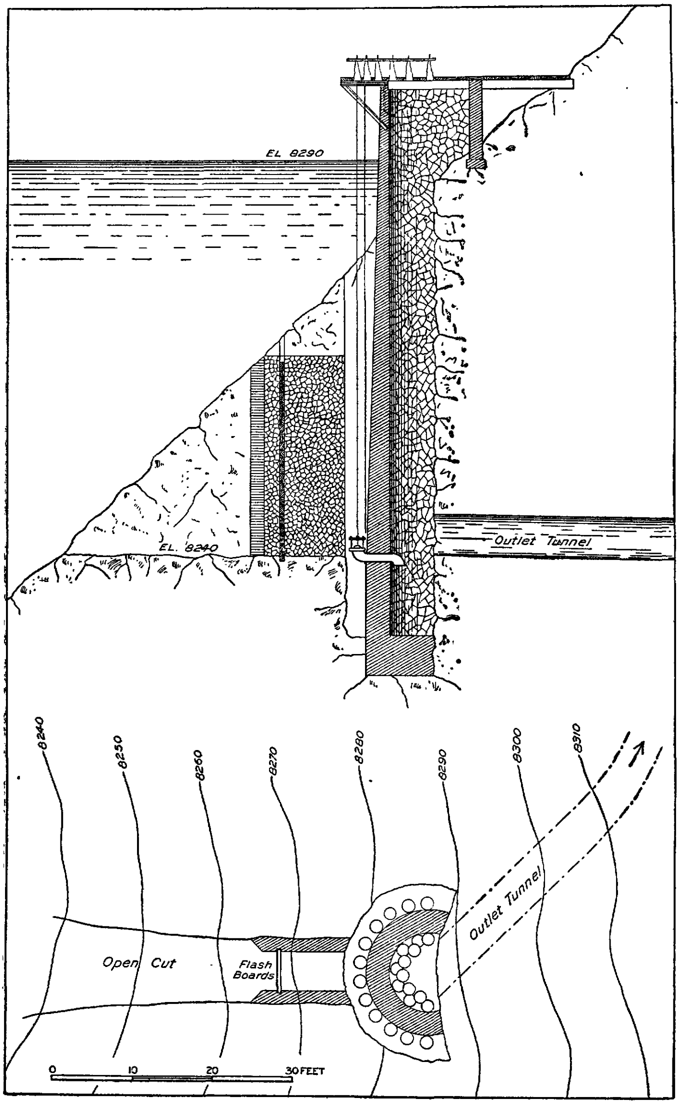


FIG. 13.—Sectional elevation and plan of gate tower for dam proposed by Kern-Rand Electric Power Company.

the most simple and economical manner. The gates are so simple and so easily opened and closed that it has not been considered necessary to provide for their repair under a full head of water in the reservoir. Fig. 12, however, shows a simple and economical way of shutting off the water after it has fallen to an elevation of 8,260 feet, or 35 feet above the base of the dam. This would prevent the necessity of emptying the reservoir for the purpose of making repairs to the gates.

Following are the estimates for three sizes of the dam proposed:

Estimate of cost of a 75-foot dam with slopes 1 to 1 and ¾ to 1.

Loose rock, 73,000 cubic yards; or 43,800 cubic yards solid at $1.50	$65,700.00
Earth, 55,870 cubic yards at $0.25	13,967.50
Extra labor on 5,000 cubic yards laid by hand, at $1	5,000.00
Tunnel, 350 feet at $12	4,200.00
Tower, gates, and connections	15,000.00
Guide walls, etc., at wasteway	15,000.00
	118,867.50
Engineering and contingencies, 10 per cent	11,886.75
Total	130,754.25

Estimate of cost of 75-foot dam with slopes 1½ to 1 and ¾ to 1.

Loose rock, 91,000 cubic yards; or 54,600 cubic yards solid at $1.50	$81,900.00
Earth, 55,870 cubic yards at $0.25	13,967.50
Extra labor on 6,000 cubic yards laid by hand, at $1	6,000.00
Tunnel, 350 feet at $12	4,200.00
Tower, gates, and connections	15,000.00
Guide walls, etc., at wasteway	15,000.00
	136,067.50
Engineering and contingencies, 10 per cent	13,606.75
Total	149,674.25

Estimate of cost of 95-foot dam with slopes 1 to 1 and ¾ to 1.

Loose rock, 110,000 cubic yards; or 66,000 cubic yards solid at $1.50	$99,000
Earth, 70,000 cubic yards at $0.25	17,500
Extra labor on 7,000 cubic yards, at $1	7,000
Tunnel, 350 feet at $12	4,200
Tower, gates, and connections, with bridge to tower	17,000
Guide walls, etc., at wasteway	20,000
	164,700
Engineering and contingencies, 10 per cent	16,470
Total	181,170

The foregoing estimates are based on the supposition that the rock will be hard enough to stand vertically around the tower and that the tunnel will not need lining.

The transmission line from the power plant in sec. 14, T. 25 S., R.

35 E., M. D. M., to Randsburg, 43 miles distant, would be over as fine a country for a pole line as can well be found—easy slopes, virtually unimproved and without tree growth. With very few exceptions a wagon could be driven, without road work, along the transmission line from the power plant to Randsburg. The highest elevation reached on the pole line would be at Walkers Pass, 5,320 feet above sea level, and at that point the snow lasts only a few days and would never interfere with the regular patrol of the line.

The following is an approximate estimate of the cost of generating and transmitting electric current from the South Fork power house, for a delivery in Randsburg of 900 horsepower, with conduit and pole-line capacity for 450 additional horsepower:

Estimate of cost of generating and transmitting electric current from South Fork power house to Randsburg.

Diversion in bed rock and 100 feet of rock channel	$4,000
Regulating gate	1,000
Riveted-steel pipe, 8,000 feet of 30-inch, gage No. 12, at $2.70	21,600
Pipe work in canyon, 8,000 feet	10,000
Flume, 3,500 feet at $3	10,500
Tunnel, 1,300 feet at $10	13,000
Canal in earth, 3,000 feet, with concrete lining	6,750
Canal in rock, 1,594 feet at $1.50 per foot run	2,391
Siphon, 1,000 feet at $3	3,000
Penstock, 4,000 feet at $4	16,000
Water wheels	6,000
Power houses, two, fireproof	6,000
Wire for transmitting current, 900 horsepower, delivered 43 miles	13,000
Telephone	2,000
Line poles (43 miles, 40 to the mile), and placing same	20,000
Electric machinery	30,000
Distribution of current at Randsburg	5,000
	170,241
Contingencies, 15 per cent	24,536
Total	195,777

A landslide has blocked the canyon and created a lake of about 40 acres area on the North Fork of Kern River just below the mouth of Whitney Creek and above the mouth of the Little Kern. This lake, known as Kern Lake, the California State engineering department, in its investigations of the Kern River drainage basin, has considered as a possible reservoir site. At the lower end of the lake the cliffs tower almost vertically above it to heights ranging from 2,000 to 3,000 feet, and estimates have been made for the blasting of large fragments into the dam site, forming a loose rock-fill dam. The capacity of the reservoir at the 220-foot level would be 46,000 acre-feet. The State engineering department considered the possibility of paving the mass of rock thus thrown down to a uniform surface and covering it with asphalt. The width of the canyon at the site is only 100 feet at the bottom and 400 feet at a height of 230 feet above the stream bed. There would be no question about the ability of the drainage basin to fill the reservoir annually, and if it is possible to construct such a dam at this place the site probably would be of value for replenishing the late summer flow for power and irrigation.

RECONNAISSANCE OF YUBA RIVER, CALIFORNIA.

By Marsden Manson.

WATERSHED.

Yuba River is a tributary of Feather River, which it enters at Marysville, 30 miles above its mouth. It drains about 1,357 square miles of the western slope of the Sierra Nevada, comprising portions of Sierra, Nevada, Plumas, and Yuba counties. The extreme length of the watershed is about 60 miles, the extreme width 36 miles. In addition to the length given there are about 11 miles of channel in the valley between the foothills and Feather River. In size Yuba River is fourth in the Sacramento Valley. Its extreme low-water discharge is about 360 cubic feet per second,[1] its mean winter discharge 1,500 cubic feet per second, and its flood discharge 26,000 cubic feet per second.[2] For the lower 10 miles of its course in the foothills the river is greatly clogged with débris from hydraulic-mining camps (estimated at many million cubic yards), and is between levees which have been raised from year to year to meet the overflow caused by the filling up of the area between them. The channel of the river in the lower foothills has been filled with cobbles and gravel to a depth of more than 100 feet. (See Pl. IV, *B*.) From the foothills to the mouth of the river at Marysville the channel is over a surface of gravel, sand, and clay, recently built up from the mines above. The channels are irregular and change from winter to winter and sometimes during the summer. It is therefore impracticable to establish low-water gaging stations which would serve for more than one summer and fall and which would be suitable for winter or flood-stage gagings.

[1] This is not as small as the natural discharge would be. The large mining companies—the South Yuba Canal Company, the North Bloomfield Gravel and Mining Company, the Milton Excelsior Water and Mining Company, the Eureka Lake and Yuba Canal Company, and others—store large volumes of water during the winter and spring months for use during periods of low water in the late summer and the early autumn.

[2] Extreme flood discharge estimated by Mr. Hubert Vischer, Asst. Engr., U. S. Engrs., at 125,000 cubic feet per second. H. R. Doc. No. 431, Fifty-sixth Congress, second session, p. 12.

The changes in the bottom and in the position of the channel are so great that the gagings at the flood stages of the river would be unsatisfactory, and if undertaken from boats would be highly dangerous, if not impossible.

The drainage basin is subdivided into five small basins, namely, North Fork, with a drainage area of 491.6 square miles; Middle Fork, with a drainage area of 218 square miles; South Fork, with a drainage area of 360 square miles; Deer Creek, with a drainage area of 89.6 square miles; and Dry Creek, with a drainage area of 105.5 square miles. In addition to these an area of 92.5 square miles drains into the main stream above the 100-foot contour. Dry Creek joins Yuba River from the north just as it leaves the foothills. The other streams unite in the mountains. The forks are perennial in flow, but the

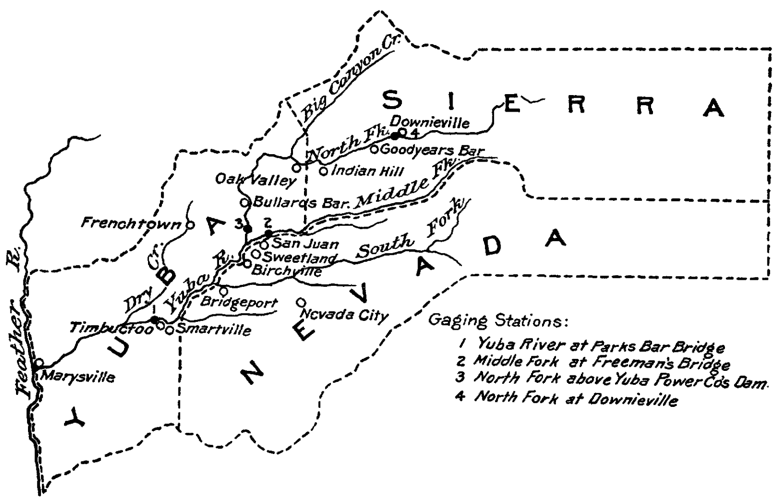
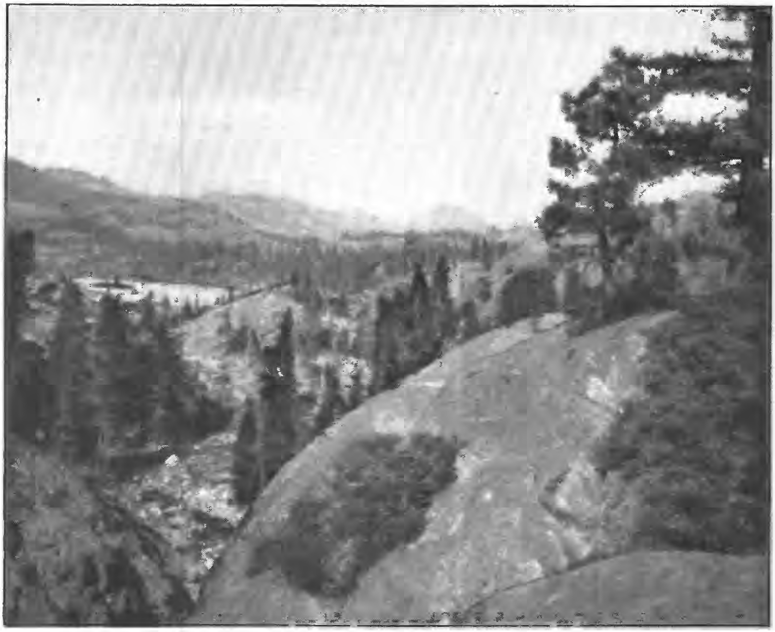


FIG. 14.—Map of Yuba River, showing location of gaging stations.

discharge of the two creeks mentioned (Deer and Dry) becomes insignificant in the late summer and early autumn.

As they merge into the valley the Sierra foothills have an elevation of about 100 feet above tide. The watershed rises gently, in rounded and broken mountains, to the crest of the Sierra, which at the headwaters of the Yuba is at a mean elevation of about 8,200 feet, with peaks rising to a height of 9,100 feet. From Mount Lincoln—a peak common to the watersheds of Yuba, American, and Truckee rivers—to a point about 2½ miles northeast of Mount Webber, the summit of the Sierra divides the watershed of Yuba River from that of Truckee River, which discharges into Humboldt Basin. Farther north from Mount Webber there is a secondary crest which divides the watersheds of Yuba and Feather rivers, the watershed of the latter stream reaching farther east, to a less elevated divide in which the passes are lower than those of the easterly crest.



A. HEAD OF SOUTH FORK OF YUBA RIVER AND LAKE SPAULDING.

B. YUBA RIVER IN THE FOOTHILLS.

TOPOGRAPHY.

The western and lower portions of the drainage area are composed of slates and kindred rock, very much eroded and merging into the gravel and alluvial deposits of the great valley of California. The upper portions of the basin are composed principally of lavas and granites, all deeply eroded, particularly the lavas. Some idea of the magnitude of the erosion may be obtained when it is considered that it has required at least 4,000 (possibly 6,000) cubic miles of denuded materials to fill the great valley of California to its present level, and that most of this has come from the Sierra Nevada.

A stratum of serpentine traverses the watershed of Yuba River in a direction generally parallel with the crest of the Sierra. It is intersected by the North Fork at Goodyears Bar, by the Middle Fork near Moores Flat, and by the South Fork just east of Washington, and leaves the drainage basin of the Yuba, passing near Towle Station on the Central Pacific Railroad. This stratum is generally softer and more easily eroded than adjoining strata, and through it the canyons of the various forks are upon lighter grades than immediately above and below, and they generally are wider. This softer material also controls the loci of longer and more deeply eroded tributaries, which afford approaches to the main canyons for roads and trails. This stratum is of further interest because it is the dividing line between the auriferous strata in the watershed. To the west of it the mines are more extensive, the occurrences of gold-bearing rock to the east being irregular and difficult to trace.

The middle and upper portions of the watersheds of the three forks differ materially. The North Fork rises in lavas which vary much in composition and hardness, but which generally afford a deep soil for timber and shrub growth. The Middle Fork rises in similar lavas and in granite. The mean elevation of the crest of the Sierra at the head of these forks is about 8,200 feet. The main and tributary streams fall rapidly, and their canyons head well up in the mountains. The sides of these canyons are covered with timber and brush, which, with the deep soil, retain the moisture and feed numerous perennial springs. (See Pl. V, *A*.) In the case of the North Fork this is particularly noticeable. The forests of its watershed make it a reliable and constant stream. The mean annual precipitation upon the watersheds of the North and Middle forks is about 54 inches. Warm rains on soft snow sometimes give a high flood run-off, but snow remains on the higher peaks until midsummer. Reservoir sites are not numerous; they will be mentioned later. The headwaters of the South Fork lie upon a broad granite surface, into which the streams have not cut deeply until the main stream reaches a point 16 miles from the summit, where it drops rapidly into a deeply eroded canyon. The eastern or upper edge of the drainage area has a mean elevation about the same as the other forks, but the 5,000-foot contour is about

20 miles to the westward. This broad surface has been denuded by glacial action, and the harder nature of the granite has not permitted a deep soil to form. The area is therefore less heavily timbered than the drainage areas of the other two forks, and its accessibility has caused it to suffer more severely from the ax of the lumberman. This topography gives a broader and more gently sloping surface than characterizes the headwaters of other Sierra Nevada streams. The surface is marked by nearly 100 glacial lakelets and valleys, affording many excellent reservoir sites which have been or are being utilized. This elevated watershed receives a mean annual precipitation of 60 inches, most of which is in the form of snow. The slow melting of the snow maintains the discharge of tributaries until June or July, which, with the natural and artificial reservoirs, makes the South Fork of the Yuba a highly valuable and reliable source of water supply.

NATURAL STORAGE OF WATER IN YUBA RIVER BASIN.

Precipitation upon the drainage basin of Yuba River is dependent upon the southerly or winter extension of the north temperate rain belt. During the summer months the more northerly position of this belt leaves California in the comparatively rainless region between the north temperate and equatorial rain belts. The rains and snows, therefore, fall from October to April, with little or no rainfall of moment from May to September, so that during the latter months the streams depend upon either natural or artificial storage. Natural storage is by snow and the slow run-off of water retained in afforested and brush-covered soils. On the South Fork artificial storage has reached a very effective stage. The precipitation ranges from 20 inches at Marysville, in the valley, to 70 inches at the summit of the Sierra.[1]

Snow storage of water is depended on during the latter part of April and into July, the run-off until June being superabundant for all purposes, but in July it begins to fall below the necessities of dependent industries, and it remains below until the autumnal rains occur. Snow storage has been made a subject of extended observation by Mr. W. F. Englebright, chief engineer of the South Yuba Canal Company, through whose courtesy the writer has been enabled to prepare a most instructive diagram of the accumulation, depth, and rate of melting of snow at Lake Fordyce (fig. 15). This lake has an elevation of 6,500 feet above tide level, and is in a region over which the annual precipitation in rain and melted snow is 70 inches. Snow begins to accumulate late in November, and reaches its maximum depth in packed snow in March. During the winter months the lower readings on the gage rod following higher readings generally indicate a packing of the snow.

[1]These figures are taken from a map prepared, under the writer's direction, for the California Water and Forest Association, showing the drainage areas, the mean annual rainfall, and the distribution of forests throughout the State.

A. CANYON OF MIDDLE FORK OF YUBA RIVER

B. MIDDLE FORK OF YUBA RIVER NEAR FREEMAN'S CROSSING

Melting begins in March and continues quite regularly until the middle of June or early July. Short storms during April and May cause offsets in the curve, which resumes a parallel line. A series of cold and heavy storms in April, 1896, caused the snow to last until July 5, while the clear, warm spring of 1897 caused it to disappear on June 7.

During the latter half of April, by means of daily reports by telephone, Mr. Englebright is enabled, through diagrams upon a larger scale, to approximate to within a few days the duration of the snow supply and the beginning of the draft on the reservoirs. Data and studies of this kind are very valuable, and suggest the importance of stations above the snow line as a means of determining the volume of snow storage available at different seasons and the ratio between the volume stored by snow and that stored by reservoirs. The discharge of the streams is maintained by snow during the spring and for half of

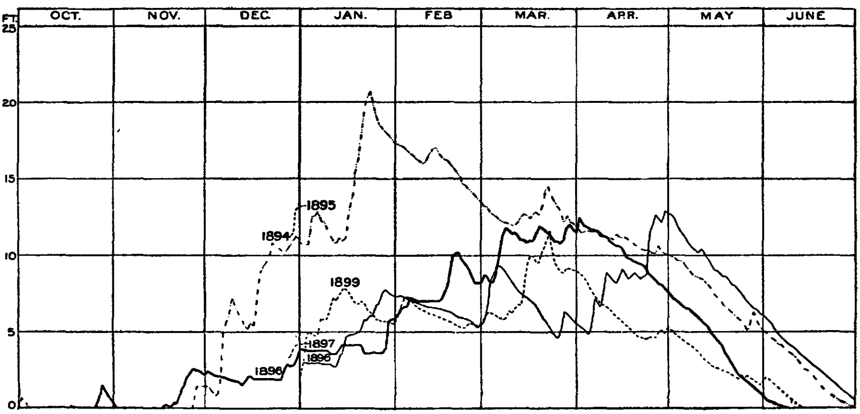


FIG. 15.—Diagram showing depth of snow at Lake Fordyce.

the summer months, and the volume and rate of the discharge can be foretold with reasonable accuracy by daily readings of gages properly located.

ARTIFICIAL STORAGE POSSIBILITIES.

The natural facilities for the storage of storm waters are particularly favorable in the upper third of the drainage basin of the South Fork. The demands for large volumes of water under high pressure to operate the mines in the middle and lower portions of that drainage basin and those on Bear and American rivers were met by the construction of large and expensive canals and storage reservoirs. Just above the great bend north of the head of Bear River and at the head of the steep canyon of the South Fork is a broad, flat, glacial valley which has been converted into a lake by the construction of a stone dam. This lake, known as Lake Spaulding and shown in Pl. IV, *A*, has a capacity of 270,000,000 cubic feet, and is the lower and controlling reservoir of a series embracing the available storage and supply above. This supply is derived from about 120 square miles, upon which the mean annual precipitation in rain and melted snow is about 5 feet. The following is a list of the storage reservoirs:

Storage reservoirs in Yuba River Basin.

Name of reservoir.	Elevation.	Area.	Capacity.	Cost of dam.
	Feet.	*Acres.*	*Gallons.*	
Meadow	7,515	300	1,275,000,000	$75,000
Stirling	7,200	100	340,000,000	20,000
White Rock	7,000	80	225,000,000	5,000
Peak Lakes (three)	6,900	150	1,275,000,000	(*a*)
Fordyce	6,500	474	5,950,000,000	300,000
Lost River	7,000	(*a*)	85,000,000	(*a*)
Fallcreek Lakes (six)	7,000	171	1,020,000,000	(*a*)
Spaulding	4,846	215	2,125,000,000	50,000
Summit Lake	6,800	400	1,938,816,000	30,000
Bear Valley	4,400	60	145,411,200	8,000
Total		1,950	*b* 14,409,227,200	478,000

a Records lost. *b* 1,921,230,293 cubic feet.

The aggregate area of these reservoirs is 3.05 square miles, and they are filled to an average depth of 22.5 feet, thus giving storage for about 12 per cent of the mean annual precipitation upon the tributary area, the remainder going to waste and to swell the floods which devastate the valley. It is possible, by raising the dams and enlarging the canals, to utilize a considerable additional portion of the precipitation. The conditions favorable to the conservation of water on the upper third of the drainage basin of the South Fork are far greater than in the lower two-thirds of that basin or in the basin of the other forks.

On the upper portion of Canyon Creek, a tributary of the South Fork, the Eureka Lake and Yuba Canal Company and the North Bloomfield Gravel and Mining Company have the following storage reservoirs:

Storage reservoirs on upper portion of Canyon Creek.

Name of reservoir.	Area.	Height.	Top length.	Barometric elevation.	Catchment area.	Capacity.	Cost.
	Acres.	*Feet.*	*Feet.*	*Feet.*	*Acres.*	*Cubic feet.*	
Bowman	500.0	100.0	425	5,450	12,093	930,000,000	$151,521
Sawmill Flat	80.6	39.2		5,780		2,000,000	Total amount expended on these dams and reservoirs, $246,000.
Shot Gun Lake	26.2	10.0		6,410		3,423,816	
Island Lake	48.8	12.8		6,690		23,027,558	
Middle Lake	11.2	12.0		6,460		2,395,800	
Crooked Lake	10.3	3.0		6,510		1,600,000	
Round Lake	8.1	11.0		6,590		2,906,630	
Fall Creek				6,690			
Jackson Lake	20.0	5.0		5,410		15,000,000	
Faucherie Lake	90.0	21.0	550	6,060	3,262	58,000,000	8,000
Weaver Lake	83.5	21.8				150,000,000	
Eureka Lake	337.3	68.2	250	6,480	3,170	661,000,000	35,000
Total						1,849,354,804	

The drainage area tributary to these reservoirs is 28.4 square miles, and it receives a total precipitation during an average year of

A. ENGLISH RESERVOIR ON MIDDLE FORK OF YUBA RIVER.

B. SMALL DAM OF ENGLISH RESERVOIR.

4,589,481,600 cubic feet, 1,849,354,804 cubic feet of which is stored, or between one-third and one-half of the mean annual precipitation.

On the Middle Fork there are no reservoirs storing water at the present time. The only site of any importance is that of the Ruyard or English reservoir (see Pl. VI), which has not been in use since the failure of the dam in June, 1883. This site has a capacity of 650,000,000 cubic feet. Weaver Lake is on the watershed of the Middle Yuba, but its catchment area is not large enough to fill it, so it is supplied from the Eureka Lake and Yuba Canal Company's ditch from Canyon Creek, a tributary of the South Yuba, and is included in the foregoing list. At Milton there is a reservoir site with an estimated capacity of 28,000,000 cubic feet. The total storage capacity on the Middle Yuba may be considered to be 678,000,000 cubic feet.

On the North Fork are the dam and headworks of the Browns Valley Irrigation District. (See Pl. VII.) The dam is a well-built crib structure, about 167 feet long on the crest, with a maximum height of 37 feet. The head gates are in concrete. For several miles above the dam the river bed is covered with gravel, sand, and cobbles on a grade slightly less than that of the original stream. This is a feature common to dams upon streams carrying mining débris. The dam thus acts as a retaining wall as well as an overflow weir. Leakage through the débris and dam is slight. The head gates open into a flume 5 feet by 7 feet, on a grade of 13 feet to the mile, and built to carry 300 second-feet of water. The greater portion of the water diverted is used to develop power at the Colgate and Browns Valley power stations of the Bay Counties Power Company, lessees of the Browns Valley Irrigation District rights. This power is transmitted to Marysville, Oroville, Wheatland, Nevada City, Grass Valley, and Sacramento. These plants are synchronized with one on the South Yuba, about 7 miles distant.

On the North Fork there are the following small lakes, which might be developed to an aggregate storage capacity of 500,000,000 cubic feet:

Reservoir sites on the North Fork.

Name of lake.	Area.
	Acres.
Upper Sardine	38.0
Lower Sardine	40.0
Young American	9.0
Volcano	2.5
Packer	7.0
Saxonia	2.5
Deer	5.0
Upper Salmon	30.0
Lower Salmon	50.0
Hawley	11.0
Spencer Lakes (two)	16.0
Sundry small lakes (five, not named)	27.0
Deadmans	3.0
Total	241.0

Assuming that artificial storage on the North Fork and the Middle Fork could be developed to a capacity equal to that above the Lake Spaulding dam, there would then be in service an area of 6.8 square miles with water at an average depth of 26.4 feet, or 5,692,000,000 cubic feet. The mean annual precipitation in the drainage basin of Yuba River is 170,829,000,000 cubic feet. The total ultimate artificial storage is less than 3.3 per cent of this precipitation, and could hardly be recognized in a gaging of the total run-off. Moreover, in the storage of water for industrial purposes the uncertainty of the character of the seasonal rainfall makes it prudent and desirable to permit the reservoirs to fill during the earlier rains, and not leave the husbanding of a supply to possible succeeding rains. Hence it generally happens that when the heavy storms of the late winter and spring months occur the reservoirs are full and the flood wave passes down without being diminished by the reservoirs. This is also true to a limited extent of regions above the snow line, where the unmelted snow constitutes a reservoir of far greater capacity than ordinarily is obtained by building dams. It happens that when late warm rains or rapid melting of the snows occurs the reservoirs are already full, and consequently do not diminish the flood volume.

It would appear, therefore, that however useful artificial reservoirs are for domestic and industrial purposes they can not be relied upon, except under unusual conditions, to decrease the heights of late winter and spring floods, and we must look elsewhere for a solution of that problem.

COMPARISON OF LOW-WATER DISCHARGE FROM A TIMBERED AREA WITH THAT FROM A COMPARATIVELY TREELESS AREA.

On the south fork of the North Fork is a watershed area of 139 square miles, which was gaged on September 19, 1900, after three successive seasons of deficient rainfall, and gave a minimum run-off of 113 second-feet, or 0.8 second-foot per square mile. This area is well covered with timber and brush, and in 120 days it gives a minimum run-off of 1,441,152,000 cubic feet.

The drainage basin of the North Fork is more heavily timbered than the basins of the other forks, and consequently it has a deeper soil, and, although only one-tenth of the total drainage area, it furnishes 75 per cent of the low-water flow of the entire drainage basin above Parks Bar.

On the south fork above Lake Spaulding there is a watershed of 120 square miles, which has heretofore been described as comparatively barren of timber, the timbered areas which once existed having been denuded. (See Pl. VIII, *A*.) The run-off of this area is practically nothing for 120 days of the year, due to the absence of forests and

A. BROWNS VALLEY IRRIGATION DISTRICT DAM FROM ABOVE

B. BROWNS VALLEY IRRIGATION DISTRICT DAM FROM BELOW brush. If this area were afforested and gave a minimum run-off of 0.8 second-foot per square mile, the discharge would be 100 second-feet, equivalent to an effective storage capacity of 1,036,800,000 cubic feet. This minimum low-water discharge of 100 second-feet for 120 days is equivalent to more than half the storage capacity of all the reservoirs above Lake Spaulding dam, which aggregate 1,375,000,000 cubic feet. As the basis of this estimate is extreme low-water discharge, it may be assumed that by afforesting the watershed this costly and extensive system of reservoirs could safely be drawn upon for double their present capacity. As what is true of portions of the watershed is true of the watershed as a whole, aggregating as it does 1,357 square miles, the value of afforesting the area becomes apparent.

It appears to the writer that the solution of the problem of storage of flood waters is not the retention of a small percentage of the storm waters behind dams, but the application of storage over the entire watershed by the systematic protection and extension of forest-covered and brush-covered areas.

DISCHARGE MEASUREMENTS OF YUBA RIVER AND ITS TRIBUTARIES.

The accompanying tables of low-water discharge measurements of Yuba River and its forks are based upon observations and gagings

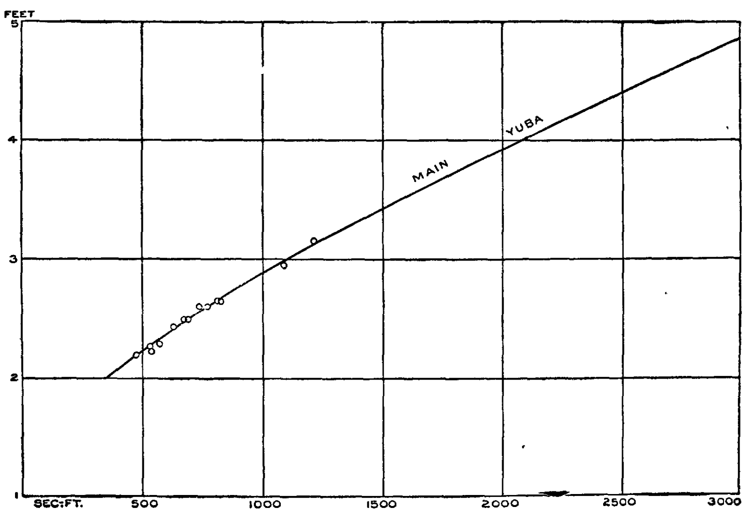


FIG. 16.—Curve showing relation of gage height to discharge of Yuba River.

made by Mr. H. D. H. Connick, under the direction of the writer, during the months of June, July, August, September, and October, 1900. The precipitation during the wet season preceding these gagings was about two-thirds to three-fourths of the mean annual rainfall. The precipitation during the two preceding wet seasons was still further below the normal.

The location of the gaging stations is shown on the map, fig. 14, page 40. The gagings were made with a large Price meter furnished by the United States Geological Survey. The usual method was pursued, namely, the cross section was divided into subsections of 5 feet each, and the velocities were observed for three minutes for each foot of depth. The integral of the discharges thus ascertained divided by the total cross-sectional area determined the mean velocity. The volumes thus determined for various stages were platted as a curve of discharge, using gage heights and discharges as ordinates, from which curve intermediate discharges were estimated to fill out the tables. For discharge curves, see figs. 16, 17, and 18.

Daily discharge of Yuba River at Parks Bar Bridge during the month of July, 1900.

Day.	Gage height.		Mean gage height.	Area of section.	Mean velocity.	Discharge.	
	6 a.m.	6 p.m.					
	Feet.	*Feet.*	*Feet.*	*Square feet.*	*Feet per second.*	*Second-feet.*	*Cubic feet per 24 hours.*
1	2.90	2.80	2.85			970.0	83,808,000
2	2.90	2.90	2.90			1,020.0	88,128,000
3	3.10	2.90	3.00			1,100.0	95,040,000
4	2.80	2.70	2.75			890.0	76,896,000
5	2.70	2.80	2.75			890.0	76,896,000
6	2.60	2.70	2.65			810.0	69,984,000
7	2.60	2.80	2.70			850.0	73,440,000
8	2.70	2.70	2.70			850.0	73,440,000
9	2.60	2.60	2.60			775.0	66,960,000
10	2.60	2.60	2.60			775.0	66,960,000
11	2.70	2.60	2.65	181.5	4.52	820.8	70,917,120
12	2.70	2.50	2.60	180.0	4.50	810.5	70,027,200
13	2.70	2.50	2.60	171.1	4.39	773.8	66,856,320
14	2.60	2.50	2.55			730.0	63,072,000
15	2.60	2.50	2.55			730.0	63,072,000
16	2.50	2.40	2.45			660.0	57,024,000
17	2.50	2.40	2.45			660.0	57,024,000
18	2.50	2.40	2.45			660.0	57,024,000
19	2.40	2.40	2.40			620.0	53,568,000
20	2.40	2.30	2.35			580.0	50,112,000
21	2.40	2.30	2.35			580.0	50,112,000
22	2.40	2.40	2.40	163.6	3.80	622.2	53,758,080
23	2.40	2.50	2.45	173.3	3.91	685.8	59,253,120
24	2.50	2.40	2.45	169.3	3.97	672.7	57,025,280
25	2.50	2.40	2.45			660.0	57,024,000
26	2.40	2.30	2.35			580.0	50,112,000
27	2.40	2.30	2.35			580.0	50,112,000
28	2.40	2.30	2.35			580.0	50,112,000
29	2.40	2.30	2.35			580.0	50,112,000
30	2.30	2.40	2.35			580.0	50,112,000
31	2.30	2.30	2.30			545.0	47,088,000
Total							1,955,059,000

A. SECOND-GROWTH FOREST DESTROYED BY FIRE.

B. HEAD OF SOUTH YUBA CANAL COMPANY'S DITCH.

Daily discharge of Yuba River at Parks Bar Bridge during the month of August, 1900.

Day.	Gage height. 6 a.m.	Gage height. 6 p.m.	Mean gage height.	Area of section.	Mean velocity.	Discharge.	Discharge.
	Feet.	*Feet.*	*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	2.30	2.30	2.30			545.0	47,088,000
2	2.20	2.30	2.25			510.0	44,064,000
3	2.20	2.20	2.20			480.0	41,472,000
4	2.20	2.20	2.20			480.0	41,472,000
5	2.20	2.20	2.20			480.0	41,472,000
6	2.20	2.20	2.20			480.0	41,472,000
7	2.30	2.20	2.25	151.8	3.54	536.8	46,379,520
8	2.30	2.20	2.25	158.7	3.59	571.2	49,251,680
9	2.30	2.20	2.25			510.0	44,064,000
10	2.20	2.10	2.15			440.0	38,016,000
11	2.20	2.20	2.20			480.0	41,472,000
12	2.10	2.20	2.15			440.0	38,016,000
13	2.20	2.30	2.25			510.0	44,064,000
14	2.20	2.30	2.25	153.0	3.49	535.0	46,094,400
15	2.10	2.20	2.15			440.0	38,016,000
16	2.20	2.20	2.20			480.0	41,472,000
17	2.10	2.10	2.10			400.0	34,560,000
18	2.10	2.20	2.15			440.0	38,016,000
19	2.10	2.20	2.15			440.0	38,016,000
20	2.30	2.20	2.25			510.0	44,064,000
21	2.30	2.30	2.30			545.0	47,088,000
22	2.40	2.30	2.35			580.0	50,112,000
23	2.30	2.20	2.25			510.0	44,064,000
24	2.30	2.20	2.25			510.0	44,064,000
25	2.20	2.10	2.15			440.0	38,016,000
26	2.10	2.10	2.10			400.0	34,560,000
27	2.20	2.10	2.10			400.0	34,560,000
28	2.10	2.10	2.10			474.2	40,970,880
29	2.10	2.10	2.10			400.0	34,560,000
30	2.20	2.20	2.20			480.0	41,472,000
31	2.20	2.10	2.15			440.0	38,016,000
Total							1,286,151,520

Daily discharge of Yuba River at Parks Bar Bridge during the month of September, 1900.

Day.	Gage height. 6 a.m.	Gage height. 6 p.m.	Mean gage height.	Area of section.	Mean velocity.	Discharge.	Discharge.
	Feet.	*Feet.*	*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	2.10	2.10	2.10			400.0	34,560,000
2	2.10	2.10	2.10			400.0	34,560,000
3	2.10	2.10	2.10			400.0	34,560,000
4	2.10	2.20	2.15			440.0	38,016,000
5	2.40	2.40	2.40			620.0	53,568,000
6	2.30	2.30	2.30			545.0	47,088,000
7	2.20	2.20	2.20			470.0	40,608,000
8	2.20	2.20	2.20			470.0	40,608,000
9	2.20	2.10	2.15			440.0	38,016,000
10	2.10	2.10	2.10			400.0	34,560,000
11	2.30	2.20	2.25			510.0	44,064,000
12	2.20	2.30	2.25			510.0	44,064,000
13	2.30	2.50	2.40			620.0	53,568,000
14	2.60	2.60	2.60	178.5	4.12	735.6	63,555,840
15	2.40	2.40	2.40			620.0	53,568,000
16	2.40	2.30	2.35			580.0	50,112,000
17	2.20	2.20	2.20			470.0	40,618,000
18	2.20	2.20	2.20			470.0	40,618,000
19	2.20	2.20	2.20			470.0	40,618,000
20	2.20	2.10	2.15			440.0	38,016,000
21	2.10	2.10	2.10			400.0	34,560,000
22	2.10	2.10	2.10			400.0	34,560,000
23	2.00	2.00	2.00			360.0	31,104,000
24	2.00	2.00	2.00			360.0	31,104,000
25	2.00	2.00	2.00			360.0	31,104,000
26	2.10	2.10	2.10			400.0	34,560,000
27	2.00	2.00	2.00			360.0	31,104,000
28	2.00	2.00	2.00			360.0	31,104,000
29	2.00	2.00	2.00			360.0	31,104,000
30	2.00	2.00	2.00			360.0	31,104,000
Total							1,158,249,840

Daily discharge of Yuba River at Parks Bar Bridge during the month of October, 1900.

Day.	Gage height.		Mean gage height.	Discharge.	
	6 a. m.	6 p. m.			
	Feet.	*Feet.*	*Feet.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	2.00	2.00	2.00	360	31,104,000
2	2.00	2.00	2.00	360	31,104,000
3	2.80	3.40	3.10	1,200	103,680,000
4	3.20	4.90	4.05	2,140	184,896,000
5	4.60	4.60	4.60	2,720	235,008,000
6	4.20	4.00	4.10	2,200	190,080,000
7	3.70	3.60	3.65	1,730	149,472,000
8	3.50	3.50	3.50	1,595	137,808,000
9	3.50	3.50	3.50	1,595	137,808,000
10	3.50	3.40	3.45	1,540	133,056,000
11	3.40	3.40	3.40	1,480	127,872,000
12	3.60	3.40	3.50	1,595	137,808,000
13	3.40	3.40	3.40	1,480	127,872,000
Total					1,727,568,000

NOTE.—On the evening of October 4 gage No. 1 was washed out. All subsequent readings were made on gage No. 2. Equation: Gage No. 2+2.2=gage No. 1. Thus: 2.7+2.2=4.9, gage height.

Daily discharge of North Fork of Yuba River at Yuba Power Company's dam during the month of July, 1900.

Day.	Gage height.		Mean gage height.	Area of section.	Mean velocity.	Discharge.	
	6 a. m.	6 p. m.					
	Feet.	*Feet.*	*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	2.07	2.07	2.07			630.0	54,432,000
2	2.06	2.06	2.06			625.0	54,000,000
3	2.05	2.05	2.05	203.1	2.98	606.0	52,358,400
4	2.05	2.00	2.03			610.0	52,704,000
5	2.00	2.00	2.00			595.0	51,408,000
6	1.95	2.00	1.98	196.4	2.88	566.8	48,971,520
7	2.00	2.00	2.00			595.0	51,408,000
8	1.95	1.95	1.95			560.0	48,384,000
9	1.90	1.85	1.88			520.0	44,928,000
10	1.85	1.80	1.83			490.0	42,336,000
11	1.80	1.80	1.80			470.0	40,608,000
12	1.75	1.75	1.75			440.0	38,016,000
13	1.75	1.75	1.75			440.0	38,016,000
14	1.75	1.75	1.75			440.0	38,016,000
15	1.75	1.75	1.75			440.0	38,016,000
16	1.75	1.75	1.75			440.0	38,016,000
17	1.70	1.70	1.70	160.3	2.73	437.7	37,817,280
18	1.70	1.70	1.70	157.0	2.66	418.7	36,175,680
19	1.70	1.70	1.70			410.0	35,424,000
20	1.65	1.65	1.65			380.0	32,832,000
21	1.65	1.65	1.65			380.0	32,832,000
22	1.65	1.70	1.68			400.0	34,560,000
23	1.70	1.70	1.70			410.0	35,424,000
24	1.70	1.65	1.68			400.0	34,560,000
25	1.65	1.65	1.65			380.0	32,832,000
26	1.65	1.65	1.65			380.0	32,832,000
27	1.65	1.65	1.65	158.5	2.31	366.1	31,631,040
28	1.60	1.60	1.60			350.0	30,240,000
29	1.60	1.60	1.60	159.2	2.33	371.4	32,088,960
30	1.60	1.60	1.60			350.0	30,240,000
31	1.60	1.60	1.60	159.1	2.28	363.9	31,440,960
Total							1,232,548,840

Daily discharge of North Fork of Yuba River at Yuba Power Company's dam during the month of August, 1900.

Day.	Gage height. 6 a. m.	Gage height. 6 p. m.	Mean gage height.	Area of section.	Mean velocity.	Discharge.	
	Feet.	*Feet.*	*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	1.60	1.60	1.60			350.0	30,240,000
2	1.55	1.55	1.55			320.0	27,648,000
3	1.55	1.55	1.55			320.0	27,648,000
4	1.55	1.55	1.55			320.0	27,648,000
5	1.55	1.55	1.55			320.0	27,648,000
6	1.55	1.55	1.55			320.0	27,648,000
7	1.55	1.55	1.55			320.0	27,648,000
8	1.55	1.55	1.55			320.0	27,648,000
9	1.55	1.55	1.55	155.4	2.11	328.4	28,373,760
10	1.55	1.55	1.55	153.0	2.10	321.7	27,794,880
11	1.55	1.55	1.55			320.0	27,648,000
12	1.55	1.55	1.55			320.0	27,648,000
13	1.55	1.55	1.55			320.0	27,648,000
14	1.55	1.55	1.55			320.0	27,648,000
15	1.55	1.55	1.55			320.0	27,648,000
16	1.55	1.55	1.55			320.0	27,648,000
17	1.55	1.55	1.55			320.0	27,648,000
18	1.55	1.55	1.55			320.0	27,648,000
19	1.50	1.50	1.50			300.0	25,920,000
20	1.50	1.50	1.50			300.0	25,920,000
21	1.50	1.50	1.50			300.0	25,920,000
22	1.50	1.50	1.50			300.0	25,920,000
23	1.50	1.50	1.50			300.0	25,920,000
24	1.50	1.50	1.50			300.0	25,920,000
25	1.50	1.50	1.50			300.0	25,920,000
26	1.50	1.50	1.50			300.0	25,920,000
27	1.49	1.49	1.49			295.0	25,488,000
28	1.49	1.48	1.49			295.0	25,488,000
29	1.48	1.48	1.48	145.8	1.93	282.1	24,373,440
30	1.47	1.47	1.47	142.7	1.99	284.6	24,589,440
31	1.47	1.47	1.47			280.0	24,192,000
Total							814,971,520

Daily discharge of North Fork of Yuba River at Yuba Power Company's dam during the month of September, 1900.

Day.	Gage height. 6 a. m.	Gage height. 6 p. m.	Mean gage height.	Discharge.	
	Feet.	*Feet.*	*Feet.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	1.46	1.46	1.46	270	23,328,000
2	1.46	1.46	1.46	270	23,328,000
3	1.46	1.45	1.46	270	23,328,000
4	1.46	1.47	1.47	280	24,192,000
5	1.48	1.49	1.49	295	25,448,000
6	1.49	1.50	1.50	300	25,920,000
7	1.50	1.50	1.50	300	25,920,000
8	1.49	1.49	1.49	295	25,488,000
9	1.49	1.48	1.49	295	25,488,000
10	1.47	1.47	1.47	280	24,192,000
11	1.47	1.48	1.48	280	24,192,000
12	1.49	1.49	1.49	295	25,488,000
13	1.50	1.56	1.53	310	26,784,000
14	1.61	1.60	1.61	355	30,672,000
15	1.55	1.50	1.53	310	26,784,000
16	1.50	1.50	1.50	300	25,920,000
17	1.49	1.49	1.49	295	25,488,000
18	1.48	1.48	1.48	280	24,192,000
19	1.47	1.47	1.47	280	24,192,000
20	1.47	1.46	1.47	280	24,192,000
21	1.46	1.46	1.46	270	23,328,000
22	1.45	1.45	1.45	266	22,982,400
23	1.44	1.43	1.44	265	22,896,000
24	1.44	1.45	1.45	266	22,982,400
25	1.45	1.46	1.46	270	23,328,000
26	1.47	1.48	1.48	280	24,192,000
27	1.47	1.48	1.48	280	24,192,000
28	1.48	1.47	1.48	280	24,192,000
29	1.47	1.47	1.47	280	24,192,000
30	1.46	1.46			
Total					710,830,800

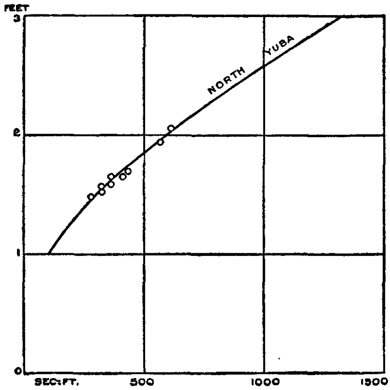


FIG. 17.—Curve showing relation of gage height to discharge of North Fork of Yuba River.

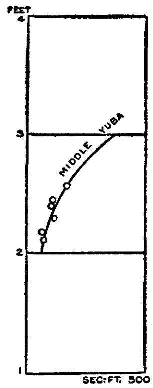


FIG. 18.—Curve showing relation of gage height to discharge of Middle Fork of Yuba River.

Daily discharge of North Fork of Yuba River at Yuba Power Company's dam during the month of October, 1900.

Day.	Gage height. 6 a. m.	Gage height. 6 p. m.	Mean gage height.	Discharge.	
	Feet.	Feet.	Feet.	Sec.-ft.	Cu. ft. per 24 hrs.
1	1.46	1.47	1.47	280	24,192,000
2	1.48	1.50	1.49	295	25,488,000
3	1.99	2.40	2.19	720	62,208,000
4	1.93	2.15	2.04	610	52,704,000
5	2.68	2.70	2.69	1,080	93,312,000
6	2.12	1.95	2.03	610	52,704,000
7	1.81	1.80	1.80	470	40,608,000
8	1.70	1.68	1.69	405	34,992,000
9	1.67	1.75	1.71	410	35,424,000
10	1.64	1.71	1.68	400	34,560,000
11	1.60	1.70	1.65	350	32,832,000
12	1.64	1.70	1.67	390	33,696,000
13	1.65	1.68	1.67	390	33,696,000
Total					556,416,000

Daily discharge of Middle Fork of Yuba River at Freeman's bridge during the month of July, 1900.

Day.	Gage height.		Mean gage height.	Area of section.	Mean velocity.	Discharge.	
	6 a. m.	6 p. m.					
	Feet.	*Feet.*	*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1			2.40	63.0	3.03	190.8	16,485,120
2			2.38			189.0	15,329,600
3			2.35	59.9	3.00	179.9	15,543,360
4			2.33	58.1	3.18	184.9	15,975,360
5			2.40			190.0	16,416,000
6	2.45	2.60	2.53			150.0	12,960,000
7	2.60	2.60	2.60	62.6	2.58	161.7	13,970,880
8	2.60	2.45	2.53			150.0	12,960,000
9	2.45	2.45	2.45			130.0	11,232,000
10	2.45	2.40	2.43			125.0	10,810,000
11	2.40	2.40	2.40			120.0	10,368,000
12	2.40	2.40	2.40			120.0	10,368,000
13	2.30	2.30	2.30			100.0	8,640,000
14	2.30	2.30	2.30			100.0	8,640,000
15	2.30	2.30	2.30			100.0	8,640,000
16	2.30	2.40	2.35			110.0	9,504,000
17	2.30	2.40	2.35			110.0	9,504,000
18	2.30	2.35	2.33			108.0	9,331,200
19	2.45	2.40	2.43			125.0	10,810,000
20	2.35	2.35	2.35			110.0	9,504,000
21	2.35	2.40	2.38			119.0	10,281,600
22	2.35	2.40	2.38			119.0	10,281,600
23	2.35	2.45	2.40			120.0	10,368,000
24	2.40	2.35	2.38			119.0	10,281,600
25	2.35	2.40	2.38			119.0	10,281,600
26	2.35	2.35	2.35			110.0	9,504,000
27	2.35	2.40	2.38			119.0	10,281,600
28	2.35	2.34	2.35			110.0	9,504,000
29	2.30	2.35	2.33	49.6	2.20	109.2	9,434,880
30	2.25	2.30	2.28			90.0	7,776,000
31	2.20	2.20	2.20			80.0	6,912,000
Total							341,898,400

Daily discharge of Middle Fork of Yuba River at Freeman's bridge during the month of August, 1900.

Day.	Gage height.		Mean gage height.	Area of section.	Mean velocity.	Discharge.	
	6 a. m.	6 p. m.					
	Feet.	*Feet.*	*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	2.20	2.20	2.20			80.0	6,912,000
2	2.15	2.20	2.18			79.0	6,825,600
3	2.15	2.15	2.15			75.0	6,480,000
4	2.15	2.15	2.15			75.0	6,480,000
5	2.15	2.15	2.15			75.0	6,480,000
6	2.15	2.15	2.15			75.0	6,480,000
7	2.15	2.15	2.15			75.0	6,480,000
8	2.15	2.15	2.15			75.0	6,480,000
9	2.15	2.15	2.15			75.0	6,480,000
10	2.15	2.15	2.15			75.0	6,480,000
11	2.15	2.15	2.15	36.5	2.17	79.3	6,851,520
12	2.15	2.15	2.15	36.7	2.13	78.1	6,747,840
13	2.15	2.15	2.15			75.0	6,480,000
14	2.15	2.15	2.15			75.0	6,480.000
15	2.15	2.15	2.15			75.0	6,480,000
16	2.15	2.15	2.15			75.0	6,480,000
17	2.15	2.15	2.15			75.0	6,480,000
18	2.15	2.15	2.15			75.0	6,480,000
19	2.15	2.15	2.15			75.0	6,480,000
20	2.15	2.15	2.15			75.0	6,480,000
21	2.15	2.15	2.15			75.0	6,480,000
22	2.15	2.15	2.15			75.0	6,480,000
23	2.15	2.15	2.15			75.0	6,4[illegible],000
24	2.15	2.15	2.15			70.0	6,[illegible]48,000
25	2.10	2.10	2.10			70.0	6,048,000
26	2.10	2.10	2.10			70.0	6,048,000
27	2.10	2.10	2.10			70.0	6,048,000
28	2.10	2.10	2.10			70.0	6,048,000
29	2.10	2.10	2.10	31.2	2.22	69.26	5,984,064
30	2.10	2.10	2.10	30.5	2.22	67.7	5,849,280
31	2.10	2.10	2.10				
Total							192,530,304

Daily discharge of Middle Fork of Yuba River at Freeman's bridge during the month of September, 1900.

Day.	Gage height.		Mean gage height.	Area of section.	Mean velocity.	Discharge.	
	6 a. m.	6 p. m.					
	Feet.	*Feet.*	*Feet.*	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	2.10	2.10	2.10			70.0	6,048,000
2	2.10	2.05	2.08			68.0	5,875,000
3	2.00	2.00	2.00			60.0	5,184,000
4	2.00	2.00	2.00			60.0	5,184,000
5	2.05	2.05	2.05			65 0	5,616,000
6	2.05	2.05	2.05				5,616,000
7	2.05	2.10	2.08			68.0	5,875,000
8	2.05	2.05	2.05			65.0	5,616,000
9	2.05	2.05	2.05			65.0	5,616,000
10	2.00	2.00	2.00			60.0	5,184,000
11	2.00	2.05	2.03			62.0	5,356,800
12	2.05	2.05	2.05			65.0	5,616,000
13	2.15	2.35	2.25			90.0	7,776,000
14	2.30	2.30	2.30			100.0	8,640,000
15	2.20	2.20	2.20			80.0	6,912,000
16	2.20	2.20	2.20			80.0	6,912,000
17	2.15	2.15	2.15			75.0	6,480,000
18	2.15	2.15	2.15	27.4	2.34	64.2	5,546,880
19	2.15	2.15	2.15			75.0	6,480,000
20	2.10	2.10	2.10			70.0	6,048,000
21	2.00	2.00	2.00			60.0	5,184,000
22	2.00	2.00	2.00			60.0	5,184,000
23	2.00	2.00	2.00			60.0	5,184,000
24	2.00	2.00	2.00			60.0	5,184,000
25	2.00	2.00	2.00			60.0	5,184,000
26	2.00	2.00	2.00			60.0	5,184,000
27	2.00	2.00	2.00			60.0	5,184,000
28	2.00	2.00	2.00			60.0	5,184,000
29	2.00	2.00	2.00			60.0	5,184,000
30	2.00	2.00	2.00			60.0	5,184,000
Total							173,421,680

Discharge of Middle Fork of Yuba River at Freeman's bridge during the month of October, 1900.

Day.	Gage height.		Mean gage height.	Discharge.	
	6 a. m.	6 p. m.			
	Feet.	*Feet.*	*Feet.*	*Sec.-ft.*	*Cu. ft. per 24 hrs.*
1	2.00	2.00	2.00	60	5,184,000
2	2.00	2.00	2.00	00	5,184,000
3	2.45	2.45	2.45	130	11,232,000
4	2.40	2.50	2.45	130	11,232,000
5	3.00	3.00	3.00	360	21,104,000
6	2.00	2.50	2.25	90	7,776,000
7	2.45	2.35	2.40	120	10,368,000
8	2.30	2.20	2.25	90	7,776,000
9	2.20	2.20	2.20	80	6,912,000
10	2.15	2.20	2.17	78	6,739,200
11	2.00	2.15	2.08	68	5,875,000
12	2.00	2.15	2.08	68	5,875,000
13	2.00	2.00	2.00	60	5,184,000
Total					110,441,200

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