LOW-FLOW FORECASTS ON ROGUE RIVER

By

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The need for forecasts of minimum flow volume and dates has been clearly expressed by Mr. Neal Shaffer, Manager of the Grants Pass Irrigation District, in the paper just presented.

The data and methods discussed in this paper are offered as a working tool to aid the management of the Grants Pass Irrigation District in evaluating its seasonal water supplies. This is one more in the series of studies in which the Soil Conservation Service cooperates with irrigation water users in Oregon by furnishing appropriate water supply forecasts at more than 70 stream stations.

The problem confronting the Grants Pass Irrigation District is renoted: When the flow of the Rogue River drops below 900 cfs at Savage Rapids Dam (a diversion structure belonging to the district) there is no longer sufficient water to meet all requirements. The district must begin a rotation of pumping to the two upper canals.

Since flows of Rogue River are not measured at Savage Rapids Dam, analysis of records is made about 18 miles upstream at the Raygold Dam stream gaging station. Several small tributaries including Sams, Kane, Galls, Sardine, Foots, Birdseye, Ward, Evans and Savage Creeks enter the Rogue between these two stations. Evans Creek is the largest of these, but, like all the others, this stream makes no important contribution to the river in the low-flow months of July, August and September. The Raygold Station therefore serves satisfactorily as a representation of the flow of Savage Rapids Dam.

Elevation at Savage Rapids Dam is 969 feet and at Raygold Dam is 1122 feet above mean sea level. The area of the watershed above Raygold is 2020 square miles. The watershed is moderately to heavily timber-covered and reaches to high elevations of 8000 feet along the summit of the Cascade Mountains in the immediate vicinity of Crater Lake and to 9497 feet at Mt. McLoughlin.

Published records of streamflow indicate that minimum day flows of 900 cfs or less have occurred in only 8 out of 54 years in the period 1906 through 1959. Momentary flows may frequently be even lower due to regulation in the hydro-power generating plant immediately upstream but these flows have not been considered in this study since they are of very short duration.

FORECAST PROCEDURE NO. 1

Attempts by Soil Conservation Service in the late forties to forecast the occurrence of minimum flows of 900 cfs or less were based on the relation between volume flow of the river for the April-July period at Raygold and the minimum flow in each irrigation season. In Table No. 1 this relationship is computed for the 54 years 1906 through 1959. The resulting equation has a standard error of estimate of plus or minus 139 at the mean of 1098 cfs. The coefficient of correlation is 0.756 and the average forecast error is 10.6 percent. Maximum errors in forecasting back on this relationship are +31 and -23 percent.

FORECAST PROCEDURE NO. 2

In order to avoid the additional errors involved in forecasting the low flow from a <u>forecast</u> of water volume (Procedure No. 1), a direct relation was established between water equivalent of snow on April 1 at Diamond Lake Snow Course and the subsequent minimum day flow. A total of 31 observations are available for this comparison. In this relation (Table No. 2) the coefficient of correlation is 0.65 and the standard error of estimate is plus or minus 183 at the mean of 1077 cfs. Average forecast error is 12 percent with maximum errors of +48 and -29 percent.

DISCUSSION OF LOW FLOW FORECAST RESULTS

It may be pointed out (See Table No.3) that forecasts by Procedure No. 1 of the 8 years of critical low flow are, with one exception, all positive in error--the average error being 10.4 percent. Results of forecasting by Procedure No. 2 for the critically low years are again, with the same single exception, all positive in error and the average error is 16.5 percent. Neither of these procedures is precise as

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TABLE I

MINIMUM DAILY FLOW ROGUE RIVER RELATED TO APRIL-JULY DISCHARGE

Water Year	(X) April-July Discharge Thous. Acre Feet	(Y) Minimum Day Flow c.f.s.	Estimated Y	Error (Percent)
1906	851	1230	1163	- 5
1907	1026	1270	1284	+ 1
1908	860	1190	1169	- 2
1909	673	1320	1040	-21
1910	626	1180	1007	-15
1911	771	1180	1108	- 6
1912	973	1250	1243	- 0
1913	1025	1180	1284	+ 9
1914	658	1180	1029	-13
1915	540	960	948	- 1
1916	759	1170	1099	- 6
1917	1304	1230	1477	+20
1918	526	1060	938	-12
1919	915	1020	1207	+18
1920	634	937	1013	+ 8
1921	921	1530	1260	-20
1922	901	1200	1198	- 0
1923	533	1050	981	- 7
1924	367	813	828	+ 2
1925	700	1110	1058	- 5
1926	259	770	774	+ 1
1927	827	1020	1146	+12
1928	702	1010	1060	+ 5
1929	603	822	991	+21
1930	339	740	808	+ 9
1931	318	615	794	+29
1932	903	920	1199	+30
1933	1020	1160	1280	+10
1934	320	734	795	+ 8
1935	774	936	1110	+19
1936	728	976	1078	+10
1937	1033	984	1289	+31
1938	1051	1210	1302	+ 8
1939	591	904	983	+ 9
1940	494	812	916	+13
1941	453	895	894	0
1942	635	902	1013	+12
1943	854	1310	1165	-11
1944	580	950	975	+ 3
1946	801	998	1138	+13
1946	774	1180	1110	- 6
1947	554	1020	957	- 5
1948	958	1190	1237	+ 4
1949	878	1130	1182	+ 5
1950	900	1209	1197	- 0
1951	727	1300	1077	-17
1952	1150	1480	13[illegible]0	- 7
1953	1070	1530	1315	-14
1954	804	1390	1131	-19
1955	703	1000	1161	+16
1956	1097	1480	1134	-23
1957	778	1220	1113	- 9
1958	897	1350	1195	-11
1959	558	1060	960	- 9
Average	757	1098	--	10.6

$Y = 573.399 + .693X$ $r = 0.756$ $Se = \pm 139$ at the mean of 1098

TABLE II

MINIMUM DAILY FLOW ROGUE RIVER RELATED TO APRIL-JULY DISCHARGE

Water Year	(X) Snow-held Water Diamond Lake April 1st (inches)	(Y) Minimum Day Flow C.F.S.	Estimated Y	Error (Percent)
1929	9.4	822	917	+12
1930	3.5	740	834	+13
1931	9.0	616	912	+48
1932	23.8	920	1121	+22
1933	33.0	1160	1251	+ 8
1934	1.4	734	804	+10
1935	10.2	936	928	- 1
1936	19.2	976	1056	+ 8
1937	23.2	984	1112	+13
1938	33.1	1210	1252	+ 3
1939	19.8	904	1064	+18
1940	9.8	812	923	+14
1941	6.7	895	879	- 2
1942	12.1	902	955	+ 6
1943	31.3	1310	1227	- 6
1944	10.6	950	934	- 2
1945	17.6	998	1033	+ 4
1946	35.9	1180	1292	+ 9
1947	12.7	1020	964	- 6
1948	25.6	1190	1146	- 4
1949	30.9	1130	1221	+ 8
1950	27.7	1200	1176	- 2
1951	40.7	1300	1360	+ 5
1952	32.5	1480	1244	-16
1953	28.0	1530	1180	-23
1954	23.2	1390	1112	-20
1955	34.7	1000	1275	+28
1956	18.8	1480	1050	-29
1957	25.2	1220	1141	- 6
1958	11.9	1350	953	-29
1959	19.8	1060	1064	0
Average	20.7	1077	--	12

Y = 784.240 + 14.143X   r = 0.65   Se = ±183 at the mean of1077

TABLE III

RESULTS OF FORECASTS OF MINIMUM DAY FLOW

Forecasts for Years of Flow Dropping Below 900 c.f.s.

Water Year	Observed Flow c.f.s.	Procedure #1 c.f.s	Error (Percent)	Procedure #2 c.f.s	Error (Percent)
1924	813	828	+ 2	--	--
1926	770	774	+ 1	--	--
1929	822	991	+21	917	+12
1930	740	808	+ 9	834	+13
1931	616	794	+29	912	+48
1934	734	795	+ 8	804	+10
1940	812	916	+13	923	+14
1941	895	894	0	879	- 2
Average Error)percent(			10.4		16.5

as a forecast but they each serve as indicators to the irrigation district management of potential trouble ahead.

Procedure No. 1 will be preferable provided relatively accurate forecasts of April-July streamflow are available for use as the independent variable. (Such forecasts have been provided in the Rogue River basin since 1952 in the monthly report of Snow Surveys and Water Supply Forecasts for Oregon published by the Soil Conservation Service of the U. S. Department of Agriculture in cooperation with Oregon Agricultural Experiment Station and Oregon State Engineer.)

FORECAST OF DATE OF LOW FLOW - PROCEDURE NO. 3

The previous forecast procedures do not indicate date of expected low flow. To determine probable date of low flow, the recession hydrograph for the dryer years was plotted on a daily flow basis. In this plotting the recession curve was always very flat as it dropped past the 900 cfs point. Conversely, it was very steep as it moved downward past the 2000 cfs point. There appeared to be far more possibility of forecasting the 2000 cfs point because it was always well defined.

A scatter diagram of this relationship shows a definite tendency toward a survilinear relationship. Since the down-curving portion of the data occurs only in the dry years evidencing the lowest flows which are of special concern herein, it seems practical to develop a linear relationship for the low flow years rather than the more complicated curvilinear relationship for all years.

Therefore, as shown in Tables No. 4A and 4B, two curves were fitted to the apparent curvilinear relationship between volume flow (April-July) of the Rogue at Raygold and the date (coded) on which the recession hydrograph dropped below 2000 cfs for the last time in the season. One curve, 4A, was computed for the data at and below 500,000 acre feet and the other curve, 4B, was computed for the data above 500,000 acre feet.

Equation 4A is of most interest since it contains the low flows of historical critical seasons. With only 7 points to define it, it has a standard error of estimate of plus or minus 20 days at the mean of 44. The coefficient of correlation is 0.82 and the average forecast error is 14.4 days. Maximum error in forecasting back on this relationship is 29 days.

Equation 4B, with 46 observations, has a standard error of estimate of plus of minus 10.9 days at the mean of 108 days. The coefficient of correlation is 0.771 and the average forecast error is 8.3 days. Maximum forecast error is 35 days.

Equations 4A and 4B forecast only the coded number of days after March 20th when the recession hydrograph last drops below 2000 cfs. It has been determined by observing data from the 8 lowest years of flow (Table 5) that an average of 58 days elapse between the 2000 cfs and 900 cfs points on those hydrographs. To obtain the date on which the recession is expected to drop below 900 cfs 58 days are added to the previous forecast date. Actually the elapsed number of days varies from 32 to 76 days.

DISCUSSION OF FORECASTS OF LOW FLOW DATE

Forecasts of the date of low flow (Table No. 6) reaching 900 cfs, using the methods outlined above and forecasting back, vary on the average 13.5 days from the actual date with a maximum error of 28 days.

Snow-pack conditions in 1961, as of date of preparing this paper, are such that this forecast method will likely be used on the first of April to estimate the date of low flow of 900 cfs in 1961.

Studies are continuing in order to improve methods discussed in this paper. It is hoped that discussion following this presentation will develop suggestions and some new ideas for improvement in these forecasts.

The author is indebted to B. L. Whaley of Portland, Oregon and Manes Barton of Reno, Nevada (both with the Soil Conservation Service) for suggestions and statistical assistance.

TABLE IV.A

DATE OF FLOW (2000 c.f.s.) ROGUE RIVER AT RAYGOLD, OREGON
(April-July volume at or below 500,000 acre feet)

Water Year	(X) April-July Discharge Thous. Acre Feet	Last Date River Flow Drops Below 2000 c.f.s.	(Y) Coded Date[1/] Flow Drops to 2000 c.f.s.	Estimated Y	Error (Days)
1924	367	5-13	54	43	-11
1926	289	3.21	1	17	±16
1930	339	5-6	47	34	-13
1931	318	4-14	25	27	+ 2
1934	320	4-12	23	27	+ 4
1940	494	5-16	57	86	+29
1941	463	6-29	101	75	-26
Average	370	5-3	44	--	14.4

$Y = -79.950 + .335X$ r + 0.82 Se = ±20 days at the mean of 44

1/ Number of days after March 20 that flow drops below 2000 c.f.s. for the last time.

TABLE IV.B

DATE OF FLOW (2000 c.f.s.) ROGUE RIVER AT RAYGOLD, OREGON
(April-July volume greater than 500,000 acre feet)

Water Year	(X) April-July Discharge Thous. Acre Feet	Last Date River flow Drops Below 2000 c.f.s.	(Y) Coded Date [1/] Flow Drops to 2000 c.f.s.	Estimated Y	Error (Days)
1906	851	7-28	130	110	-20
1907	1026	7-23	125	123	- 2
1908	860	7-24	126	111	-15
1909	673	7-13	115	98	-17
1910	626	6-27	99	94	- 5
1911	771	7-12	114	105	- 9
1912	973	7-24	126	119	- 7
1913	1025	7-31	133	122	-11
1914	658	6-26	98	97	- 1
1915	540	6-13	85	88	+ 3
1916	759	7-19	121	104	-17
1917	1304	7-24	126	142	+16
1918	526	6-10	82	87	+ 5
1920	634	6-20	92	95	+ 3
1921	991	7-26	128	120	- 8
1922	901	7-8	110	114	+ 4
1923	588	6-27	99	92	- 7
1925	700	6-24	96	100	+ 4
1927	827	7-6	108	109	+ 1
1928	702	6-13	85	100	-15
1929	603	6-21	93	93	0
1932	903	7-5	107	114	+ 7
1933	1020	7-15	117	122	+ 5
1935	774	6-24	96	105	+ 9
1936	728	6-23	95	102	+ 7
1937	1033	7-5	107	123	+16

TABLE IV.B
(Continued)

Water Year	(X) April-July Discharge Thous. Acre Feet	Last Date River Flow Drops Below 2000 c.f.s.	(Y) Coded Date 1/ Flow Drops to 2000 c.f.s.	Estimated Y	Error (Days)
1938	1051	7-3	105	124	+18
1939	591	6-7	79	92	+13
1942	635	6-29	101	95	- 6
1943	854	7-10	112	110	- 2
1944	580	6-23	95	91	- 4
1945	801	6-20	92	107	+15
1946	774	7-4	106	105	- 1
1947	554	6-20	92	89	- 3
1948	958	7-12	114	118	+ 4
1949	878	6-27	99	112	+13
1951	727	6-24	96	102	+ 6
1950	900	7-8	110	114	+ 4
1952	1150	8-5	138	131	- 7
1953	1070	8-28	161	126	-35
1954	804	7-6	108	107	- 1
1955	703	7-1	103	100	- 3
1956	1097	7-21	123	128	+ 5
1957	778	6-22	94	105	+11
1958	897	7-20	122	113	- 9
1959	558	6-11	83	90	+ 7
Average	812	7-6	106	---	8.3

Y = 50.438 + 0703X r = 0.771 Se = $\pm$10.9 days at the mean of 108

1/ Number of days after March 20 that flow drops below 2000 c.f.s. for last time.

TABLE V.

NUMBER OF DAYS ELAPSED FOR RECESSION FROM 2000 c.f.s. TO 900 c.f.s.
(Flow dropped to 900 c.f.s. only in years here listed)

Water Year	Last Date River Flow Drops Below 2000 c.f.s.	Coded Date 1/ Flow drops to 2000 c.f.s.	Number of Days for Recession from 2000 to 900 c.f.s.
1924	5-13	54	69
1926	3-21	1	58
1929	6-21	93	64
1930	5-6	47	51
1931	4-14	25	32
1934	4-12	23	64
1940	5-16	57	76
1941	6-29	101	49
Average			58 days

In the 8 years that daily flow dropped to 900 c.f.s. the average time was 58 days to drop from 2000 c.f.s. to 900 c.f.s.

1/ Number of days after March 20 that flow drops below 2000 c.f.s. for last time.

TABLE VI.

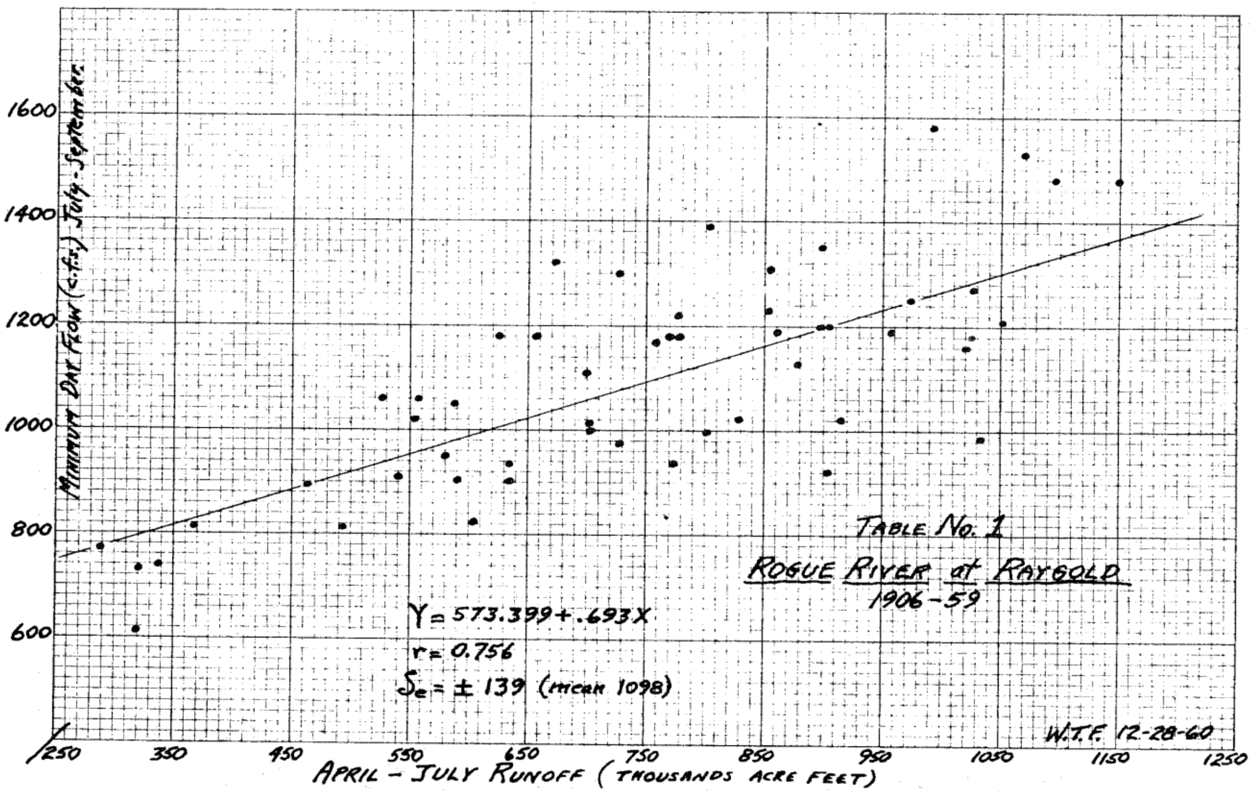
RESULTS OF FORECASTS - DATE OF LOW FLOW DROPPING TO 900 c.f.s.

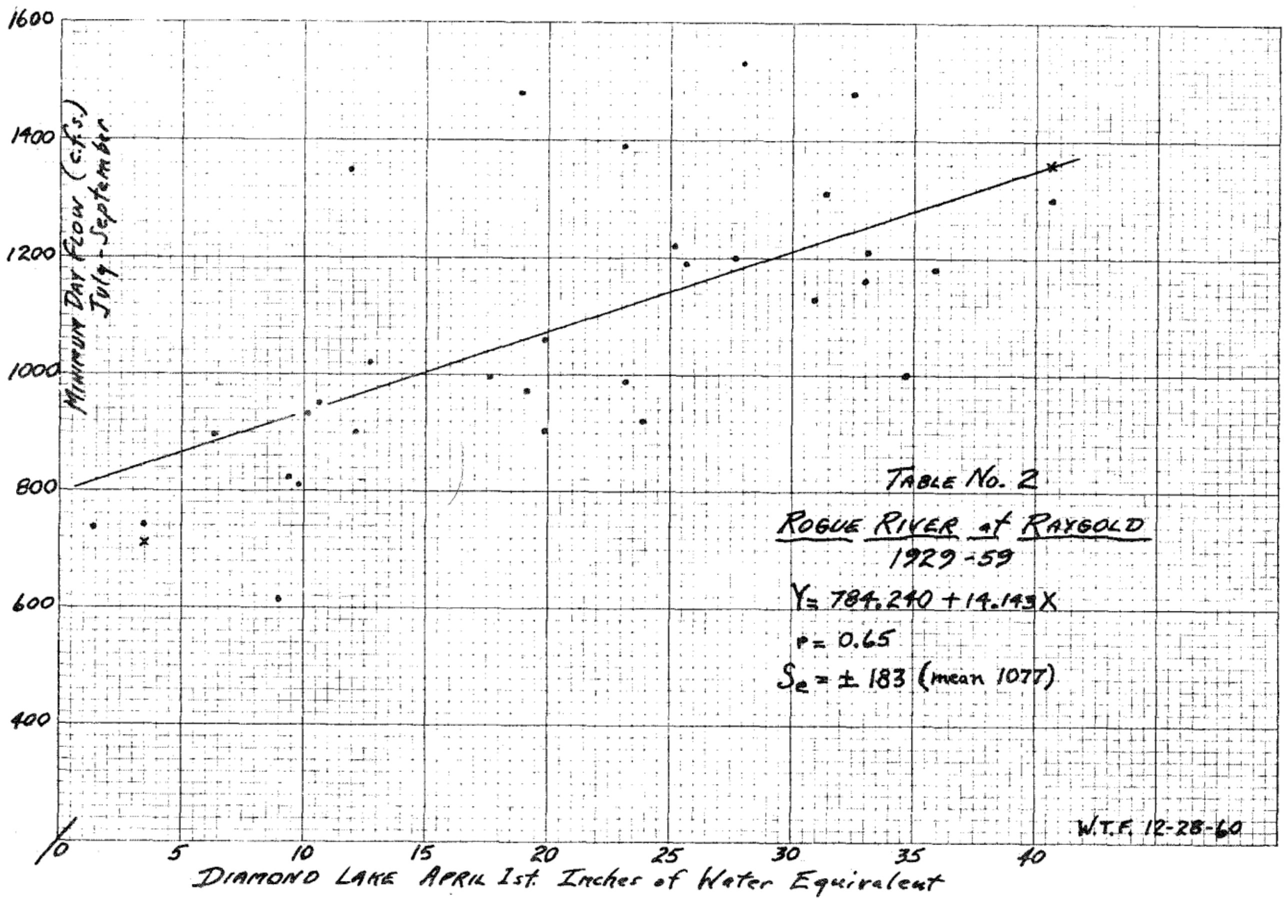
Water Year	Forecast Evaluation Used	Coded Date 1/ Flow Drops to 2000 c.f.s. Forecasted Date	Observed Date	Forecasted Date Add 58 days 2/ To Drop To 900 c.f.s.	Observed Coded Date 3/ Flow Dropped to 900 c.f.s.	Error (Days)
1924	4A	43	54	101	123	-22
1926	4A	17	1	75	59	+16
1929	4B	93	93	151	157	- 6
1930	4A	34	47	92	98	- 6
1931	4A	27	25	85	57	+28
1934	4A	27	23	85	87	- 2
1940	4A	86	57	144	133	+11
1941	4A	75	101	133	150	-17
Average						13.5 days

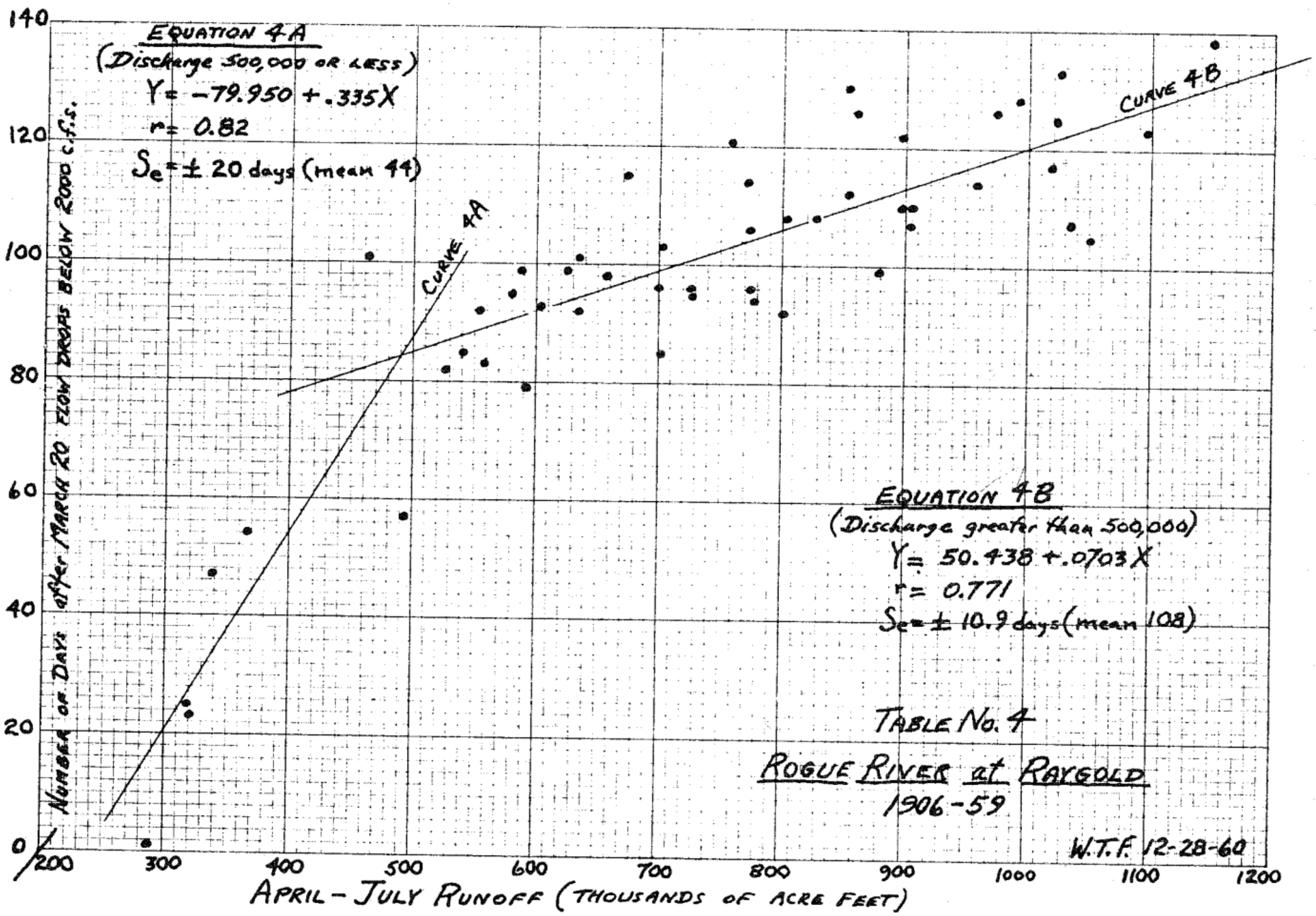
1/ Number of days after March 20 that flow drops below 2000 c.f.s. for the last time.

2/ See Table No. 5

3/ Number of days after March 20 that flow drops below 900 c.f.s.


Minimum Day Flow (c.f.s.) July - September
1600
1400
1200
1000
800
600
250
350
450
550
650
750
850
950
1050
1150
1250
April - July Runoff (thousands acre feet)
Y = 573.399 + .693X
r = 0.756
Se = ± 139 (mean 1098)
Table No. 1
Rogue River at Raygold
1906-59
W.T.F. 12-28-60


1600
1400
1200
1000
800
600
400
0
5
10
15
20
25
30
35
40
MINIMUM DAY FLOW (c.f.s.) July-September
DIAMOND LAKE APRIL 1st. Inches of Water Equivalent
TABLE No. 2
ROGUE RIVER at RAYGOLD
1929-59
Y= 784.240 + 14.143X
r= 0.65
Se = ± 183 (mean 1077)
W.T.F. 12-28-60


EQUATION 4A
(Discharge 500,000 or less)
$Y = -79.950 + .335X$
$r = 0.82$
$S_e = \pm 20$ days (mean 44)
CURVE 4A
CURVE 4B
EQUATION 4B
(Discharge greater than 500,000)
$Y = 50.438 + .0703X$
$r = 0.771$
$S_e = \pm 10.9$ days (mean 108)
TABLE No. 4
ROGUE RIVER at RAYGOLD
1906-59
W.T.F. 12-28-60
NUMBER OF DAYS after MARCH 20 FLOW DROPS BELOW 2000 c.f.s.
APRIL-JULY RUNOFF (THOUSANDS OF ACRE FEET)
0
20
40
60
80
100
120
140
200
300
400
500
600
700
800
900
1000
1100
1200