EXHIBIT 12

PART 3

APPENDIX F

HILL AND MOUNTAIN RUNOFF

APPENDIX F

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(continued)

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APPENDIX F

HILL AND MOUNTAIN RUNOFF

The hill and mountain areas producing runoff that flows onto the valley fill are comprised of 205,709 acres. The location of hill and mountain masses is shown on Plate 2, Physiography. The ungaged hill and mountain areas are composed primarily of small canyons and low hills. To facilitate computations, adjacent watersheds which had similar geologic and runoff characteristics and were tributary to the same hydrologic subarea, were grouped together into "Hill and Mountain Groups". The location and extent of these groups are shown on Figure F-1.

Availability of Data Used

The only watersheds gaged throughout the base period are those of Big Tujunga Creek above Gold Canyon and Pacoima Creek above Pacoima Dam, their combined area being equal to 86,201 acres. Of the remaining 119,508 acres, only two small watersheds, Sycamore and Haines, have reliable gaging records of significant duration. Haines Canyon data were not used because of the existence of several unmeasured diversions from the watershed.

The available data within the watershed consist of:

1. Measured runoff from Big Tujunga and Pacoima Creeks during the period 1917-1958, inclusive.

2. Measured runoff from Sycamore Canyon during the period 1938-1958, inclusive.

3. Precipitation on all hill and mountain areas. (Extension of records by Los Angeles County Flood Control District covered an 85-year period back to 1872).

4. Culture survey of hill and mountain areas made by the Referee in 1958.

The method of computing precipitation on hill and mountain groups is described in Appendix E. Annual precipitation so determined is listed in Table F-1.

Runoff measurements and records of dam operations were obtained from the Los Angeles County Flood Control District, U. S. Geological Survey and City of Los Angeles Department of Water and Power.

In order to have all runoff data on the same basis, the Big Tujunga runoff was corrected to unimpaired runoff by adjusting for change in storage in Big Tujunga Dam. The precipitation and runoff data for Tujunga, Pacoima and Sycamore watersheds are shown in Table F-2. The area of each watershed gaged is shown in Table F-3.

The three gaged watersheds in the area were not considered a sufficient number on which to base a study. The gaged watershed determined to be most similar to the hill and mountain areas of the area of investigation was Spunky Canyon, which is tributary to Bouquet Canyon and in the Santa Clara River watershed. Runoff and precipitation records for this gaged area of 1,230 acres have been maintained by the City of Los Angeles since 1932. The 85-year mean water crop for the Spunky watershed was determined from the Los Angeles County Flood Control District's 85-year isohyetal map.

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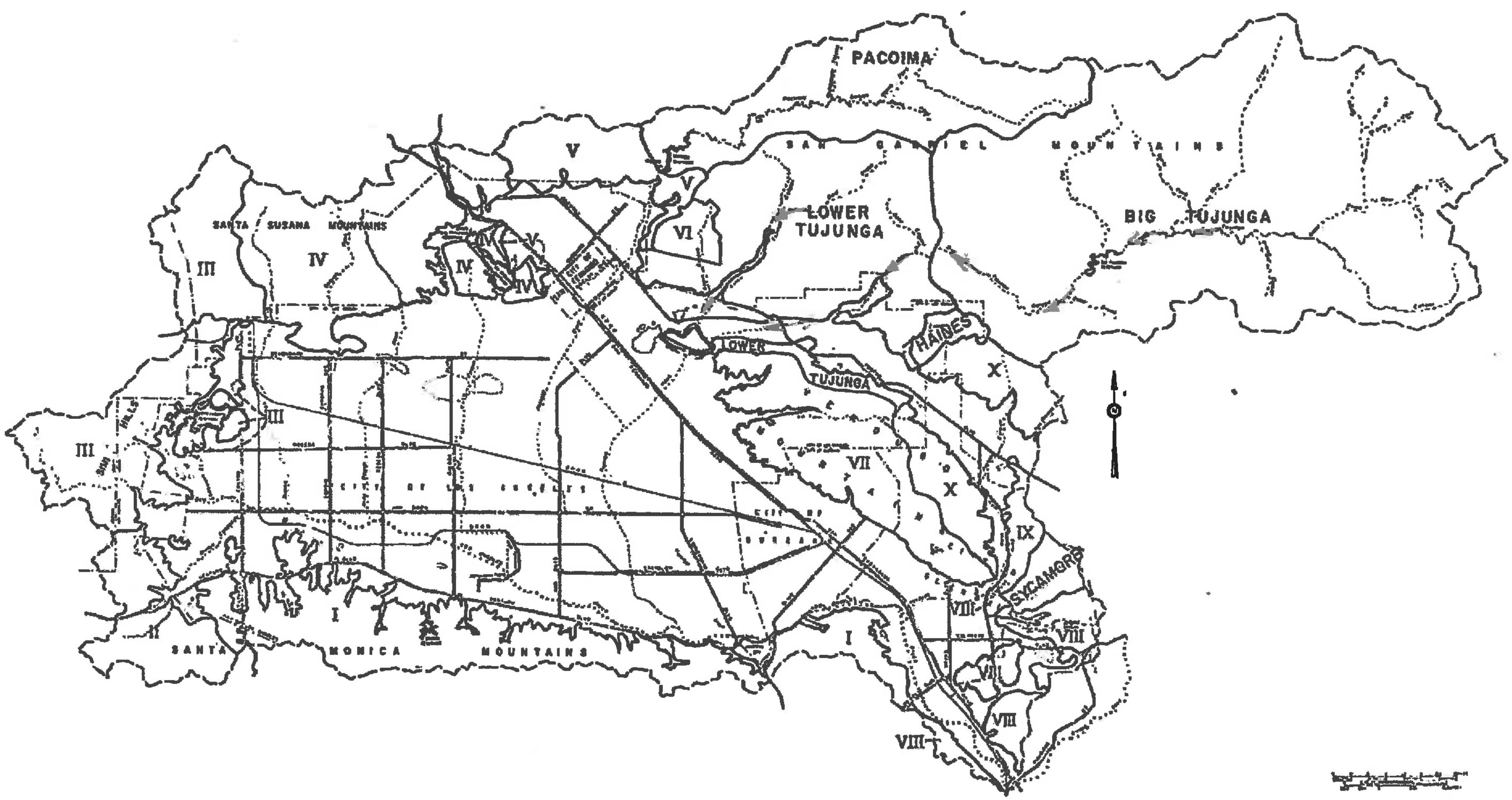

SAN FERNANDO VALLEY REFERENCE
LOCATION AND EXTENT
OF
HILL AND MOUNTAIN GROUPS

STATE WATER RIGHTS BOARD

TABLE F-1

PRECIPITATION, HILL AND MOUNTAIN GROUPS*

In Acre-Feet

Year	I + II	III	IV	V	VI	VII	VIII + Sycamore	IX	X	Lower Tujunga + Haines	Pacoima	Big Tujunga	Total
1928-29	28,596	18,280	21,847	7,852	1,785	14,310	8,157	1,983	10,365	26,121	25,551	95,167	260,014
29-30	26,946	18,722	23,293	9,065	2,121	12,744	6,664	1,585	9,309	28,199	28,648	108,762	276,058
1930-31	36,162	22,458	26,146	10,491	2,509	16,801	8,554	2,097	11,299	31,348	31,358	111,784	311,007
31-32	46,337	29,735	36,211	13,533	3,311	23,652	11,638	2,794	16,416	48,914	44,521	163,144	440,206
32-33	29,571	17,485	19,814	8,468	2,121	15,550	7,559	1,873	12,024	31,593	29,810	107,252	283,120
33-34	33,088	22,096	25,400	9,259	2,251	17,667	10,942	2,571	12,664	30,470	29,423	104,231	300,102
34-35	44,549	31,471	34,976	13,809	3,441	23,910	11,567	3,017	17,413	48,149	48,005	181,271	461,578
1935-36	30,799	20,165	24,169	9,915	2,432	14,344	8,256	1,971	10,796	29,098	29,423	102,720	284,088
36-37	56,482	37,720	42,507	16,363	4,010	26,891	13,329	3,328	20,246	57,021	56,910	214,504	549,311
37-38	60,874	36,974	41,991	17,319	4,450	28,397	14,721	3,514	21,786	61,278	66,975	237,153	595,542
38-39	49,276	26,372	33,919	13,150	3,001	23,311	11,340	2,809	15,950	43,031	41,811	154,080	418,050
39-40	37,975	24,083	28,474	10,554	2,484	17,842	8,256	1,971	11,508	32,554	33,681	113,294	322,675
1940-41	93,903	58,592	65,667	23,471	5,510	44,792	23,077	5,556	30,846	81,658	80,525	297,586	811,183
41-42	30,894	17,956	21,181	8,277	1,992	15,518	7,062	1,823	10,118	27,999	29,036	107,252	279,118
42-43	57,058	36,650	43,745	16,724	4,139	28,860	13,627	3,454	21,987	60,275	60,394	240,184	587,097
43-44	55,391	35,722	40,041	15,703	3,829	27,285	12,434	2,970	19,164	59,955	62,330	219,036	553,860
44-45	33,790	22,363	25,771	10,107	2,509	17,316	8,554	2,133	12,142	37,019	39,101	141,995	352,800
1945-46	32,359	20,844	24,508	9,468	2,302	15,964	8,157	1,912	12,484	35,213	37,553	141,995	342,759
46-47	32,953	20,751	25,163	11,234	2,846	19,029	9,748	2,299	14,842	40,625	42,585	155,591	377,666
47-48	17,240	11,303	13,774	5,277	1,294	9,172	4,675	1,136	6,621	19,434	20,906	80,061	190,893
48-49	19,049	12,570	15,711	6,532	1,630	10,258	5,272	1,229	8,176	23,426	24,003	84,593	212,449
49-50	24,874	18,490	21,995	8,129	1,914	11,357	6,635	1,408	9,164	27,362	25,938	90,635	247,901
1950-51	18,810	15,088	18,473	6,809	1,604	9,465	4,774	1,142	6,390	19,944	18,583	58,913	179,995
51-52	71,541	44,716	52,497	20,704	4,993	35,266	18,501	4,586	25,876	69,525	64,652	234,141	646,998
52-53	27,219	19,682	22,634	7,810	1,785	12,783	6,068	1,634	8,493	22,487	21,293	77,040	228,928
53-54	31,800	21,926	24,694	9,065	2,173	14,489	7,858	1,857	10,919	30,477	31,358	116,315	30[illegible],931
54-55	31,478	21,360	23,856	8,426	1,966	15,449	7,845	1,892	10,831	30,275	27,100	99,699	280,177
1955-56	38,418	26,761	32,683	11,151	2,432	17,126	9,450	2,155	12,098	33,713	31,745	107,252	324,984
56-57	27,925	20,172	23,150	8,831	2,147	15,031	7,659	1,809	10,765	29,147	25,938	98,188	270,752
57-58	65,504	48,847	54,306	18,109	4,165	28,522	14,025	3,498	22,453	60,756	58,458	229,610	608,253
Average 1928-57	38,804	25,190	29,458	11,294	2,723	19,123	9,737	2,366	13,817	38,493	38,247	139,443	368,698

* Area contained in hill and mountain groups:

Group	Area in Acres	Group	Area in Acres
I + II	25,684	VIII + Sycamore	6,661
III	17,594	IX	1,391
IV	17,582	X	7,029
V	5,873	Lower Tujunga + Haines	22,804
VI	1,786	Big Tujunga	68,111
VII	13,104	Pacoima	18,020
		Total	205,709

TABLE F-2

PRECIPITATION, RUNOFF, RETENTION, AND INDICES OF WETNESS
FOR
PACOIMA, TUJUNGA, SYCAMORE, AND SPUNKY WATERSHEDS

Year	Pacoima Watershed: Precipitation, in inches	Unimpaired runoff, in inches	Rainfall retention, in inches	Annual index of wetness: Based on 85-year mean	Based on 29-year mean	Tujunga Watershed: Precipitation, in inches	Unimpaired runoff, in inches	Rainfall retention, in inches	Annual index of wetness: Based on 85-year mean	Based on 29-year mean
1917-18	28.31	3.19	25.12	110	110	29.68	3.91	25.77	112	121
18-19	19.48	0.76	18.72	76	76	19.88	1.01	18.87	75	81
19-20	24.74	6.50	18.24	96	97	27.69	2.92	24.77	104	113
1920-21	28.39	4.84	23.55	111	111	28.12	1.85	26.27	106	115
21-22	44.73	25.69	19.04	174	175	49.50	18.15	31.35	186	202
22-23	24.37	5.22	19.15	95	95	25.96	2.59	23.37	98	106
23-24	13.32	0.36	12.96	52	52	14.36	0.65	13.71	54	59
24-25	18.00	0.62	17.38	70	70	19.91	0.65	19.26	75	81
1925-26	34.29	5.17	29.12	134	134	37.63	3.44	34.19	141	154
26-27	28.67	3.80	24.87	112	112	29.03	3.77	25.26	109	119
27-28	16.26	0.40	15.86	63	63	16.73	0.85	15.88	63	68
28-29	16.95	0.58	16.37	66	67	16.76	0.73	16.03	63	68
29-30	19.00	0.74	18.26	74	75	19.16	0.77	18.39	72	78
1930-31	20.80	0.72	20.08	81	82	19.69	0.54	19.15	74	80
31-32	29.53	5.80	23.73	115	116	28.74	3.15	25.59	108	117
32-33	19.77	1.43	18.34	77	78	18.90	1.30	17.60	71	77
33-34	19.52	2.29	17.23	76	77	18.36	1.46	16.90	69	75
34-35	31.84	3.69	28.15	124	126	31.93	2.84	29.09	120	130
1935-36	19.52	2.05	17.47	76	77	18.09	1.15	16.94	68	74
36-37	37.75	10.43	27.32	147	149	37.79	6.61	31.18	142	154
37-38	44.43	17.16	27.27	173	175	41.78	14.76	27.02	157	170
38-39	27.73	2.34	25.39	108	109	27.14	2.55	24.59	102	111
39-40	22.34	2.13	20.21	87	88	19.96	1.91	18.05	75	81
1940-41	53.41	17.11	36.30	208	211	52.42	13.91	38.51	197	213
41-42	19.26	1.27	17.99	75	76	18.89	1.78	17.11	71	77
42-43	40.06	13.73	26.33	156	158	42.31	13.39	28.92	159	172
43-44	41.34	9.95	31.39	161	163	38.58	10.32	28.26	145	157
44-45	25.94	3.23	22.71	101	102	25.01	3.23	21.78	94	102
1945-46	24.91	3.05	21.86	97	98	25.01	2.87	22.14	94	102
46-47	28.25	2.89	25.36	110	111	27.41	3.37	24.04	103	112
47-48	13.87	0.25	13.62	54	55	14.10	0.66	13.44	53	57
48-49	15.92	0.48	15.44	62	63	14.90	0.52	14.38	56	61
49-50	17.21	0.71	16.50	67	68	15.97	0.54	15.43	60	65
1950-51	12.33	0.09	12.24	48	49	10.38	0.20	10.18	39	42
51-52	42.89	11.14	31.75	167	169	41.25	7.49	33.76	155	168
52-53	14.12	0.64	13.48	55	56	13.57	0.90	12.67	51	55
53-54	20.80	1.96	18.84	81	82	20.49	1.47	19.02	77	83
54-55	17.98	0.50	17.48	70	71	17.56	0.69	16.87	66	72
1955-56	21.06	0.97	20.09	82	83	18.89	0.76	18.13	71	77
56-57	17.21	0.38	16.83	67	68	17.30	0.46	16.84	65	70
57-58	38.78	10.49	28.29	151	153	40.45	6.94	33.51	152	165
29-Year Average 1929-57	25.37	4.06	21.31	99	100	24.56	3.46	21.10	92	100

Year	Sycamore Watershed: Precipitation, in inches	Unimpaired runoff, in inches	Rainfall retention, in inches	Annual index of wetness: Based on 85-year mean	Based on 29-year mean	Spunky Canyon: Precipitation, in inches	Unimpaired runoff, in inches	Rainfall retention, in inches	Annual index of wetness: Based on 85-year mean	Based on 29-year mean
1928-29	16.41			82	83					
29-30	13.41			67	68					
1930-31	17.21			86	88					
31-32	23.41			117	120					
32-33	15.21			76	78	10.19	0	10.19	61	62
33-34	22.01			110	112	12.39	0.04	12.35	74	76
34-35	23.41			117	120	19.84	0.37	19.47	119	121
1935-36	16.61			83	85	14.04	0.11	13.93	84	86
36-37	26.81			134	137	22.73	2.12	20.61	136	139
37-38	29.61			148	151	25.48	5.21	20.27	153	155
38-39	22.81	0.97	21.84	114	116	19.11	1.23	17.88	114	117
39-40	16.61	0.69	15.92	83	85	13.34	0.26	13.08	80	81
1940-41	46.42	5.98	40.44	232	237	31.54	5.34	26.20	189	192
41-42	14.21	0.72	13.49	71	73	12.59	0.83	11.76	75	77
42-43	27.41	7.88	19.53	137	140	26.10	5.54	20.56	156	159
43-44	25.01	2.69	22.32	125	128	26.64	7.28	19.36	160	162
44-45	17.21	0.73	16.48	86	88	15.19	1.94	13.25	91	93
1945-46	16.41	0.37	16.04	82	84	16.96	0.78	16.18	102	103
46-47	19.61	0.84	18.77	98	100	17.02	0.60	16.42	102	104
47-48	9.40	0.06	9.34	47	48	8.01	0.01	8.00	48	49
48-49	10.61	0.05	10.56	53	54	9.99	0.03	9.96	60	61
49-50	13.21	0.23	12.98	66	67	13.03	0.01	13.02	78	79
1950-51	9.60	0.19	9.41	48	49	7.14	0	7.14	43	44
51-52	37.22	7.75	29.47	186	190	28.92	3.89	25.03	173	176
52-53	12.21	0.60	11.61	61	62	9.15	0.25	8.90	55	56
53-54	15.81	0.48	15.33	79	81	14.37	0.38	13.99	86	88
54-55	15.61	0.32	15.29	78	80	11.61	0.04	11.57	70	71
1955-56	19.01	0.85	18.16	95	97	14.02	0.04	13.98	84	85
56-57	15.41	0.54	14.87	77	79	13.36	0.03	13.33	80	81
57-58	28.21	2.42	25.79	141	144	31.17	3.27	27.90	187	190
29-Year Average 1929-57	19.58	—	—	98	100					

Extension of Data

In order to compare runoff characteristics of Spunky watershed with other watersheds during the selected 29-year base period, it was necessary to estimate the appropriate 29-year mean precipitation for the Spunky watershed.

A summary of the relationship of the average precipitation during the 29-year period 1928 through 1957, the 26-year period 1932 through 1958 and the 18-year period 1940 through 1958, to the normal precipitation and the average precipitation during the 29-year base period is shown in Table F-3 for the Sycamore and Spunky watersheds.

TABLE F-3

MEAN PRECIPITATION FOR
SYCAMORE AND SPUNKY WATERSHEDS

Watershed	Mean precipitation, in inches			
	85-year	1928-57	1932-58	1940-58
Sycamore, 1,733 acres	20.01	19.58	20.22	19.59
percent of 85-year mean		98	101	98
percent of 29-year mean			103	100
Spunky, 1,230 acres	16.7	(16.4)[a]	17.07	17.05
percent of 85-year mean		(98)[b]	102	102
percent of 29-year mean			(104)[a]	(104)[a]

a. Computed values.
b. Assumed.

Since the characteristics of the Sycamore and Spunky watersheds were not greatly dissimilar, it was assumed that the relationship between the 29-year and the 85-year mean precipitation for both watersheds would be the same. Therefore, in Table F-3 the 29-year mean for Spunky was taken as 98 percent of the 85-year mean.

Precipitation - Runoff Relationships

In investigating the relationship between precipitation and runoff a review was made of Bulletin 5 of the State Department of Public Works, entitled "Flow in California Streams", 1923. In Bulletin 5 the relationship between wetness and runoff as shown graphically on Plates XVIII to LIII, entitled "Curves of Probable Runoff" is shown as index of wetness versus runoff wherein:

$$\text{Index of wetness} = \frac{\text{Annual precipitation}}{\text{Mean precipitation}} \times 100$$

The relationships depicted by these curves are described in Bulletin 5 as follows:

> "These curves show the trend of the relation between the 'index of seasonal wetness' and the run-off from each drainage basin. They pass through many of the plotted points, but due to the variable weather in successive seasons which causes different fractions of the precipitation to evaporate before running off the collecting area into the stream channels, some of the points fall to the side of the mean curves. The sequence of the storms, their intensity, the weather conditions between the occurrence of storms, and the character of successive seasons, all influence this relation to an indeterminate degree. For seasons in which these conditions favor a greater fractional part of the meteoric waters evaporating to the atmosphere, the points tend to lie on the lower side of the mean curve, and for seasons favoring a small evaporation, the points tend to lie on the upper side. Successive seasons of drought or heavy floods may also influence the position of the points, for the quantity of ground water feeding the streams does not change immediately with variations in the annual precipitation. Instead, there is a certain tardiness in response which places these points on either side of the mean curve, according to very recondite relations that obtain in the sequence of seasonal rains and snows, and any one seasonal precipitation may affect the quantity of ground water reaching a stream for a period as long as three years.

"Although there are these minor influences which tend to make the relation between the 'index of seasonal wetness' and run-off an approximate one, nevertheless the data reveal that when a reasonable number of measurements of seasonal run-off are at hand, a mean curve may be drawn which will not change much in position by procuring and plotting additional measurements."

The above approach has the distinct advantage of allowing comparison of runoff characteristics of different watersheds and was adopted by the Referee to determine by a set of curves the annual mean runoff which might be expected from a given amount of precipitation under conditions of native culture.

The first step was to reduce precipitation to a dimensionless number. The index of wetness based on the mean of the 29-year base period, 1928-1957, was utilized for this purpose and is listed for each year and hill and mountain group in Table F-4.

The second factor utilized in the study is rainfall retention; i.e., the amount of precipitation that does not pass out of hill and mountain areas as runoff.

The runoff, rainfall retention and indices of wetness for the four study watersheds are listed in Table F-2.

The above data were plotted for each of the four watersheds with the index of wetness (based on a 29-year mean) as the abscissa and runoff and rainfall retention as the ordinate. The lines of best fit were drawn simultaneously for runoff and for rainfall retention and then adjusted so that the following requirements were met:

1. For the base period (1928-29 through 1956-57), the summation of the annual runoff values obtained from the curve equaled the summation of annual measured runoff values.

2. For a specific year the sum of the runoff and rainfall retention values for the curve equaled the precipitation (index of wetness multiplied by mean precipitation).

The plots of those data and the resultant curves are shown on:

Figure F-2	Pacoima
Figure F-3	Tujunga
Figure F-4	Sycamore
Figure F-5	Spunky

Review of the above curves led to the conclusion that when precipitation is below an index of wetness of 40 no runoff would normally be produced, and, therefore, the rainfall retention curves would become tangent to a line of 100 percent rainfall retention at an index wetness of 40.

The scattering of the plot of points above an index of wetness of between 150 to 200 indicates that during extremely wet years the mean rainfall retention tends to reach an optimum value and become a constant. This results in the runoff curves becoming a tangent above the index of wetness of between 150 to 200, with the tangent representing 100 percent runoff of all additional precipitation.

For comparison, the rainfall retention and runoff curves for the four watersheds were plotted together as shown on Figure F-6. The result

TABLE F-4

INDICES OF WETNESS FOR HILL AND MOUNTAIN GROUPS

BASED ON 29-YEAR AVERAGE*

Year	I + II	III	IV	V	VI	VII	VIII + Sycamore	IX	X	Lower Tujunga + Haines	Pacoima	Big Tujunga
1928-29	74	72	74	70	66	75	84	84	75	68	67	68
29-30	69	74	79	80	78	67	68	67	67	73	75	78
1930-31	93	89	89	93	92	88	88	89	82	81.	82	80
31-32	119	118	123	120	122	124	119	118	119	127	116	117
32-33	76	69	67	75	78	81	78	79	87	82	78	77
33-34	85	88	86	82	83	93	112	109	92	79	77	75
34-35	115	125	119	122	126	125	119	128	126	125	126	130
1935-36	79	80	82	88	89	75	85	84	78	76	77	74
36-37	146	150	144	145	147	141	137	141	147	148	149	154
37-38	157	147	143	153	163	149	151	153	158	159	175	170
38-39	127	105	115	116	110	122	116	119	116	112	109	111
39-40	98	96	97	93	91	93	85	84	83	85	88	81
1940-41	242	233	223	208	202	235	237	235	223	212	211	213
41-42	80	71	72	73	73	81	73	77	73	73	76	77
42-43	147	145	148	148	152	151	140	146	159	157	158	172
43-44	143	142	136	139	141	143	128	126	139	156	163	157
44-45	87	89	87	90	92	91	88	90	88	96	102	102
1945-46	83	83	83	84	85	84	84	81	90	91	98	102
46-47	85	82	85	100	104	100	100	97	108	106	111	112
47-48	44	45	47	47	47	48	48	48	48	50	55	57
48-49	49	50	53	58	60	54	54	52	59	61	63	61
49-50	64	72	75	72	70	59	68	60	66	71	68	65
1950-51	48	59	63	60	59	50	49	48	46	52	49	42
51-52	184	178	178	183	183	185	190	194	187	181	169	168
52-53	70	78	77	69	66	67	62	69	62	58	56	55
53-54	82	85	84	80	80	76	81	79	79	79	82	83
54-55	81	84	81	75	72	81	80	80	78	79	71	72
1955-56	99	106	111	99	89	90	97	91	88	88	83	77
56-57	72	80	79	78	79	79	79	77	78	76	68	70
57-58	169	194	184	160	153	149	144	148	163	158	153	165

*29-year average precipitation for the period 1928-29 through 1956-57.

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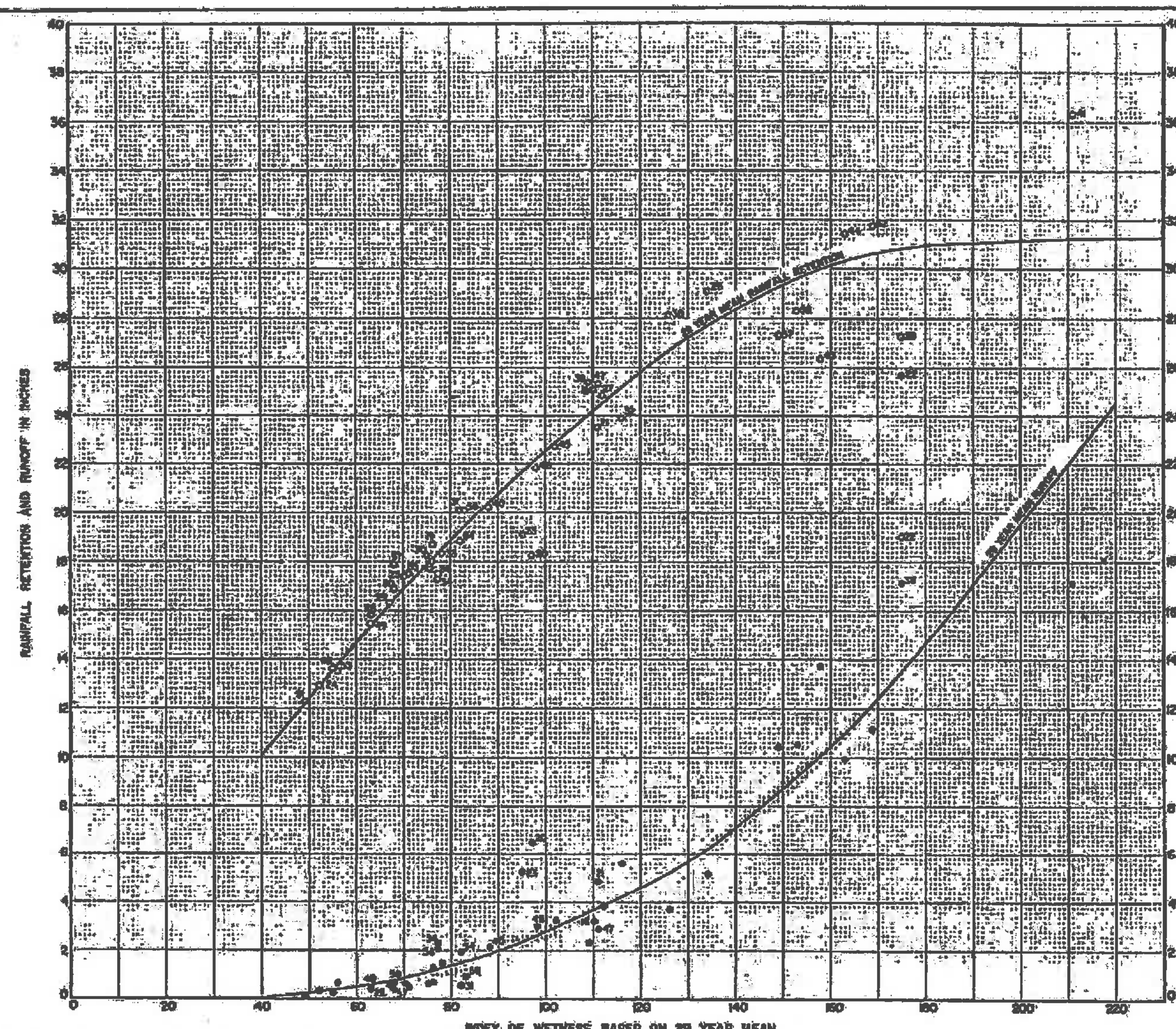
FIGURE F-2



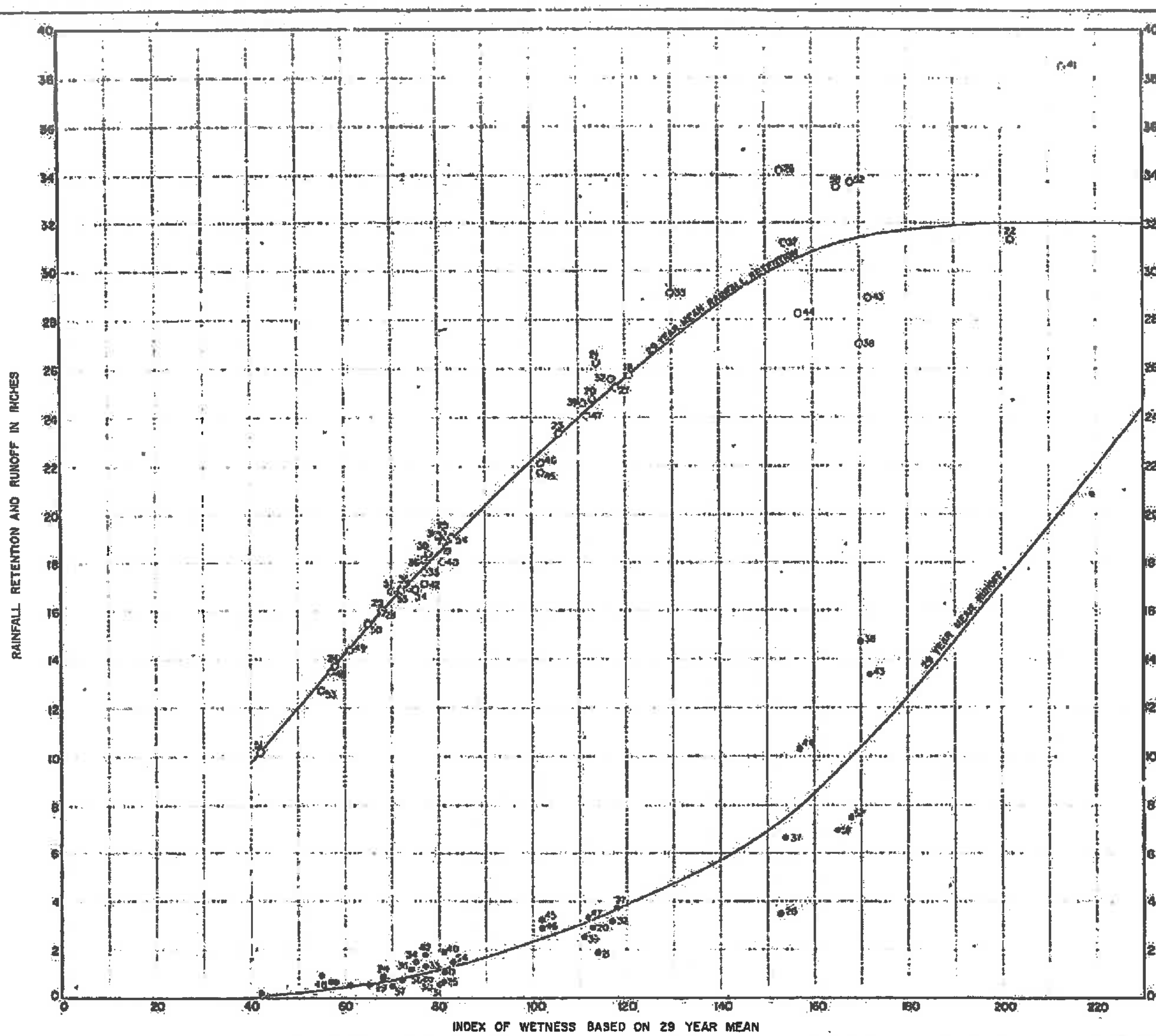
SAN FERNANDO VALLEY REFERENCE

PACOIMA WATERSHED

RAINFALL RETENTION AND RUNOFF VS. INDEX OF WETNESS

STATE WATER RIGHTS BOARD

FIGURE F-3



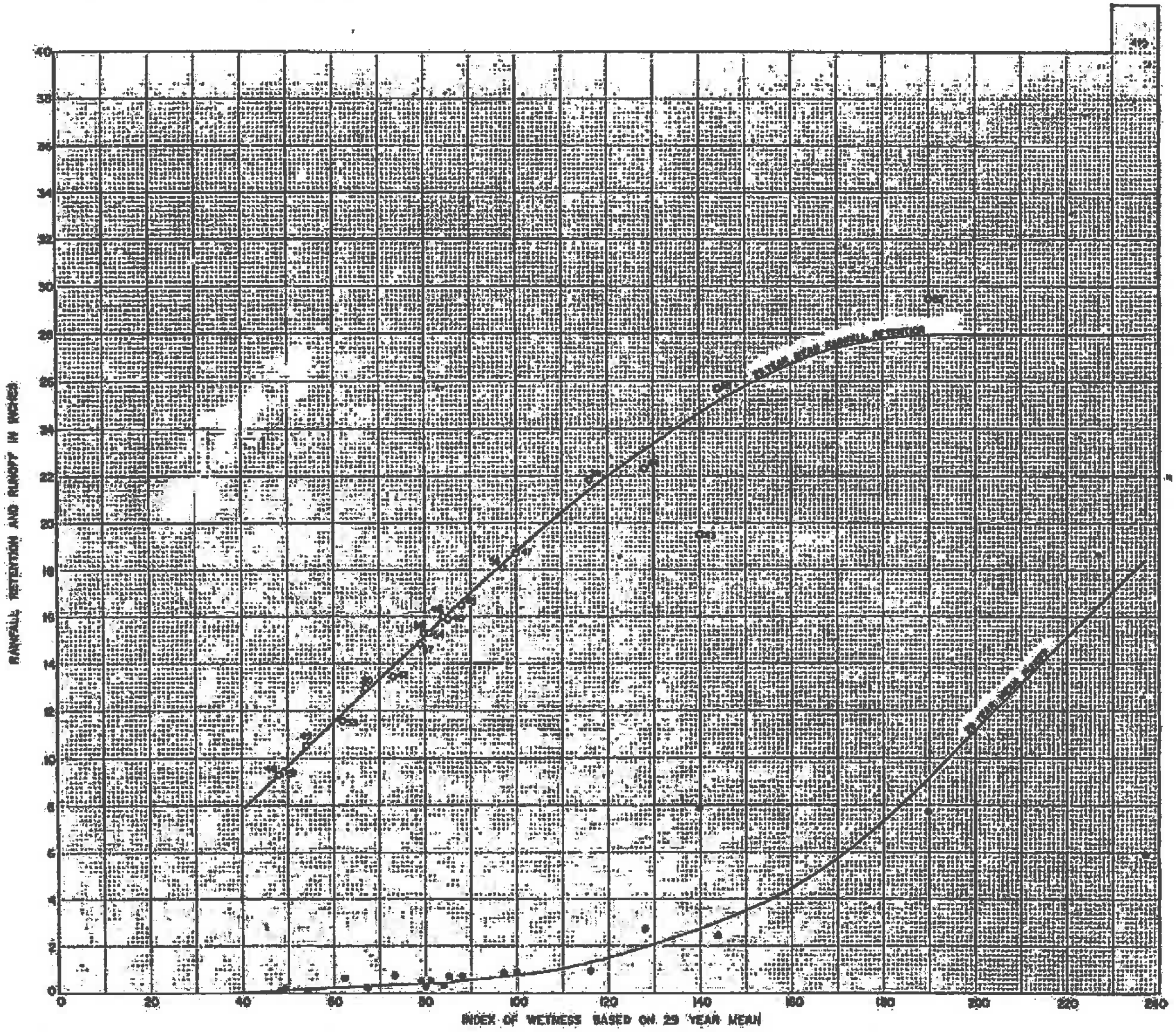
SAN FERNANDO VALLEY REFERENCE

TUJUNGA WATERSHED

RAINFALL RETENTION AND RUNOFF VS. INDEX OF WETNESS

STATE WATER RIGHTS BOARD

FIGURE F-4

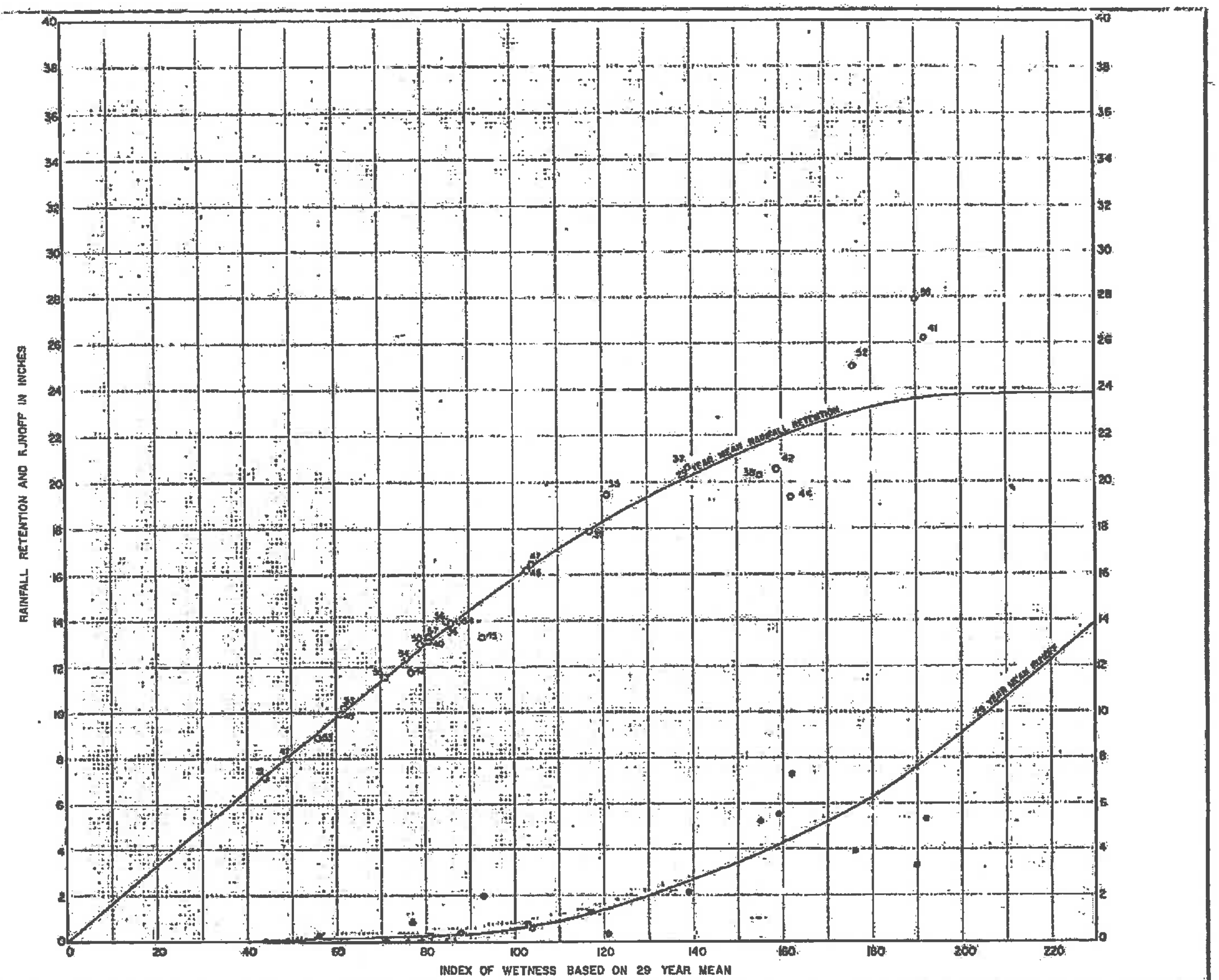


SAN FERNANDO VALLEY REFERENCE

SYCAMORE WATERSHED

RAINFALL RETENTION AND RUNOFF VS. INDEX OF WETNESS

STATE WATER RIGHTS BOARD



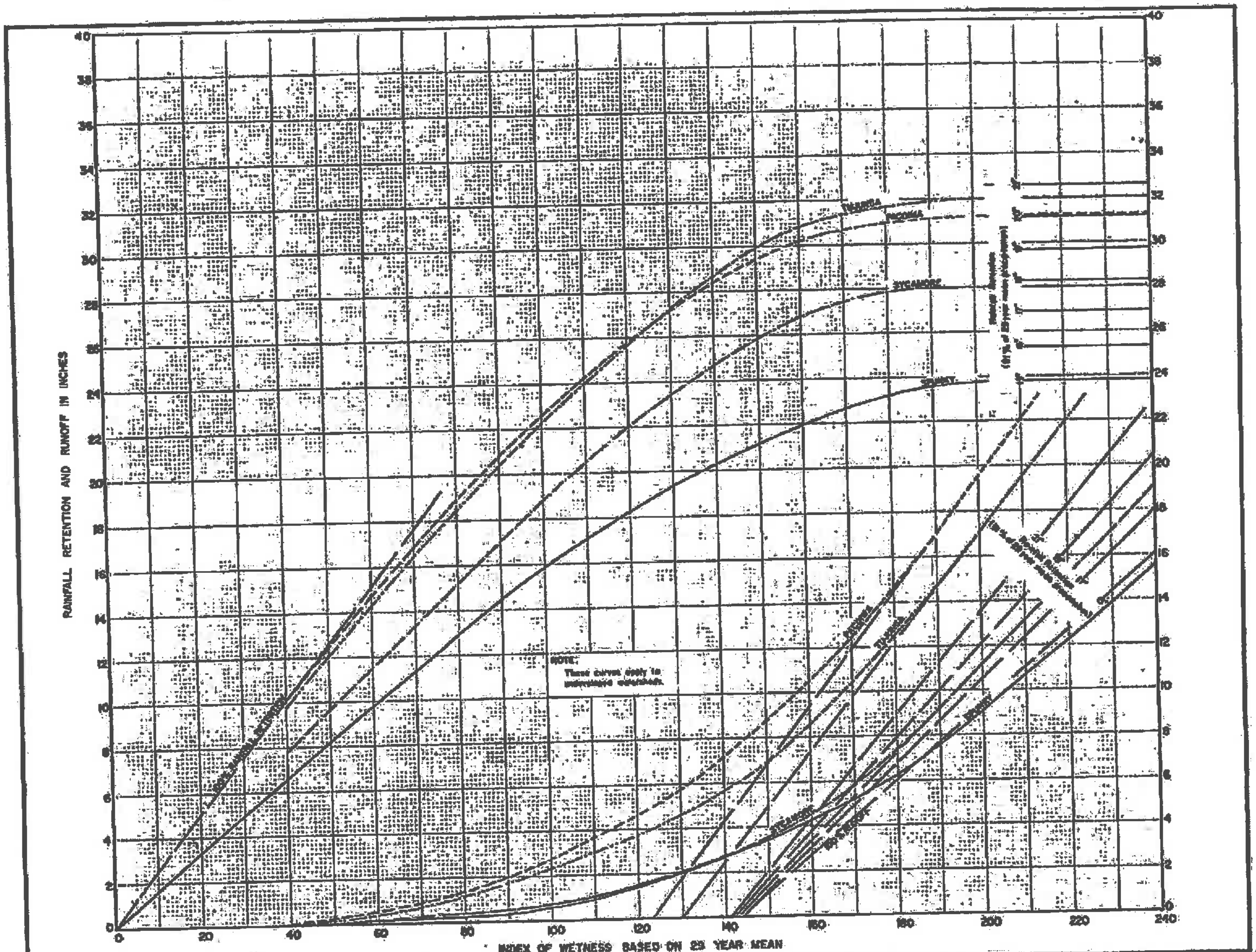
SAN FERNANDO VALLEY REFERENCE

SPUNKY WATERSHED

RAINFALL RETENTION AND RUNOFF VS. INDEX OF WETNESS

FIGURE F-5

STATE WATER RIGHTS BOARD



SAN FERNANDO VALLEY REFERENCE

MEAN RAINFALL RETENTION AND MEAN RUNOFF
vs.
INDEX OF WETNESS

FIGURE F-6

STATE WATER RIGHTS BOARD

is a family of curves having similar shapes and being controlled by these factors:

1. Rainfall retention curves tangent to the line of 100 percent rainfall retention at index of wetness of 40. This indicates that on the long-time average no runoff can be expected below an index of wetness of 40.

2. Runoff curves tangent to the line of 100 percent runoff at index of wetness of 200.

3. The intercept of the 100 percent runoff lines with the abscissa, or index of wetness at zero runoff for a given watershed is equal to maximum mean rainfall retention divided by the 29-year mean precipitation.

Construction of Runoff Curves for Hill and Mountain Groups

The set of curves in Figure F-6 was used as the basis to construct the curves for runoff of hill and mountain groups.

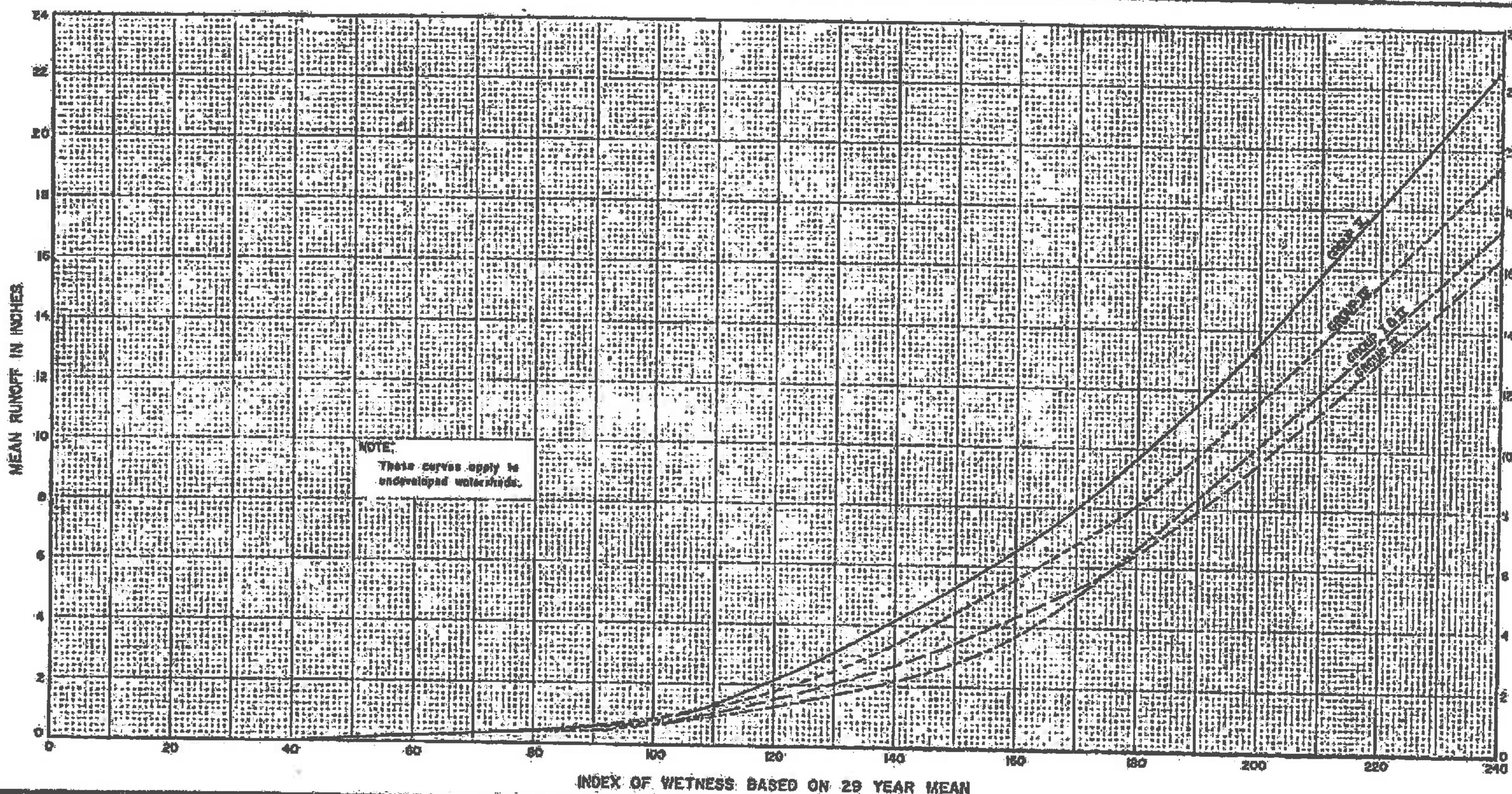
The first step was to select a parameter to space the rainfall retention curves. The mean retention of precipitation is an indication of the ability of a watershed to retain water and was found to be 91 percent for the two smaller watersheds of Sycamore and Spunky. The 29-year mean rainfall retention, based on 91 percent of mean precipitation, was selected as the parameter to space the portion of the mean rainfall retention curves above index of wetness of 200. The parameters are shown on Figure F-6. Utilizing these parameters, a mean maximum rainfall retention was obtained for the hill and mountain group. The intercept of the 100 percent runoff line with the abscissa was obtained by dividing the mean maximum rainfall retention by the 29-year mean precipitation. The 100 percent runoff line for the group was then constructed and is used as the tangent for the upper portion of the runoff curve.

The lower portion of the runoff curve for the group is drawn tangent to the abscissa at index of wetness of 40. The middle portion of the runoff curve was then drawn in preliminary location by using the curves of the four gaged watersheds as a guide. The final position of the middle portion of the curve was fixed so that the sum of the annual mean runoff values for the base period obtained from the curve equaled nine percent of the mean precipitation for the same period. The final curves for mean runoff are shown on Figure F-7 for groups I through V and Figure F-8 for the remainder of the groups.

Correction of Mean Runoff to Final Runoff

To obtain runoff values that could be used in an annual hydrologic inventory, it was necessary to determine what deviation from the mean runoff values could be expected in each of the years in the 1928-58 period. Corrections to the mean runoff were made by applying the weighted average deviation of Sycamore and Spunky watersheds expressed as a percent of the 29-year mean precipitation to the mean runoff of the groups.

Deviations for the four gaged watersheds are shown on Table F-5. Deviations for Sycamore and Spunky watersheds in years having no runoff records were estimated by correlation to the deviation of Pacoima and then

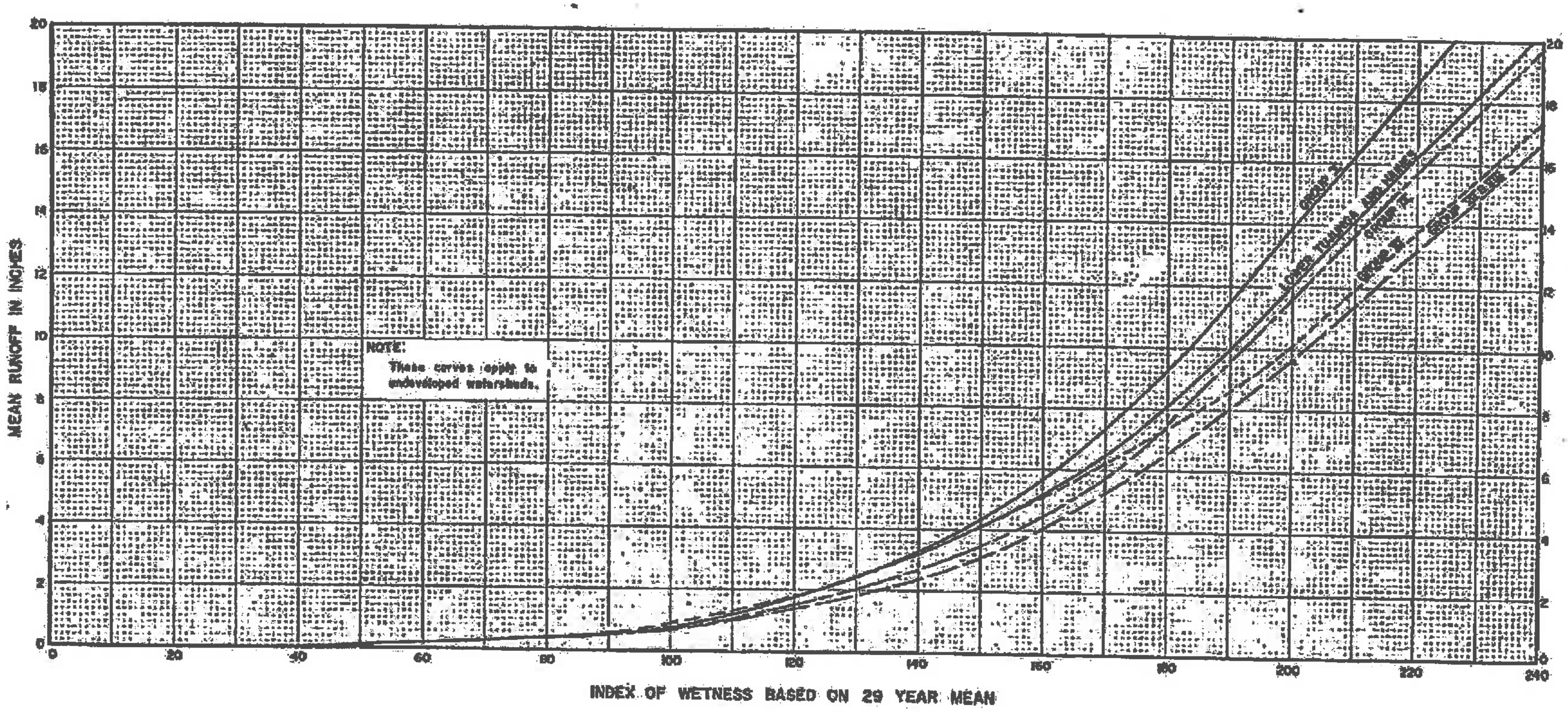


SAN FERNANDO VALLEY REFERENCE

HILL AND MOUNTAIN GROUPS
MEAN RUNOFF VS. INDEX OF WETNESS

STATE WATER RIGHTS BOARD

FIGURE F-8



SAN FERNANDO VALLEY REFERENCE

HILL AND MOUNTAIN GROUPS
MEAN RUNOFF VS. INDEX OF WETNESS

STATE WATER RIGHTS BOARD

further adjusted by trial and error so that the summation of deviations for each watershed during the 29-year base period was equal to zero.

The deviations of Sycamore and Spunky were then converted to percent of 29-year precipitation and averaged to obtain the correction factor to be applied to mean runoff. The correction factor multiplied by the 29-year mean runoff gave the correction in inches to be added or subtracted from the mean runoff to obtain the final runoff value. Table F-6 shows for each year (1928-1958) and for each group, the precipitation, mean runoff and adjusted runoff.

The final unit runoff multiplied by the acreage of each unit resulted in the annual runoff for native conditions as shown in Table F-7.

Additional Runoff Due to Development

As hill and mountain areas become transformed from native culture to residential areas the runoff from these areas will increase with the additional amount of impervious area resulting from this transformation.

The method of determining additional runoff was to compute runoff from impervious areas and then to subtract the runoff previously determined for native conditions. The resulting additional runoff is considered due to drainage conditions to be for the most part carried to the valley floor without opportunity for percolation.

Table F-8 lists the yearly values of items used in the estimation of additional runoff, the method of computation and the amount of additional runoff for the hill and mountain areas.

TABLE F-5

ADJUSTMENT OF MEAN RUNOFF VALUES

Year	Deviation[a] (in inches)				Deviation In percent of 29-year mean precipitation		
	Tujunga	Pacoima	Sycamore	Spunky	Sycamore	Spunky	Correction factor[b]
1928-29	0.1	-0.2	No Record	No Record	- 1[c]	- 1[c]	- 1
29-30	-0.3	-0.4			- 2[c]	- 2[c]	- 2
1930-31	-0.8	-0.6			- 3[c]	- 3[c]	- 3
31-32	-0.4	1.6			8[c]	8[c]	8
32-33	0.2	0.1		-0.1	1[c]	- 1	0
33-34	0.6	1.1		-0.1	5[c]	- 1	2
34-35	-1.8	-1.5		-1.2	- 7[c]	- 6	- 7
1935-36	0.4	0.9		-0.2	4[c]	- 1	2
36-37	-1.0	1.8		-0.5	9[c]	- 3	3
37-38	4.3	3.7		1.4	18[c]	9	14
38-39	-0.4	-1.3	- 0.4	0	- 2	0	- 1
39-40	0.5	0.3	0.2	0	1	- 1	0
1940-41	-6.5	-5.1	-12.4	-2.6	-63	-16	-39
41-42	0.7	0.1	0.5	0.6	3	4	3
42-43	2.6	3.6	5.2	1.3	27	8	17
43-44	2.3	-1.0	0.8	2.8	4	17	10
44-45	0.8	0.2	0.2	1.5	1	9	5
1945-46	0.5	0.4	0	0.1	0	1	0
46-47	0.3	-0.8	0.1	-0.1	0	- 1	0
47-48	0.2	-0.1	0	-0.1	0	- 1	0
48-49	0.1	-0.1	- 0.2	-0.2	- 1	- 1	- 1
49-50	0	-0.1	- 0.2	-0.3	- 1	- 2	- 1
1950-51	0	-0.1	0.1	0	0	0	0
51-52	-2.5	-1.1	- 1.5	-2.0	- 8	-12	-10
52-53	0.5	0.2	0.3	0.2	2	1	1
53-54	0	0.5	0.1	0.1	0	- 1	0
54-55	-0.1	-0.5	- 0.1	-0.2	0	- 1	0
1955-56	-0.3	-0.5	0.1	-0.3	0	- 2	- 1
56-57	-0.3	-0.4	0.2	-0.2	1	- 1	0
57-58	-2.5	1.3	- 0.6	-4.3	- 3	-26	-14

a. Actual runoff - mean runoff (from Figures F-2 through F-5).
b. Weighted average composed of 1 part Sycamore and 1 part Spunky.
c. Based on deviation of Pacoima and summation of deviations for 29-year base period = 0.

TABLE F-6

PRECIPITATION AND RUNOFF, HILL AND MOUNTAIN GROUPS*

In Inches

Year	I + II Precipitation	I + II Runoff Mean	I + II Runoff Adjusted	III Precipitation	III Runoff Mean	III Runoff Adjusted	IV Precipitation	IV Runoff Mean	IV Runoff Adjusted	V Precipitation	V Runoff Mean	V Runoff Adjusted	VI Precipitation	VI Runoff Mean	VI Runoff Adjusted	VII Precipitation	VII Runoff Mean	VII Runoff Adjusted
1928-29	13.4	0.4	0.2	12.5	0.3	0.1	14.9	0.4	0.2	16.0	0.3	0.1	12.0	0.3	0.1	13.1	0.4	0.2
29-30	[illegible]	0.3	0.0	12.8	0.4	0.1	15.9	0.4	0.0	16.5	0.4	0.0	14.3	0.4	0.0	11.7	0.3	0.0
1930-31	15.9	0.6	0.0	15.3	0.5	0.0	17.8	0.5	0.0	21.4	0.6	0.0	16.9	0.6	0.0	15.4	0.5	0.0
31-32	21.7	1.3	2.7	20.3	1.3	2.7	24.7	2.0	3.6	27.7	2.2	4.0	22.3	1.9	3.3	21.7	1.5	2.9
32-33	13.6	0.4	0.4	11.9	0.3	0.3	13.5	0.3	0.3	17.3	0.4	0.4	14.3	0.4	0.4	14.2	0.4	0.4
33-34	19.5	0.5	0.9	15.1	0.5	0.8	17.3	0.5	0.9	19.0	0.4	1.9	15.1	0.4	0.8	16.2	0.6	1.0
34-35	20.8	1.1	0.0	21.5	1.7	0.5	23.9	1.7	0.3	28.2	2.4	0.8	23.1	2.1	0.8	21.9	1.5	0.3
1935-36	14.4	0.4	0.6	13.8	0.4	0.7	16.5	0.4	0.8	20.3	0.5	1.0	16.3	0.5	0.9	13.1	0.4	0.8
36-37	26.4	2.5	3.2	25.7	3.3	4.0	29.0	3.8	4.6	33.4	4.6	5.7	26.9	3.8	4.5	24.6	2.4	3.1
37-38	28.4	3.3	5.8	25.2	3.1	5.5	28.7	3.7	6.5	35.4	5.7	8.9	29.9	5.4	7.9	26.0	3.0	
38-39	23.0	1.6	1.4	18.0	0.8	0.6	23.1	1.5	1.3	26.9	1.9	1.7	20.2	1.3	1.1	21.4	1.4	1.2
39-40	17.7	0.6	0.5	16.4	0.6	0.6	19.4	0.7	0.7	21.5	0.6	0.6	16.7	0.5	0.5	16.3	0.6	0.5
1940-41	43.9	17.7	10.5	40.0	14.9	8.2	44.8	16.2	8.4	48.0	15.4	6.4	37.0	10.5	3.4	41.0	15.8	9.0
41-42	14.4	0.4	0.9	12.3	0.3	0.8	14.5	0.3	0.9	16.9	0.4	1.1	13.4	0.3	0.8	14.2	0.4	0.9
42-43	26.7	2.6	5.7	25.0	3.0	5.9	29.9	4.2	7.6	34.2	5.1	9.0	27.8	4.3	7.4	26.4	3.1	6.1
43-44	25.9	2.4	4.2	24.4	2.8	4.5	27.3	3.0	5.0	32.1	4.1	6.4	25.7	3.2	5.0	25.0	2.5	4.3
44-45	15.8	0.5	1.4	15.2	0.5	1.4	17.6	0.5	1.5	20.7	0.5	1.7	16.9	0.6	1.5	15.9	0.5	1.4
1945-46	15.1	0.4	0.4	14.2	0.4	0.4	16.7	0.4	0.4	19.3	0.4	0.4	15.5	0.4	0.4	14.6	0.4	0.4
46-47	15.4	0.4	0.4	14.2	0.4	0.4	17.2	0.5	0.5	23.0	0.6	0.8	19.1	1.0	1.0	17.4	0.7	0.7
47-48	8.1	0.1	0.1	7.7	0.1	0.1	9.4	0.1	0.1	10.8	0.1	0.1	8.7	0.1	0.1	8.4	0.1	0.1
48-49	8.9	0.1	0.0	8.5	0.1	0.0	10.7	0.1	0.0	13.3	0.2	0.0	11.0	0.2	0.0	9.4	0.2	0.0
49-50	11.6	0.3	0.1	12.5	0.4	0.2	15.0	0.4	0.2	16.6	0.4	0.2	12.9	0.3	0.1	10.4	0.2	0.0
1950-51	8.8	0.1	0.1	10.3	0.2	0.2	12.6	0.2	0.2	13.9	0.2	0.2	10.8	0.2	0.2	8.7	0.1	0.1
51-52	33.4	7.2	5.4	30.5	5.9	4.2	35.8	7.8	5.8	42.3	10.2	7.9	33.6	7.7	5.9	32.3	7.2	[illegible]
52-53	12.7	0.3	0.5	13.4	0.4	0.6	15.5	0.4	0.6	16.0	0.3	0.5	12.0	0.3	0.5	11.7	0.3	0.5
53-54	14.9	0.4	0.4	15.0	0.5	0.5	16.9	0.4	0.4	18.5	0.4	0.4	14.6	0.4	0.4	13.3	0.4	0.4
54-55	14.7	0.4	0.4	14.6	0.4	0.4	16.3	0.4	0.4	17.2	0.4	0.4	13.2	0.3	0.3	14.1	0.4	0.4
1955-56	16.0	0.7	0.5	18.3	0.9	0.7	22.3	1.3	1.1	22.8	0.8	0.6	16.3	0.5	0.3	15.7	0.5	0.1
56-57	13.1	0.3	0.3	13.8	0.4	0.4	15.8	0.4	0.4	18.0	0.4	0.4	14.4	0.4	0.4	13.8	0.4	0.4
57-58	30.6	4.8	2.3	33.3	6.2	5.8	37.1	8.8	6.1	37.0	6.6	3.4	28.0	4.4	1.8	26.1	3.0	0.5
29-Year Average																		
1929-57	18.1	1.6	1.6	17.2	1.5	1.5	20.1	1.8	1.8	23.1	2.1	2.1	18.3	1.7	1.7	17.5	1.6	1.6

PRECIPITATION AND RUNOFF, HILL AND MOUNTAIN GROUPS*
(continued)

In Inches

Year	VIII - Sycamore Precipitation	VIII - Sycamore Runoff Mean	VIII - Sycamore Runoff Adjusted	IX Precipitation	IX Runoff Mean	IX Runoff Adjusted	X Precipitation	X Runoff Mean	X Runoff Adjusted	Lower Tujunga + Haines Precipitation	Lower Tujunga + Haines Runoff Mean	Lower Tujunga + Haines Runoff Adjusted	Pacoima Precipitation	Pacoima Gage runoff	Big Tujunga Precipitation	Big Tujunga Gage runoff
1928-29	14.7	0.4	0.2	17.1	0.4	0.2	17.7	0.4	0.2	13.7	0.3	0.1	17.0	0.6	16.6	0.7
29-30	12.0	0.3	0.0	13.7	0.3	0.0	15.9	0.3	0.0	14.8	0.4	0.0	19.0	0.6	19.2	0.8
1930-31	15.4	0.5	0.0	18.1	0.5	0.0	19.3	0.4	0.0	16.5	0.4	0.0	20.8	0.6	19.7	[illegible]
31-32	21.0	1.4	2.8	24.1	1.4	3.0	28.0	1.6	3.5	25.7	2.2	3.9	29.5	0.6	24.7	3.2
32-33	13.6	0.4	0.4	16.2	0.4	0.4	20.5	0.5	0.5	16.6	0.4	0.4	19.8	1.4	18.9	1.3
33-34	19.7	1.1	1.5	22.2	1.0	1.4	21.6	0.6	1.1	16.0	0.4	0.8	19.5	2.3	18.4	1.5
34-35	20.8	1.4	0.2	26.0	1.9	0.5	29.7	2.1	0.5	25.3	2.0	0.6	31.8	3.7	31.9	2.8
1935-36	14.9	0.4	0.8	17.0	0.4	0.8	18.4	0.4	0.9	15.3	0.4	0.6	19.5	2.1	18.1	1.2
36-37	24.0	2.2	2.9	28.7	2.7	3.5	34.6	4.0	4.9	30.0	3.9	4.7	37.8	10.4	37.6	6.6
37-38	26.5	3.2	5.7	31.2	3.8	6.7	37.2	5.3	8.6	32.2	5.1	7.9	44.4	17.2	41.8	14.8
38-39	20.4	1.3	1.1	24.2	1.5	1.3	27.2	1.4	1.2	22.6	1.2	1.0	27.7	2.3	27.1	2.6
39-40	14.9	0.4	0.4	17.0	0.4	0.4	19.6	0.4	0.4	17.1	0.5	0.5	22.3	2.1	20.0	1.9
1940-41	41.6	16.1	9.3	47.9	18.7	10.7	52.7	19.3	10.1	43.0	14.5	6.4	53.4	17.1	52.4	13.9
41-42	12.7	0.3	0.8	15.7	0.4	1.0	17.3	0.3	1.0	14.7	0.4	1.0	19.3	1.3	18.9	1.8
42-43	24.6	2.4	5.4	29.8	3.2	6.7	37.5	5.5	9.5	31.7	4.9	8.3	40.1	13.7	42.3	13.4
43-44	22.4	1.7	3.5	25.6	1.8	3.8	32.7	3.2	5.6	31.5	4.8	6.9	41.3	10.0	38.6	10.3
44-45	15.4	0.5	1.4	18.4	0.5	1.5	20.7	0.5	1.7	19.5	0.6	1.6	25.9	3.2	25.0	3.2
1945-46	14.7	0.4	0.4	16.5	0.4	0.4	21.3	0.5	0.5	18.5	0.5	0.5	24.9	3.1	25.0	2.9
46-47	17.6	0.7	0.7	19.8	0.7	0.7	25.3	1.0	1.0	21.4	0.9	0.9	28.3	2.9	27.4	3.4
47-48	8.4	0.1	0.1	9.8	0.1	0.1	11.3	0.1	0.1	10.2	0.1	0.1	13.9	0.3	14.1	0.7
48-49	9.5	0.2	0.0	10.6	0.1	0.0	14.0	0.2	0.0	12.3	0.2	0.0	15.9	0.5	14.9	0.5
49-50	12.0	0.3	0.1	12.2	0.2	0.0	15.6	0.3	0.1	14.4	0.3	0.1	17.2	0.7	16.0	0.5
1950-51	8.6	0.1	0.1	9.9	0.1	0.1	10.9	0.1	0.1	10.5	0.1	0.1	12.3	0.1	10.4	0.2
51-52	33.3	8.0	6.2	39.6	10.4	8.4	44.2	10.8	8.4	36.6	8.3	6.2	42.9	11.1	41.3	7.5
52-53	10.9	0.2	0.4	14.1	0.3	0.5	14.5	0.2	0.4	11.8	0.2	0.4	14.1	0.6	13.6	0.9
53-54	14.2	0.4	0.4	16.0	0.4	0.4	18.6	0.4	0.4	16.0	0.4	0.4	20.8	2.0	20.5	1.5
54-55	14.1	0.4	0.4	16.3	0.3	0.3	18.5	0.4	0.4	15.9	0.4	0.4	18.0	0.5	17.6	0.7
1955-56	17.0	0.7	0.3	18.6	0.6	0.4	20.7	0.5	0.3	17.7	0.5	0.3	21.1	1.0	16.9	0.6
56-57	13.8	0.4	0.4	15.6	0.4	0.4	18.4	0.4	0.4	15.3	0.4	0.4	17.2	0.4	17.3	0.5
57-58	25.3	2.6	0.1	30.2	3.3	0.4	38.3	6.1	2.8	32.0	5.0	2.1	38.8	10.5	40.5	[illegible]
29-Year Average																
1929-57	17.5	1.6	1.6	20.4	1.8	1.8	23.6	2.1	2.1	20.2	1.9	1.9	25.4	3.9	24.6	3.5

* Runoff under conditions of native culture.

TABLE F-7

RUNOFF FROM HILL AND MOUNTAIN GROUPS BASED ON NATIVE LAND USE

In Acre-Feet

Year	Tributary to San Fernando and Eagle Rock Subareas								
	I + II	III	IV	VI	VII	VIII + Sycamore	Lower Tujunga + Haines	Big Tujunga	Subtotal
1928-29	430	150	290	20	220	110	190	4,130	5,540
29-30	0	150	0	0	0	0	0	4,350	4,350
1930-31	0	0	0	0	0	0	0	3,070	3,070
31-32	5,780	3,960	5,270	490	3,170	1,550	7,410	17,900	45,530
32-33	860	440	440	60	440	220	760	7,550	10,770
33-34	1,930	1,290	1,320	120	1,090	830	1,520	7,680	15,780
34-35	0	730	440	120	330	110	1,140	14,840	17,710
1935-36	1,710	1,030	1,170	130	870	440	1,520	7,640	14,510
36-37	6,850	5,860	6,740	670	3,390	1,610	8,930	36,260	70,310
37-38	12,410	8,060	9,520	1,180	6,010	3,160	15,010	83,960	139,310
38-39	3,000	880	1,910	160	1,310	610	1,900	13,690	23,450
39-40	1,280	880	1,030	80	660	220	950	10,990	16,090
1940-41	22,680	12,020	12,310	510	9,830	5,160	12,160	78,840	153,510
41-42	1,930	1,170	1,320	120	980	440	1,900	10,690	18,550
42-43	12,200	8,650	11,130	1,100	6,660	3,000	15,770	76,040	134,550
43-44	8,990	6,600	7,330	750	4,700	1,940	13,110	57,990	101,410
44-45	3,000	2,050	2,200	220	1,530	780	3,040	17,370	30,190
1945-46	860	590	590	60	440	220	950	17,160	20,870
46-47	860	590	730	150	760	390	1,710	18,960	24,150
47-48	210	150	150	20	110	60	190	4,640	5,530
48-49	0	0	0	0	0	0	0	2,460	2,460
49-50	210	290	290	20	0	60	190	2,960	4,020
1950-51	210	290	290	30	110	60	190	1,500	2,680
51-52	11,560	6,160	8,500	880	5,900	3,440	11,780	41,320	89,540
52-53	1,070	880	880	80	550	220	760	6,510	10,950
53-54	860	730	590	60	440	220	760	8,240	11,900
54-55	860	590	590	50	440	220	760	3,580	7,090
1955-56	1,070	1,030	1,610	50	110	170	570	4,700	9,310
56-57	640	590	590	60	440	220	760	2,290	5,590
57-58	4,920	8,500	8,940	270	550	60	3,990	39,420	67,550
29-Year Average									
1929-57	3,500	2,270	2,660	290	1,740	880	3,580	19,560	34,440

RUNOFF FROM HILL AND MOUNTAIN GROUPS BASED ON NATIVE LAND USE
(Continued)

In Acre Feet

Year	Tributary to Sylmar Subarea			Tributary to Verdugo Subarea			Hill and mountain total
	V	Pacoima	Subtotal	IX	X	Subtotal	
1928-29	50	880	930	20	120	140	6,610
29-30	0	960	960	0	0	0	5,310
1930-31	0	860	860	0	0	0	3,930
31-32	1,960	8,390	10,350	350	2,050	2,400	58,280
32-33	200	1,790	1,990	50	290	340	13,100
33-34	440	2,530	2,970	160	640	800	19,550
34-35	390	5,140	5,530	60	290	350	23,590
1935-36	490	3,040	3,530	90	530	620	18,660
36-37	2,790	14,530	17,320	410	2,870	3,280	90,910
37-38	4,350	27,250	31,600	780	5,040	5,820	176,730
38-39	830	3,060	3,890	150	700	850	28,200
39-40	290	3,180	3,470	50	230	280	19,840
1940-41	3,130	25,830	28,960	1,240	6,270	7,510	189 980
41-42	540	1,980	2,520	120	590	710	21,780
42-43	4,400	20,390	24,790	780	5,570	6,350	165,690
43-44	3,130	15,490	18,620	440	3,280	3,720	123,750
44-45	830	4,910	5,740	170	1,000	1,170	37,100
1945-46	200	2,890	3,090	50	290	340	24,300
46-47	390	6,020	6,410	80	590	670	31,230
47-48	50	340	390	10	60	70	5,990
48-49	0	740	740	0	0	0	3,200
49-50	100	1,020	1,120	0	60	60	5,200
1950-51	100	70	170	10	60	70	2,920
51-52	3,860	14,360	18,220	970	4,920	5,890	113,650
52-53	250	3,500	3,750	60	230	290	14,990
53-54	200	2,940	3,140	50	230	280	15,320
54-55	200	740	940	40	230	270	8,300
1955-56	290	1,250	1,540	50	180	230	11,080
56-57	200	770	970	50	230	280	6,840
57-58	1,660	15,880	17,540	50	1,640	1,690	86,780
29-Year Average							
1929-57	1,020	6,030	7,050	220	1,260	1,480	42,970

Note: San Fernando Subarea includes Eagle Rock Subarea.

Verdugo Subarea includes the portion of Monk Hill Basin within the Upper Los Angeles River Area.

TABLE F-8

ADDITIONAL RUNOFF FROM HILL AND MOUNTAIN AREAS DUE TO URBANIZATION

Tributary to San Fernando and Eagle Rock Hydrologic Subarea

Year	Precipitation Station 295, in inches (1)	Evaporation[a], in inches (2)	Gross runoff, in inches (3)=(1)-(2)	Native runoff[b], in inches (4)	Additional runoff, in inches (5)=(3)-(4)	Developed area, in acres (6)	Percent impervious (7)	Additional runoff, in acre-feet (5)x(6)x(7)=(8)
1928-29	14.7	5.0	9.7	0.2	9.5	1,500	35	420
29-30	12.0	3.3	8.7	0.0	8.7	1,530	35	390
1930-31	15.4	4.1	11.3	0.0	11.3	1,550	35	510
31-32	21.0	5.2	15.8	2.7	13.1	1,600	35	610
32-33	13.6	2.5	11.1	0.4	10.7	1,630	35	510
33-34	19.8	2.4	17.4	1.2	16.2	1,670	35	810
34-35	20.8	6.4	14.4	0.1	14.3	1,710	35	710
1935-36	14.8	4.4	10.4	0.8	9.6	1,740	35	490
36-37	24.1	5.9	18.2	3.0	15.2	1,780	35	790
37-38	26.5	5.1	21.4	5.7	15.7	1,810	35	830
38-39	20.5	4.4	16.1	1.2	14.9	1,850	35	800
39-40	14.9	4.9	10.0	0.5	9.5	1,890	35	520
1940-41	41.6	6.4	35.2	9.9	25.3	1,930	35	1,420
41-42	12.7	5.9	6.8	0.8	6.0	1,980	35	350
42-43	24.5	4.8	19.7	5.5	14.2	2,040	35	850
43-44	22.5	4.9	17.6	3.8	13.8	2,090	35	840
44-45	15.4	4.6	10.8	1.4	9.4	2,190	35	600
1945-46	14.8	4.4	10.4	0.4	10.0	2,300	40	770
46-47	17.5	5.0	17.0	0.5	16.5	2,440	40	1,340
47-48	8.5	3.4	5.1	0.1	5.0	2,620	40	440
48-49	9.5	4.6	4.9	0.0	4.9	2,830	40	460
49-50	12.0	4.5	7.5	0.1	7.4	3,160	40	780
1950-51	8.6	4.6	4.0	0.1	3.9	3,510	45	510
51-52	33.4	6.9	26.5	5.8	20.7	3,930	45	3,050
52-53	11.0	5.1	5.9	0.4	5.5	4,450	45	920
53-54	14.7	4.0	10.2	0.4	9.8	5,070	45	1,860
54-55	14.2	6.5	7.7	0.4	7.3	5,740	45	1,570
1955-56	17.0	4.8	12.2	0.4	11.8	6,510	50	3,200
56-57	13.8	3.8	10.0	0.3	9.7	7,340	50	2,970
57-58	25.2	6.5	18.7	1.2	17.5	8,330	50	6,070

Tributary to Verdugo Hydrologic Subarea

Year	Precipitation Station 254, in inches (1)	Evaporation[c], in inches (2)	Gross runoff, in inches (3)=(1)-(2)	Native runoff[d], in inches (4)	Additional runoff, in inches (5)=(3)-(4)	Developed area, in acres (6)	Percent impervious (7)	Additional runoff, in acre-feet (5)x(6)x(7)=(8)
1949-50	18.2	5.4	12.8	0.1	12.7	70	40	30
1950-51	11.7	5.8	5.9	0.1	5.8	100	45	20
51-52	41.9	7.4	34.5	8.4	26.1	130	45	130
52-53	13.6	5.4	8.2	0.4	7.8	160	45	50
53-54	22.3	4.7	17.6	0.4	17.2	200	45	130
54-55	17.3	7.2	10.1	0.4	9.7	240	45	90
1955-56	22.0	5.0	17.0	0.3	16.7	270	50	190
56-57	17.6	5.2	12.4	0.4	12.0	330	50	170
57-58	35.9	6.9	29.0	2.8	26.2	380	50	420

Tributary to Total Valley Fill[e]

Year	Runoff, in acre-feet	Year	Runoff, in acre-feet	Year	Runoff, in acre-feet
1928-29	420	1940-41	1,420	1950-51	530
29-30	390	41-42	350	51-52	3,180
		42-43	650	52-53	970
1930-31	510	43-44	840	53-54	1,990
31-32	610	44-45	600	54-55	1,560
32-33	510				
33-34	810	1945-46	770	1955-56	3,390
34-35	710	46-47	1,340	56-57	3,140
		47-48	440	57-58	6,490
1935-36	490	48-49	460		
36-37	790	49-50	810	29-year average 1929-57	1,040
37-38	830				
38-39	800				
39-40	520				

a. Evaporation on impervious areas on valley floor in San Fernando Hydrologic Subarea.
b. Average of groups I + II and VII + Sycamore from Table F-6.
c. Evaporation on impervious areas on valley floor in Verdugo Hydrologic Subarea.
d. Group X, Table F-6.
e. Development of areas tributary to Sylmar Hydrologic Subarea was minor and additional runoff due to urbanization of these areas was nil.

Runoff into Reservoirs

Surface runoff into San Fernando, Chatsworth and Encino Reservoirs becomes a part of the amount of water available for use in the Owens water service area. This additional amount of supply to the reservoirs, computed as described herein, is utilized in the accounting made of Owens River water in Appendix J. The amount of surface runoff attributable to hill and mountain areas is also computed, since this amount of runoff would not be available for percolation in the stream system above Gage F-57.

The areas tributary to each of the three reservoirs are listed in Table F-9.

TABLE F-9

AREAS TRIBUTARY TO SAN FERNANDO, CHATSWORTH AND ENCINO RESERVOIRS

Hydrologic subarea	Reservoir	Hill and mountain group	Tributary area, in acres		Tributary period
			Hill	Valley	
San Fernando	San Fernando	IV	5,311	804	1915-1942
TOTAL - 1915 through 1942			6,115		
Sylmar	San Fernando	V	986	778	1915-1958
San Fernando	Chatsworth	III	1,940	0	1919-1958
San Fernando	Encino	I + II	1,040	0	1921-1958
TOTAL - 1921 through 1958			4,744		

Annual runoff from hill and mountain areas tributary to the reservoirs was computed as runoff per acre for the hill and mountain group in which the area was located times the acreage of the area. Annual amounts of runoff from each hill and mountain group are set forth in Table F-7. This amount was then corrected for any difference between the 85-year mean rainfall for the entire group and for the tributary area by the ratio between the 85-year precipitation on the two areas. The hill and mountain areas tributary to the reservoirs are undeveloped; hence no correction for urbanization is necessary.

Runoff from valley lands was estimated as equal to the residual rain on impervious areas determined as set forth in Appendix L. This amount was corrected for differences between the 85-year mean precipitation of the entire valley fill and of the tributary area in the same manner as hill and mountain runoff described above. Correction factors utilized were: ten percent increase for valley runoff in San Fernando Hydrologic Subarea tributary to San Fernando Reservoir; ten percent decrease in hill and mountain runoff tributary to Chatsworth; and ten percent increase in runoff tributary to Encino Reservoir. Other tributary areas did not require correction. Culture maps shown on Plates 22 through 25 were used to determine the culture on the valley fill areas during the periods involved. The portion of the tributary valley fill in the Sylmar Hydrologic Subarea was found to be ten percent impervious (1928-1958), while the portion in the San Fernando Hydrologic Subarea was five percent impervious (1928-1942).

Percolation of the combined flows of hill and mountain runoff and residual rain on valley fill areas enroute to the reservoirs was estimated as follows:

1. Area of percolation was limited to stream channels plus roadside ditches.

2. Percolation rate during flow was 0.4 inch per hour.[1]

3. Flow occurred only during days when rain exceeded 0.50 inch.

Estimated areas in which percolation of runoff could take place was approximately six acres in each of the valley fill areas tributary to San Fernando Reservoir. This acreage used with a percolation rate of 0.4 inch per hour was used to determine percolation of runoff, which was then subtracted from total runoff to yield the net surface inflow to reservoirs. The total runoff from hill and mountain and valley fill areas tributary to the reservoirs less the percolation is shown in Table F-10.

The total surface inflow from each tributary area was split into that originating in hill and mountain and in valley fill areas in the same ratio as runoff developed in hill and mountain and in valley fill areas. Surface inflow due to runoff from hill and mountain areas is shown in Table F-11.

1/ United States Department of Agriculture 1955 Year Book of Water, page 157.

TABLE F-10

ESTIMATED TOTAL SURFACE INFLOW
INTO OWENS RIVER SYSTEM RESERVOIRS

In Acre-Feet

Year	San Fernando Hydrologic Subarea Reservoir			Sylmar Hydrologic Subarea	Total
	San Fernando	Chatsworth	Encino	San Fernando Reservoir	
	(1)	(2)	(3)	(4)	(5)
1928-29	60	20	20	0	100
29-30	0	0	0	10	10
1930-31	0	0	0	20	20
31-32	1,530	400	250	370	2,550
32-33	130	40	40	70	280
33-34	400	130	80	120	730
34-35	100	70	0	80	250
1935-36	320	120	80	100	620
36-37	1,990	590	300	550	3,430
37-38	2,840	800	550	880	5,070
38-39	580	90	130	230	1,030
39-40	280	90	60	70	500
1940-41	3,640	1,200	1,000	630	6,470
41-42	370	120	80	80	650
42-43		870	540	910	2,320
43-44		660	400	650	1,710
44-45		210	130	170	510
1945-46		60	40	70	170
46-47		60	40	90	190
47-48		20	10	10	40
48-49		0	0	0	0
49-50		30	10	30	70
1950-51		30	10	10	50
51-52		620	510	810	1,940
52-53		90	50	40	180
53-54		70	40	40	150
54-55		60	40	30	130
1955-56		100	50	90	240
56-57		60	30	10	100
57-58		850	220	360	1,430
29-Year TOTAL 1929-1957	12,240	6,610	4,490	6,170	29,510

TABLE F-11

ESTIMATED SURFACE INFLOW INTO OWENS RIVER SYSTEM RESERVOIRS FROM RUNOFF ORIGINATING IN HILL AND MOUNTAIN AREAS

In Acre-Feet

Year	San Fernando Hydrologic Subarea Reservoir			Sylmar Hydrologic Subarea	Total
	San Fernando	Chatsworth	Encino	San Fernando Reservoir	
1928-29	40	20	20	0	80
29-30	0	0	0	0	0
1930-31	0	0	0	0	0
31-32	1,480	400	250	290	2,420
32-33	100	40	40	30	210
33-34	360	130	80	60	630
34-35	70	70	0	30	170
1935-36	290	120	80	60	550
36-37	1,930	590	300	450	3,270
37-38	2,780	800	550	760	4,890
38-39	520	90	130	130	870
39-40	250	90	60	30	430
1940-41	3,530	1,200	1,000	460	6,190
41-42	340	120	80	60	600
42-43		870	540	770	2,180
43-44		660	400	530	1,590
44-45		210	130	120	460
1945-46		60	40	30	130
46-47		60	40	40	140
47-48		20	10	0	30
48-49		0	0	0	0
49-50		30	10	10	50
1950-51		30	10	0	40
51-52		620	510	650	1,780
52-53		90	50	20	160
53-54		70	40	10	120
54-55		60	40	10	110
1955-56		100	50	40	190
56-57		60	30	0	90
57-58		850	220	240	1,310
29-Year TOTAL 1929-1957	11,690	6,610	4,490	4,590	27,380

APPENDIX G

IMPORT TO UPPER LOS ANGELES RIVER AREA BY CITY OF LOS ANGELES

APPENDIX G

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TABLES

APPENDIX G

IMPORT TO UPPER LOS ANGELES RIVER AREA BY CITY OF LOS ANGELES

Water Supply of City of Los Angeles
Department of Water and Power
Los Angeles Aqueduct System

The Los Angeles aqueduct system of the City of Los Angeles Department of Water and Power, the general plan and profile of which is shown on Plate 14, was constructed to utilize the water supply of Owens River and Mono Basin in serving the demands of the City of Los Angeles. Construction on the aqueduct began in 1907 and the first water was delivered to Los Angeles from the Owens Basin in November 1913, but distribution within San Fernando Valley did not begin until May 1915. In 1940 the aqueduct system was extended to include the Mono Basin and since that time aqueduct diversions have been made from both basins. Conditions and capacities stated herein are as of 1959 unless otherwise noted.

Description of Project

Mono Basin is a closed basin east of the Sierra Nevada Mountain Range draining into Mono Lake. Owens Basin is a closed basin draining into Owens Lake and is separated from the Mono Basin by a low flat divide. Diversion of the entire flow of Owens River into the aqueduct during the dry period from about 1920 to 1936 caused the bed of Owens Lake to become almost completely dry. Since that time, except for the period from 1936-37 through 1938-39, the flows into Owens Lake have been small.

The upper part of the aqueduct system starts in Mono Basin at Leevining Creek with a covered conduit to Walker Creek having a capacity of 300 cubic feet per second (cfs), as indicated on Plate 14. Walker Creek may be diverted across or into the conduit. The capacity of the conduit from Walker Creek to Parker Creek is 325 cfs. Parker Creek may also be diverted across or into the conduit. The capacity of the conduit from Parker Creek to Grant Lake is 350 cfs. Rush Creek flows directly into Grant Lake. The storage capacity of Grant Lake Reservoir is 47,525 acre-feet and facilities are provided by which water may be returned to Rush Creek below the reservoir. A covered conduit conveys the diverted water from Grant Lake to the Mono Craters Tunnel through which the Mono Basin water reaches Owens River Basin. The capacity of Mono Craters Tunnel is 365 cfs. Existing municipal water rights under Application 8042, Permit 5555, of the City of Los Angeles to waters in Mono Basin are conditioned so that simultaneous diversions shall not exceed 200 cfs from the four sources consisting of Leevining, Walker, Parker and Rush Creeks.

The City of Los Angeles has no controls on Owens River above Long Valley Reservoir; however, by agreement it is restrained from releasing water through the Mono Craters Tunnel when such release would cause the flow of the Owens River between the outlet of the tunnel and Long Valley Reservoir to exceed 400 cfs.

The capacity of Long Valley Reservoir is 183,465 acre-feet. Water from the reservoir passes through a series of three power plants located in the Owens River Gorge (see Plate 14). The power plants have a capacity of 690 cfs, but when use is made of the spillway and auxiliary outlet the discharge capacity from the reservoir is unlimited. Pleasant Valley Reservoir, located downstream from the power plants, has a storage capacity of 3,885 acre-feet and is used as an afterbay for regulating hydroelectric power peaking flows. Flow from this reservoir is usually steady. From Pleasant Valley Reservoir to Tinemaha Reservoir water is conveyed in the natural river course and there are no flow limitations other than minimum and rate of change restrictions imposed in the interest of fish life. The capacity of Tinemaha Reservoir is 16,405 acre-feet and is used to regulate flow into the Aberdeen intake of the aqueduct by holding valley runoff during shutdown for maintenance and by controlling flood waters. It is not used as a long-term storage reservoir.

The aqueduct below Aberdeen intake, which is situated downstream of Tinemaha Reservoir, is open canal in earth section to the Alabama Hills and concrete lined from there to Haiwee Reservoir (see Plate 14). The maximum capacity in this section is 700 cfs. There are numerous streams intercepted in this area and also several waste gates that are used to dewater the aqueduct for maintenance. Haiwee Reservoir, with a capacity of 58,525 acre-feet, is the lowermost reservoir in the aqueduct system in Owens Valley. Its storage is utilized to equalize flows into the conduit which delivers the water into the City of Los Angeles.

From Haiwee Reservoir to Fairmont Reservoir, which has a storage capacity of 7,507 acre-feet, the aqueduct is covered conduit or pipe section having a maximum capacity approaching 500 cfs. The conduit requires careful operation and maintenance to sustain this capacity. From Fairmont Reservoir to Dry Canyon Reservoir the capacity of the aqueduct is approximately 1,000 cfs. The Fairmont Reservoir outflow is varied to meet power peaking demands at the San Francisquito Power Plants of the City of Los Angeles and reregulated at Dry Canyon Reservoir to the constant rate required by downstream aqueduct capacity. The capacity of Dry Canyon Reservoir is 751 acre-feet. Bouquet Reservoir, with a capacity of 36,505 acre-feet, is on a spur from the aqueduct between Fairmont Reservoir and the San Francisquito Power Plants (see Plate 14). It is used as a reserve supply when the aqueduct between Haiwee Reservoir and Fairmont Reservoir is out of service. Between Dry Canyon Reservoir and San Fernando Reservoir inlet, the latter being the terminus of the aqueduct system, the maximum capacity is 485 cfs. This capacity establishes the maximum rate at which water can be delivered to Los Angeles.

Historical operation of the aqueduct indicates that all sections of the system are shut down approximately seven percent of the time for inspections and repairs. This out-of-service period must be taken into consideration in computing annual capacities.

For a limited period, the City of Los Angeles extracted water from deep wells in Owens Valley to augment its aqueduct supply. These wells were pumped continuously from May 1928 to December 1931 and were last used in January 1935. The record of Owens Valley deep wells includes all pumped and free flowing artesian water from city-owned and operated wells reaching the aqueduct from January 1918 through March 1959. There is no recorded differentiation between pumping and nonpumping periods, but inspection of the available records indicates that during pumping periods the rate of flow is considerably greater than during nonpumping periods. During the pumping periods the total quantity taken into the aqueduct system was approximately 398,000 acre-feet. During years in which there was no pumping, in the period 1918 to 1958, the annual artesian flow from wells reaching the aqueduct varied from 4,848 to 30,880 acre-feet with the average for such years approximating 11,500 acre-feet.

Since the initial aqueduct project was completed in 1913, the following improvements have been added:

Time or period of installation	Description of improvement
October 1928	Tinemaha Reservoir was completed and initial storage of water began in March 1929.
1930-33	Smooth lining was placed in the closed section of the aqueduct below Haiwee to increase the capacity.
April 1934	Bouquet Reservoir placed in service.
December 1940	Mono Basin Extension completed.
April 1941	Storage began in Long Valley Reservoir.
1952	Owens River Gorge power plants completed.
July 1956	Pleasant Valley Reservoir placed in service.

Quantity Diverted and Used

The quantity of water diverted by the City of Los Angeles from the Mono Basin-Owens River system is considered to be the inflow to Haiwee Reservoir, which is the sum of the diversion from the Owens River measured in the vicinity of Cartago at the Cottonwood Power Plant gates plus the

Cartago Station and Haiwee Reservoir. This quantity is also considered as the inflow to Haiwee Reservoir.

Diversion by the city into the aqueduct system, measured as described above for each hydrologic year of the period of record, is shown in column 1 of Table G-1. The annual amounts of water diverted from Mono Basin through the Mono Craters Tunnel are tabulated in column 6 of Table G-2. The amounts of water released from Haiwee Reservoir for delivery to the city ranged from 34,290 acre-feet in 1913-14 to 358,470 acre-feet in 1957-58. The Mono diversion from the Mono Basin into the Owens River system ranged from about 600 to 108,415 acre-feet during the period of its operation from 1934-35 through 1957-58.

Also shown in Table G-1 is the disposition of aqueduct water between Haiwee Reservoir and San Fernando Valley. Haiwee Reservoir outflow prior to July 1931 was measured at Little Lake and subsequent thereto at the Haiwee Reservoir outlet (see Plate 20). There are several unaccountable factors which may cause a difference in values of the Haiwee Reservoir outflow and the City of Los Angeles import shown in Table G-1. These factors are listed as follows:

1. Seepage and evaporation losses from the aqueduct and reservoirs. (The evaporation from Fairmont, Bouquet Canyon and Dry Canyon Reservoirs is approximately 4,800 acre-feet a year).

2. In measuring large quantities of water, the accuracy of a meter may vary by two percent, more or less. These measuring differences have been aggravated at times in the past when the flow into San Fernando Valley was the combination of three measurements.

TABLE G-1

QUANTITIES DIVERTED AND USED BY THE CITY OF LOS ANGELES
FROM OWENS VALLEY AND MONO BASIN

In Acre-Feet

Year	Amounts diverted into Haiwee Reservoir (1)	Outflow from Haiwee Reservoir (2)	Change in storage[a] (3)	Spill into Santa Clara River Basin (4)	Import into Los Angeles (5)	Unaccounted-for water[b] (2)-(3)-(4)-(5)=(6)
1913-14	34,290		- 30			
14-15	44,650		+ 10			
1915-16	66,290		- 60		43,710	
16-17	95,930	81,910	+ 140		68,180	13,590
17-18	194,730	159,840	+ 4,150		129,330	26,360
18-19	194,820	193,840	- 430		176,030	18,240
19-20	211,980	186,990	+ 1,410		202,260	-16,680
1920-21	191,860	169,950	+ 220		187,720	-17,990
21-22	245,310	207,470	+ 160		204,620	2,690
22-23	194,800	203,240	- 1,160		186,110	18,290
23-24	167,790	158,340	+ 1,070		149,660	7,610
24-25	172,790	131,020	- 3,910		127,820	7,110
1925-26	191,360	205,570	+12,310		169,700	23,560
26-27	244,260	204,860	+18,630		173,490	12,740
27-28	220,780	225,730	-26,800		194,710	57,850[c]
28-29	204,760	206,920	+ 1,700		190,100	15,120
29-30	245,550	204,310	+ 30		198,130	6,150
1930-31	245,650	225,900	+ 90		215,750	10,060
31-32	258,200	241,100	- 640		238,200	3,540
32-33	243,800	239,780	- 330		228,430	11,680
33-34	236,920	274,750	+17,810		185,580	21,360
34-35	251,230	231,760	+14,700		194,920	22,140
1935-36	247,680	257,540	- 2,120	2,040	236,940	20,680
36-37	239,250	229,620	+ 1,160	0	206,670	21,790
37-38	283,090	247,670	+ 950	2,910	209,080	34,730
38-39	261,510	293,200	- 6,240	19,850	237,250	42,330
39-40	240,870	244,710	- 860	440	217,160	27,970
1940-41	279,540	243,840	+ 5,660	8,070	200,980	29,130
41-42	293,610	298,560	- 2,700	16,860	246,350	38,050
42-43	297,270	286,070	- 7,020	1,320	264,400	27,370
43-44	307,580	303,760	+ 9,120	1,310	274,500	18,830
44-45	286,210	289,660	+ 330	2,150	267,240	19,940
1945-46	307,050	306,680	- 1,600	10	283,970	24,300
46-47	338,040	329,170	- 950	11,270	291,020	27,830
47-48	326,670	320,480	+ 2,210	0	306,460	11,810
48-49	308,940	311,780	- 2,900	0	298,460	16,220
49-50	316,050	323,180	+ 6,160	0	305,400	11,620
1950-51	356,610	323,400	- 2,410	50	317,370	6,390
51-52	330,690	335,120	- 2,160	3,970	316,570	16,740
52-53	339,950	331,870	+ 3,880	0	320,920	7,070
53-54	322,180	329,600	+ 1,320	0	318,590	9,690
54-55	339,430	331,410	- 1,260	0	316,320	16,350
1955-56	342,730	338,450	+ 650	0	321,260	16,570
56-57	324,330	332,690	- 700	170	318,390	14,630
57-58	358,470	333,850	- 6,220	40	325,390	14,640

a. Summation of Fairmont, Bouquet, Dry Canyon and St. Francis Reservoirs. Plus indicates water into storage and minus water from storage.
b. Unaccounted for water includes seepage and evaporation losses, inaccuracies of measuring devices, operational losses and distribution along the aqueduct.
c. Includes 37,990 acre-feet spilled from St. Francis Reservoir.

TABLE G-2

STREAM RUNOFF TRIBUTARY TO LOS ANGELES AQUEDUCT DIVERSION
WORKS IN MONO BASIN IN EXCESS OF HISTORIC DIVERSIONS

In Acre-Feet

Year	Leevining Creek (1)	Walker Creek (2)	Parker Creek (3)	Rush Creek (4)	Sub-total (5)	Flow through Mono Craters Tunnel[a] (6)	Runoff in excess of diversion from Mono Basin (5)-(6)=(7)
1934-35	50,535	3,709	8,280	59,113	121,637	622[b]	
1935-35	57,048	4,682	7,684	67,453	136,867	2,738	
36-37	51,895	4,909	7,761	56,734	121,299	2,412[c]	
37-38	82,034	8,614	10,919	99,564	201,131	5,568[c]	
38-39	43,665	4,279	7,261	45,567	100,772	7,376[d]	
39-40	62,160	5,053	8,039	53,167	128,419	15,268[e]	
1940-41	65,873	7,480	9,466	79,538	162,357	50,775	111,582
41-42	65,774	6,943	9,882	76,681	159,280	18,395	140,885
42-43	76,329	6,579	8,918	64,570	156,396	23,829	132,567
43-44	46,933	4,358	7,168	47,714	105,173	70,240	35,933
44-45	51,383	6,090	9,100	73,608	140,181	26,286	113,895
1945-46	52,506	5,209	8,627	62,869	129,211	13,853	115,358
46-47	34,124	4,058	6,849	45,890	90,921	25,759	65,162
47-48	37,793	3,630	6,272	46,493	94,188	92,265	1,923
48-49	30,738	3,675	6,593	53,979	94,985	104,443	0
49-50	37,317	3,154	5,750	49,141	95,362	104,598	0
1950-51	53,168	6,117	7,826	48,030	115,141	107,473	7,668
51-52	66,282	6,941	9,978	83,783	166,984	40,521	126,463
52-53	43,789	4,530	6,786	52,433	107,538	75,870	31,668
53-54	25,155	3,506	5,598	38,993	73,252	64,730	8,522
54-55	29,081	3,345	6,079	44,748	83,253	85,259	0
1955-56	56,377	7,663	9,872	83,826	157,738	108,415	49,323
56-57	45,318	4,791	7,391	56,786	114,286	61,908	52,378
57-58	50,790	6,974	10,428	70,362	138,554	32,689	105,865

a. Includes tunnel make varying from 16 to 23 cfs, of which 60 percent originates on the Mono Basin side of the hydrologic divide.
b. June through September only.
c. No record for August, September and October of 1937.
d. Tunnel holed through near the end of April. Mono Basin water could not enter Owens Valley before this time.
e. Tunnel lining completed February 1940. Before completion Owens Valley as well as Mono Basin water was pumped from shaft adits and flowed back into Mono Basin. Computations by the City of Los Angeles have been made to the "Balance Point" which was found to be in February 1940. At this time the accumulated total of Mono Basin water transferred to Owens Valley exceeded the accumulated Owens Valley water pumped into Mono Basin.

3. Varying amounts of water are lost in operational procedures. These losses are small and, with the exception of the water spilled into the Santa Clara Basin, are not measured. An additional unmeasured quantity of water was discharged in the Antelope Valley desert area during the period 1940-46 under a Court injunction to do everything possible to prevent water from reaching the Owens Lake bed. These losses have been kept to a minimum since 1947 when demands have necessitated keeping the aqueduct flow at a maximum.

4. Some water is distributed to customers directly from the aqueduct.

Quantity Available for Diversion and Use

The quantity of water available for diversion and use by the City of Los Angeles was considered to be the sum of the following four quantities:

1. Flow in aqueduct measured at the Cartago Station.

2. Flow into Owens Lake measured in Owens River at the Mt. Whitney Bridge from July 1908 through October 1918 and at the Keeler Bridge from January 1927 throughout the period of study (see Plate 14 for location of stations).

3. Change in storage in Long Valley, Pleasant Valley and Tinemaha Reservoirs. Plus change was added and negative change subtracted.

4. Runoff in Mono Basin in excess of historic diversions by the City of Los Angeles.

It is possible for the City of Los Angeles to divert with its existing works the entire Mono Basin supply from Leevining, Walker, Parker and Rush Creeks, as measured above points of diversion on these streams (see Plate 14). The city owns all of the affected irrigated lands and water rights pertaining thereto, which are situated below the points of diversion. Therefore, the estimated amount of water available for diversion by the City of Los Angeles from Mono Basin in excess of historic diversions was considered to be the combined supply of the four creeks measured as described above minus the amount entering Owens Valley through Mono Craters Tunnel. The measured flow through Mono Craters Tunnel includes a tunnel make varying from 16 to 23 cfs, of which 40 percent is Owens Valley water and has not been separated in this computation. Table G-2 shows the computation and the stream runoff in excess of the city's diversion in Mono Basin. Supply values are shown for the period of record but computations of the amounts available began in 1940 when the tunnel lining was completed and it was placed in service.

Table G-3 indicates the total quantity of water so estimated to be available in the Owens and Mono Basins for diversion by the City of Los Angeles through its aqueduct system.

TABLE G-3

STREAM RUNOFF TRIBUTARY TO LOS ANGELES AQUEDUCT DIVERSION WORKS IN OWENS VALLEY AND MONO BASIN

In Acre-Feet

Year	Diversion into: Haiwee Reservoir (1)	Flow into Owens Lake (2)	Change in storage[a] (3)	Available from Mono Basin (4)	Stream runoff tributary to diversion works (1)+(2)±(3)+(4)=(5)
1913-14	34,290	343,610			377,900
14-15	44,650	227,340			271,990
1915-16	66,290	311,720			378,010
16-17	95,930	236,080			332,010
17-18	194,730	69,140			263,870
18-19	194,820	6,420[b]			201,240
19-20	211,980	c			--
1920-21	191,860	c			--
21-22	245,310	c			--
22-23	194,800	c			--
23-24	167,790	c			--
24-25	172,790	c			--
1925-26	191,360	c			--
26-27	244,260	17,630[d]			261,890
27-28	220,780	10,750			231,530
28-29	204,760	3,110			207,870
29-30	245,550	3,330			248,880
1930-31	245,650	1,920	0		247,570
31-32	258,200	2,580	+ 850		261,630
32-33	243,800	2,450	+ 7,550		253,800
33-34	236,920	2,590	- 8,400		231,110
34-35	251,230	6,190	0		257,420

Year	Diversion into: Haiwee Reservoir (1)	Flow into Owens Lake (2)	Change in storage[a] (3)	Available from Mono Basin (4)	Stream runoff tributary to diversion works (1)+(2)±(3)+(4)=(5)
1935-36	247,680	13,650	+ 1,110		262,440
36-37	239,250	48,250	+ 7,500		295,000
37-38	283,090	221,370	- 4,410		500,050
38-39	261,510	89,280	- 90		350,700
39-40	240,870	4,830	+ 2,250		247,950
1940-41	279,540	7,280	+89,760	111,580	488,160
41-42	293,610	9,440	+12,220	140,890	456,160
42-43	297,270	9,400	+ 8,200	132,570	447,440
43-44	307,580	6,880	-16,410	35,930	333,980
44-45	286,210	6,570	+50,200	113,900	456,880
1945-46	307,060	9,720	- 1,360	115,360	430,780
46-47	338,040	7,200	-72,820	65,160	337,580
47-48	326,670	3,620	+24,310	1,920	356,520
48-49	309,940	4,070	+16,860		329,870
49-50	315,050	3,540	+ 2,470		322,060
1950-51	356,610	3,790	+26,520	7,670	394,590
51-52	330,690	5,400	+32,570	126,460	495,120
52-53	339,950	5,120	-17,210	31,670	359,530
53-54	322,180	3,760	-35,160	8,520	299,300
54-55	339,430	3,670	+ 7,470		350,570
1955-56	342,730	4,090	+56,910	49,320	453,050
56-57	324,330	4,490	-16,430	52,380	364,770
57-58	358,470	4,920	+ 7,320	105,870	476,580

a. Summation of Long Valley, Pleasant Valley and Tinemaha Reservoirs. Plus indicates water into storage and minus water from storage. Lake evaporation was not taken into consideration.
b. Month of October 1918 (station discontinued October 31, 1918).
c. No record.
d. January through September.

Bibliography

1. California State Department of Public Works, Division of Water Resources. "Report to Senate Committee on Local Governmental Agencies on Water Supply and Use of Water in Mono-Inyo Basin, California." March, 1948.

2. Lee, Charles H. "An Intensive Study of the Water Resources of a Part of Owens Valley, California." United States Department of the Interior, Geological Survey. Water Supply Paper 294. 1912.

3. United States Department of the Interior, Geological Survey. Water Supply Papers on "Surface Water Supply of the United States, Part 10, The Great Basin."

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APPENDIX H

WATER QUALITY

APPENDIX H

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APPENDIX H

WATER QUALITY

A general water quality evaluation of the Upper Los Angeles River area was made in compliance with Item I, 2, E, of the Order of Reference. The purpose of the study was to ascertain the quality of surface and ground water and effect of import thereon.

Source of Data

All available water analyses were collected from California State Department of Water Resources, Los Angeles County Flood Control District, Department of Engineering of Los Angeles County, the Plaintiff and the defendants. Additional analyses were obtained from various other individuals during the well survey conducted by the Referee. Supplemental analyses were also made by the Referee.

Compilation of Data

Surface water analyses were collected and arranged in stream mile order beginning at the confluence of the Los Angeles River with the Arroyo Seco. The stream mile numbering is shown on Plate 12 and was taken from the Official Stream Mile Maps of the California State Department of Water Resources. The ground water analyses collected were tabulated in numerical order by location number. The well location number system and the location of wells are shown on Plate 18.

Complete analyses utilized generally contained the following determinations: Specific electrical conductance, concentrations of total dissolved solids, hydrogen ion content (pH), calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, nitrate, fluoride, boron and total hardness as $CaCO_3$.

Specific electrical conductance measures the ability of water to conduct an electrical current and is a measure of the salts in solution. The standard determination of this value is given as electrical conductance (EC) x 10^6 at 25° centigrade and is expressed as micromhos. Some of the older analyses are stated as EC x 10^5. These values have been increased by a factor of ten to adjust them to the present day standard of EC x 10^6 in the tabulations. When total dissolved solids are not given in an analysis an approximate amount can be calculated by multiplying the EC x 10^6 by 0.62.

Hydrogen ion concentration (pH) shown in the tabulation is that made in the laboratory. Where field and laboratory values were indicated on collected data, only the laboratory values have been utilized although field (pH) may more accurately represent field water conditions.

Bicarbonate values reported in analyses made by the City of Los Angeles Department of Water and Power were in terms of alkalinity as $CaCO_3$. To make the sums of cations and anions more nearly balance the reported values were adjusted to ppm of HCO_3 by dividing the reported value by 50.05, the equivalent weight of $CaCO_3$, and multiplying by 61.02, the equivalent weight of HCO_3.

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Some of the analyses collected and not utilized in the study were in terms of hypothetical combinations in grains per gallon.

Methods of Classifying Waters

The most widely used criteria for determining the suitability of water for domestic and municipal use are the 1946 U. S. Public Health Service Drinking Water Standards[1/] (U.S.P.H.S.). The standards have also been adopted by the California State Department of Public Health. Limits for mineral constituents in water are divided into mandatory and recommended criteria and are shown in Table H-1.

Total hardness is a significant factor in the determination of the suitability of a water for domestic and municipal use. Waters containing 100 ppm or less of hardness (as $CaCO_3$) are considered "soft" while those with more than 200 ppm are considered "very hard".

The quality of delivered water has effects on both plant growth and ground water quality. A detailed discussion of water quality effects is contained in California State Department of Water Resources Bulletin 78.[3/]

Methemoglobinemia has been related to nitrate in water supply and is a basis for the California State Department of Public Health recommended tentative limit of 10 parts per million nitrate nitrogen (44 ppm NO_3) for safe domestic waters.

TABLE H-1

QUALITY CRITERIA FOR DOMESTIC WATER
BASED ON DRINKING WATER STANDARDS,
U. S. PUBLIC HEALTH SERVICE, 1946[1]

Mandatory limits:

Lead (Pb)	0.1 ppm
Fluoride (F)	1.5 ppm
Arsenic (As)	0.05 ppm
Selenium (Se)	0.05 ppm
Hexavalent chromium (Cr^{6+})	0.05 ppm

Nonmandatory, but recommended, limits:

Copper (Cu)	3.0 ppm
Iron (Fe) and Manganese (Mn) together	0.3 ppm
Magnesium (Mg)	125 ppm
Zinc (Zn)	15 ppm
Chloride (Cl)	250 ppm
Sulfate (SO_4)	250 ppm
Total dissolved solids (TDS)	
Desirable	500 ppm
Permitted	1,000 ppm

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Ground Water

Thomas and White[4] point out that " ... a basic distinction between meteoric and nonmeteoric waters is suggested by the fact that the hydrologic cycle includes a distillation process of vaporization and precipitation that has no counterpart in the development of nonmeteoric waters except volcanic steam. Thus meteoric water is more likely to be fresh and fresh water is much more likely to be meteoric than nonmeteoric."

Approximately 1,500 ground water analyses which were obtained from various sources and 32 analyses which were made by the Referee have been studied in detail. The chemical character of these waters indicates that they are meteoric in origin; that is, water of the hydrologic cycle which involves evaporation, atmospheric circulation, precipitation, runoff and subsurface movement. None of the analyses indicate any sources of juvenile or magmatic waters that originate deep within the earth, the latter two types being generally recognized by their highly mineralized character. Volcanic waters are distinguished by a higher temperature and by relatively high contents of fluorine, silica, boron, sulfur, carbon dioxide and antimony and by a relatively low content of calcium and magnesium as compared to waters of meteoric origin.

The ground waters occurring in the valley fill of the area of investigation are generally within the recommended limits as set forth in the U. S. Public Health Service Drinking Water Standards, 1946. The principal exceptions are those waters in the vicinity of Calabasas, which are derived from wells that penetrate the Modelo formation, and some wells in the lower part of the Verdugo Hydrologic Subarea. The nitrate content of ground water in the Verdugo Subarea has increased at a rapid rate during recent years. This phenomenon is discussed in detail later in this appendix.

The ground waters of the hydrologic subareas in general would be classed as moderately hard to very hard. The character of the water in the western portion of the San Fernando Hydrologic Subarea is predominantly calcium sulfate while in the eastern portion and in the Verdugo and Sylmar Hydrologic Subareas it is calcium bicarbonate. Plate 15 represents geochemical charts on which the percentage characteristic of waters in various locations in the basin have been plotted. These plots show that all of the natural waters are the calcium, magnesium, sulfate, bicarbonate or "hardness" group. A comparison of the plots for 1932 and 1956-57 indicates that the ground waters have remained in the same hardness group during the 24-year period.

The ground water in the Calabasas area which is pumped from the Modelo formation has total dissolved solids values ranging from 1,000 to 3,242 ppm, magnesium values as high as 150 ppm and sulfate values as high as 1,392 ppm. All of these values exceed the U. S. Public Health Service Drinking Water Standards, 1946, recommended limits.

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Sources of Nitrates in Ground Water

Elemental nitrogen exists throughout nature in combination with other elements. It occurs in very slight quantities in igneous rocks, it constitutes about four-fifths of the atmosphere, and it is an essential constituent of living organisms. These nitrogen sources often form nitrates through bacterial action or when subjected to weathering processes.

In water, nitrogen can occur in several forms depending on its state of oxidation. These forms are listed as follows:[5/]

1. Gaseous nitrogen (N_2), dissolves in water to some extent but has no major significance in water quality.
2. Organic nitrogen (N--).
3. Nitrite (NO_2-) as (N+++).
4. Nitrate (NO_3-) as (N+++++). Nitrogen exists in its highest oxidized and most stable form as nitrate.

An extensive review of available literature establishes that the significant sources of nitrate contributions to ground water are sewage, organic wastes, fertilizer, rainfall and the nitrogen fixation processes. A discussion of sources is presented as follows.

Rain Water

An analysis of rain water at Riverside, California, as published in the Division of Water Resources Office Report on the El Cajon Valley, 1955,[6/] revealed, as shown in Table H-2, a total nitrogen concentration of 0.803 parts per million and a nitrate concentration of 0.388 parts per million. It was also noted that these values may be as low as one-tenth the values reported in other areas, the difference being dependent upon the occurrence of atmospheric electrical discharges.

TABLE H-2

AVERAGE RAINFALL AND AMOUNTS OF VARIOUS NITROGEN FRACTIONS (AS NO_3) IN RAIN WATER, 1933-34[6]
(At Riverside, California)

Average yearly rainfall, in inches	Constituents in parts per million			
	NH_3	NO_2	NO_3	Total
12.98	0.402	0.013	0.388	0.803

Igneous Rocks

The occurrence of nitrates in igneous rocks was reported by Clarke, 1924[7] and by Lord Rayleigh, 1939.[8] According to Lord Rayleigh, igneous rocks contain on an average 0.00463 percent nitrogen. This nitrogen appears to be mainly in chemical combination, perhaps as ammoniacal nitrogen.

TABLE H-3

NITROGEN IN IGNEOUS ROCKS
(After Lord Rayleigh)[8]

Rock	N-(ml/g)
Dunite, average	0.045
Gabbro	0.037
Granite, average	0.037

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Research conducted by Stevenson, 1959,[9] revealed that the nitrogen content of granitic rocks is generally lower than the values reported by Rayleigh for igneous rocks as shown in Table H-3.

Several arguments have been set forth in an effort to explain the presence of ammonium salts found in volcanic emanations. Clarke, 1924,[7] reports that the nitrogen in lava is an original constituent, and not a result of organic origin. Rankama, 1950,[8] on the other hand, reports that nitrogen in lava may be of secondary origin, formed in the reaction between hot lava and atmospheric nitrogen.

No detailed information is available on the exact manner or mode of occurrence of nitrates found in some magmatic rocks. It is believed doubtful that nitrates occurring in igneous rocks can be of any material significance to the pollution of ground water in the area of investigation.

Sedimentary Rocks

Noble and Mansfield, 1922,[10] report that in certain desert areas of California, nitrate deposits as sodium nitrate have been found. These deposits occur in caliche layers about five inches thick and are associated with other water soluble salts, primarily sodium in character. Generally the nitrate deposits are associated with shale or clay formations laid down in lakes during Tertiary and Quaternary ages, and occur as a result of physical conditions reflecting climate and soil character rather than from a unique geologic formation or condition.

The sodium nitrate occurring in the caliche deposits found in California, particularly those of the Amargosa region, average less than 2.5 percent of sodium nitrate.

Nitrogen Fixation

Nitrogen fixation is defined as the process by which certain soil bacteria, such as those living symbiotically within the root nodules of various leguminous plants, have the power of bringing free nitrogen into combination. The bacteria in these root nodules first produce proteins which later decompose and ultimately yield nitrates.

Nitrogen fixation is not limited to this special case. Nearly all soils contain bacteria, both aerobic and anaerobic species, which assist in the decomposition or rotting of vegetable and animal matter with the ultimate formation of ammonia. The ammonia is converted to nitrites by nitrosifying bacteria, and then to nitrates by nitrifying bacteria, both of which are found in soils. Both of these steps are actually oxidations of the nitrogen compounds and they occur in connection with the life cycle of the bacteria. An example is farm manure which contains nitrogen as urea ($CO(NH_2)_2$) and proteins. When the manure is spread on soil, bacteria in the air and in the soil act to decompose the manure. The urea is hydrolyzed to ammonium carbonate and the proteins are changed by aerobic bacteria into ammonia. The final result is the development of nitrates.

Fertilizers

Commercial fertilizers used for agricultural purposes have been found responsible for nitrate pollution in several agricultural areas.

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Nitrate concentrations have been reported in the Redlands area in California as high as 160 ppm.[11]

The State Water Pollution Control Board's Publication No. 9[12] reports that commercial fertilizers develop nitrate by percolation through soils with some decrease in total nitrogen and that ammoniacal nitrogen, applied to soils on the surface, appears to be oxidized to nitrite and nitrate while passing through the soil. The report also notes that the passage of nitrogen through soils takes place in two steps. First, the ammonium ion is absorbed on any colloidal matter present, and secondly, if the pH is above 5.0, bacteria operates to oxidize the ammonium ion to nitrate.

Cesspool and Septic Tank Effluent

Nitrate development in septic tanks and cesspools is described as the mineralization of nitrogenous organic matter, or as the final product of the biochemical oxidation of ammonia. The nitrate concentration is generally thought to be low or nonexistent in septic tanks and cesspools because of anaerobic conditions existing in this environment. Nitrates appear to develop under the aerobic conditions existing after the sewage effluent is discharged from the cesspool or septic tank and allowed to percolate through soils, where oxygen is available. (An analysis made of fresh cesspool liquor sampled by the Referee in Verdugo City revealed the complete absence of nitrates).

Studies conducted by the Sanitary Engineering Research Project of the University of California at Lodi, California,[13] indicate that nitrate accumulation did not begin until a depth of four feet below the bottom of spreading basins filled with sewage effluent.

As a result of nitrification, nitrate concentration increased several hundred percent during the percolation through 13 feet of alluvial materials. The nitrogen available in the form of ammonia and nitrites plus the presence of oxygen would lead to conditions favorable to the biological oxidation of reduced forms of nitrogen. Nitrites present on the surface rapidly disappeared with depth, this being consistent with the appearance of nitrates.

According to data presented in the State Water Pollution Control Board Publication No. 9,[12] the average nitrate concentration of sewage in sewer mains attributable to domestic use of water is 20 to 40 parts per million total nitrogen or 88 to 176 parts per million nitrate.

Synthetic Detergents in Ground Water

Synthetic detergents have largely taken the place of soap as the household cleaner since their advent on the market after World War II. In 1948, syndets represented only 16 percent of the total annual soap and detergent sales; however, in 1957 syndets represented over two-thirds of the total sales and comprise approximately 75 percent or more of the sales today. This wholesale use of syndets in homes today has introduced a new product into sewage effluent. Unlike soap, surface active agents utilized in synthetic detergents are biologically resistant organic material.

The normal wash day synthetic detergent[14] is generally a heavily built synthetic powder and usually consists of 20 to 22 percent of surface active matter compound with about 35 to 40 percent phosphates, mainly sodium tripolyphosphate; up to 10 percent silicates; 5 percent of sodium perborate; 1 to 2 percent of sodium carboxymethylcellulose; and the remainder of various other compounds, including foam stabilizers, corrosion inhibitors, etc.

Of the basic synthetic detergents available commercially, approximately 80 percent of the total volume marketed utilized the sulphonate type surface active agent, more specifically alkyl benezene sulfonates (ABS). Most of the ABS are derived from propylene. They are inexpensive and possess excellent deterging properties making them popular in household detergent formulas.

BOD studies conducted on polypropylene benezene sulphonates by Sawyer and Ryckman, 1957,[15] show them to be extremely resistant to biological attack.

Water pollution problems related to ABS have been found responsible for foaming, taste, and odor at about one part per million. Cohen, 1959,[16] reports that as little as 0.8 parts per million syndets will foam water and that colorimetric procedures have proved to be the most valuable method for determining the microquantities of ABS concentrations in water. In most analytical procedures for ABS, methylene blue is added to a water sample and compared to a previously calibrated concentration with a spectrophotometer.

The basic weakness with this colorimetric method is low specificity. Naturally occurring materials also react to the dyes, which can lead to erroneously high results. Certain organic sulfates, sulfonates, carboxylates, phosphates and phenols react to methylene blue. Inorganic compounds, such as cyanates, nitrates, thiosulfates and thiocyanates, also interfere with this method; however, these interferences have not proved too inconvenient since the concentration of interfering substances is generally low. To make ABS values comparable with other reported values, a standard reference surfactant material is made available by the Association of American Soap and Glycerine Producers.

A longer, more complex infrared method for determining ABS concentrations has been developed; however, no laboratories in this area are equipped to handle this type of analysis.

All available evidence points out the fact that synthetic detergents in water originate only in sewage, and their presence in well water definitely establishes contamination by sewage discharge.

In addition to the contamination problems related to ABS, the large percentage of phosphates used in household synthetic detergents may afford a medium for bacterial survival in ground water and their presence in ground water should be considered.

What overall relationship, if any, synthetic detergents have with nitrates is not known; however, their introduction to the domestic household coincides with the advent of increasing nitrate ion concentrations in the study area.

Interpretation of Analyses

The tabulated data were utilized in several methods of interpreting changes in water quality. These methods included line graphs, trilinear geochemical charts, and isoplethic (lines of equal value) maps.

Isochlors (variety of isoplethic) were drawn for two separated periods, namely 1931-32 and 1951-53. These periods were selected as having the best general basin-wide coverage. The results did not show any conclusive change in chloride concentrations.

The historic presence of the boron ion was investigated since relatively high boron waters were imported from the Owens Valley for a period of time during 1932. At that time there was concern that these waters, in which the boron content reached a reported maximum of 1.44 ppm, might have adversely affected sensitive crops in the area of use.

The relative presence of boron was gaged by utilizing the boron factor (boron in ppm/EC x 10^3). This factor was conceived by J. S. Logan of the United States Bureau of Reclamation in studies in the southern part of the San Joaquin Valley and was employed as a tool to separate waters from different sources. The following is a tabulation of various boron factors from diverse sources as compiled by Logan:

Source	Boron Factor, Fb
Ocean water	0.09
Major San Joaquin streams	1.30
Petroleum brines (average)	1.30
Petroleum brines (maximum)	3.90
Sulphur Bank Hot Springs	62.00
Highest boron in water well in Arvin area	6.73

Maps showing lines of equal boron factors were prepared for 1931-32 and 1951-53. The boron factors in the 1931-32 period varied from 0.03 to 1.62 and averaged 0.41. Variation for the 1951-53 period was from 0.008 to 1.61 with an average of 0.33. A comparison of the two periods indicated no pattern of increase or decrease and no appreciable change in the boron content of the ground water.

The ground waters of the western portion of the San Fernando Hydrologic Subarea are predominately sulfate type, while those in the eastern portion are bicarbonate type. In an attempt to delineate the areas of the two types of water, an isoplethic map of sulfate-bicarbonate ratios was prepared. The ratio is expressed as:

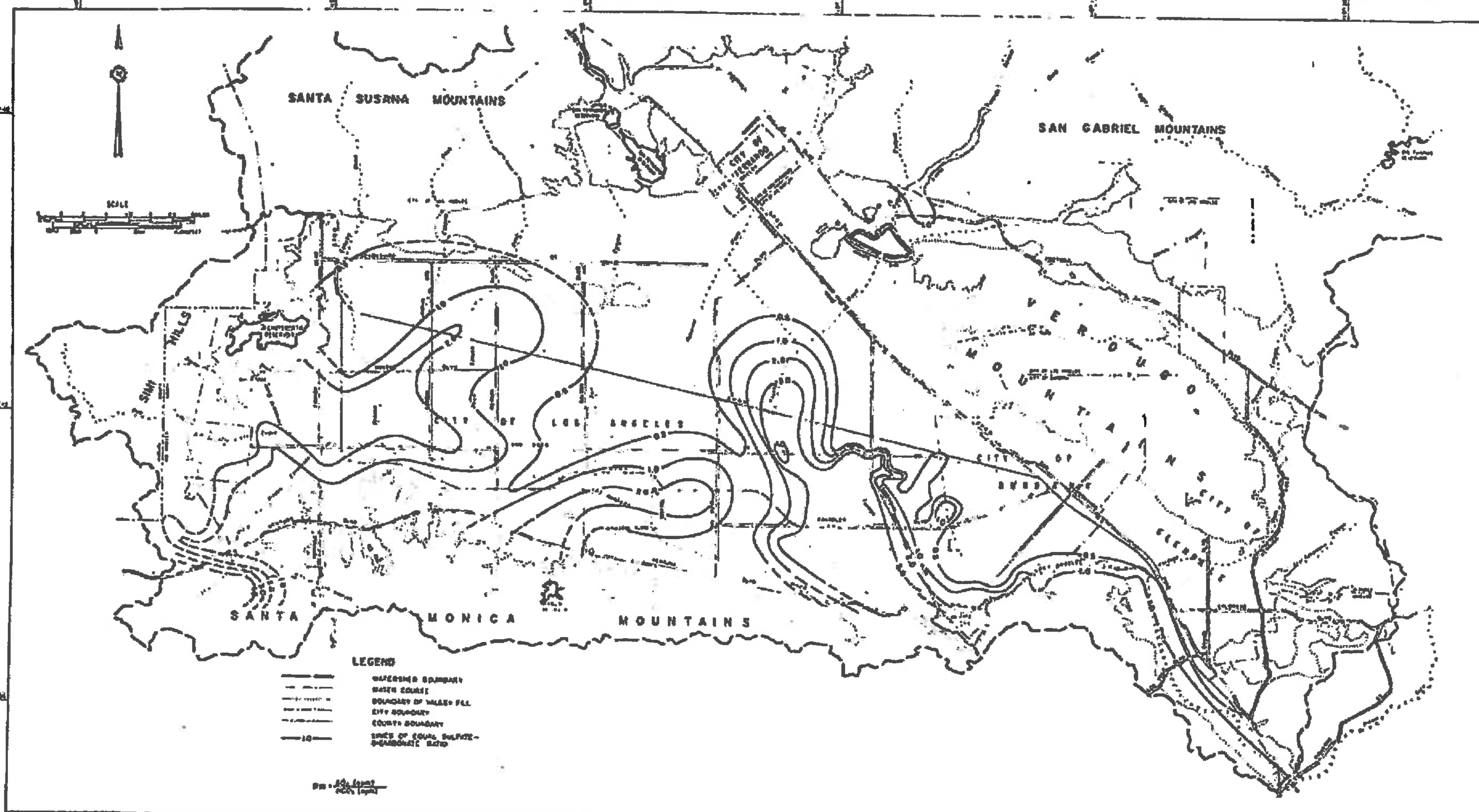
$$R_{sb} = \frac{SO_4 \text{ (epm)}}{HCO_3 \text{ (epm)}}$$

A value of one would be obtained when the constituents were equal. Numbers greater than one indicate a greater amount of sulfate present in the water, while numbers less than one indicate a dominance of bicarbonate.

The computed ratios were plotted in their proper location on a map and lines of equal sulfate-bicarbonate ratio (R_{sb}) were drawn as shown on Figure H-1. This study indicated that the distribution of the two mentioned types is much more complex than originally assumed.

Graphs, plotting parts per million versus years, were made of wells with records of analyses for a period of years at selected locations throughout the area of investigation. These graphs (Plates 17-A, 17-B, 17-C, 17-D) show the variation in total dissolved solids (TDS), sulfate (SO_4), chloride (Cl) and in some instances where records were available, nitrate (NO_3).

The constituents plotted were selected as being those important in domestic and municipal water systems. The graphs indicate that in general there has been no substantial change in ground water quality other than would normally occur due to return of irrigation water. An exception to this is found in the Verdugo Hydrologic Subarea where large increases in nitrate concentrations have taken place. This problem is discussed in detail in the following section. In other portions of the area of investigation analyses of ground waters indicate that some wells have abnormal concentrations of nitrate. Wells with nitrate concentrations of 20 ppm or greater are listed in Table H-4.



SAN FERNANDO VALLEY REFERENCE

LINES OF EQUAL SULFATE — BICARBONATE RATIO

GROUND WATER QUALITY

STATE WATER RIGHTS BOARD

TABLE H-4

NITRATE ION CONCENTRATIONS OF WELLS,
SAN FERNANDO AND SYLMAR HYDROLOGIC SUBAREAS

Well number	Nitrate concentration ppm	Date sampled
3566	30.4	8-15-54
3701B	20	10- 8-57
3785A	37	7-31-57
3790	20	6-11-58
3790D	20	6-11-58
3832J	41	7-26-57
3833F	35	9-24-57
3845A	30.8	2- 8-52
3845F	32.4	7- 2-56
3934	23	12- 4-56
3947A	62	7-11-56
3947B	44	7-11-60
3949B	20	4- 9-58
3954	32	1-15-60
3958C	34	5- 6-60
3987A	31	1-29-60
3987B	35	1-29-60
3987C	23	5- 5-60
3987D	21	2-10-60
3987E	23	2-10-60
3987F	35	1-29-60
4694	34.4	7-31-58
4735B	22	12- 4-56
4735C	24	5-27-54
4896A	30	6-12-57
4973J	93	6-27-58
4983F	28.5	9-15-53
5988A	34	7-24-57

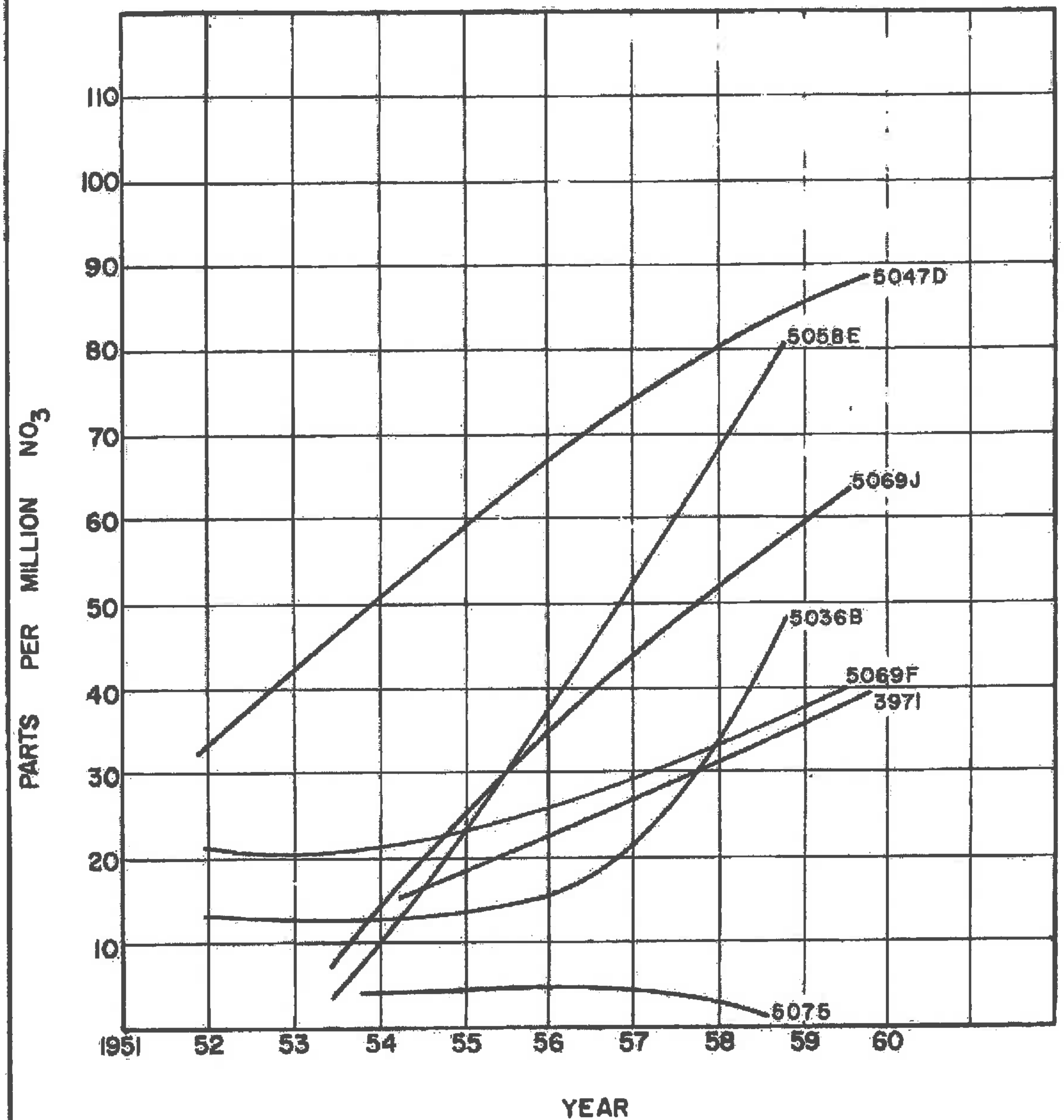
Occurrence of Nitrates in the Verdugo Hydrologic Subarea

The analyses used in this study were made by various laboratories. The methods and laboratory techniques used by these laboratories vary considerably. The Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio, reports in the 1958 "Analytical Reference Service" that the "phenoldisulfonic acid method", used by most laboratories, gives results that are almost uniformly low and that this method does not give reliable results for most operators. Statistical data presented indicate that the results of the PDA method may vary as much as 27.81 percent from the actual value. Hem,[5/] reports that the "phenoldisulfonic acid method" is best adapted for nitrate concentrations under 30 ppm, although the procedure may give rather tenuous results. For values over 30 ppm the method is inaccurate. All of the analyses available to the Referee are by the PDA method or an earlier method of similar reliability.

The nitrate ion concentrations of wells having nitrate records in the Verdugo Hydrologic Subarea have been plotted for the period 1951-52 to 1958-59 on Figure H-2 on the following page. The plots indicate sharp increases in nitrates except for well 5075, which is in the upper portion of the subarea. Since the increases in nitrates are recent they cannot be of natural causes and must therefore be due to:

1. Fertilizers applied to lawns, gardens and golf courses.

2. Oxidized cesspool and septic tank effluent.



SAN FERNANDO VALLEY REFERENCE
VERDUGO HYDROLOGIC SUBAREA
NITRATE ION INCREASE IN SELECTED WELLS

STATE WATER RIGHTS BOARD

Fertilizer as a Source of Nitrate

A general reconnaissance of the study area revealed that commercial fertilizers are being used to some extent on small private lawns and gardens and very extensively on the Oakmont Country Club turf and golf greens. The quantity of fertilizer used on private lawns and gardens is very small and no abnormal fertilizing practice was obvious in any of the residential areas.

At the Country Club, a direct relationship between fertilizers and ground water might exist. This area is sewered and serviced by Glendale Public Services. Well water pumped by the City of Glendale from well No. 3971 reflects a present nitrate concentration of 40 ppm. An irrigated turf of 110 acres located 1,500 feet upstream is fertilized with 20 tons of a 20 percent ammonia fertilizer three times per year. An additional acre and a half is treated with sulfate of ammonia, a 21 percent nitrogen fertilizer, every two weeks.

An average of about 30.5 acre-feet per month of water is applied to the golf course and greens. This figure represents about 0.25 acre-foot per acre per month.

The nitrates developed in soils through nitrogen fixation and fertilization are available to vegetation for consumption and/or reduction to nitrogen by denitrifying bacteria and released to the atmosphere, or they may be leached from the soil by irrigation water and rainfall percolating to ground water.

The amount of nitrates leached from a soil is governed by the soil-type method of fertilization, cropping practice, climate and the amount of applied water and rainfall. A review of the preceding practices suggests that sufficient nitrates are developed on the golf course to effectively contribute some nitrates to the ground water of the study area. However, sufficient water is applied through irrigation and rainfall to continually leach applied concentrations of nitrates on the ground surface and in the root zone, thereby eliminating the possibility of any very concentrated slugs reaching the water table.

Sewage as a Source of Nitrate

The portion of the Verdugo Hydrologic Subarea discharging sewage into cesspools and septic tanks was occupied by approximately 35,800 persons in 1951 and 55,300 persons in 1958.

Average nitrate concentration attributable to the domestic use of water in the study area may reach 88 to 176 parts per million.[11] Thus, if the disposal of effluent from domestic sewage through septic tanks and cesspools constitutes a continuing major source of ground water recharge, the ground water concentration will be influenced accordingly.

A study was made to determine the relationship between pumped water and cesspool effluent within a 500-foot radius (estimated average cone at depression of a pumping well) of six wells in the Verdugo Hydrologic Subarea. A house count was made on large-scale aerial photographs within the established radius and the cesspool effluent determined on the basis of 3.7 persons per dwelling. These results were compared to the pumpage of the respective well and indicated that from four to eight percent of the water pumped could be cesspool effluent falling within the assumed cone of depression around each well. What effect this volume of effluent has on the nitrate concentration in water produced in the various wells is not known exactly; however, it does suggest that cesspool effluent with a nitrate concentration in the range previously indicated may have an appreciable influence on concentration of nitrates in this water supply.

Noting the location of the high nitrate wells it is seen that these wells are situated parallel to Verdugo Wash. Topographically, and by an inspection of Plate 6, Base of Water-Bearing Series, it becomes apparent that these wells are situated so as to effectively intercept a portion of the subsurface drainage of the upper portion of the subarea. This area is coincident with the unsewered portion of the study area. Further, the area immediately around the high nitrate wells is served by the high nitrate waters pumped from these same wells.

From the preceding it is concluded that the high nitrate ion concentrations found in the Crescenta Valley County Water District wells are definitely related to the physiography and this explains the absence or very small nitrate ion concentration in wells 5076 and 5077B, located upstream.

The review of chemical analyses of well waters in the study area also revealed an increase in chloride ion, a general decrease in pH, and a recent occurrence of synthetic detergents.

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The chloride increase supports the conclusions that the nitrate pollution is originating from sewage effluent or re-use. Analysis of well No. 5058E shows a chloride concentration of 11 ppm in 1949 and 33 ppm in 1958. The nitrate concentration for this same well was 15 ppm in 1949 and 81 ppm in 1958. The decrease in pH would be expected as a result of the increase in acid salts, e.g. nitrate and chloride. A brief study on this point indicates that considerably more salts are being deposited in the subarea since 1950 than are being exported. This situation also corresponds to the rapid increase in nitrate ion concentration in the subarea.

Traces of synthetic detergents detected in all of the wells in the study area appear to establish sewage effluent as the source of nitrate pollution. A recent analysis of water from well No. 5047D noted a concentration of 0.37 parts per million synthetic detergent determined as alkyl benzene sulphonate. Most of the other wells in the study area, particularly those with high nitrate concentrations, also have concentrations of syndets.

Conclusions

Research and investigation by the Referee leads to the following conclusions regarding the Verdugo Hydrologic Subarea:

1. Nitrate concentrations occurring in the native ground waters of the Verdugo Hydrologic Subarea prior to 1950 were substantially below the California Department of Public Health recommended limit.

2. A review of existing well logs and geology indicates that nitrate yielding rocks or formations do not occur in significant quantity anywhere in the subarea.

3. The abnormal increase of nitrate ion concentrations in the ground water of the subarea is coincident with the postwar residential development of the subarea.

4. High nitrate concentrations in the well waters of the subarea are coincident with the topographic lows in the subarea.

5. The present high nitrate ion concentrations appear to be a result of cesspool effluent and the recirculation of high nitrate well water pumped within the subarea. These conclusions are corroborated by the coincident increase in chloride concentration and existence of synthetic detergents in the well waters.

Bibliography

1. United States Public Health Service, "Drinking Water Standards". 1946.

2. California State Department of Public Works, Division of Water Resources. "Ground Water Occurrence and Quality, Colorado River Basin Region". Water Quality Investigations. Report No. 4. 1954.

3. California State Department of Water Resources. "Effects of Differences in Water Quality, Upper Santa Ana Valley and Coastal San Diego County". Bulletin 78, Appendix B. 1959.

4. Thomas, H. E. and White, D. E. "Meteoric vs. Nonmeteoric Ground Water". Journal of the Irrigation and Drainage Division. A.S.C.E. Volume 85, No. IR2, Part 1. June, 1959.

5. Hem, J. D. "Study and Interpretation of the Chemical Characteristics of Natural Water". United States Geological Survey Water Supply Paper 1473. 1959.

6. California State Department of Public Works, Division of Water Resources. "El Cajon Valley Water Quality and Resources, San Diego County". Water Quality Investigations, Office Report. December, 1955.

7. Clarke, F. W. "The Date of Geochemistry". Fifth Edition. United States Geological Survey. Bulletin 770. 1924.

8. Rankama, K. and Sahama, T. G. "Geochemistry". Chicago University Press. Chicago, Illinois. 1950.

9. Stevenson, F. J. "On the Presence of Fixed Ammonia in Rocks". Science. Volume 30. July, 1959.

10. Noble, T. F. and Mansfield, G. R. "Nitrate Deposits in the Amargosa Region Southeastern California". United States Geological Survey. Bulletin 724. 1922.

11. Harmon, Judson. Oral communication.

12. California State Water Pollution Control Board. "Studies of Waste Water Reclamation and Utilization". Publication No. 9. 1954.

13. California State Water Pollution Control Board. "Waste Water Reclamation in Relation to Ground Water Pollution". Publication No. 6. 1953.

14. Puplett, P. A. R. "Synthetic Detergents; A Study of the Development and Marketing of a New Product". London, Sedgwick. 1957.

15. Sawyer, C. N. and Ryckman, D. W. "Anionic Synthetic Detergents and Water Supply Problems". Journal American Water Works Association. Volume 49. April, 1957.

16. Cohen, Jesse M. "Effects of Synthetic Detergents on Water Treatment and Quality of Water". A talk presented at a meeting of the Conference of State and Provincial Public Health Laboratory Directors in Atlantic City, New Jersey. October, 1959.