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For your consideration:

Enclosed please find a review by Dr. Luna Leopold, a Member of the National Academy of Sciences and former Chief and Senior Research Hydrologist at the U.S. Geological Survey, of the report "Analysis of the influence of water withdrawals on runoff to the Delta-San Francisco Bay ecosystem (1921-83)" by M. Rozengurt, M. Herz and S. Feld.

This report was presented by Dr. Rozengurt on July 13, 1987 at the D-1415 Hearings of the State Water Resources Control Board in Sacramento. It was funded by the San Francisco Foundation and Buck Trust, presently the Marin Community Foundation.

Sincerely,

Patricia S. Briggs

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Administrative Secretary

Enc.

SACRAMENTO DELTA WATER SUPPLY AND REVIEW OF THE TIBURON REPORT

Luna B. Leopold
Consulting Engineer

California must take heed of well documented experience in the Soviet Union where diversion of fresh water from the natural supply to an estuary has resulted in immense economic loss and the near destruction of an important estuary. x) Regulation of the Don River has resulted in an increase of salinity of the Azov Sea by a mere 7 percent and the result was to reduce total fish production from about 15 to 3 thousand tonnes annually. This has been documented in detail by Volovik (1986) and reviewed in the Tiburon report here being discussed.

The Tiburon report as it will here be called is a detailed study of the water situation in the Sacramento Delta. The reference is:

Rozengurt, M., Herz, M.J., and Feld, S., 1987, Analysis of the influence of water withdrawals on runoff to the Delta-SanFrancisco Bay ecosystem (1921-1983): Paul F. Romberg Tiburon Center for Environmental Studies, Tech. Rept. No 87-7.

This voluminous study cannot be either read or taken lightly for it is statistical, detailed, and in many places less than clear. Nevertheless the more one studies it the more impressive is the informational content. The present review deals only with the discussion and data dealing with annual flow data whereas the Tiburon report analyses both annual and monthly data.

The present discussion is an attempt to bring out those points that seem most significant and to present some reanalysis to clarify and emphasize some of the important conclusions.

The data base is reviewed in some detail. It appears that during the planning and construction stages of water development and diversion in the Sacramento system, two somewhat shortcut data compilations were used. The "Four River Index" is a data base that includes runoff from only 75 % of the total drainage area. A "modified method" had previously been employed also relecting less than the full runoff. Finally a compilation was made that estimated the runoff not only from the major rivers but included runoff from the foothill areas and is thought to represent a good approximation of the full runoff volume of 100% of the basin area. The Tiburon report shows that the planning done in the early years based on these less than full runoff volumes have given an over-optimistic picture of the water available for diversion from the Delta system.

x) emphasis added

Then using the most uptodate data base that most realistically decribes what water is really available, the report introduces a statistical analysis of this water supply. Generally this analysis is couched in the form of deviations above and below the mean or average value of the runoff series, and expressed among other ways as probability of occurrence. When values of deviation from the mean are plotted as the probability of being equalled or exceeded, the differences in actual runoff quantities among different data sets can be eliminated so that the particular length of the record becomes unimportant.

The method of analysis will be demonstrated below to help explain and support the major conclusions in the report. First, however, it would be desireable to summarize the major findings of the study.

First, the role of fresh water runoff is of highest importance in controlling salinity and the functioning of the "nutrient trap", that zone of an estuary where fresh water with its load of sediment and nutrients interacts with the saline water from the ocean. This is the area richest in plankton production where many fish species thrive as juveniles (see pp. I.3, I.6, and Fig. I.2). In the Delta area, this is between Chipps Island and Benicia. Reduction of fresh water reaching the Bay has made the saline zone move upstream and is the cause of the historic increase in salinity. The loss of fish populations, a well documented fact, is related to these complex changes. Salinity in the Delta has increased in the present century from an original value of .01-2.0 grams per liter to a present value of 1.0-14. The increase in salinity experinced in the Sea of Azov of the Soviet Union was less than two-fold whereas the increase in the Delta has been ten-fold. Even with the modest increase in the Saz of Azov the result has demonstably been disasterous in that country.

Second, the Tiburon report shows that use of an unsatisfactory data set to describe the available water has in the planning and construction stages of water development seriously underestimated the probability of critically dry conditions in the estuary. Further, the use of frequency curve analysis is necessary to evaluate properly the effect of the already operative water diversions that deplete the fresh water supply so essential to the continued functioning of the ecosystem.

Third, the report shows what should be an obvious fact, that continued diversion of the same magnitude of fresh water in dry years as well as wet years makes a much larger percentage change in available water in a dry period than in a wet one. Yet there is no attempt to adjust the amount of diversion in response to the available supply.

Fourth, the amount of water diverted has continued to increase with time despite the data on biologic populations and salinity that have given ample warning that even the present amount of diversion is impacting the ecosystem .

Both to check quantitatively the results presented on annual flows in the Tiburon report, and to explain in new words its findings, I have reanalysed some of the data. My results are in qualitative agreement with those in the report though my numbers are not as exact. One reason for this is that I have generally rounded the data to three significant figures, for my work was done by hand whereas the Tibruron computations were made on a computer.

Four sets of data were used in my analysis. They are a) the list of annual flows representing natural, unimpaired inflows to the delta; b) the regulated annual inflow to the Delta; c) the natural or unimpaired outflows from the Delta, and d) the regulated or altered outflow annual values. These tabulations of basic data are included as printed tables in this study. The annual natural inflow data are those representing the flow from all or 100% of the drainage area as previously stated as being necessary for a correct analysis.

The method of analysis is similar to that used in the Tiburon report. The data array was retabulated in order of magnitude of the values. For each the recurrence interval was calculated as n+1/m where n is the number of years of record, and m is the rank order of the value or runoff quantity. The reciprocal of recurrence interval is the probability of occurrence, that is m/n+1 is the probability. For example, the value of probability of 0.10, that is 10 chances out of 100, means that in 100 years, it is probable that 10 years will experience a flow less than the quantity specified.

To make this more specific consider Figure 1 of the present study. Four graphs are plotted. They show the probability that any value of annual flow will be equalled or exceeded. The four graphs describe the annual natural inflow to the Delta, the regulated inflow, the natural outflow, and the regulated outflow.

Consider first, the graph of natural inflow, plotted as the symbol x. There is a 50 percent probability that the annual natural inflow will be equal to or less than 25,000,000 acre feet. This is the median value of the array, that is half tha annual values are larger and half smaller. The arithmetic mean is somewhat larger, about 28.1 million. Now look at the value 25% on the bottom scale. At a probability of 25% the annual runoff value is about 37 million acre feet. This says that there is a 25% chance, one in four, that the annual value of natural inflow will be equal to or larger than 37 million. By the same token, the upper scale says that there is a 75% chance, 3 out of 4, that the annual value will be equal to or less than 37 million. In other words it is less than likely that any given year will have as large a flow as 37 million.

Now look at the lower part of the curve which is the significant part from the standpoint of the estuarine ecosystem. Where the lower scale reads 90, the graph reads 13 million acre feet. Thus 9 years out of 10 or 90 years out of 100 it is probable that the natural inflow would equal or exceed 13 million. Or from the upper scale, 10 years out of 100 can be expected to have a natural inflow less than 13 million.

The average natural inflow to the delta is about 28.1 million acre feet. It should be obvious that this average value has but little significance. Of interest is the year of short supply and the frequency with which it might be expected. This is the reason both the Tiburon report and the present analysis concentrate on frequency curves.

Consider now the comparison of the curves for the natural inflow and the natural outflow to the Delta. In Fig. 1 the former is the crosses x, and the latter is the solid circle. The two curves are nearly identical. To the extent they are the same the data show that under natural conditions water coming into the Delta was nearly the same as that amount leaving the Delta.
At the scale of this graph the amount of loss by seepage or evapotranspiration cannot be seen.

But now consider the comparison of natural inflow to the regulated inflow shown on the groph by open circles. Regulated inflow is the water allowed to flow into the Delta after diversion and after the construction of upstream dams. Diversions to southern California are the primary cause of depletion. The average regulated or man-influenced inflow is about 22.8 million acre feet. This is an average reduction of 28.1-22.8 or 5.3 million or 19 percent of the natural. Again this average reduction is not very informative. Compare the curves on the lower scale at 75 percent probability. The natural inflow expected to be equalled or exceeded 75 percent of the time or 75 years out of 100 is about 18 million acre feet. But the regulated flow will only produce 13 million, a depletion of 5 million out of the naturally expected 18 million, a reduction of nearly 30 percent.

Now consider that low flow expected 10 percent of the years or once every ten years. At this frequency the natural inflow was 12 million acre feet. The expected regulated outflow once in ten years is only 7.5 million. At this frequency the depletion of the flow into the Bay is nearly 40 percent.

The above comparisons deal with the probability of experiencing any given quantity and do not mean to apply to any particular year. However, when one looks at the probability of one in ten, it means that next year or any given year in the future has a one in ten chance of experiencing an outflow to the Bay of less than 7.5 million acre feet. Like tossing a coin, each toss has the same chance of coming up heads.

Note also that the regulated outflow to the Bay is considerably less than the regulated inflow to the Delta. This means that after regulation the losses or depletions within the Delta have increased. Before regulation the losses within the Delta were negligible as previously stated.

The Tiburon report wisely makes an important issue of the number of dry and critical years under natural as compared with regulated conditions. To check and extend those findings I have prepared Figure 2. I have used the same definitions of wet, abnormal, subnormal, dry, critically dry, and drought as used by the Dept. of Resources Bulletins 23-62 and 130-70s (see Tiburon report Table I-9 p I.45). I have added a category of very dry so that all years may be described. The definitions are given in Figure 2.

In my tables with the annual flows arranged in order of magnitude it is easy to count the number of years in each category. As Figure 2 shows, regulation and diversion of water have increased the number of years in the dry categories and reduced the number of years in the wet categories. The Figure refers to annual values of inflow to the Delta.

Years in which the inflow is considered wet have decreased from natural conditions from 17 to 9, or from 30 percent of all years to 15 percent of years.

Subnormal years have changed from 11 to 7 or from 19 percent of all years to 12 percent.

The important change is in the number of critically dry years, an increase from 8 to 23 in the period of record or from 14 percent of all years to 39 percent. Thus the amount of diversion and depletion under present conditions has doubled the number of years considered critically dry.

Further, the increase in depletion has been continuous over time. A measure of depletion is the difference between natural and regulated values of outflow from the Delta. The depletion by periods of time is shown below.

Natural outflow less Regulated Outflow
average values in millions of acre feet

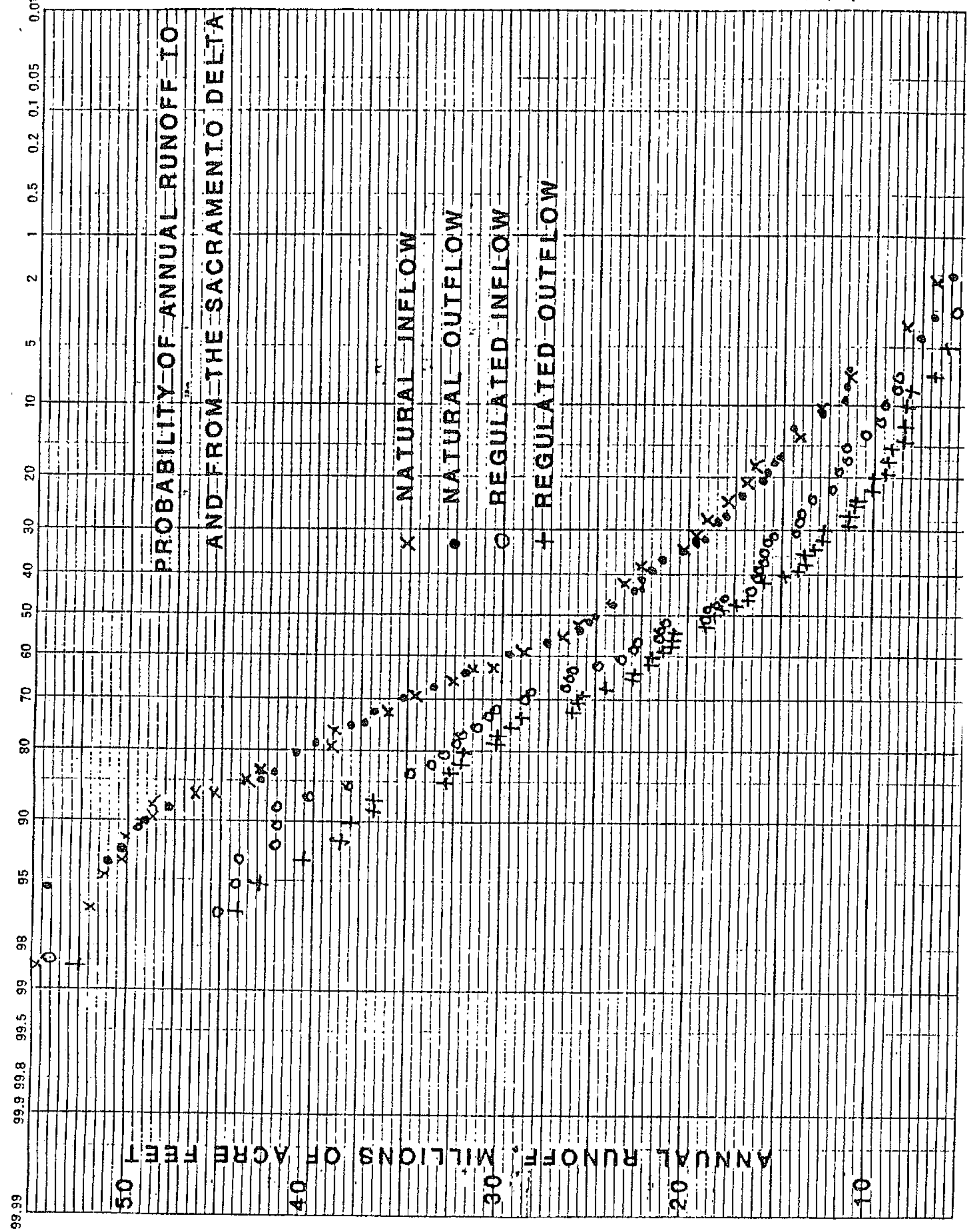
Time Period	Depletion
1921-1929	3.77
1930-1939	3.79
1940-1949	4.73
1950-1959	6.64
1960-1969	8.74
1970- 1979	10.94
1980-1982	12.70

In conclusion, my studies confirm the general conclusions in the Tiburon report. The depletions have been massive and continue to increase. They have greatly increased the percentage of years of critical drought in the Delta and the Bay.

It is my professional opinion that no set of standards of water quality can be written that can have the practical effect of protecting the ecosystem from further degradation if diversions increase over the present level. Because forecasts of runoff are imperfect the effect of diversions in a year that turns out to be dry will already have taken its toll on the ecosystem before water quality measurements can compare the condition with the standards.

The logical and in my opinion the imperative step is to preclude henceforth any additional diversions of water from the Delta system.

FIG. 1


PROBABILITY OF ANNUAL RUNOFF TO
AND FROM THE SACRAMENTO DELTA
NATURAL INFLOW
NATURAL OUTFLOW
REGULATED INFLOW
REGULATED OUTFLOW
ANNUAL RUNOFF, MILLIONS OF ACRE FEET
50
40
30
20
10
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
99.99

Number of years of different supplies of water comparing regulated flow with natural unimpaired flow, inflow to delta

Inflow to Delta

Definitions:

Normal flow is average inflow to delta in natural, unimpaired condition, 28.1 x 10^6 acre feet per year.

Abnormal is 100 to 125 % of normal or 28.1 to 35.1 x 10^6 a.f.

Wet years, runoff > 35.1 x 10^6

Subnormal 1.00 to 0.80 of normal or 28.1 to 22.5 MAF

Dry .70 to .80 normal or 19.7 to 22.5

Very dry: .57 to .70 or 16.0 to 19.7 MAF

Critically dry: less than 0.57 or 16.0 MAF

Drought: 0.30 or < 8.5 MAF

No of years in category in period of record

	Natural	%	Regulated	%
Wet	17	30	9	15
Abnormal	7	12	10	17
Subnormal	11	19	7	12
Dry	4	7	3	5
Very dry	10	18	7	12
Critically dry	8	14	23	39
	57	100	59	100
Drought	2		3	

SAN FRANCISCO BAY

DATA FILE - RGINACF - REGULATED INFLOW TO THE DELTA

ACREFEET X 1000

YEAR	O	N	D	J	F	M	A	M	J	J	A	S	ANN
2324	624	499	551	617	1254	579	622	350	113	77	105	183	55
2425	375	790	1083	1088	5632	2587	3995	3475	1422	441	227	334	214
2526	522	597	824	738	4598	1796	4052	1335	367	144	141	309	154
2627	462	1253	2834	2502	7180	4822	4951	3392	2219	591	299	388	308
2728	564	1397	1306	1543	2605	5394	5165	2040	605	293	218	360	214
2829	488	659	765	802	1384	1147	1048	1254	677	200	187	316	89
2930	418	428	2422	2009	1857	3521	2127	1478	736	240	207	398	158
3031	534	596	618	963	888	1058	493	291	133	0	38	188	58
3132	293	418	1564	2157	2330	2222	2043	2981	2153	627	202	256	172
3233	353	402	589	882	934	1612	1463	1334	1278	235	130	259	94
3334	386	516	1030	2071	1625	1728	1063	483	240	86	92	214	95
3435	325	842	796	2677	1675	2888	6960	4179	2264	459	243	345	236
3536	548	568	722	3926	7362	4059	3698	2962	1869	478	243	366	268
3637	461	487	628	807	3304	4835	4236	3811	1968	445	182	315	214
3738	578	2461	6010	2462	10398	11602	7306	7341	4963	1589	534	515	557
3839	719	838	1129	1052	1098	1636	1221	619	221	99	110	314	91
3940	432	428	726	4016	5772	8658	7371	2945	1410	333	234	432	327
4041	524	767	3672	7193	7616	7731	6709	5083	2927	1115	407	415	442
4142	586	747	3758	5524	8662	3026	5117	4447	3490	1068	348	466	372
4243	656	986	1928	5471	4422	6948	4413	2925	1727	433	265	387	305
4344	617	675	782	947	1776	2214	1233	1702	761	246	229	381	115
4445	428	1022	1439	1292	4405	2454	2267	2628	1639	634	494	588	192
4546	759	1235	4539	4946	1771	2040	2408	2572	1086	484	464	582	2288
4647	653	939	1326	938	1555	2125	1576	778	546	318	355	474	1148
4748	661	820	1684	1586	827	1295	3577	3779	2719	676	545	678	1884
4849	744	806	998	899	941	3667	2132	1832	758	441	475	552	1424
4950	529	629	610	1807	2974	2145	2682	2316	1480	529	460	582	1674
5051	707	4162	7973	4749	5086	3294	1894	2270	886	556	588	642	3280
5152	720	986	2866	6498	5978	5304	6275	6650	4085	1318	645	728	4205
5253	690	768	2518	7076	2165	1637	1731	2321	2071	568	380	759	2273
5354	759	936	1038	1987	3843	3497	3389	1376	509	282	393	563	1907
5455	643	939	1686	1729	1013	858	731	1218	604	323	334	491	1057
5556	442	649	7362	11498	5696	3950	2272	3720	2243	743	599	855	4002
5657	910	1040	970	890	1330	3970	1340	2210	1330	640	660	810	1607
5758	1280	1280	1630	2590	9900	6670	8960	4990	3270	1190	990	1120	4456
5859	990	1010	980	1890	3090	1890	930	760	510	670	760	700	1435
5960	540	500	520	780	2740	2220	1220	1050	680	660	620	600	1222
6061	520	770	1250	900	2330	1820	1040	840	670	660	720	600	1221
6162	460	530	1030	700	3830	2980	1890	1430	1060	700	770	790	1641
6263	2730	1110	2170	1360	5380	1830	6060	3530	1560	870	780	1070	2879
6364	1050	1580	1530	1810	1340	960	820	930	720	740	780	850	1313
6465	690	990	6540	8240	3230	1840	3470	2330	1410	900	970	1050	3163
6566	1150	1540	1850	2680	1960	1700	1400	940	610	740	790	700	1611
6667	640	1210	3630	3670	4700	3480	4570	4840	3980	1680	960	1290	3486
6768	1240	1100	1300	1530	2960	2690	1000	900	720	810	860	850	1603
6869	810	920	1670	7720	8850	5950	4360	4300	3130	1280	1310	1490	4224
6970	1370	1310	2840	11620	6260	3580	1020	1060	880	910	1000	1210	3322
7071	1060	1510	5170	4080	2100	2220	2520	2000	1830	1380	1440	1560	2683

REGULATED INFLOW CON'T.

YEAR	O	N	D	J	F	M	A	M	J	J	A	S	[illegible]
7172	1190	1060	1550	1470	1490	1600	890	860	870	960	1000	1100	1
7273	1120	1570	1900	6180	5600	4670	1610	1270	1090	1020	1080	1150	2
7374	1210	3770	4860	8570	3590	2650	6750	2160	1760	1470	1600	1710	4
7475	1500	1600	1890	1450	3340	4390	2470	2260	1830	1260	1340	1420	2
7576	1520	1610	1820	1140	870	1020	840	740	700	790	890	830	1
7677	580	360	540	670	490	440	370	490	420	520	480	420	[illegible]
7778	290	430	770	4360	3540	5450	3790	2840	1220	1010	1130	1290	2
7879	1020	980	1000	1890	2540	2560	1290	1360	920	940	1080	1010	1
7980	990	1080	1500	7440	7230	6350	2060	1700	1460	1340	1060	1200	3
8081	960	850	1220	1270	1560	1970	1200	990	740	1030	1000	840	1
8182	700	2340	5430	6020	5360	5310	8770	4080	2140	1540	1560	1890	4

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1921	436	3000	4084	6679	4496	5462	3875	4522	3332	982	417	335	37620
1922	330	464	1636	1497	4484	3457	4565	7665	5494	1376	483	324	31765
1923	390	783	3240	2451	1604	1784	4161	4128	2206	1065	393	357	22602
1924	404	375	468	566	1318	656	1092	1006	352	249	179	179	8924
1925	320	869	1148	1132	6058	3650	4691	4307	2204	823	397	304	25703
1926	350	454	708	910	4246	1979	4603	2326	871	382	234	220	17323
1927	289	2455	2414	2928	8827	4508	6003	4810	3395	1074	416	320	37439
1928	351	1643	1295	1704	2591	7511	4519	3706	1181	507	387	257	25152
1929	273	514	700	655	1343	1440	1780	2642	1462	456	195	210	11670
1930	211	247	2870	1042	2315	3547	2509	2470	1621	497	250	247	19106
1931	277	430	353	886	837	1307	1277	1180	455	192	152	156	7502
1932	263	359	2401	1025	2006	1943	3065	4582	3179	985	339	228	22974
1933	220	266	401	800	645	2196	2154	3590	2605	564	234	204	12893
1934	247	302	1286	1760	1974	2129	1709	1084	528	242	169	185	11665
1935	245	924	879	2610	2013	2934	7838	5338	3145	811	343	342	27292
1936	334	357	521	4247	7897	3466	4576	4148	2546	843	327	248	20510
1937	260	273	454	619	3619	4675	4633	5022	3635	753	288	225	24276
1938	344	2009	6158	2454	8447	11189	7528	8681	5870	2016	712	461	55810
1939	573	645	841	849	941	2226	3470	1523	659	314	216	251	11508
1940	370	307	658	5182	8147	6179	5572	4285	2016	624	328	309	36025
1941	390	624	4603	6127	7616	6710	6702	6770	3819	1618	624	449	45647
1942	464	691	4698	6062	7351	2848	5006	5622	4742	1699	609	429	41121
1943	461	1232	2315	6752	3866	7506	5056	4087	2482	1063	498	369	35667
1944	417	474	550	890	1910	2591	2135	3680	1884	807	331	261	15938
1945	350	1386	1704	1243	5789	2856	3330	6264	2846	1017	418	293	25546
1946	667	1566	6381	3387	1631	2804	3977	4036	1793	693	378	305	27599
1947	400	1021	1236	641	1925	3035	2405	2155	1170	389	260	244	14971
1948	692	506	489	2145	769	2029	5372	5141	3645	926	393	333	22520
1949	358	474	719	567	1116	4692	3752	3724	1571	441	286	246	17946
1950	277	381	414	2402	3597	2980	4366	4120	2240	665	314	288	22044
1951	1016	6079	8097	5028	4544	3421	3190	3574	1654	637	370	303	37913
1952	463	1068	4636	6123	5019	5538	7470	8613	5117	2205	754	501	40107
1953	438	509	2614	7216	1839	2617	3785	3826	3703	1430	526	437	28940
1954	439	887	847	2875	3703	4583	5482	3606	1505	636	402	367	25332
1955	378	836	1658	1646	1130	1442	2250	3562	1948	566	312	290	16018
1956	303	615	12618	10926	5390	3797	4064	5957	3844	1585	624	471	50392
1957	628	594	600	879	3339	4167	2680	4424	2625	743	398	429	21514
1958	946	901	1925	3271	11029	6961	8900	7777	4096	1729	769	536	49520
1959	484	520	576	2666	3518	2256	2482	1910	1044	443	297	508	16705
1960	349	334	437	1003	4236	3633	2783	2506	1324	429	284	277	17875
1961	316	781	1559	1037	2568	2275	2251	2339	1233	401	323	286	15349
1962	322	578	1360	981	5659	3134	4387	3414	2653	666	371	287	24008
1963	3214	774	2319	2217	6101	2754	7309	5775	2882	1192	534	433	35584
1964	575	1931	935	2046	1154	1290	2112	2659	1621	509	292	250	15424
1965	345	1009	11763	8065	2795	2332	6015	4285	2996	1359	811	417	42272
1966	419	1722	1323	2604	2072	2947	3762	2731	888	427	306	295	19496
1967	293	1582	3900	5153	3220	5277	5519	7594	6202	2797	775	453	42785
1968	488	541	960	2115	4790	3125	2425	2323	1081	478	449	331	19110
1969	473	974	2375	11363	7697	5097	6327	6555	4932	1902	690	467	51161
1970	639	675	4231	14492	4022	4115	2067	3043	2049	771	441	362	36926
1971	497	2426	4666	3906	2240	4674	2500	4645	3627	1247	549	461	32918
1972	505	693	1487	1521	2096	3838	2772	2575	1532	493	313	418	18343
1973	602	1519	2266	6175	5739	4421	3723	5310	2370	716	434	391	33096
1974	634	1662	4925	5148	2716	8417	6400	5299	3482	1415	646	655	49285
1975	401	615	966	1163	4312	6538	3708	6139	4626	1250	509	497	30684
1976	945	915	812	613	1054	1447	1420	1460	499	402	420	334	10276
1977	316	356	317	479	447	534	838	905	662	250	225	508	4501
1978	201	476	2282	1397	7999	7174	5880	5431	4083	1714	566	726	41961
1979	366	529	525	2039	3124	3228	3141	3036	3848	1461	378	318	21137
1980	600	591	1657	5459	8603	4695	3724	4165	3130	1786	542	489	40171
1981	407	386	1024	2043	2078	3085	2548	2238	960	360	254	268	15651
1982	607	5302	7243	5201	7431	6660	11107	6680	3665	1605	714	832	57315
1983	1437	2677	5522	6735	9749	15890	6708	8739	8199	3978	1485	866	72045
SUM	31274	70723	154357	220626	250253	255057	263696	267072	164467	61132	27322	22514	1788493
AVE	496	1123	2450	3502	3972	4049	4186	4239	2611	970	434	357	28389

DWR DOP STATEWIDE PLANNING BRANCH

f— 11.1?? 18264 39815 56755 69053 65857 69772 68941 43520 15770 ?234 5950 352?

? /sec. 228 517 1128 1613 1955 1865 1976 1952 1232 447 205 168 1110

SAN FRANCISCO BAY

DATA FILE - RGFLACF - REGULATED OUTFLOW FROM THE DELTA

ACREFEET X 1000

YEAR	O	N	D	J	F	M	A	M	J	J	A	S	AN
2122	384	512	1566	1649	4226	3386	3909	5242	3761	791	110	240	258
2223	468	897	3358	2646	1660	1501	3576	2562	1332	413	70	290	187
2324	500	439	538	716	1431	581	584	247	000	0000	0000	29	47
2425	301	769	1167	1115	6872	2350	4245	3331	1353	213	11	185	219
2526	388	570	836	1083	4358	1665	3795	1289	210	000	000	166	144
2627	371	2236	2272	2801	4911	8540	5465	3311	2082	359	85	238	326
2728	508	1452	1359	1716	2539	4524	3989	1955	444	60	8	210	214
2829	349	711	856	873	1482	1297	1153	1154	565	000	000	174	85
2930	289	322	2297	2151	1931	3570	2088	1394	583	22	7	260	149
3031	438	535	533	1055	918	1058	424	231	000	0000	0000	40	48
3132	170	386	1744	2158	2548	2183	1982	2893	1992	399	00	110	165
3233	217	309	577	1007	927	1647	1387	1259	1118	8	000	112	84
3334	290	411	1100	2014	1769	1683	1005	391	92	0000	0000	78	85
3435	207	850	808	2897	1699	3106	7015.	4052	2110	234	35	197	232
3536	459	489	709	3971	7888	3992	3687	2909	1730	256	31	230	258
3637	356	383	666	900	3710	5211	4263	3708	1805	220	000	163	212
3738	469	2041	5508	2635	9296	11918	7328	6918	4800	1360	322	375	529
3839	629	804	1076	1070	1134	1687	1151	518	54	0000	0000	171	80
3940	326	326	663	4317	6068	8685	7352	2859	1248	107	18	280	322
4041	416	685	4014	7412	7832	7901	5830	5011	2762	882	189	263	441
4142	488	688	3854	5754	3823	3086	3247	4398	3329	833	130	314	369
4243	539	1010	1950	5692	4486	7196	4405	2831	1568	199	49	235	301
4344	490	595	747	979	1972	2229	1256	1635	603	11	15	231	107
4445	341	1072	1474	1268	4629	2584	2197	2535	1479	404	279	438	187
4546	713	1176	4753	4948	1783	2072	2353	2494	920	253	250	430	221
4647	526	942	1318	970	1588	2182	1499	669	384	75	131	315	105
4748	604	736	607	1547	820	1387	3591	3752	2545	427	319	518	168
4849	608	674	956	911	959	3856	2038	1700	582	158	223	383	130
4950	379	561	591	1945	3102	2219	2742	2206	1278	265	230	435	159
5051	635	4324	8293	4973	5112	3367	1817	2166	670	274	316	442	323
5152	591	953	3101	6882	6048	5628	6186	6520	3941	1081	423	587	418
5253	575	759	2571	7184	2158	1701	1853	2280	1980	344	188	576	221
5354	610	880	966	1986	4014	3672	3459	1820	376	59	179	437	184
5455	531	953	1773	1925	1053	860	780	1191	437	109	139	351	101
5556	334	601	8049	11896	5940	3987	2407	3674	2139	533	410	703	406
5657	763	931	880	913	1383	3890	1157	2049	944	141	205	527	137
5758	1127	1155	1628	2766	10301	6894	9231	4964	3033	732	547	832	431
5859	769	874	907	1967	3230	1729	645	454	102	149	297	525	116
5960	318	355	451	826	2824	2087	988	758	252	132	143	305	94
6061	279	768	1172	944	2284	1717	785	536	231	96	221	305	93
6162	230	488	966	658	4152	2956	1627	1105	639	166	284	486	137.
6263	2697	971	2135	1442	5448	1820	6110	3262	1159	343	288	722	264
6364	829	1572	1437	1857	1212	810	531	589	328	186	271	526	101
6465	475	934	6707	8370	3147	1699	3415	2009	990	352	492	746	293.
6566	898	1543	1893	2714	1948	1509	1127	604	170	195	273	390	132
6667	396	1308	3636	3750	4866	3342	4512	4434	3672	1440	582	990	329
6768	1002	990	1212	1548	3018	2382	582	402	216	222	312	360	126
6869	330	630	1542	7620	9340	5520	4150	3860	2780	786	744	1308	386

REGULATED OUTFLOW CON'T. *Table 3 cont'd*

YEAR	O	N	D	J	F	M	A	M	J	J	A	S	A
6970	1170	1200	2740	11280	6534	3300	660	648	372	318	474	876	29
7071	810	1662	5022	3828	2046	1890	2208	1596	1272	708	786	1188	23
7172	840	834	1440	1278	1314	1092	456	324	186	384	396	648	9
7273	708	1554	1626	6108	6126	4510	1302	714	438	288	366	678	24
7374	846	3600	4590	8244	3510	4512	6450	1536	1026	570	774	1266	36
7475	1146	1404	1686	1105	2545	3056	1760	1611	1298	616	478	737	17
7576	816	972	1206	600	414	438	456	252	252	264	234	174	6
7677	232	216	259	268	272	188	182	248	149	195	149	172	2
7778	128	238	522	4069	3119	5260	3646	2573	541	244	353	725	21
7879	592	650	540	1877	2574	2342	862	826	317	331	214	301	11
7980	481	725	1170	7270	7005	6099	1708	1286	885	688	262	589	30
8081	453	374	767	1118	1247	1817	694	561	274	326	194	280	6
8182	321	2139	5113	6015	4937	4937	8361	3555	1690	1030	820	1540	38

Natural and regulated inflow to the delta, annual, acre feet

	1	2	3						
	Water year	Natural inflow (1) AF×10³	Regulated inflow (2)	Diff Col 2 − Col 3					
1	1921	38682							
2	22	32693							
3	23	23594							
4	24	8202	5574						
5	25	26718	21449						
6	26	18495	15473						
7	27	38442	30898						
8	28	26241	21490						
9	29	12895	8927						
10	30	20304	15841						
11	31	8756	5800						
12	32	24021	17246						
13	33	14142	9471						
14	34	12852	9534						
15	35	28341	23653						
16	36	30325	26801						
17	37	25118	21479						
✓ 18	38	56529	55759						
19	39	12754	9106						
20	40	36990	32757						
21	41	46590	44209						
22	42	42009	37239						
23	43	36437	30561						
24	44	17105	11563						
25	45	26533	19290						
26	46	28662	22886						
27	47	16209	11483						
28	48	23708	18847						
29	49	19087	14245						
30	50	23161	16743						

(1) Table I 10 p. I 46 Tiburon report
(2) Table 1 this report

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Natural & regulated inflow to the delta

	1	2	3					
	Water year	Natural inflow AF 10^{-3}	Regulated inflow	Diff Col 2 - Col 3				
1	1951	38611	32807					
2	52	48775	42053					
3	53	30104	22734					
4	54	26530	19072					
5	55	17165	10574					
6	56	51646	40029					
7	57	22686	16074					
8	58	50064	44566					
9	59	17945	14358					
10	60	19131	12220					
11	61	16626	12215					
12	62	25125	16419					
13	63	36550	28796					
14	64	16652	13136					
15	65	43125	31634					
16	66	20704	16119					
17	67	43537	34861					
18	68	20311	16032					
19	69	52137	42245					
20	1970	37956	33229					
21	71	34088	26830					
22	72	19591	14032					
23	73	34662	28496					
24	74	50238	40183					
25	75	31737	24873					
26	76	11606	12754					
27	77	6756	5953					
28	78	48846	26700					
29	79		16672					
30	- 80		33556					
	81		13667					
	82		45349					
	Ave	28115	22823					

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Delta Unimpaired Total Outflow from Table 2, annual and regulated outflow from Table 3

	Year	Natural outflow AF×10^6	Regulated outflow	Diff Col 2 - Col 3	Ave depletion in decade			
1	1921	37.62						
2	22	31.76	25.88	5.88				
3	23	22.60	18.77	3.83				
4	24	6.92	4.73	2.19				
5	25	25.70	21.91	3.79	3.77			
6	26	17.32	14.41	2.91				
7	27	37.44	32.67	4.77				
8	28	25.15	21.49	3.66				
9	29	11.67	8.58	3.09				
10	30	19.12	14.91	4.21				
11	31	7.50	4.83	2.67				
12	32	22.98	16.56	6.42				
13	33	12.89	8.49	4.40				
14	34	11.67	8.58	3.09	3.79			
15	35	27.29	23.21	4.08				
16	36	29.51	25.85	3.66				
17	37	24.28	21.25	3.03				
18	38	55.81	52.97	2.84				
19	39	11.51	8.06	3.45				
20	40	36.02	32.25	3.77				
21	1941	45.65	44.20	1.45				
22	42	41.12	36.94	4.18				
23	43	35.67	30.16	5.51				
24	44	15.94	10.76	5.18	4.73			
25	45	25.55	18.70	6.85				
26	46	27.60	22.14	5.46				
27	47	14.97	10.60	4.37				
28	48	22.52	16.85	5.67				
29	49	17.95	13.05	4.90				
30	1950	22.04	15.95	6.09				

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Unimpaired Natural & regulated outflow from the delta

from Table 2

	Year	Natural outflow AF x 10^6	Regulated outflow (Table 3)	Diff Col 2 - Col 3	ave depletion			
1	1951	37.91	32.39	5.52				
2	52	48.11	41.82	6.29				
3	53	28.94	22.17	6.77				
4	54	25.33	18.46	6.87				
5	55	16.02	10.10	5.92	6.64			
6	56	50.39	40.67	9.72				
7	57	21.51	13.78	7.73				
8	58	49.52	43.11	6.41				
9	59	16.71	11.65	5.06				
10	60	17.87	9.44	8.43				
11	61	15.35	9.34	6.01				
12	62	24.01	13.76	10.25				
13	63	35.58	26.45	9.13				
14	64	15.42	10.15	5.27	8.74			
15	65	42.27	29.34	12.93				
16	66	19.50	13.26	6.24				
17	67	42.71	32.93	9.78				
18	68	19.11	12.65	6.46				
19	69	51.46	38.61	12.85				
20	70	31.9[illegible]	[illegible].57	7.3[illegible]				
21	71	32.92	23.02	9.90				
22	72	18.34	9.19	9.15				
23	73	33.70	24.44	9.26				
24	74	49.28	36.92	12.36				
25	75	30.68	17.44	13.24	10.94			
26	76	20.28	6.08	14.20				
27	77	5.50	2.53	2.97				
28	78	41.98	21.42	20.56				
29	79	21.94	11.55	10.39				
30	80	40.17	30.05	10.12				

Unimpaired natural outflow from delta

	year	Natural outflow (from Table 2)	Regulated outflow	Diff Col 2 – Col 3	ave depletion			
1	1981	15.65	6.86	8.79	12.70			
2	82	57.31	38.11	19.20				
3	83	72.04						
4								
5	ave.	28.39						
6								
7								
8								
9								
10								
11								
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Natural unimpaired inflow to delta (57 years)

	AF $\times 10^{-6}$ ranked	$\frac{n+1}{m}$	prob.	AF $\times 10^{-6}$ ranked	$\frac{n+1}{m}$	prob.		
1	56.5	58.0	.017	25.1				
2	52.1	29.0	.034	24.0	1.81	.552		
3	51.0	19.3	.052	23.7				
4	50.2	14.5	.069	23.5	1.71	.586		
5	50.0	11.6	.086	23.1				
6	48.8	9.7	.103	22.7	1.61	.621		
7	48.8	8.3	.121	20.7				
8	46.6	7.2	.138	20.3	1.53	.655		
9	43.5	6.44	.155	20.3				
10	43.1	5.8	.172	19.5	1.45	.690		
11	42.0			19.1				
12	38.6	4.8	.207	19.0	1.38	.724		
13	38.6			18.5				
14	38.4	4.14	.24	17.9	1.31	.759		
15	37.9			17.2				
16	36.5	3.62	.276	17.1	1.26	.793		
17	36.4			16.6				
18	34.6	3.22	.310	16.6	1.21	.828		
19	34.1			16.2				
20	32.7	2.90	.345	14.1	1.16	.862		
21	31.7			12.9				
22	30.3	2.63	.379	12.8	1.11	.897		
23	30.1			12.7				
24	28.6	2.41	.414	11.6	1.07	.931		
25	28.3			8.8				
26	26.7	2.23	.448	8.2	1.04	966		
27	26.5			6.7	1.01	.983		
28	26.5	2.07	.483					
29	26.2							
30	25.1	1.93	.517					

Regulated Inflow to delta
59 yrs.

	AF $\times 10^{-6}$ ranked	$\frac{n+1}{m}$ = RI (yrs)	probabil	AF $\times 10^{-6}$ ranked	$\frac{n+1}{m}$ = RI (yrs)	prob.		
1	55.8	60	.017	19.1	1.93	.52		
2	45.3	30	.033	18.8	1.87	.53		
3	44.6	20	.050	17.2	1.82	.55		
4	44.2	15	.067	16.7	1.77	.57		
5	42.2	12	.083	16.7	1.71	.58		
6	42.0	10	.100	16.4	1.67	.60		
7	40.2	8.6	.117	16.1	1.62	.62		
8	40.0	7.5	.133	16.1	1.58	.63		
9	37.2	6.7	.150	16.0	1.54	.65		
10	34.9	6.0	.167	15.8	1.50	.67		
11	33.6	5.45	.183	15.5	1.46	.68		
12	33.2	5.0	.20	14.4	1.43	.70		
13	32.8	4.6	.22	14.2	1.40	.72		
14	32.8	4.3	.23	14.0	1.36	.73		
15	31.6	4.0	.25	13.7	1.33	.75		
16	30.9	3.7	.27	13.1	1.30	.77		
17	30.6	3.53	.28	12.8	1.28	.78		
18	28.8	3.33	.30	12.2	1.25	.80		
19	28.4	3.16	.32	12.2	1.22	.82		
20	26.8	3.00	.33	11.6	1.20	.83		
21	26.8	2.86	.35	11.5	1.18	.85		
22	26.7	2.73	.37	10.5	1.15	.87		
23	24.9	2.61	.38	9.5	1.13	.88		
24	23.7	2.50	.40	9.5	1.11	.90		
25	22.9	2.40	.42	9.1	1.09	.92		
26	22.7	2.31	.43	8.9	1.07	.93		
27	21.5	2.22	.45	5.9	1.05	.95		
28	21.5	2.14	.47	5.8	1.03	.97		
29	21.4	2.07	.48	5.6	1.02	.98		
30	19.2	2.00	.50					

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Natural unimpaired outflow from delta 63 yrs.

	AF x 10^{-6} ranked	$\frac{n+1}{m}$	probab		AF x 10^{-6}	$\frac{n+1}{m}$	probab	AF x 10^{-6}
1	72.0	64	.016		25.5	2.86	.484	7.5
2	57.3	32	.031		25.3	2.00	.500	6.9
3	55.8	21.3	.047		25.1	1.93	.516	5.5
4	51.5	16	.063		24.3	1.88	.531	
5	50.4	12.8	.078		24.0	1.83	.547	
6	49.5	10.7	.094		22.9	1.78	.562	
7	49.3	9.1	.109		22.6	1.73	.578	
8	48.1	8.0	.125		22.5	1.68	.594	
9	45.6	7.1	.141		22.0	1.64	.609	
10	42.7	6.4	.156		21.9	1.60	.625	
11	42.3	5.8	.172		21.5	1.56	.641	
12	41.9	5.3	.188		20.3	1.52	.656	
13	41.1	4.9	.203		19.5	1.49	.672	
14	40.2	4.6	.219		19.1	1.45	.687	
15	37.9	4.3	.234		19.1	1.42	.703	
16	37.6	4.0	.250		18.3	1.39	.719	
17	37.4	3.8	.266		17.9	1.36	.734	
18	36.9	3.6	.281		17.9	1.33	.750	
19	36.0	3.4	.297		17.3	1.31	.766	
20	35.7	3.2	.313		16.7	1.28	.781	
21	35.6	3.0	.328		16.0	1.25	.797	
22	33.7	2.91	.344		15.9	1.23	.812	
23	32.9	2.78	.359		15.6	1.21	.828	
24	31.8	2.67	.375		15.4	1.18	.844	
25	30.7	2.56	.391		15.3	1.16	.859	
26	29.5	2.46	.406		14.9	1.14	.875	
27	28.9	2.37	.422		12.9	1.12	.891	
28	27.6	2.29	.437		11.7	1.10	.906	
29	27.3	2.21	.453		11.7	1.08	.922	
30	25.7	2.13	.469		11.5	1.07	.937	

Regulated outflow from delta (Table 3)
(59 years)

	AF $\times 10^{-6}$ ranked	$\frac{n+1}{m}$	prob.	AF $\times 10^{-6}$ ranked	$\frac{n+1}{m}$	prob.		
1	53.0	60	.017	18.5	1.94	.517		
2	44.2	30	.033	17.4	1.87	.533		
3	43.1	20	.050	16.8	1.82	.550		
4	40.7	15.0	.067	16.6	1.76	.567		
5	38.6	12.0	.083	15.9	1.71	.583		
6	38.1	10.0	.100	14.9	1.67	.600		
7	36.9	8.57	.117	14.4	1.62	.617		
8	36.9	7.5	.133	13.8	1.58	.633		
9	32.9	6.7	.150	13.8	1.54	.650		
10	32.7	6.0	.167	13.2	1.50	.667		
11	32.4	5.45	.183	13.0	1.46	.683		
12	32.2	5.0	.200	12.6	1.43	.700		
13	30.2	4.61	.217	11.6	1.39	.717		
14	30.0	4.28	.233	11.5	1.36	.733		
15	29.5	4.00	.250	10.8	1.33	.750		
16	29.3	3.75	.267	10.6	1.30	.767		
17	26.4	3.52	.283	10.1	1.28	.783		
18	25.9	3.33	.300	10.1	1.25	.800		
19	25.8	3.16	.317	9.4	1.22	.817		
20	24.4	3.00	.333	9.3	1.20	.833		
21	23.2	2.86	.350	9.2	1.18	.850		
22	23.0	2.73	.367	8.6	1.15	.867		
23	22.2	2.60	.383	8.6	1.13	.883		
24	22.1	2.50	.400	8.5	1.11	.900		
25	21.9	2.40	.417	8.1	1.09	.917		
26	21.5	2.31	.433	6.9	1.07	.933		
27	21.4	2.22	.450	6.1	1.05	.950		
28	21.2	2.14	.467	4.8	1.03	.967		
29	18.8	2.06	.483	4.7	1.02	.983		
30	18.7	2.00	.500					