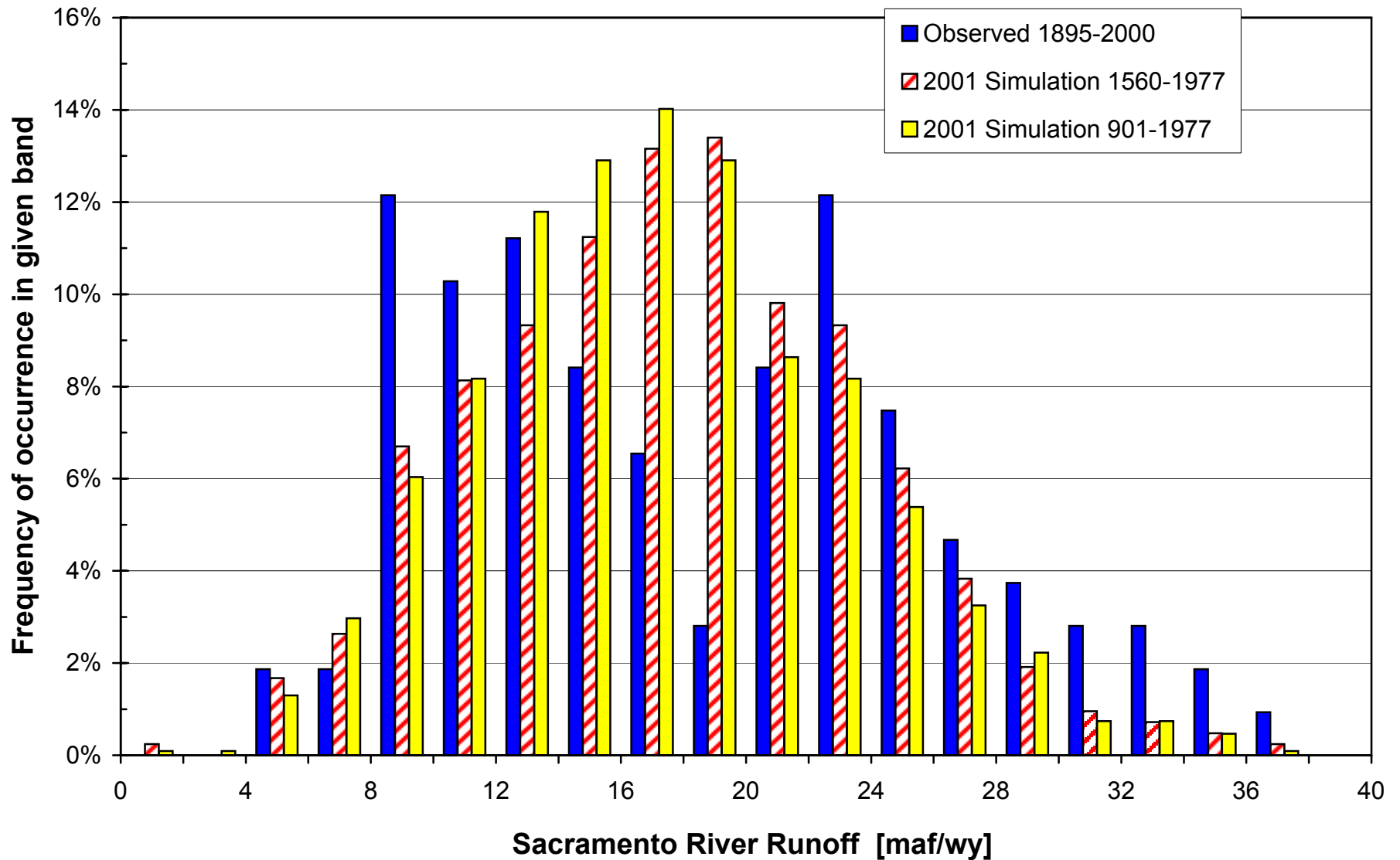
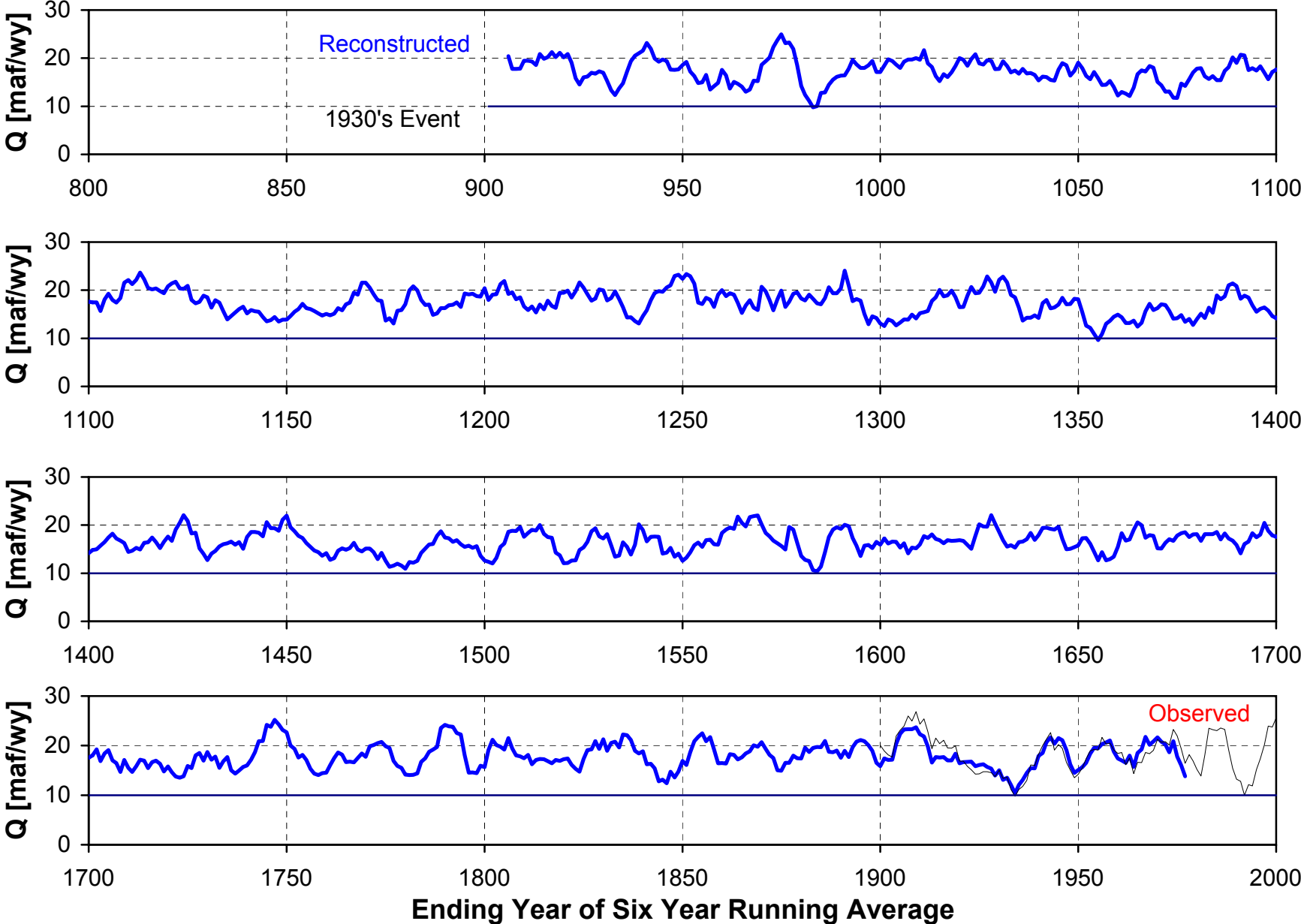


## Tree Ring Simulation: Historical Probability distribution

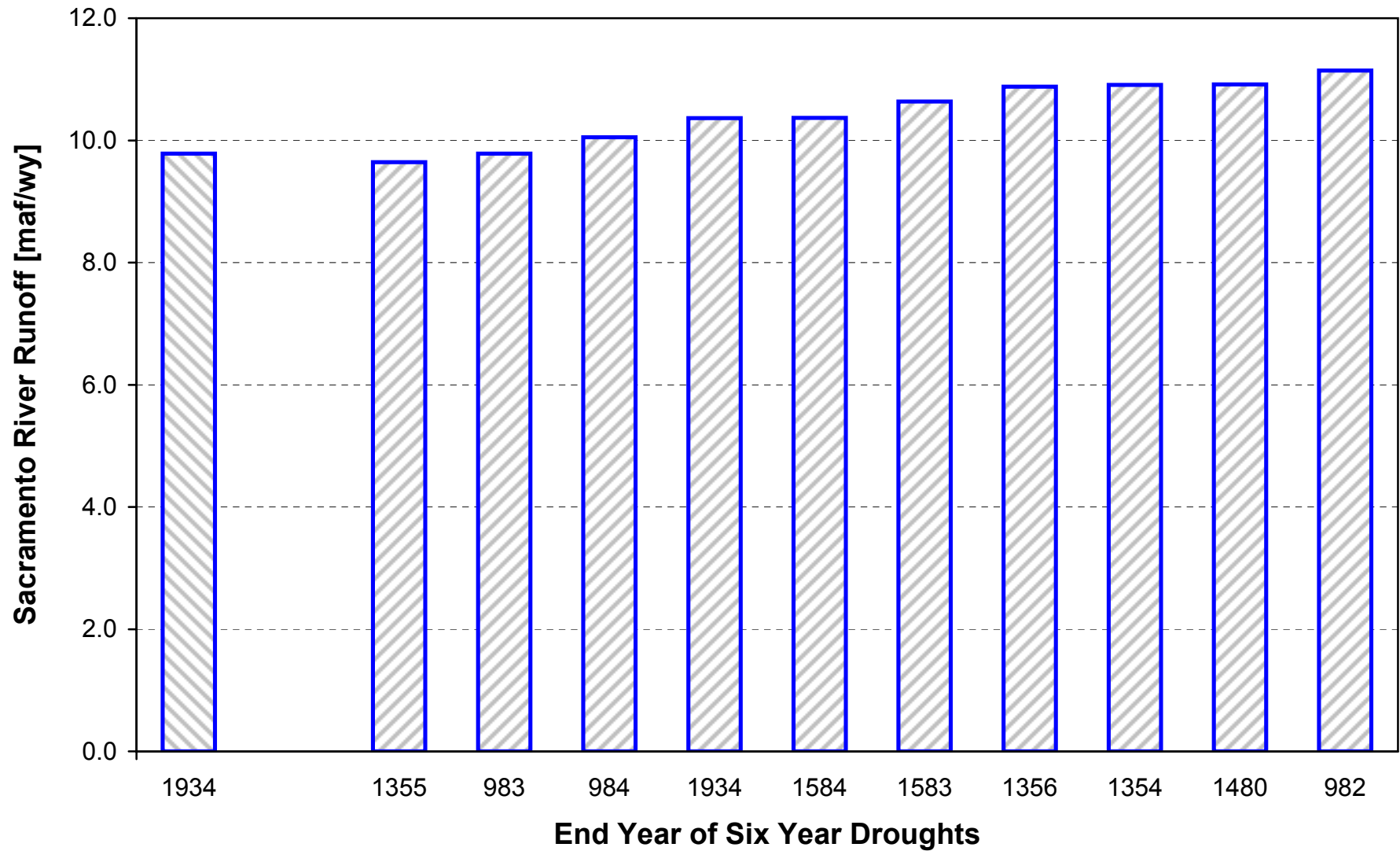


# Year 901-1977 Sacramento River Runoff Reconstruction

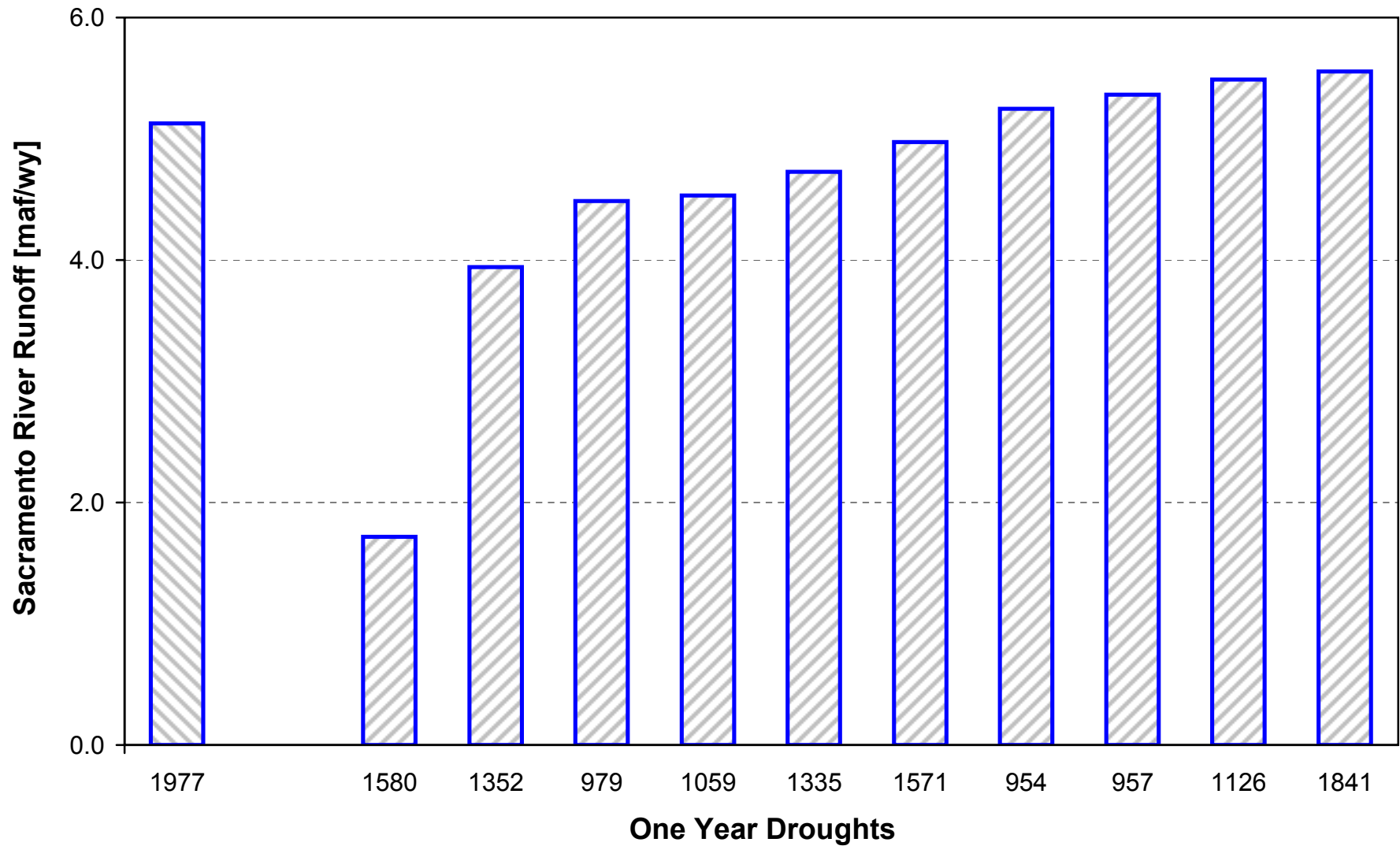


Source: Report by Dr. David Meko for DWR, 2001; Reconstructed Sacramento River System Runoff from Tree Rings

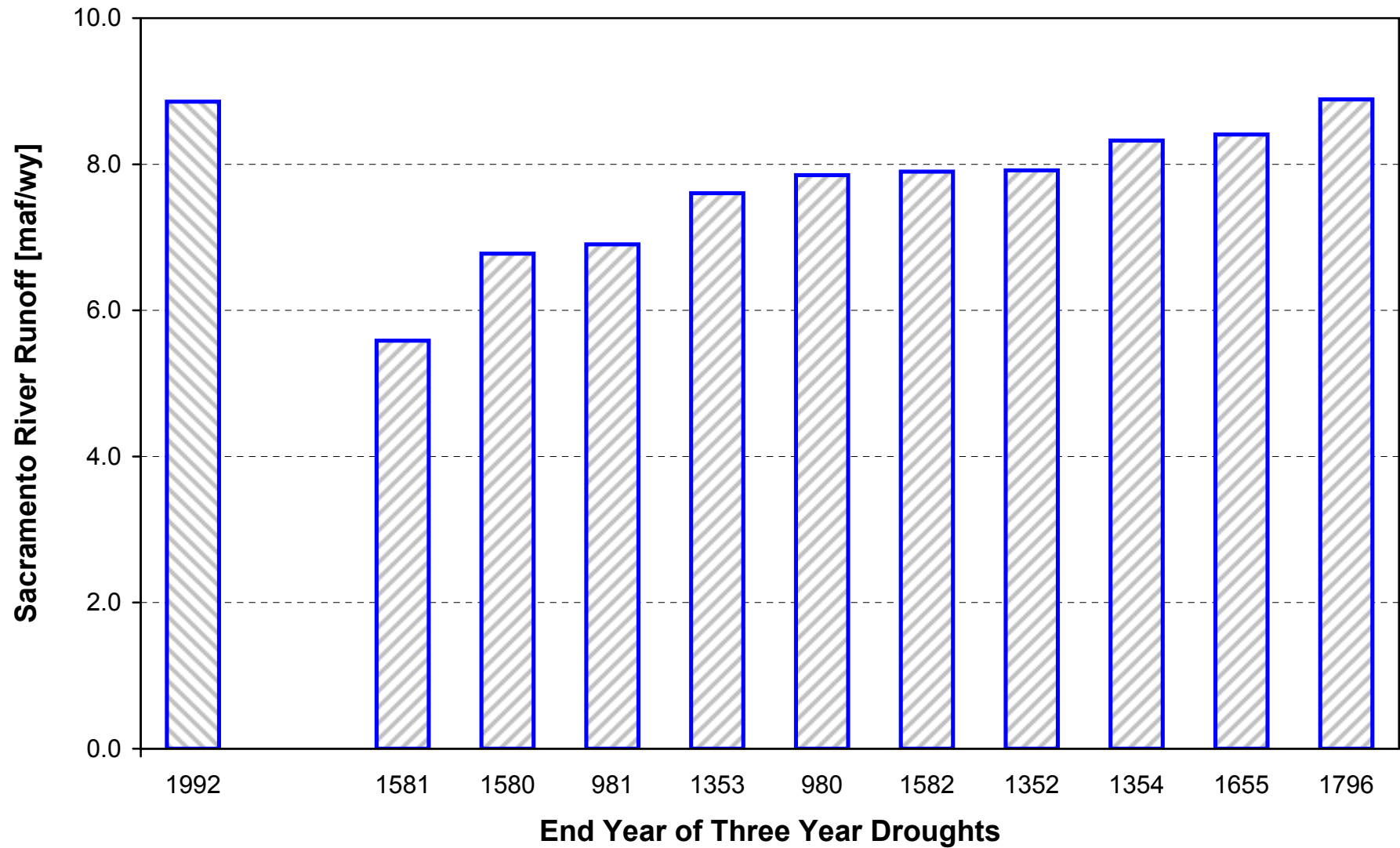
### Sacramento River 901-1977 Runoff Reconstruction Tree-Ring Study 10 Lowest Six Year Running Averages



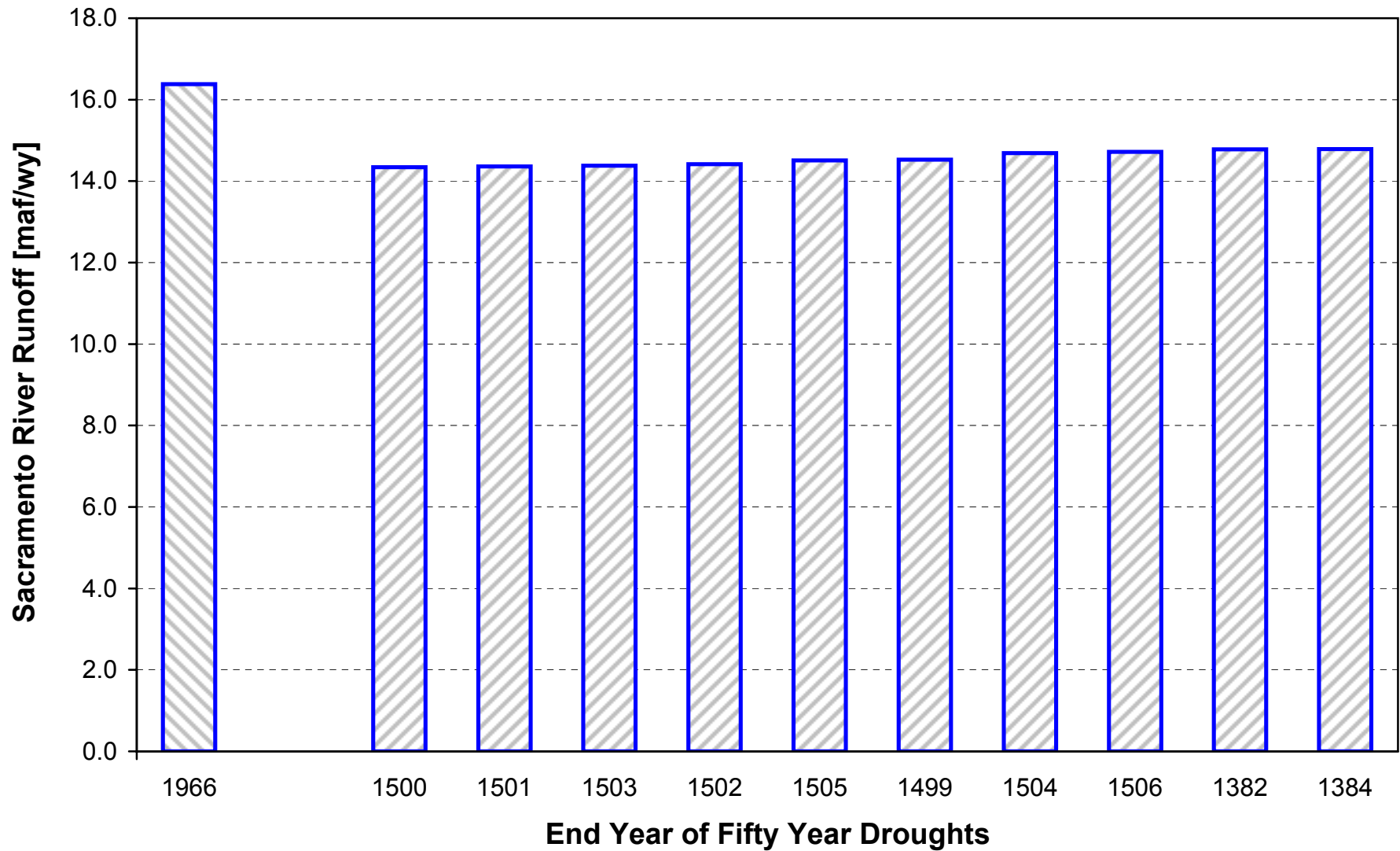
### Sacramento River 901-1977 Runoff Reconstruction Tree-Ring Study 10 Lowest Water Years



### Sacramento River 901-1977 Runoff Reconstruction Tree-Ring Study 10 Lowest Three Year Running Averages



### Sacramento River 901-1977 Runoff Reconstruction Tree-Ring Study 10 Lowest Fifty Year Running Averages



## **Reconstruction of 1000 Years of Sacramento River System Runoff Using Tree Rings**

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### **BIOGRAPHICAL SKETCH**

Mr. Roos is Chief Hydrologist (part time) with the California Department of Water Resources (DWR) in Sacramento, in its Division of Flood Management. He had 43 years of experience as a water engineer with DWR when he retired from full time service in July 2000. He continues to work part time as a retired annuitant. Prior to retirement, he oversaw work on flood forecasting, hydrology, water supply and snowmelt forecasting, staff meteorology, and related subjects. As Chief Hydrologist, he also provided (and continues to provide) advice on drought, floods, global warming, and weather modification and tries to keep abreast of ongoing water and flood planning studies.

Mr. Roos received a B.S. in Civil Engineering from San Jose State University in 1957 and has been employed by the Department of Water Resources since then. His career began with a series of studies on channels, levees, proposed water transfer works, and water quality in the Sacramento-San Joaquin River Delta. From 1965 through 1978, he worked on various water planning studies and reservoir system operation studies, and evaluated water requirements, supplies, and potential water system developments in the Department's Division of Planning.

In 1979, he began his current assignment in the Division of Flood Management, primarily on flood and water supply forecasting. He was one of the authors of several editions of DWR Bulletin 160, the Department's main water planning document. During the past 10 years, he has had opportunity to share expertise in Israel, northern India, Nigeria, and China.

# RECONSTRUCTION OF 1000 YEARS OF RUNOFF FOR THE SACRAMENTO RIVER SYSTEM USING TREE RINGS

by  
Maurice Roos<sup>a</sup>

Our measured record of floods and runoff is rather short for determining hydrologic risks, extending back only about 100 years with some mostly qualitative information for perhaps another 100 years. We don't really know whether the past century is a reasonable measure of our Northern California climate. Tree rings are indicative of past climate. With proper selection and measurement they can provide us data on past climate and runoff. The basic principle is measurement of annual ring thickness. Wet years tend to have wide rings and dry years thin rings. Certain trees, particularly western juniper and blue oak, seem to have the best correlations with water year runoff here in northern California.

In sampling, one looks for old trees near the lower (drier) end of their range. Normally two cores are taken from each tree with an incremental borer. These core samples are less than a pencil width in diameter and don't hurt the tree. In the case of dead wood or old stumps, a cross sectional cut can be made for a more complete sample. Often by overlapping dead wood ring patterns with that of living trees, the record can be extended even further back.

The cores are mounted and very carefully measured in the lab one by one. Eventually all the trees from a particular area are measured and an average of 20 or so trees becomes a composite site index. The site indexes are correlated with measured runoff to develop relationships which then are used to extend the runoff record back in time.

The most relevant previous work was the 1986 reconstruction of Sacramento River flows since 1560 by Earle and Fritts of the University of Arizona Laboratory of Tree Ring Research. This reconstruction relied heavily on tree ring samples from the early 1980's in northern California and central Oregon. Since that time there has been a great expansion of the available tree ring data for studying Sacramento River flow. For the 400-500 year time window, the most important element has been the collection of blue oak chronologies from the foothills flanking the Central Valley. The expanded network and greater length of record was found to improve the length and quality of Sacramento River reconstruction.

Last year, Dr. David Meko of the University of Arizona Laboratory of Tree Ring Research completed a two-year study for DWR reconstructing Sacramento River

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system runoff from tree rings. (Meko, 2001). The Sacramento River system is the unimpaired runoff of the Sacramento near Bend Bridge, Feather, Yuba and American Rivers (the so-called Four River Index) used for classifying the water year for the Delta. The reconstruction went back to year 901. A similar reconstruction was made for Feather River unimpaired runoff. Calibration and reconstruction proceeded in three time intervals: 901-1299 using the oldest sites, 1300-1607 using more conifer sites (nearly twice as many) and 1608-1977, which included the blue oak cores. The south central Oregon junipers was the most important predictors for the first two segments of reconstructed runoff and the blue oaks for the last period. Calibration correlation ( $R^2$ ) was surprisingly good ranging from about 60 percent in the first segment to 67 percent in the second period and about 80 for the last 400-year period, which included the blue oak record. According to David Meko, these are some of the best matches the Tree Ring Lab has seen in this kind of work.

The Sacramento and Feather River reconstructions show very similar patterns. The main reason is that most of the same tree ring sites were used in both reconstructions. Of course, the Feather River basin lies pretty close to the middle of the four river Sacramento River systems and one would expect a tight fit.

Results show an interesting characteristic about the 20<sup>th</sup> century, compared to the 1000 years of record. The modern record is rather thin on the number of years in the middle categories – the near normal years. The median measured runoff since 1906 for the Sacramento River system is about 16 MAF per year; the average is a little higher at 18 MAF. The 20<sup>th</sup> century has actually had more dry and wet years than the near normal band from 14 to 20 MAF. However, the reconstructed record, whether the 400 or so years which used the oak cores, or the longer 1000 year record shows a greater frequency of the near normal categories. The same comment could be made about the Feather River reconstruction, although not quite as much so.

Much water planning has for California been based on the 2 six year droughts in northern California, that of 1929-34 and the more recent 1987-92 drought. In this the reconstructions are encouraging. The indicated severity of the two 20<sup>th</sup>-century droughts is about as bad as it gets in the 1000-year reconstruction.

But there are worse shorter droughts in the reconstructed record. The worst single year was 1580 in which runoff seems to have been only about 1/3 that of 1977, our driest single year of record. The years around 1580 also were indicated to be much drier for two and three-year droughts compared to 1976-77 (3.7 compared to 6.7 MAF) and 1990-92 (5.6 compared to 8.9 MAF). The Francis Drake expedition reported some very unusual cold weather on the California coast in 1579, which may indicate unusual weather conditions that year and the following winter. The 50-year sequences seem to also have been appreciably drier in the latter part of the 15<sup>th</sup> and 14<sup>th</sup> centuries, with average runoff around 80 percent compared to near 90 percent for the 1917-1966 lowest sequence in the measured record. Although tree rings are not the best indicator of flood years, we could probably expect that the frequency of flooding

was less in the dry half centuries. It may be that flood frequencies undergo a shift from time to time and the 20<sup>th</sup> century drier 50-year period from 1917 through 1966 tends to depress the flood frequency curves compared to more “normal” centuries.

Although I’m not sure how useful the tree ring reconstruction is for flood planning, I do think it has given water supply planners a wealth of data to use in testing alternatives.

### **Acknowledgements**

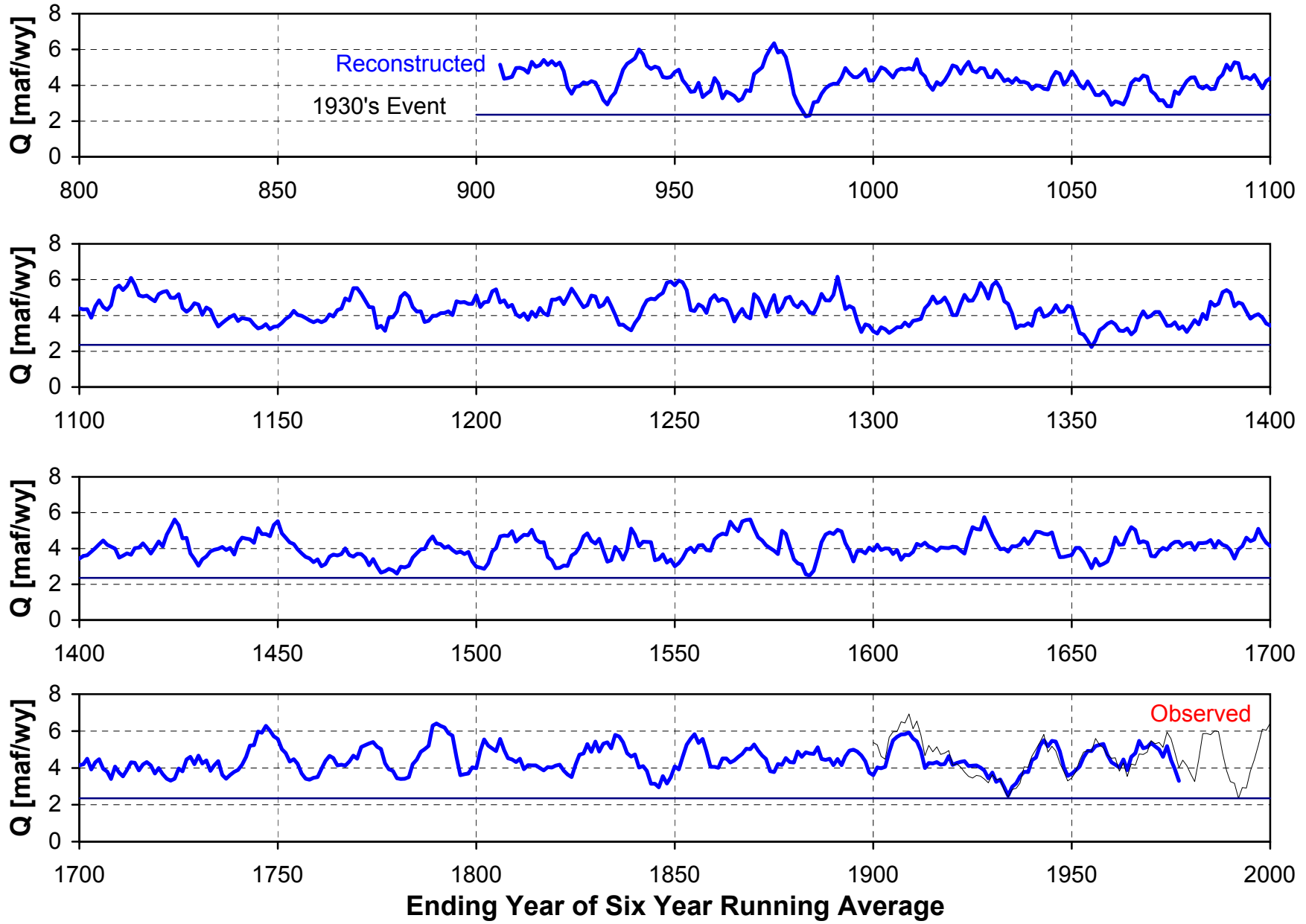
The author wishes to thank Pierre Stephens of the Hydrology Branch in the Department of Water Resources, Division of Flood Management, for his assistance in preparing the charts and tables attached to this paper. Also, it should be recognized that the author is reporting on the extensive studies done by Dr. David Meko of the Laboratory of Tree-Ring Research, who wrote the 2001 report upon which this paper was based.

### **References**

Earle, Christopher J and Fritts, Harold C. 1986. *Reconstructing Riverflow in the Sacramento Basin Since 1560*. Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ. (Report to the California Department of Water Resources in June, 1986).

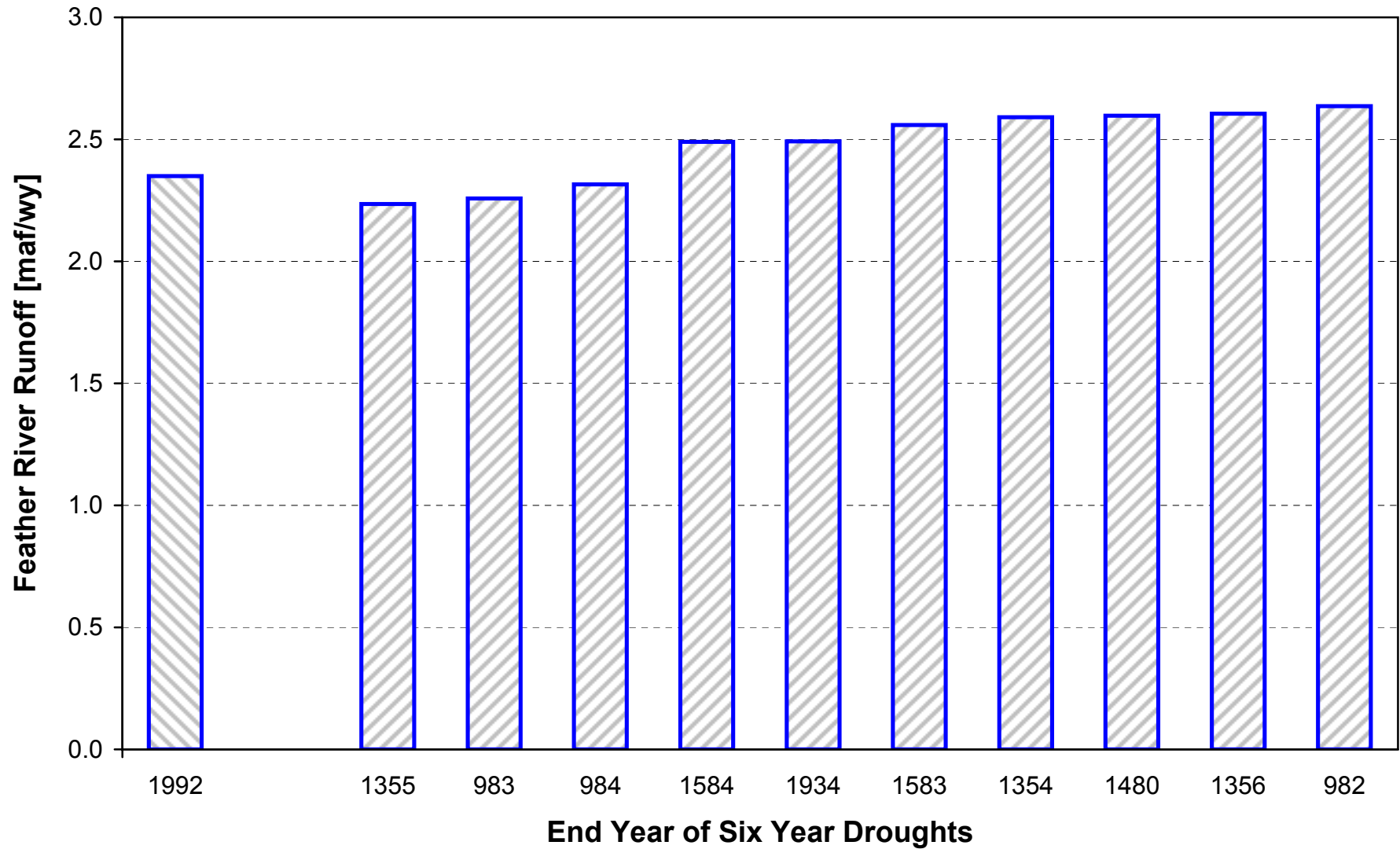
Meko, David M., 2001. *Reconstructed Sacramento River System Runoff from Tree Rings*. Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ. (Report prepared for the California Department of Water Resources in July, 2001).

# Year 901-1977 Feather River Runoff Reconstruction

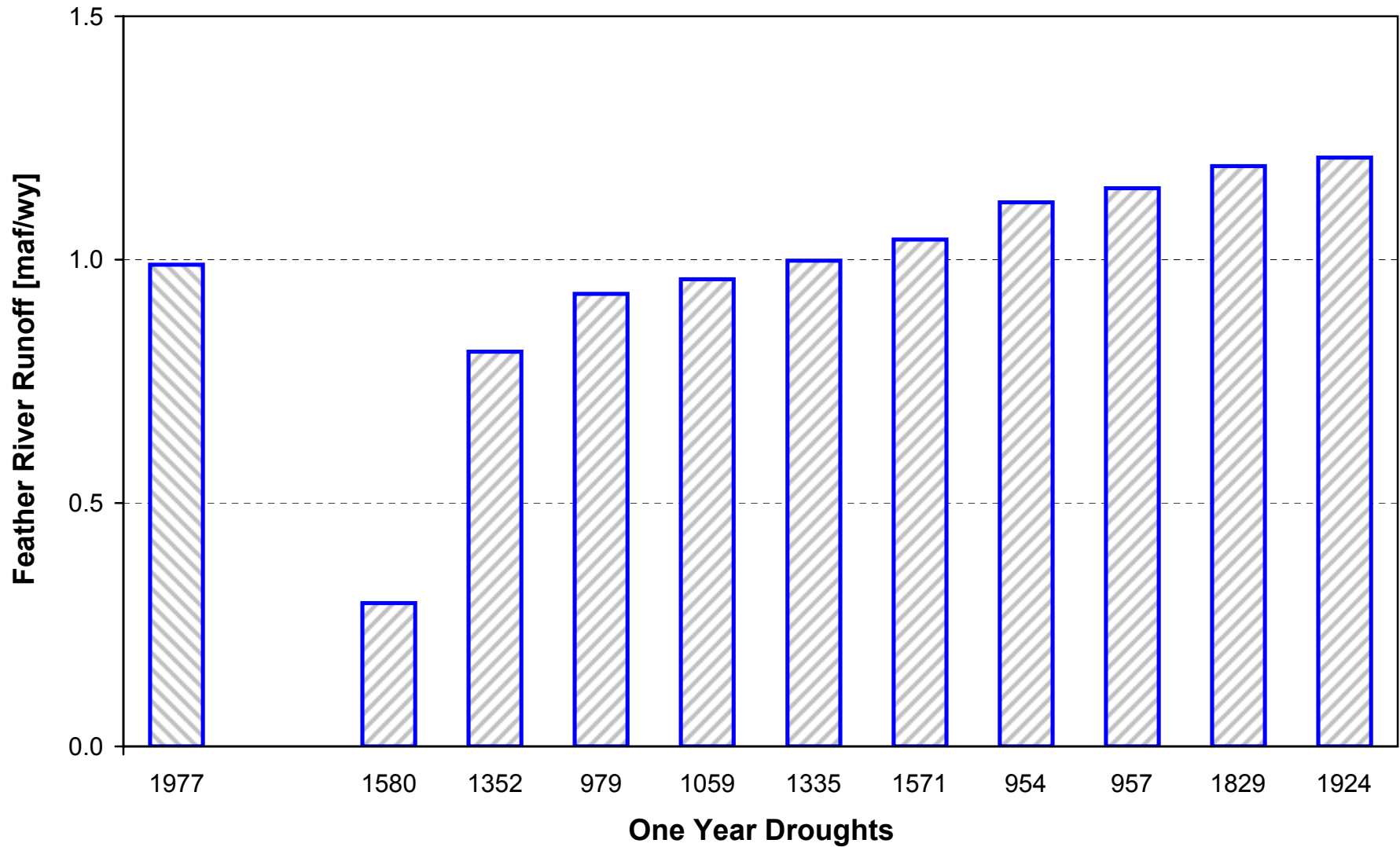


Source: Report by Dr. David Meko for DWR, 2001; Reconstructed Sacramento River System Runoff from Tree Rings

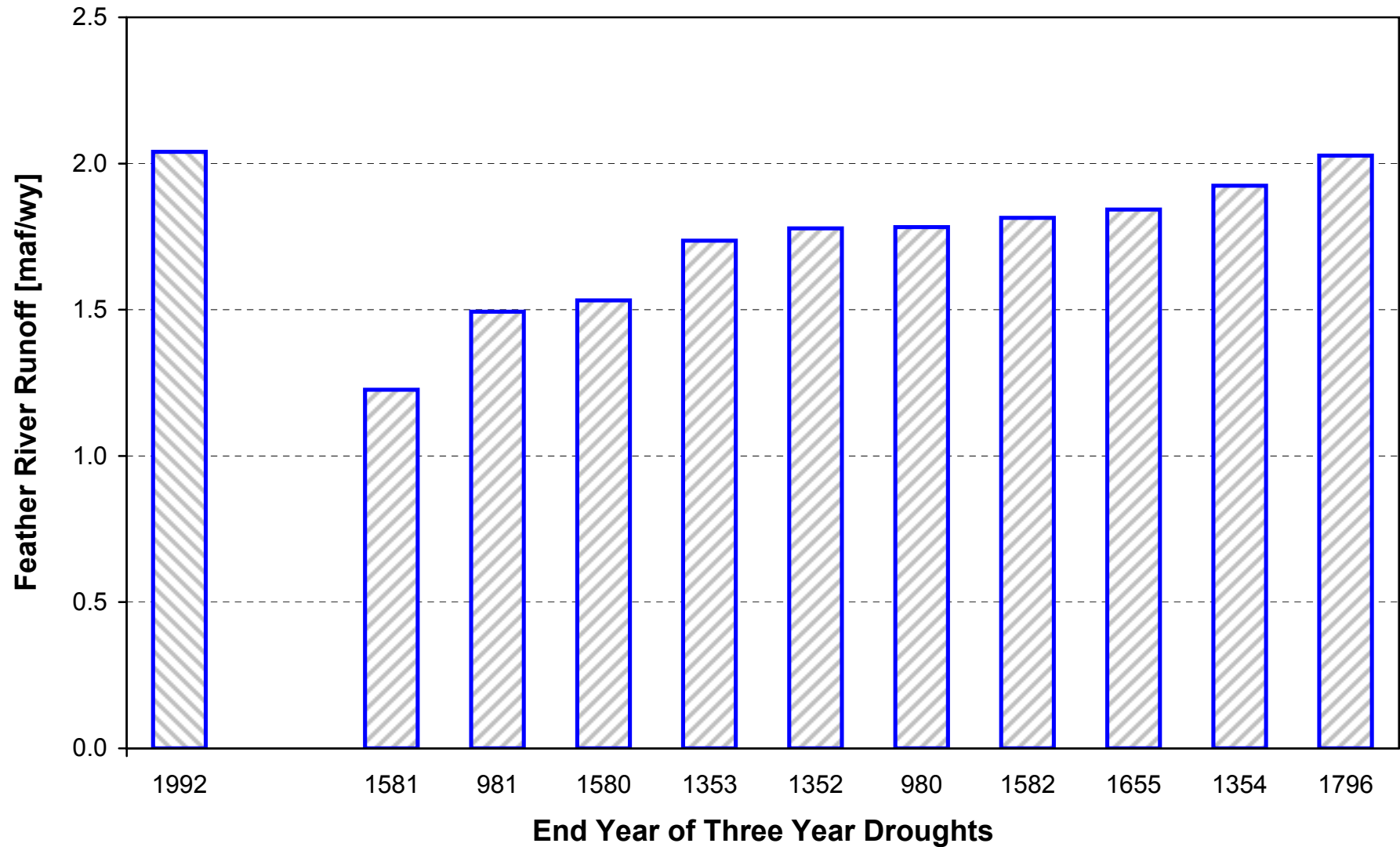
### Feather River 901-1977 Runoff Reconstruction Tree-Ring Study 10 Lowest Six Year Running Averages



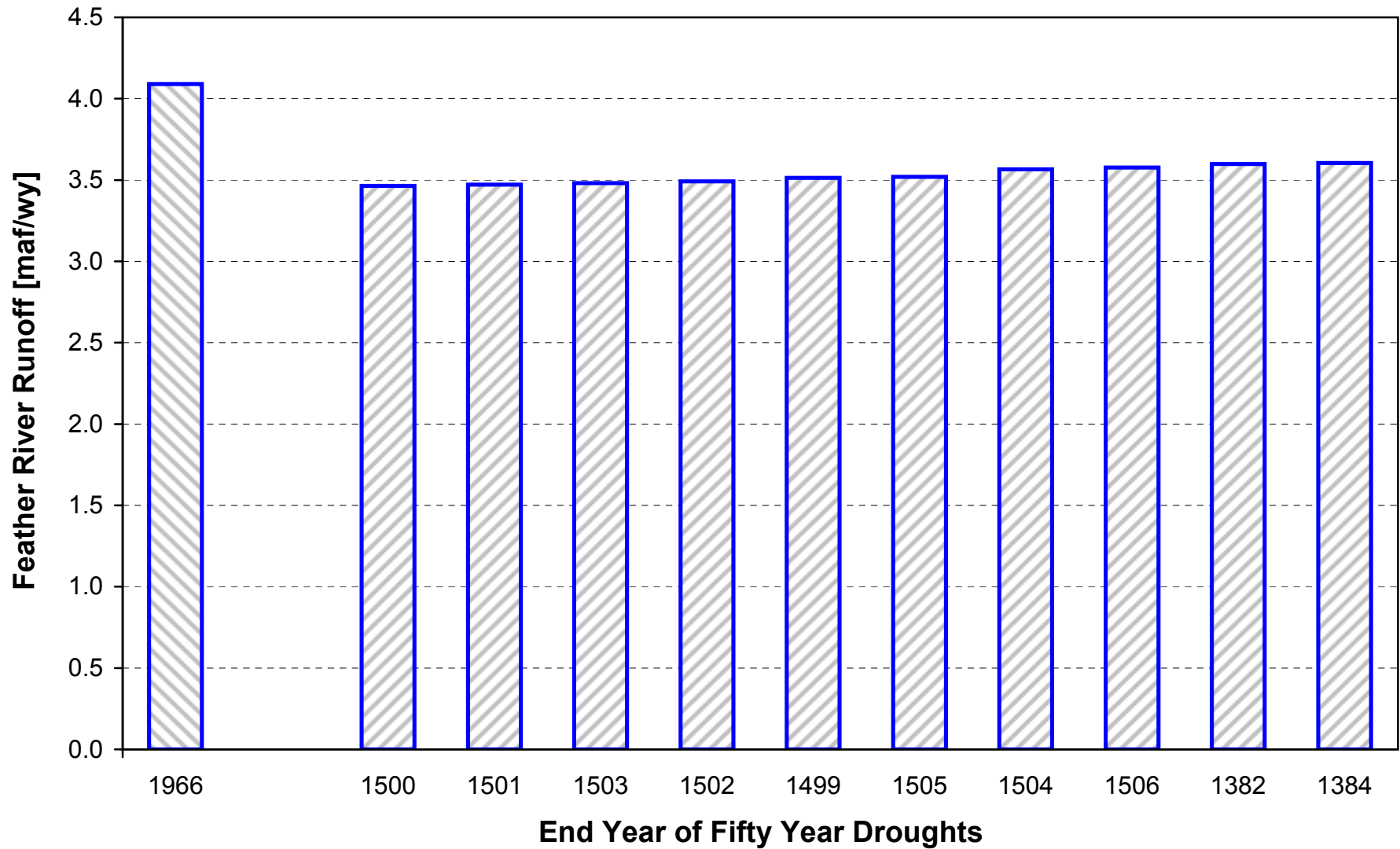
### Feather River 901-1977 Runoff Reconstruction Tree-Ring Study 10 Lowest Water Years



### Feather River 901-1977 Runoff Reconstruction Tree-Ring Study 10 Lowest Three Year Running Averages



### Feather River 901-1977 Runoff Reconstruction Tree-Ring Study 10 Lowest Fifty Year Running Averages



# Year 901-1977 Sacramento River Runoff Reconstruction

Runoff in million acre feet for water year from report by Dr. David Meko for DWR, 2001; Reconstructed Sacramento River System Runoff from Tree Rings

Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff		
901	29.9	941	28.6	981	8.8	1021	16.0	1061	15.1	1101	19.7	1141	13.6	1181	26.4	1221	16.9	1261	12.4
902	14.5	942	14.4	982	16.3	1022	16.1	1062	13.3	1102	17.5	1142	17.9	1182	18.5	1222	19.8	1262	23.5
903	17.1	943	14.1	983	10.0	1023	28.0	1063	15.9	1103	7.8	1143	17.9	1183	7.7	1223	16.5	1263	14.3
904	14.4	944	15.2	984	13.3	1024	20.1	1064	24.4	1104	22.6	1144	12.6	1184	18.4	1224	22.2	1264	6.2
905	23.1	945	19.7	985	21.0	1025	11.8	1065	21.1	1105	24.1	1145	9.7	1185	13.0	1225	23.2	1265	21.0
906	23.5	946	24.5	986	7.8	1026	20.0	1066	15.2	1106	16.2	1146	11.0	1186	18.1	1226	16.4	1266	23.5
907	14.0	947	17.8	987	18.4	1027	21.5	1067	13.4	1107	16.5	1147	17.4	1187	13.6	1227	8.7	1267	19.0
908	14.4	948	14.0	988	22.7	1028	15.6	1068	20.3	1108	23.1	1148	12.1	1188	20.4	1228	22.6	1268	14.0
909	17.6	949	14.9	989	13.6	1029	17.5	1069	13.8	1109	26.9	1149	20.3	1189	14.1	1229	27.9	1269	11.5
910	24.3	950	20.5	990	14.8	1030	20.3	1070	6.6	1110	25.9	1150	12.9	1190	18.3	1230	20.9	1270	35.3
911	23.1	951	23.6	991	21.2	1031	21.3	1071	17.0	1111	18.9	1151	14.1	1191	16.6	1231	10.7	1271	15.1
912	22.6	952	12.5	992	16.2	1032	14.0	1072	7.1	1112	21.4	1152	16.3	1192	19.0	1232	19.4	1272	12.9
913	9.5	953	12.3	993	29.4	1033	13.9	1073	13.7	1113	25.7	1153	20.6	1193	16.3	1233	17.0	1273	5.9
914	28.2	954	5.2	994	17.0	1034	17.8	1074	12.4	1114	14.5	1154	18.9	1194	14.8	1234	13.2	1274	27.9
915	11.5	955	15.7	995	9.2	1035	13.6	1075	13.4	1115	16.1	1155	14.7	1195	31.1	1235	17.5	1275	22.2
916	26.5	956	29.7	996	14.8	1036	26.0	1076	24.6	1116	24.2	1156	11.9	1196	16.9	1236	8.1	1276	15.0
917	29.5	957	5.4	997	24.5	1037	15.7	1077	14.2	1117	20.2	1157	11.7	1197	17.4	1237	11.1	1277	21.7
918	16.2	958	16.9	998	21.5	1038	14.5	1078	15.5	1118	18.1	1158	13.3	1198	16.0	1238	14.7	1278	22.9
919	14.8	959	16.3	999	15.7	1039	11.5	1079	22.0	1119	23.0	1159	17.8	1199	15.8	1239	13.9	1279	7.7
920	22.7	960	21.5	1000	16.8	1040	10.8	1080	17.2	1120	23.4	1160	21.1	1200	25.2	1240	22.5	1280	19.9
921	15.5	961	8.7	1001	17.3	1041	18.5	1081	14.1	1121	19.5	1161	12.7	1201	16.6	1241	24.9	1281	20.0
922	15.7	962	13.4	1002	22.8	1042	25.2	1082	14.4	1122	26.3	1162	14.1	1202	23.3	1242	20.5	1282	22.0
923	10.1	963	13.8	1003	22.3	1043	12.3	1083	10.8	1123	11.9	1163	18.5	1203	18.0	1243	20.1	1283	16.8
924	8.5	964	14.3	1004	17.1	1044	13.7	1084	19.0	1124	17.5	1164	10.7	1204	28.9	1244	17.0	1284	17.1
925	23.6	965	12.9	1005	11.3	1045	25.1	1085	16.8	1125	27.0	1165	25.5	1205	19.5	1245	13.0	1285	6.7
926	23.8	966	15.1	1006	24.8	1046	18.9	1086	17.2	1126	5.5	1166	23.0	1206	9.1	1246	27.9	1286	27.7
927	20.2	967	11.5	1007	19.9	1047	16.1	1087	25.9	1127	15.4	1167	25.5	1207	18.7	1247	27.4	1287	33.4
928	14.5	968	24.5	1008	23.0	1048	12.2	1088	18.8	1128	28.1	1168	11.2	1208	14.5	1248	32.3	1288	14.5
929	13.0	969	12.9	1009	24.2	1049	18.2	1089	23.4	1129	19.9	1169	33.6	1209	20.5	1249	21.6	1289	16.9
930	6.6	970	34.8	1010	15.0	1050	24.0	1090	12.1	1130	15.3	1170	10.5	1210	17.3	1250	11.9	1290	23.1
931	13.6	971	17.2	1011	23.2	1051	18.3	1091	26.8	1131	14.1	1171	19.4	1211	15.1	1251	18.9	1291	28.8
932	12.1	972	19.7	1012	8.3	1052	9.3	1092	16.4	1132	15.0	1172	14.7	1212	13.7	1252	25.3	1292	8.7
933	14.2	973	24.6	1013	15.3	1053	11.8	1093	7.8	1133	12.2	1173	18.2	1213	11.1	1253	18.2	1293	14.3
934	22.8	974	33.4	1014	11.6	1054	21.3	1094	20.9	1134	17.6	1174	10.3	1214	24.3	1254	8.6	1294	17.2
935	19.2	975	20.1	1015	18.0	1055	10.5	1095	20.5	1135	9.5	1175	9.0	1215	14.5	1255	19.8	1295	14.6
936	21.4	976	23.6	1016	23.6	1056	15.4	1096	17.6	1136	19.5	1176	13.4	1216	28.2	1256	19.8	1296	6.7
937	26.4	977	18.2	1017	19.6	1057	18.7	1097	18.7	1137	18.5	1177	12.9	1217	8.4	1257	16.3	1297	16.1
938	19.2	978	11.7	1018	14.2	1058	13.9	1098	8.2	1138	19.3	1178	30.4	1218	11.4	1258	16.4	1298	18.4
939	17.1	979	4.5	1019	23.2	1059	4.5	1099	16.8	1139	15.1	1179	19.1	1219	29.9	1259	33.6	1299	12.5
940	26.2	980	7.4	1020	21.4	1060	10.2	1100	24.0	1140	9.4	1180	17.8	1220	24.5	1260	14.0	1300	10.2

## Year 901-1977 Sacramento River Runoff Reconstruction

Runoff in million acre feet for water year from report by Dr. David Meko for DWR, 2001; Reconstructed Sacramento River System Runoff from Tree Rings

Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff
1301	11.8	1341	23.2	1381	19.1	1421	14.0	1461	11.9	1501	16.5	1541	8.5	1581	9.3	1621	16.8
1302	14.5	1342	16.1	1382	11.8	1422	28.3	1462	15.1	1502	16.5	1542	18.4	1582	12.7	1622	9.3
1303	14.0	1343	14.0	1383	18.9	1423	23.4	1463	20.5	1503	16.3	1543	13.0	1583	21.5	1623	23.9
1304	13.1	1344	14.0	1384	12.8	1424	23.5	1464	14.5	1504	27.5	1544	18.3	1584	11.3	1624	27.7
1305	16.0	1345	22.6	1385	31.0	1425	9.6	1465	11.8	1505	11.6	1545	13.9	1585	11.9	1625	25.1
1306	14.3	1346	20.7	1386	15.2	1426	10.9	1466	17.4	1506	23.2	1546	13.6	1586	19.7	1626	15.6
1307	11.4	1347	14.9	1387	22.5	1427	14.7	1467	18.6	1507	17.8	1547	14.6	1587	27.9	1627	16.3
1308	20.8	1348	16.5	1388	25.6	1428	8.9	1468	6.8	1508	16.2	1548	7.3	1588	22.2	1628	24.0
1309	9.1	1349	20.7	1389	21.2	1429	16.6	1469	18.0	1509	21.2	1549	16.8	1589	24.3	1629	13.2
1310	19.8	1350	13.2	1390	9.5	1430	15.8	1470	18.2	1510	15.3	1550	9.3	1590	9.2	1630	17.3
1311	17.3	1351	6.6	1391	15.2	1431	17.7	1471	11.7	1511	16.4	1551	17.8	1591	17.0	1631	14.8
1312	15.6	1352	3.9	1392	19.2	1432	14.1	1472	12.8	1512	27.0	1552	20.0	1592	18.0	1632	7.5
1313	24.2	1353	12.2	1393	20.1	1433	20.4	1473	10.0	1513	17.0	1553	23.7	1593	13.3	1633	18.2
1314	25.2	1354	8.8	1394	16.0	1434	11.5	1474	14.6	1514	23.1	1554	10.7	1594	12.6	1634	20.8
1315	18.4	1355	13.1	1395	13.2	1435	18.0	1475	8.3	1515	10.0	1555	11.3	1595	11.3	1635	20.4
1316	11.7	1356	20.6	1396	13.0	1436	17.9	1476	10.6	1516	11.5	1556	17.6	1596	22.2	1636	17.7
1317	18.5	1357	19.5	1397	17.1	1437	13.7	1477	13.2	1517	15.6	1557	18.6	1597	17.8	1637	17.9
1318	21.5	1358	7.5	1398	15.2	1438	17.4	1478	15.0	1518	8.5	1558	14.1	1598	14.1	1638	15.2
1319	16.0	1359	17.4	1399	13.2	1439	12.1	1479	7.8	1519	13.7	1559	23.3	1599	21.2	1639	9.5
1320	12.6	1360	11.6	1400	13.4	1440	26.2	1480	10.5	1520	13.2	1560	25.3	1600	9.0	1640	26.9
1321	18.9	1361	9.8	1401	17.0	1441	24.1	1481	16.9	1521	10.4	1561	15.6	1601	18.9	1641	29.2
1322	25.8	1362	13.4	1402	13.9	1442	17.8	1482	9.7	1522	14.5	1562	20.1	1602	16.0	1642	17.9
1323	29.3	1363	19.2	1403	21.8	1443	13.1	1483	15.5	1523	15.8	1563	16.9	1603	20.2	1643	16.4
1324	13.6	1364	10.7	1404	19.5	1444	12.7	1484	24.9	1524	21.4	1564	29.4	1604	13.8	1644	14.5
1325	16.6	1365	9.7	1405	18.9	1445	29.9	1485	13.2	1525	17.0	1565	15.6	1605	14.1	1645	13.2
1326	20.6	1366	16.4	1406	18.1	1446	18.5	1486	15.8	1526	20.4	1566	20.5	1606	14.4	1646	11.5
1327	31.3	1367	24.2	1407	11.0	1447	24.1	1487	17.4	1527	23.4	1567	27.4	1607	6.4	1647	16.3
1328	18.3	1368	22.6	1408	11.3	1448	14.7	1488	19.8	1528	18.0	1568	21.5	1608	23.0	1648	18.5
1329	17.6	1369	11.4	1409	18.9	1449	26.7	1489	21.1	1529	6.0	1569	17.7	1609	19.5	1649	18.5
1330	28.6	1370	13.2	1410	8.2	1450	17.9	1490	17.3	1530	18.6	1570	18.3	1610	18.4	1650	16.6
1331	20.5	1371	14.4	1411	20.6	1451	15.6	1491	12.3	1531	22.4	1571	5.0	1611	24.6	1651	22.3
1332	13.3	1372	15.8	1412	21.6	1452	13.5	1492	11.1	1532	6.2	1572	16.3	1612	12.2	1652	11.9
1333	15.8	1373	17.0	1413	9.1	1453	18.2	1493	19.5	1533	9.4	1573	21.9	1613	10.7	1653	9.0
1334	15.4	1374	12.5	1414	19.6	1454	12.2	1494	14.8	1534	19.4	1574	18.4	1614	17.5	1654	8.6
1335	4.7	1375	12.0	1415	19.5	1455	20.4	1495	18.0	1535	22.6	1575	14.3	1615	17.9	1655	7.5
1336	12.2	1376	17.2	1416	14.0	1456	12.8	1496	18.7	1536	12.7	1576	13.9	1616	14.4	1656	26.8
1337	24.3	1377	6.1	1417	15.1	1457	11.3	1497	9.5	1537	12.8	1577	33.0	1617	28.7	1657	12.2
1338	13.1	1378	19.1	1418	13.8	1458	11.4	1498	13.5	1538	18.5	1578	12.9	1618	11.3	1658	13.3
1339	19.0	1379	9.5	1419	16.9	1459	13.5	1499	7.5	1539	34.9	1579	5.8	1619	10.7	1659	12.0
1340	12.1	1380	19.8	1420	26.4	1460	15.6	1500	8.8	1540	12.3	1580	1.7	1620	18.3	1660	20.9
																1700	23.1

## Year 901-1977 Sacramento River Runoff Reconstruction

Runoff in million acre feet for water year from report by Dr. David Meko for DWR, 2001; Reconstructed Sacramento River System Runoff from Tree Rings

Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff
1701	17.1	1741	17.8	1781	18.0	1821	15.9	1861	19.7	1901	28.7	1941	23.1
1702	24.1	1742	19.5	1782	9.6	1822	9.9	1862	22.6	1902	17.4	1942	31.0
1703	10.0	1743	24.6	1783	7.9	1823	15.3	1863	16.4	1903	18.5	1943	22.1
1704	20.3	1744	23.7	1784	27.3	1824	12.0	1864	6.4	1904	27.0	1944	13.5
1705	20.1	1745	34.0	1785	24.4	1825	33.8	1865	18.5	1905	24.3	1945	16.9
1706	10.7	1746	23.1	1786	25.4	1826	27.8	1866	26.9	1906	23.6	1946	19.7
1707	13.6	1747	26.1	1787	20.7	1827	16.8	1867	22.3	1907	29.1	1947	11.2
1708	13.5	1748	13.9	1788	12.5	1828	19.8	1868	29.7	1908	17.3	1948	13.5
1709	24.4	1749	18.1	1789	30.9	1829	5.8	1869	14.9	1909	20.8	1949	11.9
1710	10.9	1750	20.8	1790	31.3	1830	23.8	1870	12.0	1910	18.6	1950	17.1
1711	15.0	1751	17.9	1791	22.4	1831	19.8	1871	10.2	1911	21.8	1951	20.5
1712	17.7	1752	19.2	1792	24.9	1832	37.3	1872	19.7	1912	11.3	1952	24.9
1713	21.4	1753	15.5	1793	13.1	1833	18.2	1873	18.3	1913	9.6	1953	22.1
1714	12.3	1754	17.1	1794	10.8	1834	12.9	1874	14.9	1914	24.2	1954	20.5
1715	15.4	1755	12.1	1795	5.9	1835	21.5	1875	14.5	1915	20.1	1955	11.7
1716	18.2	1756	10.0	1796	10.0	1836	22.8	1876	21.6	1916	19.3	1956	22.1
1717	16.7	1757	12.1	1797	22.7	1837	14.1	1877	10.1	1917	17.7	1957	22.7
1718	14.0	1758	17.6	1798	24.1	1838	24.4	1878	28.5	1918	11.2	1958	27.2
1719	12.1	1759	17.9	1799	22.2	1839	14.9	1879	15.1	1919	17.7	1959	8.7
1720	18.6	1760	17.7	1800	9.1	1840	15.7	1880	14.6	1920	12.4	1960	11.9
1721	8.2	1761	21.0	1801	26.6	1841	5.6	1881	27.6	1921	21.7	1961	9.4
1722	13.0	1762	18.7	1802	22.5	1842	23.6	1882	16.3	1922	19.6	1962	19.2
1723	15.1	1763	18.6	1803	16.3	1843	8.4	1883	15.1	1923	17.9	1963	31.3
1724	15.8	1764	15.2	1804	21.9	1844	8.7	1884	29.7	1924	5.7	1964	13.7
1725	24.8	1765	8.9	1805	18.6	1845	16.9	1885	14.7	1925	19.3	1965	25.6
1726	15.8	1766	18.3	1806	23.1	1846	11.2	1886	22.2	1926	13.1	1966	16.4
1727	23.6	1767	20.1	1807	14.2	1847	19.8	1887	14.4	1927	18.6	1967	24.3
1728	16.0	1768	24.0	1808	14.0	1848	16.5	1888	15.8	1928	17.7	1968	9.6
1729	5.9	1769	24.1	1809	15.3	1849	15.6	1889	17.3	1929	9.3	1969	35.6
1730	26.3	1770	11.0	1810	19.5	1850	21.4	1890	20.9	1930	12.0	1970	18.6
1731	15.3	1771	21.9	1811	22.8	1851	12.1	1891	23.0	1931	7.9	1971	20.3
1732	19.5	1772	19.5	1812	11.8	1852	26.6	1892	14.8	1932	15.6	1972	12.8
1733	10.2	1773	22.5	1813	19.4	1853	33.1	1893	26.3	1933	10.1	1973	15.3
1734	23.8	1774	25.5	1814	15.0	1854	21.7	1894	22.4	1934	7.4	1974	22.7
1735	11.0	1775	18.7	1815	15.1	1855	20.2	1895	19.4	1935	19.6	1975	17.1
1736	10.4	1776	9.1	1816	17.3	1856	11.5	1896	19.3	1936	18.0	1976	7.7
1737	11.1	1777	6.2	1817	20.1	1857	17.3	1897	18.3	1937	16.3	1977	7.3
1738	23.4	1778	13.4	1818	15.7	1858	11.8	1898	7.9	1938	21.3		
1739	14.5	1779	20.1	1819	18.2	1859	16.0	1899	11.9	1939	9.9		
1740	25.5	1780	17.5	1820	17.0	1860	22.1	1900	18.4	1940	22.4		

# Year 901-1977 Feather River Runoff Reconstruction

Runoff in million acre feet for water year from report by Dr. David Meko for DWR, 2001; Reconstructed Sacramento River System Runoff from Tree Rings

Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff
901	8.1	941	7.6	981	2.0	1021	4.0	1061	3.6	1101	4.9	1141	3.3	1181	7.0	1221	4.0
902	3.4	942	3.6	982	3.9	1022	3.9	1062	3.3	1102	4.4	1142	4.6	1182	4.5	1222	5.0
903	4.0	943	3.4	983	2.3	1023	7.3	1063	3.9	1103	1.8	1143	4.3	1183	1.7	1223	4.3
904	3.4	944	3.6	984	3.2	1024	5.2	1064	6.1	1104	5.7	1144	3.0	1184	4.5	1224	5.5
905	5.8	945	5.1	985	5.3	1025	2.9	1065	5.4	1105	6.1	1145	2.3	1185	3.2	1225	5.9
906	6.2	946	6.5	986	1.8	1026	5.0	1066	3.7	1106	3.9	1146	2.7	1186	4.5	1226	4.0
907	3.4	947	4.6	987	4.6	1027	5.4	1067	3.2	1107	3.9	1147	4.3	1187	3.3	1227	1.9
908	3.6	948	3.3	988	5.7	1028	3.8	1068	5.0	1108	5.9	1148	2.9	1188	4.9	1228	5.8
909	4.4	949	3.6	989	3.4	1029	4.5	1069	3.4	1109	7.4	1149	5.1	1189	3.4	1229	7.4
910	6.3	950	5.3	990	3.7	1030	5.2	1070	1.4	1110	6.6	1150	3.1	1190	4.5	1230	5.2
911	5.9	951	6.0	991	5.3	1031	5.2	1071	4.3	1111	4.6	1151	3.4	1191	4.1	1231	2.4
912	5.7	952	3.0	992	3.9	1032	3.4	1072	1.6	1112	5.4	1152	4.0	1192	4.6	1232	4.8
913	2.2	953	2.9	993	7.7	1033	3.3	1073	3.3	1113	6.6	1153	5.1	1193	3.9	1233	4.2
914	7.3	954	1.1	994	4.0	1034	4.5	1074	3.0	1114	3.6	1154	4.8	1194	3.6	1234	3.2
915	2.7	955	3.8	995	2.1	1035	3.3	1075	3.3	1115	4.0	1155	3.8	1195	8.1	1235	4.4
916	6.9	956	8.1	996	3.6	1036	6.7	1076	6.4	1116	6.2	1156	2.8	1196	4.1	1236	1.8
917	7.7	957	1.1	997	6.5	1037	3.9	1077	3.4	1117	5.0	1157	2.7	1197	4.2	1237	2.5
918	4.0	958	4.1	998	5.5	1038	3.5	1078	3.8	1118	4.4	1158	3.2	1198	3.9	1238	3.6
919	3.5	959	3.8	999	3.9	1039	2.7	1079	5.5	1119	5.7	1159	4.5	1199	4.0	1239	3.4
920	5.9	960	5.4	1000	4.1	1040	2.6	1080	4.2	1120	5.9	1160	5.4	1200	6.5	1240	5.7
921	3.7	961	1.9	1001	4.2	1041	4.6	1081	3.4	1121	4.8	1161	3.1	1201	4.1	1241	6.2
922	4.0	962	3.2	1002	5.9	1042	6.5	1082	3.5	1122	6.5	1162	3.4	1202	5.7	1242	5.2
923	2.3	963	3.4	1003	5.8	1043	2.9	1083	2.6	1123	2.7	1163	4.7	1203	4.4	1243	4.9
924	1.9	964	3.5	1004	4.1	1044	3.3	1084	4.7	1124	4.3	1164	2.5	1204	7.5	1244	4.1
925	5.9	965	3.1	1005	2.6	1045	6.5	1085	4.3	1125	7.0	1165	6.6	1205	4.6	1245	3.2
926	6.0	966	3.7	1006	6.3	1046	4.7	1086	4.4	1126	1.2	1166	5.9	1206	2.1	1246	7.0
927	5.0	967	2.7	1007	4.9	1047	3.9	1087	6.8	1127	3.6	1167	6.6	1207	4.8	1247	7.1
928	3.5	968	6.1	1008	5.6	1048	2.8	1088	4.7	1128	7.4	1168	2.6	1208	3.5	1248	8.7
929	3.1	969	3.0	1009	6.2	1049	4.5	1089	6.0	1129	4.7	1169	8.9	1209	5.1	1249	5.3
930	1.5	970	9.2	1010	3.6	1050	6.3	1090	2.9	1130	3.8	1170	2.4	1210	4.3	1250	2.8
931	3.2	971	4.2	1011	6.0	1051	4.6	1091	6.9	1131	3.5	1171	4.8	1211	3.7	1251	4.8
932	2.8	972	4.8	1012	1.9	1052	2.1	1092	4.1	1132	3.7	1172	3.6	1212	3.4	1252	6.4
933	3.5	973	6.4	1013	3.6	1053	2.7	1093	1.7	1133	2.8	1173	4.5	1213	2.6	1253	4.5
934	6.0	974	8.6	1014	2.7	1054	5.2	1094	5.2	1134	4.3	1174	2.5	1214	6.2	1254	2.0
935	4.6	975	4.9	1015	4.5	1055	2.5	1095	5.2	1135	2.2	1175	2.0	1215	3.4	1255	4.9
936	5.3	976	6.1	1016	6.2	1056	3.7	1096	4.3	1136	5.0	1176	3.2	1216	7.2	1256	5.1
937	7.0	977	4.6	1017	5.1	1057	4.5	1097	4.7	1137	4.5	1177	3.1	1217	2.0	1257	4.0
938	4.8	978	2.8	1018	3.4	1058	3.4	1098	1.9	1138	4.6	1178	8.0	1218	2.7	1258	4.3
939	4.3	979	0.9	1019	5.9	1059	1.0	1099	4.1	1139	3.6	1179	4.7	1219	7.9	1259	9.1
940	6.9	980	1.6	1020	5.5	1060	2.4	1100	6.2	1140	2.2	1180	4.4	1220	6.2	1260	3.4

# Year 901-1977 Feather River Runoff Reconstruction

Runoff in million acre feet for water year from report by Dr. David Meko for DWR, 2001; Reconstructed Sacramento River System Runoff from Tree Rings

Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff		
1301	2.8	1341	5.9	1381	4.9	1421	3.3	1461	2.8	1501	4.1	1541	1.9	1581	2.2	1621	4.2	1661	6.5
1302	3.5	1342	3.9	1382	2.8	1422	7.3	1462	3.7	1502	4.2	1542	4.4	1582	3.0	1622	2.2	1662	4.4
1303	3.3	1343	3.3	1383	4.8	1423	6.0	1463	5.0	1503	3.9	1543	3.0	1583	5.6	1623	6.3	1663	3.3
1304	3.2	1344	3.4	1384	3.1	1424	6.1	1464	3.5	1504	7.2	1544	4.4	1584	2.7	1624	7.6	1664	6.5
1305	3.9	1345	5.8	1385	8.1	1425	2.2	1465	2.8	1505	2.8	1545	3.3	1585	2.8	1625	6.2	1665	5.3
1306	3.5	1346	5.1	1386	3.7	1426	2.5	1466	4.3	1506	5.8	1546	3.3	1586	4.9	1626	4.0	1666	4.2
1307	2.7	1347	3.5	1387	5.6	1427	3.5	1467	4.7	1507	4.4	1547	3.6	1587	7.2	1627	4.0	1667	2.1
1308	5.1	1348	4.0	1388	6.6	1428	2.1	1468	1.5	1508	4.1	1548	1.6	1588	5.5	1628	6.4	1668	4.9
1309	2.0	1349	5.2	1389	5.5	1429	4.0	1469	4.4	1509	5.5	1549	4.1	1589	6.3	1629	3.4	1669	2.9
1310	5.0	1350	3.1	1390	2.2	1430	3.9	1470	4.5	1510	3.7	1550	2.2	1590	2.1	1630	4.4	1670	2.0
1311	4.1	1351	1.5	1391	3.6	1431	4.4	1471	2.8	1511	3.9	1551	4.4	1591	4.2	1631	3.9	1671	5.2
1312	3.8	1352	0.8	1392	4.9	1432	3.5	1472	3.0	1512	7.0	1552	5.0	1592	4.3	1632	1.7	1672	6.0
1313	6.4	1353	2.9	1393	5.2	1433	5.1	1473	2.3	1513	4.3	1553	6.1	1593	3.3	1633	4.3	1673	3.1
1314	6.4	1354	2.0	1394	4.0	1434	2.7	1474	3.5	1514	5.9	1554	2.5	1594	3.0	1634	5.3	1674	4.3
1315	4.6	1355	3.1	1395	3.1	1435	4.4	1475	1.9	1515	2.3	1555	2.7	1595	2.7	1635	5.3	1675	4.6
1316	2.7	1356	5.3	1396	3.1	1436	4.5	1476	2.5	1516	2.7	1556	4.4	1596	5.6	1636	4.3	1676	2.9
1317	4.6	1357	4.9	1397	4.2	1437	3.3	1477	3.2	1517	4.0	1557	4.5	1597	4.3	1637	4.6	1677	5.3
1318	5.3	1358	1.7	1398	3.7	1438	4.2	1478	3.7	1518	1.9	1558	3.4	1598	3.4	1638	3.6	1678	4.6
1319	3.9	1359	4.2	1399	3.2	1439	2.9	1479	1.7	1519	3.3	1559	5.8	1599	5.2	1639	2.3	1679	4.0
1320	3.0	1360	2.6	1400	3.2	1440	6.6	1480	2.5	1520	3.2	1560	6.4	1600	2.0	1640	7.1	1680	4.5
1321	4.6	1361	2.3	1401	4.1	1441	6.1	1481	4.2	1521	2.4	1561	3.8	1601	4.6	1641	7.6	1681	2.3
1322	6.5	1362	3.2	1402	3.3	1442	4.2	1482	2.3	1522	3.4	1562	5.1	1602	3.8	1642	4.2	1682	5.1
1323	7.6	1363	4.8	1403	5.5	1443	3.0	1483	3.8	1523	3.8	1563	4.2	1603	4.9	1643	4.0	1683	5.3
1324	3.3	1364	2.5	1404	4.9	1444	3.0	1484	6.4	1524	5.5	1564	7.7	1604	3.3	1644	3.4	1684	4.7
1325	4.0	1365	2.2	1405	4.5	1445	7.8	1485	3.1	1525	4.1	1565	3.9	1605	3.4	1645	3.1	1685	4.9
1326	5.2	1366	4.0	1406	4.5	1446	4.7	1486	3.9	1526	5.1	1566	5.1	1606	3.4	1646	2.7	1686	2.1
1327	8.2	1367	6.2	1407	2.6	1447	6.1	1487	4.3	1527	6.0	1567	7.2	1607	1.4	1647	3.7	1687	4.5
1328	4.6	1368	5.7	1408	2.6	1448	3.5	1488	4.9	1528	4.5	1568	5.5	1608	5.5	1648	4.3	1688	3.8
1329	4.3	1369	2.7	1409	4.8	1449	6.8	1489	5.4	1529	1.3	1569	4.4	1609	4.8	1649	4.3	1689	4.9
1330	7.7	1370	3.1	1410	1.9	1450	4.4	1490	4.1	1530	4.5	1570	4.6	1610	4.4	1650	3.7	1690	3.3
1331	5.3	1371	3.5	1411	5.1	1451	3.8	1491	2.9	1531	5.8	1571	1.0	1611	6.1	1651	5.4	1691	2.2
1332	3.1	1372	3.9	1412	5.3	1452	3.2	1492	2.6	1532	1.3	1572	4.1	1612	2.8	1652	2.7	1692	5.2
1333	3.8	1373	4.2	1413	2.1	1453	4.5	1493	4.8	1533	2.1	1573	5.6	1613	2.4	1653	2.0	1693	5.5
1334	3.7	1374	3.1	1414	4.9	1454	2.9	1494	3.6	1534	5.0	1574	4.5	1614	4.2	1654	1.8	1694	6.6
1335	1.0	1375	2.9	1415	5.0	1455	5.1	1495	4.4	1535	5.8	1575	3.5	1615	4.3	1655	1.7	1695	3.7
1336	2.9	1376	4.2	1416	3.3	1456	3.0	1496	4.6	1536	2.9	1576	3.4	1616	3.4	1656	6.9	1696	3.8
1337	6.2	1377	1.3	1417	3.6	1457	2.6	1497	2.1	1537	3.1	1577	8.9	1617	7.3	1657	3.1	1697	5.8
1338	3.0	1378	4.8	1418	3.4	1458	2.7	1498	3.2	1538	4.5	1578	3.1	1618	2.6	1658	3.3	1698	2.4
1339	4.6	1379	2.3	1419	4.1	1459	3.2	1499	1.6	1539	9.4	1579	1.2	1619	2.4	1659	2.8	1699	3.7
1340	2.9	1380	5.0	1420	6.9	1460	3.8	1500	1.9	1540	2.9	1580	0.3	1620	4.6	1660	5.1	1700	5.5

## Year 901-1977 Feather River Runoff Reconstruction

Runoff in million acre feet for water year from report by Dr. David Meko for DWR, 2001; Reconstructed Sacramento River System Runoff from Tree Rings

Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff	Year	Runoff
1701	4.1	1741	4.4	1781	4.5	1821	3.9	1861	4.9	1901	7.0	1941	5.8
1702	5.6	1742	4.9	1782	2.1	1822	2.1	1862	5.8	1902	4.2	1942	8.2
1703	2.3	1743	6.2	1783	1.8	1823	3.7	1863	4.0	1903	4.6	1943	5.7
1704	4.7	1744	6.2	1784	7.4	1824	2.9	1864	1.4	1904	6.5	1944	3.4
1705	4.7	1745	7.8	1785	6.5	1825	8.5	1865	4.6	1905	6.3	1945	4.1
1706	2.4	1746	6.0	1786	6.9	1826	7.3	1866	6.9	1906	5.6	1946	5.3
1707	3.1	1747	6.6	1787	5.3	1827	4.2	1867	5.8	1907	7.7	1947	2.7
1708	3.2	1748	3.3	1788	3.2	1828	5.2	1868	7.6	1908	4.3	1948	3.0
1709	6.3	1749	4.3	1789	8.4	1829	1.2	1869	3.8	1909	5.2	1949	2.9
1710	2.7	1750	5.4	1790	8.1	1830	6.2	1870	2.9	1910	4.5	1950	4.1
1711	3.5	1751	4.5	1791	5.8	1831	5.2	1871	2.6	1911	5.3	1951	5.3
1712	4.5	1752	4.7	1792	6.4	1832	9.8	1872	5.3	1912	2.6	1952	6.5
1713	5.6	1753	3.8	1793	3.4	1833	4.8	1873	4.8	1913	2.0	1953	5.7
1714	3.0	1754	4.1	1794	2.5	1834	3.2	1874	3.6	1914	5.9	1954	5.1
1715	3.9	1755	2.8	1795	1.3	1835	5.5	1875	3.5	1915	5.1	1955	2.8
1716	4.6	1756	2.3	1796	2.3	1836	5.6	1876	5.5	1916	5.0	1956	5.7
1717	4.3	1757	2.8	1797	6.1	1837	3.4	1877	2.3	1917	4.5	1957	5.7
1718	3.5	1758	4.4	1798	6.6	1838	6.2	1878	7.5	1918	2.8	1958	6.8
1719	3.0	1759	4.5	1799	5.4	1839	3.7	1879	3.4	1919	4.6	1959	2.0
1720	4.7	1760	4.3	1800	2.2	1840	3.9	1880	3.4	1920	3.1	1960	2.7
1721	1.9	1761	5.5	1801	7.0	1841	1.2	1881	7.1	1921	5.6	1961	2.1
1722	3.1	1762	4.9	1802	6.0	1842	6.1	1882	3.8	1922	5.4	1962	4.7
1723	3.7	1763	4.3	1803	4.0	1843	1.8	1883	3.7	1923	4.7	1963	8.4
1724	4.0	1764	3.7	1804	5.7	1844	2.0	1884	7.2	1924	1.2	1964	3.3
1725	6.3	1765	2.0	1805	4.6	1845	3.8	1885	3.3	1925	4.8	1965	6.4
1726	3.8	1766	4.5	1806	6.1	1846	2.7	1886	5.6	1926	3.1	1966	3.9
1727	5.8	1767	5.2	1807	3.4	1847	4.9	1887	3.3	1927	4.9	1967	6.1
1728	4.0	1768	6.3	1808	3.4	1848	3.7	1888	3.5	1928	4.5	1968	2.3
1729	1.2	1769	6.3	1809	3.6	1849	3.9	1889	4.2	1929	2.1	1969	8.7
1730	6.8	1770	2.7	1810	4.9	1850	5.6	1890	5.0	1930	3.1	1970	4.6
1731	3.8	1771	5.9	1811	5.7	1851	2.8	1891	5.3	1931	1.7	1971	5.3
1732	4.8	1772	5.1	1812	2.7	1852	6.7	1892	3.6	1932	3.9	1972	2.9
1733	2.4	1773	5.7	1813	4.6	1853	9.0	1893	6.2	1933	2.4	1973	3.7
1734	5.7	1774	6.7	1814	3.4	1854	5.7	1894	5.3	1934	1.7	1974	5.8
1735	2.7	1775	4.7	1815	3.6	1855	5.3	1895	4.5	1935	5.0	1975	4.1
1736	2.3	1776	2.1	1816	4.1	1856	2.7	1896	4.4	1936	4.3	1976	1.7
1737	2.5	1777	1.2	1817	4.9	1857	4.0	1897	4.1	1937	3.9	1977	1.5
1738	6.1	1778	3.2	1818	3.7	1858	2.7	1898	1.6	1938	5.4		
1739	3.4	1779	5.1	1819	4.4	1859	3.9	1899	2.6	1939	2.4		
1740	6.3	1780	4.3	1820	4.0	1860	5.7	1900	4.4	1940	5.6		