WATER RESOURCES ANALYSIS
AND INFORMATION SECTION

Office Report No. 44

# THE DEVELOPMENT OF STATIONARY TIME SERIES FOR FOUR DISCHARGE MEASUREMENT STATIONS IN THE OKANOGAN BASIN

by

Robert T. Milhous
Water Resources Engineer

(For Use by the Water Resources Management Division)

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Department of Ecology
Olympia, Washington

# T A B L E  O F  C O N T E N T S

# INTRODUCTION

The purpose of this report is to present information on the discharge of the Okanogan River at the following stations:

| | |
|---|---|
| Okanogan River at Oroville | (USGS No. 12-4395) |
| Okanogan River near Tonasket | (USGS No. 12-4450) |
| Okanogan River at Malott | (USGS No. 12-4472) |

and the following station on the Similkameen River:

| | |
|---|---|
| Similkameen River near Nighthawk | (USGS No. 12-4425) |

The locations of the stations are shown in Figure 1. Over the years considerable development has occurred in both the Canadian and United States portions of the Okanogan/Similkameen Basins. Consequently, the discharge measurements represent a time series of flow measurements collected over a time when the expected flow (mean) has been changed by man's developmental activities. The information in this paper modifies the measured flows to a consistent time series, depending on assumptions related to the activities of man.

In the Okanogan Basin the major modifications are irrigation works in both British Columbia and Washington, and the flood control works on the Okanagan in British Columbia. A total of about 100,600 acres of land are irrigated in the Okanogan Basin. The control works on the outlet of Okanagan Lake have been modified over the years as shown in Table 1. The growth in irrigated lands in the basin is shown in Figure 2. This diagram, in conjunction with Table 1, clearly indicates the extensive changes made by man in the Okanogan system. Many of the changes and impacts on the flows of the Okanogan system have been discussed by the writer in Office Reports 36 and 43.

This report presents information on the measured flows of the Okanogan system, on a procedure used to develop flows with a consistent set of assumptions on operations of the Okanagan system in British Columbia, and the results of the analysis.

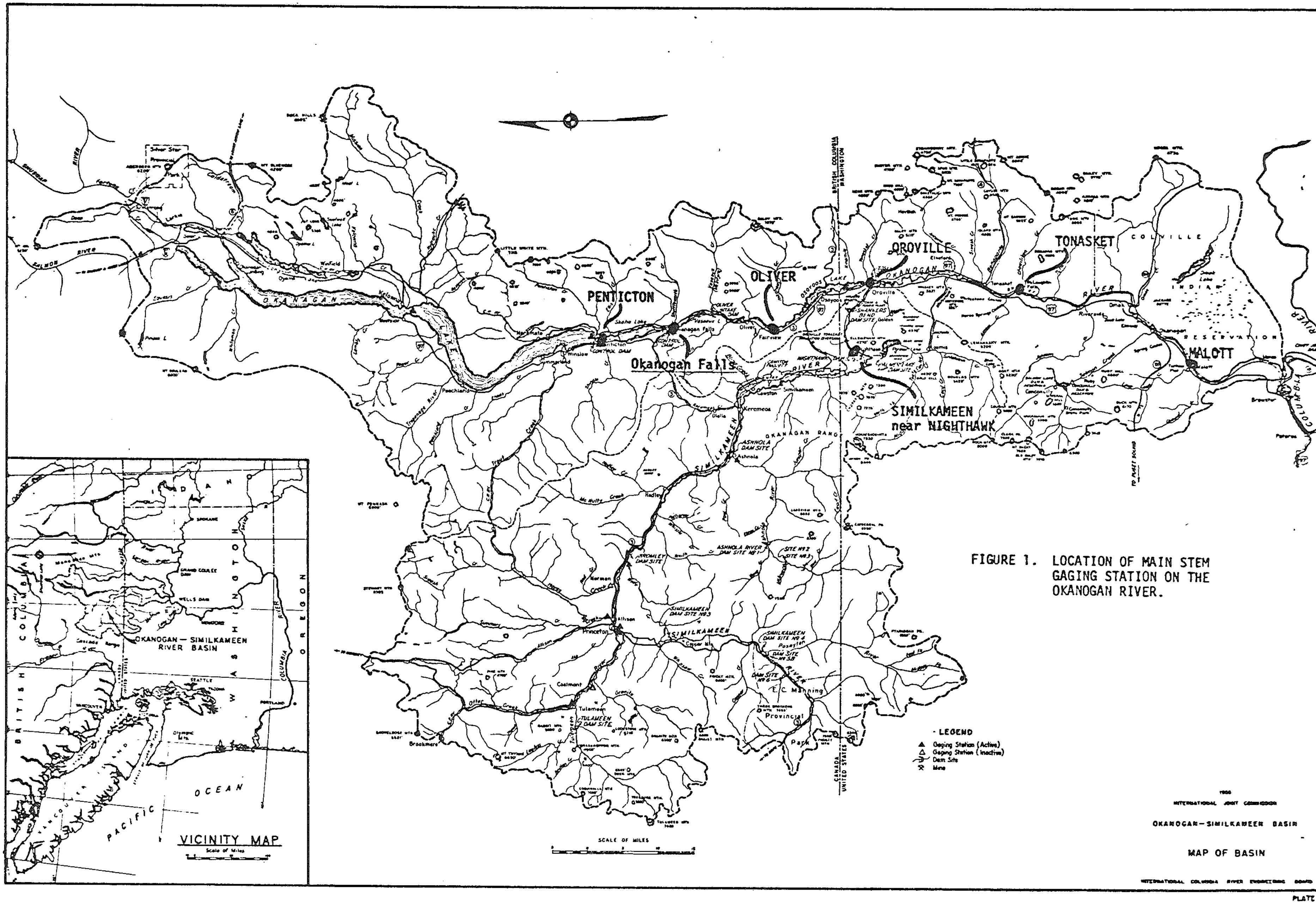


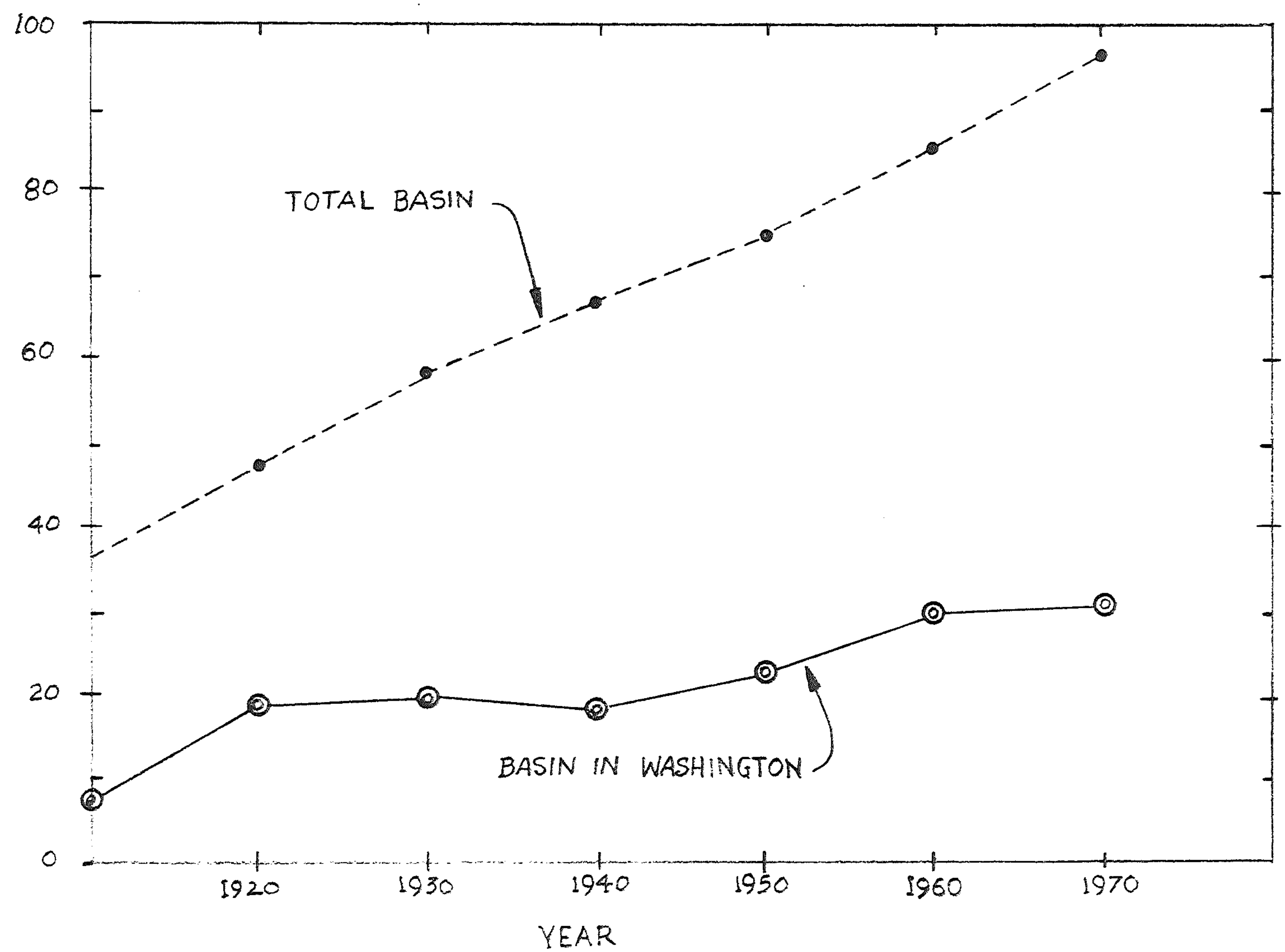

FIGURE 1. LOCATION OF MAIN STEM GAGING STATION ON THE OKANOGAN RIVER.

TABLE 1. INFORMATION ON CONTROL DAM AT OUTLET OF OKANOGAN LAKE.

| PERIOD | SILL ELEVATION | TOP OF DAM | OPERATING RANGE | ACTIVE CAPACITY (kilo ac-ft) |
|---|---|---|---|---|
| March 1915-October 1920 | 97.0 | 101.0 | NA | NA |
| October 1920-1922 | 97.0 | 102.0 | NA | NA |
| 1922-1955(?) | 97.0 | NA | 99.5-102.5 | 253 |
| 1955(?)-Present | 93.7 | 105.4 | 99.1-103.1 | 337 |

P.W.C. Datum

FIGURE 2. HISTORIC TRENDS IN IRRIGATED LAND IN THE OKANOGAN BASIN.



# M E A S U R E D   F L O W S

The measured flows at the four stations of interest were analyzed. Information on the flows of the Okanogan and Similkameen Rivers are available at the following stations:

| USGS NUMBER | STATION NAME | DRAINAGE AREA (SQUARE MILES) | PERIOD OF RECORD (COMPLETE WATER YEARS) |
|---|---|---|---|
| 12-4385 | Okanagan River at Okanagan Falls | 2650 | 1916 - 1974 |
| 12-4395 | Okanogan River at Oroville | 3210 | 1943 - 1974 |
| 12-4425 | Similkameen River near Nighthawk | 3550 | 1929 - 1974 |
| 12-4395 | Similkameen River near Oroville | 3580 | 1912 - 1928 |
| 12-4450 | Okanogan River near Tonasket | 7280 | 1930 - 1974 |
| 12-4460 | Okanogan at Okanogan * | 7880 | 1912 - 1929 |
| 12-4472 | Okanogan River at Malott | 8100 | 1959 - 1966 |
| 12-4473 | Okanogan River near Malott | 8220 | 1966 - 1974 |

* Estimated monthly flows for 1926-1929

The monthly records for the Okanogan River at Okanogan and near Tonasket have been grouped into equivalent record for the Okanogan near Tonasket of from 1912 to 1974. Also, monthly flows for the Similkameen River near Oroville, corrected for diversions through the Oroville-Tonasket Canal, have been added to the Similkameen near Nighthawk for a record of 1912 to 1974.

Considerable information for the period 1921 through 1970 is given in the various reports of the Consultative Board under the Canada-British Columbia Okanagan Basin Agreement.

The analysis reported in following sections of this report used the B.C./Canada Okanagan Study results and the flow measurement stations on the Okanogan near Oroville, Okanogan near Tonasket, and the Similkameen near

Nighthawk. Consequently, the station with the shortest record controlled the length of record used in the analysis--in this study, the Okanogan at Oroville has the shortest record (1943-present). This, and the fact the data in the B.C. Okanagan Study is for 1921-1970, results in a period of 1943-1970 being used for the analysis reported here. The period 1943-1970 does have larger flows than the longer period 1916-1970 as is shown in Table 2. Most of the water in the Okanogan River in Washington reaches the river either from the Similkameen Basin above Nighthawk or from the Okanagan above Okanagan Falls. Information on these are also given in Table 2. The change in flow for two periods is shown in Figure 3.

An analysis of the frequency of average monthly flows has been made for the period 1916-1970 and 1943-1970. The results are presented in Tables 4 through 10. Measurement at the station(s) on the Okanogan at Malott are for a short period with only data available for 1954-1974. These data have been analyzed and the results presented in Table 11.

Factors related to the use of the 28-year period 1943-1970 as the "base period" are discussed in a following section.

## ADJUSTMENT OF FLOWS

The starting point for adjustment of the flows in the Okanogan River to a common basis is the outlet of Okanagan Lake in British Columbia and the measurement station on the Similkameen River near Nighthawk. The combined drainage area is 5,890 square miles, 70 percent of the total basin area of 8,400 square miles. The flow under 1970 conditions is 2,129 kilo acre-feet, 89 percent of the net basin discharge of 2,384 kilo acre-feet.

A schematic diagram of the Okanogan Basin below Okanogan Lake and Nighthawk on the Similkameen is given in Figure 4. Estimates of the flows at Penticton with 1970 and 2020 levels of development in the Okanogan Lake Basin have been made by the British Columbia Water Resources Service. Using these flows and measured flows of the Similkameen River near Nighthawk, along with estimates of depletions in the basin below Penticton and in the Similkameen, estimates

TABLE 2. AVERAGE MONTHLY FLOWS FOR THREE STATIONS IN THE OKANOGAN BASIN.

| MONTH | OKANAGAN AT OKANAGAN FALLS | | SIMILKAMEEN NEAR NIGHTHAWK | | OKANOGAN NEAR TONAKSET | | FLOW AT OKANAGAN FALLS + FLOW NEAR NIGHTHAWK | | NET INCREASE IN FLOW BETWEEN GAGES | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1916-1970 (cfs) | 1943-1970 (cfs) | 1916-1970 (cfs) | 1943-1970 (cfs) | 1916-1970 (cfs) | 1943-1970 (cfs) | 1916-1970 (cfs) | 1943-1970 (cfs) | 1916-1970 (cfs) | 1943-1970 (cfs) | 1916-1942 (cfs) |
| Oct. | 421 | 499 | 762 | 802 | 1282 | 1410 | 1183 | 1301 | 90 | 109 | 70 |
| Nov. | 413 | 484 | 892 | 970 | 1437 | 1581 | 1305 | 1454 | 132 | 127 | 137 |
| Dec. | 414 | 492 | 769 | 843 | 1316 | 1460 | 1183 | 1335 | 133 | 125 | 141 |
| Jan. | 394 | 467 | 632 | 663 | 1183 | 1274 | 1026 | 1130 | 157 | 144 | 170 |
| Feb. | 393 | 468 | 665 | 695 | 1227 | 1341 | 1058 | 1163 | 169 | 178 | 160 |
| Mar. | 443 | 508 | 673 | 655 | 1245 | 1310 | 1116 | 1163 | 129 | 147 | 110 |
| Apr. | 503 | 576 | 1950 | 1668 | 2490 | 2315 | 2453 | 2244 | 37 | 71 | 2 |
| May | 721 | 779 | 7970 | 8466 | 8506 | 9073 | 8691 | 9245 | 185 | 172 | 198 |
| June | 825 | 843 | 8731 | 9838 | 9744 | 10876 | 9556 | 10681 | 188 | 195 | 181 |
| July | 673 | 684 | 2887 | 3248 | 3587 | 3844 | 3560 | 3932 | 27 | -84 | 142 |
| Aug. | 528 | 592 | 877 | 996 | 1322 | 1416 | 1405 | 1588 | -83 | -172 | - 9 |
| Sept. | 459 | 552 | 603 | 668 | 1019 | 1148 | 1062 | 1220 | -43 | 72 | -162 |
| Annual (kilo acre-feet) | 373 | 419 | 1651 | 1782 | 2073 | 2235 | 2024 | 2201 | 49 | 34 | 64 |

FIGURE 3. CHANGE IN FLOW OF THE OKANOGAN RIVER BELOW NIGHTHAWK AND OKANOGAN FALLS AND ABOVE TONASKET.

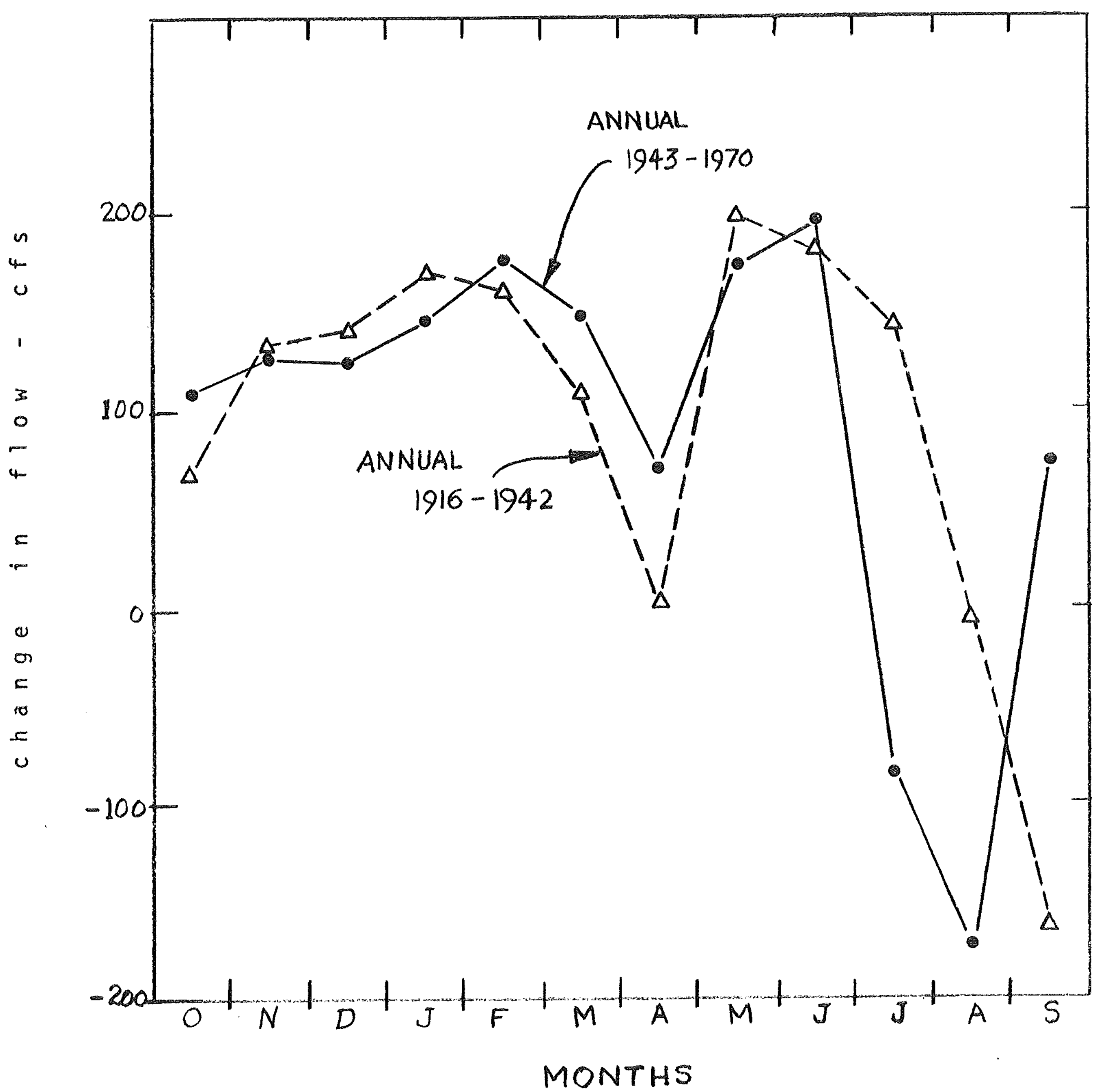


TABLE 3

## FREQUENCY AND WATER USE DATA

FOR Similkameen River near Nighthawk. U.S.G.S. GAGE 12-4425

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 780 | 865 | 761 | 689 | 768 | 764 | 1555 | 7674 | 11278 | 3463 | 933 | 614 |
| Discharge not exceeded two in three years | 844 | 948 | 831 | 757 | 844 | 835 | 1729 | 8386 | 12460 | 3799 | 1034 | 673 |
| Discharge not exceeded one in two years ($Q_2$) | 704 | 777 | 662 | 629 | 704 | 701 | 1410 | 7232 | 10097 | 2957 | 835 | 549 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 410 | 430 | 335 | 362 | 411 | 417 | 768 | 4651 | 5395 | 1402 | 442 | 300 |
| $Q_2 - Q_{10}$ | 294 | 347 | 326 | 267 | 293 | 284 | 642 | 2581 | 4702 | 1555 | 394 | 250 |
| Water Use (Depletions) | | | | | | | | | | | | |

Period of Record 1959 - 1974 Remarks: Measured flows, log-normal distribution.

ECY 070-99

TABLE 4

FREQUENCY AND WATER USE DATA

FOR Okanagan River at Okanogan Falls, B.C. . U.S.G.S. GAGE 12-4385

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 421 | 413 | 414 | 394 | 393 | 443 | 503 | 721 | 825 | 673 | 528 | 459 |
| Discharge not exceeded two in three years | 466 | 449 | 462 | 434 | 443 | 496 | 562 | 802 | 911 | 735 | 580 | 506 |
| Discharge not exceeded one in two years ($Q_2$) | 333 | 316 | 292 | 274 | 284 | 331 | 400 | 611 | 672 | 528 | 429 | 370 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 122 | 110 | 74 | 70 | 76 | 99 | 145 | 272 | 271 | 197 | 175 | 145 |
| $Q_2 - Q_{10}$ | 211 | 205 | 218 | 204 | 208 | 232 | 255 | 340 | 401 | 331 | 254 | 225 |
| Water Use (Depletions) | | | | | | | | | | | | |

Period of Record 1916 - 1970 Remarks: Measured flows, log-normal distribution.

TABLE 5

FREQUENCY AND WATER USE DATA

FOR Okanogan River at Tonasket. U.S.G.S. GAGE 12-4450

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 1282 | 1437 | 1316 | 1183 | 1227 | 1245 | 2490 | 8506 | 9744 | 3587 | 1322 | 1019 |
| Discharge not exceeded two in three years | 1409 | 1582 | 1449 | 1308 | 1353 | 1369 | 2700 | 9356 | 10853 | 3953 | 1456 | 1121 |
| Discharge not exceeded one in two years ($Q_2$) | 1153 | 1300 | 1189 | 1066 | 1125 | 1147 | 2135 | 7929 | 8744 | 3057 | 1135 | 886 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 635 | 723 | 641 | 578 | 649 | 677 | 1061 | 4848 | 4653 | 1421 | 539 | 440 |
| $Q_2 - Q_{10}$ | 518 | 576 | 540 | 488 | 476 | 471 | 1074 | 3082 | 4120 | 1636 | 596 | 446 |
| Water Use (Depletions) | | | | | | | | | | | | |

Period of Record 1916 - 1970 Remarks: Measured flows, log-normal distribution.

ECY 070-99

Table 6 FREQUENCY AND WATER USE DATA

FOR Similkameen River near Nighthawk. U.S.G.S. Gage 12-4425.

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 762 | 892 | 769 | 632 | 665 | 673 | 1950 | 7970 | 8731 | 2887 | 877 | 603 |
| One in Two Year Discharge ($Q_2$) | 667 | 777 | 674 | 566 | 597 | 620 | 1566 | 7453 | 7872 | 2473 | 784 | 542 |
| One in Ten Year Discharge ($Q_{10}$) | 357 | 400 | 351 | 313 | 335 | 382 | 694 | 4606 | 4196 | 1185 | 426 | 306 |
| $Q_2 - Q_{10}$ | 310 | 377 | 323 | 253 | 262 | 238 | 872 | 2847 | 3676 | 1288 | 358 | 236 |
| Water Use | | | | | | | | | | | | |

Period of Record: 1916 - 1970. Remarks: Measured flows, log-normal distribution measurements of the Similkameen River near Oroville used for the period 1916-1928. These were corrected for the measured Oroville-Tonasket Canal diversions.

TABLE 7

## FREQUENCY AND WATER USE DATA

FOR Okanagan River at Okanagan Falls. U.S.G.S. GAGE 12-4385

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 499 | 484 | 492 | 467 | 468 | 508 | 576 | 779 | 843 | 684 | 592 | 552 |
| Discharge not exceeded two in three years | 553 | 529 | 541 | 519 | 521 | 568 | 648 | 868 | 938 | 757 | 655 | 613 |
| Discharge not exceeded one in two years ($Q_2$) | 442 | 409 | 415 | 406 | 412 | 426 | 495 | 682 | 749 | 617 | 538 | 497 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 226 | 190 | 189 | 196 | 203 | 181 | 223 | 333 | 383 | 334 | 299 | 266 |
| $Q_2 - Q_{10}$ | 216 | 219 | 226 | 211 | 208 | 245 | 273 | 350 | 366 | 282 | 239 | 231 |
| Water Use (Depletions) | | | | | | | | | | | | |

Period of Record 1943 - 1970 Remarks: Measured flows, log-normal distribution.

ECY 070-99

TABLE 8

# FREQUENCY AND WATER USE DATA

FOR Okanogan at Oroville . U.S.G.S. GAGE 12-4395

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 576 | 559 | 557 | 556 | 551 | 553 | 670 | 1068 | 1080 | 657 | 505 | 535 |
| Discharge not exceeded two in three years | 638 | 613 | 612 | 617 | 609 | 616 | 752 | 1185 | 1202 | 724 | 556 | 596 |
| Discharge not exceeded one in two years ($Q_2$) | 522 | 493 | 486 | 499 | 501 | 481 | 574 | 943 | 919 | 554 | 434 | 459 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 287 | 256 | 245 | 264 | 281 | 229 | 256 | 476 | 413 | 249 | 208 | 211 |
| $Q_2 - Q_{10}$ | 235 | 237 | 241 | 234 | 221 | 251 | 318 | 466 | 506 | 304 | 226 | 248 |
| Water Use (Depletions) | | | | | | | | | | | | |

Period of Record 1943 - 1970 Remarks: Measured flows, log-normal distribution.

ECY 070-99

TABLE 9 FREQUENCY AND WATER USE DATA

FOR Similkameen at Nighthawk. U.S.G.S. GAGE 12-4425

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 802 | 970 | 843 | 663 | 695 | 655 | 1668 | 8466 | 9838 | 3248 | 996 | 668 |
| Discharge not exceeded two in three years | 876 | 1065 | 923 | 724 | 758 | 710 | 1837 | 9292 | 10803 | 3565 | 1091 | 727 |
| Discharge not exceeded one in two years ($Q_2$) | 731 | 865 | 744 | 618 | 644 | 620 | 1467 | 7927 | 9173 | 2875 | 898 | 600 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 426 | 466 | 391 | 385 | 397 | 414 | 751 | 4935 | 5633 | 1515 | 502 | 337 |
| $Q_2 - Q_{10}$ | 305 | 399 | 353 | 233 | 247 | 206 | 717 | 2992 | 3540 | 1360 | 396 | 262 |
| Water Use (Depletions) | | | | | | | | | | | | |

Period of Record 1943 - 1970 Remarks: Measured flows, log-normal distribution.



ECY 070-99

TABLE 10

FREQUENCY AND WATER USE DATA

FOR Okanogan near Tonasket . U.S.G.S. GAGE 12-4450

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 1410 | 1581 | 1460 | 1274 | 1341 | 1310 | 2315 | 9073 | 10876 | 3844 | 1416 | 1148 |
| Discharge not exceeded two in three years | 1541 | 1734 | 1604 | 1393 | 1462 | 1436 | 2556 | 9967 | 11950 | 4226 | 1552 | 1256 |
| Discharge not exceeded one in two years ($Q_2$) | 1330 | 1482 | 1349 | 1223 | 1286 | 1243 | 2117 | 8470 | 10121 | 3419 | 1267 | 1031 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 856 | 927 | 806 | 831 | 878 | 809 | 1206 | 5214 | 6166 | 1818 | 691 | 572 |
| $Q_2 - Q_{10}$ | 474 | 555 | 544 | 392 | 408 | 434 | 911 | 3256 | 3954 | 1601 | 576 | 459 |
| Water Use (Depletions) | | | | | | | | | | | | |

Period of Record 1943 - 1970 Remarks: Measured flows, log-normal distribution.

ECY 070-99

TABLE 11

# FREQUENCY AND WATER USE DATA

FOR Okanogan at Malott. U.S.G.S. GAGE 12-4473

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 1326 | 1349 | 1300 | 1267 | 1441 | 1531 | 2426 | 8259 | 12586 | 4222 | 1415 | 1064 |
| Discharge not exceeded two in three years | 1447 | 1476 | 1421 | 1381 | 1571 | 1682 | 2683 | 9064 | 13901 | 4599 | 1549 | 1177 |
| Discharge not exceeded one in two years ($Q_2$) | 1248 | 1294 | 1190 | 1221 | 1387 | 1420 | 2203 | 7688 | 11102 | 3537 | 1216 | 970 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 803 | 874 | 702 | 846 | 958 | 856 | 1223 | 4707 | 5679 | 1616 | 591 | 545 |
| $Q_2 - Q_{10}$ | 445 | 420 | 488 | 375 | 430 | 564 | 980 | 2981 | 5423 | 1920 | 625 | 425 |
| Water Use (Depletions) | | | | | | | | | | | | |

Period of Record 1959 - 1974 Remarks: Measured flow, log-normal distribution.

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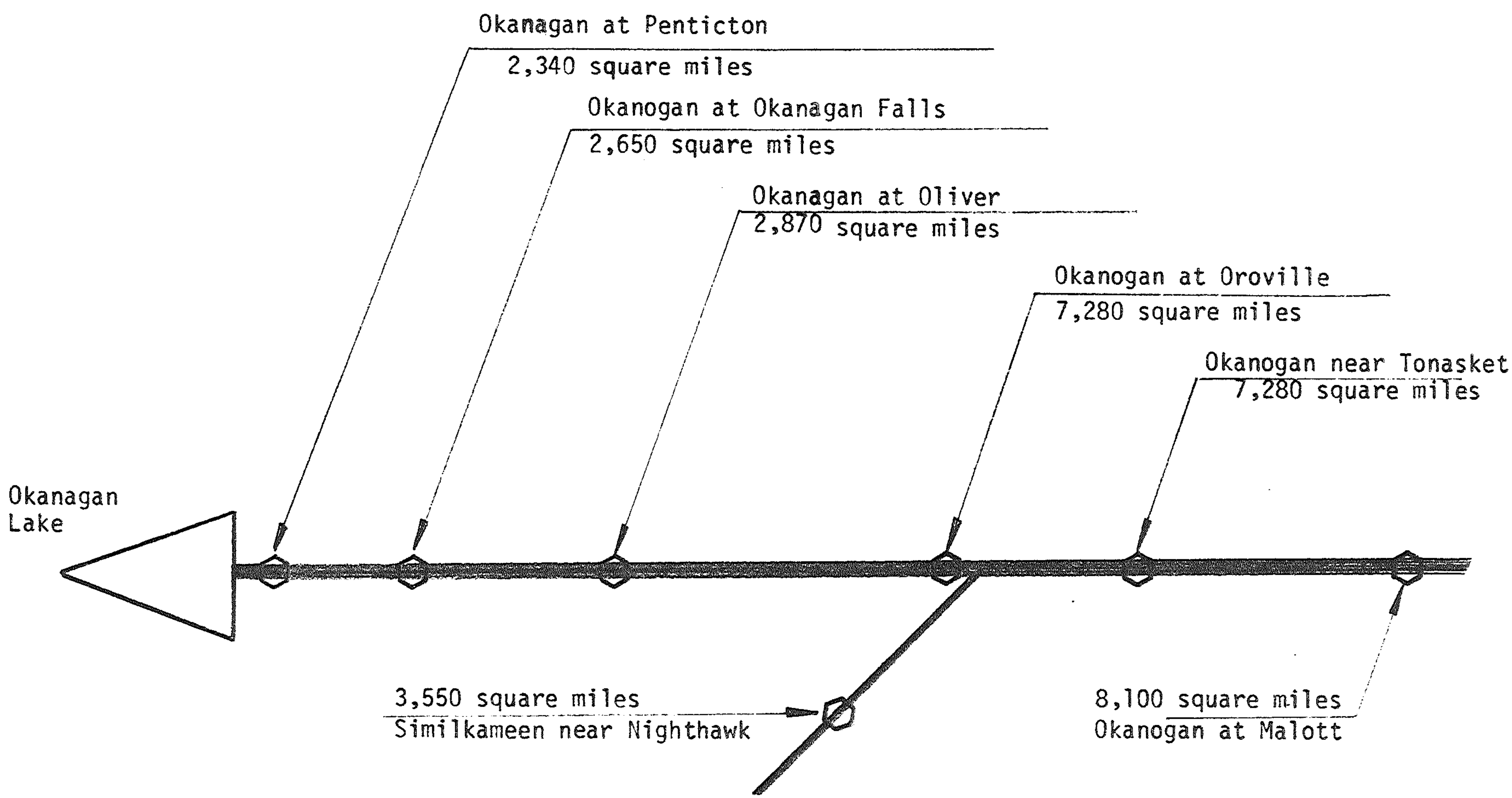
FIGURE 4. SCHEMATIC OF THE OKANOGAN RIVER BELOW OKANAGAN LAKE AND NIGHTHAWK ON THE SIMILKAMEEN.



of the flows in the Okanogan River at Oroville and Tonasket can be made by adjusting the measured flows. Considerable information on the technique has been presented previously (Office Report No. 36) and will not be repeated here.

The paragraphs that flow present information on the assumption made for each subbasin of the Okanogan Basin.

<u>Okanagan Lake Subbasin</u>

The principal element of concern here is the outflow from Okanagan Lake at Penticton. The Canada-British Columbia report on the Okanagan Basin presents a number of alternatives. Three of these are given in Table 12, along with the measured flows, for the calendar years 1942 through 1970. The measured flows and the two alternatives for 1970 conditions are shown in Figure 5. The future operation of the lake will have a significant impact on the flows from the lake.

The flows during a 1944 type water year are shown on Figure 6. The average annual discharge for the 1942-1970 period was 382 kilo acre-feet under 1970 conditions, compared to 153 kilo acre-feet for 1944 with alternative 00 and 1944 kilo acre-feet with alternative 03. The measured flow during the 1944 water year was 148 kilo acre-feet. The average annual flow in the Okanogan at Oroville is 451 acre-feet under 1970 conditions; hence, the annual flow from Okanagan Lake is 85 percent of the flow at Oroville.

<u>Middle Okanogan Subbasin</u>

There are about 14,000 acres of irrigated land in the British Columbia portion of the subbasin. The use with 1970 conditions of development was:

| | |
|---|---|
| Irrigation--------------------- | 62,860 acre-feet |
| Municipal and Domestic--------- | 2,110 acre-feet |
| Industrial--------------------- | 1,500 acre-feet |
| T O T A L | 66,470 acre-feet |

The depletions are about 32,400 acre-feet (49 percent of the diversions). The irrigation use is 4.5 acre-feet per acre per year and the municipal,

TABLE 12. AVERAGE MONTHLY FLOW FROM OKANAGAN LAKE (1942-1970).

| M O N T H | MEASURED | 1970 CONDITIONS | | 2020 CONDITIONS |
|---|---|---|---|---|
| | | RUN 00 | RUN 03 | RUN 00 |
| October | 489 | 492 | 130 | 454 |
| November | 461 | 493 | 855 | 452 |
| December | 461 | 493 | 821 | 452 |
| January | 456 | 505 | 859 | 457 |
| February | 442 | 764 | 769 | 714 |
| March | 478 | 223 | 242 | 230 |
| April | 514 | 750 | 636 | 742 |
| May | 599 | 731 | 650 | 720 |
| June | 739 | 728 | 728 | 730 |
| July | 709 | 437 | 318 | 439 |
| August | 638 | 421 | 236 | 406 |
| September | 588 | 331 | 151 | 337 |
| Annual (Kilo acre-feet) | 396 | 382 | 382 | 368 |

in cubic feet per second

FIGURE 5. FLOWS FROM OKANAGAN LAKE WITH ALTERNATIVE OPERATING CRITERIA (1942-1970).

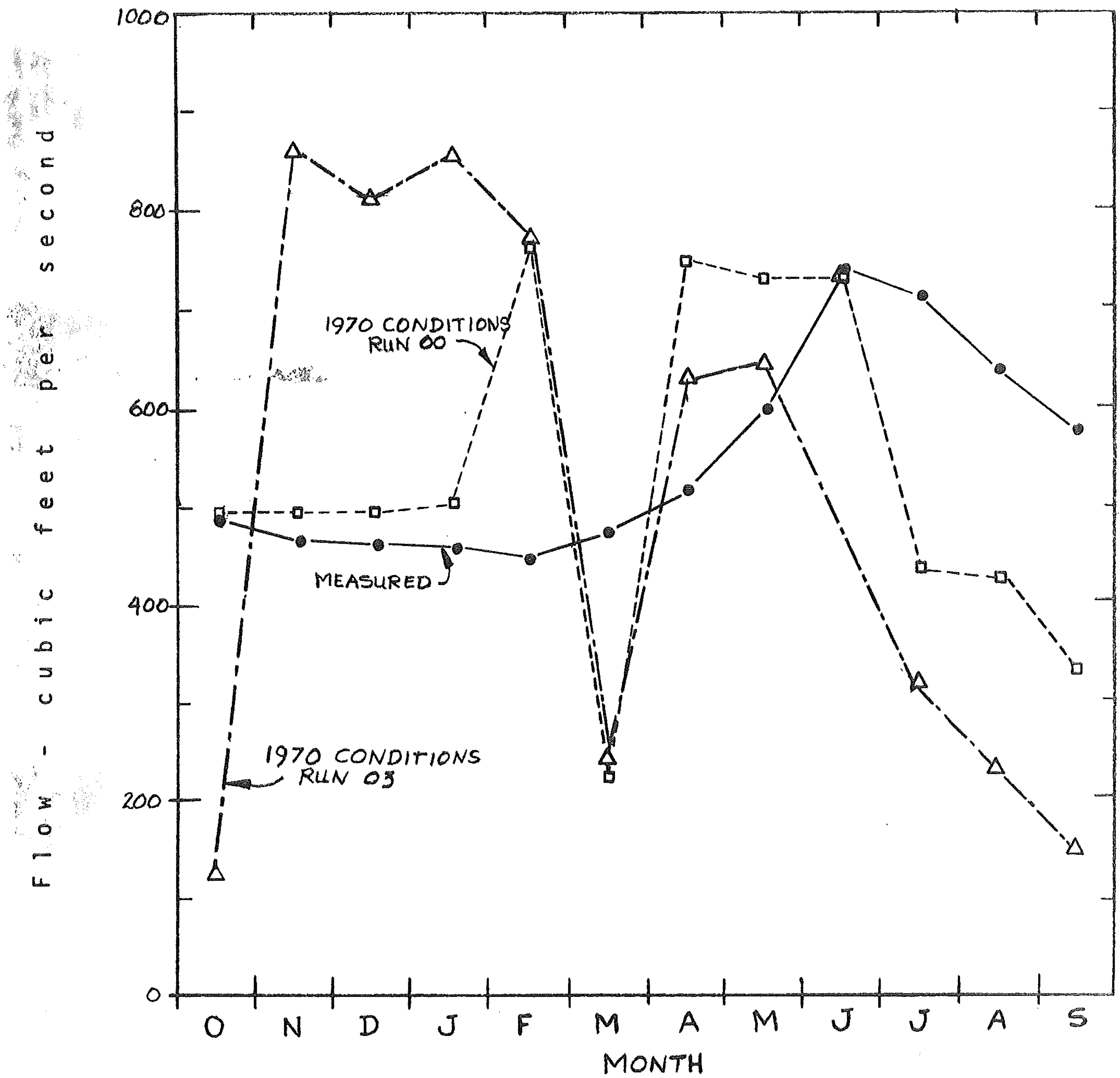
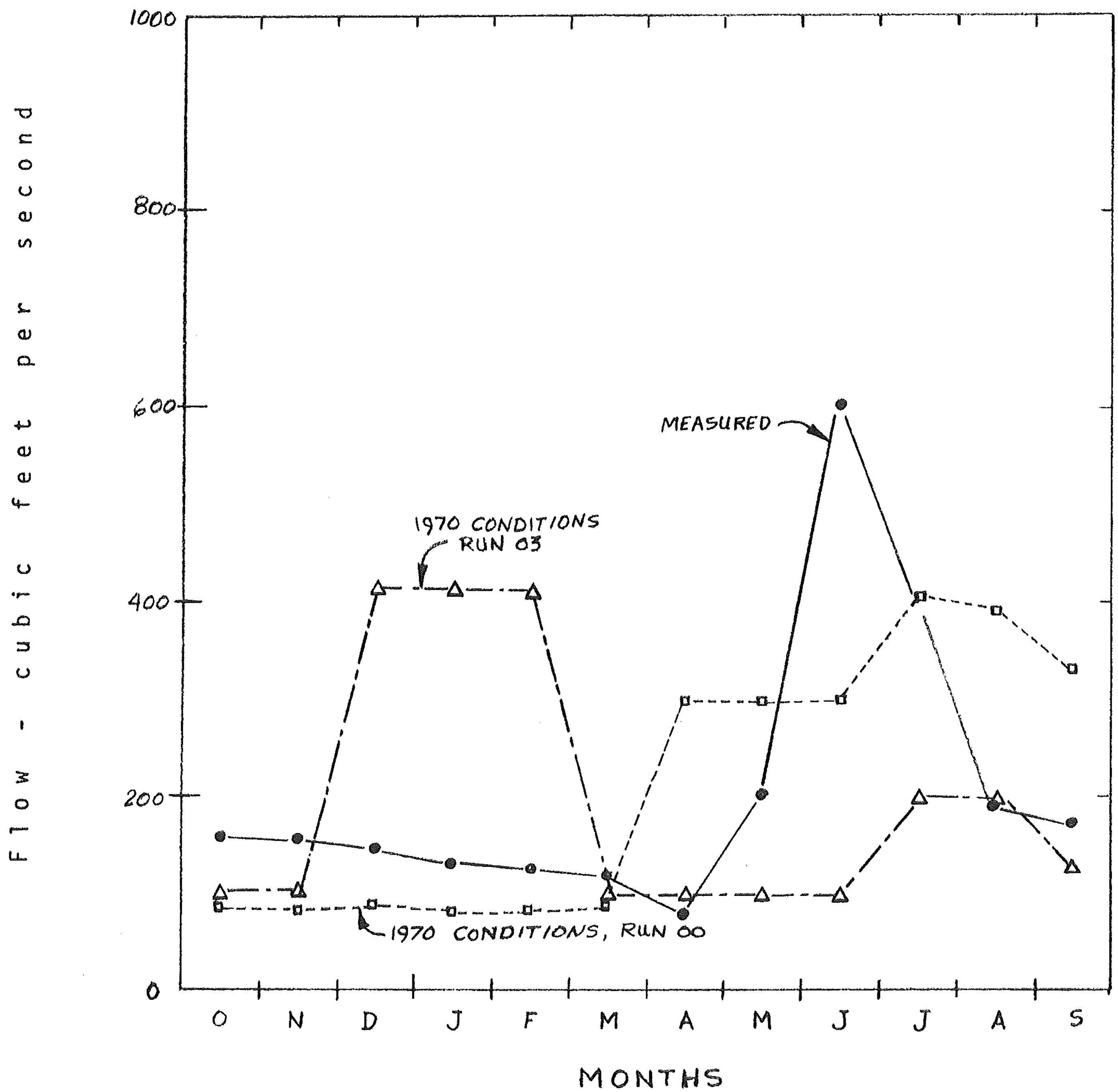


FIGURE 6. FLOWS FROM OKANAGAN LAKE DURING A 1944 TYPE WATER YEAR WITH ALTERNATIVE OPERATING CRITERIA.



industrial, and domestic use 0.33 acre-feet per capita per year (294 U.S. gallons per capita per day). The use and depletions were obtained from the Canada-British Columbia Okanagan report. Elsewhere in the report is information on the variation in depletions over time. The values for 1970 are for a total depletion of 40.7 acre-feet--this is significantly different than the 32.4 reported above. A comparison of the monthly values is given in Table 13. The data in Tables C.5 through C.7 of the Canada, B.C./ Okanagan Study have been used in the analysis report in this report.

The variation of depletions in the Middle Okanagan over time are given in Figure 7.

The total depletions in the Middle Okanogan Subbasin are given in Table 14. These include net return flows from diversions from the Similkameen in Washington.

Future conditions are hard to estimate because of uncertainty of the future water use in British Columbia. The Canada-British Columbia Okanagan report indicates there will be a 38 percent increase in consumptive use by 2020. It is likely the Oroville-Tonasket Irrigation District facilities will be rehabilitated by 2020 and no additional lands irrigated in the Washington portion of the Middle Okanagan Subbbasin. The depletions under 2020 conditions are given in Table 15.

Similkameen Subbasin

Considerable water is diverted from the Similkameen Subbasin to the Lower and Middle Okanagan Subbasins. Most of the diversion occurs below the discharge measurement station near Nighthawk.

The variation over the years of irrigated lands in the Similkameen Subbasin is given in Figure 8. The data for Washington are from Simons (1953) and for 1967 and 1972 from Soil Conservation Service data. Because of the different data sources, the decrease in irrigated lands may not be the same as is shown.

The estimates for irrigated land in the British Columbia portion of the subbasin vary from 6,000 to 6,500 acres; 6,200 acres have been used in this report.

TABLE 13. COMPARISON OF ESTIMATE DEPLETION FROM THE MIDDLE OKANOGAN AS GIVEN IN THE BRITISH COLUMBIA OKANAGAN BASIN STUDY.

| MONTH | TABLE 3.5 | TABLES C.5 through C.7 |
|---|---|---|
| October | -2,790 | -3,300 |
| November | -1,540 | -1,900 |
| December | -1,520 | -1,900 |
| January | -1,220 | -1,500 |
| February | -1,230 | -1,500 |
| March | - 800 | -1,000 |
| April | -1,200 | -1,500 |
| May | 6,100 | 7,600 |
| June | 11,460 | 14,200 |
| July | 11,170 | 14,000 |
| August | 11,450 | 14,200 |
| September | 2,600 | 3,300 |
| Annual | 32,400 | 40,700 |

Source: Appendix I of the report of the Canada-British Columbia Okanagan Basin Study Team.

FIGURE 7. DEPLETIONS IN THE MIDDLE OKANAGAN SUBBASIN, BRITISH COLUMBIA.

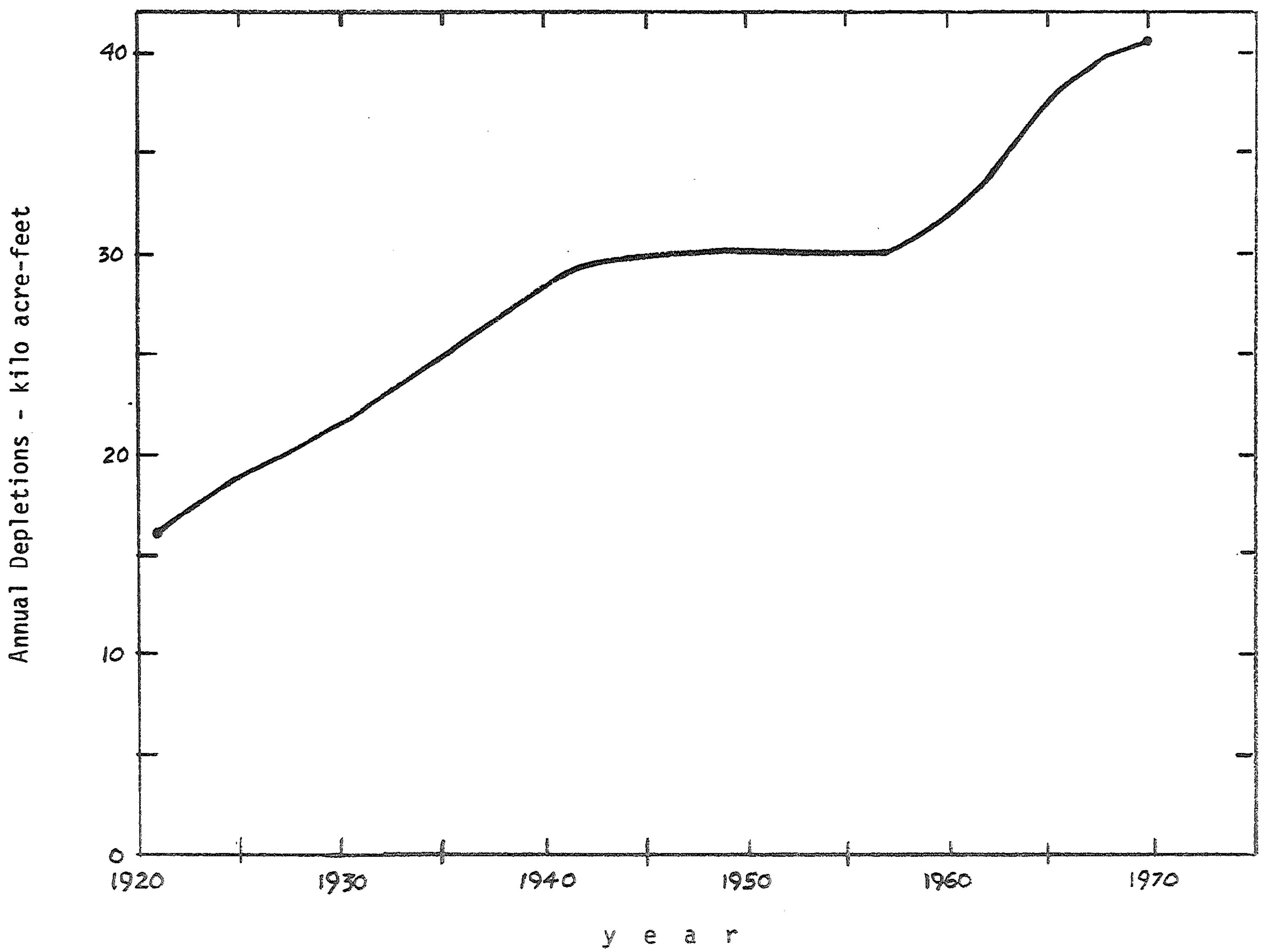


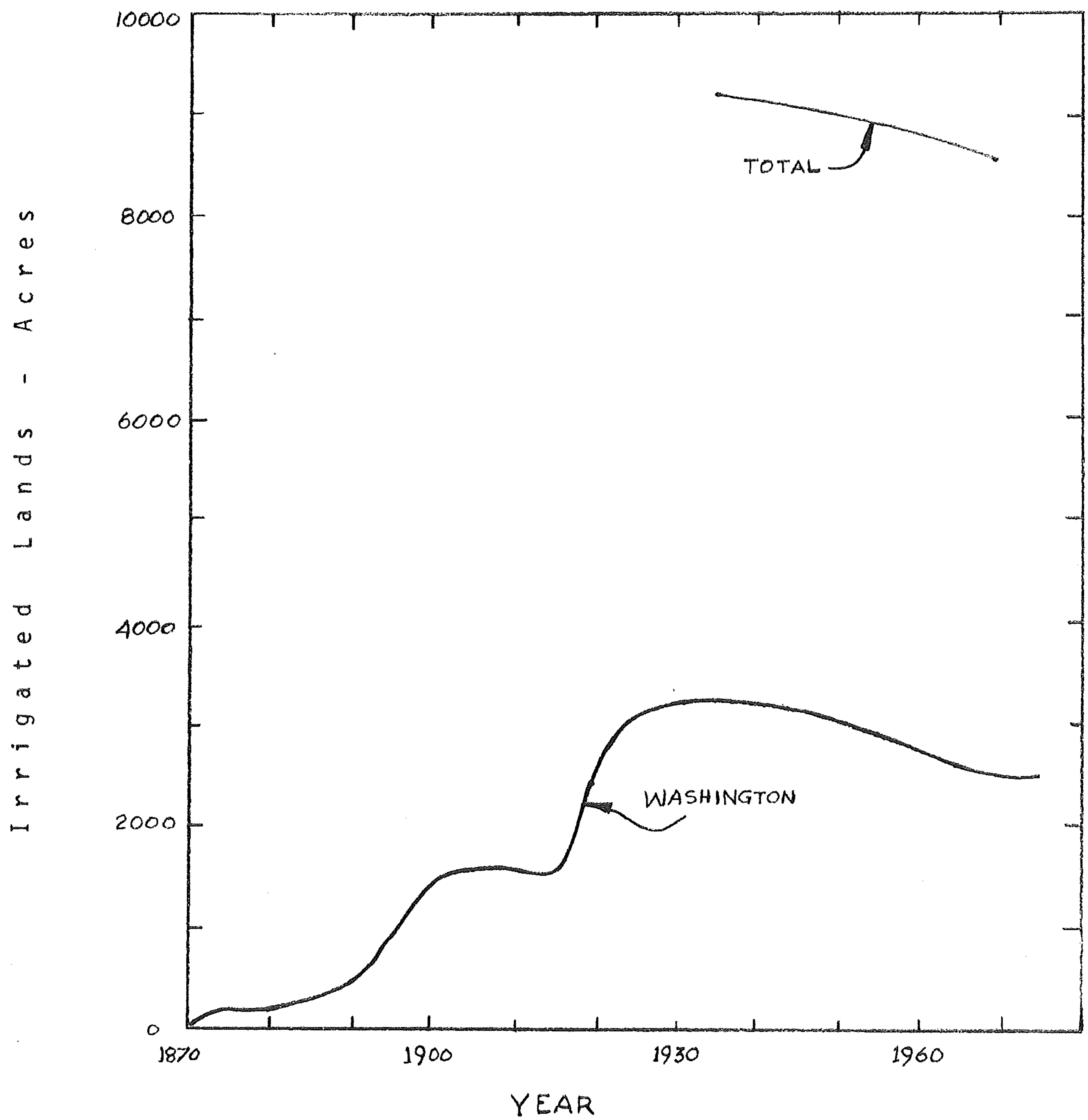
TABLE 14. DEPLETIONS FROM THE MIDDLE OKANOGAN SUBBASIN--1970 CONDITIONS.

| MONTH | DEPLETIONS IN BRITISH COLUMBIA | NET DEPLETIONS IN WASHINGTON | TOTAL DEPLETIONS (cfs) |
|---|---|---|---|
| October | -54 | -10 | -64 |
| November | -32 | - 7 | -39 |
| December | -31 | - 6 | -37 |
| January | -24 | - 6 | -30 |
| February | -27 | - 5 | -32 |
| March | -16 | - 4 | -20 |
| April | -25 | - 4 | -29 |
| May | 124 | - 8 | 116 |
| June | 239 | -11 | 228 |
| July | 228 | -12 | 216 |
| August | 231 | -10 | 221 |
| September | 56 | -10 | 46 |
| Annual | 56 | - 8 | 48 |

TABLE 15. DEPLETIONS FROM THE MIDDLE OKANAGAN SUBBASIN--2020 CONDITIONS

| M O N T H | DEPLETIONS IN BRITISH COLUMBIA (cfs) | DEPLETIONS IN WASHINGTON (cfs) | TOTAL DEPLETIONS (cfs) |
|---|---|---|---|
| October | -74 | - 4 | -78 |
| November | -44 | - 3 | -47 |
| December | -43 | - 3 | -46 |
| January | -33 | - 3 | -36 |
| February | -37 | - 3 | -40 |
| March | -22 | - 2 | -24 |
| April | -34 | - 3 | -37 |
| May | 170 | - 6 | 164 |
| June | 329 | - 4 | 325 |
| July | 314 | - 2 | 312 |
| August | 318 | - 1 | 317 |
| September | 77 | - 1 | 76 |
| Annual | 77 | - 3 | 74 |

FIGURE 8. IRRIGATED LANDS IN THE SIMILKAMEEN SUBBASIN ABOVE NIGHTHAWK, WASHINGTON.



Information on water use in the Similkameen Subbasin is given in Office Report No. 43. The only new development up to probably 2020 will be an increase in diversions from Toats Coulee Creek to the Lower Okanogan Subbasin. The present and future depletion from the Similkameen above Nighthawk are given in Table 16. The depletions have been assumed to be constant over the period 1943 to 1970.

### Lower Okanogan Subbasin

The information on irrigated lands in the section subbasin above Tonasket are about 13,400 acres at present. From 1930 to about 1950, something like 10,500 acres were irrigated. The increase occurred from 1950 to 1960. Information on water use in the Lower Okanogan is given in Office Report No. 43.

The depletions in the Lower Okanogan above Tonasket and the Similkameen Subbasin below Nighthawk are given in Table 17.

### Total Depletions Below Okanagan Lake

A table of the total depletions from the Okanogan Basin above Tonasket and below Okanagan Lake is given in Table 18. These represent the best estimates of depletions for the Okanogan Basin below Okanagan Lake available at this time. The data needed to estimate the monthly depletions below Tonasket are not available at this time.

## THE BASE PERIOD

The base period used in the analysis presented in this report is water years 1943 through 1970. This period was used because of the nature of the data available. The question at hand is just how representative of the long-term water supply is the 28-year period 1943-1970.

Data are available for the discharge measurement station on the Similkameen River near Nighthawk for the water years 1912 through 1975. The waters of

TABLE 16. DEPLETIONS IN THE SIMILKAMEEN SUBBASIN.

| MONTH | PRESENT | 2020 | CHANGE |
|---|---|---|---|
| October | -18 | -18 | 0 |
| November | -13 | -13 | 0 |
| December | -15 | -15 | 0 |
| January | -13 | -13 | 0 |
| February | -12 | -12 | 0 |
| March | - 1 | 4 | 5 |
| April | 32 | 38 | 6 |
| May | 124 | 155 | 31 |
| June | 152 | 181 | 29 |
| July | 152 | 152 | 0 |
| August | 132 | 132 | 0 |
| September | 31 | 31 | 0 |
| Annual | 46 | 52 | 6 |

TABLE 17. DEPLETIONS FROM LOWER OKANOGAN SUBASIN ABOVE TONASKET AND THE SIMILKAMEEN BELOW NIGHTHAWK.

| M O N T H | PRESENT CONDITIONS (cfs) | 2020 CONDITIONS (cfs) | CHANGE (cfs) |
|---|---|---|---|
| October | 1 | 5 | 4 |
| November | -24 | -10 | 14 |
| December | -25 | -11 | 14 |
| January | -17 | - 7 | 10 |
| February | -15 | - 5 | 10 |
| March | - 8 | 0 | 8 |
| April | 36 | 23 | -13 |
| May | 138 | 98 | -40 |
| June | 161 | 148 | -13 |
| July | 190 | 199 | 9 |
| August | 180 | 156 | -24 |
| September | 123 | 64 | -59 |
| Annual | 62 | 55 | - 7 |

TABLE 18. DEPLETIONS FROM THE OKANOGAN BASIN BELOW OKANAGAN LAKE AND ABOVE TONASKET.

| MONTH | PRESENT CONDITIONS (cfs) | 2020 CONDITIONS (cfs) | CHANGE (cfs) |
|---|---|---|---|
| October | -81 | -91 | -10 |
| November | -76 | -70 | 6 |
| December | -77 | -72 | 5 |
| January | -60 | -56 | 4 |
| February | -59 | -57 | 2 |
| March | -29 | -20 | 9 |
| April | 39 | 24 | -15 |
| May | 378 | 417 | 39 |
| June | 541 | 654 | 113 |
| July | 558 | 663 | 105 |
| August | 533 | 605 | 72 |
| September | 200 | 171 | -29 |
| Annual | 156 | 181 | 25 |

the Similkameen Basin are utilized for irrigation and this use has varied over the years but the impact of the diversions is less than for any other station in the Okanogan Basin with a long record.

The average monthly flows for six lengths of record are given in Table 19. The average annual discharge for the 1943-1970 period is about 7 percent larger than for the 1912-1975 period. The one-in-two year and one-in-ten year average monthly flows calculated using the two lengths of record are given in Table 20. These data clearly indicate the 1912-1975 period had less annual runoff than the 1943-1970 period.

A cursory review of precipitation records in the San Juan Islands over the period 1891 to 1973 indicates the period 1943-1970 had about 1 percent more rainfall than the 1891 to 1973, but that the period 1912-1973 had about 2 percent less than 1891 to 1973. This information suggests that the period 1943-1970 is as good an estimator of the long-term yield as the period 1912-1975.

Another source of information on the long-term yield of streams in the Columbia Basin is the discharge record for the Columbia River at The Dalles. Information on the discharge of the Columbia River at The Dalles is given in Table 21. This information clearly indicates the 1943-1970 period is an exceptable estimator of the long-term water yield in the Columbia Basin. Consequently, the results of frequency analysis of the flow data for the 1943-1970 period can be used as an estimation of the long-term frequency distributions.

## THE EQUATIONS

The equation used to adjust the flows at three of the four measurement stations are present in this section. The notation used is the same as used in the computer program. A listing of the computer program is given in the appendix.

TABLE 19. AVERAGE MONTHLY FLOWS FOR THE SIMILKAMEEN NEAR NIGHTHAWK.

| MONTH | PERIOD OF RECORD | | | | | |
|---|---|---|---|---|---|---|
| | 1912 to 1975 (64 yrs) | 1943 to 1970 (28 yrs) | 1929 to 1970 (42 yrs) | 1912 to 1928 (17 yrs) | 1959 to 1970 (11 yrs) | 1929 to 1945 (17 yrs) |
| October | 741 | 802 | 758 | 753 | 926 | 639 |
| November | 850 | 970 | 912 | 713 | 1066 | 813 |
| December | 727 | 843 | 766 | 653 | 955 | 660 |
| January | 610 | 663 | 614 | 636 | 830 | 512 |
| February | 648 | 895 | 670 | 604 | 882 | 598 |
| March | 667 | 654 | 680 | 608 | 808 | 677 |
| April | 1892 | 1668 | 2059 | 1691 | 1686 | 2510 |
| May | 7993 | 8466 | 7984 | 7665 | 7428 | 7118 |
| June | 9050 | 9838 | 8504 | 8085 | 10947 | 6972 |
| July | 3004 | 3248 | 2777 | 2874 | 3199 | 2240 |
| August | 898 | 996 | 866 | 874 | 926 | 685 |
| September | 601 | 668 | 601 | 609 | 690 | 477 |
| Annual (kilo acre-feet) | 1668 | 1793 | 1641 | 1556 | 1780 | 1441 |

(USGS Gage 12-4425); data for the Similkameen near Oroville (corrected for Oroville-Tonasket Canal diversions) was used for the period 1912 to 1928.

TABLE 20. COMPARISON OF MEASURED FLOWS IN THE SIMILKAMEEN RIVER NEAR NIGHTHAWK FOR THE IMPACT OF RECORD LENGTH.

| MONTH | AVERAGE MONTHLY FLOW NOT EXCEED ONE IN TWO YEARS | | | AVERAGE MONTHLY FLOW NOT EXCEED ONE IN 10 YEARS | | |
|---|---|---|---|---|---|---|
| | 1912 to 1975 | 1943 to 1970 | RATIO | 1912 to 1975 | 1943 to 1970 | RATIO |
| October | 658 | 731 | 1.11 | 365 | 426 | 1.17 |
| November | 744 | 865 | 1.16 | 391 | 466 | 1.19 |
| December | 639 | 744 | 1.16 | 340 | 391 | 1.15 |
| January | 551 | 618 | 1.12 | 313 | 385 | 1.23 |
| February | 585 | 644 | 1.10 | 336 | 397 | 1.18 |
| March | 614 | 620 | 1.01 | 378 | 414 | 1.10 |
| April | 1537 | 1467 | 0.95 | 695 | 751 | 1.08 |
| May | 7460 | 7927 | 1.06 | 4596 | 4935 | 1.07 |
| June | 8028 | 9173 | 1.14 | 4133 | 5633 | 1.36 |
| July | 2555 | 2875 | 1.13 | 1209 | 1515 | 1.25 |
| August | 804 | 898 | 1.12 | 437 | 502 | 1.15 |
| September | 545 | 600 | 1.10 | 315 | 337 | 1.07 |

TABLE 21. AVERAGE ANNUAL DISCHARGE OF THE COLUMBIA RIVER AT THE DALLES.

| MONTH | MEASURED | | "NATURAL" | |
|---|---|---|---|---|
| | 1,000 ac-ft | Ratio | 1,000 ac-ft | Ratio |
| 1878 - 1974 | 141,100 | 1.00 | 146,700 | 1.00 |
| 1943 - 1970 | 138,400 | 0.98 | 146,300 | 1.00 |
| 1912 - 1974 | 133,700 | 0.95 | 141,600 | 0.97 |
| 1929 - 1970 | 130,800 | 0.93 | 139,470 | 0.95 |
| 1912 - 1942 | 127,000 | 0.90 | 132,500 | 0.90 |

Okanogan at Oroville (USGS No. 12-4395)

The data used to calculate the flows at Oroville are:

| | |
|---|---|
| Measured discharge of the Okanagan at Penticton---------------- | QPM |
| Measured discharge of the Okanogan at Oroville----------------- | QOM |
| Calculated discharge of the Okanagan at Penticton (from Canada-British Columbia Okanagan Report)------------ | QPC |
| Depletions - Penticton to Okanagan Falls---------------------- | DPOF |
| - Okanagan Falls to Oliver------------------------ | DOFO |
| - Oliver to Oroville------------------------------ | DOOW |
| (from Canada-British Columbia Okanagan Report) | |

The depletions for the Middle Okanagan in British Columbia is:

$$DOV = DPOF + DOFO + DOOW$$

The natural inflows between Oroville and Penticton is:

$$QNOV = QOM - QPM + DOV$$

The flows under 1970 conditions are calculated using the following equation where D700 is the depletion in the Middle Okanagan Subbasin in British Columbia.

$$QOC = QPC + QNOV - D700$$

The D700 term was adjusted in most cases to remove the return flows from the Washington portion of the base so as to have the case of no development in Washington and 1970 conditions in British Columbia.

Similkameen near Nighthawk (USGS No. 12-4425)

The equation used to estimate the natural flows of the Similkameen near Nighthawk is:

$$QSC = QS + DEPS$$

where QS is the measured discharge
DEPS is the estimates of the depletion
QSC is the calculated discharge

Okanogan near Tonasket (USGS No. 12-4450)

The equations used to estimate the flows of the Okanogan River near Tonasket are:

$$DQLO = QT - (QOM + QS)$$

Where QT is the measured flow near Tonasket and DQLO is the measured change in flow between the two upstream gages (Nighthawk and Oroville) and Tonasket.

$$QTC = QOC + QSC + DQLON$$

where QTC is the calculated discharge near Tonasket and DQLON is the estimated depletion from the Okanogan Basin between Oroville/Nighthawk and Tonasket.

Frequency Analysis

The frequency analysis reported in this report was made assuming a log-normal distribution.

## THE RESULTS

The results of the analysis of the data for 1943-1970 are given in Tables 22 through 26. The estimated values are for 1970 conditions of development in the British Columbia Okanagan Basin and no development in the Similkameen in British Columbia or the portion of the Okanogan Basin in Washington. Two estimates were made using the results of alternative operation studies for the Okanagan Lake.

## THE MALOTT GAGE

Information on the water supply and water use at the discharge measurement station on the Okanogan River near Malott is hard to develop because of the short period of record for the station and the lack of information on water

TABLE 22

# FREQUENCY AND WATER USE DATA

FOR Similkameen near Nighthawk. U.S.G.S. GAGE 12-4425

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 784 | 957 | 828 | 650 | 683 | 654 | 1698 | 8590 | 9990 | 3400 | 1128 | 699 |
| Discharge not exceeded two in three years | 857 | 1051 | 906 | 710 | 745 | 709 | 1871 | 9423 | 10964 | 3733 | 1234 | 762 |
| Discharge not exceeded one in two years ($Q_2$) | 711 | 851 | 727 | 604 | 632 | 619 | 1501 | 8059 | 9335 | 3045 | 1041 | 633 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 409 | 454 | 377 | 373 | 386 | 413 | 780 | 5055 | 5780 | 1659 | 627 | 366 |
| $Q_2 - Q_{10}$ | 303 | 397 | 350 | 231 | 246 | 206 | 722 | 3004 | 3555 | 1386 | 414 | 268 |
| Water Use (Depletions) | -18 | -13 | -15 | -13 | -12 | - 1 | 32 | 124 | 152 | 152 | 132 | 31 |

Period of Record 1943 - 1970 Remarks: Adjusted for depletions, log-normal distribution.



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TABLE 23

# FREQUENCY AND WATER USE DATA

FOR Okanogan at Oroville . U.S.G.S. GAGE 12-4395

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 581 | 592 | 591 | 618 | 873 | 290 | 912 | 1132 | 990 | 341 | 252 | 269 |
| Discharge not exceeded two in three years | 647 | 663 | 658 | 691 | 1004 | 238 | 964 | 1232 | 1071 | 370 | 270 | 287 |
| Discharge not exceeded one in two years ($Q_2$) | 507 | 513 | 506 | 536 | 736 | 152 | 703 | 928 | 800 | 302 | 230 | 264 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 245 | 239 | 231 | 252 | 291 | 40 | 274 | 398 | 336 | 164 | 141 | 206 |
| $Q_2 - Q_{10}$ | 262 | 274 | 275 | 284 | 444 | 112 | 429 | 529 | 464 | 138 | 89 | 58 |
| Water Use (Depletions) | -10 | - 7 | - 6 | - 6 | - 5 | - 4 | - 4 | - 8 | -11 | -12 | -10 | -10 |

Period of Record 1943 - 1970 Remarks: RUN A: 1970 condition in British Columbia, Lake Okanagan operation study 00, no development in Washington. Log-normal distribution.

TABLE 24

FREQUENCY AND WATER USE DATA

FOR Okanogan at Oroville. U.S.G.S. GAGE 12-4395

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 205 | 967 | 929 | 956 | 879 | 309 | 801 | 1044 | 987 | 223 | 79 | 91 |
| Discharge not exceeded two in three years | 223 | 1069 | 1025 | 1055 | 1005 | 270 | 750 | 1089 | 1053 | 172 | 54 | 86 |
| Discharge not exceeded one in two years ($Q_2$) | 184 | 907 | 878 | 904 | 758 | 182 | 459 | 722 | 639 | 89 | 33 | 56 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 104 | 557 | 554 | 571 | 327 | 56 | 106 | 212 | 144 | 13 | 7 | 16 |
| $Q_2 - Q_{10}$ | 80 | 351 | 325 | 333 | 431 | 126 | 353 | 510 | 495 | 77 | 26 | 40 |
| Water Use (Depletions) | -10 | - 7 | - 6 | - 6 | - 5 | - 4 | - 4 | - 8 | -11 | -12 | -10 | -10 |

Period of Record 1943 - 1970

Remarks: RUN B: 1970 conditions in British Columbia, Lake Okanagan operation study 03, no development in Washington. Log-normal distribution.

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TABLE 25

# FREQUENCY AND WATER USE DATA

FOR Okanogan near Tonasket . U.S.G.S. GAGE 12-4450

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 1398 | 1580 | 1456 | 1308 | 1638 | 1038 | 2619 | 9386 | 11083 | 3852 | 1458 | 1024 |
| Discharge not exceeded two in three years | 1531 | 1735 | 1602 | 1438 | 1819 | 1122 | 2900 | 10320 | 12173 | 4223 | 1586 | 1114 |
| Discharge not exceeded one in two years ($Q_2$) | 1287 | 1467 | 1345 | 1246 | 1528 | 922 | 2355 | 8709 | 10346 | 3486 | 1368 | 966 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 766 | 888 | 799 | 812 | 907 | 514 | 1266 | 5250 | 6371 | 1968 | 881 | 630 |
| $Q_2 - Q_{10}$ | 520 | 578 | 546 | 434 | 621 | 408 | 1089 | 3459 | 3975 | 1518 | 487 | 335 |
| Water Use (Depletions) | -27 | -44 | -46 | -36 | -31 | -16 | 64 | 254 | 302 | 330 | 302 | 144 |

Period of Record 1943 - 1970 Remarks: RUN A: 1970 conditions in the Okanagan Basin in British Columbia, Lake Okanagan operation study 00, and no development in the Similkameen Basin or the Okanagan Basin in Washington. Log-normal distribution.

TABLE 26

# FREQUENCY AND WATER USE DATA

FOR Okanogan near Tonasket . U.S.G.S. GAGE 12-4450

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 1023 | 1954 | 1794 | 1645 | 1644 | 1057 | 2509 | 9299 | 11081 | 3728 | 1272 | 846 |
| Discharge not exceeded two in three years | 1113 | 2134 | 1959 | 1784 | 1822 | 1144 | 2782 | 10235 | 12185 | 4084 | 1386 | 919 |
| Discharge not exceeded one in two years ($Q_2$) | 943 | 1861 | 1704 | 1597 | 1538 | 944 | 2194 | 8582 | 10305 | 3314 | 1162 | 763 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 547 | 1238 | 1123 | 1147 | 929 | 532 | 1082 | 5076 | 6254 | 1778 | 688 | 437 |
| $Q_2 - Q_{10}$ | 368 | 623 | 580 | 450 | 609 | 412 | 1112 | 3506 | 4052 | 1536 | 474 | 326 |
| Water Use (Depletions) | -27 | -44 | -46 | -36 | -31 | -16 | 64 | 254 | 302 | 330 | 302 | 144 |

Period of Record 1943 - 1970 Remarks: RUN B: 1970 conditions in the Okanagan Basin in British Columbia, Lake Okanagan operation study 03, and no development in the Similkameen Basin on the Okanogan Basin in Washington. Log-normal distribution.

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use in the Salmon and Johnson Creek drainages. The best estimates are given in Table 27. The "natural" change in flow was used to estimate the mean flows given in Table 28. The ratio of mean flows for Malott near Tonasket was used to estimate the remaining flows shown on the table.

These estimates are quite approximate as is shown by the difference between the estimated "natural" annual change in flow and the estimated "natural" annual runoff--these should be about the same.

TABLE 27. WATER SUPPLY FACTORS IN THE OKANOGAN BASIN BETWEEN TONASKET AND MALOTT.

| MONTH | WATER USE (cfs) | MEASURED CHANGE IN FLOW (1961-70) (cfs) | NATURAL CHANGE IN FLOW (cfs) | ESTIMATED NATURAL RUNOFF (cfs) |
|---|---|---|---|---|
| October | -15 | 69 | 54 | 30 |
| November | - 2 | 123 | 121 | 34 |
| December | - 4 | 93 | 87 | 31 |
| January | - 3 | 105 | 102 | 29 |
| February | - 4 | 146 | 142 | 37 |
| March | 13 | 110 | 123 | 64 |
| April | 78 | 70 | 148 | 156 |
| May | 153 | - 3 | 150 | 390 |
| June | 167 | 380 | 447 | 321 |
| July | 67 | 109 | 176 | 95 |
| August | 33 | 39 | 72 | 53 |
| September | 2 | 41 | 43 | 34 |
| Annual (kilo acre-feet) | 23.2 | 76.7 | 99.9 | 76.9 |

TABLE 28

# FREQUENCY AND WATER USE DATA

FOR Okanogan at Malott. U.S.G.S. GAGE 12-4472

| | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Discharge | 1452 | 1701 | 1543 | 1410 | 1780 | 1161 | 2767 | 9536 | 11530 | 4028 | 1530 | 1067 |
| Discharge not exceeded two in three years | 1590 | 1868 | 1698 | 1550 | 1976 | 1255 | 3064 | 10485 | 12664 | 4416 | 1664 | 1161 |
| Discharge not exceeded one in two years ($Q_2$) | 1337 | 1579 | 1425 | 1343 | 1660 | 1031 | 2488 | 8848 | 10763 | 3645 | 1436 | 1006 |
| Discharge not exceeded one in ten years ($Q_{10}$) | 796 | 956 | 847 | 875 | 986 | 575 | 1338 | 5334 | 6628 | 2058 | 924 | 656 |
| $Q_2 - Q_{10}$ | 541 | 623 | 878 | 468 | 674 | 456 | 1150 | 3514 | 4135 | 1587 | 512 | 350 |
| Water Use (Depletions) | -42 | -46 | -50 | -39 | -35 | 0 | 142 | 407 | 469 | 397 | 335 | 146 |

Period of Record Equivalent to 1943-1970 Remarks: Uses Run A results for Okanogan at Tonasket.

# B I B L I O G R A P H Y

Canada-British Columbia Consultative Board - Okanogan Basin Agreement.

- Main Report
- Appendix I: Water Quantity in the Okanagan Basin.
- Appendix III: Water Quantity Alternatives and Supporting Water Quantity Data.

Office of the Study Director. March 1974.

Milhous, R. T. An Initial Analysis of the Flow of the Main Stem of the Okanogan River in Washington. Office Report No. 43 . Water Resources Analyses and Information Section, Office of Water Programs, Department of Ecology, February 1976.

Richardson, Don. Natural Monthly Streamflow in the Okanogan Basin. Office Report No. 38. Water Resources Analysis and Information Section, Office of Water Programs, Department of Ecology, January 1976.

# A P P E N D I X

COMPUTER PROGRAM FOR CALCULATION OF FLOWS AT OROVILLE

AND TONASKET ON THE OKANOGAN RIVER.

```
                  PROGRAM OROVW(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      3           DIMENSION YER6(50),YER7(50),YER8(50),YER9(50)
      3           DIMENSION DPSUM(50),DOFSUM(50),DOBSUM(50),DOVSUM(50),YER(50)
      3           DIMENSION DOV(50,12),QMOV(50,12),QNOV(50,12)
      3           DIMENSION QPM(50,12),DPOF(50,12),DOFO(50,12),DOOW(50,12)
      3           DIMENSION QT(50,12),QTC(50,12),QS(50,12),QSC(50,12)
      3           DIMENSION DLO(50,12),QPC(50,12)
      3           DIMENSION AAA(8),AMO(12)
      3           DIMENSION ADQLO(12)
      3           DIMENSION TQ(50)
      3           DIMENSION D700(12),DEPS(12),DL0(50,12)
      3           DIMENSION YER1(50),YER2(50),YER3(50),YER4(50),YER5(50)
      3           DIMENSION QOM(50,12),QOC(50,12),DQLO(50,12),DQLON(50,12)
      3           DIMENSION L070(12)
      3           REAL L070
      3           INTEGER YER1,YER2,YER3,YER4,YER5,YER6,YER7,YER8,YER9,YER
      3           READ(5,201) ID,IC,N
     15           READ(5,199) STAN
     23       199 FORMAT(A8)
     23       201 FORMAT(2A4,2X,I2)
     23           WRITE(6,202) ID,IC,N
     35       202 FORMAT(10X,2A4,2X,I2)
     35           READ(5,227) (AMO(I),I=1,12)
     43       227 FORMAT(12A6)
     43           DO 550 IM=1,6
     45           READ(5,551)(AAA(I),I=1,8)
     52           WRITE(6,552)(AAA(I),I=1,8)
     60       550 CONTINUE
     62       551 FORMAT(8A10)
     62       552 FORMAT(10X,8A10)
     62           READ(5,215)(DEPS(I),I=1,12)
     70           WRITE(6,320)(DEPS(I),I=1,12)
     76           READ(5,215)(D700(I),I=1,12)
    104           WRITE(6,320)(D700(I),I=1,12)
    112       215 FORMAT(10X,12F5.0)
    112           DO 101 I=1,N
    114           DPSUM(I)=0.0
    115           DOFSUM(I)=0.0
    117           DOBSUM(I)=0.0
    120           DOVSUM(I)=0.0
    122       101 CONTINUE
    124           CALL CANFIN(YER,N1,QPM)
    126           IF(N.NE.N1) GO TO 701
    130           CALL CANFIN(YER3,N3,DPOF)
    133           IF(N.NE.N3)GO TO 701
    135           CALL CANFIN(YER4,N4,DOFO)
    140           IF(N.NE.N4)GO TO 701
    142           CALL CANFIN(YER5,N5,DOOW)
    145           IF(N.NE.N5)GO TO 701
    147           WRITE(6,204)
    153       204 FORMAT(//1H1,48HDEPLETIONS IN BRITISH COLUMBIA IN KILO ACRE-FEET)
    153           WRITE(6,205)
    157       205 FORMAT(24X,10HPENTICTION,4X,10HOKAN FALLS,8X,6HOLIVER,6X,8HOKANAGA
                 1N)
    157           WRITE(6,224)
```

```
      224 FORMAT(10X,4HYEAR,15X,2HTO,9X,2HTO,16X,2HTO,10X,6HVALLEY)
          WRITE(6,207)
      207 FORMAT(24X,10HOKAN FALLS,6X,6HOLIVER,9X,8HOROVILLE//)
          DO 102 J=1,N
          DO 103 I=1,12
          DPSUM(J)=DPSUM(J)+DPOF(J,I)
          DOFSUM(J)=DOFSUM(J)+DOFO(J,I)
          DOBSUM(J)=DOBSUM(J)+DOOW(J,I)
          DOV(J,I)=DPOF(J,I)+DOFO(J,I)+DOOW(J,I)
      103 CONTINUE
          DOVSUM(J)=DPSUM(J)+DOFSUM(J)+DOBSUM(J)
          WRITE(6,203) YER(J),DPSUM(J),DOFSUM(J),DOBSUM(J),DOVSUM(J)
      203 FORMAT(/10X,I4,6X,4(9X,F5.1))
      102 CONTINUE
          WRITE(6,226)
      226 FORMAT(1H1,33HMONTHLY OKANAGAN VALLEY DEPLETION)
          DO 225 J=1,N
          WRITE(6,228)YER(J),(DOV(J,I),I=1,12)
      225 CONTINUE
          WRITE(6,222)
      222 FORMAT(1H1,36HMEASURED FLOWS: OKANAGAN AT OROVILLE)
          CALL HEADER
          DO 115 J=1,N
          READ(5,211) YER2(J),(QOM(J,I),I=1,12)
          WRITE(6,217)YER2(J),(QOM(J,I),I=1,12)
      115 CONTINUE
          WRITE(6,206)
      206 FORMAT(//1H1,34HNET INFLOWS PENTICTION TO OROVILLE//)
          WRITE(6,307)
      307 FORMAT(10X,4HYEAR,10X,8HMEASURED)
          DO 104 J=1,N
          DO 105 I=1,12
          QMOV(J,I)=QOM(J,I)-QPM(J,I)
          QNOV(J,I)=QMOV(J,I)+DOV(J,I)/0.06
      105 CONTINUE
          WRITE(6,217)YER2(J),(QMOV(J,I),I=1,12)
      308 FORMAT(10X,I4,10X,F10.0,10X,F10.0)
      104 CONTINUE
          WRITE(6,206)
          WRITE(6,221)
      221 FORMAT(10X,4HYEAR,10X,6HVIRGIN)
          DO 317 J=1,N
          WRITE(6,217) YER2(J),(QNOV(J,I),I=1,12)
      317 CONTINUE
          CALL CANFIN(YER6,N6,QPC)
          IF(N.NE.N6)GO TO 701
          WRITE(6,208)
      208 FORMAT(//1H1,26HOKANOGAN RIVER AT OROVILLE/)
          WRITE(6,209)
      209 FORMAT(10X,4HYEAR,10X,15HCACULATED FLOWS//)
          DO 106 J=1,N
          DO 107 I=1,12
          QOC(J,I)=QPC(J,I)+QNOV(J,I) - D700(I)
      107 CONTINUE
          WRITE(6,217)YER(J),(QOC(J,I),I=1,12)
      106 CONTINUE
```

```
 513          WRITE(6,219)
 516      219 FORMAT(1H1,39HMEASURED FLOWS SIMILKAMEEN AT NIGHTHAWK//)
  16          CALL HEADER
 517          DO 108 J=1,N
 521          READ(5,211)YER7(I),(QS(J,I),I=1,12)
 535      211 FORMAT(12X,I4,3X,6F8.0/19X,6F8.0)
 535          WRITE(6,217)YER7(I),(QS(J,I),I=1,12) <-
 552      108 CONTINUE
 555          WRITE(6,220)
 560      220 FORMAT(1H1,35HMEASURED FLOWS OKANOGAN NR TANESKET//)
 560          CALL HEADER
 561          DO 109 J=1,N
 563          READ(5,211)YER8(I),(QT(J,I),I=1,12)
 577          WRITE(6,217)YER8(I),(QT(J,I),I=1,12)
 614      109 CONTINUE
 617          DO 110 J=1,N
 620          CALL LODEP(J,N,DLO)
 622          DO 111 I=1,12
 624          DQLO(J,I)=QT(J,I)-(QOM(J,I)+QS(J,I))
 635          DQLON(J,I)=DQLO(J,I)+DLO(J,I)
 644          QSC(J,I)=QS(J,I)+DEPS(I)
 652          QTC(J,I)=QOC(J,I)+QSC(J,I)+DQLON(J,I)
 663      111 CONTINUE
 664      110 CONTINUE
 667          WRITE(6,121)
 672      121 FORMAT(1H1,25HLOWER OKANAGAN DEPLETIONS)
 672          DO 122 J=1,N
 674          WRITE(6,217) YER(J),(DQLO(J,I),I=1,12)
 710      122 CONTINUE
 713          DO 318 I=1,12
 714          ADQLO(I)=0.0
 715          DO 319 J=1,N
 717          ADQLO(I)=ADQLO(I)+DQLO(J,I)
 724      319 CONTINUE
 726      318 CONTINUE
 730          Z=FLOAT(N)
 731          ADQLO(I)=ADQLO(I)/Z
 733      320 FORMAT(//9X,12(5X,F5.0))
 733          WRITE(6,320)(ADQLO(I),I=1,12)
 740          WRITE(6,121)
 744          DO 123 J=1,N
 746          WRITE(6,217) YER(J),(DQLON(J,I),I=1,12)
 762      123 CONTINUE
 765          WRITE(6,216)
 770      216 FORMAT(1H1,10X,45HCALCULATED FLOWS FOR SIMILKAMEEN NR NIGHTHAWK//)
 770          DO 112 J=1,N
 772      217 FORMAT(05X,I4,12(5X,F5.0))
 772          WRITE(6,217)YER(J),(QSC(J,I),I=1,12)
1006      112 CONTINUE
1011          WRITE(6,218)
1014      218 FORMAT(1H1,10X,41HCALCULATED FLOWS FOR OKANAGAN NR TANESKET//)
1014          DO 113 J=1,N
1016          WRITE(6,217)YER(J),(QTC(J,I),I=1,12)
 032      113 CONTINUE
1035      228 FORMAT(05X,I4,12(5X,F5.1))
1035          DO 117 I=1,12
```

```
      SUBROUTINE STATMD(N,STAN,YER,Q,AMT)
      DIMENSION Q(200),X(200),DX(200),YER(200)
      INTEGER YER,STAN
      QSUM=0.0
      XSUM=0.0
      S2X=0.0
      S3X=0.0
      DO 100 J=1,N
      X(J)=ALOG10(Q(J))
      XSUM=XSUM+X(J)
      QSUM=QSUM+Q(J)
  100 CONTINUE
      Z=FLOAT(N)
      XMEAN=XSUM/Z
      QMEAN=QSUM/Z
      DO 101 J=1,N
      DX(J)=X(J) - XMEAN
      S2X=S2X + (DX(J)**2.0)/(Z-1.0)
      S3X =S3X + DX(J)**3.0
  101 CONTINUE
      SKEW=((Z/((Z-1.0)*(Z-2.0)))*S3X)/S2X**1.5
      RS2X=S2X**0.5
      WRITE(6,110) AMT
  110 FORMAT(1H1,11HMONTH OF    ,A6)
      DO 102 J=1,N
      WRITE(6,103)YER(J),Q(J),AMT
  102 CONTINUE
      WRITE(6,104) STAN,QMEAN,XMEAN,RS2X,S2X,SKEW
      RFAC=-1.282
      DFAC=-1.282
      XN10=XMEAN-1.282*RS2X
      XR10 = XMEAN + RFAC*RS2X
      XD10 = XMEAN + DFAC*RS2X
      QXMEAN=10.0**XMEAN
      QXN10=10.0**XN10
      QXR10=10.0**XR10
      QXD10=10.0**XD10
      WRITE(6,107)QMEAN,QXMEAN,QXN10,QXR10,QXD10
      XN50=XMEAN-2.054*RS2X
      XN25=XMEAN-1.751*RS2X
      XN05=XMEAN-0.842*RS2X
      XN80=XMEAN+0.842*RS2X
      XN90=XMEAN+1.282*RS2X
      QXN50=10.0**XN50
      QXN25=10.0**XN25
      QXN05=10.0**XN05
      QXN80=10.0**XN80
      QXN90=10.0**XN90
      WRITE(6,18)QXN50,QXN25,QXN10,QXN05,QXMEAN,QXN80,QXN90
      XN03=XMEAN - 0.43*RS2X
      QXN03 = 10.0**XN03
      QAVAN =QXMEAN -QXN10
      XN67=XMEAN+0.43*RS2X
       QXN67=10.0**XN67
      WRITE(6,108) STAN,QMEAN,QXN67,QXMEAN,QXN03,QXN10,QAVAN
```

5

```
    333     108   FORMAT(///10X,A8,10X,6F10.0)
    333      18   FORMAT(10X,6F10.0)
    333     103   FORMAT(10X,I4,10X,F10.0,15X,A6)
    333     104   FORMAT(10X,I8,10X,5F15.5)
    333     107   FORMAT(10X,5F10.0)
    333           RETURN
    334           END
STATMD
```

```
                SUBROUTINE LODEP(J,N,DLO)
     6          DIMENSION F(12),DLO(50,12)
     6          INTEGER YSC
     6          DATA(F(I),I=1,12)/0.01,-0.18,-0.19,-0.13,-0.11,-0.06,0.27,1.03,1.
               120,1.42,1.34,0.92/
     6          YSC=-N+70+J
    10          IF(YSC.LE.50) ALO=10500.0
    14          IF(YSC.GE.60) ALO=13400.0
    20          IF(YSC-50)5,5,6
    22        6 IF(YSC-60)7,5,5
    25        7 Z=FLOAT(YSC)
    27          Z=Z-50.0
    31          ALO=Z*290.0+10500.0
    34        5 DO 100 I=1,12
    36          DLO(J,I)=(ALO/100.0)*F(I)
    45      100 CONTINUE
    47          RETURN
    47          END
LODEP
```

```
                SUBROUTINE HEADER
     2          DIMENSION AS(10),AY(10),AI(10),AU(10),AM(12),AMM(12)
     2          INTEGER FT
     2          READ(5,601) (AS(I),I=1,10)
    10          READ(5,601) (AY(I),I=1,10)
    16          WRITE(6,603) (AS(I),I=1,10)
    24          WRITE(6,603) (AY(I),I=1,10)
    32          READ(5,601) (AI(I),I=1,6),(AU(I),I=1,4)
    42          WRITE(6,603)(AI(I),I=1,6),(AU(I),I=1,4)
    52          READ(5,104) (AM(J),J=1,12)
    60          READ(5,200) STAN,FT,M
    72          WRITE(6,205) STAN,FT,M
   104          WRITE(6,105)(AM(J),J=1,12)
   112      104 FORMAT(12A6)
   112      105 FORMAT(/1X,4HYEAR,10X,12A10/)
   112      600 FORMAT(1H1,10A4)
   112      601 FORMAT(10A4)
   112      603 FORMAT(10X,10A4)
   112      200 FORMAT(A8,12X,I1,9X,I2)
   112      205 FORMAT(10X,A10,2I10)
   112          RETURN
   113          END
HEADER
```

```
          SUBROUTINE CANFIN(YER,N,Q)
    6     DIMENSION YER(50),FC(50,12),Q(50,12)
    6     DIMENSION AS(10),AY(10),AI(10),AU(10),AM(12),AMM(12)
    6     INTEGER YER,YERC
    6     INTEGER P,Z
    6     INTEGER FT,FTY
    6     I=0
    7     J=1
   10     READ(5,601)  (AS(I),I=1,10)
   15     READ(5,601)  (AY(I),I=1,10)
   23     WRITE(6,600)  (AS(I),I=1,10)
   31     WRITE(6,603)  (AY(I),I=1,10)
   37     READ(5,601)  (AI(I),I=1,6),(AU(I),I=1,4)
   47     WRITE(6,603)(AI(I),I=1,6),(AU(I),I=1,4)
   57     READ(5,104)  (AM(J),J=1,12)
   65     READ(5,200)STAN,N,FT,M,Z
  104     WRITE(6,205)STAN,N,FT,M,Z
  123     IF(FT.EQ.0)FT=3
  127 205 FORMAT(5X,A10,4I10)
  127 104 FORMAT(12A6)
  127 105 FORMAT(/1X,4HYEAR,10X,12A10/)
  127 600 FORMAT(1H1,10A4)
  127 601 FORMAT(10A4)
  127 603 FORMAT(10X,10A4)
  127     WRITE(6,105)(AM(J),J=1,12)
  135     IF(M.EQ.0) GO TO 206
  140     DO 107 II=1,M
  142     K=II + (12-M)
  145     AMM(II)=AM(K)
  147 107 CONTINUE
  151     P=M+1
  152     DO 106 II=P,12
  153     K=II-M
  155     AMM(II)=AM(K)
  157 106 CONTINUE
  161     J=1
  162     IF(FT.EQ.1) GO TO 41
  164     IF(FT.EQ.2) GO TO 42
  165     IF(FT.EQ.3) GO TO 43
  167     IF(FT.EQ.4) GO TO 44
  170     READ(5,005)YERC,(FC(J,I),I=1,12)
  205     GO TO 45
  210  41 READ(5,001)YERC,(FC(J,I),I=1,12)
  225     GO TO 45
  230  42 READ(5,002)YERC,(FC(J,I),I=1,12)
  245     GO TO 45
  250  43 READ(5,003)YERC,(FC(J,I),I=1,12)
  265     GO TO 45
  270  44 READ(5,004)YERC,(FC(J,I),I=1,12)
  305  45 YER(1)=YERC
  310     WRITE(6,202)YER(1),(FC(J,I),I=1,12)
  330     DO 101 J=2,N
  334     L=J-1
  336     IF(Z.EQ.0) GO TO 203
  337     READ(5,001) YER(J),(FC(J,I),I=1,12)
```

```
360          GO TO 204
363      203 IF(FT.EQ.1) GO TO 51
365          IF(FT.EQ.2) GO TO 52
367          IF(FT.EQ.3) GO TO 53
370          IF(FT.EQ.4) GO TO 54
372          READ(5,005) YER(L),(FC(J,I),I=1,12)
413          GO TO 204
416       51 READ(5,001) YER(L),(FC(J,I),I=1,12)
440          GO TO 204
443       52 READ(5,002) YER(L),(FC(J,I),I=1,12)
465          GO TO 204
470       53 READ(5,003) YER(L),(FC(J,I),I=1,12)
512          GO TO 204
515       54 READ(5,004) YER(L),(FC(J,I),I=1,12)
537      204 WRITE(6,202)YER(L),(FC(J,I),I=1,12)
563          DO 102 II=1,M
567          K=II+(12-M)
572          Q(L,II)=FC(L,K)
577      102 CONTINUE
601          P=M+1
603          DO 103 II=P,12
604          K=II-M
606          Q(L,II)=FC(J,K)
613      103 CONTINUE
615      101 CONTINUE
617          N=N-1
620          WRITE(6,105)(AMM(J),J=1,12)
626          DO 209 L=1,N
632          WRITE(6,202)YER(L),(Q(L,II),II=1,12)
653      209 CONTINUE
660          GO TO 207
660      206 DO 208 J=1,N
662          IF(FT.EQ.1) GO TO 61
664          IF(FT.EQ.2) GO TO 62
665          IF(FT.EQ.3) GO TO 63
667          IF(FT.EQ.4) GO TO 64
670          READ(5,005) YER(J),(FC(J,I),I=1,12)
712       61 READ(5,001) YER(J),(FC(J,I),I=1,12)
736          GO TO 65
741       62 READ(5,002) YER(J),(FC(J,I),I=1,12)
763          GO TO 65
766       63 READ(5,003) YER(J),(FC(J,I),I=1,12)
1010         GO TO 65
1013      64 READ(5,004) YER(J),(FC(J,I),I=1,12)
1035      65 WRITE(6,202)YER(J),(Q(J,I),I=1,12)
1061     208 CONTINUE
1066     200 FORMAT(A8,2X,I2,8X,I1,9X,I2,8X,I2)
1066     202 FORMAT(2X,I4,12F10.1)
1066     001 FORMAT(10X,I4,1X,12F5.0)
1066     002 FORMAT(10X,I4,1X,12F5.2)
1066     003 FORMAT(12X,I4,3X,6F8.0/19X6F8.0)
1066     004 FORMAT(5X,I4,1X,12F5.1)
1066     005 FORMAT(11X,I4,12F5.0)
1066     207 RETURN
1067         END
CANFIN
```