# REPORT ON THE FISHERIES PROBLEMS ASSOCIATED WITH THE PROPOSED DIVERSION OF WATER FROM SHUSWAP RIVER TO OKANAGAN LAKE

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Vancouver, B. C.

August, 1969

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## INTRODUCTION

The Water Resources Service of the British Columbia Department of Lands, Forests and Water Resources (1966) has reported the findings of an investigation of the Shuswap-Okanagan Lake Water Supply Canal, which was made under the auspices of the Agricultural Rehabilitation and Development Act. The purpose of the investigation was to study the feasibility of augmenting agricultural water supplies in the Okanagan Valley by diverting water from the Shuswap River (FIGURE 1). The study considered two possible means of diverting water from the Lower Shuswap River near Enderby through a canal to the north end of Okanagan Lake. A number of variations in the amount of water to be diverted and the amount of residual flow in the Shuswap River below Enderby were also considered. The report refers to the water necessary for fishery requirements in the Okanagan River below Skaha Lake, but makes no reference to possible fishery problems in the Shuswap River that would be associated with the diversion being studied. Subsequent reports (1967,1968) examined the effect of the diversion on water supply and water levels in the Shuswap River system, in Shuswap Lake, and in the South Thompson River watershed. A fourth report (1969) summarized the preceeding reports and presented revised figures on present and future water requirements.

Since the diversion as considered by the Water Resources Service would interfere seriously with the stocks of salmon and trout utilizing the Shuswap River system and the Okanagan River, this report has been prepared to provide information on the fishery problems and the requirements for protection of these valuable stocks, and to consider alternate means of obtaining water which would avoid or minimize the fishery problems. The study of fishery problems has been based on the diversion proposed in the 1966 and subsequent reports. Further revisions of the proposal may necessitate reconsideration of the fishery problems.

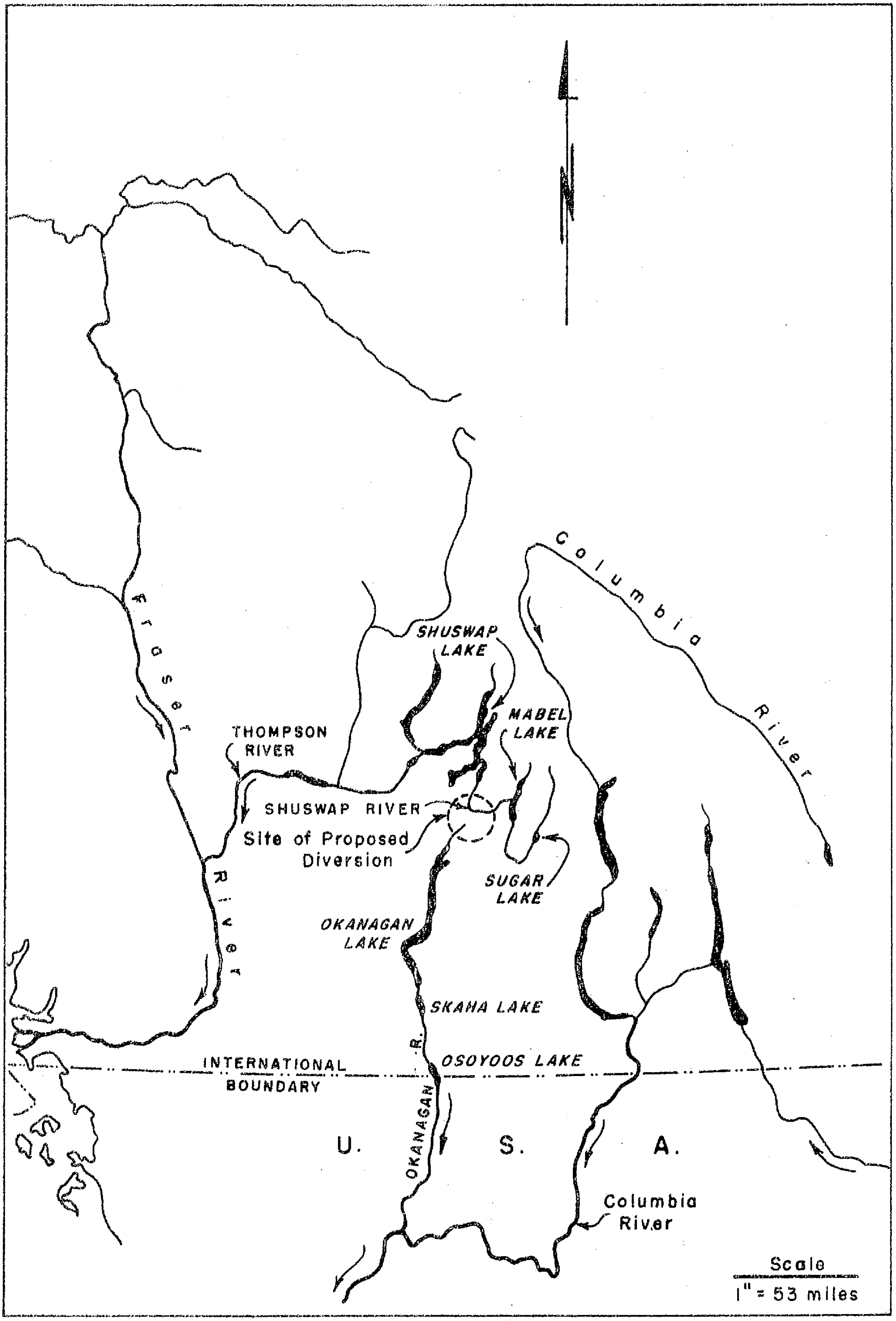


FIGURE 1 - Location map showing site of proposed diversion.

## FISHERY RESOURCES OF THE SHUSWAP RIVER SYSTEM

The Shuswap River system supports three species of Pacific salmon; sockeye (Oncorhynchus nerka), chinook (O. Tshawytcha), and coho (O. kisutch). A variety of freshwater species valuable to the sport fishery are also supported within the system. These include kokanee (O. nerka), the landlocked form of sockeye salmon, rainbow trout (Salmo gairdneri), cutthroat trout (Salmo clarki), Dolly Varden (Salvelinus malma), lake trout (Salvelinus namaycush) and mountain whitefish (Prosopium williamsoni).

### Sockeye Salmon

Historial records of the escapements of sockeye to Shuswap River are sparse. Crawford (1902) reports that there were a great many sockeye spawning in the river below Mabel Lake in 1901 and smaller numbers in 1902. Babcock (1914) notes that in years of big runs the river was always filled with sockeye. In 1913 a local resident reported less than 50 fish compared with thousands in 1909. The record refers to salmon as far upstream as Shuswap Falls (FIGURE 2) but does not distinguish between the spawning grounds upstream and downstream from Mabel Lake.

It would appear from the limited records that cyclic dominance was in effect at least in the Lower Shuswap River below Mabel Lake prior to 1913 on the 1905-1909 cycle with a sub-dominant run on the following year, a pattern coinciding with that of the quadrennially dominant pattern of the Adams River run (Ward and Larkin, 1964). However, slides in the Fraser Canyon in 1913 apparently decimated these runs so that only fragmentary escapements occurred until the completion of the Hell's Gate fishways in 1945. It is possible that the original runs to the Middle Shuswap River (above Mabel Lake) were completely eliminated as there is no record of spawning sockeye in this area from 1921 to 1949.

Starting in 1950 small but increasing populations were re-established in this section of the Middle Shuswap River (TABLE 1) which probably originated from Lower Shuswap River stock. These were augmented by two eyed-egg transplants of Adams River stock, the first consisting of 1,396,000 eggs in 1954 and the second of 622,000 eggs in 1959. It appears that the egg transplants were at least partly responsible for the re-establishment of these stocks as may be observed by the increase in escapement in 1958. Although no spawners from the 1959 egg

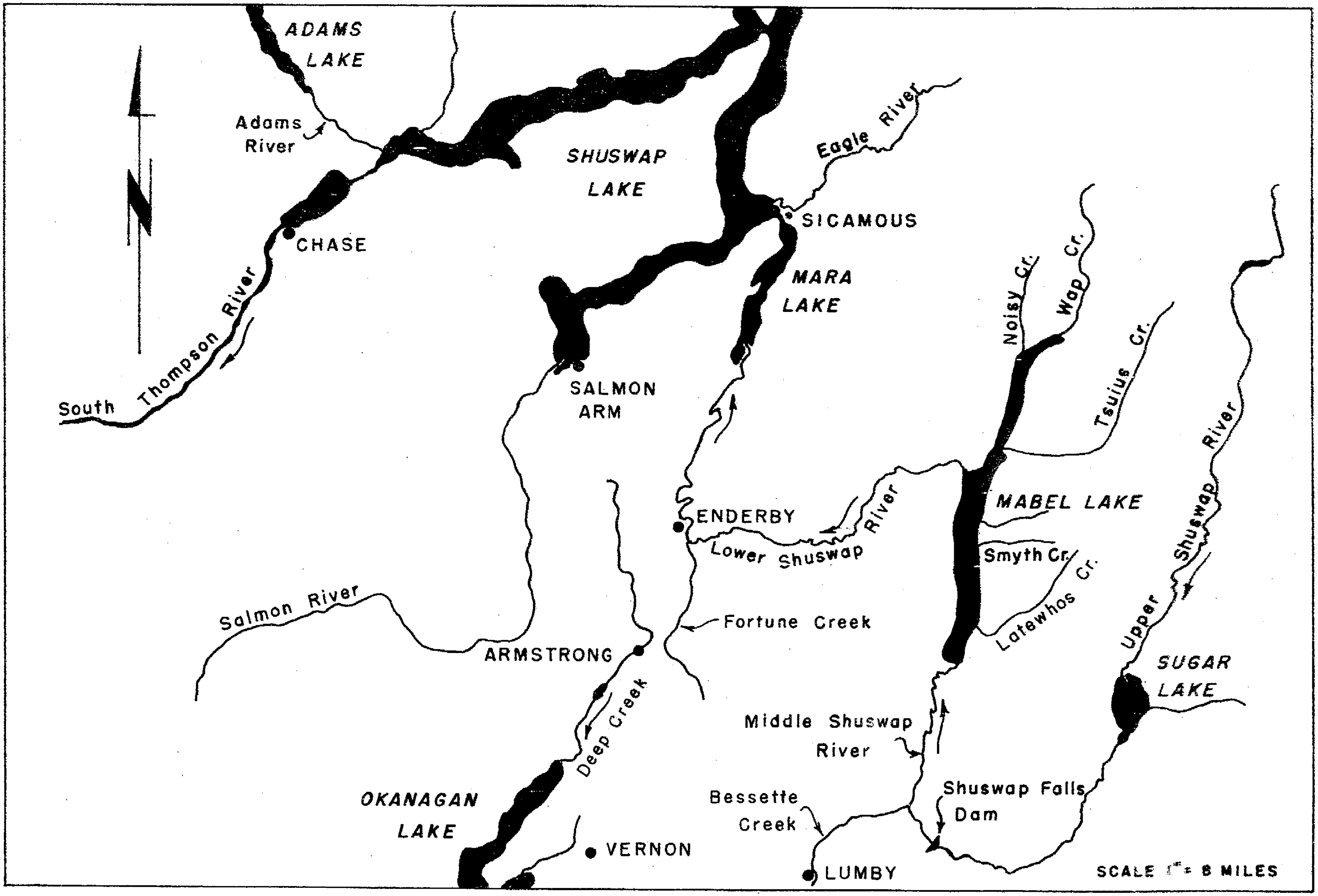


FIGURE 2 - Site map of proposed diversion.

plant were observed during a limited survey in 1963, a small spawning population was observed for the first time on this cycle in 1967.

TABLE 1 - Sockeye escapements to Middle Shuswap River above Mabel Lake, 1950 to 1967.

| Year | Number | Peak of Spawning |
|---|---|---|
| 1950 | 50 | - |
| 1954 | 61 | Oct. 13 - 22 |
| 1958 | 499 | Oct. 28 -Nov.3 |
| 1962 | 457 | Oct. 22 - 27 |
| 1966 | 1,872 | Oct. 14 - 20 |
| 1967 | 58 | Oct. 18 - 22 |

The spawning ground in Middle Shuswap River extends from about one half mile below the hydroelectric dam at Shuswap Falls to a point approximately 6 miles downstream. It comprises an area of about 340,000 sq yd which could support a population of about 340,000 spawners, or many times more than the present escapements.

The sockeye offspring produced from the spawning in this area incubate during the winter months, emerge from the gravel as fry in April and May of the following spring and proceed downstream to Mabel Lake. They then spend a full year in Mabel Lake before proceeding down the Lower Shuswap River and out to sea in April, May and June of the following year (FIGURE 3). On the basis of lake area and plankton abundance, it is estimated that the Mabel Lake rearing area could support the progeny from about 214,000 spawners, indicating a potential spawning population size about two-thirds of that based on the available spawning ground.

Records from 1921 to 1942 show small populations of sockeye in Lower Shuswap River downstream from the rapids near the outlet of Mabel Lake (TABLE 2).

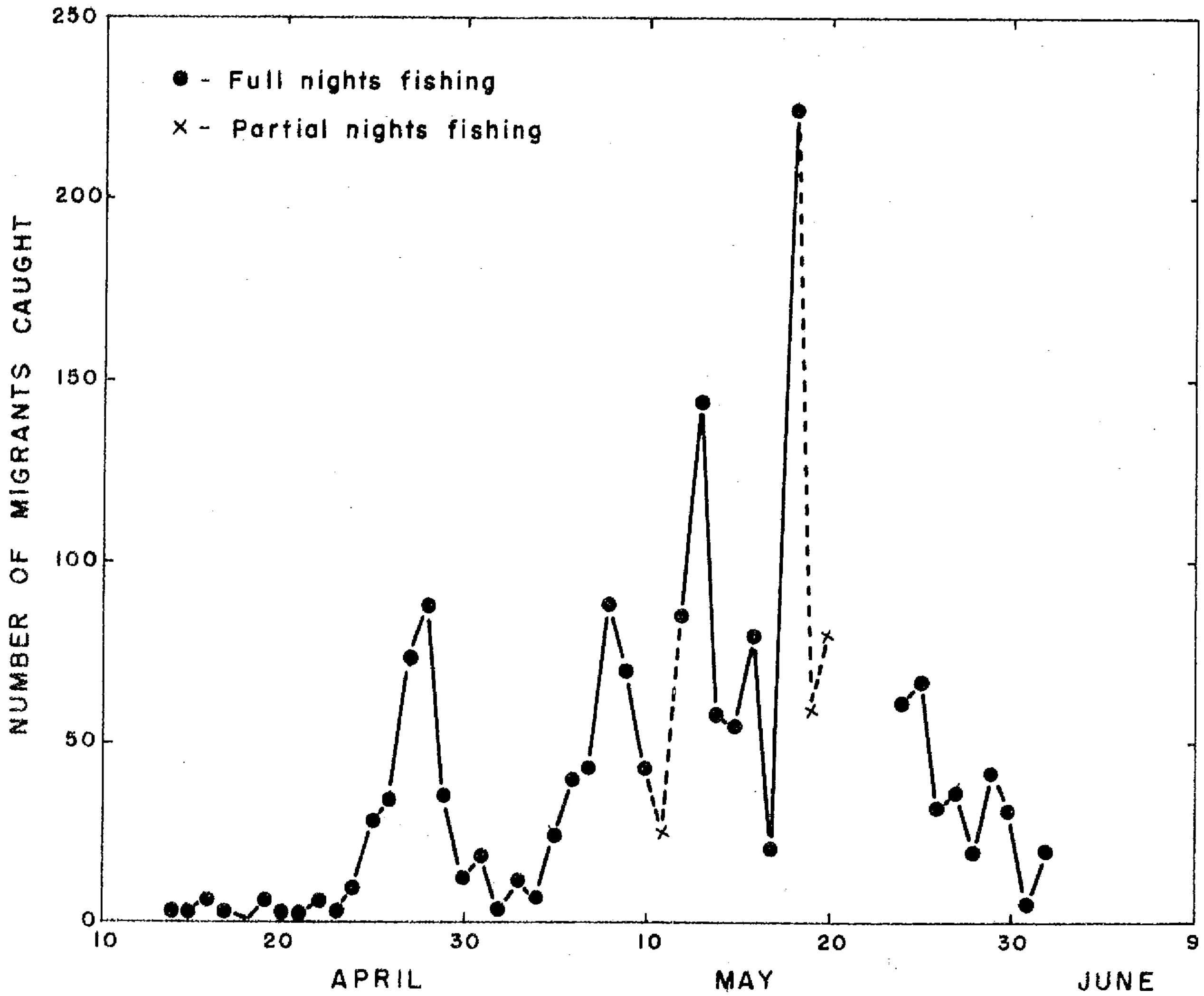


FIGURE 3 - Migration timing of sockeye smolts leaving Mabel Lake, 1968 as shown by nightly catches in a 4 ft by 4 ft fyke net.

TABLE 2 - Historical records of sockeye escapements to Lower Shuswap River.

| Year | Number | Dates Present |
|---|---|---|
| 1921 | Several hundred | October |
| 1922 | Medium run | September, October |
| 1934 | Light run 100 - 300 | below Mabel Lake October 1 |
| 1935 | Light run 0 - 50 | |
| 1936 | Light run, 200 | during October |
| 1938 | Usual small run, | arrived October 3 |
| 1939 | Very light run, 1 - 50 | |
| 1940 | None present | |
| 1942 | 2,000 reported by residents | October, run over by November 1 |

A noticeable increase in the number of spawners in this area was first observed in 1942 and since that time the runs have increased considerably (TABLE 3). Cyclic dominance appears to be reforming on the 1950-1954 cycle with the sub-dominant year on the 1951-1955 cycle. Very few fish have been observed in the other cycle years. Again this is similar to that of the Adams River where this new pattern of dominance has existed since 1922.

TABLE 3 - Sockeye escapements to Lower Shuswap River 1946 to 1967.

| Year | Number | Dates Present | Peak of Spawning | Success of Spawn Per Cent |
|---|---|---|---|---|
| 1946 | 828 | Oct 1-Nov 10 | Oct 15-20 | 100 |
| 1950 | 12,000 | Oct 10-Nov 10 | - | 99.1 |
| 1954 | 17,462 | Oct 5- | Oct 15-21 | 100 |
| 1955 | 23 | - | Oct 15-18 | - |
| 1956 | 6 | - | Oct 20-23 | - |
| 1957 | 2 | - | - | - |
| 1958 | 9,387 | Oct 13- | Nov 3-5 | - |
| 1962 | 31,205 | - | Oct 21-26 | - |
| 1963 | 23* | - | - | - |
| 1966 | 24,629 | - | Oct 13-16 | 100 |
| 1967 | 5,951 | Oct 1 | Oct 18-21 | 97.4 |

* Probably very low estimate because of limited observations.

The adult runs of the Lower and Middle Shuswap Rivers and the Adams River migrate through the commercial fishery at approximately the same time. Therefore it has not been practical to curtail fishing intensity specifically for these smaller runs, as had been the case for many of the other depleted races, without permitting too much escapement to the Adams River. Hence, the rebuilding of the runs to the Shuswap River system to their earlier levels has progressed at a less rapid rate than would be the case if special protection could be provided in a practical manner. With the use of more successful techniques in artificial propagation currently being developed, it is believed that the rate of rehabilitation can be greatly increased in the near future.

Practically all of the sockeye spawning in Lower Shuswap River occurs between Kingfisher Creek and the Trinity Valley road bridge (FIGURE 4). Distribution of spawners for the two largest runs is shown in TABLE 4.

TABLE 4 - Sockeye spawning distribution in Lower Shuswap River, 1962 and 1966.

| Year | Location | Per Cent of Spawners |
|---|---|---|
| 1962 | Kingfisher Creek to Hupel | 29 |
| | Hupel to Fall Creek | 13 |
| | Fall Creek to lower end of "The Islands" | 57 |
| | Lower end of "The Islands" to Trinity Valley Bridge | 1 |
| 1966 | Kingfisher Creek to Hupel | 22 |
| | Hupel to Fall Creek | 10 |
| | Fall Creek to Trinity Valley Bridge* | 68 |

* Nearly all in the vicinity of "The Islands".

It is estimated that the portion of the river from the rapids near Mabel Lake downstream to the lower end of the Islands contains approximately 750,000 sq yd of stream bed suitable for spawning sockeye. The portion of river from the lower end of the Islands to Trinity Valley Bridge contains much finer gravel not normally utilized by sockeye but well suited for kokanee. On the basis of the available spawning ground area, the Shuswap River below Mabel Lake could support a sockeye population approaching 750,000 spawners.

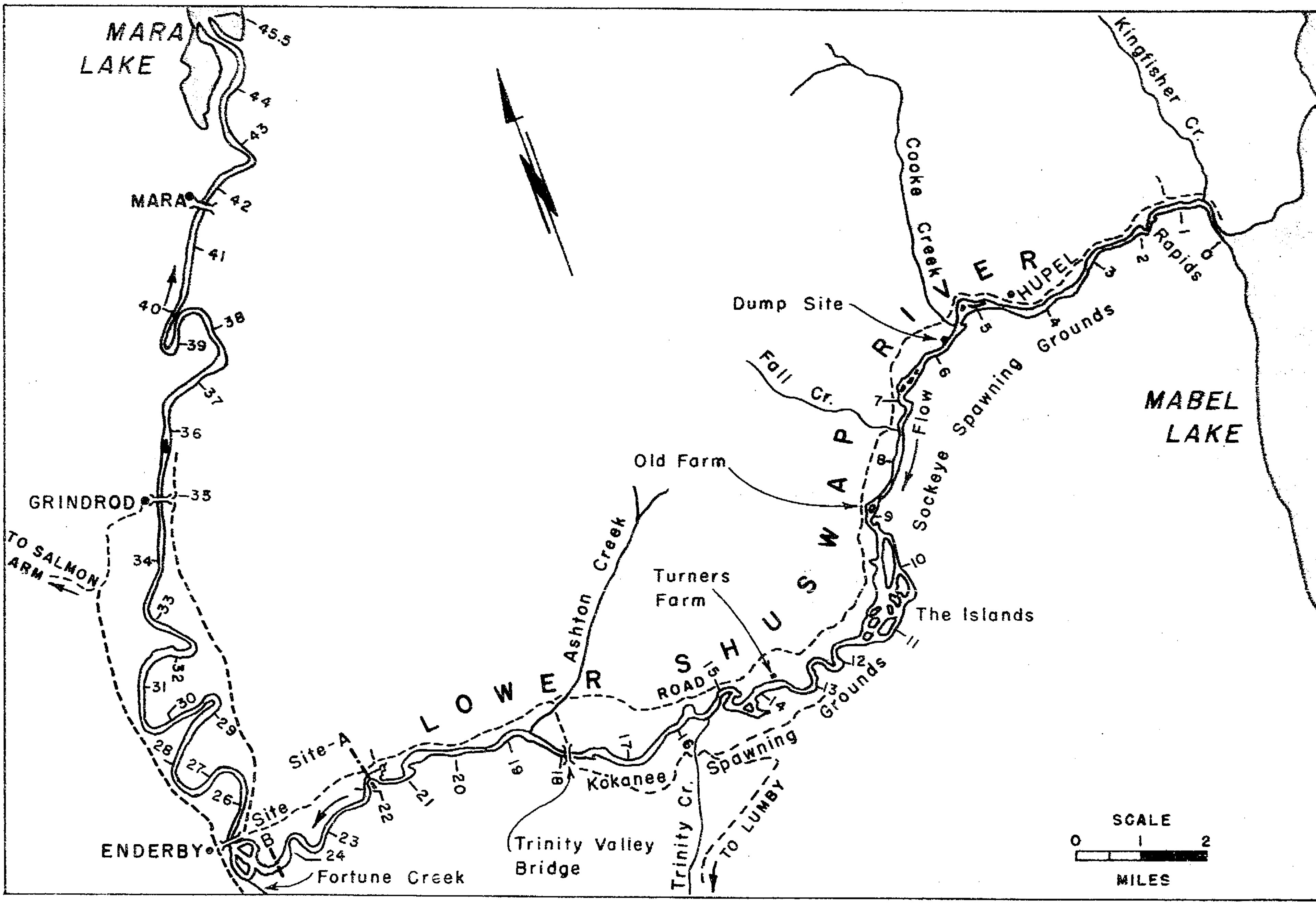


FIGURE 4 - Lower Shuswap River.

The sockeye fry emerge from the gravel in April and May (FIGURE 5) and proceed downstream to Mara Lake. On the basis of lake area and plankton abundance it is estimated that Mara Lake could support the progeny from about 78,000 sockeye spawners. While the rearing of sockeye from Lower Shuswap River appears to be primarily in Mara Lake, it is possible that some fry go directly into Shuswap Lake as well. Observations in 1956 of the sockeye smolts that produced the very large 1958 run, showed the smolts in the Salmon Arm section of Shuswap Lake were 10% larger than in other parts of the lake. Thus, it would appear that Shuswap Lake could support additional fry from Lower Shuswap River, but it is not possible to establish numbers on the basis of present knowledge. It would be expected from experience elsewhere that greater fry production in Lower Shuswap river would result in the displacement of fry from Mara Lake into Shuswap Lake.

## Kokanee

The Lower Shuswap River is utilized by substantial kokanee runs which move upstream from the Shuswap-Mara Lake system during August, September and October to spawn. The peak of spawning usually occurs in the period October 15-24 (TABLE 5). Population estimates as large as 337,000 kokanee spawners have been recorded. The spawning grounds extend from near the outlet of Mabel Lake downstream to Enderby, but the majority of the fish spawn in the 6 miles upstream from the Trinity Valley Bridge (FIGURE 4). The section of river between Enderby and Trinity Valley Bridge has been examined only occasionally but is considered to support few kokanee spawners. The kokanee fry produced from these spawning grounds emerge in April and May (FIGURE 5) and migrate downstream to Mara Lake and possibly Shuswap Lake as well.

Kokanee fry cannot be distinguished from sockeye fry by visual examination because they are of the same species. However, since kokanee eggs are smaller than sockeye eggs, the developing embryos and fry are also smaller. The length range of the two groups captured in Lower Shuswap River overlap considerably but the wet weight and dry weight of the two approach being exclusive (FIGURE 6). The approximate mean length, wet weight and dry weight of the respective groups estimated from FIGURE 6 are shown in TABLE 6.

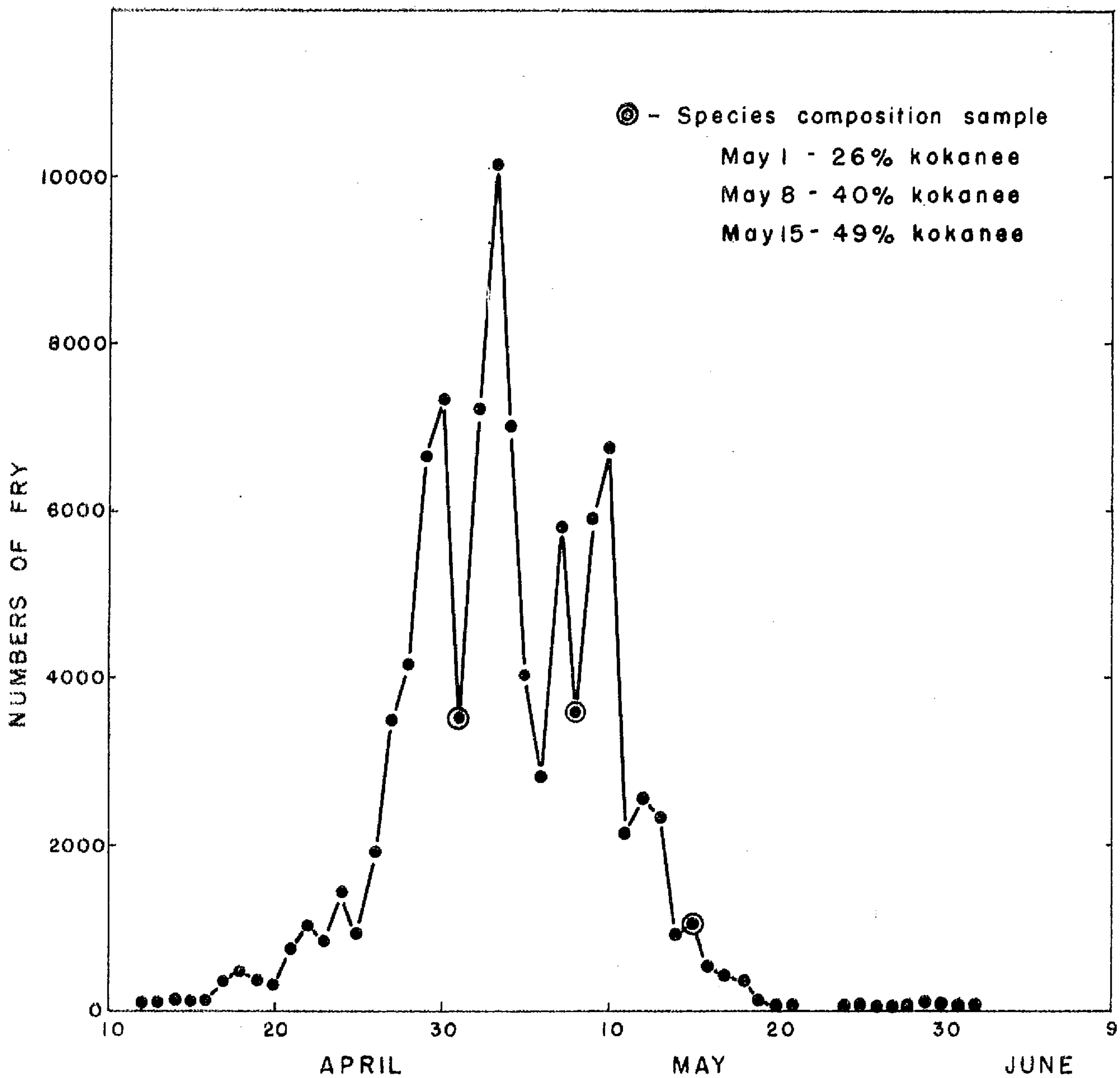


FIGURE 5 - Lower Shuswap River sockeye and kokanee fry migration 1968.

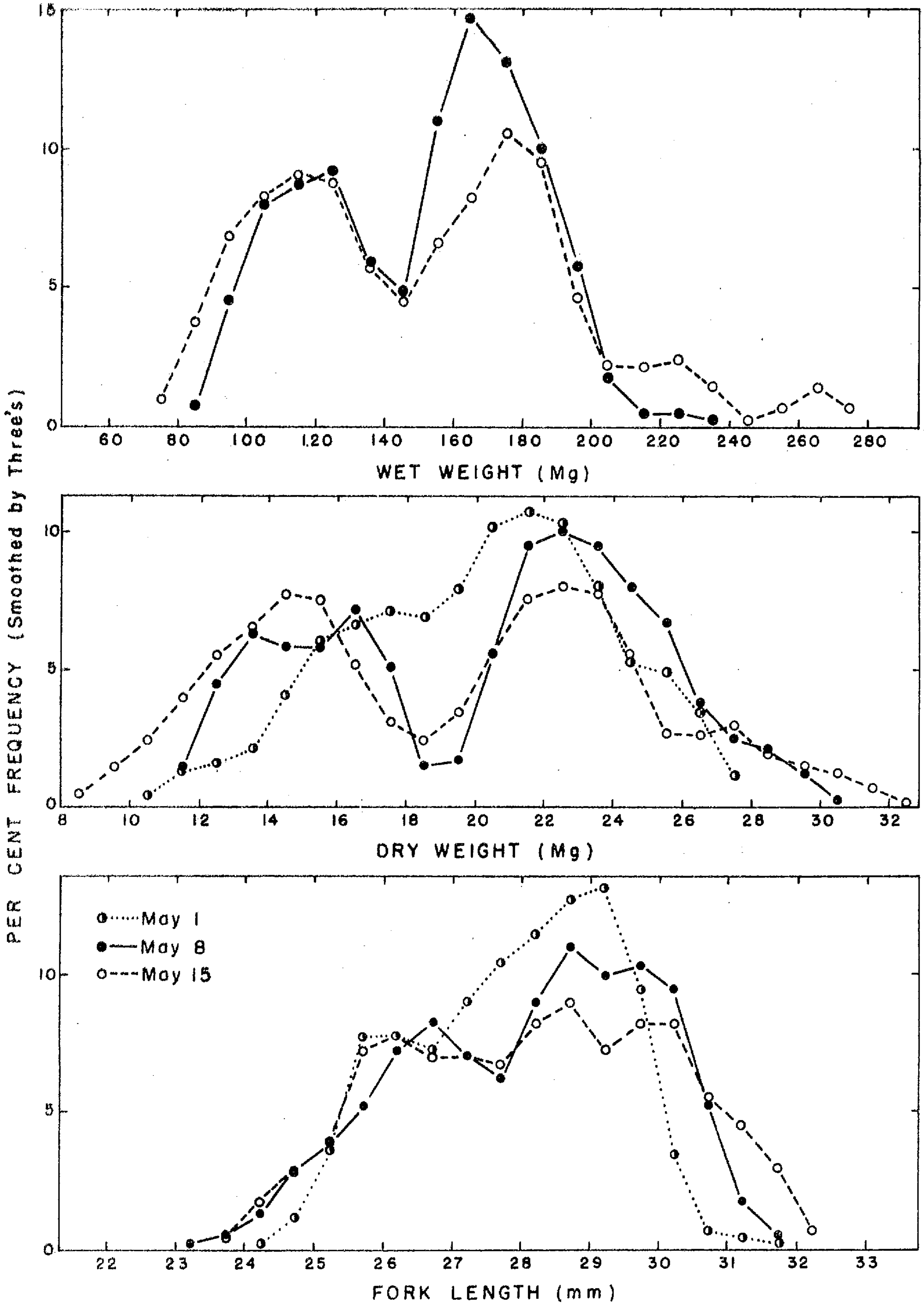


FIGURE 6 - Size distribution of sockeye and kokanee fry caught in Lower Shuswap River, 1968.

TABLE 5 - Kokanee spawning populations in Lower Shuswap River, 1953 to 1966.

| Year | Estimated Number of Spawners | Duration of Spawning | Peak of Spawning |
|---|---|---|---|
| 1953 | 9,200 | Oct. 14 - 29 | |
| 1954 | 111,700 | Oct. 5 - 28 | Oct. 10 - 15 |
| 1955 | 90,000 | Oct. 7 - 28 | Oct. 15 - 18 |
| 1956 | 124,200 | Oct. 11 - 31 | Oct. 20 - 23 |
| 1957 | 115,000 | - Oct. 31 | - |
| 1958 | 86,700 | Oct. 14 - 28 | - |
| 1961 | 37,500 | Oct. 13 - | Oct. 15 - 18 |
| 1962 | 337,000 | Oct. 12 - Nov. 6 | Oct. 12 - 24 |
| 1963 | Present | Oct. 1 - | - |
| 1965 | 75,000 | - | - |
| 1966 | 50,000 | Oct. 14 - 25 | |

TABLE 6 - Average size of sockeye and kokanee fry caught in Lower Shuswap River, 1968.

| | Kokanee | Sockeye |
|---|---|---|
| Mean Dry Weight | 15 mg | 23 mg |
| Mean Wet Weight | 115 mg | 170 mg |
| Mean Length | 26.5mm | 29 mm |

Samples taken during the 1968 migration (FIGURE 5) contained an increasing percentage of kokanee as the season progressed, indicating that the timing of emergence and migration of kokanee fry is similar to but slightly later than that of sockeye.

Mabel Lake also supports a kokanee population which spawns in several tributary streams (TABLE 7). The largest spawning runs usually occur in Middle Shuswap River where the main spawning grounds are in the 6 miles of river downstream from the hydroelectric dam, and in Bessette Creek. The spawning grounds in the other Mabel Lake tributaries are located almost exclusively in

TABLE 7 - Kokanee spawning populations in Mabel Lake tributaries, 1954 to 1963.

| Year | Stream | Estimated No. Spawners | Peak of Spawning |
|---|---|---|---|
| 1954 | Wap Cr. | 860 | Sept. 30-Oct. 4 |
| | Cottonwood Cr. | 1,270 | Oct. 8-12 |
| | Noisy Cr. | 2,360 | Oct. 4-8, or later |
| | Middle Shuswap R. | 9,410 | Oct. 1-6 |
| 1955 | Wap Cr. | 2,530 | Oct. 2-5 |
| | Cottonwood Cr. | 1,700 | Oct. 4-7 |
| | Noisy Cr. | 730 | Oct. 2-5 |
| | Middle Shuswap R. | 51,500 | Oct. 3-5 |
| | Bessette Cr. | 8,630 | Oct. 1-4 |
| 1956 | Wap Cr. | 10,700 | Oct. 1-3 |
| | Cottonwood Cr. | 540 | Oct. 1-3 |
| | Noisy Cr. | 110 | Oct. 1-2 |
| | Middle Shuswap R. | 21,050 | Oct. 1-3 |
| | Bessette Cr. | 4,830 | Oct. 1-2 |
| 1957 | Bessette Cr. | 4,600 | Oct. 4-8* |
| 1958 | Wap Cr. | 390 | Sept. 28-Oct. 5 |
| | Cottonwood Cr. | 0 | - |
| | Noisy Cr. | 280 | Sept. 28-Oct. 5 |
| | Middle Shuswap R. | 15,870 | Sept. 25-Oct. 1 |
| | Bessette Cr. | 200 | Sept. 25-Oct. 1 |
| 1960 | Bessette Cr. | 8,050 | Sept. 25-28 |
| 1961 | Middle Shuswap R. | 33,350 | Oct. 1 |
| | Bessette Cr. | 9,260 | Sept. 27 |
| 1962 | Middle Shuswap R. | +13,000 | Sept. 25* |
| | Bessette Cr. | + 3,700 | Sept. 25* |
| 1963 | Middle Shuswap R. | 50,000 | Sept. 18-25 |
| | Bessette Cr. | 15,600 | Sept. 18-23 |

* Estimated.

the lower reaches of streams flowing into Mabel Lake. Spawning generally occurs from September 20 to October 20, with the peak in early October, and the fry migrate downstream to Mabel Lake in April and May.

There is a sport fishery for kokanee in Shuswap Lake and Mabel Lake which contributes to the recreational use of these lakes. In addition, the young kokanee provide an important source of food for the large rainbow trout, lake trout and Dolly Varden.

## Chinook and Coho Salmon

The Shuswap River and its tributaries support annual runs of chinook and coho salmon. During the period of record (1942-1968), escapements of chinook have ranged in magnitude from less than 1,000 to in excess of 5,000 fish (TABLE 8). From 10% to 20% of the run commonly occupies spawning area in tributaries of Mabel Lake, primarily in the section of the Middle Shuswap River extending 6 miles downstream from Shuswap Falls (FIGURE 2). The remainder of the population spawns in the Lower Shuswap River between Fortune Creek and Mabel Lake. Their distribution within this section is shown in TABLE 9. Adult chinook arrive in the spawning areas from mid-July until mid-September. Spawning commences in early October, commonly peaks October 15-20 and is virtually completed by November 10. The eggs and alevins remain in the gravel until early spring whereupon they emerge as fry. The downstream migration of fry to the lower river or lakes commences during the first week in April, peaks between mid-April and early May and is nearing completion by June 1 (FIGURE 7). At the time of migration the fry range in length from 34 to 48 mm (FIGURE 8). Nearly the entire daily migration occurs during the 13 hour period between 1900 and 0800 the day following and approximately 90% of the migration takes place during the hours of darkness (FIGURE 9).

A portion of the chinook fry take up residence in fairly discrete sections of the river adjacent to the spawning areas. Observations have shown that the majority occupy the margin of the main river channel in association with a number of other species (TABLE 10). Their presence in these areas as late as October 12 suggests that they remain in the vicinity until their seaward migration as 89 to 127 mm smolts in late April and May the year following (FIGURE 7).

TABLE 8 - Escapements of chinook and coho salmon spawning in Lower Shuswap River, and the Middle Shuswap - Bessette Creek area 1942-1968.

| | Lower Shuswap | | Middle Shuswap - Bessette | |
|---|---|---|---|---|
| Year | Chinook | Coho | Chinook | Coho |
| 1942 | 5-10,000 | 1-2,000 | 500-1,000 | 100- 300 |
| 1943 | 1- 2,000 | 100- 300 | 300- 500 | 100- 300 |
| 1944 | 1- 2,000 | 50- 100 | - | - |
| 1945 | 2- 5,000 | 1-2,000 | 300- 500 | 100- 300 |
| 1946 | 1- 2,000 | 1-2,000 | 300- 500 | 1-2,000 |
| 1947 | 500- 1,000 | - | 1- 50 | - |
| 1948 | 1- 2,000 | 1-2,000 | 100- 300 | 1-2,000 |
| 1949 | - | 2-5,000 | 300- 500 | - |
| 1950 | 2- 5,000 | 2-5,000 | 100-2,000 | 500-1,000 |
| 1951 | - | - | 500-1,000 | - |
| 1952 | 2- 5,000 | - | 1-2,000 | - |
| 1953 | 5-10,000 | 2-5,000 | 500-1,000 | 1-2,000 |
| 1954 | 1- 2,000 | - | - | 500-1,000 |
| 1955 | 2- 5,000 | 2-5,000 | 1-2,000 | 2-5,000 |
| 1956 | 2- 5,000 | 1-2,000 | 1-2,000 | 500-1,000 |
| 1957 | 2- 5,000 | 500-1,000 | 1-2,000 | 300- 500 |
| 1958 | 5-10,000 | 2-5,000 | 500-1,000 | 1-2,000 |
| 1959 | 1- 2,000 | 1-2,000 | 500-1,000 | 500-1,000 |
| 1960 | - | - | - | - |
| 1961 | 2- 5,000 | 500-1,000 | 1-2,000 | 2-5,000 |
| 1962 | 2- 5,000 | 500-1,000 | 500-1,000 | 500-1,000 |
| 1963 | 2- 5,000 | 500-1,000 | 500-1,000 | 1-2,000 |
| 1964 | 2- 5,000 | 2-5,000 | 500-1,000 | 2-5,000 |
| 1965 | 1- 2,000 | 100- 300 | 300- 500 | 2-5,000 |
| 1966 | 2- 5,000 | 300- 500 | 300- 500 | 1-2,000 |
| 1967 | 5-10,000 | 100- 300 | 1-2,000 | 100- 300 |
| 1968 | 2- 5,000 | 100- 300 | 1-2,000 | 2-5,000 |

TABLE 9 - Chinook spawning distribution in Lower Shuswap River from Mabel Lake to Fortune Creek, 1967 and 1968.

| Sections | River Mileage | 1967 No. Counted | 1967 % of Total Count | 1968* No. Counted | 1968* % of Total Count |
|---|---|---|---|---|---|
| Lake to Kingfisher Creek | 0.0 to 0.7 | 177 | 6.0 | 164 | 6.5 |
| Lower 1/3 of Canyon to End | 1.7 to 2.0 | 2 | 0.1 | 0 | 0 |
| Below Canyon to Hupel Pool | 2.0 to 4.6 | 874 | 29.8 | 795 | 31.4 |
| Hupel Pool to Cook Creek Dump Site | 4.6 to 5.5. | 473 | 16.2 | 451 | 17.8 |
| Cook Creek Dump Site to Fall Creek | 5.5 to 7.5 | 224 | 7.6 | 323 | 12.7 |
| Fall Creek to Old Farm | 7.5 to 9.0 | 488 | 16.7 | 438 | 17.3 |
| Old Farm through Islands | 9.0 to 11.7 | 505 | 17.2 | 274 | 10.8 |
| Below Islands to Turners Farm | 11.7 to 14.0 | 56 | 1.9 | 23 | 0.9 |
| Turners Farm to Trinity Creek | 14.0 to 15.5 | 20 | 0.1 | 0 | 0 |
| Trinity Creek to Ashton Creek Mouth | 15.5 to 18.7 | 37 | 1.3 | 21 | 0.8 |
| Ashton Creek Mouth to Dam Site "A" | 18.7 to 22.0 | 70 | 2.4 | 45 | 1.8 |
| Below Dam Site "A" to Fortune Creek | 22.0 to 24.4 | 3 | 0.1 | 0 | 0 |
| | | 2,929 | | 2,534** | |

* Jack to Adult ratio 55:45

** Including 11 holding fish, not including 34 dead spawned.

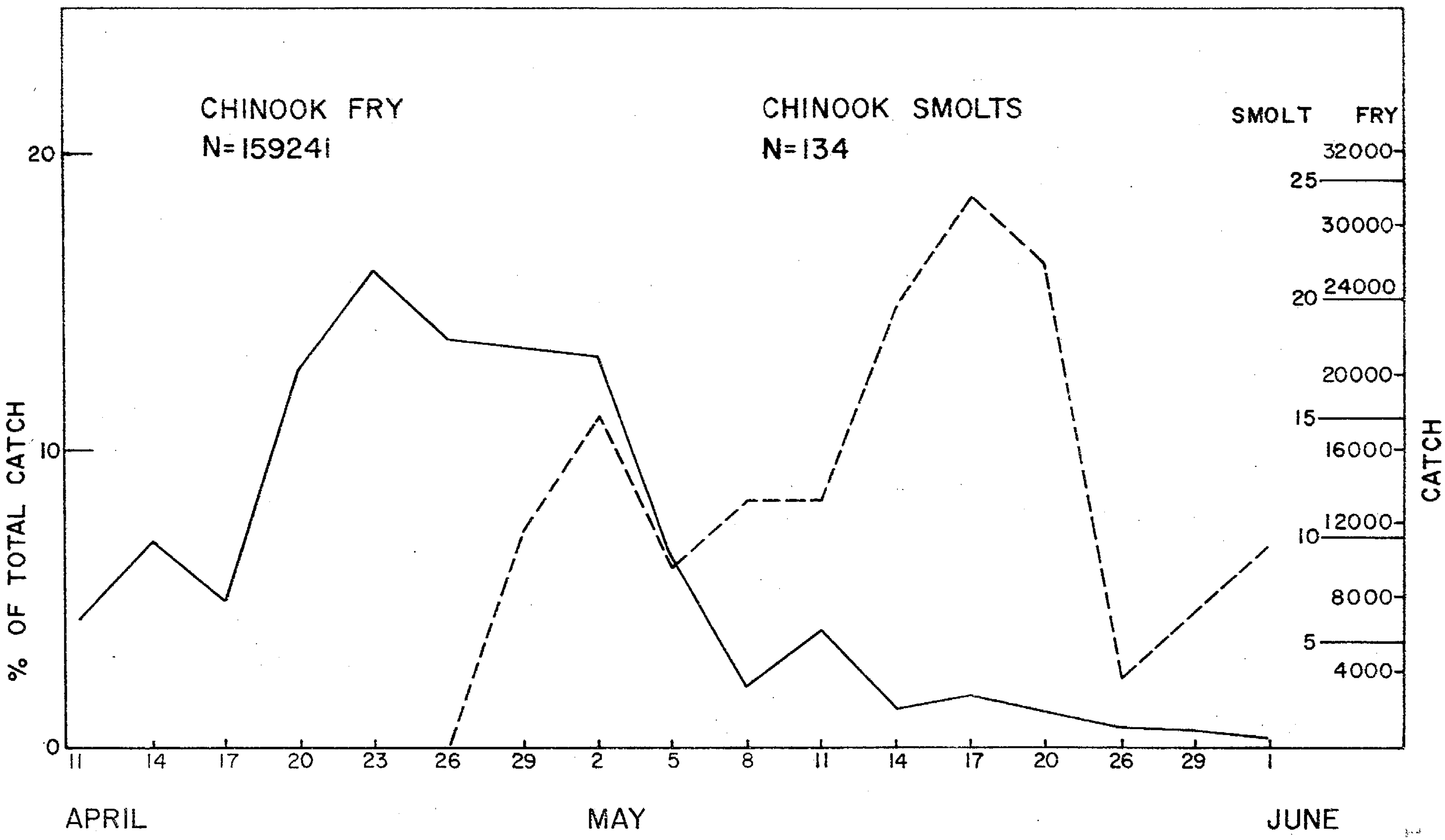


FIGURE 7 - Timing of Chinook salmon fry and smolt migration down Lower Shuswap River, 1968.

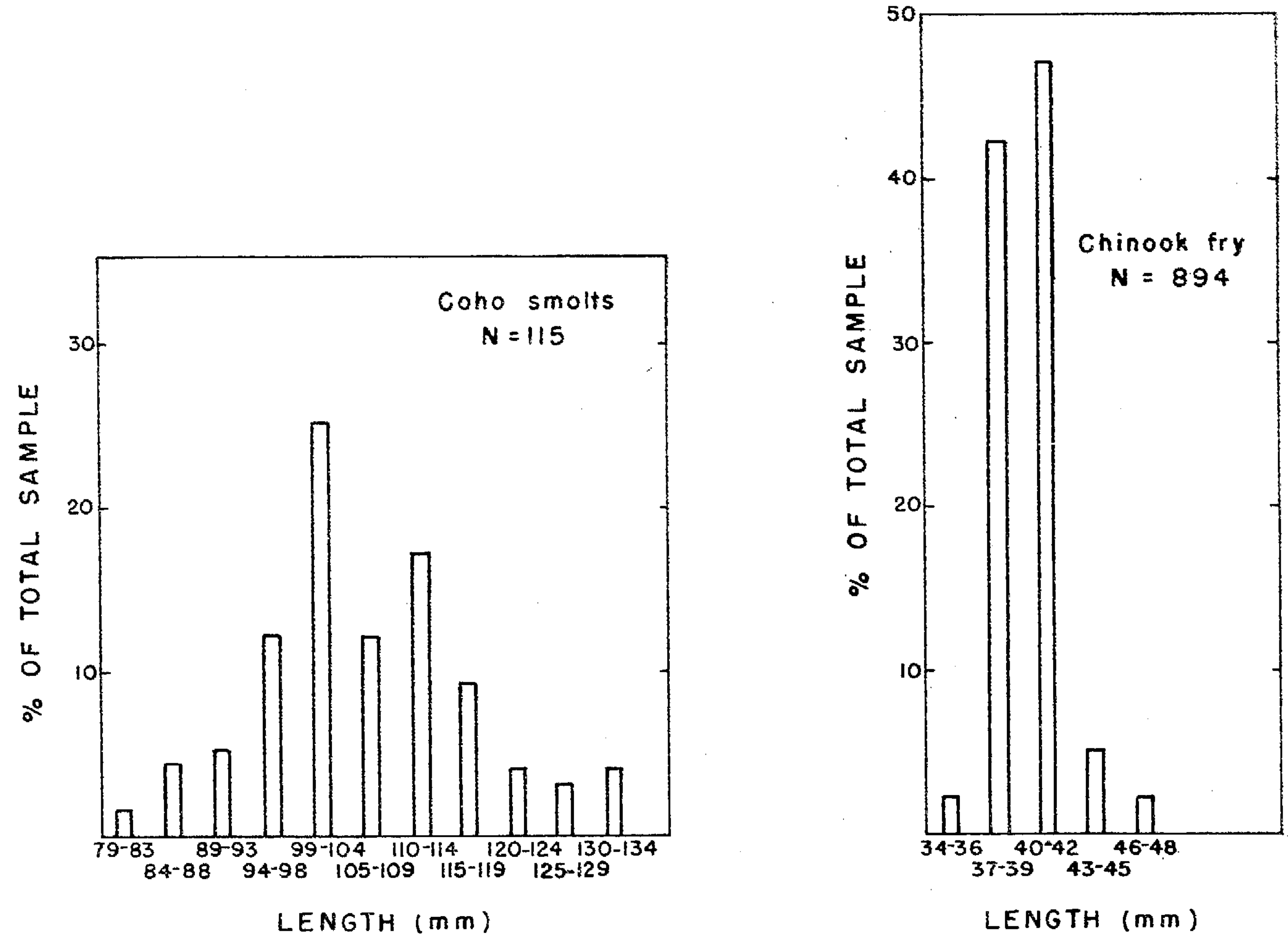


FIGURE 8 - Length frequency distribution of downstream migrant coho smolts and chinook fry, Lower Shuswap River, 1968.

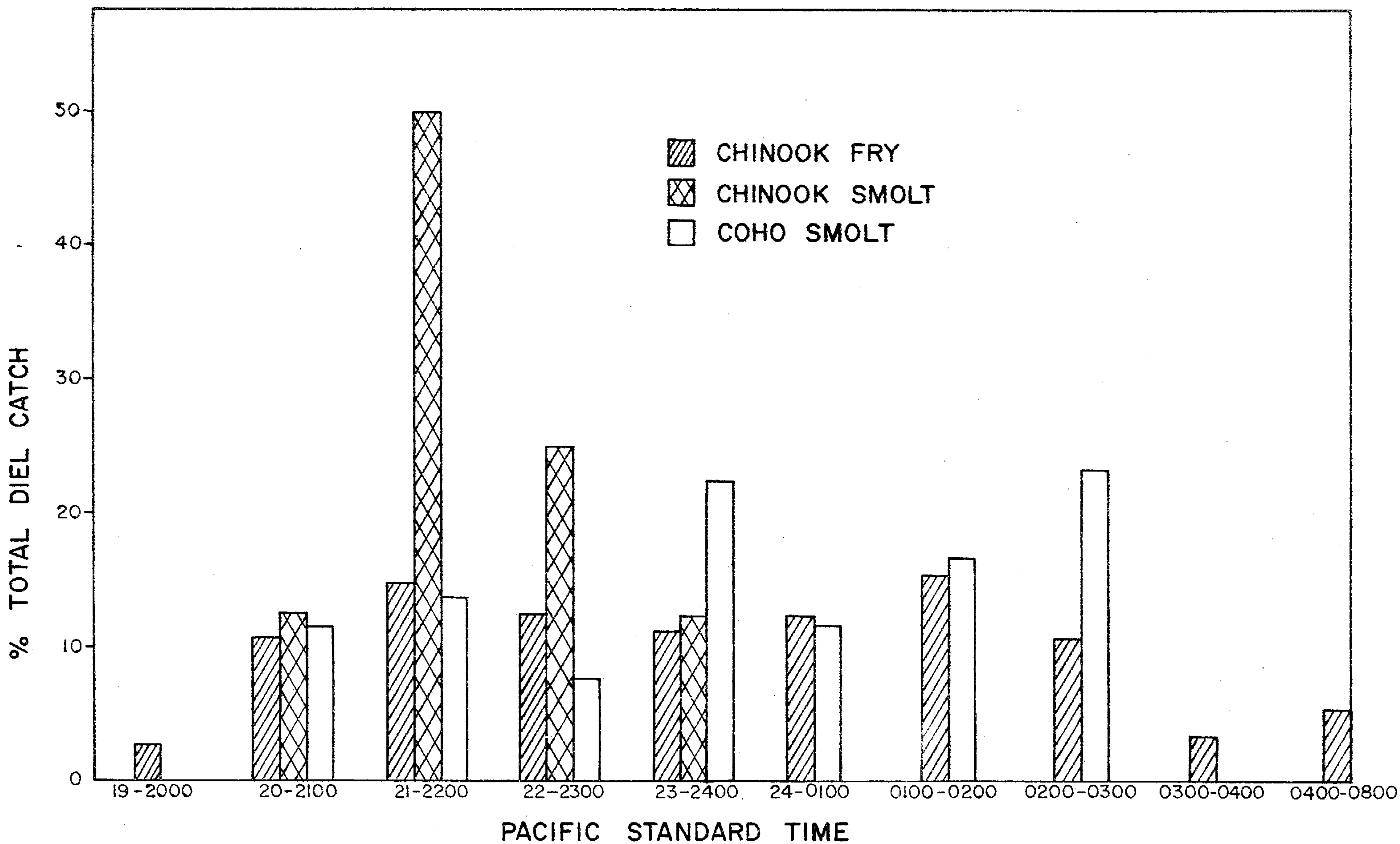


FIGURE 9 - Timing of diel migration of coho smolts, and chinook fry and smolts in the Lower Shuswap River, 1968.

# TABLE 10 - Periodic Distribution and Abundance of Resident Chinook and Coho Salmon, Lower Shuswap River, 1968.

| Date | Stream Section | Depth Range (ft) | Velocity Range (fps) | Water Temp. °F | Bottom Composition | Number of Juvenile Salmon: Chinook | Coho | Non-Salmon Observed: Shiner | White Fish | Squaw Fish | Sucker | Dace |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr 23 | Old Farm - left bank flood channel | 0.5 - 1.0 | 0.1 - 0.5 | 43 | Mud, sand, gravel | 400 | 50 | 0 | 0 | 0 | 0 | 0 |
| | Above Islands - right bank flood channel | 0.2 - 1.0 | 0.1 - 0.5 | 43 | Mud, sand | 200 | 0 | 3 | 0 | 0 | 0 | 0 |
| Aug 6 | Mabel Lake - Kingfisher Creek left and right banks | 0.5 - 2.0 | 0.1 - 2.5 | 68 | Sand, cobbles | 0 | 0 | 2000+ | 100+ | 100+ | 0 | 0 |
| | Right bank side channel above Hupel | 1.0 - 1.5 | 0.1 - 3.0 | 52-68 (springs) | Sand, gravel | 32 | 125 | 300+ | 0 | 300+ | 0 | 0 |
| | Right bank flood channel above Cooke Creek | 1.0 - 1.5 | 0.1 - 0.5 | 52-58 (springs) | Mud, silt, gravel | 0 | 725 | 100+ | 0 | 0 | 0 | 0 |
| | Right bank flood channels and main channel, Cooke to Fall Creek | 1.0 - 2.5 | 0.5 - 2.5 | 61-70 | Sand, fine gravel, cobbles | 370 | 40 | 2000+ | few | 1000+ | 0 | 500+ |
| | Old Farm - left bank flood channel | 1.0 - 1.5 | 0.5 - 1.0 | 65 | Sand, gravel | 49 | 25 | - | - | - | - | - |
| | Right bank flood channels, Old Farm to Islands | 1.5 - 2.0 | 0.1 - 1.5 | 69 | Silt, sand, fine gravel | 90 | 2 | 500+ | 0 | 300+ | 0 | 100+ |
| | Left bank side channel Old Farm to Islands | 1.5 | 0.1 - 1.5 | 54-70 (springs) | Sand, gravel | 120 | 1100 | - | - | - | - | - |
| | Right bank channel through Islands | 1.5 | 0.5 - 2.0 | 71 | Sand, gravel cobbles | 2 | 3 | 500+ | 0 | 300+ | 0 | 200+ |
| | Main channel, left bank through Islands | 1.0 - 7.0 | 0.5 - 3.0 | 69 | Sand, gravel cobbles | 97 | 6 | 100+ | 10 | 20 | 10 | 20 |
| | Left and right bank side channels below Turner Farm | 2.5 - 4.0 | 0.5 - 1.0 | 72 | Sand, silt, fine gravel | 2 | 0 | 200+ | 0 | 200 | 0 | 0 |
| | Trinity Creek to Ashton Creek, flood channels left and right banks | 1.0 - 3.0 | 0.1 - 1.5 | 71 | Sand, silt | 3 | 0 | 1000+ | 10 | 500+ | 0 | 200+ |
| | Ashton Creek to Dam site A, main-stem and side channels | 1.0 - 3.0 | 0.1 - 2.5 | 71 | Sand, gravel cobbles | 12 | 0 | 100+ | 15 | 20 | 10+ | 100+ |
| Oct 9 | Right bank flood channel and main channel Cooke Creek - Fall Creek | 1.0 - 3.0 | 1.0 - 1.5 | 52 | Cobbled | 16 | 0 | 0 | 6 | - | - | - |
| | Left bank Fall Creek to Old Farm | 0.5 - 1.0 | 0.1 - 1.5 | 52 | Gravel, sand | 0 | 0 | 20 | 0 | 0 | 0 | 0 |
| | Main channel left bank through Islands | 1.5 - 4.5 | 1.5 - 2.5 | 52 | Gravel | 23 | 0 | 100 | 3 | - | - | - |

Between 70% and 90% of the annual run of several hundred to 5,000 coho (TABLE 8) pass through the Lower Shuswap River and Mabel Lake en route to spawning areas in Middle Shuswap River, Bessette and Wap Creeks (FIGURE 2). The remainder spawn in the Lower Shuswap River upstream from Fall Creek (FIGURE 4).

Coho arrive on their respective spawning grounds during October and November. Spawning commences in November and continues into December. Incubation extends throughout the winter and early spring and the fry emerge in April and May. The majority of fry remain in the stream until their downstream migration as smolts in April and May the following year (FIGURE 10). At this time they range between 79 and 134 mm in length (FIGURE 8). The distribution of rearing coho in Lower Shuswap River is shown in TABLE 10. Observations have indicated that the bulk of the coho in this portion of the system occupy the smaller side channels which during the non-freshet period are partially or wholly serviced by groundwater, thus providing an environment which is as much as $16^{\circ}$F cooler than that of the main river channel.

## Sport Fish

In addition to kokanee, all of the sport fish species referred to previously are present in Mabel Lake and the Shuswap River. Some knowledge of spawning habits and angling use of these species was gathered during surveys in 1968. Estimates of their abundance are not presently available, but information pertaining to size, distribution and spawning behavior is given in TABLE 11.

The main spawning areas for rainbow trout from Mabel Lake are in the Wap Creek drainage, tributary to Mabel Lake, and in the Bessette Creek drainage, tributary to Middle Shuswap River. A few trout from Mabel Lake spawn downstream in the Lower Shuswap River and in Kingfisher Creek. Resident trout to $3\frac{1}{2}$ pounds in weight in Lower Shuswap River probably spawn in gravelled areas upstream of Enderby. Dolly Varden have been observed spawning in autumn months in Wap and Tsuius Creeks tributary to Mabel Lake and in Kingfisher Creek. Lake trout from Shuswap Lake probably spawn in tributaries of Lower Shuswap River downstream of Kingfisher Creek.

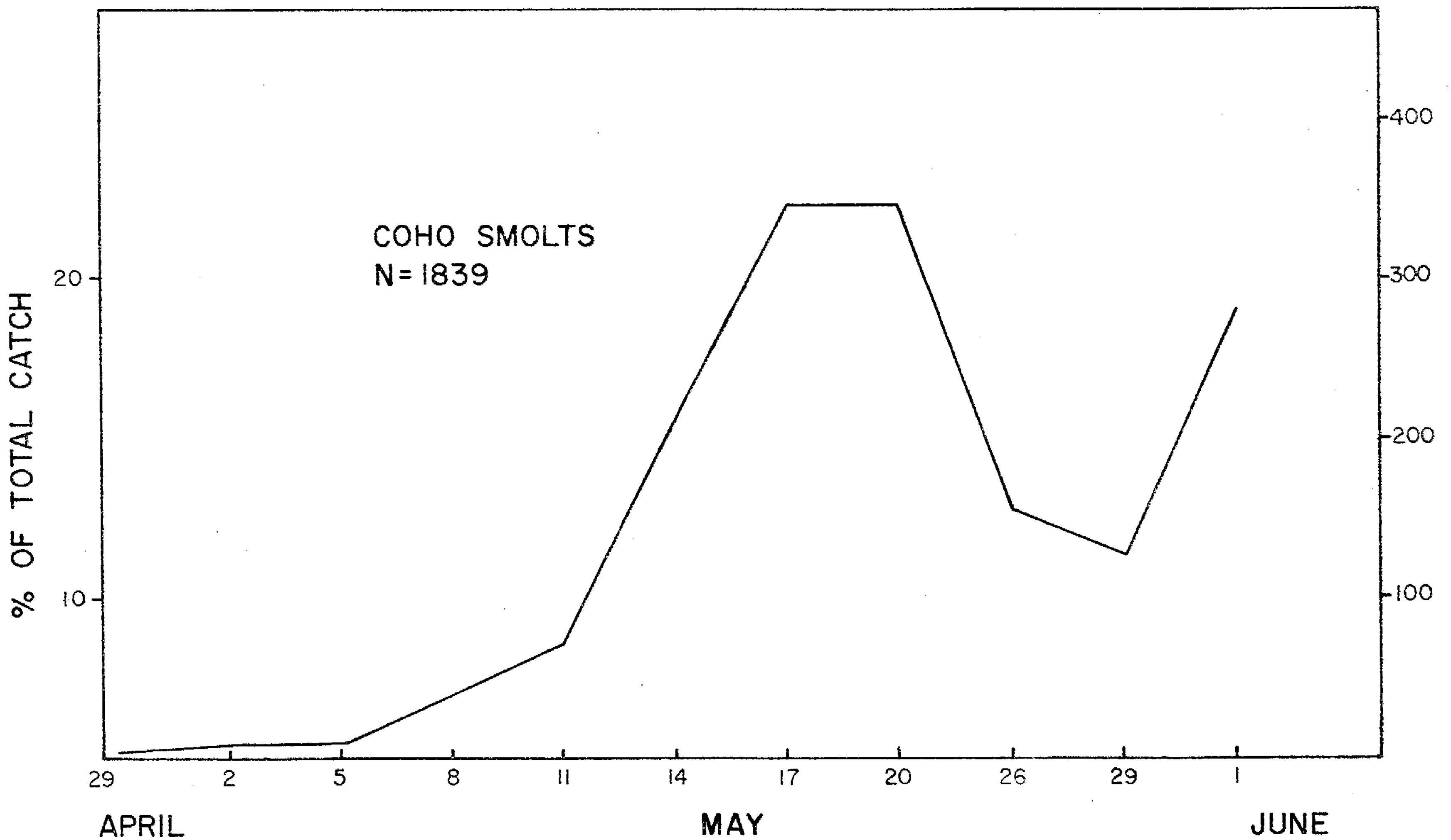


FIGURE 10 - Timing of coho salmon smolt migration down the Lower Shuswap River, 1968.

TABLE 11 - Sport fish populations in Shuswap River and Mabel Lake.

| SPECIES | ADULT DISTRIBUTION | SPAWNING | | REMARKS |
|---|---|---|---|---|
| | | Time | Location | |
| Rainbow Trout | Mabel Lake<br>Shuswap River | April – May | Tributaries to Mabel Lake, and Shuswap River | Caught in Mabel and Shuswap Lakes. Weight up to 12 pounds. |
| Cutthroat Trout | Mabel Lake | Feb. – May | Small tributaries to Mabel Lake and Shuswap River | Small cutthroat trout caught in Mabel and Shuswap Lakes at weights up to 4 pounds. |
| Dolly Varden | Mabel Lake<br>Shuswap River | Aug. – Nov. | Tributaries to Mabel Lake and Shuswap River. | Mostly caught in Mabel Lake at weights to 9½ pounds. |
| Lake Trout | Mabel Lake | Fall Months | Mabel Lake | Caught in Mabel Lake at weights to 24 pounds. |
| Mountain Whitefish | Mabel Lake<br>Shuswap River and tributaries | Mid-Nov. | Tributaries to Mabel Lake and Shuswap River | There is a small fishery for whitefish in Mabel Lake, Shuswap River and tributaries. Weight to 1½ pounds. |

Lake trout spawn on gravel bars in Mabel Lake in autumn months. There is no period of river residence during the life cycle of these fish. Mountain whitefish are largely stream resident fish. Spawning occurs in fall months.

Mabel Lake supports an excellent sport fishery for rainbow trout to 12 lb, lake trout to 24 lb and Dolly Varden to 10 lb in weight during spring, early summer and fall months. One large lodge and about 150 summer cabins are established on the lake. To a large extent the sport fishery has attracted this settlement. Fishing pressure is light in Lower Shuswap River except for angling for chinook salmon in summer months. About 200 chinooks are caught annually in this fishery. Fishing effort for rainbow trout and whitefish in the river is largely restricted to pools in the vicinity of Kingfisher Creek.

Shuswap Lake supports a good fishery for all of the sport fish previously cited.

## Value of Fishery

In the last four cycle years of the dominant cycle, the Shuswap River sockeye run (Lower and Middle Shuswap combined) has contributed an average of 63,300 sockeye per cycle to the commercial sockeye catch (TABLE 12).

TABLE 12 - Shuswap River sockeye run dominant cycle catch and run size.

| Year | Commercial Fishery | Indian Fishery | Total Run |
|---|---|---|---|
| 1954 | 124,000 | 400 | 142,000 |
| 1958 | 70,800 | 200 | 80,900 |
| 1962 | 25,300 | 1,600 | 58,600 |
| 1966 | 33,000 | 1,800 | 61,200 |

At current wholesale domestic prices of $50.00 per case, this catch would be valued at $300,000 for each dominant cycle run. The runs also contribute substantial numbers of fish to the Indian subsistance fishery along the migration route. Historical records indicate substantially larger sockeye runs to the river than now occur, and spawning grounds and lake rearing areas are available to support much larger runs. Using the same average returns as the existing Shuswap River sockeye runs, the rearing area in Mabel Lake could produce a catch of 706,000 sockeye on the dominant cycle, with a value of $3,360,000, and the rearing area in Mara Lake could produce a catch of 257,000 sockeye on the dominant cycle, with a value of $1,225,000. As previously discussed the potential of Shuswap Lake for rearing sockeye fry from Lower Shuswap River cannot be stated definitely at this time, but there appears to be considerable rearing capacity available which would increase the potential of the Lower Shuswap River sockeye run considerably above the value indicated by Mara Lake alone. Current plans recently announced by the Commission call for an expanded construction program involving artificial aids for the production of sockeye fry. These plans include Mabel Lake and the Middle Shuswap River among others with the Mabel Lake project being held in abeyance pending the outcome of the current diversion studies.

It is not possible to place a value on the kokanee and other sports fish sought by anglers in Mabel Lake and Shuswap River. It is evident however that these fish constitute an integral part of the recreational value of the area, which has attracted much interest in establishing summer camps. The large runs of kokanee in Shuswap River also contribute to the recreational use of Shuswap Lake.

The stocks of chinook and coho originating in the Shuswap River are subjected to commercial and sports fisheries in tidal waters, and also are caught in significant numbers during their up-river migration by sport fishermen and by the Indian food fishery. The average annual value of these catches is estimated to be $349,200 (TABLE 13), based on an average annual escapement of 6,200 chinook and 3,100 coho.

A catch to escapement ratio of 4 to 1 for chinook and 3 to 1 for coho was applied to determine the total number of fish taken by all of the fisheries. Chinook and coho salmon catch in tidal waters was divided between commercial and sports fisheries at a ratio of 3 to 1 for chinook and 2 to 1 for coho.

TABLE 13 - Calculated average annual value of catches of chinook and coho salmon originating from the Shuswap River.

| Fishery | Species | Number of Fish | Annual Value |
|---|---|---|---|
| Commercial | Chinook | 18,600 | $180,790 |
| | Coho | 6,200 | 23,060 |
| Tidal Sport | Chinook and Coho | 9,300 | 116,250 |
| Non-tidal Sport | Chinook | 1,900 | 28,500 |
| Indian | Chinook | 100 | 600 |
| TOTAL | | | $349,200 |

The value of commercial caught chinook and coho was calculated by assuming an average weight of 12 lb for chinook and 6 lb for coho, and using the 1968 average market value (canned and fresh) of $0.81 and $0.62 per pound respectively. The value of chinook and coho caught by anglers in tidal waters was calculated from the total catch applying the average catch per boat-day and the average number of fishermen per boat to determine the average number of fishermen involved in catching the fish and applying an angler-day value of $5.00 to determine the annual value. The non-tidal sports fishery value was determined by equating the catch attributable to the Shuswap River escapement to the average fisherman-day success and applying the same angler-day value. The value of the Indian food fishery was determined on the basis of an average weight of 12 lb for each chinook and a value of $0.50 per pound.

## FISHERY RESOURCES OF THE OKANAGAN RIVER

The portion of Okanagan River lying between Osoyoos Lake and the dam at the outlet of Vaseux Lake (FIGURE 11) supports an annual spawning population of sockeye salmon. During the 16-yr period of record their numbers have ranged from approximately 2,000 to over 50,000 fish (TABLE 14). There is no clear evidence of numerically dominant year class common to many sockeye populations. The average escapement in the period 1952-1968 has been 23,000 sockeye.

TABLE 14 - Sockeye spawning escapements to Okanagan River 1952-1968.

| 1964 Cycle | 1965 Cycle | 1966 Cycle | 1967 Cycle |
|---|---|---|---|
| 1952 - 24,000 | 1953 - 34,000 | 1954 - 10,000 | 1955 - 50,000+ |
| 1956 - 39,000 | 1957 - 25,000+ | 1958 - 31,000 | 1959 - 40,000 |
| 1960 - 8,000 | 1961 - 2,000+ | 1962 - 6,000 | 1963 - 16,000 |
| 1964 - 12,000 | 1965 - 5,000 | 1966 - 45,000 | 1967 - 23,000 |
| 1968 - 15,000 | | | |

Since construction in 1956 of the flood control canal, which extends from a point some 1,000 ft south of the Highway 97 bridge downstream to Osoyoos Lake, the spawning population has quite consistently distributed in the following manner (FIGURE 11):

- Osoyoos Lake to McDonald's Bridge - no spawning.
- McDonald's Bridge to Oliver Bridge - scattered light spawning in the vicinity of drop structures.
- Oliver Bridge to Park Rill - medium density.
- Park Rill to McIntyre Creek - medium to heavy density.
- McIntyre Creek to S. O. L. P. Dam - very light density.

Spawning activity begins during the third week in September, peaks in mid-October and is virtually completed by November 1. The eggs develop in the gravel throughout the winter and the fry emerge and migrate downstream to Osoyoos Lake from the first week in March until early May (FIGURE 12). The young sockeye remain for a year in Osoyoos Lake before proceeding to the ocean.

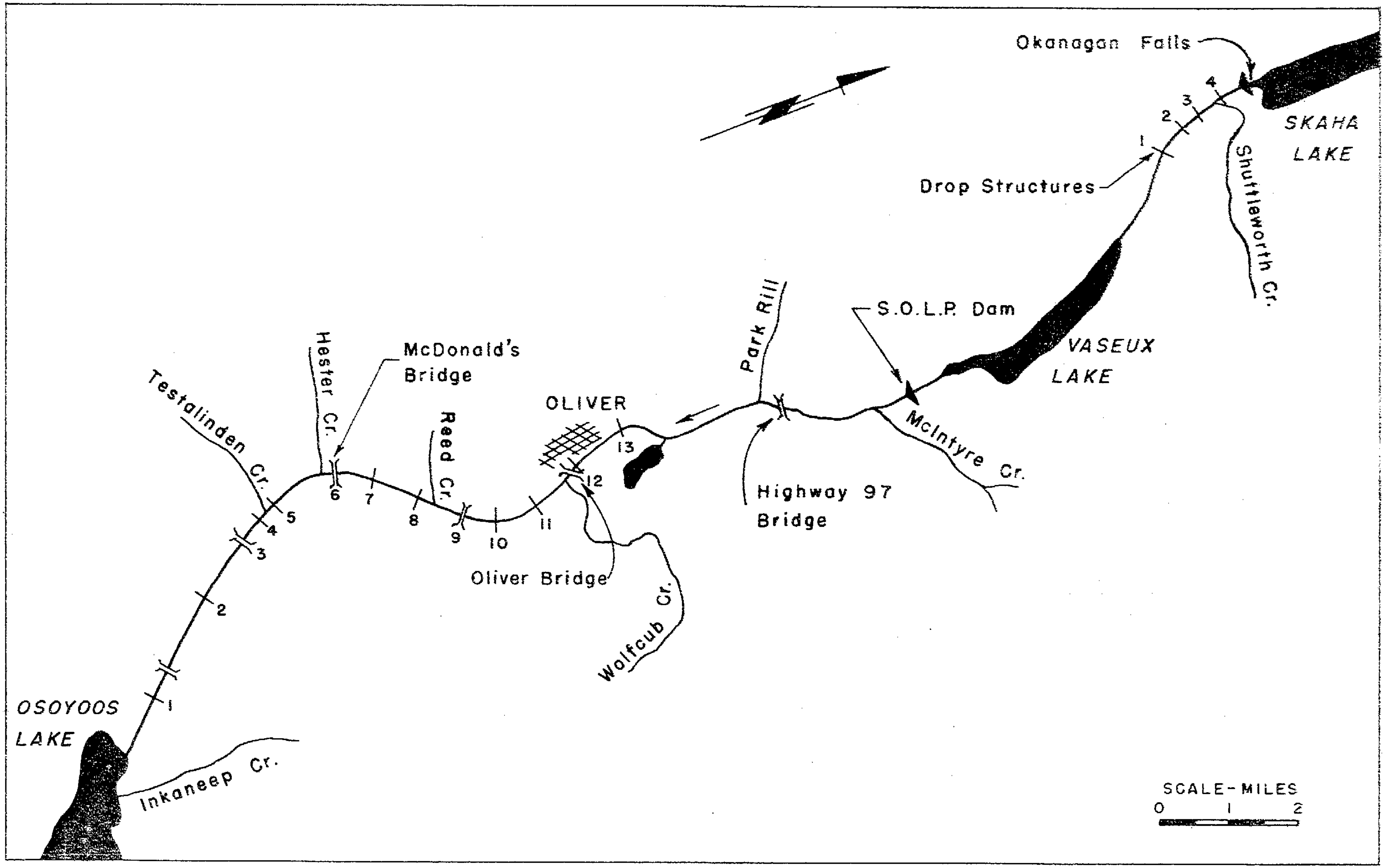


FIGURE 11 - Okanagan River from Skaha Lake to Osoyoos Lake.

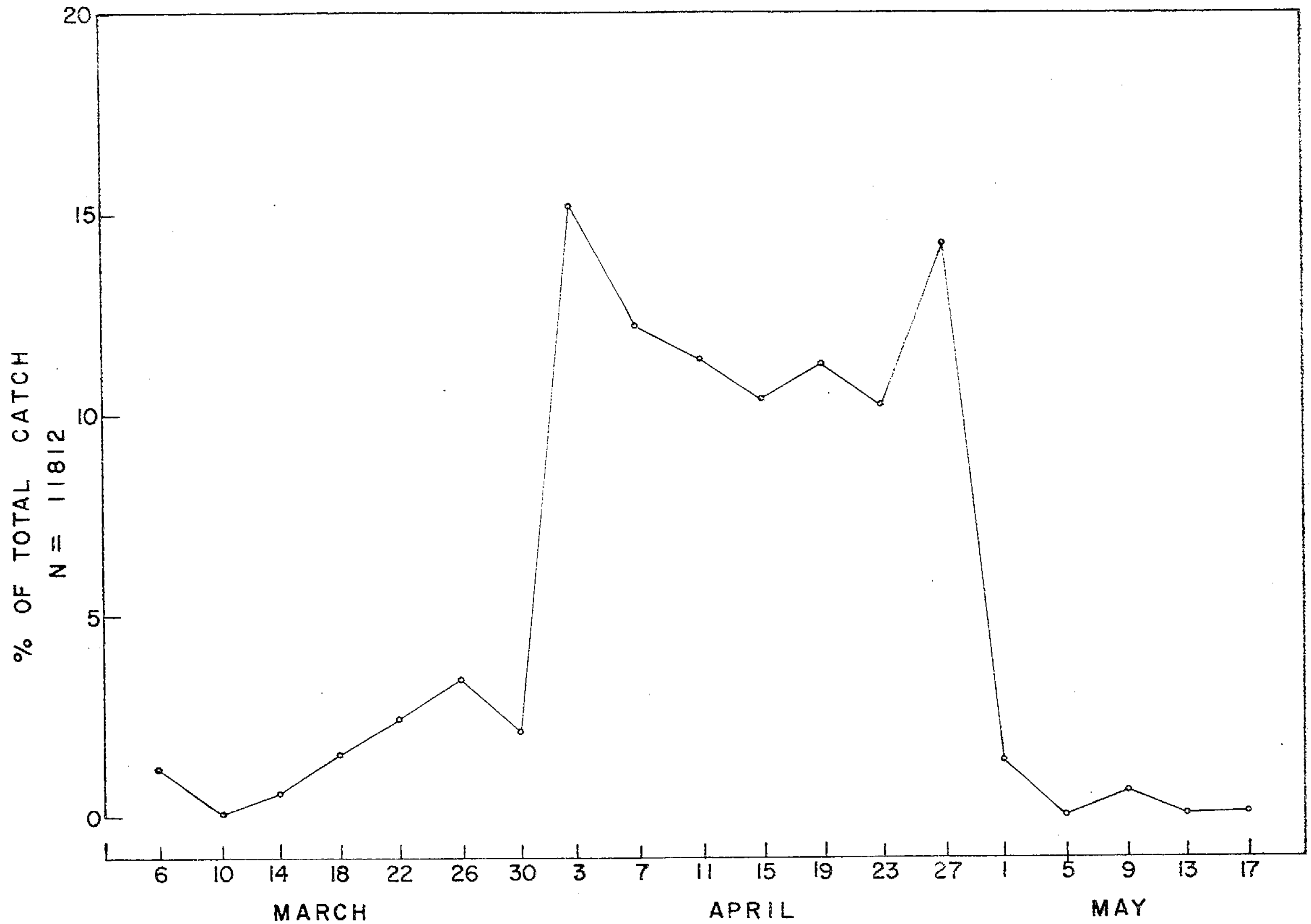


FIGURE 12 - Timing of Sockeye fry downstream migration in Okanagan River, 1968.

In 1956, in consideration of fisheries requirements for suitable spawning, migration and incubation flows and of the requirements necessary to ensure the continued operation of pump intakes in the vicinity of drop structures 5 & 12, the schedule of flows in TABLE 15 was suggested.

TABLE 15 - 1956 fisheries flow schedule for Okanagan River.

| | Period | Flow |
|---|---|---|
| Spawning | Sept. 10 to Oct. 25 | 500 cfs min. |
| Incubation | Oct. 25 to Feb. 10 | 250 cfs min or 50% of spawning flow. |
| Fry Migration | Feb. 10 to May 10 | An increase in discharge rather than decrease. |

These flows were based on the knowledge that under the 1956 operating requirements sufficient water was available to provide an adequate depth of water on heavily utilized spawning areas, particularly those in the unimproved section with its numerous side channels. Flows lower than 400 cfs result in serious obstructions at drop structures 5 & 12.

A new survey and reassessment of the Okanagan River spawning grounds has recently been made and has led to a revision of the fishery flow requirements which are discussed in a later section and summarized in TABLE 41.

The average annual escapement of sockeye salmon to the Okanagan River during the 17 years of record (TABLE 14) is 23,000 fish. Catch to escapement ratios have ranged from 0.6 to 1 to 6 to 1. For the purpose of this analysis, a catch to escapement ratio of 2 to 1 (46,000 to 23,000) has been used. By applying an average of 17 fish per case and a wholesale domestic (U.S.) value of $55.00 per case, the annual value, primarily to United States fishermen, is calculated to be $148,830. Recent surveys of the spawning potential of the river indicate that the area could accommodate upward of 100,000 fish thus increasing its potential value to more than $600,000 annually.

Sport fish populations in Okanagan River consist of rainbow trout (to 2.5 lb), kokanee, mountain whitefish, largemouth bass (<u>micropterus salmonides</u>), and Eastern brook trout (<u>Salvelinus fontinalis</u>). Fishing pressure is moderate for trout, bass and kokanee between Okanagan Falls and Vaseux Lake in spring and fall months. Sport fishing pressures are light downstream of Vaseux Lake.

## PROPOSED DIVERSION FROM LOWER SHUSWAP RIVER

The Water Resources Service 1966 study examined the present and future water requirements of the Okanagan Valley and the North Okanagan area between Enderby and Okanagan Lake. It considered that all available tributary inflow to this region is now fully utilized in some years. Consequently any further requirements from Okanagan Lake and Okanagan River would require a new source of water. The study examined the feasibility of obtaining such additional water from Lower Shuswap River to meet two stages of estimated future requirements as detailed in TABLE 16, with and without provision of flows for fisheries purposes in Okanagan River.

TABLE 16 - Present and future stages of development of North and South Okanagan regions studied by the Water Resources Service.

| Scheme | Irrigated Area Acres | Population | Okanagan River Flows for Fisheries Purposes, Acre Feet, (in addition to Minimum River flow) |
|---|---|---|---|
| Present 1966 | 60,072 | 84,000 | 100,000 |
| 1 | 110,000 | 140,000 | Nil |
| 2 | 110,000 | 140,000 | 94,000 |
| 3 | 183,046 | 281,000 | Nil |
| 4 | 183,046 | 281,000 | 82,000 |

The storage and diversion requirements for each of Scheme 1 to 4 were analyzed in conjunction with assumed residual flows of 500 cfs, 800 cfs, and 1,100 cfs in the Shuswap River below the diversion during the diversion period from April 1 to September 30. Schemes 1 and 2 represent an initial stage of development with approximately double the present water requirements, and Schemes 3 and 4 represent the ultimate development, which might be attained by the end of this century. The difference between Schemes 3 and 4 is in the amount of water provided for fisheries purposes in the Okanagan River. The Water Resources Service selected Scheme 3 for detailed study since it provided some water for fisheries purposes in the Okanagan River (in the form of a minimum flow of 125 cfs) and at the same time provided water requirements for the projected ultimate development.

The present (1966) annual water requirements of the region are estimated on the basis of a population of 84,000 people and a total of 60,072 acres of land under irrigation. An allowance is made for discharge of 150 cfs from Okanagan Lake to provide a minimum flow of 125 cfs in the Okanagan River, or 108,000 acre-ft annually. Reference is also made to flow required for fisheries purposes in the Okanagan River as established by the Department of Fisheries of Canada (TABLE 15). The requirement of 500 cfs from September 10 to October 25, 250 cfs from October 25 to February 10, and 250 cfs or more from February 10 to May 10 would add 83,000 acre-ft annually to the 125 cfs minimum flow requirement. Not all of the water diverted for irrigation, domestic and industrial purposes is consumed, and the Water Resources Service estimates that substantial quantities of return flow would be obtained. Return flows to Okanagan Lake may actually be used several times, but re-use of return flow to the Okanagan River would depend on the point of return in relation to downstream intakes in Canada. Recoverable return flows reduce the total quantity of water required to supply the various uses. Details of the estimates of water requirement and return flow are given in TABLE 17 and show that the present net requirement is 215,917 acre-ft.

The Water Resources Service has computed the annual inflow to Okanagan Lake for the period 1922-1964, and for the same period it has estimated the annual consumptive use of water in the watershed (TABLE 18). The combined figures give the total net yearly inflow to the watershed. The average yearly watershed inflow of 397,110 acre-ft exceeds the estimated present net requirement of 215,917 acre-ft, but in a number of years with inflow considerably less than average, there would not have been enough water to meet the present requirement.

The Water Resources Service estimates that within the limits of 1,000 ft elevation above Okanagan Lake and River, and 10 miles from the lake or river edge, there are 122,974 acres of potentially irrigable land, which could be serviced from Okanagan Lake or River (TABLE 19).

TABLE 17 - Estimated present (1966) annual water requirements and return flows for North and South Okanagan Regions, in acre-ft.

| REGION | WATER USE Irrigation | Water Works | Total |
|---|---|---|---|
| Okanagan River and Tributaries | 52,334 | 7,365 | 59,699 |
| Okanagan Lake and Tributaries | 131,550 | 14,093 | 145,643 |
| North Okanagan | 5,988 | 944 | 6,932 |
| Total | 189,872 | 22,402 | 212,274 |
| RETURN FLOW | | | |
| Okanagan River and Tributaries | 25,120 | 4,787 | 29,907 |
| Okanagan Lake and Tributaries | 63,144 | 9,161 | 72,305 |
| North Okanagan | 1,768 | 377 | 2,145 |
| Total | 90,032 | 14,325 | 104,357 |
| Net Water Requirement | | | 107,917 |
| Okanagan River Minimum | | | 108,000 |
| Total | | | 215,917 |

TABLE 18 - Computed annual inflow to Okanagan Lake and estimated total Okanagan Lake watershed runoff in acre-ft for the period April 1 to March 31 for the years 1922 - 1964.

| YEAR | Computed Inflow* | Estimated Consumptive Use** | Estimated Total Watershed Runoff |
|---|---|---|---|
| 1922-23 | 306,488 | 6,784 | 313,272 |
| 1923-24 | 393,214 | 8,252 | 401,466 |
| 1924-25 | 140,614 | 9,719 | 150,333 |
| 1925-26 | 240,812 | 11,186 | 251,998 |
| 1926-27 | 86,726 | 12,653 | 99,379 |
| 1927-28 | 442,892 | 14,121 | 457,013 |
| 1928-29 | 615,502 | 15,588 | 631,090 |
| 1929-30 | 107,776 | 17,055 | 124,831 |
| 1930-31 | 82,516 | 18,522 | 101,038 |
| 1931-32 | 79,990 | 19,989 | 99,979 |
| 1932-33 | 370,480 | 21,456 | 391,936 |
| 1933-34 | 548,984 | 22,924 | 571,908 |
| 1934-35 | 436,156 | 24,391 | 460,547 |
| 1935-36 | 489,202 | 25,858 | 515,060 |
| 1936-37 | 347,746 | 27,325 | 375,071 |
| 1937-38 | 371,322 | 28,792 | 400,114 |
| 1938-39 | 276,176 | 30,259 | 306,435 |
| 1939-40 | 198,712 | 31,727 | 230,439 |
| 1940-41 | 149,034 | 33,194 | 182,228 |
| 1941-42 | 309,014 | 34,661 | 343,675 |
| 1942-43 | 457,206 | 36,128 | 493,334 |
| 1943-44 | 219,762 | 37,595 | 257,357 |
| 1944-45 | 261,020 | 39,062 | 300,082 |
| 1945-46 | 419,316 | 40,530 | 459,846 |
| 1946-47 | 548,142 | 41,997 | 590,139 |
| 1947-48 | 188,608 | 43,464 | 232,072 |
| 1948-49 | 742,644 | 44,931 | 787,575 |
| 1949-50 | 427,736 | 46,399 | 474,135 |
| 1950-51 | 493,412 | 47,865 | 541,277 |
| 1951-52 | 571,718 | 49,333 | 621,051 |
| 1952-53 | 437,840 | 50,800 | 488,640 |
| 1953-54 | 342,694 | 52,267 | 394,961 |
| 1954-55 | 563,298 | 53,734 | 617,032 |
| 1955-56 | 452,154 | 55,202 | 507,356 |
| 1956-57 | 522,040 | 56,669 | 578,709 |
| 1957-58 | 450,470 | 58,136 | 508,606 |
| 1958-59 | 348,588 | 59,603 | 408,191 |
| 1959-60 | 630,014 | 61,070 | 691,084 |
| 1960-61 | 305,585 | 62,537 | 368,122 |
| 1961-62 | 277,548 | 64,005 | 341,553 |
| 1962-63 | 269,004 | 65,472 | 334,476 |
| 1963-64 | 208,273 | 66,939 | 275,212 |
| Average | 360,248 | | 397,110 |

* From Table 1, Appendix 2.1 and ** Table 1, Appendix 4.1, Water Resources Service Report, 1966.

TABLE 19 - Present and potentially irrigable lands in Okanagan and North Okanagan Region, in acres.

| Area | Irrigated 1966 | Potentially Irrigable | Total |
|---|---|---|---|
| North Okanagan | 4,277 | 52,000 | 56,277 |
| Okanagan Lake | 592 | 45,861 | 46,453 |
| Okanagan River | 9,935 | 25,113 | 35,048 |
| Lake Tributaries | 43,701 | 0 | 43,701 |
| River Tributaries | 1,567 | 0 | 1,567 |
| Total | 60,072 | 122,974 | 183,046 |

To irrigate this area and to supply future industrial and water works requirements, the Water Resources Service has estimated the ultimate net water requirement of the North and South Okanagan Regions to be 448,697 acre ft, as detailed in TABLE 20.

TABLE 20 - Estimated ultimate annual water requirements and return flows for North and South Okanagan Regions, in acre-ft.

| REGION | WATER USE<br>Irrigation | Water Works and Industrial | Total |
|---|---|---|---|
| Okanagan River and Tributaries | 166,598 | 58,197 | 224,795 |
| Okanagan Lake and Tributaries | 267,757 | 84,430 | 352,187 |
| North Okanagan | 78,788 | 15,632 | 94,420 |
| Total | 513,143 | 158,259 | 671,402 |
| | RETURN FLOW | | |
| Okanagan River and Tributaries | 79,967 | 37,828 | 117,795 |
| Okanagan Lake and Tributaries | 128,523 | 54,880 | 183,403 |
| North Okanagan | 23,258 | 6,249 | 29,507 |
| Total | 231,748 | 98,957 | 330,705 |
| Net Water Requirement | | | 340,697 |
| Okanagan River Minimum | | | 108,000 |
| Total | | | 448,697 |

On the basis of the minimum annual net watershed runoff of 96,200 acre-ft, and withdrawal of up to one half of the 84,000 acre-ft of emergency storage from Okanagan Lake per year, and reuse of 25,000 acre-ft of return flow, the Water Resources Service estimates a net new annual water requirement of 191,077 acre-ft for the South Okanagan (TABLE 21). In addition, the requirement of 94,420 acre-ft for the North Okanagan would make a total new annual water requirement of 285,497 acre-ft.

TABLE 21 - Estimated ultimate annual new water requirement for the North and South Okanagan Regions, in acre-ft.

| | Supply | Requirement |
|---|---|---|
| South Okanagan Net Requirement | | 354,277 |
| Minimum Tributary Inflow | 96,200 | |
| Okanagan Lake 0.5 feet | 42,000 | |
| Return Flow Reuse | 25,000 | |
| Total | 163,200 | |
| Net new water required | | 191,077 |
| North Okanagan | | 94,420 |
| Total new water required | | 285,497 |

The North Okanagan requirement would be diverted every year, but the amount of diversion to the South Okanagan region would depend on actual inflow to Okanagan Lake. In some years no diversion would be necessary. The total monthly diversion requirements for the North and South Okanagan regions during the irrigation period for a number of years, as estimated by the Water Resources Service, are given in TABLE 22. The monthly diversion requirements for the North Okanagan area are given in TABLE 23. The minimum diversion of approximately 20 cfs is for domestic and industrial uses in the North Okanagan area and would be delivered by pipeline separate from the irrigation diversion.

The Water Resources Service has proposed diversion of the foregoing water requirements from the Lower Shuswap River near Enderby via a canal which would traverse the North Okanagan area adjacent to Fortune and Deep Creeks, and would enter Okanagan Lake through Deep Creek (FIGURE 13). Two methods of diverting the water into the canal have been considered. Gravity flow could be obtained

TABLE 22 - Estimated total monthly diversion in cfs required for North and South Okanagan Regions from Shuswap River during the period April to September on the basis of historic water supplies and anticipated ultimate water demand for Scheme 3, alternate 2 or 3 of Water Resources Service study.*

| Year | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| 1924 | 200 | 550 | 700 | 680 | 680 | 320 |
| 1925 | 20 | 210 | 350 | 330 | 330 | 150 |
| 1926 | 320 | 800 | 970 | 930 | 930 | 450 |
| 1927 | 20 | 210 | 350 | 330 | 330 | 150 |
| 1928 | 20 | 210 | 350 | 330 | 330 | 150 |
| 1929 | 300 | 760 | 920 | 890 | 890 | 420 |
| 1930 | 360 | 850 | 1,000 | 980 | 980 | 480 |
| 1931 | 400 | 930 | 1,100 | 1,060 | 1,060 | 520 |
| 1932 | 20 | 200 | 350 | 330 | 330 | 150 |
| 1960 | 20 | 200 | 350 | 330 | 330 | 150 |
| 1961 | 20 | 200 | 350 | 330 | 330 | 150 |
| 1962 | 20 | 200 | 350 | 330 | 330 | 150 |
| 1963 | 50 | 290 | 420 | 410 | 410 | 190 |
| 1964 | 20 | 200 | 350 | 330 | 330 | 150 |
| 1965 | 20 | 200 | 350 | 330 | 330 | 150 |

* From Drawing 3.1 Water Resources Service Report (1967).

TABLE 23 - North Okanagan area monthly diversion requirements from the Shuswap River.

| Month | Diversion in cfs |
|---|---|
| April | 21 |
| May | 210 |
| June | 346 |
| July | 337 |
| August | 337 |
| September | 152 |
| October | 20 |
| November | 21 |
| December | 19 |
| January | 19 |
| February | 21 |
| March | 19 |

From Table 7.2 Water Resources Service Report (1966).

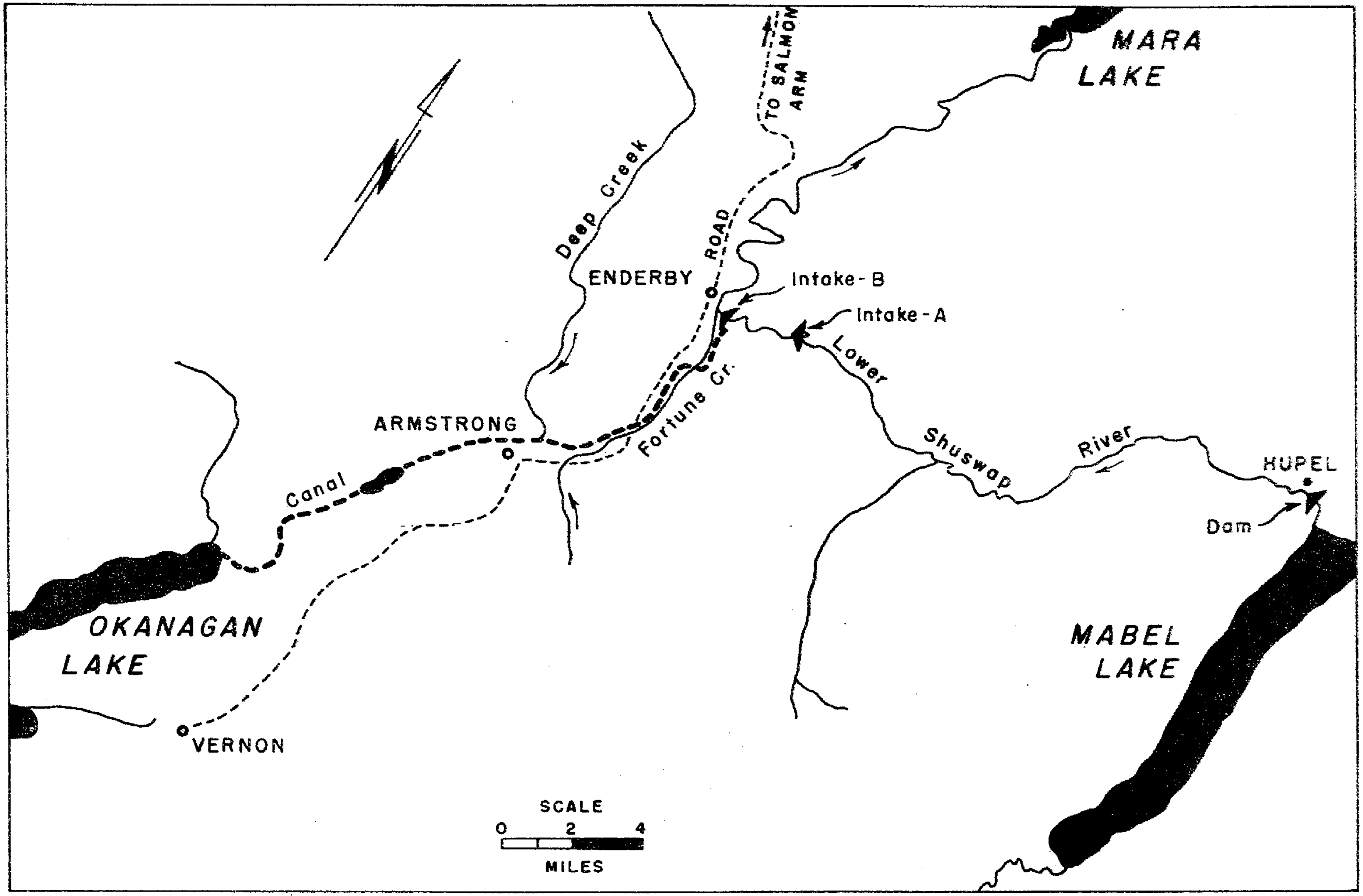


FIGURE 13 - Proposed diversion intakes, canal and storage dam for diversion of water from Lower Shuswap River to Okanagan Lake.

by constructing a dam at Site A which would raise the river level approximately 35 ft to a forebay elevation of 1,185 ft. The suitability of this site for a dam has not been determined, but the Water Resources Service does not regard the site as favorable. Alternatively, the water could be pumped up 30 ft from the forebay of a low diversion dam at Site B near Enderby. It is proposed that this gated structure would maintain a forebay level of at least 1,150 ft during the irrigation period (FIGURE 14). The Water Resources Service suggests a pumping capacity of 1,000 cfs for irrigation and a separate 20 cfs pump for the North Okanagan area domestic and industrial requirement.

In August, the diversion requirement would exceed the minimum mean monthly discharge in the Shuswap River at Enderby (TABLE 24).

TABLE 24 - Estimated maximum monthly diversion requirements from Shuswap River and recorded minimum mean monthly discharge in the Shuswap River at Enderby.

| Month | Maximum Diversion cfs | Minimum Mean Monthly Discharge of Shuswap River |
|---|---|---|
| January | 19 | 510 |
| February | 21 | 396 |
| March | 19 | 465 |
| April | 400 | 630 |
| May | 930 | 3,178 |
| June | 1,100 | 5,170 |
| July | 1,060 | 2,300 |
| August | 1,060 | 908 |
| September | 520 | 878 |
| October | 20 | 821 |
| November | 21 | 686 |
| December | 19 | 592 |

In addition, it would be necessary to maintain certain minimum flows in Lower Shuswap River below the diversion to fulfill the needs of transportation, water supply and fisheries. The Water Resources Service considered three possible minimum flows, 500 cfs, 800 cfs and 1,100 cfs for purposes of examining the effect on storage requirements. Since the natural flow in Lower Shuswap River would not always be sufficient to provide water for the proposed diversion and maintain minimum flows below the diversion, the Water Resources Service proposed to regulate the discharge of the river by means of storage on Mabel Lake.

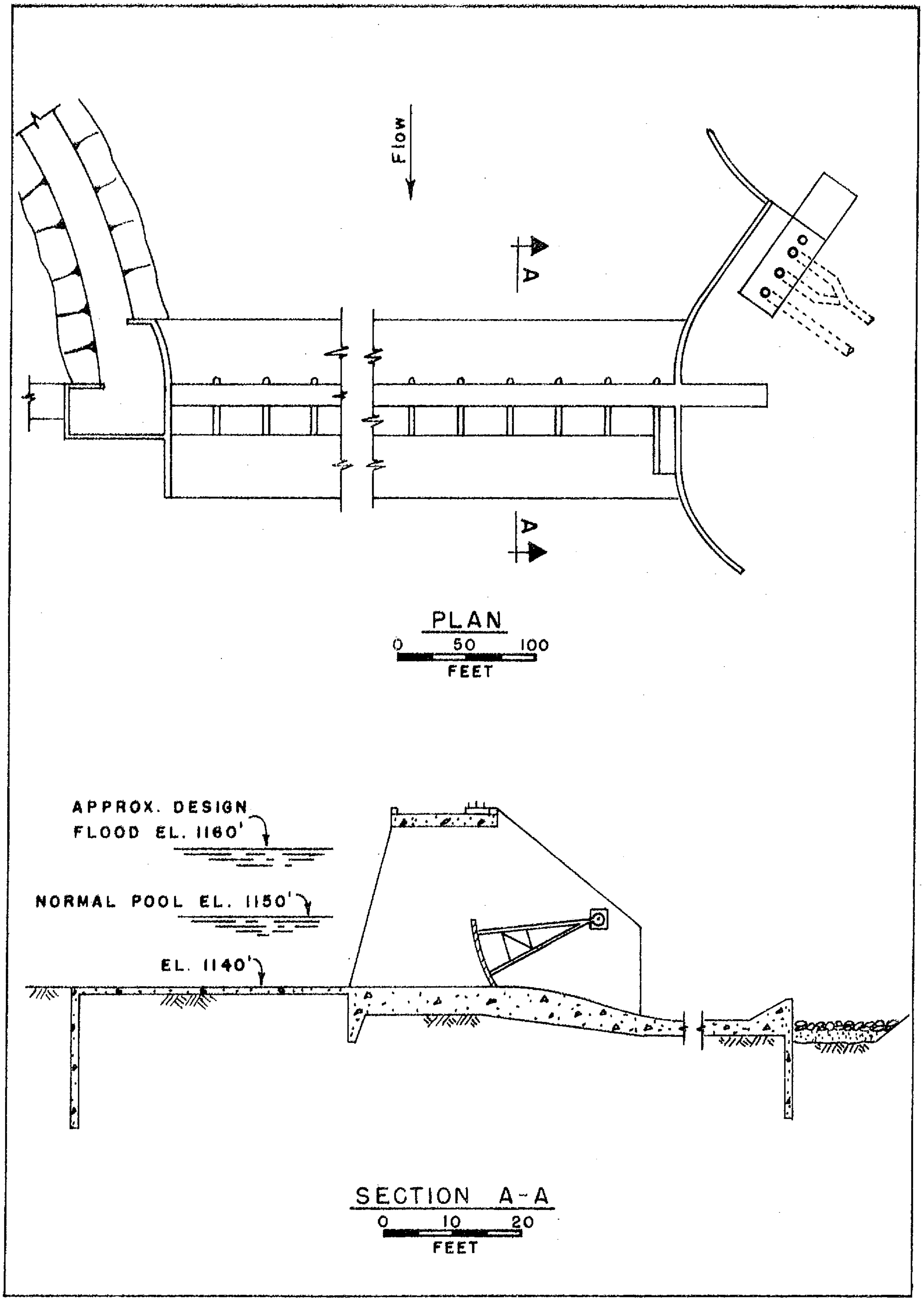


FIGURE 14 - Proposed diversion dam at Site B near [illegible].

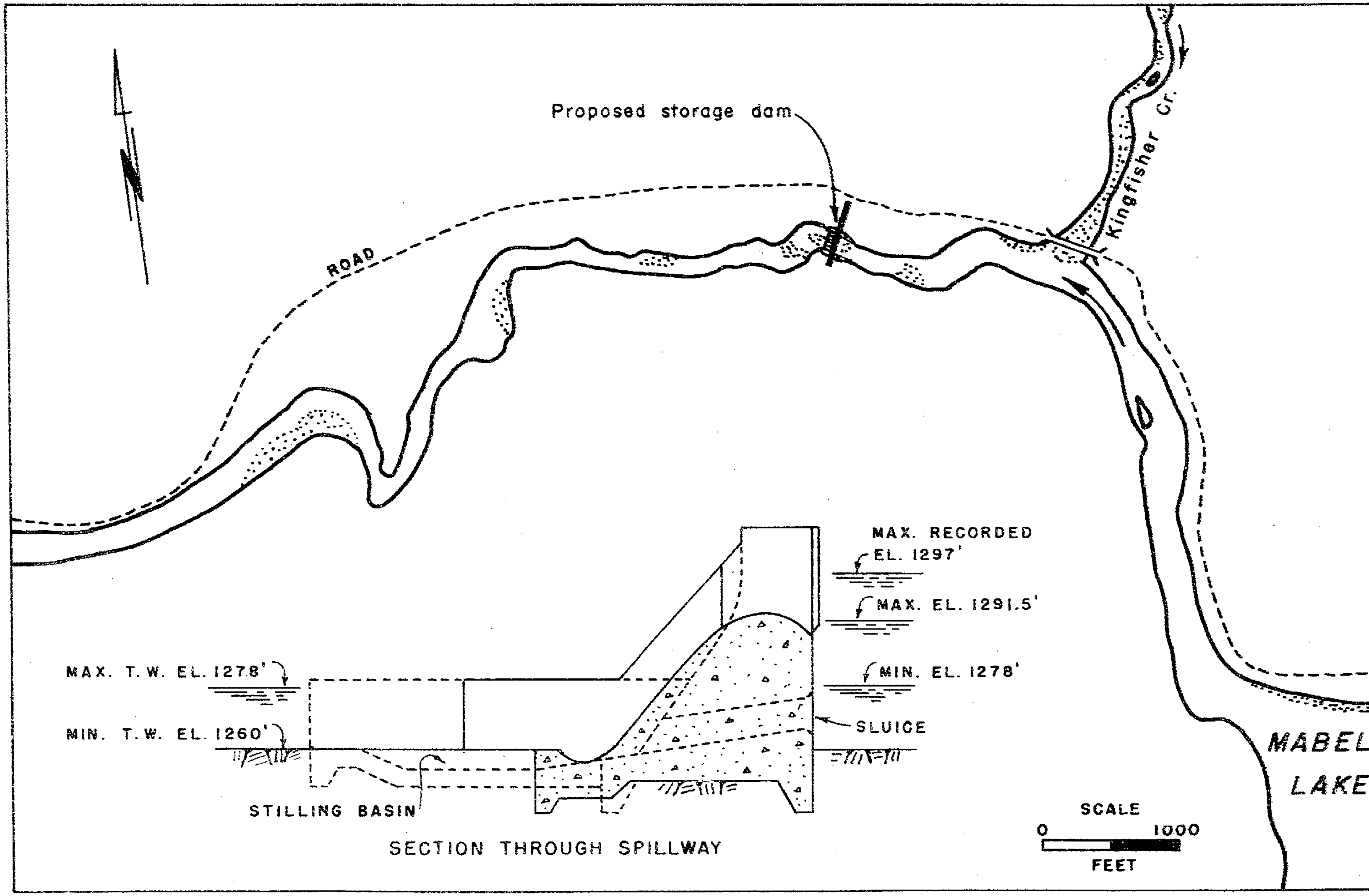


FIGURE 15 - Proposed storage dam at Mabel Lake.

The proposed dam for this purpose would be located downstream from Mabel Lake at a site investigated previously by the Fraser River Board (1958) (FIGURE 15). The Water Resources Service study considers the storage requirements for the Scheme 3 diversion and concludes that with a minimum flow of 1,100 cfs below the diversion during the irrigation period, 191,000 acre-ft of storage in Mabel Lake would be required. It is proposed to obtain this storage between elevations 1,291.2 and 1,278.7 ft on Mabel Lake. The maximum recorded level is elevation 1,297 ft, but the normal minimum level is elevation 1,286.5 ft, so that the proposed operation would require drawing the lake level down 7.8 ft below the normal minimum. A channel would have to be dredged between the lake and the dam to allow this drawdown. Water would be retained in the lake during the spring freshet period for subsequent release in August and September. The full amount of the indicated storage required would only be needed under extreme conditions, and in some years little or no drawdown would be necessary. If the minimum required flow in Lower Shuswap River is set at 500 cfs, the study indicates that 57,000 acre-ft of storage would be required, and for this condition the storage would be between elevation 1,290 and 1,286.5 ft.

## EFFECT OF THE PROPOSED DIVERSION ON WATER REQUIREMENTS OF SHUSWAP RIVER AND SOUTH THOMPSON RIVER WATERSHEDS

Subsequent to its 1966 report, the Water Resources Service (1968) analyzed the present, future and ultimate water requirements of the South Thompson River watershed to determine the effects of the proposed diversion on the water sources necessary to supply these requirements.

Historic records of discharge in Shuswap River and the South Thompson River were adjusted to account for the present consumptive use of water, and the effects of the present operation of the Shuswap Falls hydroelectric plant and its associated storage on Sugar Lake. The data obtained for the South Thompson River at Chase and for three locations on the Shuswap River for the drought year 1929-30 are included in TABLE 25.

TABLE 25 - South Thompson and Shuswap River discharges in cfs under present development and for ultimate use of water in combination with Scheme 3 diversion to Okanagan Lake, for drought year 1929-30.

| MONTH | South Thompson at Chase Present | South Thompson at Chase Ultimate | Shuswap at Mara Lake Present | Shuswap at Mara Lake Ultimate | Shuswap at Enderby Present | Shuswap at Enderby Ultimate | Shuswap at Shuswap Falls Present | Shuswap at Shuswap Falls Ultimate |
|---|---|---|---|---|---|---|---|---|
| April | 2,634 | 2,783 | 970 | 1,133 | 944 | 1,100 | 691 | 693 |
| May | 6,527 | 5,952 | 2,994 | 1,169 | 2,770 | 1,100 | 2,061 | 2,065 |
| June | 19,563 | 15,666 | 9,214 | 5,974 | 8,641 | 6,021 | 4,651 | 4,530 |
| July | 17,185 | 12,869 | 3,097 | 601 | 2,964 | 1,100 | 1,434 | 1,181* |
| August | 7,275 | 4,661 | 1,467 | 563 | 1,403 | 1,100 | 776 | 534 |
| September | 4,864 | 3,502 | 1,121 | 1,397 | 1,072 | 1,418 | 604 | 629 |
| October | 3,848 | 3,505 | 831 | 882 | 794 | 790 | 412 | 430 |
| November | 3,278 | 3,241 | 783 | 689 | 783 | 644 | 449 | 457 |
| December | 2,550 | 2,579 | 824 | 805 | 837 | 781 | 584 | 594 |
| January | 2,204 | 2,276 | 773 | 780 | 743 | 722 | 462 | 469 |
| February | 2,177 | 2,270 | 735 | 772 | 704 | 717 | 458 | 463 |
| March | 2,530 | 2,633 | 936 | 955 | 875 | 889 | 532 | 533 |

* Incorrectly stated as 2065 cfs in Water Resources Service Report (1968).

The estimates of ultimate annual consumptive use of water in the South Thompson River watershed are summarized in TABLE 26.

TABLE 26 - Estimated ultimate annual consumptive use of water in the South Thompson River watershed for domestic, industrial and irrigation purposes.

| Section of Watershed | Ultimate Consumptive Water Use Acre-ft |
|---|---|
| Kamloops to Chase | 82,412 |
| Shuswap Lake exclusive of Shuswap River | 285,867 |
| Mara Lake to Mabel Lake | 115,740 |
| Mabel Lake to Sugar Lake | 65,140 |
| Total | 549,159 |

The minimum recorded annual discharge in the South Thompson River at Chase (in 1929-30) was 4,381,270 acre-ft and in the Shuswap River at Enderby was 1,357,096 acre-ft, in the same year. In comparison, the ultimate consumptive use of water in the watershed upstream from Chase was estimated to be 549,159 acre-ft, of which 180,880 acre-ft would be required from the Shuswap River above Mara Lake.

The Water Resources Service examined these consumptive uses in combination with the proposed Scheme 3 diversion to Okanagan Lake to determine the effect on discharges of the South Thompson and Shuswap Rivers (TABLE 25). It was concluded that the water resources of the South Thompson River system were adequate to supply the ultimate consumptive use diversions without undue depletion in any portion of the watershed, and that a major portion of the streamflow would be retained, which it was believed would be adequate for all non-consumptive purposes. However, it was noted that during July and August of a drought year the minimum flow in Lower Shuswap River below Enderby would be reduced substantially below the 1,100 cfs criterion because of consumptive use between Enderby and Mara Lake.

# EFFECTS OF THE PROPOSED DIVERSION ON THE FISHERY RESOURCES

The diversion of water from Lower Shuswap River to Okanagan Lake as proposed by the Water Resources Service (1966) would interfere seriously with the stocks of salmon and trout utilizing the Shuswap River system. The minimum flows proposed in the Okanagan River under Scheme 3 also would reduce seriously the production of sockeye which spawn in the Okanagan River. The following sections present detailed evaluation of each of the fishery problems that can be foreseen on the basis of present knowledge of the various fish species that would be affected. This evaluation is based on the diversion as previously detailed, and any modifications or changes in the proposal would require reconsideration of the effects on the fish.

## Potential loss of fish from Shuswap River through the diversion canal

The Water Resources Service proposal for diversion of water from Lower Shuswap River makes no provision for screens at the water intake to prevent salmon and trout from being diverted into the proposed canal. The proposed diversion in the period April to September would encompass the period of downstream migration of fry and smolts, and the period of upstream migration of adult salmon, trout and kokanee. In addition, chinook salmon fry and trout are resident in the river during this entire period. Because of the large amount of water to be diverted, major losses of all species down the canal could be expected. This loss would not necessarily be in direct proportion to the fraction of river flow being diverted. Monan et al (1969) found that up to 40% of chinook salmon migrants in the Snake River above the Brownlee reservoir were in the one-third of the river adjacent to the bank. Mains and Smith (1964) found a similar tendency for chinook fry and juveniles to be more concentrated near the river banks in the Snake River at Central Ferry and in the Columbia River above the Snake River. This loss of juvenile and adult salmon would deplete the salmon stocks to a serious extent, and the contribution of trout and kokanee to sports fishing would also be severely reduced.

The losses of fry and smolts as well as adult fish could largely be prevented by installation of suitable screens at the diversion intake. Despite the provision of screens designed in accordance with the best available information, it must be recognized that some losses of fry would occur as a result of impingement on the screens or exhaustion trying to escape from the screens. The magnitude of such losses cannot be determined in advance, and would depend on the condition and behavior of the fry, and the flow pattern in the river in the vicinity of the intake.

Fish Passage at the Proposed Diversion Dams near Enderby

The Water Resources Service reports do not indicate any provision for fish passage facilities at either of the proposed diversion dams near Enderby. At Site A, with a difference in elevation between headwater and tailwater of up to 35 ft, depending on discharge, all upstream migrations of salmon, trout and kokanee to their spawning grounds would be blocked. At Site B, there would be a difference in elevation between headwater and tailwater of up to 10 ft during the period April to September when the diversion gates are lowered. This structure would also obstruct all upstream migration to the spawning grounds.

The provision of fishways at either of these diversion dams would not guarantee satisfactory upstream passage of fish. Because the minimum flow and the undiverted water would be discharged through the spill gates at either dam, it would be difficult to ensure attraction of the fish to the fishway entrances, even with a fishway on each bank and auxiliary attraction flow discharged at the fishway entrances. In the occasional extreme drought period when the full diversion flow would be needed, and when discharge in Lower Shuswap River would also be low, the attraction problem could be minimized by discharging most of the minimum flow through the fishway entrance or adjacent gates in the dam. However, in most years, particularly before the predicted ultimate demand is reached, there would be large spills through the gates which would reduce any attraction to the fishways. Under these circumstances fish could be delayed before finding a fishway entrance. For sockeye salmon such delays could result in death before spawning or reduced reproductive capacity (Thompson, 1945).

Sudden changes in discharge in Shuswap River resulting from operation of the diversion could cause migrating fish to move downstream temporarily until a stable flow was established, thereby causing further delay of fish (Andrew and Geen,1960). A similar situation could be created at the end of the diversion season by release of water impounded in the forebay of the diversion dam. In addition, abrupt decreases in discharge can result in stranding of both adult and juvenile salmon and trout.

The downstream movements of fry and smolts in Lower Shuswap River would also be affected at either of the proposed diversion dams. In years with surplus water and large spills at the diversion dam the fish might not have any difficulty in finding passage through the dams. However, in drought years with only the specified minimum flow being discharged at the dam, fry in particular may have difficulty finding the spill outlet if it is submerged and may be delayed in their migration. Provision for surface spills would be necessary to minimize such delay. Turbulence and abrasion associated with passage of fry over or under gates may also result in injury of some fish (Andrew and Geen,1958).

### Fish Passage at the Proposed Mabel Lake Storage Dam

The Water Resources Service reports also do not indicate any provision for fish passage facilities at the Mabel Lake storage dam. With regulation as proposed, the lake elevation would range from 1,277 to 1,291.5 ft and the elevation of tailwater at the dam would range from 1,260 to about 1,278 ft. The differences between lake level and tailwater would range from 17 to 29 ft. This dam would completely obstruct all upstream migration of salmon to spawning grounds lying upstream, and would also halt any migration of sportsfish fry and adults into Mabel Lake.

A fishway would be required to provide upstream passage for adult salmon and trout. The operating conditions at the proposed dam would require a deep fishway of the weir and pool type with segmented weirs adjustable for variations in elevation and head difference. Such a fishway would be complex to operate and would require full coordination with storage regulating operations throughout the year. Such a fishway would not provide upstream passage for sportsfish fry, and these fish probably would have to be collected and transported into Mabel Lake.

As at the diversion dam sudden changes in discharge resulting from operation of the storage dam could cause upstream migrating fish to move downstream temporarily until a stable flow was established, thereby causing delay.

Advance salmon fry and smolts would be migrating out of Mabel Lake during April, May and June. At these times part of the normal outflow from the lake would be retained for subsequent release in August and September. Consequently these fish would have to pass under the spillway gates or through the submerged conduit at the proposed dam. Tests in a sluice gate at the Seton Creek dam with a head difference of 25 ft, showed a mean mortality of 7.4% to sockeye smolts (Andrew and Geen, 1958). While conditions for fish passage at the proposed Mabel Lake dam would not be strictly comparable to those at the Seton Creek dam, there would be sufficient turbulence and abrasion that significant mortality or injury could be expected.

## Flooding and Degrading of Spawning Grounds

The proposed diversion dam at Site B would have a forebay elevation of 1,150 ft or higher, creating an impoundment which would extend about 4.5 miles upstream at low river discharge, and would inundate scattered chinook salmon and kokanee spawning grounds in the section of river between mile 20 and mile 22 below Mabel Lake (FIGURE 4). If the diversion gates were removed at the end of September, water levels over these spawning grounds would return to near normal levels before the chinook salmon spawned, but the value of these areas would undoubtedly be reduced by accumulations of silt and debris during the period they were flooded.

The proposed diversion dam at Site A would have a forebay elevation of 1,185 ft, creating an impoundment which would extend 12.4 miles upstream. This impoundment would cover between 2 and 3 miles of sockeye spawning ground and about 12.4 miles of spawning ground used by kokanee. In addition, 6% of the chinook salmon spawning population utilize this area, as well as trout. The flooding of these spawning grounds would make them useless.

The proposed storage dam and dredged channel below Mabel Lake would destroy some sockeye spawning grounds and spawning area utilized by over 6% of the chinook salmon spawning population. The regulation of Mabel Lake below its normal elevation might also cause degrading of the lower reaches of tributaries to Mabel Lake, such as Wap Creek, Noisy Creek, Cottonwood Creek, and Middle Shuswap River and destroy spawning areas used by kokanee (Goodman, 1967). Obstructions could also be formed at the creek mouths which would prevent upstream migration of kokanee, salmon and trout.

## Migration Through Diversion Dam Impoundments

In the impoundments upstream from either of the proposed diversion dams at Site A or B the river velocity would be reduced and travel time of the water would be increased compared with the river. Estimates of water travel time in each impoundment for various discharges are given in TABLE 27.

TABLE 27 - Estimated travel time through impoundments above proposed diversion dams at Sites A and B, and through the same length of Lower Shuswap River.

| Impoundment | River Discharge cfs | Travel Time in Hours Existing River | Modified River |
|---|---|---|---|
| Site A at Elevation 1185 ft | 500 | 22.9 | |
| | 681 | | 652.5 |
| | 878 | 17.1 | |
| | 1,161 | | 388.4 |
| | 1,597 | | 282.1 |
| | 2,000 | 12.2 | |
| | 2,052 | | 223.4 |
| | 2,487 | | 182.8 |
| | 3,310 | 10.2 | |
| | 4,000 | 9.5 | |
| Site B at Elevation 1150 ft | 500 | 10.7 | 35.2 |
| | 1,000 | 7.0 | 17.3 |
| | 2,487 | | 7.1 |
| | 3,310 | 3.0 | |
| | 5,480 | 2.8 | |

For the storages and diversions estimated by the Water Resources Service with ultimate development in the Shuswap River watershed and the North and South Okanagan Regions, the mean monthly discharges in Lower Shuswap River upstream from either of the diversion dams in the drought period 1929-1931 are shown in TABLE 28.

TABLE 28 - Mean monthly discharge of Lower Shuswap River above proposed diversion dams at Sites A or B for 1929-1931 water years with ultimate development, and at Enderby for present development, in cfs.

| | | ULTIMATE DEVELOPMENT | | | PRESENT DEVELOPMENT |
|---|---|---|---|---|---|
| | MONTH | Lower Shuswap River at Enderby | Canal Diversion | Lower Shuswap River above Diversion | Lower Shuswap River at Enderby |
| 1929 | April | 1,100 | 292 | 1,392 | 944 |
| | May | 1,100 | 750 | 1,850 | 2,770 |
| | June | 6,021 | 900 | 6,921 | 8,641 |
| | July | 1,100 | 888 | 1,988 | 2,964 |
| | August | 1,100 | 888 | 1,988 | 1,403 |
| | September | 1,418 | 433 | 1,851 | 1,072 |
| | October | 790 | 19 | 809 | 794 |
| | November | 644 | 20 | 664 | 783 |
| | December | 781 | 19 | 800 | 837 |
| 1930 | January | 722 | 19 | 741 | 743 |
| | February | 717 | 21 | 738 | 704 |
| | March | 889 | 19 | 908 | 875 |
| | April | 1,100 | 350 | 1,450 | 2,647 |
| | May | 2,325 | 839 | 3,164 | 3,814 |
| | June | 5,215 | 1,000 | 6,215 | 6,612 |
| | July | 1,266 | 967 | 2,233 | 3,590 |
| | August | 1,100 | 967 | 2,067 | 1,454 |
| | September | 1,493 | 467 | 1,960 | 979 |
| | October | 709 | 19 | 728 | 715 |
| | November | 862 | 20 | 882 | 947 |
| | December | 767 | 19 | 786 | 894 |
| 1931 | January | 862 | 19 | 881 | 863 |
| | February | 754 | 21 | 775 | 793 |
| | March | 1,203 | 19 | 1,222 | 1,103 |

The estimated travel times through the impoundments above Sites A and B for the discharges as proposed and for the corresponding discharges in the existing river for the water years 1929-1931 are given in TABLE 29. The changes of 18 hr or less in travel time through the river above the Site B dam are not considered to be sufficient to have any significant effect on upstream migration of adult fish or on the downstream migration of fry and smolts.

TABLE 29 - Estimated travel time through impoundments above proposed diversion dams at Sites A and B, and through the same length of the existing Lower Shuswap River for water years 1929-1931 and ultimate development as proposed by the Water Resources Service.

| | | TRAVEL TIME IN HOURS | | | |
|---|---|---|---|---|---|
| | | Site A Impoundment | | Site B Impoundment | |
| | MONTH | Existing River | With Dam at Elev. 1185 ft | Existing River | With Dam at Elev. 1150 ft |
| 1929 | April | 16.2 | 322 | 7.2 | 12.7 |
| | May | 11.0 | 248 | 3.4 | 9.5 |
| | June | - | - | - | - |
| | July | 10.7 | 236 | 3.2 | 8.9 |
| | August | 14.0 | 236 | 5.5 | 8.9 |
| | September | 15.5 | 248 | 6.6 | 9.5 |
| | October | 17.9 | 547 | 8.2 | 21.7 |
| | November | 18.0 | 672 | 8.2 | 26.5 |
| | December | 17.4 | 554 | 7.8 | 21.8 |
| 1930 | January | 18.4 | 600 | 8.5 | 23.7 |
| | February | 19.0 | 600 | 8.8 | 24.0 |
| | March | 17.0 | 488 | 7.6 | 19.3 |
| | April | 11.1 | 310 | 3.5 | 12.2 |
| | May | 9.7 | - | 3.0 | - |
| | June | - | - | - | - |
| | July | 10.0 | 204 | 3.0 | 8.0 |
| | August | 13.9 | 228 | 5.4 | 8.6 |
| | September | 16.2 | 236 | 7.1 | 9.1 |
| | October | 18.8 | 610 | 8.7 | 24.2 |
| | November | 16.5 | 504 | 7.2 | 20.0 |
| | December | 16.9 | 568 | 7.5 | 22.4 |
| 1931 | January | 17.2 | 504 | 7.7 | 19.8 |
| | February | 17.9 | 575 | 8.1 | 22.6 |
| | March | 15.4 | 368 | 6.4 | 14.3 |

Water travel time through the river above Site A dam from July to October during the period of upstream migration of adult fish could be increased as much as 25 days. Under these low velocity conditions, it is possible the fish would wander in the impoundment and some may not complete their migration (Andrew and Geen, 1960).

The changes in travel time during the spring months when fry are moving downstream could have very significant effects on behavior and survival of fry. In the natural river the fry orient to the current (negative rheotaxis) and swim actively downstream during their nocturnal migration (Hartman, Heard and Drucker, 1967). With a normal flow time of 16 hr or less in this section of river, fry would migrate through the area very rapidly, probably in 2 days or less. However, in the impoundment of the dam at Site A, the water travel time would be as much as 322 hr. With reduced current for orientation fry might tend to remain in the impoundment, or at least be greatly delayed in reaching Mara Lake. Because of possible starvation in the restricted area of the impoundment and increased opportunity for predation, such a large increase in the time required to reach the rearing area in Mara Lake and Shuswap Lake could greatly reduce fry survival.

### Discharge and Temperature at Spawning Grounds in Lower Shuswap River above the Diversion Impoundments

The method of regulating the outflow of Mabel Lake proposed by the Water Resources Service would alter discharge over the spawning grounds in the Lower Shuswap River, as previously indicated in TABLE 28. The indicated small changes in flows during the salmon spawning period in October and November and the winter incubation period should not affect significantly the utilization of the spawning grounds or the maintenance of water cover over the deposited eggs during the winter.

The reductions in discharge in the spring months would not affect significantly the travel time for fry or smolts through this section of river.

During the spring months, when water would be stored in Mabel Lake, discharge in the river would be less than for the normal river. At this time of year, the river generally warms as it flows downstream (TABLE 30). With reduced flow and

TABLE 30 - Mean daily water temperatures in $^{O}F$ for Lower Shuswap River at Hupel and at Grindrod, April, May, June, 1968.

| | APRIL | | | MAY | | | JUNE | | |
|---|---|---|---|---|---|---|---|---|---|
| DATE | Hupel | Grindrod | Diff. | Hupel | Grindrod | Diff. | Hupel | Grindrod | Diff. |
| 1 | 41.5 | 42.5 | 1.0 | 43.8 | 47.3 | 3.5 | 54.3 | 54.5 | 0.2 |
| 2 | 41.0 | 44.2 | 3.2 | 46.0 | 46.5 | 0.5 | 51.5 | 53.5 | 2.0 |
| 3 | 40.9 | 43.8 | 2.9 | 47.6 | 48.7 | 1.1 | 51.5 | 52.5 | 1.0 |
| 4 | 40.8 | 43.0 | 2.2 | 45.9 | 50.3 | 4.4 | 52.0 | 53.3 | 1.3 |
| 5 | 41.3 | 44.5 | 3.2 | 43.3 | - | - | 53.1 | 54.0 | 0.9 |
| 6 | 41.0 | 44.0 | 3.0 | 44.4 | 44.8 | 0.4 | 54.8 | 54.5 | -0.3 |
| 7 | 41.5 | 43.5 | 2.0 | 46.5 | 46.1 | -0.4 | 54.1 | 55.8 | 1.7 |
| 8 | 41.8 | 43.5 | 1.7 | 48.0 | 48.0 | 0.0 | 54.3 | 54.9 | 0.6 |
| 9 | 43.5 | 44.8 | 1.3 | 47.8 | 49.5 | 1.7 | 54.5 | 56.0 | 1.5 |
| 10 | 42.8 | 46.0 | 3.2 | 48.3 | 51.0 | 2.7 | 54.5 | 56.5 | 2.0 |
| 11 | 41.5 | 45.0 | 3.5 | 48.9 | 51.0 | 2.1 | 53.5 | 55.5 | 2.0 |
| 12 | 40.8 | 42.8 | 2.0 | 49.3 | 51.0 | 1.7 | 52.8 | 54.0 | 1.2 |
| 13 | 39.8 | 40.8 | 1.0 | 51.7 | 51.0 | -0.7 | 53.5 | 54.0 | 0.5 |
| 14 | 40.5 | 39.5 | -1.0 | 49.3 | 52.4 | 3.1 | 53.9 | 54.5 | 0.6 |
| 15 | 40.3 | 40.5 | 0.2 | 50.2 | 51.5 | 1.3 | 55.0 | 55.5 | 0.5 |
| 16 | 41.3 | 41.3 | 0.0 | 50.8 | 51.5 | 0.7 | 56.5 | 56.3 | -0.2 |
| 17 | 42.3 | 43.4 | 1.1 | 51.5 | 52.3 | 0.8 | 56.3 | 56.8 | 0.5 |
| 18 | 40.8 | 44.5 | 3.7 | 52.2 | 53.0 | 0.8 | 54.5 | 56.0 | 1.5 |
| 19 | 41.5 | 44.5 | 3.0 | 52.2 | 53.5 | 1.3 | 56.7 | 56.5 | -0.2 |
| 20 | 41.8 | 44.2 | 2.4 | 50.5 | 52.3 | 1.8 | 54.7 | 57.0 | 2.3 |
| 21 | 42.8 | - | - | 51.5 | 51.0 | -0.5 | 55.0 | 56.5 | 1.5 |
| 22 | 43.3 | 47.1 | 3.8 | 52.8 | 52.0 | -0.8 | 55.5 | 56.5 | 1.0 |
| 23 | 43.8 | 47.0 | 3.2 | 52.3 | 52.5 | 0.2 | 56.7 | 57.5 | 0.8 |
| 24 | 43.5 | 46.0 | 2.5 | 52.8 | 51.5 | -1.3 | 56.9 | 58.0 | 1.1 |
| 25 | 43.5 | 46.0 | 2.5 | 52.0 | 53.5 | 1.5 | 58.3 | 58.3 | 0.0 |
| 26 | 44.5 | 46.9 | 2.4 | 50.3 | 53.5 | 3.2 | 57.8 | 59.0 | 1.2 |
| 27 | 43.7 | 47.5 | 3.8 | 52.7 | 52.5 | -0.2 | 53.7 | 56.8 | 3.1 |
| 28 | 45.8 | 48.4 | 2.6 | 53.5 | 54.0 | 0.5 | 54.5 | 54.8 | 0.3 |
| 29 | 47.0 | 50.8 | 3.8 | 53.6 | 55.0 | 1.4 | 55.5 | 56.5 | 1.0 |
| 30 | 45.3 | 50.5 | 5.2 | 51.1 | 53.4 | 2.3 | 55.6 | 56.8 | 1.2 |
| 31 | | | | 54.3 | 53.0 | -1.3 | | | |
| Mean Discharge at Enderby - cfs | | 1,700 | | | 6,730 | | | 12,100 | |

TABLE 31 - Mean daily water temperatures in $^{\circ}F$ for Lower Shuswap River at Hupel and at Grindrod, July, August, September, 1968.

| | JULY | | | AUGUST | | | SEPTEMBER | | |
|---|---|---|---|---|---|---|---|---|---|
| DATE | Hupel | Grindrod | Diff. | Hupel | Grindrod | Diff. | Hupel | Grindrod | Diff. |
| 1 | 55.9 | 57.5 | 1.6 | 69.4 | 69.8 | 0.4 | 63.3 | 64.5 | 1.2 |
| 2 | 57.3 | 58.3 | 1.0 | 70.3 | 71.1 | 0.8 | 63.5 | 63.0 | -0.5 |
| 3 | 61.0 | 60.5 | -0.5 | 71.7 | 73.8 | 2.1 | 63.5 | 63.5 | 0.0 |
| 4 | 62.3 | 62.8 | 0.5 | 72.1 | 72.4 | 0.3 | 63.8 | 63.3 | -0.5 |
| 5 | 62.5 | 63.0 | 0.5 | 71.0 | 72.0 | 1.0 | 65.0 | 64.3 | -0.7 |
| 6 | 62.5 | 64.3 | 1.8 | 68.5 | 70.5 | 2.0 | 64.5 | 65.3 | 0.8 |
| 7 | 63.8 | 64.0 | 0.2 | 68.8 | 69.5 | 0.7 | 64.0 | 64.0 | 0.0 |
| 8 | 63.9 | 66.0 | 2.1 | 69.3 | 69.3 | 0.0 | 63.8 | 64.8 | 1.0 |
| 9 | 64.3 | 65.8 | 1.5 | 68.5 | 69.3 | 0.8 | 64.3 | 64.8 | 0.5 |
| 10 | 65.6 | 65.5 | -0.1 | 69.1 | 69.3 | 0.2 | 64.0 | 64.0 | 0.0 |
| 11 | 66.6 | 66.5 | -0.1 | 68.7 | - | - | 64.5 | 64.8 | 0.3 |
| 12 | - | 67.0 | - | 64.8 | 68.0 | 3.2 | 65.0 | 65.0 | 0.0 |
| 13 | 64.5 | 66.0 | 1.5 | 64.2 | 66.3 | 2.1 | 64.3 | 63.3 | -1.0 |
| 14 | 61.8 | - | - | 64.5 | 65.5 | 1.0 | 62.5 | 61.8 | -0.7 |
| 15 | 62.4 | 62.0 | -0.4 | 64.0 | 64.5 | 0.5 | 61.8 | 61.0 | -0.8 |
| 16 | 63.5 | 63.5 | 0.0 | 64.3 | 64.5 | 0.2 | 61.3 | 59.8 | -1.5 |
| 17 | 63.1 | 65.0 | 1.9 | 64.8 | 65.5 | 0.7 | 59.0 | 59.3 | 0.3 |
| 18 | 63.5 | 63.5 | 0.0 | 64.8 | 64.8 | 0.0 | 59.8 | 57.5 | -2.3 |
| 19 | 61.5 | 63.3 | 1.8 | 64.5 | 65.2 | 0.7 | 59.5 | 58.5 | -1.0 |
| 20 | 59.8 | 62.0 | 2.2 | 63.0 | 64.5 | 1.5 | 58.5 | 57.5 | -1.0 |
| 21 | 60.5 | 61.5 | 1.0 | 63.0 | 63.3 | 0.3 | 58.5 | 57.3 | -1.2 |
| 22 | 60.5 | 62.3 | 1.8 | 63.5 | 63.0 | -0.5 | 57.8 | 57.5 | -0.3 |
| 23 | 60.5 | 63.0 | 2.5 | 63.3 | 62.8 | -0.5 | 58.5 | 57.5 | -1.0 |
| 24 | 63.8 | 63.5 | -0.3 | 62.5 | 62.5 | 0.0 | 58.5 | 57.5 | -1.0 |
| 25 | 64.5 | 65.0 | 0.5 | 60.5 | 62.3 | 1.8 | 59.0 | 57.8 | -1.2 |
| 26 | 66.6 | 66.3 | -0.3 | 60.8 | 61.8 | 1.0 | 58.8 | 58.5 | -0.3 |
| 27 | 68.1 | 68.8 | 0.7 | 61.0 | 60.8 | -0.2 | 58.5 | 57.8 | -0.7 |
| 28 | 69.8 | 70.3 | 0.5 | 61.8 | 61.5 | -0.3 | 58.5 | 57.3 | -1.2 |
| 29 | 69.2 | 70.9 | 1.7 | 62.3 | 62.5 | 0.2 | 58.8 | 58.3 | -0.5 |
| 30 | 68.1 | 69.5 | 1.4 | 62.5 | 63.5 | 1.0 | 58.8 | 59.0 | 0.2 |
| 31 | 68.2 | 69.4 | 1.2 | 63.8 | 63.5 | -0.3 | | | |
| Mean Discharge at Enderby - cfs | | 7,100 | | | 2,630 | | | 3,450 | |

the accompanying reduced water depth and increased travel time, the water temperature would increase more than normal. However on the basis of the temperature rise recorded in 1968, it is not anticipated that the increases caused by reduced flows would be very great in the section of river above the impoundments.

In August and September, discharges would be greater than in the normal river and the increases or decreases in temperature which normally occur as the water flows downstream (TABLE 31) would tend to be reduced. However, the temperature of Lower Shuswap River at this time would depend largely on the temperature of the water being discharged from storage on Mabel Lake. For the existing natural outlet, the discharge from Mabel Lake is drawn largely from the warm surface layers. However, with the large drawdown of lake level required by the proposed regulation of flow, water could be drawn from as low as 28 ft below the lake surface. Water at this level could be $10^{\circ}F$ to $20^{\circ}F$ colder than at the surface (FIGURE 16). These reduced temperatures could affect the rearing of the chinook fry which remain in the river until they migrate as smolts.

Because of the proposed rapid drawdown of Mabel Lake during August and September, water temperatures in Lower Shuswap River in early October could be lower than normal, but as the lake surface temperature is modified by the weather, temperatures probably would soon approach normal (FIGURE 17) and remain so during the winter. Lowering of water temperature during the early part of the incubation period of salmon eggs would delay the development of the eggs and could cause the fry to hatch and emerge from the gravel at a time when environmental conditions were not conducive to maximum survival (Andrew and Geen, 1960).

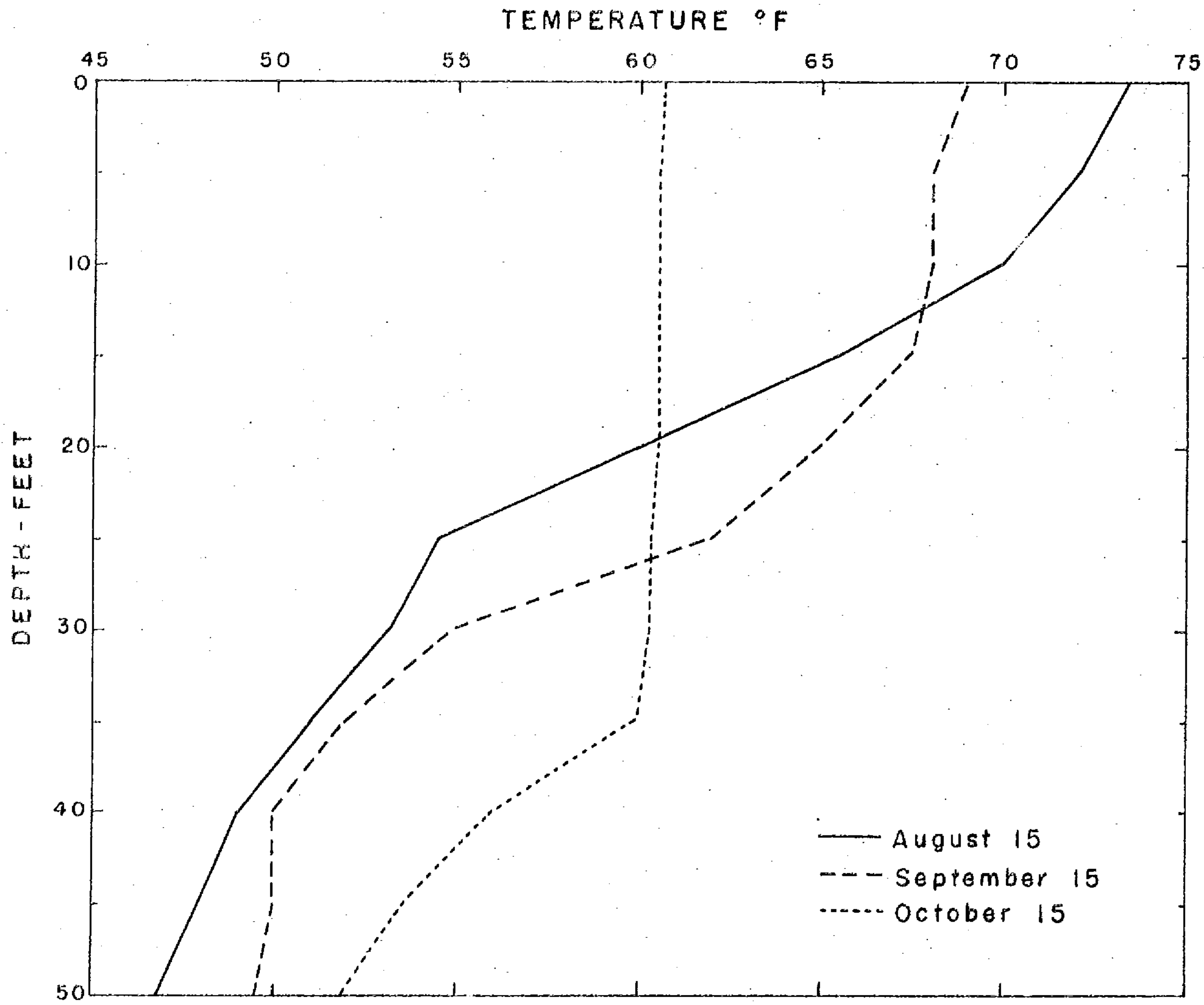


FIGURE 16 - Mabel Lake bathythermographs, August, September and October, 1957.

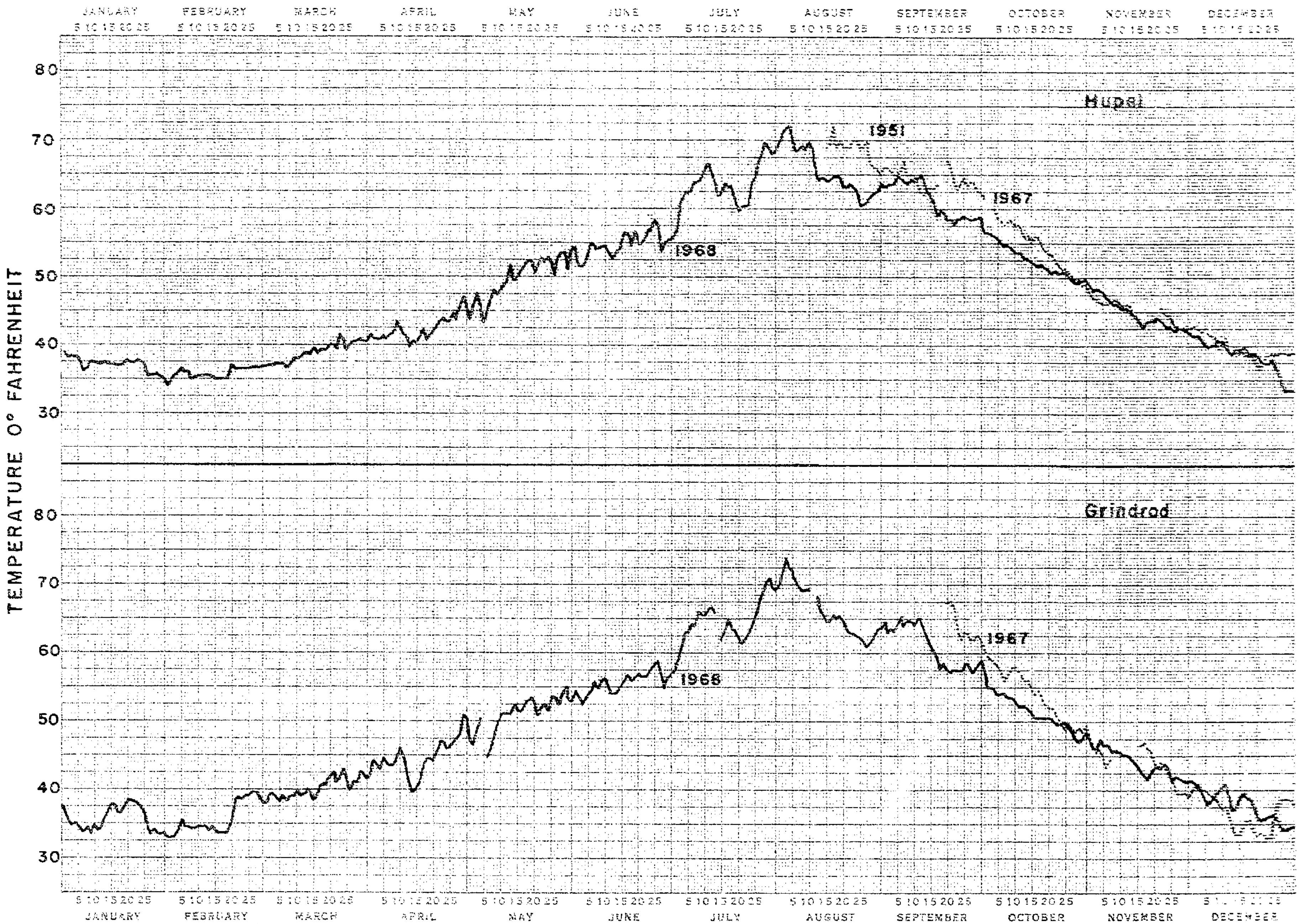


FIGURE 17 - Mean daily water temperatures in Lower Shuswap River at Hupel and Grindrod, 1951, 1967, 1968.

Water Temperature in the Diversion Dam Impoundments

As previously mentioned, the impoundments above either of the proposed diversion dams would increase the time required for water to flow down Lower Shuswap River. The impoundments also would increase the depth of flowing water in those portions of the river. These changes in characteristics of the river would affect the temperature of the river in the impoundments, as well as downstream.

A detailed study of the effects of the impoundments on river temperature would require records of air temperature and humidity, water temperature, wind velocity, solar radiation, back radiation, and evaporation, most of which are not available for the Shuswap River valley. However, it was considered that an indication of the magnitude of the anticipated temperature changes could be obtained using available records from weather stations within the same climatic zone, together with estimates of solar and back radiation and evaporation determined from established principles (Raphael, 1961).

Because of the many possible combinations of the variables that would affect water temperature, the preliminary studies were limited to selected conditions which would result in maximum changes in temperatures. The periods selected for study were the beginning of July when incoming solar radiation would be near maximum, and the end of September when the river would normally start to cool as it flows downstream. Methods described by Raphael (1961) were used to calculate the heat budget of the water and the resulting changes in water temperature. In making the calculations a sequence of clear hot days was assumed with a wind speed of 5 mph, barometric pressure of 28.8 in hg, and radiation, humidity and air temperature as shown in TABLE 32 and TABLE 33. It was also assumed that turbulence in the river would prevent stratification. The river discharges indicated by the 1966 Water Resources Service studies were used, which do not include allowance for future consumptive use of water within the Shuswap River Valley. However, it is considered the results obtained are sufficiently indicative of the changes that might occur to serve present purposes. Once a definite plan of development is established, more detailed studies of potential temperature changes may be necessary.

TABLE 32 - Mean daily solar radiation, relative humidity and air temperature used for calculating changes in mean daily water temperature in Lower Shuswap River.

| PERIOD | Solar Radiation BTU/sq ft/day | Relative Humidity % | Air Temp. °F |
|---|---|---|---|
| July | | | |
| Days 1-3 | 2907 | 69 | 72 |
| Day 4 | 2878 | 69 | 72 |
| Day 5 | 2870 | 69 | 72 |
| Day 6 | 2863 | 69 | 72 |
| Day 7 | 2856 | 69 | 72 |
| September | | | |
| Day 1 | 1760 | 79.5 | 60 |

TABLE 33 - Mean hourly solar radiation, relative humidity and air temperature used for calculating changes in mean hourly water temperatures in Lower Shuswap River for a day in early July.

| Standard Time Hours | Solar Radiation BTU/sq ft/hr | Relative Humidity % | Air Temp. °F |
|---|---|---|---|
| 0-1 | 0 | 84.6 | 55.0 |
| 1-2 | 0 | 86.8 | 53.5 |
| 2-3 | 0 | 88.1 | 52.5 |
| 3-4 | 2.0 | 89.0 | 54.0 |
| 4-5 | 19.5 | 88.8 | 57.5 |
| 5-6 | 61.5 | 85.9 | 61.5 |
| 6-7 | 115.5 | 81.3 | 65.5 |
| 7-8 | 169.5 | 76.0 | 69.0 |
| 8-9 | 219.5 | 71.0 | 72.5 |
| 9-10 | 262.0 | 66.1 | 75.5 |
| 10-11 | 292.0 | 61.7 | 79.0 |
| 11-12 | 306.0 | 57.8 | 82.5 |
| 12-13 | 306.0 | 54.0 | 85.5 |
| 13-14 | 292.0 | 50.5 | 89.5 |
| 14-15 | 262.0 | 47.5 | 91.5 |
| 15-16 | 219.5 | 45.4 | 89.5 |
| 16-17 | 169.5 | 45.4 | 85.5 |
| 17-18 | 115.5 | 47.9 | 80.0 |
| 18-19 | 61.5 | 51.5 | 74.5 |
| 19-20 | 19.5 | 56.3 | 70.0 |
| 20-21 | 2.0 | 66.0 | 66.5 |
| 21-22 | 0 | 75.3 | 63.5 |
| 22-23 | 0 | 80.1 | 60.5 |
| 23-24 | 0 | 83.0 | 57.5 |

The temperature in the impoundment above the proposed dam at Site A was examined for a drought year regulated flow of 2,487 cfs in July 1929 (based on Water Resources Service, 1967). At this discharge the flow through time would be approximately 8 days. Records of surface water temperatures at Mabel Lake (TABLE 34) indicated that a temperature of 70°F or higher might occur early in July, so calculations were made of the temperature rise that would occur with water entering the impoundment with mean daily temperatures of 70°F and 75°F.

TABLE 34 - Water surface temperatures of Mabel Lake in July.

| DATE | Time PST | Temperature °F |
|---|---|---|
| July 24, 1956 | 1115 | 73 |
| July 12, 1957 | 0820 | 66 |
| July 12, 1958 | 1115 | 69 |
| July 11, 1959 | 1030 | 67 |
| July 12, 1960 | 1300 | 69 |
| July 13, 1961 | 1000 | 75 |
| July 12, 1962 | 0935 | 63.2 |
| July 14, 1963 | 1105 | 67.0 |
| July 13, 1964 | 1300 | 70.5 |
| July 12, 1965 | 1010 | 63.8 |
| July 2, 1966 | 1200 | 58.5 |
| July 13, 1967 | 0800 | 66.5 |
| July 10, 1968 | 0830 | 68.5 |

TABLE 35 - Estimated temperature increase in impoundment above Site A dam early in July with a discharge of 2,487 cfs.

| | Day | Temperature °F | |
|---|---|---|---|
| Initial Temperature | 0 | 70 | 75 |
| Final Temperature | 8 | 80.7 | 82.8 |
| Increase | | 10.7 | 7.8 |

The estimates (TABLE 35) indicate a temperature rise of 8 to 11°F within the impoundment depending on starting temperature, with temperatures at the downstream end of the impoundment reaching about 80°F or more. In the unregulated river, the discharge was 3,310 cfs in July of the same year, and with a starting temperature of 70°F it is estimated (FIGURE 18) the temperature rise would be 5.3°F.

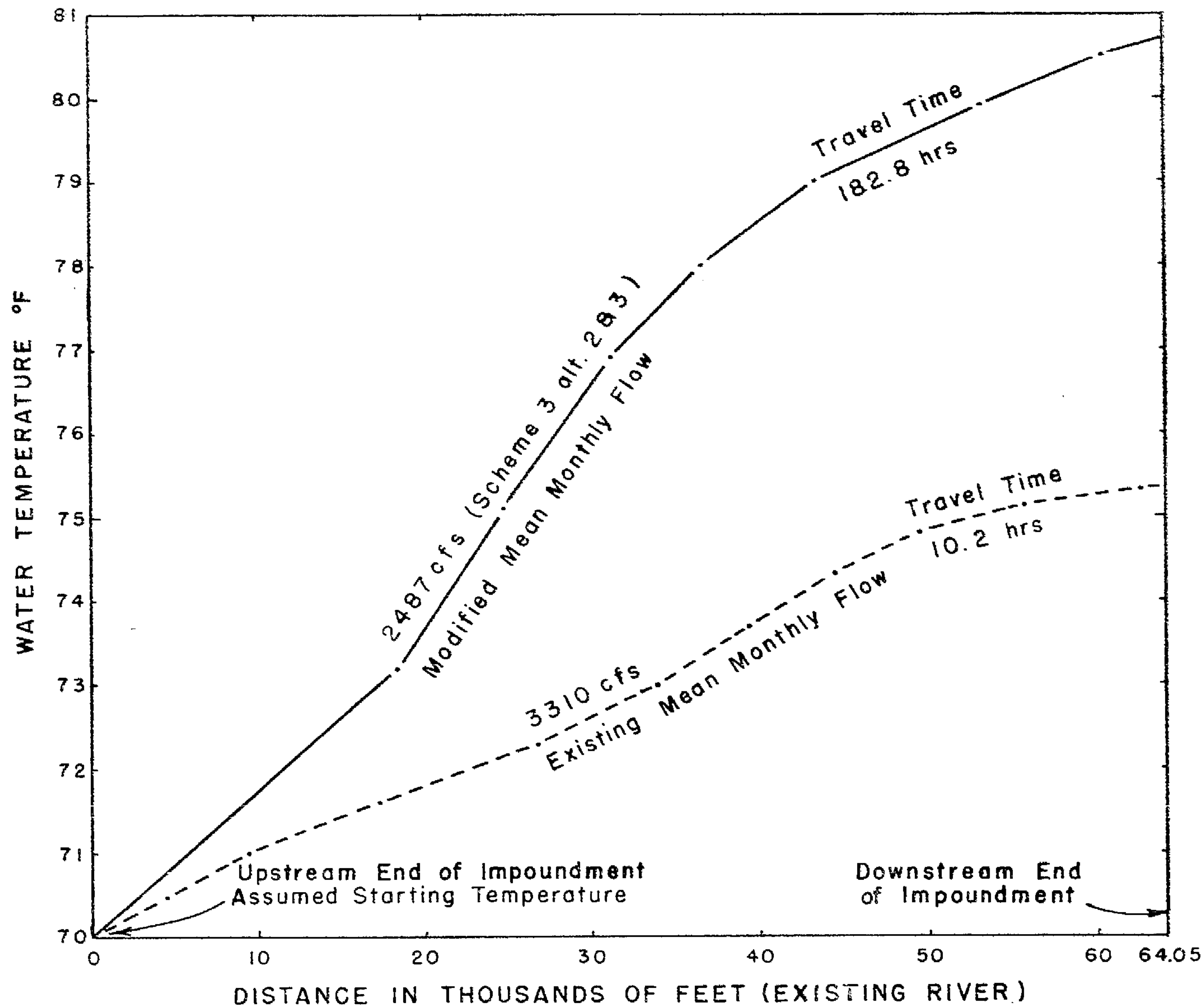


FIGURE 18 - Effect of impoundment above diversion dam A on temperature in Shuswap River, during July 1929 for the extreme weather conditions and water temperatures assumed.

While temperatures this high may only occur in extreme cases, the results illustrate the very significant changes in temperature that could be caused in the summer by the proposed dam at Site A. Such high temperatures could result in mortality to resident salmon and trout (Brett, 1952).

A similar study was made for the Site A dam for the latter part of September, using a drought year regulated flow of 2,052 cfs and a mean daily temperature of 67°F (FIGURE 17) for water entering the impoundment. At this discharge the flow through time would be 9 days. For these conditions it was calculated that the water temperature would increase 3.0°F. In the unregulated river the flow was 878 cfs in September, the travel time would be 17 hr, and the calculated temperature rise for the same climatic condition was 3.5°F. At this time of year the effects of reduced velocity in the impoundment were aprroximately counterbalanced by the increased depth.

The temperature changes in the impoundment above the proposed dam at Site B were examined in a similar way, but because of the shorter travel times, estimates were made for each hour. For these estimates a starting temperature of 70°F was used, corresponding to the mid-day temperature. In the impoundment at a regulated flow of 2,487 cfs travel time would be 7 hr and the calculated temperature rise was 2.26°F. In the unregulated river with a flow of 3,310 cfs and a travel time of 3 hr, the calculated temperature rise was 2.23°F. For this impoundment under the assumed conditions the effects of increased depth and reduced velocity approximately counterbalance. Since these calculations indicated the impoundment would have only minor effect on temperature under extreme conditions no studies were made of September conditions.

### Water Temperatures in Lower Shuswap River Downstream from the Diversion

Water temperatures in Lower Shuswap River downstream from the proposed diversion were examined in a similar manner described for the impoundments above the diversion.

At the proposed July 1929 discharge of 1,567 cfs below the diversion (Water Resources Service, 1967), the travel time from Site B to Mara Lake would be approximately 36 hr, depending on Mara Lake elevation. With a starting temperature of 67°F at 6 a.m. the rise in temperature to Mara Lake was calculated to be 10.14$^{O}$F. With the minimum flow of 1,100 cfs estimated by the Water Resources Service (1968) when consumptive use of water in the Shuswap River valley is accounted for, the temperature increase would be even greater. With the unregulated July 1929 flow of 3,310 cfs, the travel time would be approximately 24 hr, and with a starting temperature of 67$^{O}$F the rise in temperature to Mara Lake was calculated to be only 4.8$^{O}$F under the same climatic conditions.

Using the dam at Site A for the diversion, initial water temperatures at the dam would be higher than for the Site B dam because of warming in the impoundment as already discussed. With higher starting temperatures at the diversion, the temperature increase to Mara Lake would not be as large as estimated above for Site B, but the final temperatures at Mara Lake could be higher. Increases in temperature during July and August at the start of the spawning migrations of chinook salmon and kokanee, when water temperatures are already high, could delay the migration of these fish and could also affect their survival (Andrew and Geen, 1960).

In September, it is estimated there could be a temperature rise of 3.4$^{O}$F between Site B and Mara Lake at a flow of 500 cfs under extreme climatic conditions. However since as previously shown the impoundments would not alter temperatures very much in the latter part of September, similar increases could occur in the normal river under similar climatic conditions.

## Flows Required for Migration Between Mara Lake and the Proposed Diversion Sites

The Water Resources Service studies have considered three alternative minimum flows in the Shuswap River below the proposed diversion at Enderby, 500 cfs, 800 cfs and 1,100 cfs, and selected 1,100 cfs as the basis for detailed examination of the proposed diversion. While the stated minimum flow would be supplied immediately below the diversion, the estimated future consumptive use of water from the river down to Mara Lake would reduce this flow substantially (TABLE 25).

Lower Shuswap River below Enderby is the migration route for salmon, trout and kokanee enroute to and from the spawning grounds located upstream. It is essential that sufficient flow be maintained in the river for these fish to migrate without obstruction. In addition, any minimum flow established should

TABLE 36 — Minimum discharge in CFS, Shuswap River at Enderby and at Hupel, April and September, 1912-1936 and 1951-1964.

| YEAR | LOWER SHUSWAP RIVER AT ENDERBY April | LOWER SHUSWAP RIVER AT ENDERBY September | LOWER SHUSWAP RIVER AT HUPEL April | LOWER SHUSWAP RIVER AT HUPEL September |
|---|---|---|---|---|
| 1912 | 755 | 1,680 | | |
| 1913 | 603 | 2,180 | | |
| 1914 | 1,020 | 1,210 | | |
| 1915 | 1,260 | 1,340 | | |
| 1916 | 1,620 | 1,520 | | |
| 1917 | 500 | 1,200 | | |
| 1918 | 1,500 | 1,200 | | |
| 1919 | 770 | 1,200 | | |
| 1920 | 725 | 1,950 | | |
| 1921 | 1,090 | 1,500 | | |
| 1922 | 550 | 1,340 | | |
| 1923 | 920 | 1,070 | | |
| 1924 | 890 | 1,150 | | |
| 1925 | 1,320 | 1,230 | | |
| 1926 | 1,120 | 1,090 | | |
| 1927 | 870 | 1,600 | | |
| 1928 | 2,510 | 795 | 1,880 | 775 |
| 1929 | 511 | 758 | 520 | 708 |
| 1930 | 822 | 790 | 565 | 750 |
| 1931 | 1,110 | 1,050 | 844 | 911 |
| 1932 | 1,600 | 1,480 | 1,240 | 1,290 |
| 1933 | 1,700 | 1,550 | 799 | 1,360 |
| 1934 | 2,670 | 1,040 | 1,780 | 945 |
| 1935 | 1,070 | 1,380 | 922 | 1,330 |
| 1936 | | | | |
| 1951 | | | | |
| 1952 | | | 602 | 1,070 |
| 1953 | | | 822 | 1,230 |
| 1954 | | | 1,290 | 3,940 |
| 1955 | | | 836 | 1,230 |
| 1956 | | | 836 | 1,050 |
| 1957 | | | 912 | 1,460 |
| 1958 | | | 984e | 944 |
| 1959 | | | 926 | 1,860 |
| 1960 | | 1,490 | 2,480e | 1,370 |
| 1961 | 1,550 | 1,220 | 1,330 | 1,310 |
| 1962 | 1,010 | 1,700 | 705 | 1,780 |
| 1963 | 1,250 | 1,360 | 1,360 | 1,470 |
| 1964 | 973 | 2,770 | 725 | 2,680 |

e - estimated

be exclusive of possible future consumptive use of water from the river between Mara Lake and the diversion site.

Normal minimum river discharge in April ranges from 500 cfs to 2,500 cfs, and in September ranges from 708 cfs to 3,940 cfs (TABLE 36).

The minimum flow in April most frequently is between 500 and 1,250 cfs, and in September is most frequently between 1,000 and 1,250 cfs (TABLE 37).

TABLE 37 - Frequency of minimum flows in Shuswap River at Enderby in April and September.

| FLOW RANGE cfs | OCCURRENCE IN 29 YEARS OF RECORDS April | September |
|---|---|---|
| 500-750 | 5 | - |
| 750-1000 | 7 | 3 |
| 1000-1250 | 7 | 11 |
| 1250-1500 | 2 | 7 |
| 1500-1750 | 5 | 5 |
| 1750-2000 | - | 1 |
| 2000-2250 | - | 1 |
| 2250-2500 | - | - |
| 2500-2750 | 2 | - |
| 2750-3000 | - | 1 |

It is considered therefore that the minimum flow of 1,100 cfs in April should be satisfactory for the downstream migration of fry and smolts. During May, June, July, and August the river discharge at Enderby would be 1,100 cfs or more, depending on watershed runoff, but would be reduced from existing conditions. With reduced discharge in July and August and consequently reduced water depth and increased travel time to Mara Lake, the temperature of the river would increase more than under existing conditions, and could affect the migration of adult salmon as previously discussed. In September the minimum flow of 1,100 cfs should be satisfactory for fish migration, since salmon are known to have migrated up Lower Shuswap River in a flow of 944 cfs in 1958.

## Rearing in Mabel, Mara and Shuswap Lakes

The proposed regulation of Mabel Lake, including lowering the minimum level 7.8 ft below normal, would alter the seasonal pattern of water levels very significantly (FIGURE 19), as well as the outflow discharges. This

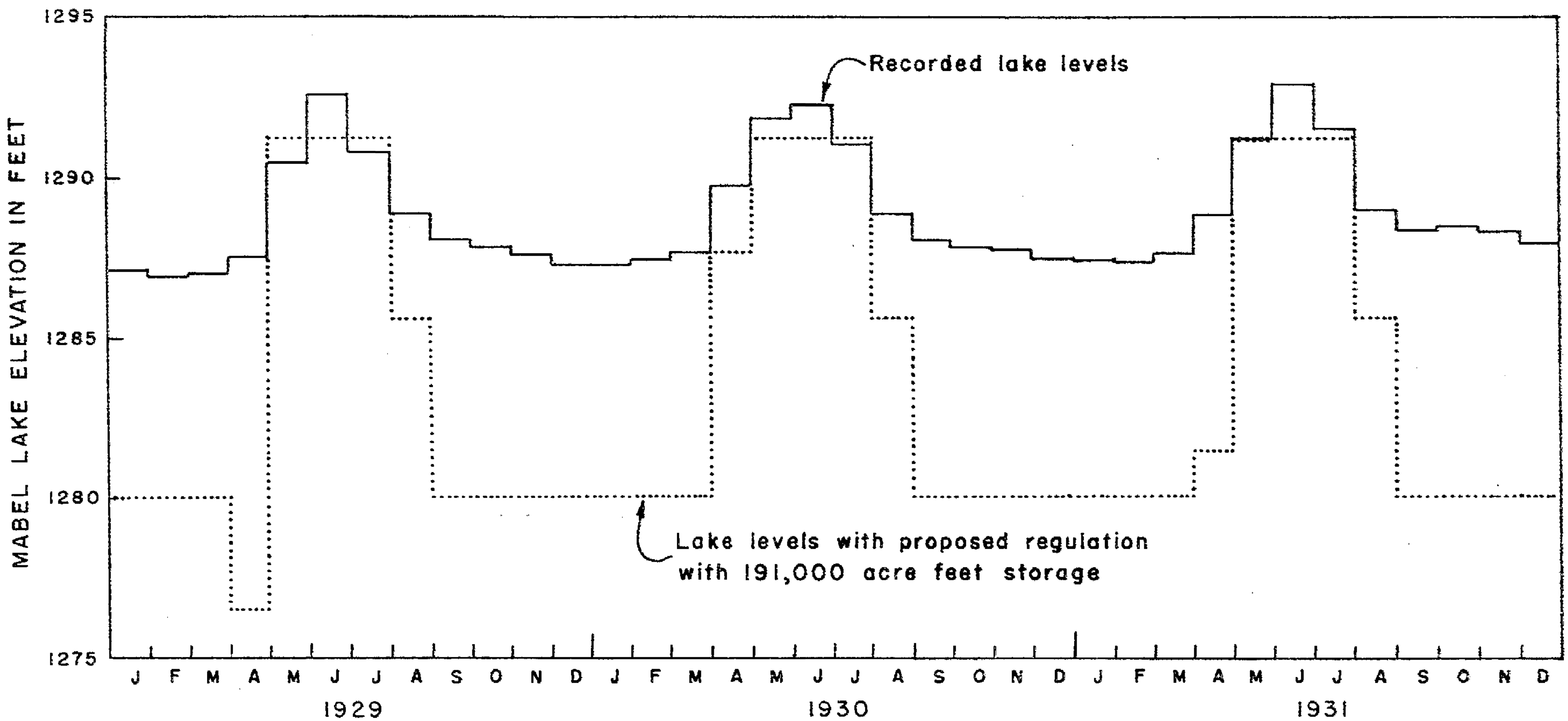


FIGURE19 - Proposed regulation of storage in Mabel Lake for low runoff years 1929-31.

lowering of the normal minimum lake level would reduce the area of the productive littoral zone in the lake, and consequently would reduce production of trout. The exposure of the lake bottom in this littoral zone would also destroy lake bottom fauna on which trout feed, and would further reduce production of trout.

The large quantity of water withdrawn from the upper levels of Mabel Lake during August and September may seriously reduce the available zooplankton in Mabel lake. Measurements of the vertical distribution of zooplankton at two locations in Shuswap Lake indicates that one half or more of the zooplankton are in the top 20 ft (TABLE 38). Data on zooplankton and associated water temperatures and dissolved solids for Mabel Lake and Shuswap Lake indicate that production of zooplankton in Mabel Lake is comparable to Shuswap Lake (FIGURE 20). Zooplankton are the chief diet of juvenile salmon (Ricker, 1937), and the loss of zooplankton from Mabel Lake in August and September during part of the primary growth period would reduce the growth of the young salmon. There is evidence that reduced growth would result in subsequent reduced survival of the fish to adult salmon (Ricker, 1962). The withdrawal of large amounts of water during August and September also may so alter the thermal structure of the lake, that the productive growing period for juvenile salmon would be reduced.

TABLE 38 - Vertical distribution of zooplankton in Shuswap Lake.

| Depth Feet | Day Volume ml | Cumulative % | Night Volume ml | Cumulative % |
|---|---|---|---|---|
| | | At Canoe, July 31, 1959 | | |
| 0-20 | 1.89 | 49.7 | 1.39 | 52.2 |
| 20-40 | 1.12 | 79.1 | 0.51 | 71.5 |
| 40-60 | 0.55 | 93.9 | 0.55 | 92.0 |
| 60-80 | 0.16 | 98.0 | 0.08 | 95.1 |
| 80-100 | 0.08 | 100.0 | 0.13 | 100.0 |
| | | At Seymour Arm July 31, August 1, 1959 | | |
| 0-20 | 0.41 | 56.1 | 0.46 | 49.0 |
| 20-40 | 0.13 | 74.0 | 0.29 | 80.0 |
| 40-60 | 0.06 | 82.1 | 0.08 | 88.5 |
| 60-80 | 0.08 | 93.0 | 0.05 | 93.8 |
| 80-100 | 0.05 | 100.0 | 0.06 | 100.0 |

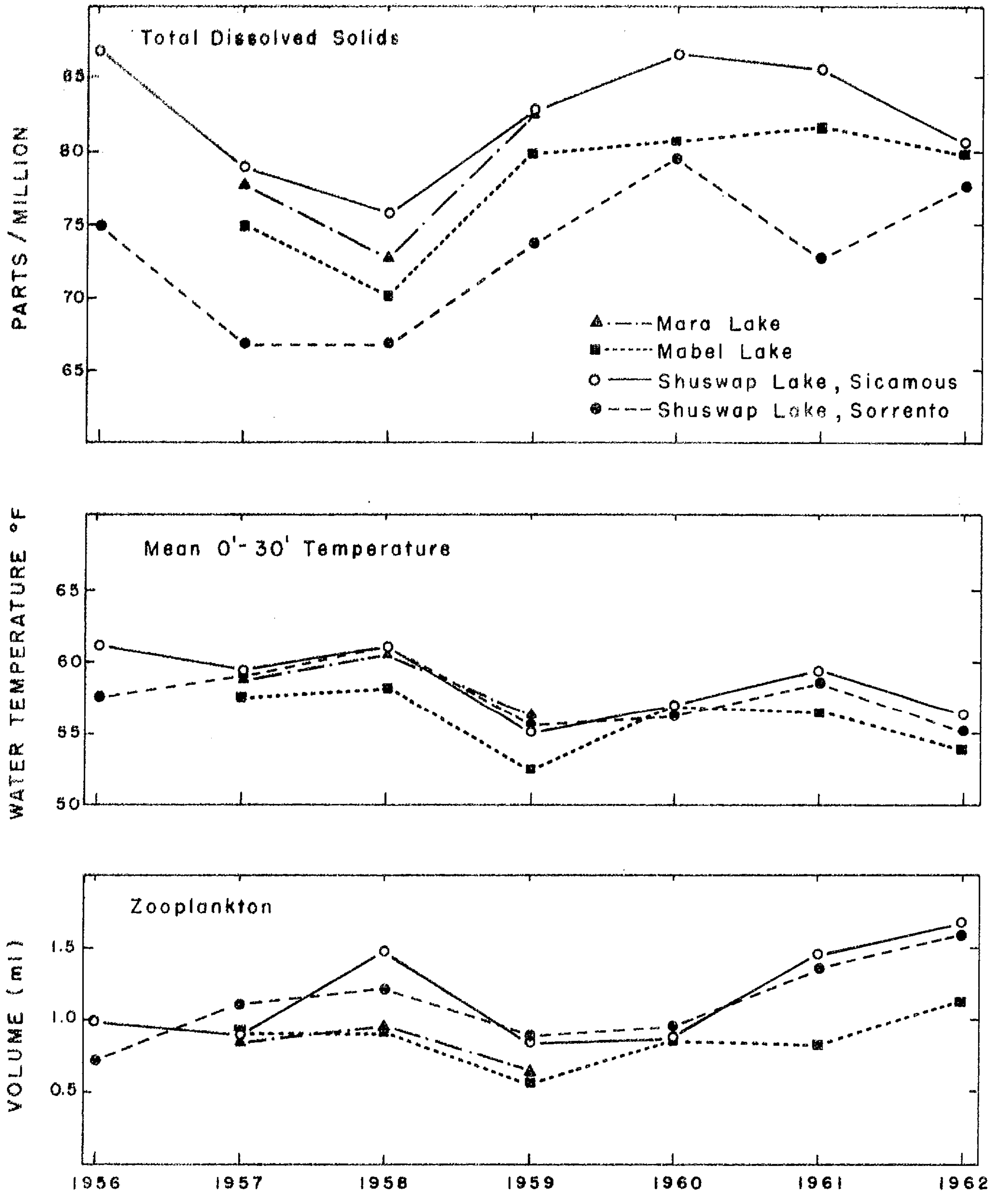


FIGURE 20 - Zooplankton, total dissolved solids and water temperature Shuswap, Mara and Mabel Lakes. (Mean of six monthly samples in the period May to October).

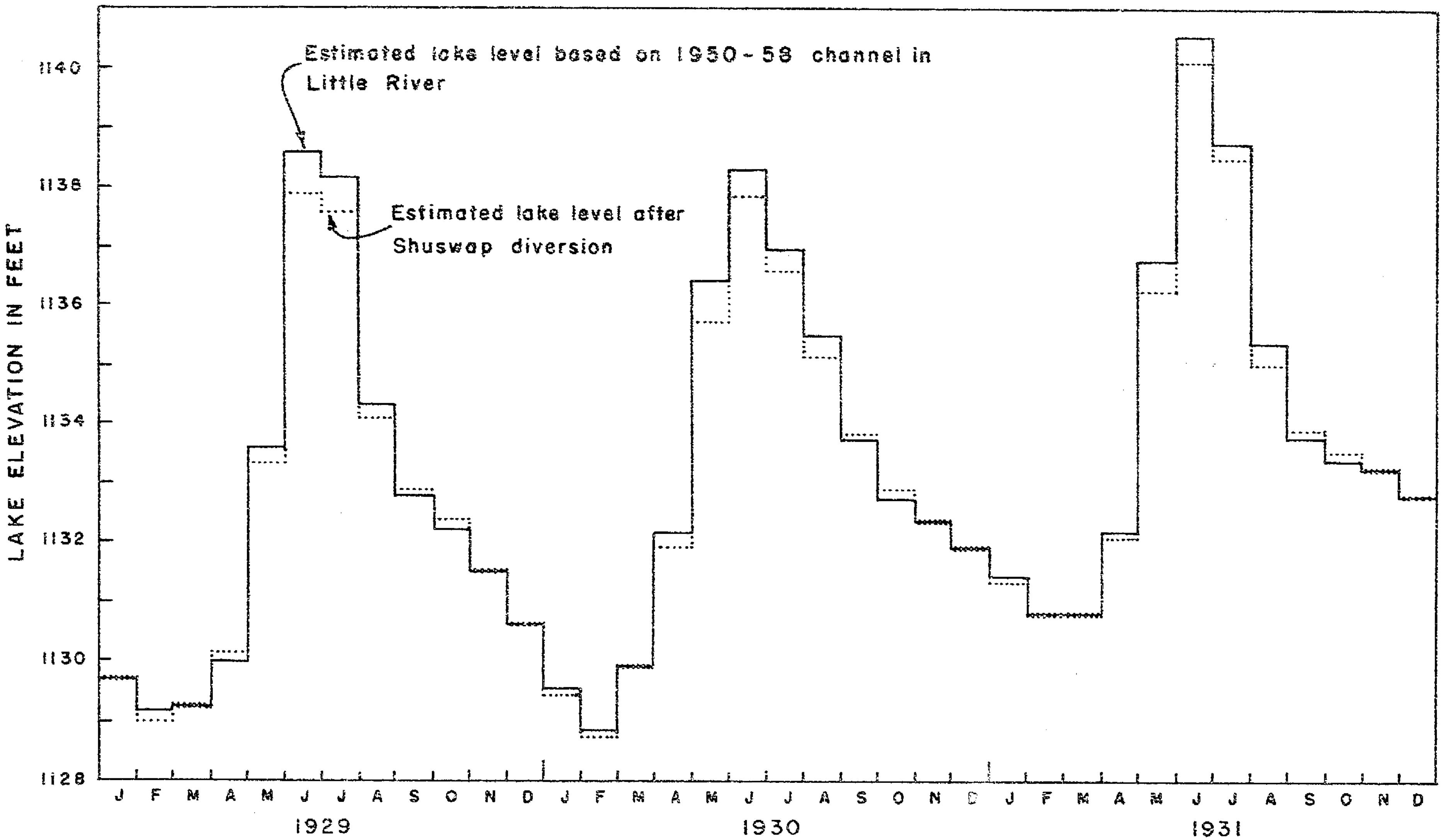


FIGURE 21 - Estimated effect of proposed diversion on Shuswap Lake water levels, 1929-1931.

The proposed diversion from the Shuswap River near Enderby would also affect water levels on Shuswap Lake, lowering levels by as much as 0.7 ft in the freshet period (FIGURE 21). There is no evidence that this difference would affect fish populations in Shuswap and Mara Lakes.

The proposed diversion could alter the productive rearing zone for sockeye in Mara Lake. Bathythermograph records for Mara Lake and Shuswap Lake at Sicamous show that the productive rearing zone between temperatures of $50^{\circ}$F and $64^{\circ}$F (Donaldson and Foster, 1941) extends to a greater depth in Mara Lake than in Shuswap Lake at Sicamous. The difference in depth-temperature structure of the lakes is illustrated by data for 1968 (FIGURE 22) and the difference in productive rearing zone is illustrated by data for the same year (FIGURE 23). The greater depth of the warmer productive rearing zone in Mara Lake appears to be due to the large inflow from Shuswap River to Mara Lake during the freshet period. Consequently, any reduction in these flows, such as would result from the proposed diversion, would tend to reduce the depth of the productive zone in Mara Lake and make it more like Shuswap Lake, thereby reducing the rearing capacity of Mara Lake.

As previously mentioned, water temperatures in Lower Shuswap River below Enderby would be increased in the summer by the proposed diversion. The warmer river water would flow onto the surface of Mara Lake where it would tend to increase the temperature of the surface waters of the lake, but it is not anticipated that any warming effect would extend through Mara Lake into Shuswap Lake.

## Spawning in Little River, South Thompson River and Thompson River

The proposed diversion from the Shuswap River would modify the outflow from Shuswap Lake down Little River (TABLE 39). Little River supports a large run of sockeye salmon, and the spawning grounds in the South Thompson River downstream from Little Shuswap Lake support substantial runs of sockeye and chinook salmon. It is necessary to maintain normal relationships between river discharge at the time of spawning and during the subsequent incubation period to prevent loss of eggs due to exposure or freezing.

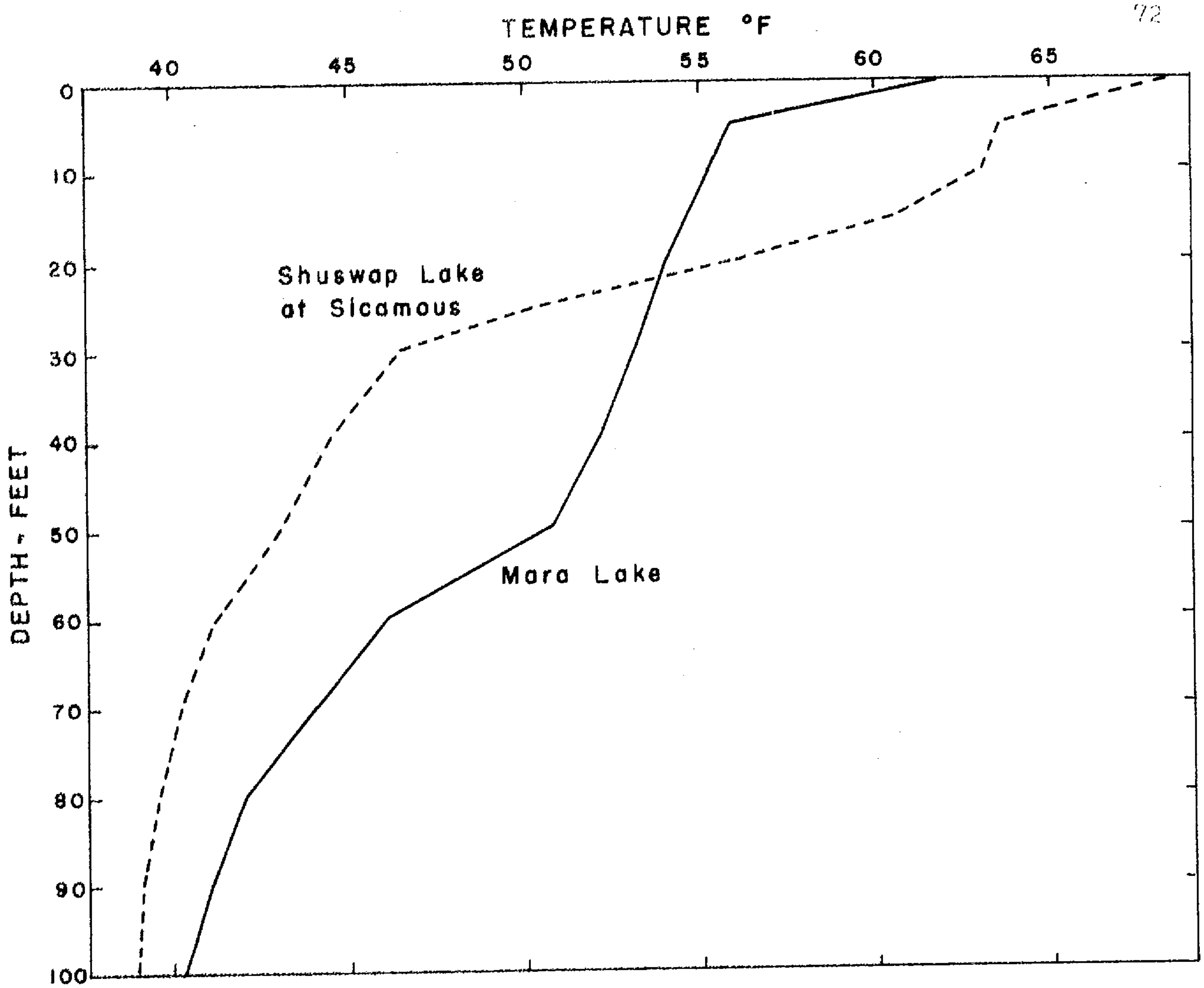


FIGURE 22 - Temperature of Mara Lake compared with Shuswap Lake at Sicamous, June 9, 1968.

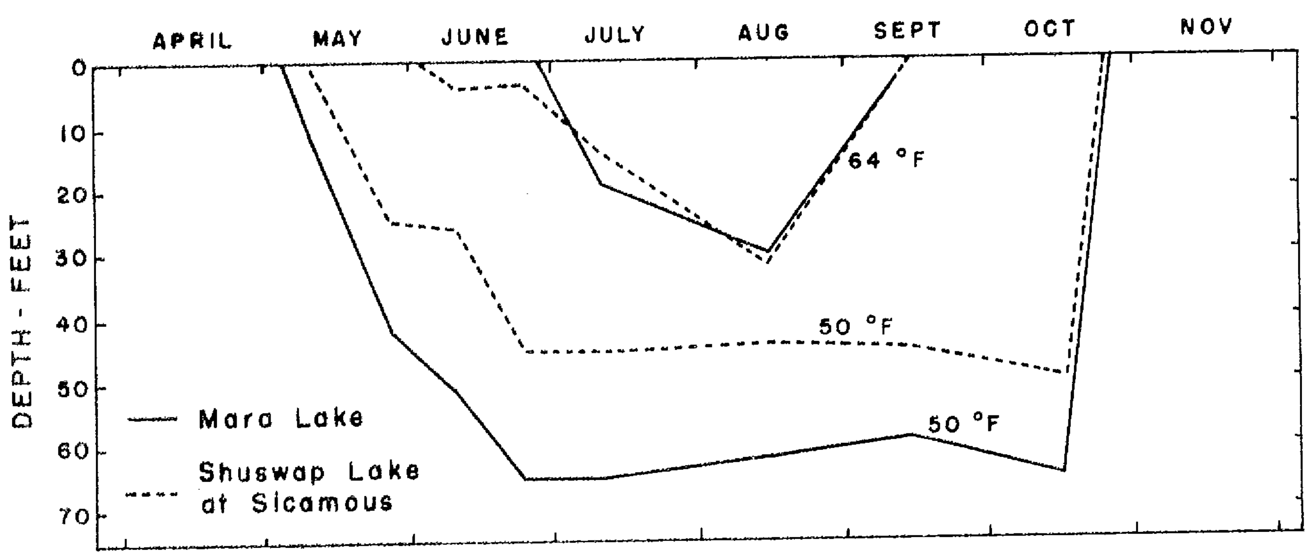


FIGURE 23 - Productive rearing zone in Mara Lake compared with Shuswap Lake at Sicamous, 1968.

TABLE 39 - Estimated changes in mean monthly outflow from Shuswap Lake with Scheme 3 diversion.

| | | SHUSWAP LAKE OUTFLOW CFS | |
|---|---|---|---|
| | DATE | Present Development | With Scheme 3 Diversion |
| (1929) | April | 2,634 | 2,648 |
| | May | 6,527 | 5,908 |
| | June | 19,563 | 16,840 |
| | July | 17,185 | 15,088 |
| | August | 7,275 | 6,741 |
| | September | 4,864 | 4,985 |
| | October | 3,848 | 4,021 |
| | November | 3,278 | 3,273 |
| | December | 2,550 | 2,494 |
| (1930) | January | 2,204 | 2,140 |
| | February | 2,177 | 2,126 |
| | March | 2,530 | 2,488 |
| | April | 4,837 | 4,264 |
| | May | 12,438 | 10,635 |
| | June | 18,375 | 16,570 |
| | July | 13,514 | 12,022 |
| | August | 9,754 | 8,822 |
| | September | 6,354 | 6,442 |
| | October | 4,629 | 4,818 |
| | November | 4,166 | 4,152 |
| | December | 3,644 | 3,560 |
| (1931) | January | 3,265 | 3,173 |
| | February | 3,068 | 3,002 |
| | March | 2,766 | 2,729 |

As shown in TABLE 39, discharges during the spawning period in October would be slightly higher, and discharges from November to March would be slightly lower for the proposed diversion. However, the changes indicated are not considered sufficient to result in any significant loss of eggs due to exposure or freezing.

The indicated changes in discharge would also apply to the Thompson River, but the resulting effect on water levels would be obscured by the unchanged flow from the North Thompson River, and the effect on spawning grounds in the Thompson River below Kamloops Lake would be negligible.

### Migration, Spawning, Incubation and Rearing of Okanagan River Sockeye

The proposed minimum flow of 125 cfs for the Okanagan River during the spawning and incubation season could lead to a number of flow conditions or combinations of flows detrimental to sockeye production.

Many of the 500 domestic, industrial, and irrigation intakes in the Okanagan River are too high to pump water when the channel discharge is less than 400 cfs. To overcome this problem, some drop structures are blocked with stop-logs to maintain a higher water surface. Under these conditions, drop structures 5 and 12 have become serious obstructions to upstream migration. This situation has been observed with great concern in the past. The proposed minimum flow of 125 cfs would significantly increase the potential losses of sockeye at the critical drop structures due to reduced tailwater levels and discharge characteristics.

Recent spawning distribution surveys have shown that 80% of the sockeye spawners utilize 82,000 sq yds of good spawning gravel available at 300 cfs in the unimproved river section located between McIntyre Creek and 1.2 miles upstream of drop structure 13 (FIGURE 11).

Field observations indicate that optimum spawning conditions in this section occur at flows of 250 to 300 cfs. A minimum flow of 125 cfs as proposed by the Water Resources Service would reduce the wetted perimeter and alter the velocity depth characteristics in the river channel, thus reducing the optimum spawning area by approximately 25%.

Assuming a spawning discharge of 250-300 cfs, a minimum flow of 125 cfs during the incubation period would result in dewatering and/or exposure of eggs to freezing. These detrimental effects would virtually be eliminated with a minimum flow of 170 cfs during the incubation period.

In severe drought years such as 1926, 1929, 1930 and 1931, the quantity of water proposed to be diverted to Okanagan Lake would be much greater than the runoff from the Okanagan Lake watershed (TABLE 18). The water diverted from Shuswap River would mix with the surface layers of Okanagan Lake and, consequently, in drought years it would be possible for the residual flow in Okanagan River to contain a high proportion of Shuswap River water. This change in water quality in Okanagan River may affect the rearing environment for sockeye in Osoyoos Lake and may also affect the homing of Okanagan River sockeye from the Columbia River to their spawning grounds. The diluting effect would be much less in other years because of the lesser amount of water proposed to be diverted and the greater inflow to Okanagan Lake, and presumably the effect on rearing and homing of sockeye would be minimal under these conditions. The potential problem of possible transfer of fish diseases from the Shuswap River system to the Okanagan River system should not be overlooked. No information is available at present to determine whether any of the foregoing problems might be significant considerations.

It is not anticipated that the introduction of water from Shuswap Lake to Okanagan Lake would result in any changes in the temperatures in Okanagan River during the spawning and incubation period of Okanagan River sockeye.

## Summary of Effects on the Salmon and Trout Populations

In summary, the diversion of water from Shuswap River to the North and South Okanagan Regions, as proposed by the Water Resources Service, without provision of fish protective facilities, would eliminate the runs of sockeye, chinook and coho salmon to the Lower and Middle Shuswap River; eliminate the stocks of kokanee that spawn in the Lower Shuswap River; eliminate the stocks of rainbow trout that spawn at the outlet of Mabel Lake and virtually eliminate those that spawn in the Lower Shuswap River; reduce or eliminate the stocks of kokanee and trout that spawn in tributaries of Mabel Lake; and reduce the productivity of sockeye runs that spawn in Okanagan River.

Provision of fish facilities in the Lower Shuswap River would not completely eliminate losses to the fishery. Obstruction and delay at damsites and in impoundments, changes in water temperature and flow regime, and problems associated with canal intake screens would combine to reduce the stocks of salmon, kokanee and trout. In addition, permanent loss of spawning area upstream from the damsites would be unavoidable.

## EXAMINATION OF WATER SUPPLY AND STORAGE REQUIREMENTS

The following sections of this report reconsider the storage requirements on Okanagan Lake for flood control and the flow requirements in Okanagan River for fisheries purposes, as well as the ultimate consumptive water requirements in the Shuswap River watershed, and assess the effect of these requirements on the proposed diversion from Shuswap River.

### Okanagan Lake Storage

The Water Resources Service has estimated, on the basis of Scheme 3, that 354,277 acre-ft of water would be needed in a drought year to supply the requirements of the South Okanagan region for the estimated ultimate consumption. As previously noted in TABLE 18, the estimated average annual runoff from Okanagan watershed is 397,110 acre-ft. This amount would be sufficient for the estimated ultimate requirement of the South Okanagan region if surplus water in wet years could be stored to make up shortage in dry years. Data on estimated annual surpluses and shortages are presented in TABLE 40. The years 1924-1948 are the most critical with respect to water shortages with a total cumulative shortage of 918,555 acre-ft, and would require up to 10.9 ft of storage in Okanagan Lake (including the 1 ft of storage now allocated for emergency use) to make up the deficiencies. At present, 4 ft of storage space in Okanagan Lake (elevation 1123.8-1119.8 ft) is reserved for storage of freshets to prevent flooding along the Okanagan River. One additional foot (elevation 1119.8-1118.8 ft) is reserved for emergency water supply at 0.5 ft per year in drought periods. Elevations 1123.8 and 1118.8 ft are the upper and lower limits of the desired range of levels in Okanagan Lake. Freshet storage space is reserved in Okanagan Lake because Okanagan River below the lake is limited to 2,100 cfs capacity (Water Resources Service, 1966), which is not sufficient to pass a major freshet without some regulation. Even if this reserved space could all be used for

TABLE 40 - Estimated annual shortages and surpluses of water in acre-ft in Okanagan Lake watershed in relation to the estimated ultimate water requirements (354,277 acre-ft) of the South Okanagan region, for water year commencing April 1 for the period 1922-1964.

| Year | Annual Watershed Supply | Annual Surplus | Annual Shortage | Cumulative Total Shortage |
|---|---|---|---|---|
| 1922-23 | 313,272 | | 41,005 | 41,005 |
| 1923-24 | 401,466 | 47,189 | | 0 |
| 1924-25 | 150,333 | | 203,944 | 203,944 |
| 1925-26 | 251,998 | | 102,279 | 306,223 |
| 1926-27 | 99,379 | | 254,898 | 561,121 |
| 1927-28 | 457,013 | 102,736 | | 458,385 |
| 1928-29 | 631,090 | 276,813 | | 181,572 |
| 1929-30 | 124,831 | | 229,446 | 411,018 |
| 1930-31 | 101,038 | | 253,239 | 664,257 |
| 1931-32 | 99,979 | | 254,298 | 918,555 |
| 1932-33 | 391,936 | 37,659 | | 880,896 |
| 1933-34 | 571,908 | 217,631 | | 663,265 |
| 1934-35 | 460,547 | 106,270 | | 556,995 |
| 1935-36 | 515,060 | 160,783 | | 396,212 |
| 1936-37 | 375,071 | 20,794 | | 375,418 |
| 1937-38 | 400,114 | 45,837 | | 329,581 |
| 1938-39 | 306,435 | | 47,842 | 377,423 |
| 1939-40 | 230,439 | | 123,838 | 501,261 |
| 1940-41 | 182,228 | | 172,049 | 673,310 |
| 1941-42 | 343,675 | | 10,602 | 683,912 |
| 1942-43 | 493,334 | 139,057 | | 544,855 |
| 1943-44 | 257,357 | | 96,920 | 641,775 |
| 1944-45 | 300,082 | | 54,195 | 695,970 |
| 1945-46 | 459,846 | 105,569 | | 590,401 |
| 1946-47 | 590,139 | 235,862 | | 354,539 |
| 1947-48 | 232,072 | | 122,205 | 476,744 |
| 1948-49 | 787,575 | 433,298 | | 43,446 |
| 1949-50 | 474,135 | 119,858 | | 0 |
| 1950-51 | 541,277 | 187,000 | | 0 |
| 1951-52 | 621,051 | 266,774 | | 0 |
| 1952-53 | 488,640 | 134,363 | | 0 |
| 1953-54 | 394,961 | 40,684 | | 0 |
| 1954-55 | 617,032 | 262,755 | | 0 |
| 1955-56 | 507,356 | 153,079 | | 0 |
| 1956-57 | 578,709 | 224,432 | | 0 |
| 1957-58 | 508,606 | 154,329 | | 0 |
| 1958-59 | 408,191 | 53,914 | | 0 |
| 1959-60 | 691,084 | 336,807 | | 0 |
| 1960-61 | 368,122 | 13,845 | | 0 |
| 1961-62 | 341,553 | | 12,724 | 12,724 |
| 1962-63 | 334,476 | | 19,801 | 32,525 |
| 1953-64 | 275,212 | | 79,065 | 111,590 |

storage which could be carried over from year to year, it would not be possible to supply the full requirements of a drought period such as 1924-1948. However, if the discharge capacity of the Okanagan River could be increased, some reserved storage on Okanagan Lake could be released for carry-over storage, thereby reducing the amount of water required from outside the watershed. For example, if the discharge capacity of the first 2 miles of Okanagan River below Okanagan Lake could be increased to 2,700 cfs, the same as the next 2 miles down to Skaha Lake, it is estimated approximately 2 ft of storage would be required to regulate the 1948 freshet, leaving the balance of 2 ft of the present reserved storage which could be used for carry-over. This storage, added to the 0.5 ft per year emergency storage, would reduce substantially the quantity of water required from outside the watershed in a drought year.

It is evident that some diversion of water from outside the Okanagan watershed would be needed in drought years, as well as to supply new requirements in the North Okanagan region, but it is suggested that study be made of the feasibility of increasing the discharge capacity of the Okanagan River to obtain carry-over storage space in Okanagan Lake which could reduce considerably the cost of obtaining water from outside the watershed.

In addition, when the consumption of water from Okanagan Lake reaches the magnitude estimated for ultimate development, the flood storage space requirement could be reduced and be used instead for carry-over storage for water supply.

## Fisheries Flow Requirements in Okanagan River

The estimated ultimate water requirements of the South Okanagan region used in conjunction with Scheme 3 for the proposed diversion from the Lower Shuswap River did not include any water in the Okanagan River for fisheries purposes, other than the minimum flow of 125 cfs. As previously mentioned, it was determined in 1956 as a result of analysis of Okanagan River discharges that certain flows could be provided for fisheries purposes (TABLE 15). These flows were selected to provide adequate water depth in the unimproved portion of the river where there were numerous side channels.

Over the past 10 years, diking and channeling of the unimproved section of the river has gradually eliminated some of the productive side channels. As previously mentioned, recent surveys have shown that 80% of the sockeye utilize 82,000 sq yd of spawning ground available at flows of 250 to 300 cfs in the unimproved river section. On the basis of these and other recent survey observations previously referred to, it is considered that the flow requirements for fisheries purposes could be reduced to the quantities given in TABLE 41.

TABLE 41 - Revised Okanagan River fisheries flow requirements

| | Period | Discharge |
|---|---|---|
| Spawning | September 10 to October 31 | 250 cfs min. 470 cfs max. |
| Incubation and Fry Migration | October 31 to April 30 | 170 cfs min. |

A discharge of 170 cfs during the incubation and fry migration period is specified in conjunction with flows of 250 cfs minimum up to 470 cfs during the spawning period. When discharges exceeding 470 cfs occur during the spawning period, the required discharge during the incubation period can be determined by limiting the range from maximum to minimum discharge to less than 300 cfs.

Part of these flows would be provided by the 125 cfs minimum flow specified by the Water Resources Service and the additional water needed to provide the minimum flows specified in TABLE 41 would be 29,040 acre-ft annually.

To prevent drop structures 5 and 12 from becoming serious obstructions to upstream migrants due to addition of stop-logs, it would be necessary to modify all high intakes in the Okanagan River so that they would be capable of pumping at the minimum discharge of 125 cfs.

Water Requirements of Okanagan Region

As previously mentioned, the Water Resources Service has estimated that 191,077 acre-ft of water would be needed from the Lower Shuswap River to supply the net ultimate requirements of the South Okanagan region in a drought year, and an additional 94,420 acre-ft per annum would be needed to supply the ultimate water use in the North Okanagan region. The amount of diversion to the South Okanagan in any year at ultimate development would depend on availability of water within the watershed, whereas the amount diverted to the North Okanagan would depend primarily on weather during the growing season.

The foregoing estimate does not include any water for fisheries purposes in the Okanagan River, other than the minimum flow of 125 cfs. As previously stated, the revised flows for fisheries purposes in Okanagan River would increase the water use from Okanagan Lake by 29,040 acre-ft annually, increasing diversion quantities by the same amount, and giving a total diversion, including the North Okanagan, of 314,537 acre-ft annually.

The 1966 Water Resources Service study allowed for a reduction in water use of 41,000 acre-ft under severe drought conditions, but this allowance was deleted from the 1969 report, and instead an allowance of 25,000 acre-ft was made for re-use of return flow. The 1969 report also provides water in drought years for areas now supplied from tributaries of Okanagan Lake and River when the tributary inflow is less than the irrigation diversion requirement, whereas such provision was not made in the 1966 report. This evolution in planning indicates that there may be scope for further consideration of the water requirements, particularly with respect to the amount of water available for re-use. It is suggested, therefore, that a detailed study should be made of the feasibility of re-use of water and the quantity of water available for re-use. In this way, full advantage may be taken of any possible reductions in the amount and cost of new water required.

## Mabel Lake Storage Required by Scheme 3

The Water Resources Service report (1967) states that 191,000 acre-ft of storage would be required on Mabel Lake to maintain the stipulated minimum flow at Enderby and provide the proposed diversion. This storage would be required mainly in August and September with some held over to April. The reports do not detail the derivation of the storage requirement and the same figure is used in the 1968 study in which historic flows were modified to present development. Independent study has shown that, on the basis of present development, the stated flows would be obtained with 89,708 acre-ft of storage for use in August and September and 15,041 acre-ft for use in April, making a total of 104,749 acre-ft.

In the 1968 study of the ultimate consumptive water requirements of the Shuswap River valley, the Water Resources Service did not indicate any revision to the storage on Mabel Lake, although more storage than previously estimated would be required to supply the proposed diversion and the ultimate consumptive use from the Shuswap River. Independent study indicates that 235,555 acre-ft would be required for this purpose. As previously noted the Scheme 3 proposal with 191,000 acre-ft storage did not maintain the required 1,100 cfs minimum flow between Enderby and Mara Lake because of ultimate consumptive use of water between these points.

It would appear that the storage requirement in Mabel Lake may be substantially more than indicated by the Water Resources Service when the ultimate consumptive water requirement of the Shuswap River valley is considered in conjunction with the proposed diversion, thereby increasing the fisheries problems associated with storage on Mabel Lake.

## Water Requirements of Shuswap River Valley

Before considering diversion of water from the Shuswap River it would appear essential to evaluate the ultimate water requirements within the Shuswap River valley to determine if there would be a surplus of water available for diversion. The Water Resources Service (1968) has studied the possible ultimate water requirements of the valley (TABLE 26) and has estimated an annual consumptive use of 180,880 acre-ft on the basis of what appear to be very generous assumptions as to ultimate population and area of land under irrigation. In comparison, the minimum annual runoff of the Shuswap River at Enderby is 1,357,096 acre-ft.

Discharge records from Middle Shuswap River at Shuswap Falls previously given in TABLE 25 show that there is sufficient water each month in the Middle Shuswap River to supply the estimated requirements (65,140 acre-ft annually) and still maintain ample flows in the river. However, downstream from Mabel Lake, because of the distribution of runoff in relation to consumptive use, there would not be sufficient water in August and September to supply the estimated use and maintain the minimum flow of 1,100 cfs in the Lower Shuswap River below the diversion site (TABLE 42). On the basis of the 1929 water year the shortage in August and September would total 97,226 acre-ft.

TABLE 42 - Ultimate development outflow from Mabel Lake compared with estimated ultimate development requirement between Mabel Lake and Mara Lake including 1,100 cfs minimum flow from May to September, for 1929-1931 water years, in acre-ft.

| | Month | Mabel Lake Outflow* | Requirements Mabel Lake to Mara Lake | Shortage |
|---|---|---|---|---|
| (1929) | April | 58,092 | | |
| | May | 168,392 | 68,200 | 0 |
| | June | 407,524 | 66,000 | 0 |
| | July | 171,472 | 97,805 | 0 |
| | August | 36,700 | 110,631 | 73,931 |
| | September | 42,705 | 66,000 | 23,295 |
| | October | 49,241 | | |
| | November | 44,498 | | |
| | December | 46,356 | | |
| (1930) | January | 47,258 | | |
| | February | 40,524 | | |
| | March | 43,572 | | |
| | April | 133,662 | | |
| | May | 224,517 | 68,200 | 0 |
| | June | 312,667 | 66,000 | 0 |
| | July | 201,518 | 93,031 | 0 |
| | August | 39,075 | 106,973 | 67,898 |
| | September | 40,825 | 66,000 | 25,175 |
| | October | 46,102 | | |
| | November | 45,507 | | |
| | December | 49,104 | | |
| (1931) | January | 50,895 | | |
| | February | 46,817 | | |
| | March | 54,970 | | |

* Water Resources Service data from routing calculations.

On the basis of the estimated ultimate consumptive use of water within the Shuswap valley, storage of 97,226 acre-ft would be required either on Sugar Lake or Mabel Lake to supply the requirements between Mabel Lake and Mara Lake. To avoid interference with the fisheries resource and the considerable recreational use of Mabel Lake, it would be desirable to utilize storage on Sugar Lake. The existing dam at Sugar Lake provides storage of 100,000 acre-ft which is used to regulate flows for the hydroelectric plant at Shuswap Falls. This plant, which is now operated by the British Columbia Hydro Authority, has a capacity of 6,500 kw. With the current incorporation of the various power generation and distribution facilities in the Okanagan under the British Columbia Hydro Authority, and the completion of the large hydroelectric projects on the Columbia River, this small plant will no longer constitute a significant power source in the network. It is suggested that consideration be given to a gradual shift in emphasis on the use of storage at Sugar Lake from hydroelectric purposes to water supply purposes, as determined by actual needs for water supply. This plan would ensure an adequate water supply for the estimated needs of the Shuswap River valley.

As shown in TABLE 42, water surplus to the Shuswap River valley needs would be available during May, June and July. In addition, some surplus water would be available below Enderby during the winter months. It is suggested that only these surplus waters should be considered for diversion from Shuswap River, if this is the source of water to be used to supply the needs of the North and South Okanagan regions. Unless additional storage can be obtained at Sugar Lake, no diversion from the Shuswap River at Enderby would be possible during August and September. However, if Mara Lake is considered as a source of water instead of Shuswap River, it would appear that diversion could be made in any month, since there appears to be substantial inflow to Shuswap Lake in excess of estimated ultimate consumptive requirements.

## SUGGESTED ALTERNATE DIVERSION OF WATER TO NORTH AND SOUTH OKANAGAN

Study of the water resources and water requirements of the North and South Okanagan regions indicates an apparent potential need for additional water supply. Because of its proximity to Okanagan Lake, the Lower Shuswap River is the obvious source of such water in terms of cost, but as previously discussed diversion of water from Lower Shuswap River as proposed by the Water Resources Service would have very serious consequences to the fishery resources of the Shuswap River. The following section of this report suggests an alternate diversion scheme from Mara Lake which would deliver the required water and which would minimize fisheries problems.

As previously mentioned, the proposed Scheme 3 diversion of water from the Shuswap River at Enderby and the associated storage at Mabel Lake would present many fisheries problems which would seriously affect the stocks of fish dependent upon the Shuswap River and Mabel Lake. Furthermore, consideration of the estimated ultimate water requirements of the Shuswap River valley has indicated a potential shortage of water in August and September, even without any diversion to North and South Okanagan, which would require development of substantial storage on Mabel Lake or Sugar Lake. The existing Sugar Lake storage capacity would be adequate to provide the potential storage of water for use within the Shuswap River valley without affecting the stocks of fish in Mabel Lake and in the Shuswap River. Consequently, it is suggested this storage be reserved to supply eventual water requirements within the Shuswap River valley. To supply water for the North and South Okanagan regions and at the same time avoid the fisheries and recreational use problems that would be associated with use of Mabel Lake for storage, it is suggested the following alternate diversion from Mara Lake be considered.

It has been shown previously that during the months of May, June and July there was sufficient surplus water in the Shuswap River below Mabel Lake to provide the annual ultimate requirement of the North and South Okanagan regions. The problem is to store some of this water so that it can be delivered to the Okanagan at a rate consistent with requirements and available storage space on Okanagan Lake. Because of their size, Shuswap, Mara and Okanagan Lakes provide large natural storage basins which could be used for this purpose with only minor changes in lake level. The elevation of Shuswap and Mara Lakes ranges from 1130.3 to 1147.1 ft compared with the elevation of 1150 ft proposed for the diversion dam forebay and pumping plant at Enderby, so the additional pumping lift from Mara Lake would not be very great. It is suggested therefore, that if the estimated ultimate new water requirements of the North and South Okanagan regions are to be obtained from the Shuswap River system, the diversion could be made by pumping from Mara Lake.

To reduce costs and to limit the changes in level of Mara, Shuswap and Okanagan Lakes it is suggested that diversion to the South Okanagan region be made from June to March when necessary. This diversion must be consistent with the regulation obtainable from the storage space on Okanagan Lake above the minimum elevation of 1118.8 ft set for emergency conditions in drought years. The diversion to the North Okanagan region would be made at the rate required by seasonal water demand.

The operation of such a scheme has been examined for the years 1924-1932, which include the 3 years of lowest recorded inflow to Okanagan Lake as well as 2 years with inflow well above average. The net water requirement of the South Okanagan region is estimated to be 383,317 acre-ft, comprising 354,277 acre-ft (TABLE 21) and the 29,040 acre-ft of additional water for fisheries requirements in the Okanagan River. In a drought year similar to 1931-1932, this water would be obtained from the sources indicated in TABLE 43, and would include a total of 216,338 acre-ft diverted from Mara Lake. Diversion of this volume, plus an additional 94,438 acre-ft to supply the North Okanagan, would be scheduled as shown in TABLE 44 to limit the maximum diversion to 640 cfs. For purposes of the study it was considered that water would be diverted to Okanagan Lake during the winter months. During extreme winter conditions however, pumping could be discontinued and the canal drained and the reduction in quantity of water diverted because of such action could be compensated readily by increasing the discharge in February or March.

TABLE 43 - Source of water supply for South Okanagan Region in a drought year similar to 1931-1932 at ultimate development.

| Source | Acre Feet |
|---|---|
| Tributary runoff | 99,979 |
| 0.5 ft on Okanagan Lake | 42,000 |
| Re-use | 25,000 |
| Shuswap Diversion | 216,338 |
| Total | 383,317 |

TABLE 44 - Schedule of diversions to North and South Okanagan Regions in a drought year similar to 1931-1932.

| Month | North Okanagan Acre-ft | South Okanagan Acre-ft | Total Acre-ft | Canal Flow cfs |
|---|---|---|---|---|
| April | 900 | 0 | 900 | 15 |
| May | 13,368 | 0 | 13,368 | 217 |
| June | 21,487 | 16,596 | 38,083 | 640 |
| July | 22,072 | 17,281 | 39,353 | 640 |
| August | 22,047 | 17,306 | 39,353 | 640 |
| September | 9,444 | 28,639 | 38,083 | 640 |
| October | 1,100 | 23,250 | 24,350 | 396 |
| November | 1,017 | 22,500 | 23,517 | 395 |
| December | 830 | 23,250 | 24,080 | 392 |
| January | 695 | 23,250 | 23,945 | 389 |
| February | 735 | 21,016 | 21,751 | 392 |
| March | 743 | 23,250 | 23,993 | 390 |
| Total | 94,438 | 216,338 | 310,776 | |

Using the diversion schedule proposed in TABLE 44, study of records of Okanagan Lake levels for the period 1924-1932 indicates that a level of 1121.8 ft would be required on May 31 at the beginning of a drought period of up to 2 years duration to prevent the lake level from being drawn down below the minimum of 1118.8 ft. Details of the calculated levels of Okanagan Lake for the period 1924-1931 are given in TABLE 45. The requirement of elevation 1121.8 ft at May 31 would not be inconsistent with flood storage requirements in Okanagan Lake, since in years of very high runoff the lake level would be higher than this on May 31. In some other years, it might be necessary to raise lake level slightly to 1121.8 ft,but there would still be sufficient space for freshet storage, even without considering the ultimate consumptive use of water. Using the foregoing diversion schedule, details of the monthly water requirements of the South Okanagan region and the monthly diversions from Mara Lake (or surplus spills from Okanagan Lake) for the period 1924-1931 are given in TABLE 46.

TABLE 45 - Calculated levels of Okanagan Lake in ft for the period 1924-1931 with diversion as proposed, starting at elevation 1121.805 ft on May 31, 1924.

| | Month end elevation of Okanagan Lake, ft* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | 1924 | 1925 | 1926 | 1927 | 1928 | 1929 | 1930 | 1931 |
| Jan. | - | 20.224 | 20.772 | 19.937 | 21.836 | 21.652 | 20.880 | 20.493 |
| Feb. | - | 20.544 | 20.682 | 20.047 | 21.896 | 21.522 | 21.120 | 20.633 |
| Mar. | - | 20.730 | 20.731 | 21.223 | 21.800 | 21.611 | 21.406 | 20.919 |
| Apr. | - | 21.367 | 21.317 | 20.434 | 21.280 | 21.706 | 21.922 | 21.094 |
| May | 21.805 | 22.930 | 21.830 | 21.766 | 24.013 | 21.685 | 21.934 | 21.450 |
| June | 21.351 | 22.852 | 21.084 | 22.250 | 23.796 | 21.624 | 21.758 | 20.967 |
| July | 20.341 | 21.867 | 20.143 | 21.288 | 23.470 | 20.676 | 20.905 | 20.248 |
| Aug. | 19.355 | 20.744 | 19.095 | 20.226 | 22.245 | 19.992 | 20.055 | 19.152 |
| Sept. | 19.016 | 20.387 | 18.830 | 20.403 | 21.682 | 20.263 | 19.887 | 18.945 |
| Oct. | 19.282 | 20.593 | 19.115 | 21.154 | 21.621 | 20.439 | 19.952 | 19.070 |
| Nov. | 19.580 | 20.482 | 19.373 | 21.425 | 21.972 | 20.527 | 20.190 | 19.318 |
| Dec. | 19.869 | 20.575 | 19.592 | 21.728 | 21.694 | 20.666 | 20.229 | 19.608 |

* add 1100.0 ft to get elevation.

TABLE 46 - South Okanagan region ultimate development net monthly water supply needed, monthly diversion from Mara Lake or monthly surplus spill from Okanagan Lake for the years 1924-1931, in acre-ft.

| | Supply Needed | Diversion from Mara Lake or surplus spill from Okanagan Lake | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | all Years | 1924 | 1925 | 1926 | 1927 | 1928 | 1929 | 1930 | 1931 |
| Jan. | 5,256 | - | 23,250 | 0 | 23,250 | 0 | 0 | 23,250 | 23,250 |
| Feb. | 5,047 | - | 21,016 | 0 | 21,016 | 0 | 0 | 21,016 | 21,016 |
| Mar. | 7,642 | - | 14,896 | 0 | 23,250 | 26,544* | 0 | 23,250 | 23,250 |
| Apr. | 5,468 | 0 | 0 | 0 | 0 | 114,845* | 0 | 0 | 0 |
| May | 52,664 | 0 | 0 | 0 | 0 | 106,928* | 0 | 0 | 0 |
| June | 89,496 | 16,596 | 16,596 | 16,596 | 0 | 66,889* | 16,596 | 16,596 | 16,596 |
| July | 88,052 | 17,281 | 17,281 | 17,281 | 0 | 0 | 17,281 | 17,281 | 17,281 |
| Aug. | 90,334 | 17,306 | 17,306 | 17,306 | 0 | 0 | 17,306 | 17,306 | 17,306 |
| Sept. | 33,652 | 28,639 | 28,639 | 28,639 | 0 | 0 | 28,639 | 28,639 | 28,639 |
| Oct. | -756 | 23,250 | 23,250 | 23,250 | 0 | 0 | 23,250 | 23,250 | 23,250 |
| Nov. | 3,326 | 22,500 | 3,247 | 22,500 | 0 | 0 | 22,500 | 22,500 | 22,500 |
| Dec. | 3,136 | 23,250 | 0 | 23,250 | 0 | 0 | 23,250 | 23,250 | 23,250 |

* indicates surplus spill

The suggested pumped diversion from Mara Lake would reduce the level of Mara and Shuswap Lakes not more than 0.56 ft (TABLE 47) compared to 0.7 ft for the Water Resources Service Scheme 3 (FIGURE 23) under present development conditions in the Shuswap Lake watershed. The largest reductions would be in the winter months, whereas under Scheme 3 they would be during the freshet period.

TABLE 47 - Decrease in level of Shuswap Lake from present development under proposed diversion from Mara Lake to Okanagan Region for 1929-1931 water years.

| Month | Decrease in level in ft 1929 | 1930 | 1931 |
|---|---|---|---|
| Jan. | - | 0.50 | 0.39 |
| Feb. | - | 0.54 | 0.45 |
| Mar. | - | 0.56 | 0.45 |
| Apr. | 0 | 0.37 | - |
| May | 0.05 | 0.13 | - |
| June | 0.14 | 0.14 | - |
| July | 0.20 | 0.21 | - |
| Aug. | 0.24 | 0.25 | - |
| Sept. | 0.35 | 0.30 | - |
| Oct. | 0.38 | 0.33 | - |
| Nov. | 0.40 | 0.31 | - |
| Dec. | 0.44 | 0.31 | - |

The effect of the reduced levels on outflow from Shuswap Lake in the critical low flow years is shown in TABLE 48. The discharge from the lake down Little River would be reduced approximately 500 cfs in September and approximately 300 cfs at low water, but the normal relationship between minimum flow and flow at spawning would be maintained. Since reductions of this size would occur only in years of extreme drought, it is not considered these changes would affect significantly the production of salmon in Little River or in the South Thompson and Thompson Rivers.

Because of the distance between Mara Lake and Enderby a canal would be the most economical means of carrying water from Mara Lake to connect to the previously proposed canal starting at Enderby. From information available, topography along the east side of the Shuswap River valley presents several

TABLE 48 - Estimated changes in mean monthly outflow from Shuswap Lake with suggested diversion from Mara Lake for 1929-1931 water years.

| | Date | Shuswap Lake Outflow cfs Present Development | With Suggested Diversion |
|---|---|---|---|
| 1929 | May | 6,527 | 6,436 |
| | June | 19,563 | 19,042 |
| | July | 17,185 | 16,551 |
| | Aug. | 7,275 | 6,808 |
| | Sept. | 4,864 | 4,342 |
| | Oct. | 3,848 | 3,444 |
| | Nov. | 3,278 | 2,918 |
| | Dec. | 2,550 | 2,243 |
| 1930 | Jan. | 2,204 | 1,891 |
| | Feb. | 2,177 | 1,840 |
| | Mar. | 2,530 | 2,137 |
| | Apr. | 4,837 | 4,293 |
| | May | 12,438 | 12,077 |
| | June | 18,375 | 17,886 |
| | July | 13,514 | 12,918 |
| | Aug. | 9,754 | 9,186 |
| | Sept. | 6,354 | 5,811 |
| | Oct. | 4,629 | 4,185 |
| | Nov. | 4,166 | 3,790 |
| | Dec. | 3,644 | 3,331 |
| 1931 | Jan. | 3,265 | 2,913 |
| | Feb. | 3,067 | 2,697 |
| | March | 2,766 | 2,454 |

obstacles to canal construction, and location of a canal on the west side of the valley does not appear practical because of existing roads and a railroad. Therefore, a canal location on the valley floor east of the river has been selected for study and cost estimates (FIGURE 24).

The intake and pumping station at Mara Lake would include screens to exclude trout and salmon fry. At this location in a lake as opposed to a river, the fry would be less likely to encounter the screens. In addition, the fry would be more advanced than when in the river and would have improved swimming capability, and there would be little tendency for impingement of fry on the screens. Because of the greater depth of water available at the intake and the

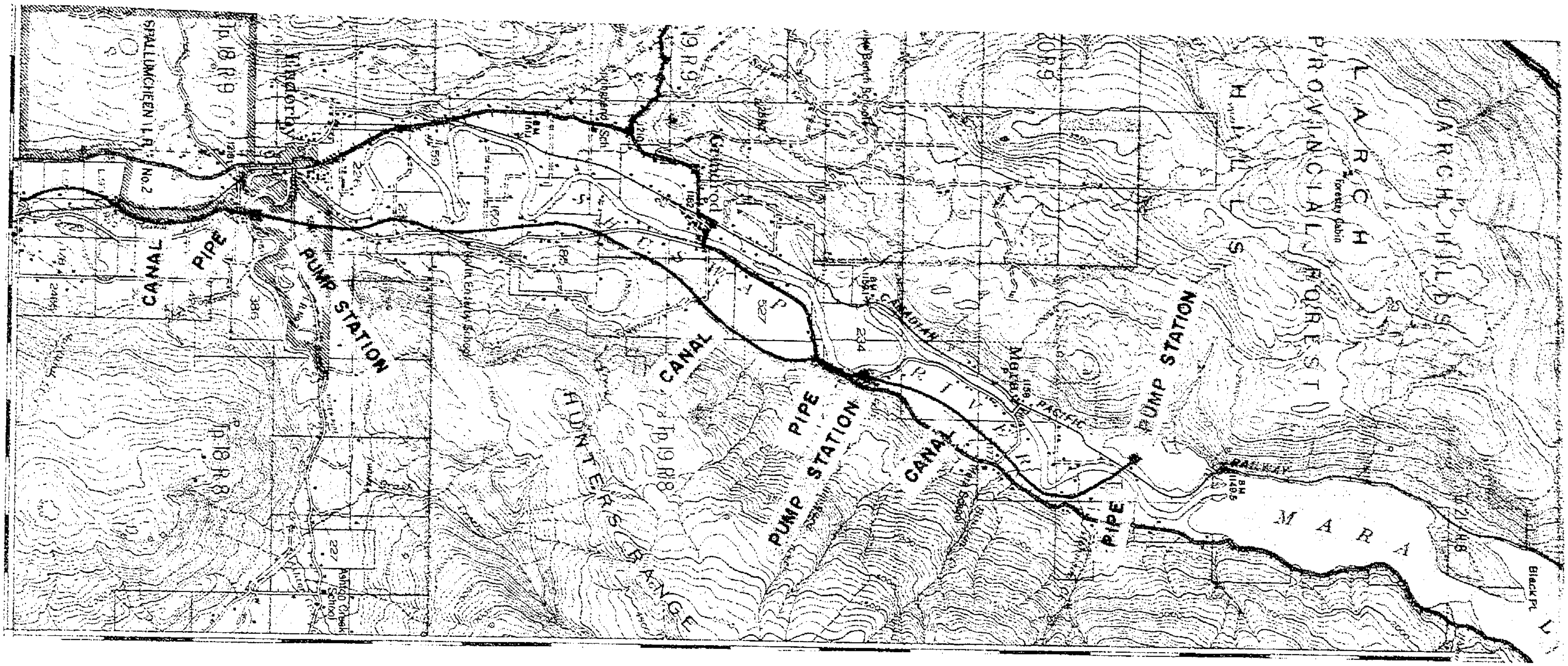


FIGURE 24 - Proposed canal and pumping stations between Mara Lake and Enderby, connecting to canal to Okanagan Lake.

reduced quantity of water diverted, the screening installation at the Mara Lake intake would cost less than one-third of a screen installation at the proposed intake in the Lower Shuswap River at Enderby. An intermediate pumping station and pipeline river crossing would be required to keep the canal at a reasonable elevation in relation to the valley floor. A third pumping station and pipeline river crossing would be required at Enderby, from which the water would be delivered to the canal previously proposed. The canal would have a capacity of 640 cfs and the section previously proposed by the Water Resources Service (with a capacity of 1,100 cfs) could be reduced in size and cost. No storage dam would be required at Mabel Lake and no diversion dam would be required at Enderby.

Preliminary estimates of the cost of this suggested diversion have been made on the same basis as the Water Resources Service (1966) estimates for the Scheme 3 diversion to obtain comparable cost figures. No detailed design has been made of structures, nor have any field surveys been made on which to base such design, other than the surveys made by the Water Resources Service. Detailed study of the diversion probably would indicate numerous revisions which would alter the cost estimates. Nevertheless, the estimates shown in TABLE 49, are presented to indicate the apparent feasibility of the diversion in relation to the Scheme 3 diversion proposed by the Water Resources Service. The total cost of the diversion from Mara Lake including screens at the intake is estimated at $12,733,000, compared with an estimated cost of $14,438,000 for the Scheme 3 diversion with dams at Enderby and Mabel Lake without fish protective facilities which could cost several million dollars. Thus the suggested diversion from Mara Lake offers the prospect of a substantial saving in cost of the facilities required, and in addition would provide the water required without interfering seriously with the fisheries resources of the South Thompson River system, including Mara Lake, Mabel Lake and Lower and Middle Shuswap Rivers.

TABLE 49 - Preliminary cost estimate of suggested diversion from Mara Lake to Okanagan Lake.

| Item | Mara Lake to Enderby | Enderby to Okanagan Lake |
|---|---|---|
| Excavation | $ 533,835 | $ 1,049,616 |
| Canal Road | 513,500 | 711,000 |
| Canal Paving (10%) | 130,355 | 230,951 |
| Right-of-way | 90,055 | 150,000 |
| Clearing | 74,560 | 124,000 |
| Fencing | 96,044 | 133,000 |
| Drainage | 130,000 | 180,000 |
| Concrete checks | 123,000 | 123,000 |
| Concrete Siphon | - | 240,000 |
| Wasteways | 172,000 | 172,000 |
| Drop structures | - | 100,000 |
| Chutes | - | 53,000 |
| Otter Lake Dam | - | 200,000 |
| Fortune Creek Improvements | - | 50,000 |
| Highway and Farm Bridges | 350,000 | 350,000 |
| Pipe River Crossings | 1,618,732 | - |
| Pumping Plant 1 | 796,176 | - |
| Pumping Plant 2 | 436,500 | - |
| Pumping Plant 3 | 942,840 | - |
| Screens at Intake | 312,000 | - |
| Total | $ 6,319,597 | $ 3,866,567 |
| Engineering and Contingencies 25% | 1,579,899 | 966,642 |
| Combined Total | $12,732,705 | |

The Water Resources Service (1966) estimate of annual cost of the Scheme 3 diversion from Lower Shuswap River, adjusted to the maximum annual diversion of 285,497 acre-ft, is given in TABLE 50. The annual cost of the suggested diversion from Mara Lake, estimated on the basis used by the Water Resources Service (1966), but for the maximum annual diversion of 310,776 acre-ft, is also given in TABLE 50 for comparison. The suggested diversion from Mara Lake has a slight annual cost advantage per acre-ft in this comparison because of the larger amount of water diverted. These estimates are made only for purposes of comparison of the diversion proposals using the same unit price structure. Actual costs would depend on the price structure prevailing at the time of construction.

TABLE 50 - Estimated annual cost of suggested diversion of water from Mara Lake compared with the proposed Scheme 3 diversion from Lower Shuswap River.

| | Suggested Diversion from Mara Lake | Proposed Scheme 3 Diversion |
|---|---|---|
| Interest and Amortization | $ 954,953 | $ 1,082,850 |
| Operation and Maintenance | 320,452 | 214,680 |
| Pumping Power Cost | 196,079 | 116,395 |
| Total | $1,471,484 | $ 1,413,925 |
| Cost per acre-ft | $ 4.74 | $ 4.95 |

## CONCLUSIONS AND RECOMMENDATIONS

The diversion of water from Shuswap River to the North and South Okanagan regions as proposed by the Water Resources Service, without provision of fish protective facilities, would eliminate the runs of sockeye, chinook and coho salmon to the Lower and Middle Shuswap River; eliminate the stocks of kokanee that spawn in the Lower Shuswap River; eliminate the stocks of rainbow trout that spawn at the outlet of Mabel Lake and virtually eliminate those that spawn in the Lower Shuswap River; reduce or eliminate the stocks of kokanee and trout that spawn in tributaries of Mabel Lake; and reduce the productivity of sockeye runs that spawn in Okanagan River. These salmon runs make valuable contributions to the commercial fishery in the sea, and there is potential for very substantial increases in production of sockeye. The chinook salmon, kokanee, trout and other sports fish also contribute substantially to the growing recreational fishery in the Shuswap area. This important resource cannot be disregarded in the planning of utilization of water from Shuswap River. Therefore it is recommmnded that further consideration be given to the probable water requirements of the North and South Okanagan regions and to alternate available sources of supply or alternate methods of diversion from the Shuswap Lake watershed, taking into account the requirements for protection of the fishery resources of the Shuswap and Okanagan Rivers.

Estimates of the ultimate consumptive water requirements of the Shuswap River valley indicate that eventually storage will be required on the river system to supply water requirements in some months. The storage already existing in Sugar Lake would be adequate for this purpose but there would be no surplus storage for other purposes. In view of the small capacity of the hydroelectric plant at Shuswap Falls now operated in conjunction with this storage, it is suggested that eventually, when required, emphasis on the use of this storage should be shifted from power to water supply. The hydroelectric plant could continue in operation at reduced capacity or, depending on circumstances at the time, might not be required.

Allowing for the estimated ultimate consumptive use of water from the Shuswap River, there would be a surplus of water sufficient to supply the estimated additional water requirements of the North and South Okanagan regions. However, storage of the surplus water would be necessary to permit delivery in accordance with the seasonal requirements of the Okanagan regions.

It would be feasible to use the emergency storage space available in Okanagan Lake in conjunction with the natural storage effect on Shuswap Lake to supply the estimated water requirements of the Okanagan regions by diversion from Mara Lake. The size and cost of canals and pumping stations required for such a diversion could be reduced by considering delivery of water to the South Okanagan region on an annual basis using a schedule of diversion flows as suggested in this report. It is estimated that the capital and annual costs of such a diversion, including necessary fish screens at the water intake, would be less than the cost of the diversion from the Lower Shuswap River at Enderby not including the cost of fish protection facilities. The diversion from Mara Lake would not affect the fishery resources of the Shuswap River system, Mara Lake, Shuswap Lake or the South Thompson River, if operated in the manner suggested in this report. It also would avoid interference with recreational use of Mabel Lake and would not affect significantly the use of Shuswap Lake. Therefore, if the Shuswap Lake watershed is the only practical source of the additional water required by the North and South Okanagan regions, the diversion from Mara Lake described in this report is recommended in preference to the proposed diversion from Lower Shuswap River near Enderby with upstream storage on Mabel Lake.

It is recognized that other possibilities exist for diversion, such as from Sugar Lake, and that further study as planned may determine an economically feasible alternate diversion. The effects of such an alternate on the fisheries resources of the Shuswap River system cannot be determined until details of the alternate plan are known, but the discussions of fisheries problems contained in this report should serve as a guide in evaluating proposals which might result in similar problems.

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