Canada
Department of Agriculture
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WATER SUPPLY AND WATER USE

ON

PENTICTON AND ELLIS CREEKS

Prepared by:

R.R. Rodgers and
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P.F.R.A. Hydrology Division
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SUMMARY AND CONCLUSIONS

THE PROBLEM

On Penticton and Ellis Creeks most of the high irrigation and municipal demands occur after spring runoff - during the low summer flows. Storage is needed to meet these summer peak demands and to allow for population growth. The question is: how much storage and where? This report reviews the improvement in water supply which could be made from a 10,000 acre-foot reservoir on Penticton Creek (located near the present Penticton Dam No. 2).

WATER SUPPLY FOR PRESENT NEEDS

A 4,800 acre-foot reservoir (located as above) would assure satisfaction of all present irrigation and municipal water demands in a very dry year. If two such very dry years would occur successively, there would be no shortage in water supply providing there were 5,200 acre-feet of storage available.

WATER SUPPLY FOR FUTURE NEEDS

In order to meet the projected 1980 irrigation and municipal demands in a very dry year, a reservoir below the junction of Penticton and Corporation Creeks with a capacity of 9,800 acre-feet is needed. If two such years should occur successively, storage totalling 13,100 acre-feet would just meet the demand. A "very dry" year is equivalent to the lowest runoff year observed in this area since about 1920. By combining two such years in sequence, a severe condition is obtained for study purposes. If water supplies are adequate under such conditions, failure under actual future conditions will be unlikely.

Similarly, storage needed to meet projected 1990 irrigation and municipal demands in one and two dry years are 11,900 and 18,700 acre-feet respectively.

ELLIS CREEK

If the suspended silt problem could be overcome on nearby Ellis Creek and the runoff combined with Penticton Creek above diversions, the storage possibilities are such that a bountiful water supply for the City of Penticton area could be assured.

INTRODUCTION

This study was undertaken in response to a request by the P.F.R.A. Saskatchewan Regional Engineer. The purposes of the study are to assess water use, water supply and the benefits of storage development on Penticton and Ellis Creeks in British Columbia's Okanagan Valley.

Reference to the key map shows that both watersheds drain from east to west down mountainous slopes to the Okanagan Valley at Penticton. The mean basin elevation of Penticton Creek watershed is 4,941 feet above mean sea level (a.m.s.l.), and that of Ellis Creek is 4,780 feet a.m.s.l. Both waterways have a total fall in excess of 4,000 feet. Streams in the upper regions flow in rocky well-defined channels which deepen to gorges at lower elevations. There are very few good reservoir sites because of steep stream gradients and narrow channel confines. Most of the area is well forested. Although there are some existing storage works (see Fig. 1) they are difficult to maintain and their effectiveness in stream regulation is limited by their inaccessibility. Stored waters must travel many miles of stream channel before being rediverted.

At present Penticton experiences municipal and irrigation water shortages in a dry year because storage facilities are inadequate on Penticton and Ellis Creeks. In an average year, peak summer demands must be met by pumping from Okanagan Lake. Winter municipal demands are sometimes supplied by pumping from Okanagan Lake.

In this report, an estimate has been made of the available streamflow in minimum and average years. Present and future water demands have been compiled, and finally the water supply has been compared with the demands in order to determine the adequacy or inadequacy of the water supply.

The balance of the report describes how this was done under three main headings:

Basic Information

Contains estimates of minimum and average annual runoff for both Penticton Cr. and Ellis Cr. watersheds as well as present and future municipal and irrigation demands.

Water Supply Studies

Outlines the method and assumptions used to compare water supply and water demands.

Conclusions in Detail

The findings of the study and the inferences which can be made therefrom are summarized.

The above headings summarize this report. Details of the work done and calculations made may be found in the Appendices.

BASIC INFORMATION

RUNOFF

Published streamflow data[1] were not sufficient to establish directly reliable runoff figures for Penticton and Ellis Creeks watersheds. These figures were obtained by methods described in Appendix 1 and are listed below for reference.

	Average Annual Runoff (ac.ft.)*	Minimum Year Runoff (ac.ft.)*
Penticton Creek Watershed	43,000	9,600
Upper Penticton Reservoir[2].....	8,900	2,000
Ellis Creek Watershed	37,000	8,400
Ellis Creek Dam #4	11,000	2,500

* rounded figures

The average and minimum year hydrographs of natural streamflow on Penticton Creek at Penticton are shown in Fig. 2. A five-year period of record was used to obtain daily flow hydrographs. Appendix IV describes how the minimum and average year hydrographs were constructed from this basic data.

MUNICIPAL USE OF WATER

The studies described in Appendix III-A concerning future municipal water requirements were based on extrapolated per capita consumption and population growth.

The 1953 per capita consumption was 130 gallons per capita per day (g.c.d). Fig. 3(b) projects this to 196 g.c.d. by 1980, and 200 g.c.d. by 1990.

It was considered that Penticton would show an initial annual population increase of 5% tapering to 3% over the next 28 years. This provides for a population growth from 14,550 (1962) to 43,100 (1990). Details of this population analysis are in Appendix II.

Figs. 3(a), (b), (c) show the estimated growth of population, per capita consumption and annual municipal water demand to 1990 for city growth.

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1 "Pacific Drainage" Water Resources Branch, Department of Northern Affairs and National Resources.

2 See Key Map (Fig. 1).

IRRIGATION USE OF WATER

The figures used for the average monthly application of irrigation water to both the Penticton and the Ellis Creek irrigation systems are based on information which is contained in Brief No. 42 of the Proceedings of the "Reclamation Committee In The Okanagan Valley".[1] An average daily irrigation hydrograph was constructed in order to give a total of 4½ months of application at rates comparable to those used on the Penticton Creek irrigation system in recent years.

Total irrigation demands for the Ellis Creek and Penticton systems are listed in Table 1 as well as present and future irrigable acreages. Appendix III-B describes in more detail the methods used to estimate irrigation requirements.

DEVELOPMENT POSSIBILITIES

Preliminary field inspection by engineering staff of the Saskatchewan Regional Office pointed out some of the obstacles to reservoir development in the Penticton area. Also many of the existing reservoirs are in need of major repairs to maintain or regain their original storage capacities. Steep stream gradients and narrow valleys lead to high costs per acre-foot of storage. From these considerations it was decided to evaluate the water supply benefits from one large reservoir, rather than several small reservoirs.

From a preliminary inspection, it appeared feasible to consider development of a 10,000 acre-foot reservoir, which would combine the surface areas of Penticton Creek Reservoirs No. 1 and No. 2 (see Fig. 1). Proper location of the dam would enlarge the drainage area to include Corporation Creek. The total drainage area would be 12.30 square miles. An access road to this site already exists. The average annual runoff to this reservoir would be about 9,000 acre-feet.

MISCELLANEOUS INFORMATION

Eight recent reports were made available to P.F.R.A. concerning Penticton's water problems. These reports provided valuable background information, particularly regarding municipal consumption. They are summarized and listed below:

1. "Preliminary Report on Water Supply for Irrigation and Domestic Purposes in the City of Penticton" - August 22/55 by E. R. Gayfer, Superintendent of Works.

   - An extensive report on domestic and irrigation water supply and demands, investigating many solutions.

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1 "Proceedings of the Reclamation Committee in the Okanagan Valley", Brief No. 42, July 23rd and 24th, 1963. Page 6 and 7.

2. "Preliminary Report on a Proposed Domestic Water System to Serve the Skaha Lake Suburb - Penticton B.C."
June 12/56 - by Associated Engineering Services Ltd.

   - Provides preliminary plans and cost estimates for a domestic water system to meet the requirements of the Skaha Lake Suburb.

3. "Report on the City of Penticton Water Supply"
October 5/56 - by Associated Engineering Services Ltd.

   - Investigates the feasibility of increased storage on Ellis and Penticton Creeks as opposed to pumping from Skaha or Okanagan Lake. A phased program of development is put forth.

4. A Report on the Cost of Pumping Domestic Water from Skaha Lake
May 27/57 - by Associated Engineering Services Ltd.

5. A Summary of Past Reports and Problems on Domestic and Irrigation Water Supply for the City of Penticton
October 7/57 - by H. G. Andrew, City Clerk.

6. A Report in the Matter of the Storage and Distribution of Domestic and Irrigation Water
December 16/57 - by D. K. Penfold, R.PE. (B.C.)

7. Proceedings of the Reclamation Committee in the Okanagan Valley, Brief No. 42.
July 23-24, 1963 - Department of Agriculture, Government of British Columbia, Kelowna, B. C.

8. Letter from the Mayor of Penticton to the P.F.R.A. Regional Engineer, September 12/63.

WATER SUPPLY STUDIES

METHOD

Water supply studies were conducted for both present and future needs. They were made by graphically comparing municipal and irrigation demands with natural streamflow hydrographs and reservoir releases.

The same basic method was used for both studies. First the average daily municipal demand was plotted for each month of the year; next the irrigation demand hydrograph was plotted for the period May 1st to September 15th. By adding the ordinates of these two curves the total demand curve was obtained.

The recession portion of the minimum-year hydrograph was then superimposed on the total demand curve. This showed what portion of the total demand could be satisfied by natural streamflow in a dry year and the date on which reservoir releases would have to begin.

The area between the total demand curve and the stream hydrograph is the amount of water that must be released from storage to meet the demand. This release begins in mid-summer and continues throughout the winter until the rising limb of the spring hydrograph exceeds the daily demand. During April and May natural streamflow meets the total demand and replenishes the reservoirs.

Figs 4 and 5 depict the occurrence of two successive dry years followed by an average year. The minimum runoff of 2,000 acre feet per year for the Upper Penticton Creek area would be caught and stored during the spring runoff of the first and second years. Because the total demand curve rises above the streamflow hydrograph, reservoir releases are required. These releases continue until storage is depleted or, until the rising limb portion of the average-year hydrograph rises to exceed the demand.

ASSUMPTIONS

The assumptions used in the water supply studies are as follows:

1. The Upper Penticton area could have a total live-storage capacity of 10,000 acre feet. In a year of average runoff 9,000 acre feet will be impounded; in a very dry year the "minimum year" flow of 2,000 acre feet will be impounded.

2. Releases for municipal purposes can be made from the Upper Penticton reservoir under summer and winter conditions if water is available.

3. Unregulated winter flows in Penticton Creek were not used in this report for municipal purposes. This assumption is made to add a safety factor to the results of the water supply studies. If the winter flow is used for municipal demands the storage requirements would be decreased accordingly.

4. It is assumed in this report that no municipal water will be pumped from Okanagan Lake. This adds a safety factor to the results.

5. The flow in Corporation Creek and any releases from Corporation Creek Reservoir will be diverted into the proposed Upper Penticton Reservoir.

6. The flow in Ellis Creek will be used solely for the Ellis Creek irrigation system.

RESULTS

The results of the water supply studies are shown on Figs. 4 and 5 and are given below. Table II. summarizes the supply and use of water for the studies.

With the occurrence of one very dry year and:

(i) present demands 1962-63 - storage requirements would total 4,800 acre feet, of which 2,200 acre feet would meet the irrigation demand.

(ii) future demands 1980-81 - storage requirements would total 8,700 acre feet, of which 2,100 acre feet would meet the irrigation demand.

(iii) future demands 1990-91 - storage requirements would total 11,900 acre feet, of which 2,100 acre feet would meet the irrigation demand.

With the occurence of two consecutive dry years and:

(i) present demands 1962-64 - storage requirements would total 5,200 acre feet, of which 2,200 acre feet would meet the irrigation demand.

(ii) future demands 1980-82 - storage requirements would total 13,100 acre feet, of which 2,100 acre feet would meet the irrigation demand. In this report it is assumed that irrigation has "first call" on the stored water.

(iii) future demands 1990-92 - storage requirements would total 18,700 acre feet, of which 2,100 acre feet would satisfy the irrigation demand. It should be re-emphasized that these storage figures are related to a specific site. If alternative downstream sites were available, the storage requirements would be less. It should also be noted that 10,000 acre feet appears to be a reasonable upper limit to storage potential at the site in question from an hydrologic point of view.

If continuous winter flows of 2, 3, or 4 c.f.s. could be relied upon in Penticton Creek during the winter period of October 1 to April 30, and if these flows could be used to meet the municipal demand during the same period, storage requirements over two severely dry years would be reduced from 18,700 acre feet to 17,000, 16,300, and 15,500 acre feet respectively.

CONCLUSIONS IN DETAIL

From the investigations carried out in the course of this study the following conclusions can be drawn:

1. The estimated average annual and minimum runoff on Penticton and Ellis Creeks are as listed below:

	Average Annual Runoff (ac.ft.)*	Minimum year Runoff (ac.ft.)*
Penticton Creek Watershed	43,000	9,600
Ellis Creek Watershed	37,000	8,400
Upper Penticton Area[1]	8,900	2,000
Ellis Dam #4	11,000	2,500

* rounded figures

These flows are primarily due to spring runoff with some contribution from fall rains.

2. Water demands

Unless water charges rise or connections are metered, Penticton's high municipal demand can be expected to continue unabated for some time and to reach 200 gallons per capita per day by the year 1990. The population growth shows no sign of dropping off. Thus the estimated municipal demand of nearly 11,600 acre feet in the year 1990 is fairly reasonable.

The estimated future irrigation demands should be reliable as the unit rate of application used is that desired for good irrigation practice in the area. Expansion of irrigable lands is curtailed by mountainous terrain.

3. Storage requirements

For present needs a total of 5,200 acre feet of storage in the Upper Penticton Reservoir would prevent water shortages in the event of two consecutive dry years occurring. 1990 demands of 18,700 acre feet call for 10,000 acre feet of storage in the Upper Penticton area plus storage somewhere else in the Penticton Creek or Ellis Creek watersheds.

It is felt that use of two consecutive dry years as a design criteria may be too severe. Instead, design should be based on the occurrence of one dry year.

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1 See key map (Fig. 1)

For one dry year, a total of 4,800 acre feet of storage in the Upper Penticton Reservoir would assure a stable water supply at present for Penticton.

For one dry year, future (1990) demands call for 11,900 acre feet of storage to assure that no water shortages would occur.

4. Reservoir operation

With no balancing reservoir immediately above the City of Penticton, particular thought must be given to reservoir operation. Day by day summer demands must be drawn from streamflow made up mainly of released water. If too much water is released or if releases continue longer than required, a large portion of stored water could be wasted.

5. Ellis Creek Dam #4

Because the Ellis Creek Dam #4 area has a greater average annual runoff than the Upper Penticton area, 10% to 20% smaller storage works would yield a similar assured flow. However, to integrate Ellis Creek and Penticton Creek two problems must be overcome. First, a balancing flume or main would be needed to connect their waters above diversion points; and second, the suspended sediment problem on Ellis Creek must be solved.

APPENDIX 1

RUNOFF DETERMINATIONS

A. Streamflow Records

The streamflow records for Penticton and Ellis Creeks are of a very poor quality. Irrigation diversion records have been obtained since 1919 on Penticton Creek and since 1922 on Ellis Creek. Unfortunately, this data is of little use in reconstructing total streamflow.

B. Total Average Annual Runoff - Penticton Creek

Records for gauging stations $8NM_{32}$[1] and $8NM_{76}$[2] were combined for the period April to September inclusive for the years 1937 to 1941 to give a total runoff of 120,382 acre feet or 24,076 acre feet per year average. Total runoff for Trout Creek for the same period was found to be 134,093 acre feet or 26,819 acre feet per year. The total long-term (25 years) runoff for Trout Creek was 1,195,585 acre feet or 47,823 acre feet per year. Penticton Creek's long-term average annual runoff was found by the following ratio: (see Table III for streamflow records):

$$\frac{\text{Av. Ann. runoff Pent. Cr. (short term)}}{\text{Av. Ann. runoff Trout Cr. (short term)}} = \frac{\text{Av. Ann. runoff Pent. Cr. (long term)}}{\text{Av. Ann. runoff Trout Cr. (long term)}}$$

OR

$$\frac{24{,}076 \text{ ac. ft.}}{26{,}819 \text{ ac. ft.}} = \frac{\text{Long term av. ann. runoff Pent. Cr.}}{47{,}823 \text{ ac. ft.}}$$

Long term average annual runoff for Penticton Creek is thereby estimated at 42,945 acre feet per year. A graphical correlation with Trout Creek indicated a minimum year runoff (1931) of about 8,000 acre feet. The quality of the correlation and hence the estimate is not good.

The term annual flows for the purpose of computation means the April-September flows. The flows during the other six months are discussed in the results of the water supply studies in this report.

C. Average Runoff at Various Elevations

The drainage areas of both Penticton Creek and Ellis Creek watersheds were determined as well as the total area lying between 500 foot contour intervals (as shown in Table IV).

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1 $8NM_{32}$ - Located on main diversion canal.

2 $8NM_{76}$ - Located below diversion on Penticton Creek.

APPENDIX 1 (continued)

C. Average Runoff at Various Elevations (continued)

Previous studies by P.F.R.A. Hydrology Division for the eastern slopes of the Rocky Mountains indicated a logarithmic increase in average annual runoff with elevation (see Fig. 6).

On Fig. 6 point "A" was established by plotting mean basin elevation for Penticton Creek against average annual runoff per square mile. By trial and error a straight line was fitted passing through "A". The slope of this line was varied until the summation of the areas between the 500-foot contour intervals, in square miles, times the unit runoff for the mean contour elevation equalled the average annual runoff assumed for the Penticton Creek watershed. From the slope of this line it was determined that:

$$\frac{\text{Runoff @ R}}{(\text{Mean Elev.@R})^K} \qquad \frac{\text{Runoff @ S}}{(\text{Mean Elev.@S})^K}$$

The constant "K" was found to equal 0.972.

The line could be used to determine the average annual runoff of any portion of Penticton Creek watershed once the drainage area and the mean elevation of that portion was known.

D. Minimum Runoff at Various Elevations

The minimum unit runoff determinations were based on an observation by Gayfer[1] that "in the dry years of the 1920's and 1930's the No. 1 dam never quite failed to fill." The reservoir referred to is the Penticton Creek Irrigation Reservoir No. 1 with a storage capacity of 1,200 acre feet and a drainage area of 7.16 square miles.

Plotting the point of minimum unit runoff of this reservoir against the mean elevation of the reservoir's drainage area gave a point of minimum unit runoff (point "B" on Fig. 6). A line through this point and parallel to the line of average annual unit runoff, enabled an estimate of the minimum unit runoff of any portion of Penticton Creek watershed to be made. Mean basin elevations and drainage areas were determined for existing reservoirs in both Penticton Creek and Ellis Creek watersheds. Table V gives the results of these plots showing the minimum runoff, as well as the average annual runoff, for each reservoir and the entire Penticton Creek watershed. An estimate of Ellis Creek runoff is given, also based on the mean basin elevation alone.

It is worth noting that the minimum year runoff estimated in this way (9,620) compares reasonably well with the 8,000 acre feet minimum year runoff indicated by the Trout Creek correlation mentioned earlier.

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1 "Preliminary Report on Water Supply for Irrigation and Domestic Purposes in the City of Penticton" by E. R. Gayfer, Supt. of Works, August 22, 1955, Page App. 5

APPENDIX 1 (continued)

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$$\frac{\text{Runoff @ R}}{(\text{Mean Elev.@R})^K} \qquad \frac{\text{Runoff @ S}}{(\text{Mean Elev.@S})^K}$$

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The line could be used to determine the average annual runoff of any portion of Penticton Creek watershed once the drainage area and the mean elevation of that portion was known.

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APPENDIX II

POPULATION ESTIMATES

Dominion census figures were used to estimate the future population of Penticton. Populations of other cities of British Columbia were used to obtain growth trends in the area. Table VI shows the annual percentage change in the population of these centres.

Projections were made from 1961 to 1990 for both a 5% annual increase and a 3% annual increase as shown in Fig. 3 and listed in Table VII.

Penticton's Town Plan[1] gives a projection to 1971 of almost 28,000. This projection as well as the 5% annual increase indicate a high rate of growth while the 3% annual increase appears to be too conservative.

The rate of population growth used in this report decreases from 5% in 1961 to 3% in 1990. This gives a population of 14,550 in 1962 and 43,100 in 1990. The City of Penticton can make provision for a future population of 48,000 people, using only its non-agricultural land.[2]

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1 "Preliminary Report on Water Supply for Irrigation and Domestic Purposes in the City of Penticton" by E. R. Gayfer, Supt. of Works, August 22, 1955. p. 5

2 Letter from the Mayor of Penticton to the P.F.R.A. Regional Engineer, September 12, 1963.

APPENDIX III

WATER REQUIREMENTS

A. MUNICIPAL

Municipal water consumption in Penticton is presently unmetered, consequently the per capita consumption is high. This high consumption is aided by high garden and park demands, low rainfall at Penticton and some irrigation water being supplied from city mains.

In 1952-53 the average annual consumption was 130 gallons per capita per day (g.c.d.)[1]. A graphical projection was made in Fig. 3(b) assuming an average annual consumption of 200 g.c.d. by 1990. This figure, while being high, is quite reasonable if the connections remain unmetered and the uninhibited habits of water consumption are continued.

Monthly distribution was based on actual consumption for 1953. Table VIII shows monthly and average daily distributions for the years 1962, 1980 and 1990. Fig. 3(c) shows the estimated annual consumption to 1990 for a total population of 43,100.

It should be noted that estimates of short-term peak demands and fire protection requirements have not been made as they are not pertinent to this basic water supply study.

B. IRRIGATION

There are two separate irrigation systems on the east side of the Okanagan Valley at Penticton. Both receive water by flume systems. The northern one is served by Penticton Creek and presently has about 1480 irrigable acres. An additional 80 acres may be added to the area in the future; when this is combined with an estimated loss to residential area of 140 acres, it would reduce the total irrigable area in 1980-1990 to 1420 acres.

The second or southern system presently has about 710 acres under irrigation. Approximately 250 acres of this are supplied by pumping from Okanagan River and the remainder from Ellis Creek by gravity flow. This system is expected to have approximately 480 irrigable acres in 1980-1990. (see Table 1)

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1 "Preliminary Report on Water Supply for Irrigation and Domestic Purposes in the City of Penticton" by E. R. Gayfer, Supt. of Works, August 22, 1955, Table II - 1 p.4

APPENDIX III (continued)

B. IRRIGATION (continued)

The computations of average rates of application were based on information contained in Brief No. 42[1]. The total yearly applications of irrigation water to both systems are 6.9 inches per acre per month.

The observed daily diversions to the Penticton Creek irrigation system were averaged for the period 1947 to 1958 to obtain the pattern of application or the average daily irrigation hydrograph for the period May 1st to Sept. 15th. The ordinates of this average daily hydrograph were adjusted so that the total annual requirement would be 3,830 acre feet under present conditions[2] and 3,670 acre feet under future conditions[3]. (see Fig. 7)

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1 "Proceedings of the Reclamation Committee in the Okanagan Valley", Brief No. 42, July 23rd and 24th, 1963. pages 6 and 7.

2 A total of 31 inches on 1480 acres

3 A total of 31 inches on 1420 acres

APPENDIX IV

HYDROGRAPHS OF PENTICTON CREEK STREAMFLOW

A. Average Year

Hydrographs of daily flows on Penticton Creek were plotted and analyzed for the period 1937 to 1941 inclusive. The hydrograph for 1936 was rejected because of obviously inaccurate records.

Spring flows for each year were smoothed by eliminating auxiliary peaks (Fig.8) and were plotted on semilog paper (Fig. 9) to determine the average rising limb of the average year hydrograph for the period 1937 to 1941.

The recession portion of each year's hydrograph was smoothed out to eliminate the effects that short rainfalls and reservoir releases had on the hydrograph as shown in Fig. 10. Any sharp peak occurring after a significant rainfall at Penticton was eliminated. Any foreshortened peak or "hump" that occurred without a significant preceding rainfall was assumed due to storage releases and was also eliminated. The smoothed-out recession portion of each year's hydrograph was then plotted on semilog paper to obtain an average recession curve for the period 1936 to 1941. (Fig. 11)

Using the average rising limb and the average recession curve the average hydrograph for the period 1937 to 1941 was drawn (Fig. 2). From this hydrograph the April to July runoff equals about 9,350 c.f.s. days or about 80% of the average annual flow.

In Appendix 1 the average annual runoff for the period 1937 to 1941 was used with Trout Creek flows to obtain the long term average annual runoff for Penticton Creek. Similarly the hydrograph of average annual spring runoff was made larger than the 1937 to 1941 hydrograph as the flows for this period appear below those expected in an average year.

An earlier flood study on Penticton Creek done by F.F.R.A. Hydrology Division indicated that the mean annual flood peak for Penticton Creek near the City of Penticton would be about 375 cubic feet per second (c.f.s.) (mean daily). This figure was used for the peak of the long term average year hydrograph. The rising limb and receding portion were patterned after the 1937 to 1941 hydrograph. A total of 14,600 c.f.s. days lies under the average year hydrograph, approximately 70% of the assumed annual flow for Penticton Creek.

APPENDIX IV (continued)

B. Minimum Year

The minimum year hydrograph was obtained in a manner somewhat similar to the average year hydrograph. First the minimum annual runoff for the Penticton Creek watershed (9,620 acre feet--see Appendix 1) was reduced by the estimated amount of runoff which would be impounded in the Upper Penticton Reservoir (2,000 acre feet). The minimum year hydrograph (April-June) was then patterned after the 1937 to 1941 hydrograph so it arbitrarily contained 3,330 c.f.s. days or about 90% of the adjusted minimum year flow.

The percentage of a year's total flow contained within these part-year hydrographs decreases as the year in question gets wetter. This is as expected because in a very dry year there will be few if any auxiliary peaks of any significance lying outside the April--June runoff period. In a very wet year, however, the streamflow might be represented by a series of overlapping hydrographs because of recurring heavy rains.

C. Flood Potentials for Penticton and Ellis Creeks.

Although the streamflow data available for flood study in the Penticton area are of poor quality, an estimate of flood flows has been attempted. When using the table shown below, the following should be kept in mind:

(1) The flood flows given are mean daily flows and may be increased by the factors noted in the table to obtain an estimate of the instantaneous peak flow.

(2) No consideration has been given to existing or natural storages which might somewhat reduce flood peaks by delaying or impounding a portion of the flow.

The data were examined on a regional basis as follows:

(a) The Mean Annual Flood was selected after studying streams in the Penticton-Princeton-Kamloops area with similar exposures and elevations.

(b) Frequency characteristics were based on the slopes of frequency curves of eight neighboring streams, having in mind several physiographic characteristics.

APPENDIX IV (continued)

PENTICTON & ELLIS CREEKS' FLOOD POTENTIAL

		The probable odds are	that a mean daily flood peak will occur in any yr exceeding	Factor for instantaneous * flood peak
PRESENT CONDITIONS	At lower end of Penticton Creek (near existing City dam)	1:10 1:25 1:100	630 c.f.s. 740 c.f.s. 900 c.f.s.	1.5
	At the outlet of the "Upper Penticton Reservoir Area"	1:10 1:25 1:100	130 c.f.s. 150 c.f.s. 190 c.f.s.	1.9
	At lower end of Ellis Creek (above the City of Penticton)	1:10 1:25 1:100	580 c.f.s. 680 c.f.s. 820 c.f.s.	1.5
FUTURE CONDITIONS **	At lower end of Penticton Creek (near existing City dam)	1:10 1:25 1:100	530 c.f.s. 620 c.f.s. 750 c.f.s.	1.5

* The mean daily flood peaks may be multiplied by the factors given to obtain an estimate of the instantaneous flood peak.

** With proposed storage of 10,000 acre-feet assumed to effectively stop flood flows from the "UPPER PENTICTON RESERVOIR AREA."

TABLE 1

SUMMARY OF DEMANDS AND ACREAGES

FOR

PENTICTON & ELLIS CREEKS IRRIGATION SYSTEMS

IRRIGATION SYSTEM	PAST DEMANDS FOR PERIOD 1947 to 1958			PRESENT ACREAGE & DEMANDS		ASSUMED ACREAGE CHANGES		1980 - 1990 ACREAGE & DEMANDS	
	Minimum Yearly	Maximum Yearly	Average Yearly	Total Acreage	Yearly Demands	Additions	Loss to Residential	Total Acreage	Yearly Demands
PENTICTON CREEK	2,470 ac.ft.	4,715 ac.ft.	3,660 ac.ft.	1,480 acres	3,830 ac.ft.	80 acres	140 acres	1,420 acres	3,670 ac.ft.
ELLIS CREEK	1,380* ac.ft.	3,110* ac.ft.	2,330* ac.ft.	710 acres	1,840 ac.ft.	100 acres	330 acres	480 acres	1,250 ac.ft.

* Prorated from an assumed 450 acres to 700 acres

TABLE II
SUMMARY OF WATER SUPPLY STUDIES FOR A PERIOD OF TWO CONSECUTIVE DRY YEARS*

YEAR	1962	1963	1964	1980	1981	1982	1990	1991	1992
Population Estimates of Penticton	14,550	15,270	16,000	31,130	32,260	33,410	43,100	44,400	45,700
Municipal Demands in Acre Feet	3,220	3,460	3,720	8,240	8,530	8,880	11,600	11,950	12,350
Irrigation Demands in Acre Feet	3,830	3,830	3,830	3,670	3,670	3,670	3,670	3,670	3,670

Required Reservoir Releases (in Acre Feet)

To Supply Municipal Needs	JUN 29 - DEC 31	JAN 1 - APR 13 JUN 28 - DEC 31	JAN 1 - MAR 11	JUN 19 - DEC 31	JAN 1 - APR 22 JUN 18 - DEC 31	JAN 1 - MAR 21	JUN 14 - DEC 31	JAN 1 - APR 26 JUN 13 - DEC 31	JAN 1 - MAR 25
	1,960	2,620	350	5,200	6,720	900	7,400	9,850	1,290
To Supply Irrigation Needs	JUN 18 - SEP 15	JUN 18 - SEP 15	JAN 1 - MAR 1	JUN 18 - SEP 15	JUN 18 - SEP 15	JAN 1 - MAR 1	JUN 18 - SEP 15	JUN 18 - SEP 15	JAN 1 - MAR 1
	2,130	2,130	none	2,030	2,030	none	2,030	2,030	none

Size of Reservoir Needed to Supply (in Acre Feet)

PERIOD	1962 — 1964	1980 — 1982	1990 — 1992
Irrigation Demand	2,200	2,100	2,100
Municipal Demand	3,000	11,000	16,600
Irrigation and Municipal Demand	5,200	13,100	18,700

ASSUMPTIONS:
1. When no reservoir releases are needed, streamflow in Penticton Creek will meet the demands.
2. The minimum runoff caught in the proposed Upper Penticton Reservoir is 2,000 acre feet per year.
3. The winter flow in Penticton Creek is not used to meet demands.
4. Pumping of lake water is not employed to meet demands.

Using the same assumptions as above with the exception of 3., the amount of storage needed to meet the municipal demands is as follows: (in acre feet)

PERIOD	1962 - 1964	1980 - 1982	1990 - 1992
Using a flow in Penticton Creek = 2 cfs from Oct 1 to April 30	1,200	9,300	14,900
Using a flow in Penticton Creek = 3 cfs from Oct 1 to April 30	700	8,600	14,200
Using a flow in Penticton Creek = 4 cfs from Oct 1 to April 30	100	7,800	13,400

* Refer to Figures 4 and 5

TABLE 111

RECORDED* FLOWS OF PENTICTON AND TROUT CREEKS (Acre feet)

Penticton Cr. near Penticton--Combined flows of gauging Stations $8NM_{76}$ and $8NM_{32}$

YEAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	TOTAL
1937	547	8,842	11,406	2,699	1,371	89	24,954
1938	1,892	15,157	6,271	2,380	1,543	143	27,386
1939	2,428	9,279	5,444	3,044	1,377	54	21,626
1940	1,154	11,154	4,022	2,503	295	95	19,223
1941	2,541	8,547	7,313	3,296	2,343	3,153	27,193
						TOTAL	120,382
						AVERAGE	24,076

Trout Creek near Foulder--Gauging Station No. $8NM_{54}$

YEAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	TOTAL
1922	1,309	13,958	13,863	2,152	1,537	595	33,414
1923	3,808	19,615	22,134	6,395	3,136	1,428	56,516
1924	1,607	13,589	3,570	2,398	738	297	22,199
1925	3,808	20,538	6,723	2,583	1,599	416	35,667
1926	4,641	5,780	1,785	1,660	615	297	14,778
1927	1,606	13,651	16,660	4,981	2,829	2,737	42,464
1935	3,272	29,515	22,550	10,684	3,751	2,737	72,709
1936	5,117	13,897	7,854	3,628	3,074	1,130	34,700
1937	1,309	13,220	15,767	4,366	3,874	1,725	40,261)
1938	4,820	22,321	7,140	3,320	2,706	1,249	41,556)
1939	2,618	6,395	3,391	2,952	1,845	357	17,558) **
1940	2,142	6,456	2,023	1,599	1,353	416	13,989)
1941	3,035	1,845	5,652	4,181	3,874	2,142	20,729)
1942	5,890	34,803	25,050	6,333	4,550	3,034	79,660
1944	1,130	7,686	16,124	4,735	3,874	1,963	35,512
1945	2,202	29,023	28,322	6,456	3,997	2,261	72,261
1946	4,820	49,315	25,644	5,903	3,566	2,439	91,687
1947	3,153	14,450	7,318	3,505	3,566	1,606	33,598
1948	2,201	38,616	31,476	7,010	7,194	5,236	91,733
1949	4,522	32,098	8,270	4,673	3,935	2,558	56,056
1950	2,201	19,800	31,654	6,088	3,935	2,975	66,653
1951	6,069	34,373	12,555	4,120	3,689	1,904	62,710
1952	5,176	21,644	8,389	4,981	3,812	2,142	46,144
1953	1,369	18,017	22,670	9,101	5,288	1,547	57,992
1954	1,487	20,230	17,731	7,071	4,058	4,462	55,039
						TOTAL	1,195,585
						AVERAGE	47,823

* Streamflow in c.f.s. obtained from "Surface Water Supply of Canada--Pacific Drainage". Dept. of Northern Affairs & National Resources & converted to ac.ft.

** Total (1937 to 1941) = 134,093 Average (1937 to 1941) = 26,819

TABLE V

RESULTS OF RUNOFF DETERMINATIONS FROM FIG. 6

BASIN	Col. 1 MEAN BASIN ELEVATION (ft.)	Col. 2 DRAINAGE AREA (sq.mi.)	Col. 3 MINIMUM UNIT RUNOFF (ac.ft/sq.mi/yr)	Col. 4 TOTAL MINIMUM RUNOFF (ac.ft/yr)	Col. 5 AVERAGE ANNUAL UNIT RUNOFF (ac.ft/sq.mi/yr)	Col. 6 TOTAL AVERAGE ANNUAL RUNOFF (ac.ft/yr)
				Col.2 x Col.3		Col.2 x Col.5
Penticton Creek Watershed	4,941	67.19	143	9,620	639	42,945
Howard Lake (West Dam)	6,250[e]	0.55	181	99.5	800	440
Reed Lake	6,100[e]	0.59	176	104.0	780	460
Corporation Creek Reservoir	6,000[e]	0.274	175	48.0	775	210
Proposed Res. on Municipal Creek	5,873	1.80	170	306.0	755	1,360
Penticton Creek Res. #1	5,740	7.20	167	1,200	740	5,330
Penticton Creek Res. #2	5,410	4.83	156	754.0	700	3,380
Crow Reservoir	5,042	2.13	146	311	650	1,390
Ellis Creek Watershed	4,780	60.41	139	8,400	620	37,450
Ellis Dam #1	5,360	3.66	155	566	685	2,510
Ellis Dam #4	5,100	16.92	147	2,490	655	11,080

[e] Estimated

TABLE VI

CENSUS FIGURES

FOR

SELECTED BRITISH COLUMBIA CITIES

CITY	DOMINION CENSUS FIGURES				ANNUAL % CHANGE BETWEEN CENSUS YEARS		
	1941	1951	1956	1961	1941 - 51	1951-56	1956-61
Penticton	5,777	10,548	11,790	13,859	8.25%	2.36%	3.55%
Kelowna	5,118	8,517	8,924	13,188	6.65%	0.96%	9.55%
Kamloops	5,959	8,099	8,884	10,076	3.59%	1.94%	2.68%
Nanaimo	6,636	7,196	12,570	14,135	0.85%	14.98%	2.49%
Trail	9,392	11,430	11,319	11,580	2.08%	-0.19%	0.46%

TABLE VII

POPULATION GROWTH FOR THE CITY OF PENTICTON

USING

(a) 3% annual increase
(b) 5% annual increase and
(c) tapering annual increase
(used in this report)

		5 yrs	10 yrs	15 yrs	20 yrs	25 yrs	29 yrs
	1961	1966	1971	1976	1981	1986	1990
3% population coefficient		1.16	1.34	1.56	1.81	2.09	2.36
3% annual increase	13,859	16,100	18,600	21,600	25,100	29,000	32,800
5% population coefficient		1.28	1.63	2.08	2.65	3.39	4.12
5% annual increase	13,859	17,700	22,600	28,800	36,800	47,000	57,200
5% annual increase in 1961 tapering to 3% annual increase by 1990	13,859	17,560	21,869	26,796	32,260	38,146	43,094

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TABLE VIII

DISTRIBUTION OF PENTICTON'S YEARLY MUNICIPAL & IRRIGATION DEMANDS

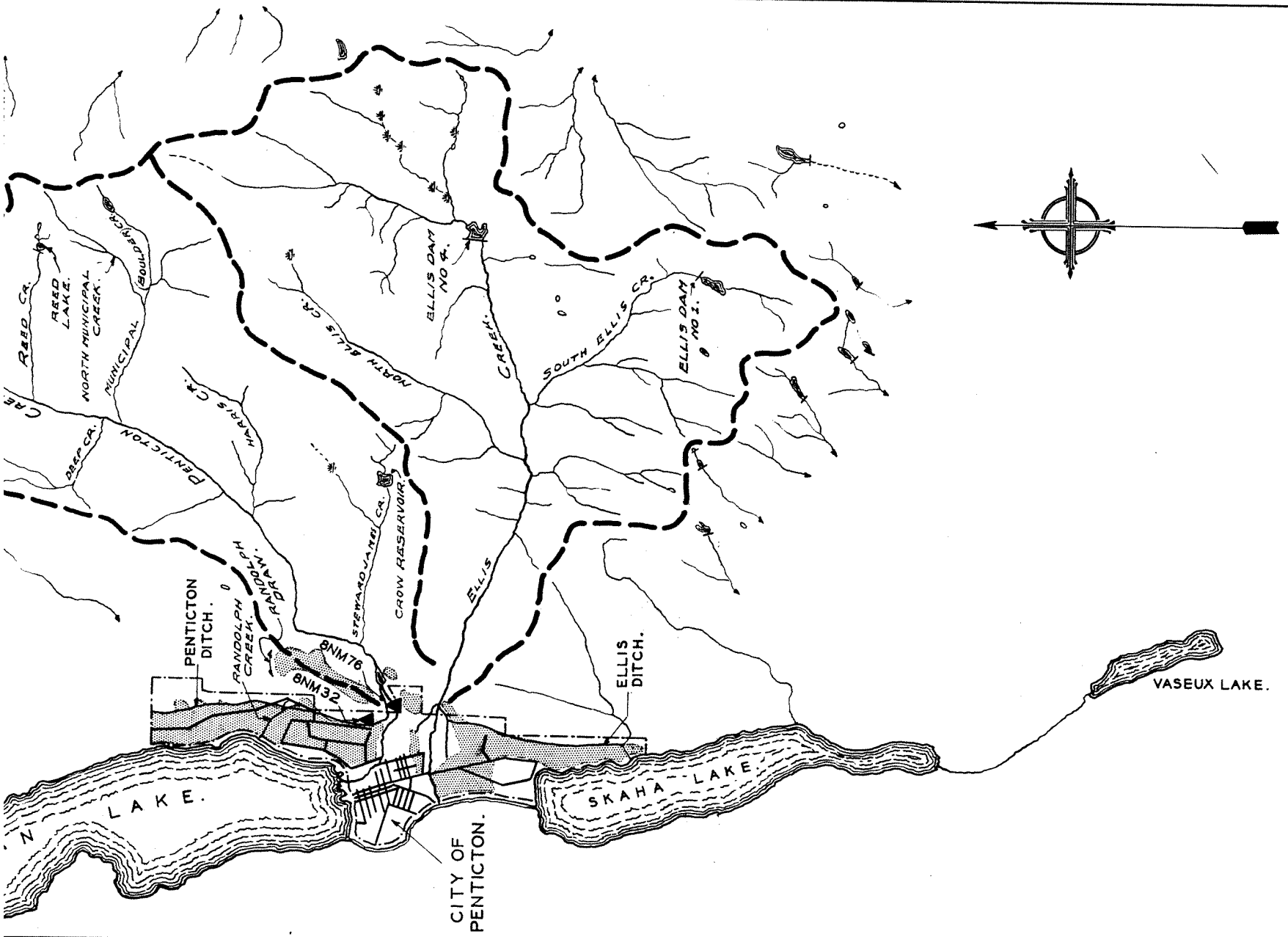
CITY USE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Municipal Use 1953 (m.g.)	20	24	23	29	48	51	83	81	51	38	35	27	510
Percentage of Year's total	3.92	4.71	4.51	5.69	9.41	10.00	16.27	15.88	10.00	7.45	6.86	5.29	100.00
Projected Municipal Demand 1963[1] in acre feet	136	163	156	198	326	346	563	549	346	258	238	181	3,460
Average Daily Use for a Month in acre feet	4.39	5.82	5.03	6.60	10.50	11.50	18.15	17.70	11.50	8.33	7.94	5.84	
Projected Municipal Demand 1980[2] in acre feet	323	387	371	460	775	824	1338	1315	824	623	565	435	8,240
Average Daily Use for a Month in acre feet	10.41	13.81	11.97	18.30	25.00	27.50	43.20	42.40	27.50	20.20	18.80	14.00	
Projected Municipal Demand 1990[3] in acre feet	455	546	523	664	1094	1160	1885	1840	1160	864	795	614	11,600
Average Daily Use for a Month in acre feet	14.7	19.5	16.9	22.1	35.3	38.6	60.8	59.3	38.6	27.8	26.5	19.8	
IRRIGATION USE[4] (Ellis Creek Irrigation Excluded)													
In 1963 in acre feet	0	0	0	0	540	996	1115	1045	134	0	0	0	3,830
In 1980 & 1990 in acre feet	0	0	0	0	517	954	1068	1003	128	0	0	0	3,670

1 Based on consumption of 169 gallons per capita day and city population of 15,265

2 " " " " 196 " " " " " " " " 31,125

3 " " " " 200 " " " " " " " " 43,094

4 Based on irrigation hydrograph in Fig. 7.



Scale: 1 inch = 2 miles (approximately)

PREPARED BY: R. K. Rodgers.

DRAWN BY: O. J. L.

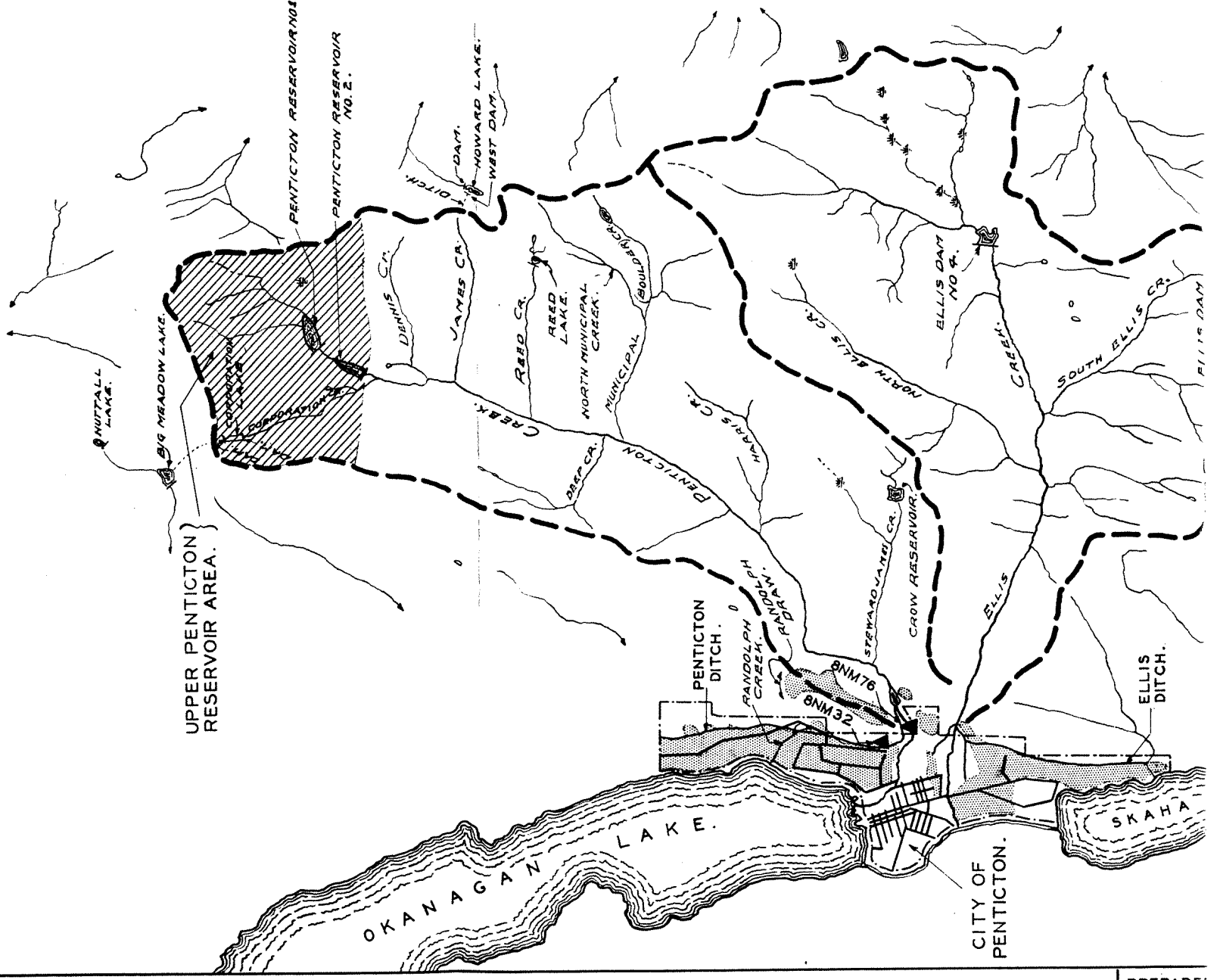
CANADA–DEPT. OF AGRICULTURE
P.F.R.A. HYDROLOGY DIVISION

KEY MAP
PENTICTON AND ELLIS CREEK WATERSHED

NOV. 1962

HYD-C-211

FIG. 1



LEGEND

WATERSHED BOUNDARY

CITY BOUNDARY

STREAM FLOW GAUGING STATION

PRESENT AND FUTURE IRRIGATED LANDS

UPPER PENTICTON RESERVOIR WATERSHED

IRRIGATION DITCH

Scale: 1 inch = 2 miles (approximately)

PREPARE

P.R.

DRAWN B

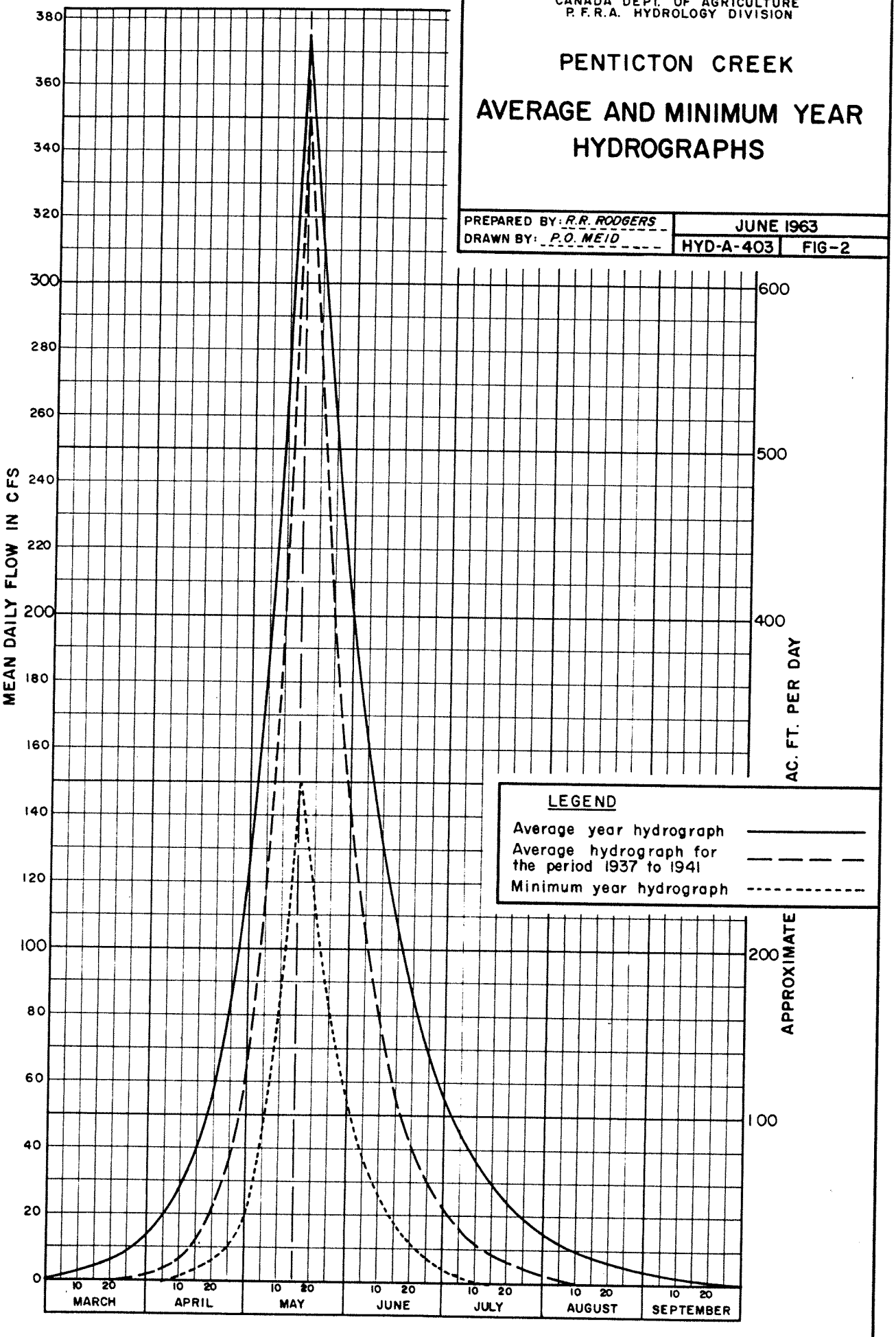
CANADA DEPT. OF AGRICULTURE
P.F.R.A. HYDROLOGY DIVISION

PENTICTON CREEK

AVERAGE AND MINIMUM YEAR HYDROGRAPHS

PREPARED BY: R.R. RODGERS
DRAWN BY: P.O. MEID

JUNE 1963
HYD-A-403 | FIG-2



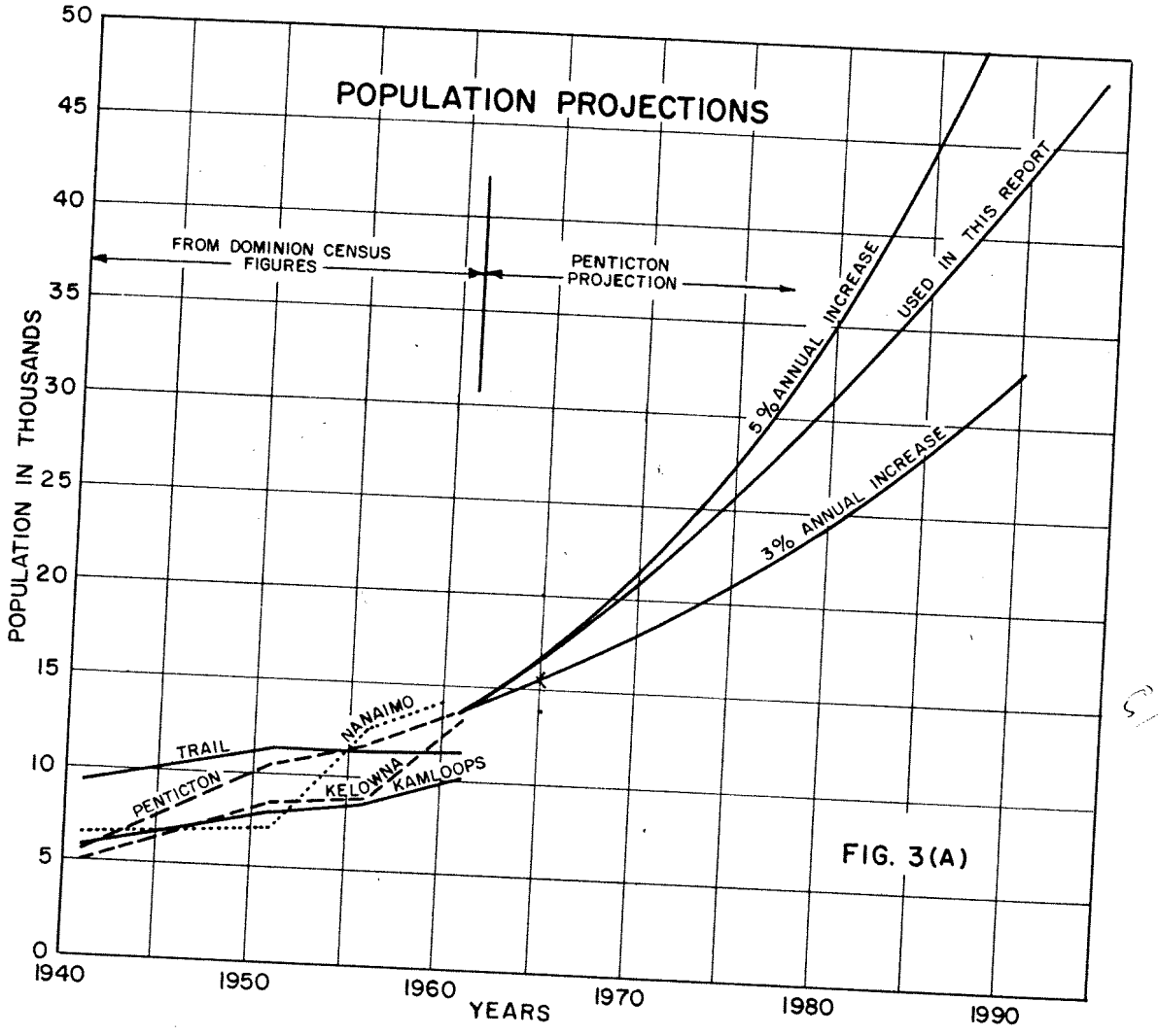


FIG. 3(A)

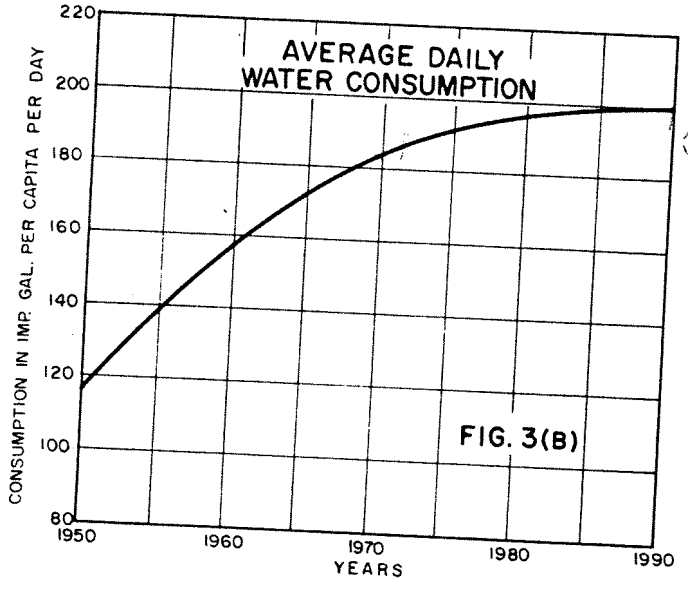


FIG. 3(B)

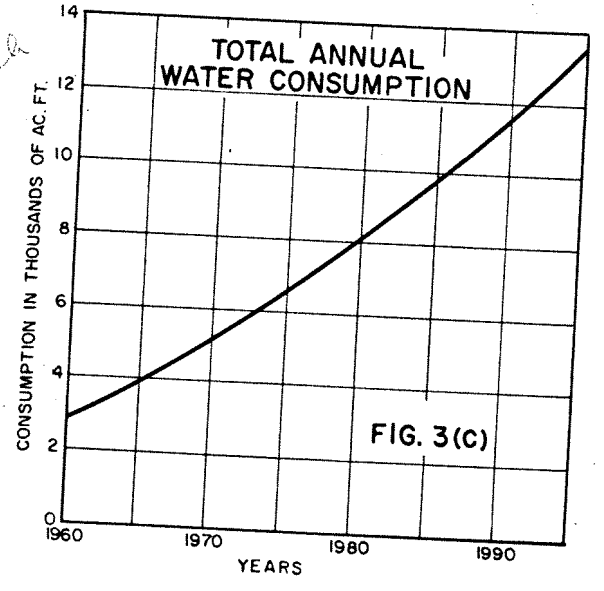
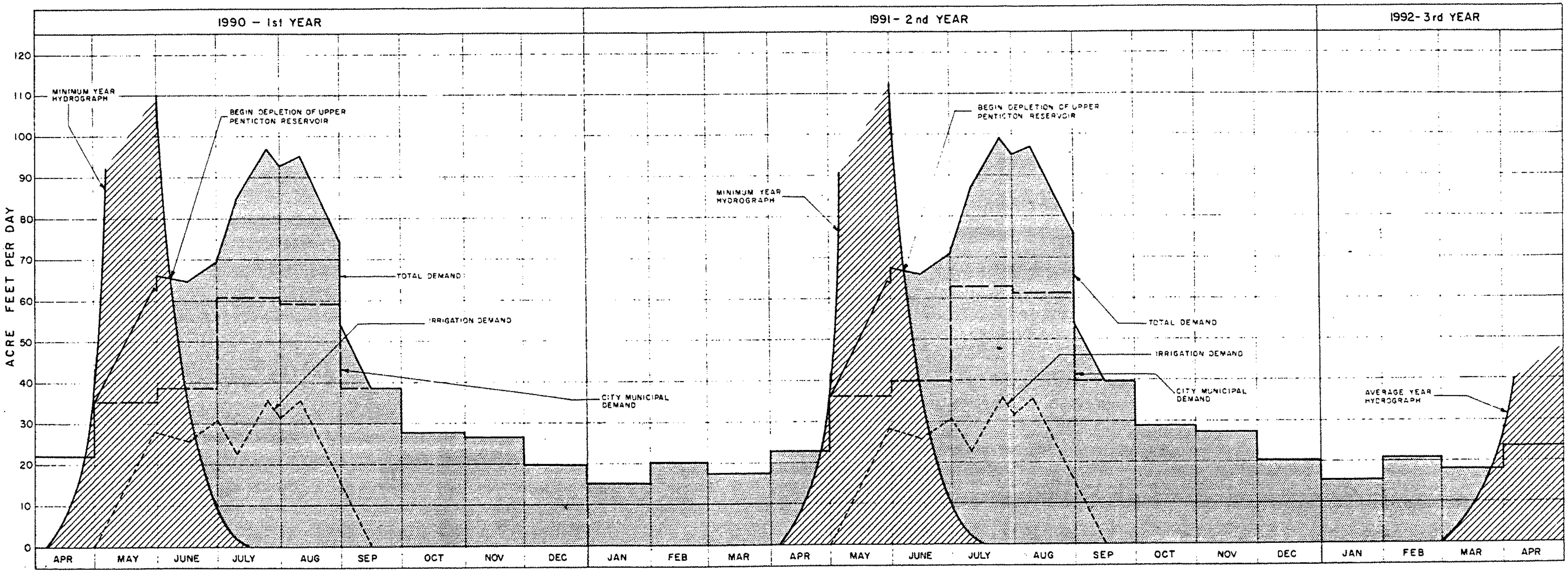


FIG. 3(C)

PREPARED BY: W. L. Kreuder DRAWN BY: P.O. Meid	CANADA DEPT. OF AGRICULTURE P.F.R.A. HYDROLOGY DIVISION CITY OF PENTICTON POPULATION AND WATER CONSUMPTION PROJECTIONS	OCT. 1963 HYD-A-404 FIG.- 3



LEGEND

Municipal Demand

Irrigation Demand

Total Demand

Supplied from Natural Streamflow

" " Upper Penticton Reservoir and by other means.

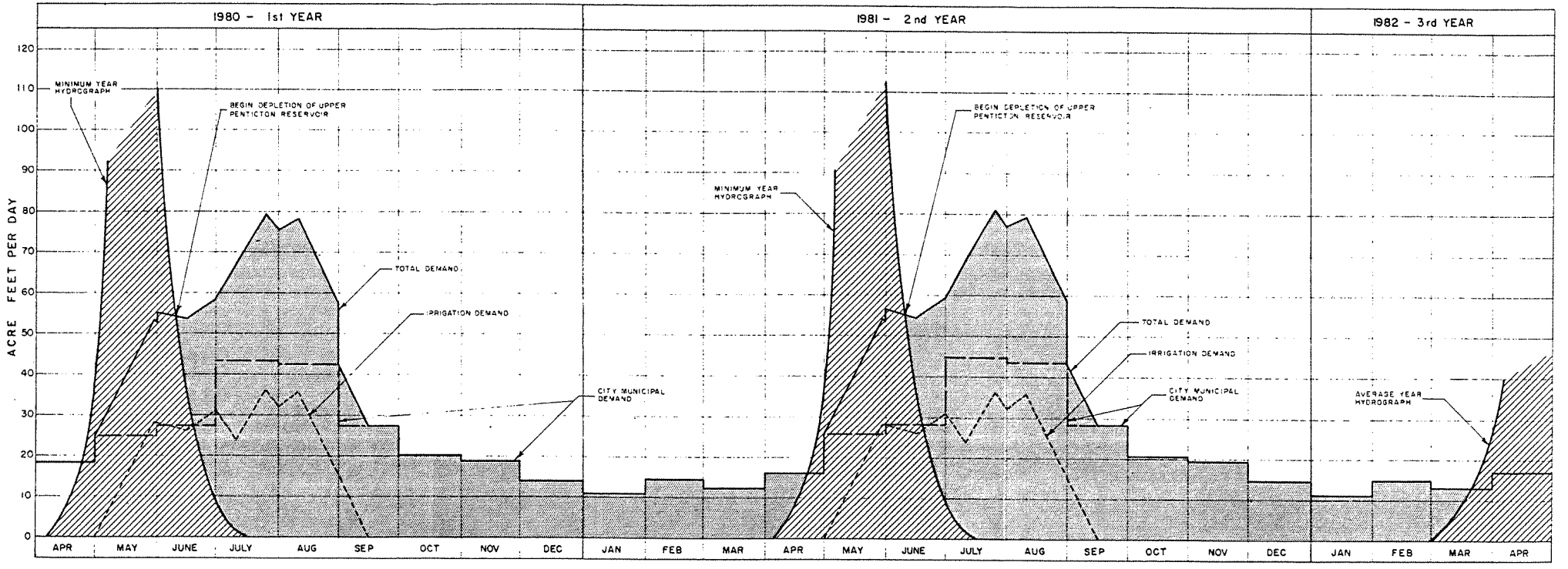
CANADA DEPT OF AGRICULTURE
P.F.R.A. HYDROLOGY DIVISION

PENTICTON CREEK

TOTAL SUPPLY AND DEMAND CURVES

FUTURE WATER DEMANDS
TWO DRY YEARS

PREPARED BY W.L. Kreuder	OCT. 1963	
DRAWN BY P.O. Meld	HYD-C-222	FIG-5A



LEGEND

Municipal Demand

Irrigation Demand

Total Demand

Supplied from Natural Streamflow

" " Upper Penticton Reservoir

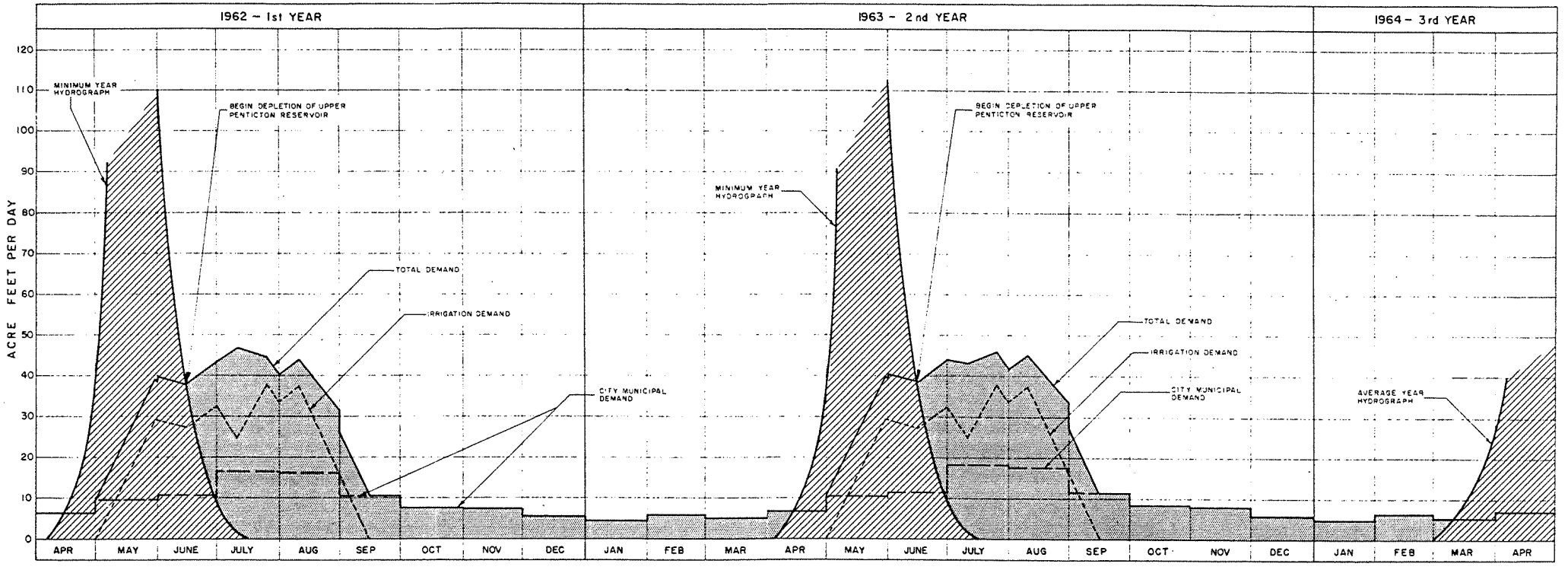
and by other means

CANADA DEPT. OF AGRICULTURE
P.F.R.A. HYDROLOGY DIVISION

PENTICTON CREEK
TOTAL SUPPLY AND DEMAND CURVES

FUTURE WATER DEMANDS
TWO DRY YEARS

PREPARED BY W.L. Kreuder	OCT. 1963	
DRAWN BY P.O. Meid	HYD-C-209	FIG-5



LEGEND

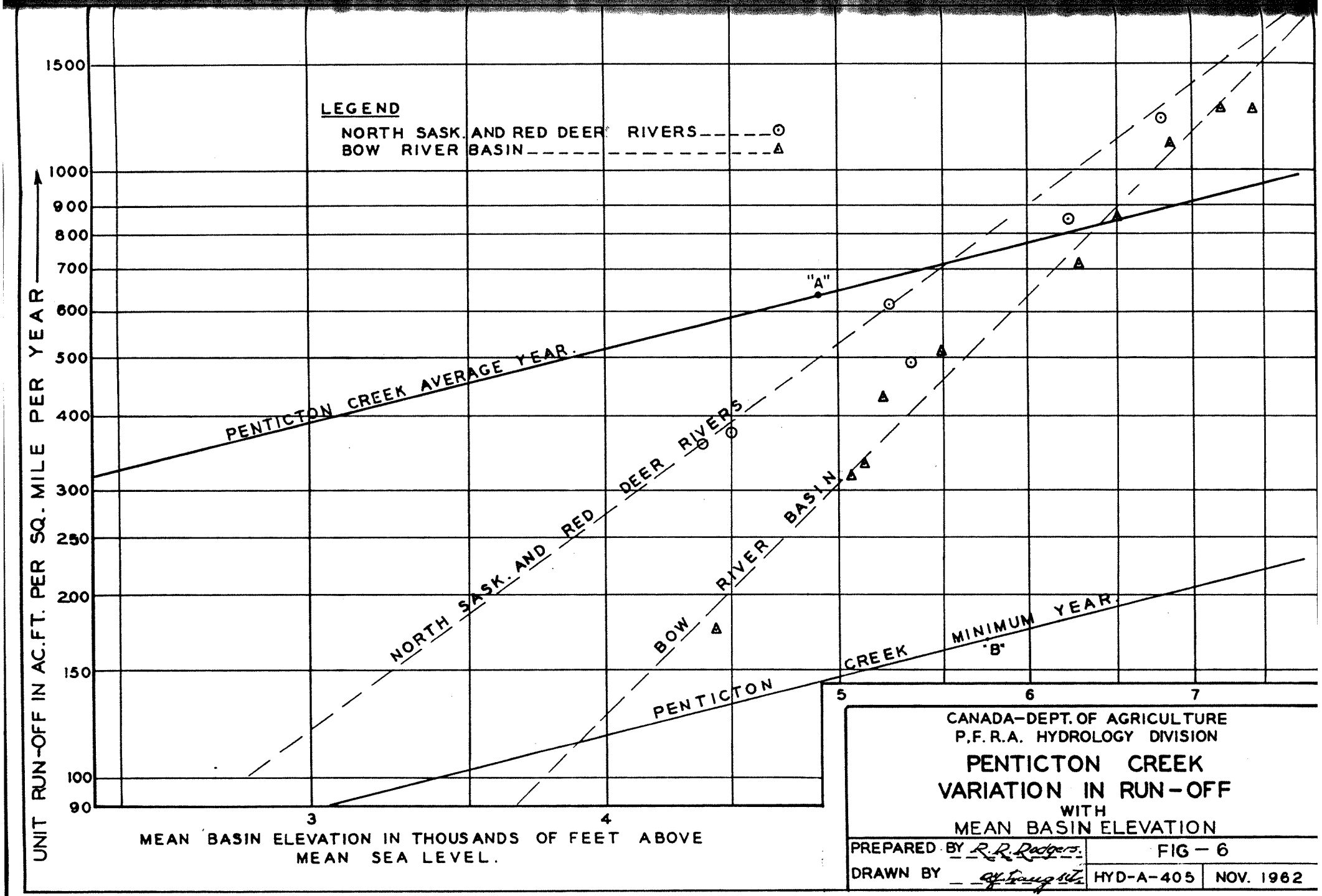
Municipal Demand
Irrigation Demand
Total Demand
Supplied from Natural Streamflow
" " Upper Penticton Reservoir
and by other means

CANADA DEPT. OF AGRICULTURE
P.F.R.A. HYDROLOGY DIVISION

PENTICTON CREEK
TOTAL SUPPLY AND DEMAND CURVES

PRESENT WATER DEMANDS
TWO DRY YEARS

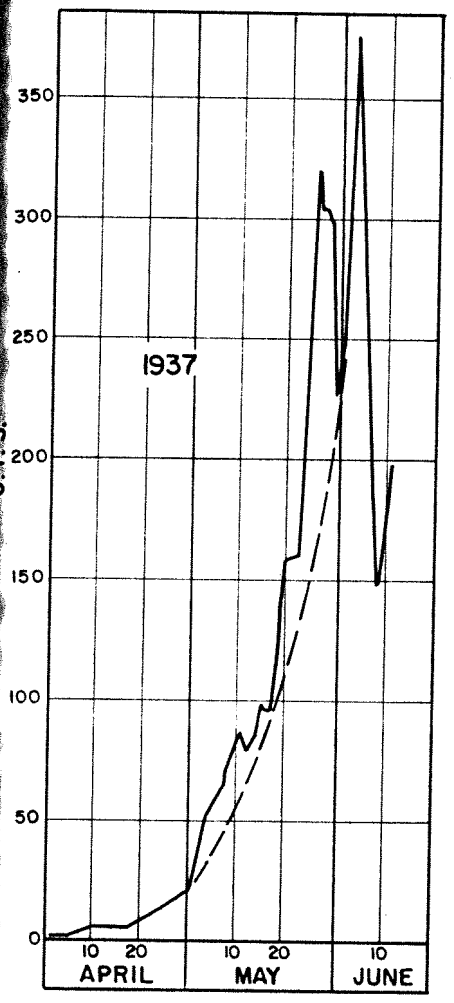
PREPARED BY W.L. Kreuder	OCT. 1963	
DRAWN BY P.Q. Meid	HYD-C-208	FIG-4

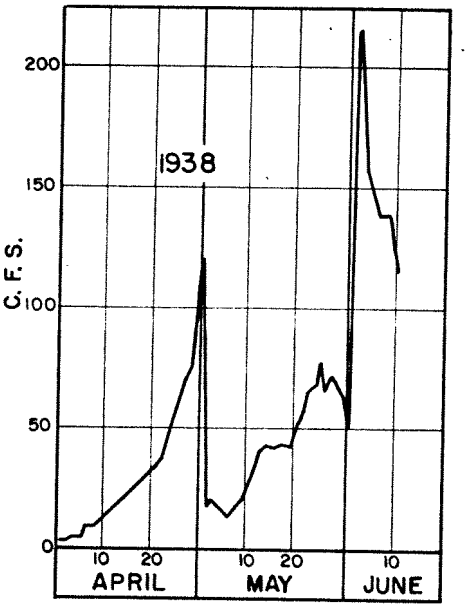


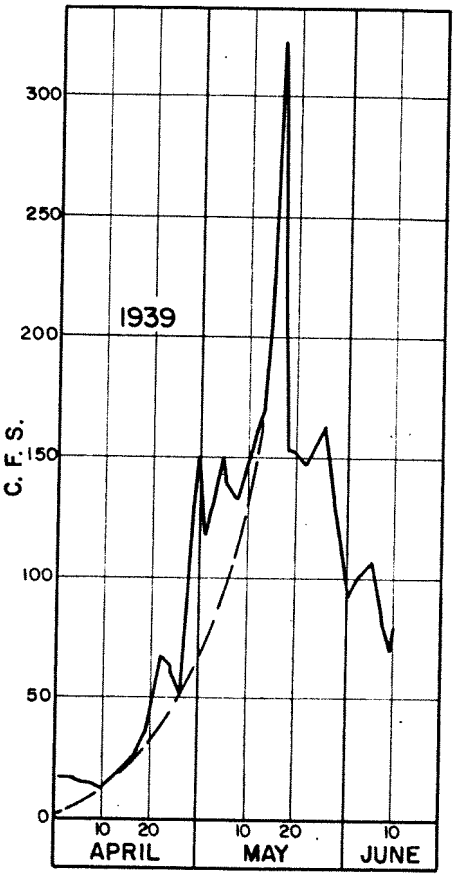
CANADA–DEPT. OF AGRICULTURE
P.F.R.A. HYDROLOGY DIVISION

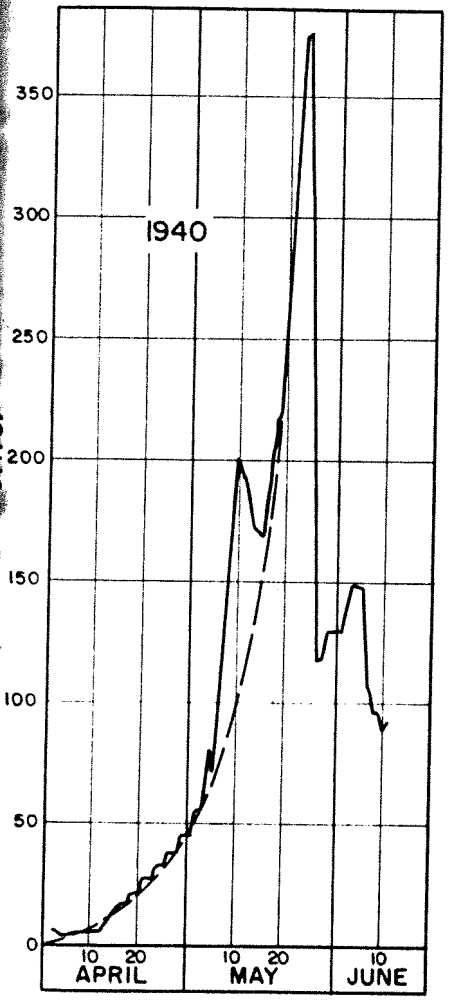
PENTICTON CREEK VARIATION IN RUN-OFF WITH MEAN BASIN ELEVATION

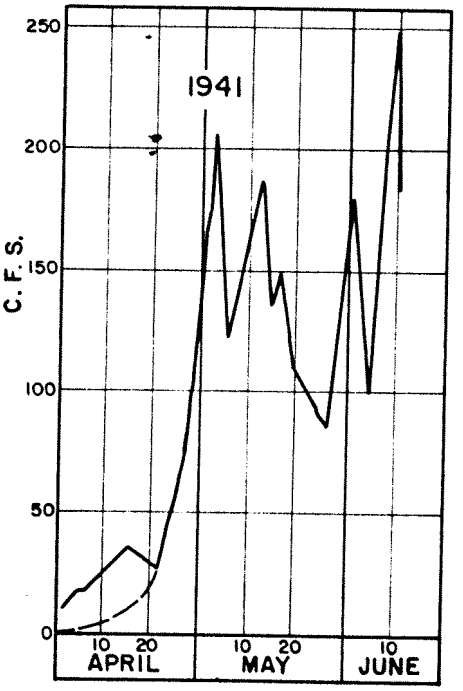
PREPARED BY R.R. Rodgers	FIG – 6	
DRAWN BY	HYD-A-405	NOV. 1962











CANADA DEPT. OF AGRICULTURE
P.F.R.A. HYDROLOGY DIVISION

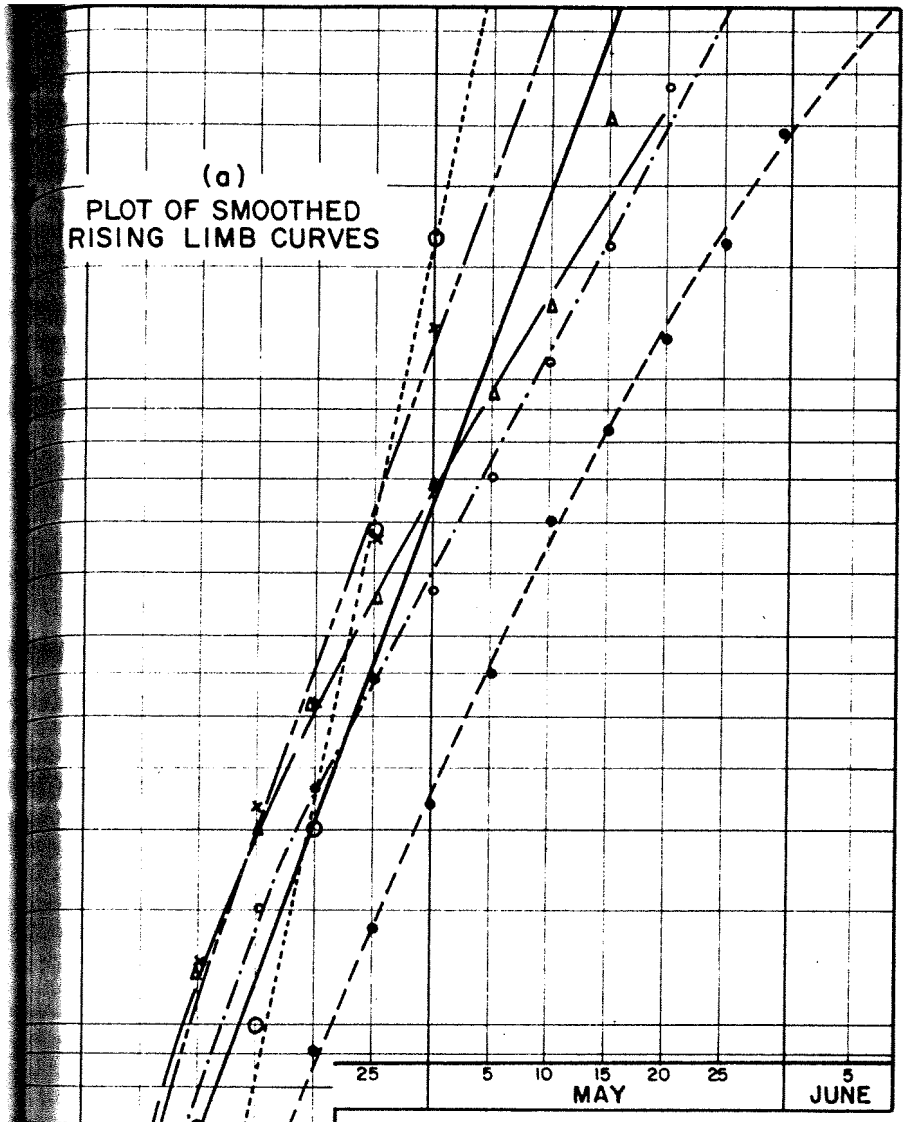
PENTICTON CREEK
ADJUSTED RISING LIMB HYDROGRAPHS

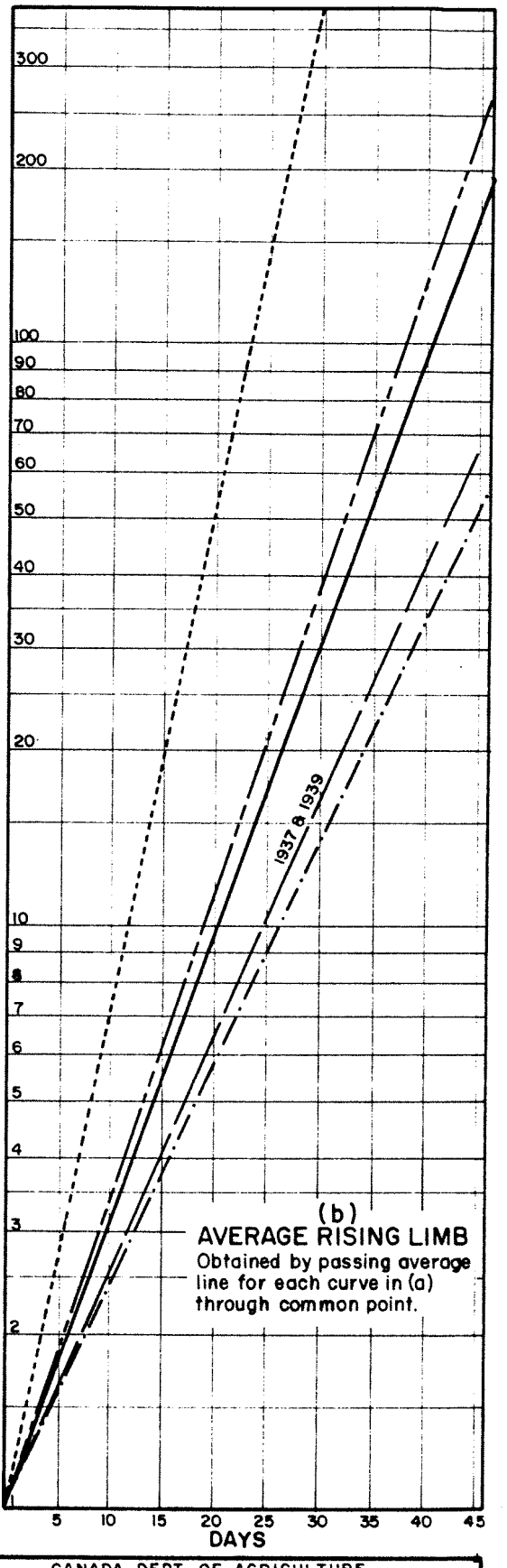
PREPARED BY: R.R. RODGERS	JUNE 1963	
DRAWN BY: P.O. MEID	HYD-A-443	FIG.- 8

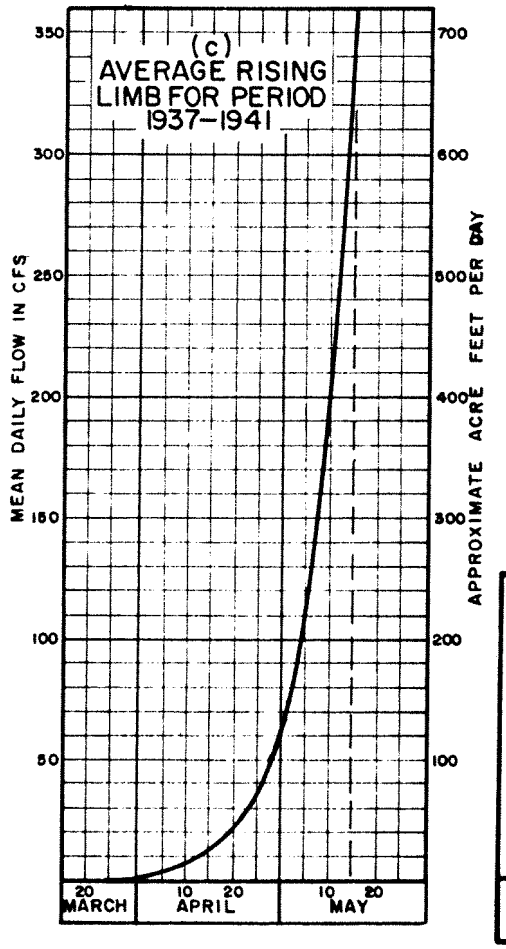
LEGEND

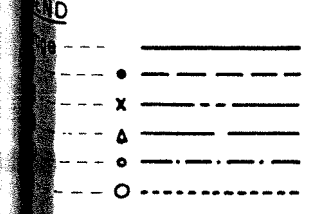
Recorded Streamflow ——————

Assumed Rising Limb — — — —







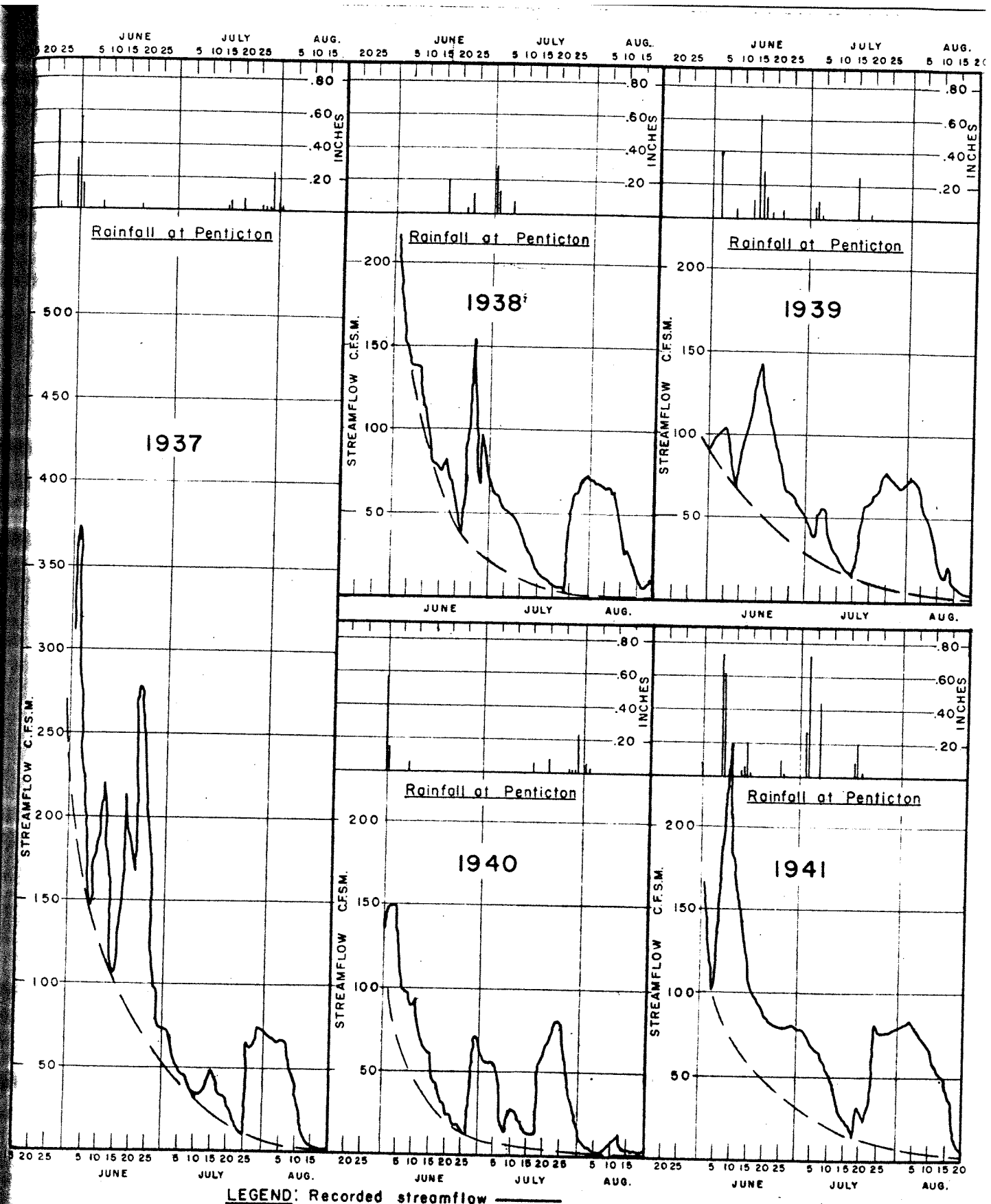


CANADA DEPT. OF AGRICULTURE
P.F.R.A. HYDROLOGY DIVISION

PENTICTON CREEK

ANALYSIS OF RISING LIMB HYDROGRAPHS

PREPARED BY: R.R. RODGERS	JUNE 1963	
DRAWN BY: P.O. MEID	HYD-A-444	FIG – 9



PREPARED BY R.R.Rodgers	CANADA DEPARTMENT OF AGRICULTURE P.F.R.A. HYDROLOGY DIVISION PENTICTION CREEK ADJUSTED RECESSION HYDROGRAPHS	FIG. - 10
DRAWN BY GDS		HYD. A - 406 Nov. 1962

P.F.R.A. HYDROLOGY DIVISION

PENTICTON CREEK

ANALYSIS OF RECESSION CURVE HYDROGRAPHS

PREPARED BY: R.R. RODGERS	JUNE 1963	
DRAWN BY: P.O. MEID	HYD-A-445	FIG - 11