REPORT

OF

COLUMBIA RIVER TREATY

CANADIAN AND UNITED STATES ENTITIES

for the period

1 October 1970

to

30 September 1971

October 1971

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INTRODUCTION

This report describes the joint actions of the Canadian and United States Entities during the period 1 October 1970 to 30 September 1971, in discharging their responsibility for formulating, and carrying out, operating arrangements necessary to implement the Columbia River Treaty.

Previous reports on this subject are:-

Period covered	Date of Report
16 September 1964 to 30 September 1967	22 April 1968
1 October 1967 to 30 September 1968	January 1969
1 October 1968 to 30 September 1969	April 1970
1 October 1969 to 30 September 1970	December 1970

ORGANIZATION AND MEETINGS

The names of the members of the two Entities and their representatives are shown in Appendix A.

During the period 1 October 1970 to 30 September 1971, the Canadian and United States Entities held two regular meetings and Entity representatives and co-ordinators met on five occasions.

The two international committees, listed in Appendix B, which were established effective 19 September 1968, continued their work. These two committees directed and coordinated studies with the support of the staffs of B.C. Hydro and Power Authority, Bonneville Power Administration and the U.S. Corps of Engineers, North Pacific Division.

The Entities received reports and recommendations on operating procedures, facilities and other matters essential to Columbia River Treaty implementation from the international committees. Where necessary, formal agreement on various items was reached by the Entities and Appendix C lists these official agreements reached and recorded during the period of this report.

CONSTRUCTION OF THE TREATY STORAGE PROJECTS

Construction work on Mica and Libby proceeded on schedule during the year. Two Columbia Construction Progress reports, Nos. 21 and 22, were issued by B.C. Hydro and Power Authority on the construction of Mica and the Division Engineer, North Pacific Division, Corps of Engineers, U.S. Army, issued reports Nos. 6 and 7 on the progress of construction of the Libby dam project.

Because these reports give a detailed description of the construction achieved on the projects during this period, it is not considered necessary to repeat the information in this report.

The procurement and preparation of the land required for that portion of the Libby reservoir in Canada is a responsibility of the Government of the Province of British Columbia.

All the necessary clearing, acquisition and relocation of roads and highways is proceeding according to schedule and no difficulties are envisaged in completing this work to meet the operating requirements of the Libby reservoir.

COLUMBIA STORAGE OPERATION - OPERATING ARRANGEMENTS

During the period covered by this report, both Duncan and Arrow reservoirs were operated for power and flood control.

During this reporting year the Canadian entitlement to downstream power benefits from Duncan and Arrow had been purchased by the Columbia Storage Power Exchange and transferred and assigned to the Bonneville Power Administration. The United States Entity delivered capacity and energy to the C.S.P.E. participants in accordance with the Canadian Entitlement Exchange Agreement dated 13 August 1964.

The operation of the storages was generally in accordance with:

(a) "Hydroelectric Operating Plans for Canadian Storage during the Operating Years 1969-70 through 1974-75", dated 15 February 1969, and the amendment thereto dated September 1969.

(b) "Columbia River Treaty Detailed Operating Plan for Canadian Storage - 1 July 1970 through 31 July 1971", dated 15 September 1970.

(c) "Detailed Operating Plan for Columbia River Treaty Storage - 1 July 1971 through 31 July 1972", dated 19 August 1971.

(d) "Interim Flood Control Operating Plan for Duncan and Arrow Reservoirs", dated November 12, 1968.

Attached to this report as Appendix D is "Report on Operation of Columbia River Treaty Projects - 1 August 1970 through 31 July 1971", dated September 1971, which gives a detailed description of the operation of the Treaty storages for the first ten months of the 12-month period of this report.

A brief description follows of the operation of Duncan and Arrow reservoirs during the period 1 October 1970 to 30 September 1971.

Commencing in mid-September 1970, the Duncan reservoir was drawn down, from the normal full pool of 1892 feet, at a relatively constant rate, reaching elevation 1807 feet at the end of February. Because of the flow conditions prevailing the reservoir was then kept at this elevation until early in May and thereafter the reservoir was refilled at a relatively constant rate, reaching normal full pool elevation at the end of July 1971. It was kept at approximately 1892 feet during August and September 1971.

On 18 August 1970, Arrow reservoir was at the normal full pool elevation of 1444 feet and thereafter was drawn down to elevation 1383 feet by mid-January. Because of the run-off conditions prevailing the elevation was maintained at approximately 1385 feet until early in March. From mid-March to late April the elevation was 1377 feet, the normal low pool elevation. Filling commenced on 22 April and reached elevation 1444 feet on 21 July. During the period 22 July to the end of September 1971 the level of the reservoir was over 1444 feet. The operation of this additional storage was in accordance with an agreement dated January 8, 1971 made between Bonneville Power Administration and B.C. Hydro and Power Authority. The releases of this extra two feet of storage did not conflict with the Detailed Operating Plan agreed upon by the two entities.

OPERATING COMMITTEE ACTIVITIES

In accordance with its terms of reference the Operating Committee was reponsible throughout the year for implementing the current hydro-electric and flood control operating plans for the storage provided in Canada under the Columbia River Treaty. This aspect of the Committee's work is described in Appendix D, "Report on Operation of Columbia River Treaty Projects", dated September 1971.

During the year, the Operating Committee commenced studies necessary for producing the Hydroelectric Operating Plan for Canadian Storage Operating Year 1976-77, and Studies for the Determination of Downstream Power Benefits for 1976-77.

The operating year 1976/77 is the first year in which the Operating Plans will be required to consider the operation of the first two generators to be installed at Mica, which have been scheduled for the Fall of 1976. In accordance with paragraph 7 of Annex A of the Treaty, studies are being made of plans designed to achieve optimum power generation at-site in Canada and downstream in Canada and the United States of America. These are complex studies and involve interpretation of the intent of paragraph 7. It will probably be late in 1971 before the studies are completed.

In addition, studies and a report were made on the Detailed Operating Plan for Columbia River Treaty Storage - 1 July 1971 through 31 July 1972, on which an agreement was signed in September 1971*.

In September 1970, the Operating Committee produced a report on "The Initial Filling of Mica Reservoir" which showed the probable Mica

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* See Appendix C, Item 2

storage content under different conditions of loads and flows. In the Fall of 1971 the Bonneville Power Administration reviewed the latest load forecasts for the Pacific Northwest Area and arising out of this review an addendum dated 8 September 1971 was prepared by the Operating Committee for the September 1970 report. This report showed that the probability of Mica reservoir filling to the desirable level was improved as compared with the report dated September 1970.

During the previous year members of the Operating Committee had considered the possible effects of modifications to the present International Joint Commission Order on Kootenay Lake and this work continued during 1971-71.

On April 29, 1971 the International Joint Commission received an application from Cominco Ltd., for approval to store 2 feet of water in Kootenay Lake during 1971/2 and 1972/3, in addition to the storage approved in the Order. The two entities considered this subject because it could affect the operating plans made in accordance with the Treaty.

However, in May 1971, Cominco Ltd., withdrew the application and Kootenay Lake will continue to be operated under the 1938 IJC Order.

HYDROMETEOROLOGICAL COMMITTEE ACTIVITIES

The Hydrometeorological Committee held meetings from time to time during the year. The Committee's recommendation "Hydrometeorological Supporting Facilities" dated October 1970 was sent by the Entities in December 1970 to the Permanent Engineering Board for information.

By letter, dated 25 June 1971, the Permanent Engineering Board concurred with the Committee's recommendation on "Hydrometeorological System Treaty Facilities" dated October 1970 and an agreement was signed between the Entities in September 1971*. This recommendation is a consolidated listing of Treaty Facilities and it supersedes the Treaty Facilities listing dated September 1968, as well as the Facilities listings and Recommendations Nos. 1, 3 and 5.

"Columbia River Treaty Hydrometeorological Supporting Facilities", dated October 1970, was submitted to the Entities in November 1970. The Entities accepted this recommendation and informational copies were sent to the Permanent Engineering Board in December 1970.

Recommendation No.6, "Interim Plan for Exchange of Hydrometeorological Data", dated 28 May 1969, covered the period 1 May 1969 to 31 July 1971. The Committee, by agreement of 15 July 1971, recommended to the Entities that this plan remain in force until a revised interim plan now in preparation is approved and becomes effective. The Entities sent this extension agreement to the Permanent Engineering Board for its consideration in August 1971.

COOPERATION WITH PERMANENT ENGINEERING BOARD

The Entities continued cooperating with the Permanent Engineering Board in the discharge of its functions and a joint meeting of the Permanent Engineering Board and the Entities was held on 18 May 1971.

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* See Appendix C, Item 3

Semi-annual reports were forwarded by the Entities to the Board covering the period 1 October 1970 to 31 March 1971 and 1 April 1971 to 30 September 1971.

In addition, the construction progress reports - B.C. Hydro's Reports Nos. 21 & 22 on Mica, and the Corps of Engineers' Reports Nos. 6 & 7 on Libby, were supplied to the Permanent Engineering Board.

APPENDIX A

COLUMBIA RIVER TREATY ENTITIES

CANADA

THE HON. R.G. WILLISTON
CHAIRMAN

Director
British Columbia Hydro and Power Authority
Vancouver, B.C.

UNITED STATES OF AMERICA

MR. HENRY R. RICHMOND
CHAIRMAN

Administrator
Bonneville Power Administration
Department of the Interior
Portland, Oregon

BRIGADIER-GENERAL ROY S. KELLEY
(Up to 31 July 1971)

BRIGADIER-GENERAL K.T. SAWYER
(From 1 August 1971)

Division Engineer
North Pacific Division
Corps of Engineers, U.S. Army
Portland, Oregon

Canadian Entity Representatives

MR. W.D. KENNEDY

Manager
Canadian Entity Services
British Columbia Hydro and Power Authority
Vancouver, B.C.

United States Entity Coordinators

MR. BERNARD GOLDHAMMER
COORDINATOR

Asst. Administrator for Power Management
Bonneville Power Administration
Portland, Oregon

MR. GORDON FERNALD
COORDINATOR

Chief, Engineering Division
North Pacific Division
Corps of Engineers, U.S. Army
Portland, Oregon

MR. H. KROPITZER
SECRETARY

Executive Assistant to the Administrator
Bonneville Power Administration
Portland, Oregon

COLUMBIA RIVER TREATY

INTERNATIONAL COMMITTEES

The official membership of the two International Committees for the year 1 October 1970 to 30 September 1971, was as follows:

	Canadian Section	United States Section
COLUMBIA RIVER TREATY OPERATING COMMITTEE	P.R. Purcell (Chairman)	C.E. Hildebrand (Co-Chairman)(1)
	D.R. Forrest	D.J. Lewis(1) (Up to July 1971)
	W.E. Kenny	D.M. Rockwood(1) (From August 1971)
		H.M. McIntyre (Co-Chairman)(2)
		C.W. Blake(2)
COLUMBIA RIVER TREATY HYDROMETEOROLOGICAL COMMITTEE	P.R. Purcell (Chairman)	F.A. Limpert (Chairman)(2)
	U. Sporns	D.M. Rockwood(1)

All Canadian Committee members represent B.C. Hydro and Power Authority. United States Committee members represent (1) United States Corps of Engineers, or (2) Bonneville Power Administration.

APPENDIX C

COLUMBIA RIVER TREATY

OFFICIAL AGREEMENTS OF THE ENTITIES

1 OCTOBER 1970 - 30 SEPTEMBER 1971

Item No.	Date Agreement Signed by Entities	Description
1.	16 & 21 October 1970	Columbia River Treaty Detailed Operating Plan for Canadian Storage 1 July 1970 through 31 July 1971, dated 15 September 1970.
2.	30 September 1971	Detailed Operating Plan for Canadian River Treaty Storage 1 July 1971 through 31 July 1972 dated 19 August 1971
3.	30 September 1971	Columbia River Treaty Hydrometeorological System "Treaty Facilities" dated October 1970.

APPENDIX D

"Report on Operation of Columbia River Treaty Projects
1 August 1970 through 31 July 1971"

dated September 1971

ATTACHED

REPORT ON

OPERATION OF COLUMBIA RIVER

TREATY PROJECTS

1 AUGUST 1970 THROUGH 31 JULY 1971

COLUMBIA RIVER TREATY OPERATING COMMITTEE

H. M. McIntyre
Bonneville Power Administration
Co-Chairman, U.S. Section

C. E. Hildebrand
Corps of Engineers
Co-Chairman, U.S. Section

C. W. Blake
Bonneville Power Administration
Member, U.S. Section

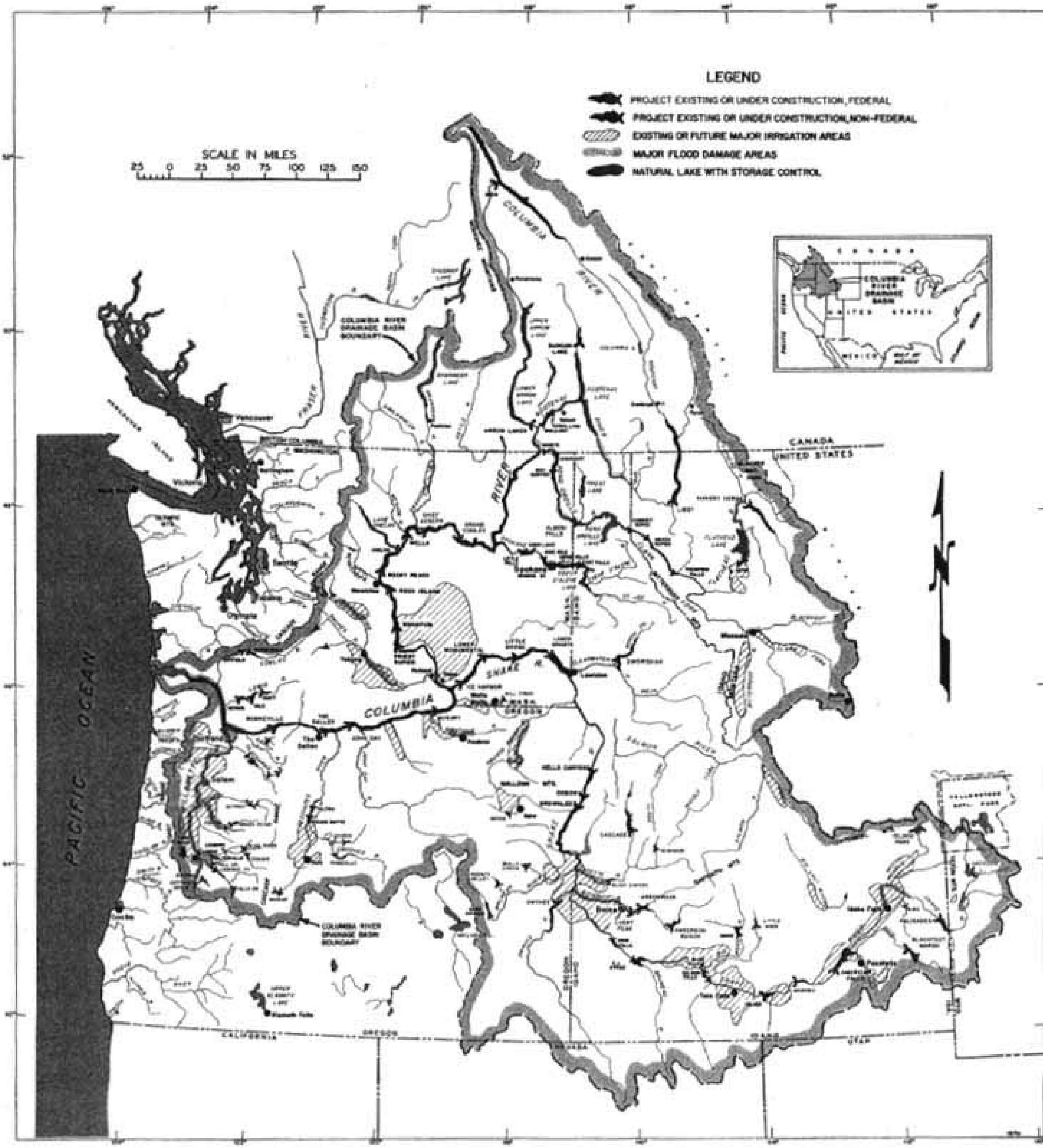
D. J. Lewis
Corps of Engineers
Member, U.S. Section

P. R. Purcell
B. C. Hydro & Power Authority
Chairman, Canadian Section

W. E. Kenny
B. C. Hydro & Power Authority
Member, Canadian Section

D. R. Forrest
B. C. Hydro & Power Authority
Member, Canadian Section

COLUMBIA RIVER BASIN



REPORT ON

OPERATION OF COLUMBIA RIVER TREATY PROJECTS

1 AUGUST 1970 THROUGH 31 JULY 1971

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REPORT ON

OPERATION OF COLUMBIA RIVER TREATY PROJECTS

1 AUGUST 1970 THROUGH 31 JULY 1971

I. INTRODUCTION

The Treaty between Canada and the United States of America relating to the cooperative development of the water resources of the Columbia River Basin requires that storage reservoirs constructed under the Treaty be operated for the purposes of increasing hydroelectric power generation and flood control in the United States and Canada.

The Columbia River Treaty Operating Committee was established on 19 September 1968 by the United States and Canadian Entities to be responsible for preparing and implementing annual operating plans as required by the Columbia River Treaty. Under its terms of reference the Operating Committee prepares an annual report reviewing the preceding year's operation of Treaty storage reservoirs. This is the third report and covers the operating year 1 August 1970 through 31 July 1971. The report reviews and records the actual operation of the Duncan and Arrow projects for power and flood control and the major effects of their operation downstream in Canada and the United States. Both projects were fully operational for power and flood control during the year covered by this report.

During the year power and energy related to the Canadian share of the hydroelectric power generation was delivered to the participants of the Columbia Storage Power Exchange (CSPE). The CSPE is a group of utilities in the United States who purchased the Canadian entitlement and exchanged such entitlement with the Bonneville Power Administration (BPA) for specified amounts of power and energy. The deliveries to the CSPE participants were in accordance with the terms of the Canadian Entitlement Exchange Agreements.

II. OPERATING CRITERIA

A. General

The Columbia River Treaty requires that the reservoirs constructed in Canada be operated pursuant to flood control and hydroelectric operating plans developed thereunder. Annex A of the Treaty stipulates that the United States Entity will submit flood control operating plans and that the Canadian Entity will operate in accordance with flood control storage diagrams or any variation which the Entities agree will not derogate from the desired aim of the flood control plan. Annex A also provides for the development of hydroelectric operating plans five years in advance to furnish the entities with an Assured Operating Plan for Canadian Storage. In addition, Article XIV.2.k. of the Treaty provides that a Detailed Operating Plan may be developed to produce more advantageous results through use of current estimates of loads and resources. The Protocol to the Treaty provides further detail and clarification of the principles and requirements of Annex A. The Principles and Procedures of 25 July 1967, together with the Interim Flood Control Operating Plan of 12 November 1968, both developed by the Operating Committee, establish the general criteria of operations.

The Assured Operating Plan dated 15 February 1969 established Operating Rule Curves for Duncan and Arrow during the 1970-71 operating year. The Operating Rule Curves provide guidelines for refill levels as well as drawdown levels. They were derived from Critical Rule Curves, Assured Refill Curves, and simulated Variable Refill Curves and are consistent with flood control requirements, as described in the Principles and Procedures. The Flood Control Storage Reservation Curves were established to conform to the Interim Flood Control Operating Plan.

The Detailed Operating Plan established Operating Rule Curves based on power loads and resource data available just prior to the operating year for use in actual operations. The Variable Refill Curves and flood control requirements subsequent to 1 January 1971 are determined on the basis of seasonal volume runoff forecasts during actual operations.

B. Power Operation

The Detailed Operating Plan was designed to achieve optimum power generation downstream in the United States, consistent with project operating limits and flood control requirements.

The power facilities in the United States which are downstream from the Treaty storage projects are all operated under the Pacific Northwest Coordination Agreement dated September 1964. Optimum generation in the United States was assured by the adoption, in the Assured and Detailed Operating Plans, of criteria and operating guides designed to coordinate the operation of Treaty projects with the projects operating under the Agreement. Optimum operation of Treaty reservoirs was accomplished, for the actual water condition experienced, by operating within the limits of the Critical Rule Curves, Assured Refill Curves, Variable Refill Curves, Flood Control Storage Reservation Curves and related criteria determined in accordance with the Detailed Operating Plan.

C. Flood Control Operation

The Interim Flood Control Operating Plan was designed to minimize flood damage both in Canada and in the United States.

The flood control operation during the drawdown period consists of evacuating and holding available, consistent with refill criteria, storage space sufficient to control the maximum flood that may occur under forecast conditions. Runoff volume forecasts are the criteria for determining the volume of storage space required.

Flood control operation of the Columbia River Treaty projects during the refill period is controlled in part by the computed Initial Controlled Flow of Columbia River at The Dalles. Other operating rules and local criteria were utilized to prepare day-to-day streamflow forecasts for key points in Canada and the United States, and establish the operations of the flood control storage. These forecasts were prepared daily by the Cooperative Columbia River Forecasting Unit for periods of 30 to 45 days using both moderate and severe snowmelt sequences.

III. WEATHER AND RIVER CONDITIONS

A. Weather

Summer and early fall precipitation over much of the Columbia River Basin was below normal, causing depletion of ground water and soil moisture. Rainfall amounts increased as the season advanced but subnormal precipitation persisted through October and November 1970 over most northern portions of the basin. However, by the end of December the snowpack was generally near or above normal, with some Cascade Range locations reporting the greatest water equivalent of record for so early in the season. For the Columbia River Basin as a whole the precipitation over the snow accumulation season was markedly above normal. Chart 1 shows the geographical distribution of the accumulated 7-month (October 1970 - April 1971) precipitation over the entire Columbia River Basin, expressed as percentage of the 1953-67 average. As shown, roughly half of the basin had more than 120 percent of average precipitation and large areas in the Snake River Basin had more than 150 percent of average.

Temperatures were colder than normal for the months of October, December and March while November, January and February were warmer than normal except for cold air anomalies in northeast Washington and the upper Columbia River Basin in Canada. Long-term minimum temperature records were broken in October and March while record high readings were noted in November.

Charts 2 and 3 depict the sequence of precipitation and temperature during the March-July season, which includes the primary snowmelt period. Chart 2 applies to the upper Columbia and Kootenay River Basins in Canada, and Chart 3 is for the entire Columbia River Basin above The Dalles, Oregon. In the derivation of the basin-average indexes, the wet areas which produce the most runoff are more heavily weighted than the dry areas which usually produce less runoff. Since the major portion of the runoff which occurs during this season is produced by snowmelt, the temperature sequences shown on Charts 2 and 3 are of special significance to system reservoir regulation in that they largely control the generation of streamflow.

B. <u>Streamflow</u>

River flows were below normal in the summer and fall seasons, reflecting the weather conditions. In August and September 1970, the middle and lower Columbia River natural flow dropped well below critical-year levels, necessitating drafting of some reservoirs below critical rule curves to meet firm power loads. The above-normal winter precipitation produced improved river flows, although runoff lagged the precipitation and remained subnormal for some months. During the October-December period, the natural flow of Columbia River at Grand Coulee and Bonneville Dams averaged 84 and 97 percent of median, respectively. River conditions continued to improve in late winter, reflecting the precipitation and temperature patterns. By late January 1971 the earlier threat of a critical power situation because of low streamflow had been eliminated and by 1 March it was apparent that the seasonal runoff volume of the lower Columbia River would be well above normal.

The above-normal tempratures of the first half of May, as shown on Charts 2 and 3, produced the first pronounced snowmelt rise of the season. Headwater streams in British Columbia responded to the warming and Duncan and Arrow reservoir inflows increased sharply in early May. The cool, wet weather which prevailed throughout June and early July resulted in two moderate inflow peaks into both reservoirs in June and a secondary peak in July. Maximum mean daily inflows of the season were 165 thousand cubic feet per second(kcfs) on 3 June for Arrow and 17 kcfs on 23 June for Duncan. Inflow hydrographs for these reservoirs are shown on Charts 4 and 5. Generated flows at three downstream points, Columbia River at Birchbank, Grand Coulee Dam and The Dalles are shown for the main snowmelt period by the unregulated hydrographs on Charts 6, 7 and 10.

C. Seasonal Runoff Volumes

Volume of runoff during the snowmelt season, as well as the variation with time, is of great importance because the reservoir regulation plans are determined in part by the expected runoff volume. Runoff volume forecasts, based on precipitation and snowpack data, were prepared for a large number of locations in the Columbia River Basin and updated each month as the season advanced. Table 1 lists the seasonal volume inflow forecasts for Duncan and Arrow projects and the unregulated runoff of Columbia River at The Dalles. The forecasts for Duncan and Arrow inflow were prepared by B. C. Hydro & Power Authority and those for the lower Columbia River by the Cooperative Columbia River Forecasting Unit. Also shown on Table 1 are the actual volumes for these three locations for the April-August 1971 season.

Actual April-August runoff volumes, adjusted for upstream reservoir storage effects, are listed for seven locations in the following tabulation:

STREAM AND LOCATION	THOUSANDS OF ACRE-FEET	PERCENT OF 1953-67 AVERAGE
Duncan Reservoir Inflow	2,190	99
Columbia River at Mica Dam	12,300	102
Arrow Reservoir Inflow	24,400	104
Columbia River at Birchbank	45,800	106
Grand Coulee (FDR) Reservoir Inflow	71,900	110
Snake River near Clarkston	35,400	151
Columbia River at The Dalles	117,300	118

Comparison of the above tabulation with the seasonal precipitation map on Chart 1 reveals the general relationship between snow-accumulation season precipitation and snowmelt season runoff when expressed in percent of average.

IV. STORAGE OPERATION

A. General

During the drawdown period, the Canadian Treaty storage was operated on the basis of a regular weekly request for storage release. Mid-week revisions were made when required as agreed by the Operating Committee. The Operating Committee consulted with West Kootenay Power and Light Company regarding the operation of Kootenay Lake prior to establishing the Canadian storage releases. This coordination was necessary because operation of Duncan project and projects in the United States upstream from Waneta Dam affects the operation of Cominco-West Kootenay plants. The operation of Kootenay Lake, in turn, affects the downstream projects in Canada and in the United States.

The regular weekly requests for the release of stored water for power purposes were directed to the whole of Canadian storage. The Canadian Section, after consultation with the United States Section and the West Kootenay Power and Light Company, decided upon the distribution of the release between Arrow and Duncan reservoirs.

During the periods of flood control regulation, the daily outflows of Duncan and Arrow were specified by the United States Section after consultation with the Canadian Section. The daily discharges were based upon the flood control criteria of the Interim Flood Control Plan and the streamflow forecasts.

B. Duncan Operation

(1) Reservoir Evacuation Period. Drafting of Duncan reservoir during the 1970-71 Operating Year began on 13 Spetmeber 1970, approximately one month later than the start of Arrow storage draft. Purpose of this delayed start of Duncan storage draft was to permit the released water to be used for power generation at the Cominco-West Kootenay plants on the lower Kootenay River in British Columbia. Likewise, the outflow during the period September through January was adjusted as necessary to provide good water usage at these plants. The draft was temporarily halted on 19 January when continued high inflows into the lower Columbia River necessitated reducing the Duncan outflow approximately to inflow. Chart 4 shows the inflow, outflow, elevation and computed rule curves for the thirteen-month period July 1970 through July 1971.

Duncan reservoir was held near 1828 feet from 19 January to 12 February when the reservoir drafting was resumed to provide the required storage space for flood control purposes by 28 February. The maximum outflow was limited to 10 kcfs during the drawdown period because of possible downstream erosion problems. Generally high streamflows at that time did not permit the water which was drafted from Duncan reservoir to be used by the downstream Cominco-West Kootenay plants. Duncan reservoir reached a minimum elevation of 1807.4 feet on 26 February and was held near this elevation until the refill period began.

(2) Flood Control Refill Period. Refill of Duncan began on 7 May. The outflow was maintained generally between 100 and 1,000 cfs until 29 July, when it was increased in an attempt to avoid later exceeding the desired 10 kcfs limit.

As shown on Chart 4, the filling was somewhat earlier than the computed Variable Refill Curves. Computation of the Variable Refill Curves for Duncan reservoir is described in Table 3. The reservoir reached full pool, elevation 1892 feet, on 30 July. Moderately high reservoir inflows after that time necessitated outflows in excess of 10 kcfs during 1-4 August. Maximum outflow was 12 kcfs on 3 August.

C. Arrow Operation

(1) Reservoir Evacuation Period. Arrow reservoir was at elevation 1446 feet when the drafting began on 14 August 1970. By 19 August the water in the additional two feet of storage provided for in the 7 July 1970 agreement between B. C. Hydro and BPA had been released and the reservoir reached the normal full pool elevation of 1444 feet. Drafting continued and the reservoir was about 3.5 feet below its Critical Rule Curve elevation on 31 August. Although Duncan reservoir was above its Critical Rule Curve, the total Canadian storage was well below the Critical Rule Curve. Arrow reservoir continued to be operated at levels below its Critical Rule Curve until approximately 23 January. The excess storage releases at Arrow and at reservoirs in the United States to below Critical Rule Curve levels were made on a provisional basis to carry Federal System firm loads in August and to serve a part of the interruptible industrial load during the period September through early January. Chart 5 shows the Arrow inflow, outflow and reservoir elevation for the period July 1970 through July 1971.

Natural streamflows in the Columbia River System increased significantly in mid-January as the result of heavy winter rainfall in the lower portions of the basin. At about this time, the outflows from the Arrow project were reduced approximately to inflow and Arrow reservoir was held between elevations 1383 and 1385 feet from mid-January until the end of February. Storage draft of Arrow was resumed on 1 March. The reservoir reached its normal minimum level of 1377 feet by the last week of March, and it was held near this level until 20 April. The provision in the BPA-B. C. Hydro agreement, made early in January to draft Arrow to elevation 1374 feet if required to meet system load demand, was not invoked because of the above-normal runoff experienced during the balance of the year.

(2) Flood Control Refill Period. The inflow to Arrow project began its normal seasonal rise during the second half of April. On 25 April the outflow was reduced to 5 kcfs for part of the day to facilitate an inspection in connection with the operation of the Castlegar ferry immediately downstream from Arrow dam. The outflow was maintained between 6 and 12 kcfs through most of the last week of April to provide for calibration measurements of the low-level ports and to assist in reducing nitrogen supersaturation in the lower Columbia.

Beginning on 2 May Arrow project was operated on free-flow conditions in accordance with the flood control operating plan and remained on free-flow until 14 May, by which time the involuntary storage in Arrow resulted in a reservoir elevation of 1391.2 feet at the Fauquier gage. The observed flow of the lower Columbia at The Dalles reached the Initial Controlled Flow, 550 kcfs, on 11 May. Table 2 shows the computation of the Initial Controlled Flow. Controlled storing of water commenced on 14 May and continued through May and June in the interest of controlling flows in the lower Columbia River. Refilling the storage space at Grand Coulee and Arrow projects was coordinated in accordance with the flood control operating plan, as shown on Chart 8. Arrow reservoir reached normal full pool, elevation 1444 feet, on 22 July. Two additional feet of storage between elevations 1444 and 1446 feet were filled by 29 July in accordance with an agreement between B. C. Hydro and BPA.

V. DOWNSTREAM EFFECTS OF STORAGE OPERATION

A. Power

Deliveries of power and energy provided for under the Canadian Entitlement Exchange Agreements and attributable to Arrow and Duncan under the provisions of these agreements continued through the 1970-71 Operating Year. Generation at the projects in the United States for this purpose during the period 1 April 1970 through 31 March 1971 was 572 average megawatts at rates up to 980 megawatts. Subsequent to 31 March 1971, the energy amount remained at 572 average megawatts, but the maximum rate of generation increased to 987 megawatts.

The estimated firm load-resource balance for the United States Pacific Northwest Coordinated System showed about 90 average megawatts firm energy in excess of firm loads during the storage draft period 1 August 1970 through 15 April 1971. The estimated potential secondary energy requirements of the Coordinated System for interruptible industrial loads and replacement of thermal and other higher cost generation varied by months from 1500 to 1825 average megawatts. On 1 February 1971, this estimate was reduced 500 average megawatts to reflect cutback in production by industries.

About mid-July 1970, the Columbia River flow dropped below the critical-year level. The combination of low flow, generator unit outages for required maintenance and limitations on power operations for non-power purposes required Federal surplus energy deliveries to markets outside the Pacific Northwest area be discontinued on 21 July 1970. Secondary energy deliveries to the private utilities and interruptible industrial customers were curtailed during the period 23-30 July.

The power situation for the entire Pacific Northwest was extremely critical during August and secondary energy deliveries were again curtailed on 14 August. Streamflows of Columbia River on 20 August were running 75 percent of critical, which was the lowest of record for that time of year. Reservoirs were drafted below rule curves on a provisional basis and spill was required at Grand Coulee Dam to supply water required at downstream plants to meet firm loads. During period of curtailment the industries purchased replacement energy from non-Federal sources. In September, BPA began serving half of its interruptible industrial loads from provisional releases of reservoir storage. The Federal system operated with insufficient resources to serve total requirements until the middle of January.

Natural flows of Columbia River at Grand Coulee and Bonneville increased sharply from near critical-year flows during the first week in January to well above median by 15 January. Storage energy of reservoirs of the Coordinated System increased from about 1300 megawatt-months below operating rule curves on 6 January to over 5000 megawatt-months above on 31 January. Part of this increase resulted from lowering the 31 January refill curve at Duncan by 8.1 feet and at Hungry Horse by 32 feet based on the volume inflow forecasts made early in January. Direct service to public agency secondary loads was restored 8 January 1971. On 16 January service was restored to industrial interruptible and private utility secondary loads. No difficulties were encountered in serving total loads for the balance of the year.

The agreement between BPA and B. C. Hydro made early in January 1971 provided for the draft from Arrow reservoir of an additional three feet of storage below normal low pool, if needed. A condition of these arrangements was that in no event would the release or refill of the additional storage result in a reduction in the downstream power and flood control benefits provided for under the Columbia River Treaty. The improved runoff conditions made draft of the additional three feet unnecessary.

The Federal system suffered two major transmission outages and the loss of a major power resource during the Operating Year. On 17 December 1970, ten transmission towers in the northern California section of the Pacific Northwest-Southwest AC Intertie 500-kv lines were destroyed or damaged during a severe snow and ice storm. Continued severe weather and difficult access slowed repairs. One line was returned to service on 20 January and the other on 30 January. The Hanford steamplant was shut down on 28 January 1971 for an indefinite period and remained out of service the balance of the year. On 9 February 1971 a strong earthquake in the Los Angeles, California, area caused extensive damage to the Sylmar DC Terminal of the 750-kv Pacific Northwest-Southwest intertie. This line was estimated to be out of service for 18 months to two years. These outages had no major effect on the power situation because of the improved streamflow condition. Sufficient Northwest-Southwest intertie capacity was available to meet firm energy commitments; however, the capacity for energy exchange agreement between BPA and the City of Los Angeles cannot be implemented until the DC line is returned to service.

B. Flood Control

Operation of Duncan project reduced the peak stage of Kootenay Lake by about 0.8 foot. The combined regulation of Arrow and Duncan projects reduced the peak discharge of Columbia River at Birchbank, British Columbia, 17 miles upstream from the international boundary, from a computed unregulated value of 259 kcfs to an actual peak of 193 kcfs. The corresponding reduction of stage at Trail, British Columbia, amounted to an estimated six feet. Chart 6 shows the observed discharge at Birchbank for the period 1 July 1970 through 31 July 1971 as well as the unregulated discharge for May-July 1971. Chart 6 also shows the adjusted 15-year average discharge at Birchbank to provide a basis of comparison. Since the natural regulation of pre-existing natural lakes has been removed in the adjustments, the 15-averages do not represent true average natural flows.

The actual peak inflow to F. D. Roosevelt Lake at Grand Coulee Dam was 325 kcfs on 14 May 1971 when the outflow was 232 kcfs. The computed unregulated peak inflow was 406 kcfs on 12 June, at which time the actual outflow was 256 kcfs. Chart 7 shows the regulation during the period July 1970-July 1971. Chart 8 documents the relative filling of Arrow and Grand Coulee during the principal filling period and compares the coordinated regulation of the two reservoirs to guidelines in the Interim Flood Control Operating Plan. The guideline shown on Chart 8 is based on relative space available on 9 May, two days before the flow of Columbia River at The Dalles reached the computed Initial Controlled Flow of 550 kcfs.

The computed unregulated peak discharge of Columbia River at The Dalles was 741 kcfs on 30 May 1971. Computation of unregulated flow was based on adjustments for the effects of reservoir regulation and major irrigation diversions, by routing unregulated streamflows through the river system. In this computation the routings reflect conditions of freeflow through existing structures which control natural lakes. Coordinated flood control regulations of the overall Columbia Basin system of reseroirs resulted in an observed peak discharge at The Dalles of 557 kcfs, which occurred on 13 May. The corresponding reduction of peak stage at Vancouver, Washington, was from an unregulated stage of 24.9 feet to an observed maximum stage of 20.2 feet. Bankfull stage at Vancouver, Washington, a key index station for evaluating flooding on the lower Columbia River, is considered to be 16 feet.

A comparison of the 1970-71 observed discharge and the adjusted average discharge for the period 1953-67 for Columbia River at The Dalles is shown on Chart 9. Chart 10 separates the effects of Duncan and Arrow projects from those of all other major storage projects on the flow of Columbia River at The Dalles during the period April through July 1971. Arrow and Duncan contributed about 27 percent of the total effective storage during the period of flood control regulation for the lower Columbia River.

REFERENCES

The following documents governed the operation of the Columbia Treaty Projects during the period 1 August 1970 through 31 July 1971.

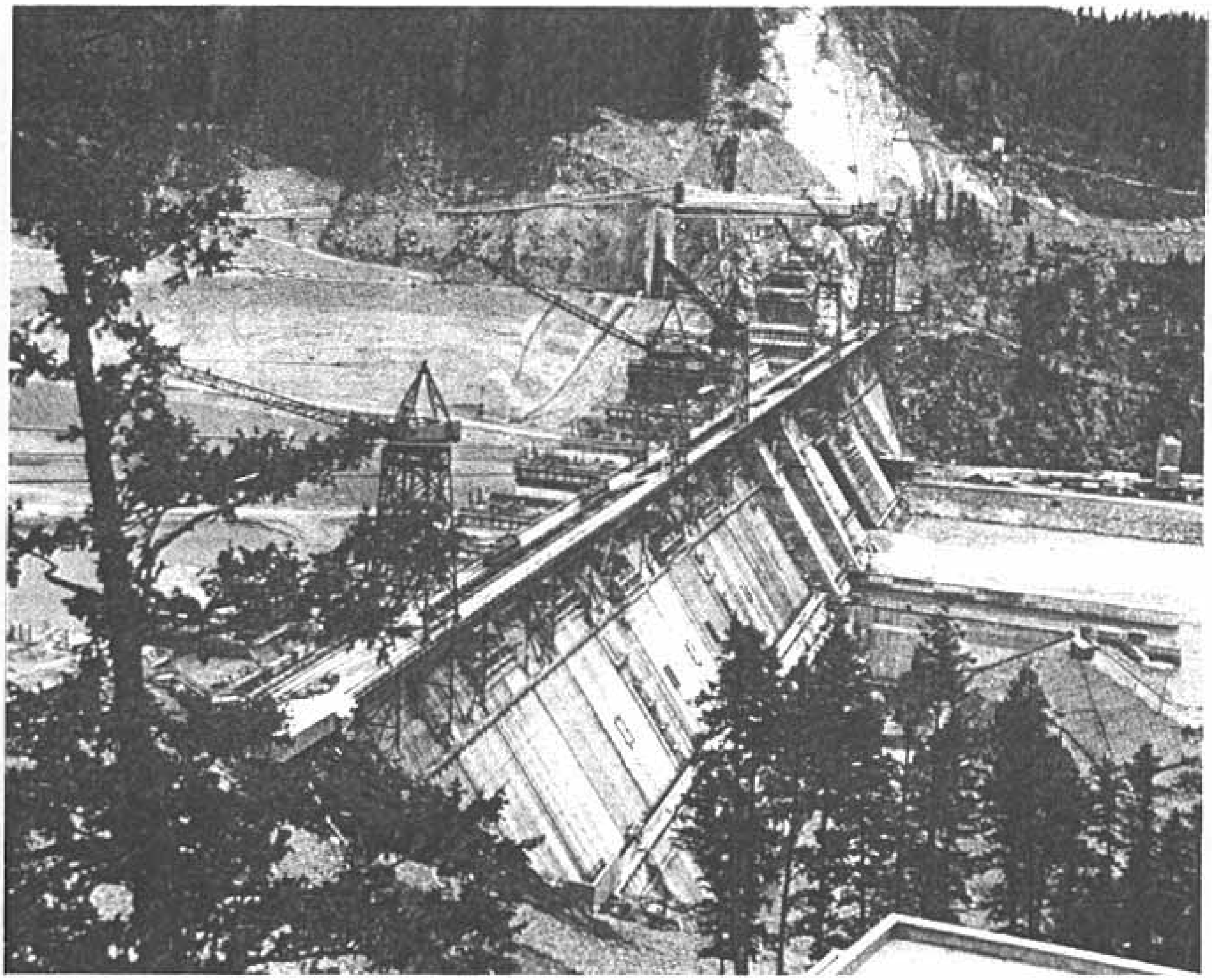
1. "Principles and Procedures for the Preparation and Use of Hydroelectric Operating Plans for Canadian Treaty Storage", dated 25 July 1967.

2. "Columbia River Treaty Hydroelectric Operating Plan for Canadian Storage, Operating Year 1975-76" dated 1 July 1970.

3. "Columbia River Treaty Detailed Operating Plan for Canadian Storage, 1 July 1970 through 31 July 1971", dated 15 September 1970.

4. "Interim Flood Control Operating Plan for Duncan and Arrow Reservoirs", dated 12 November 1968.

LIBBY DAM



View of downstream face of Libby Dam, showing construction progress as of 20 May 1971. Located on Kootenai River in northwestern Montana, the dam will rise about 420 feet above bedrock and will be 2900 feet long at the crest. This view was taken from the visitors' viewpoint on the right bank.

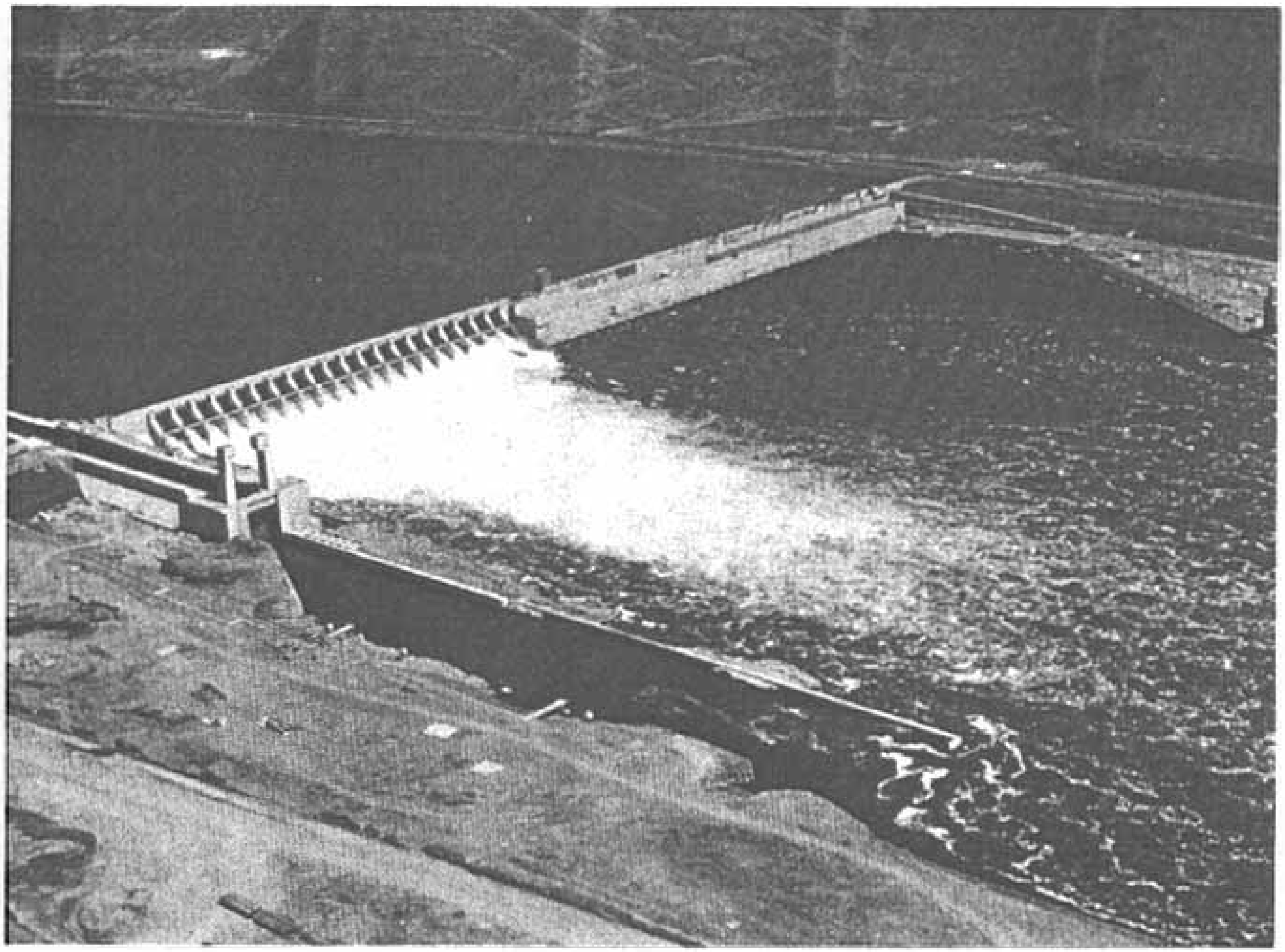
U.S. Corps of Engineers Photograph

MICA DAM

Aerial view of upstream face of Mica Dam , showing construction progress as of 18 May 1971. Located near the Big Bend of the upper Columbia River in British Columbia, Mica will be a key project in the development of the Columbia River.

B.C. Hydro Photograph

JOHN DAY DAM



John Day Dam is located on the lower Columbia River 110 miles east of Portland, Oregon. By November 1971 the generating capability will be over 2480 megawatts. The single-lift navigation lock, shown on the left (Washington) side of the photograph, has one of the highest lifts in the world.

U.S. Corps of Engineers Photograph

SEASONAL VOLUME RUNOFF FORECASTS
MILLIONS OF ACRE-FEET
1971

Forecast Date - 1st of:	Duncan Lake Inflow Most Probable 1 Apr - 31 Aug	Duncan Lake Inflow 95% Probable Date - 31 Jul	Arrow Lake Inflow Most Probable 1 Apr - 31 Aug	Arrow Lake Inflow 95% Probable Date - 31 Jul	Unregulated Runoff Columbia River at The Dalles, Oregon Most Probable 1 Apr - 31 Aug
January	2.01	1.37	21.1	15.3	101
February	2.20	1.57	22.6	17.0	116
March	2.19	1.57	22.8	16.9	110
April	2.23	1.59	23.1	17.1	119
May	2.26	1.53	22.9	15.7	119
June	2.28	1.13	23.4	10.8	121
July					
Actual	2.19		24.4		117

COMPUTATION OF INITIAL CONTROLLED FLOW
COLUMBIA RIVER AT THE DALLES, OREGON
9 MAY 1971

Forecast of May - August Unregulated Runoff Volume, MAF		105
Less Observed Runoff Volume 1-8 May, MAF		7
Less Upstream Storage Corrections, MAF		
Arrow	5.0	
Duncan	1.3	
Hungry Horse	1.6	
Flathead Lake	0.5	
Noxon	0.1	
Pend Oreille	0.4	
Grand Coulee	4.5	
Brownlee	1.0	
John Day	0.3	
TOTAL	14.7	15
Forecast of Adjusted Residual Runoff Volume, MAF		83
Computed Initial Controlled Flow (From Chart 1, of Interim Flood Control Plan), KCFS		550
Observed Flow on 11 May (two days after Computation Date of Initial Controlled Flow), KCFS		549

DUNCAN RESERVOIR

TABLE 3

COMPUTATION OF VARIABLE REFILL CURVES

Forecast Data	Initial	1971 Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1
1. Probable Feb. 1-July 31 inflow, KSFD		864.4	942.7	938.7	961.0	972.0	990.7
2. 95% forecast error, KSFD		191.5	150.7	129.8	116.8	106.9	95.5
3. 95% confidence Feb. 1-July 31 inflow, KSFD 1/		672.9	792.0	808.9	844.2	865.1	895.2
4. Observed Feb. 1-date inflow, KSFD		0.0	0.0	18.5	40.5	92.2	327.0
5. 95% confidence date-July 31 inflow, KSFD 2/		672.9	792.0	790.4	803.7	772.9	568.2
Assumed Feb. 1-Jul. 31 inflow, % volume		100.0					
Assumed Feb. 1-Jul. 31 inflow, KSFD 3/		672.9					
Min. Feb. 1-Jul. 31 outflow, KSFD		18.1					
Min. Jan. 31 reservoir content, KSFD 4/		61.4					
Min. Jan. 31 reservoir elev., ft. 5/		1804.8					
Jan. 31 Variable Refill Curve, ft. 6/	1812.9	1804.8					
Assumed Mar. 1-Jul. 31 inflow, % volume		98.1	98.1				
Assumed Mar. 1-Jul. 31 inflow, KSFD 3/		660.2	777.0				
Min. Mar. 1-Jul 31 outflow, KSFD		15.3	15.3				
Min. Feb. 28 reservoir content, KSFD 4/		71.3	4.8				
Min. Feb. 28 reservoir elev., ft. 5/		1806.6	1792.4				
Feb. 28 Variable Refill Curve, ft. 6/	1813.9	1806.6	1792.4				
Assumed Apr. 1-Jul. 31 inflow, % volume		96.1	96.1	98.0			
Assumed Apr. 1-Jul. 31 inflow, KSFD 3/		646.9	761.1	774.6			
Min. Apr. 1-Jul. 31 outflow, KSFD		12.2	12.2	12.2			
Min. Mar. 31 reservoir content, KSFD 4/		81.5	4.8	4.8			
Min. Mar. 31 reservoir elev., ft. 5/		1808.4	1792.4	1792.4			
Mar. 31 Variable Refill Curve, ft. 6/	1815.4	1808.4	1792.4	1792.4			
Assumed Apr. 16-Jul. 31 inflow, % volume		94.6	94.6	96.5	98.5		
Assumed Apr. 16-Jul. 31 inflow, KSFD 3/		636.7	749.2	762.7	791.6		
Min. Apr. 16-Jul. 31 outflow, KSFD		10.7	10.7	10.7	10.7		
Min. Apr. 15 reservoir content, KSFD 4/		90.2	4.8	4.8	4.8		
Min. Apr. 15 reservoir elev., ft. 5/		1809.9	1792.4	1792.4	1792.4		
Apr. 15 Variable Refill Curve, ft. 6/	1816.1	1809.9	1792.4	1792.4	1792.4		
Assumed May 1-Jul. 31 inflow, % volume		91.1	91.1	92.9	94.8		
Assumed May 1-Jul. 31 inflow, KSFD 3/		613.1	721.5	734.3	761.9		
Min. May 1-Jul. 31 outflow, KSFD		9.2	9.2	9.2	9.2		
Min. Apr. 30 reservoir content, KSFD 4/		112.3	4.8	4.8	4.8		
Min. Apr. 30 reservoir elev., ft. 5/		1813.7	1792.4	1792.4	1792.4		
Apr. 30 Variable Refill Curve, ft. 6/	1818.1	1813.7	1792.4	1792.4	1792.4		
Assumed June 1-Jul. 31 inflow, % volume		71.7	71.7	73.1	74.6	78.7	
Assumed June 1-Jul. 31 inflow, KSFD 3/		482.7	568.3	571.8	599.5	608.3	
Min. June 1-Jul. 31 outflow, KSFD		6.1	6.1	6.1	6.1	6.1	
Min. May 31 reservoir content, KSFD 4/		239.6	154.0	144.4	122.8	114.2	
Min. May 31 reservoir elev., ft. 5/		1832.8	1820.3	1818.8	1815.4	1814.0	
May 31 Variable Refill Curve, ft. 6/	1835.2	1832.8	1820.3	1818.8	1815.4	1814.0	
Assumed Jul. 1-Jul. 31 inflow, % volume		33.9	33.9	34.6	35.3	37.2	47.3
Assumed Jul. 1-Jul. 31 inflow, KSFD 3/		228.3	268.9	270.4	283.7	287.5	268.8
Min. Jul. 1-Jul. 31 outflow, KSFD		3.1	3.1	3.1	3.1	3.1	3.1
Min. June 30 reservoir content, KSFD 4/		491.0	450.4	445.8	436.3	431.5	450.5
Min. June 30 reservoir, elev., ft. 5/		1865.5	1860.5	1859.9	1858.7	1858.1	1860.5
June 30 Variable Refill Curve, ft. 6/	1870.3	1865.5	1860.5	1859.9	1858.7	1858.1	1860.5
July 31 Variable Refill Curve, ft.	1892.0	1892.0	1892.0	1892.0	1892.0	1892.0	1892.0

1/ Line 1 - Line 2
2/ Line 3 - Line 4
3/ Preceding Line x Line 5
4/ Full content (716.2 KSFD) plus preceding line less line preceding that with a minimum content of 4.8
5/ From reservoir elevation - storage content table dated April 24, 1968
6/ Lower of elevation on preceding line or elevation determined prior to year (Initial)

OCTOBER 1970 – APRIL 1971 PRECIPITATION
PERCENT OF 1953–67 AVERAGE

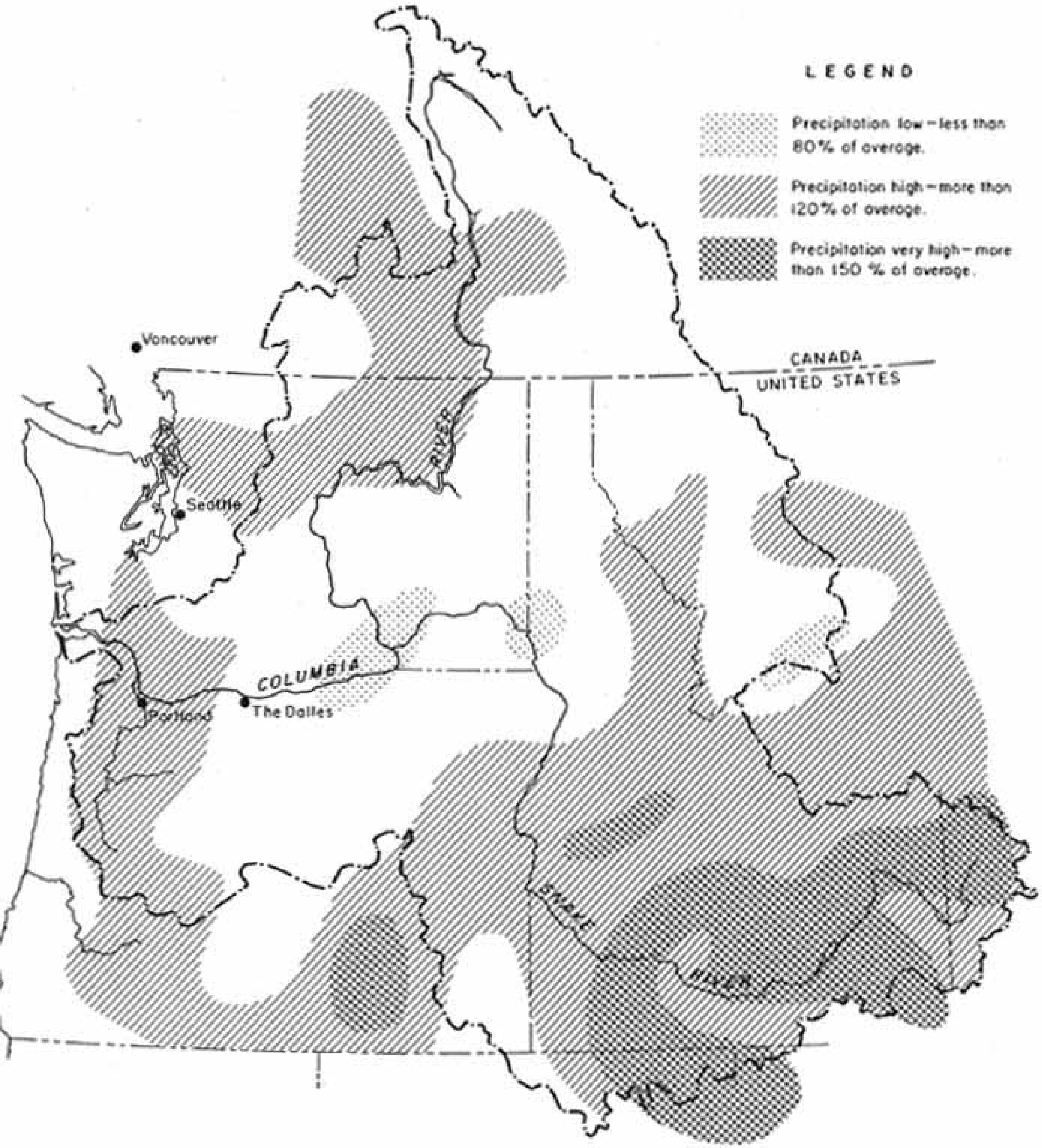
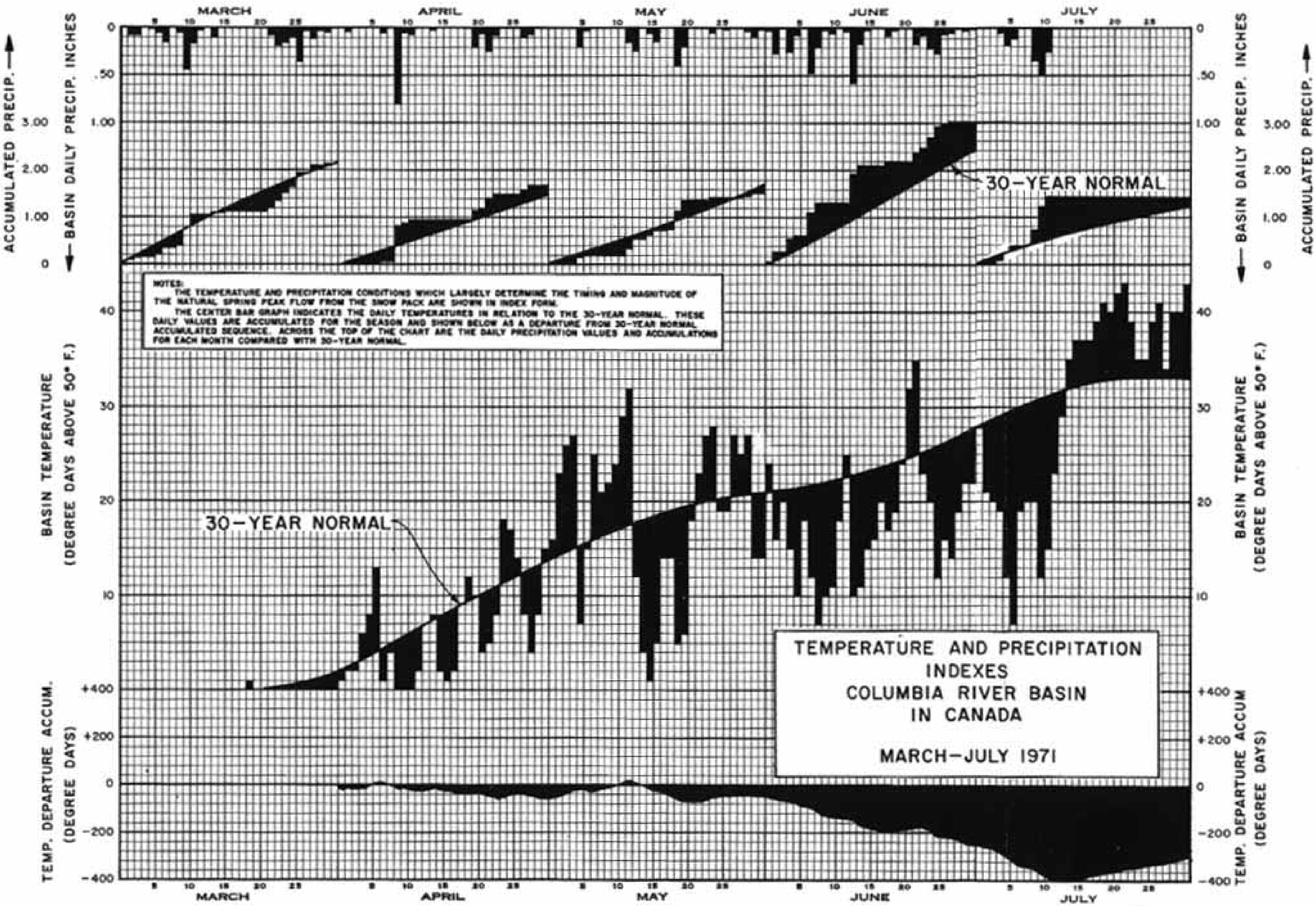
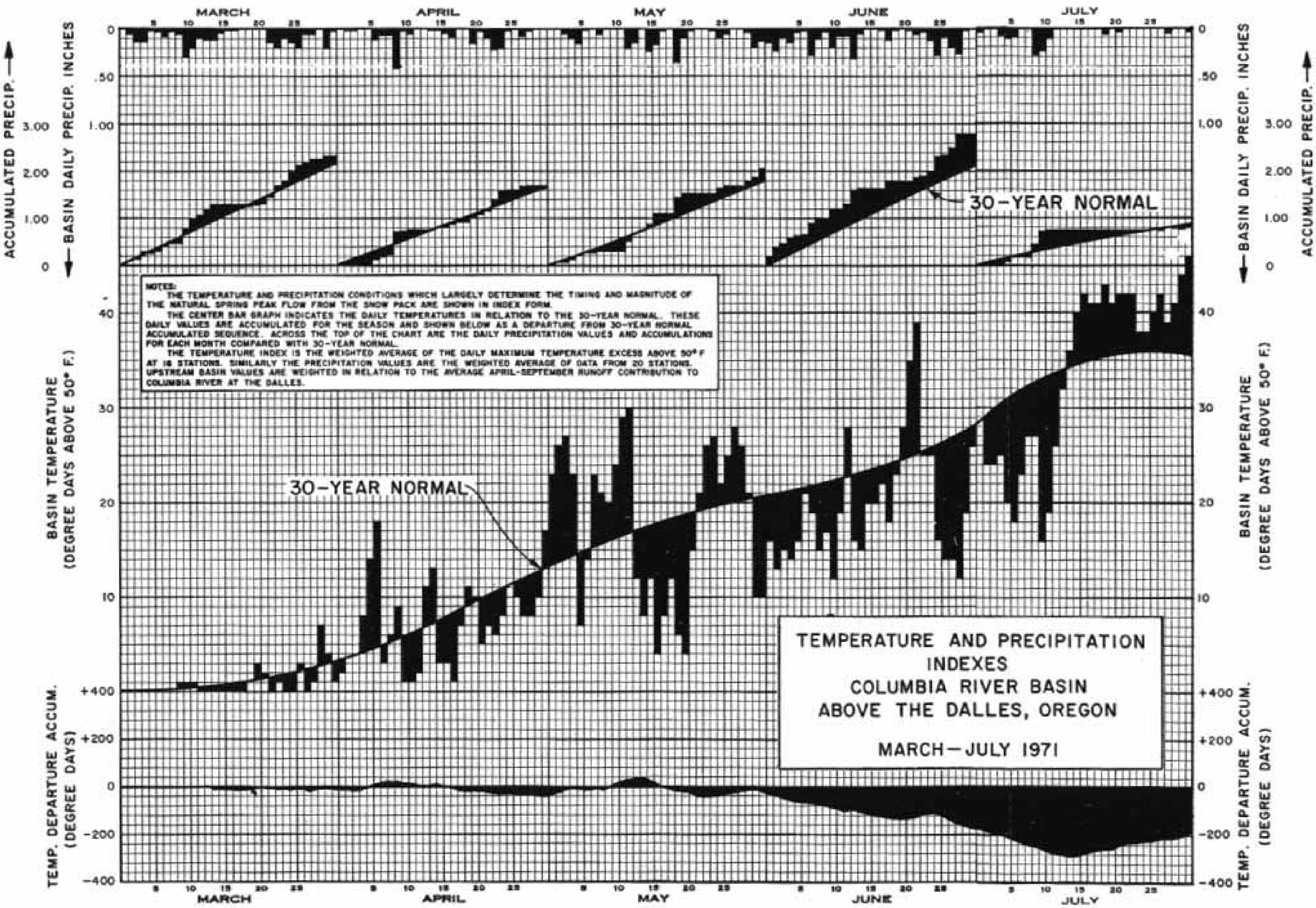


CHART 2



MARCH
APRIL
MAY
JUNE
JULY
5
10
15
20
25
ACCUMULATED PRECIP.
BASIN DAILY PRECIP. INCHES
0
.50
1.00
3.00
2.00
1.00
0
30-YEAR NORMAL
NOTES:
THE TEMPERATURE AND PRECIPITATION CONDITIONS WHICH LARGELY DETERMINE THE TIMING AND MAGNITUDE OF THE NATURAL SPRING PEAK FLOW FROM THE SNOW PACK ARE SHOWN IN INDEX FORM.
THE CENTER BAR GRAPH INDICATES THE DAILY TEMPERATURES IN RELATION TO THE 30-YEAR NORMAL. THESE DAILY VALUES ARE ACCUMULATED FOR THE SEASON AND SHOWN BELOW AS A DEPARTURE FROM 30-YEAR NORMAL ACCUMULATED SEQUENCE. ACROSS THE TOP OF THE CHART ARE THE DAILY PRECIPITATION VALUES AND ACCUMULATIONS FOR EACH MONTH COMPARED WITH 30-YEAR NORMAL.
BASIN TEMPERATURE
(DEGREE DAYS ABOVE 50° F.)
40
30
20
10
30-YEAR NORMAL
TEMP. DEPARTURE ACCUM.
(DEGREE DAYS)
+400
+200
0
-200
-400
TEMPERATURE AND PRECIPITATION
INDEXES
COLUMBIA RIVER BASIN
IN CANADA
MARCH-JULY 1971

CHART 3



MARCH
APRIL
MAY
JUNE
JULY
ACCUMULATED PRECIP.
BASIN DAILY PRECIP. INCHES
30-YEAR NORMAL
BASIN TEMPERATURE (DEGREE DAYS ABOVE 50° F.)
30-YEAR NORMAL
TEMP. DEPARTURE ACCUM. (DEGREE DAYS)
NOTES:
THE TEMPERATURE AND PRECIPITATION CONDITIONS WHICH LARGELY DETERMINE THE TIMING AND MAGNITUDE OF THE NATURAL SPRING PEAK FLOW FROM THE SNOW PACK ARE SHOWN IN INDEX FORM.
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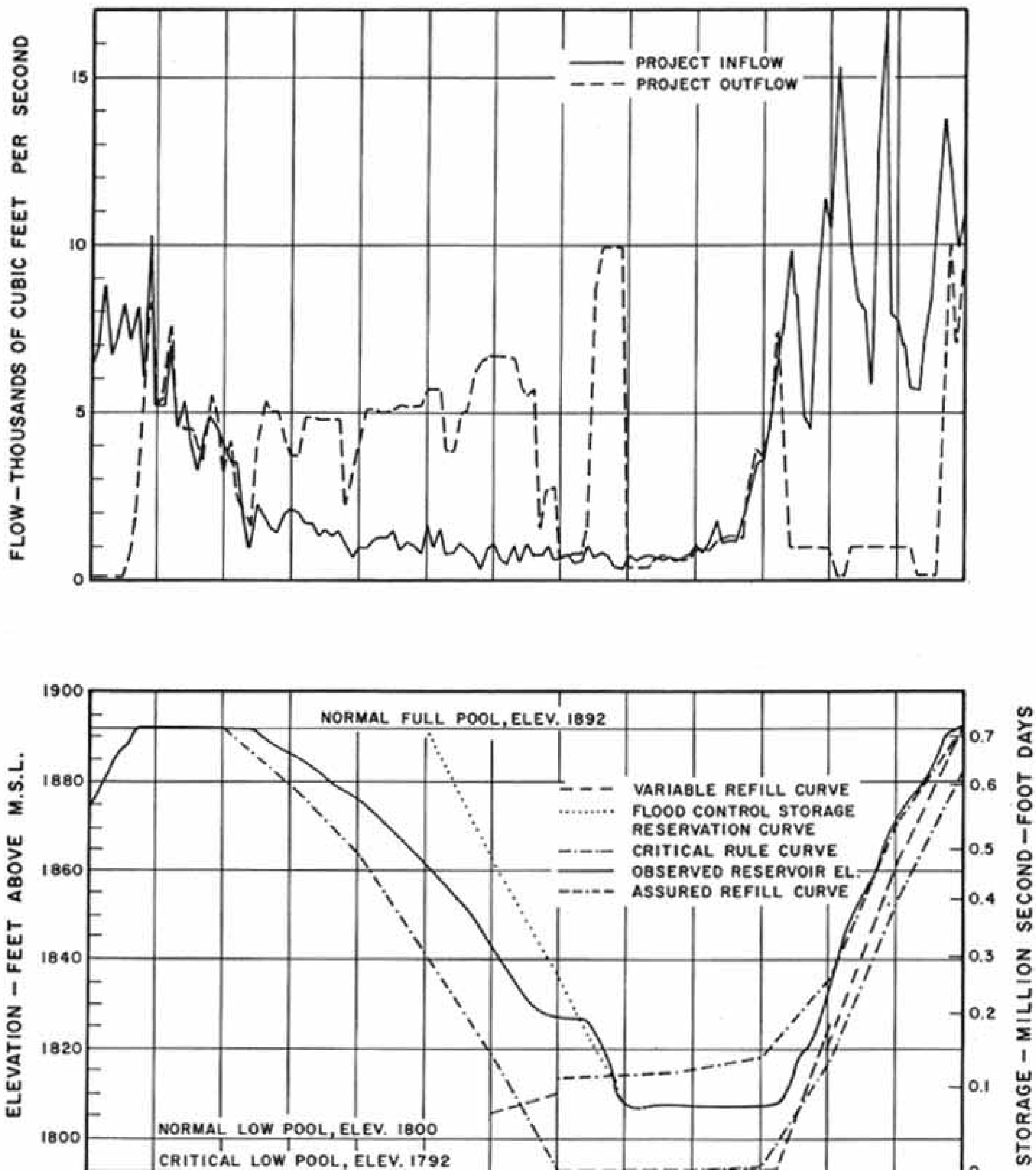
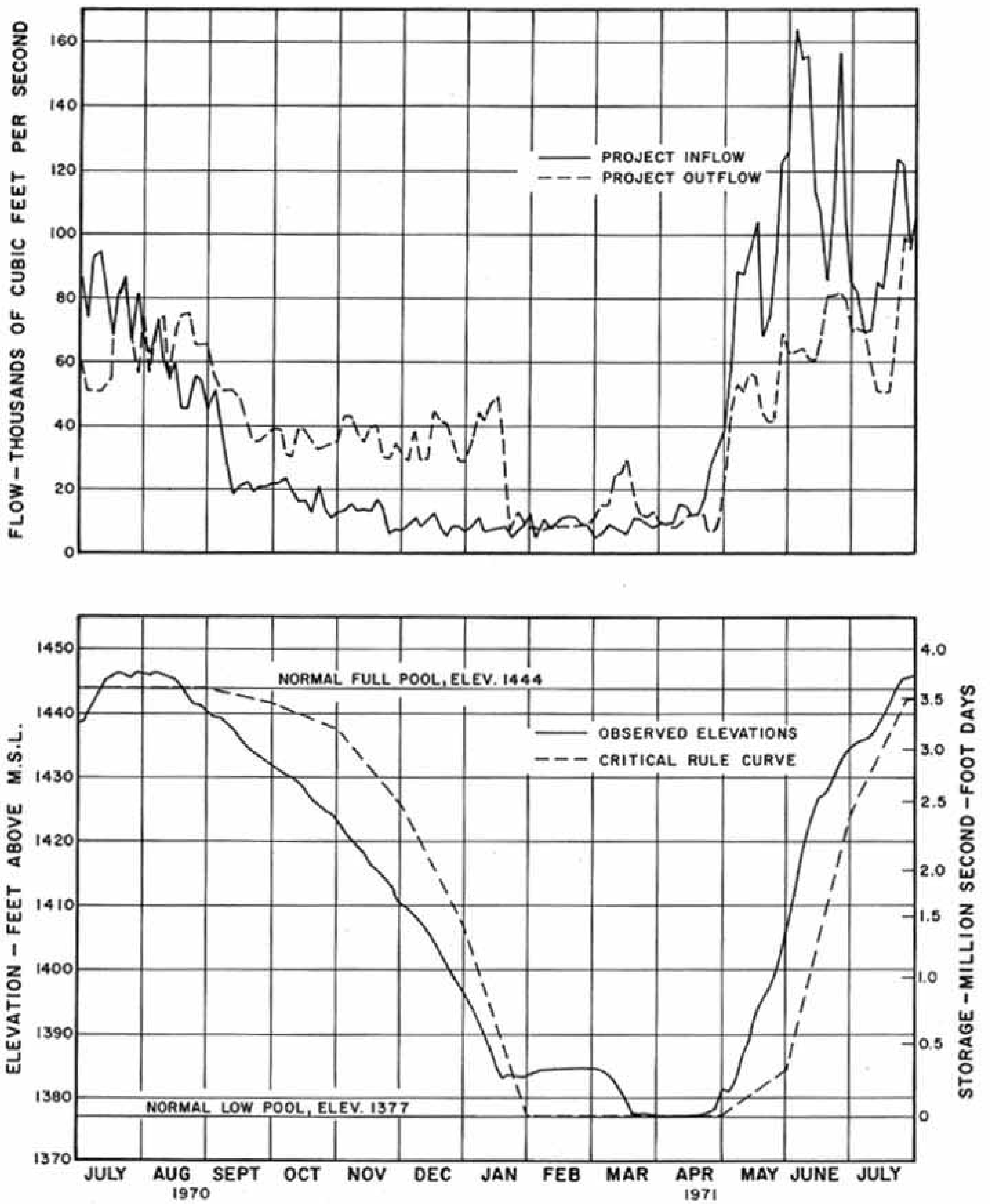
THE TEMPERATURE INDEX IS THE WEIGHTED AVERAGE OF THE DAILY MAXIMUM TEMPERATURE EXCESS ABOVE 50° F AT 16 STATIONS. SIMILARLY THE PRECIPITATION VALUES ARE THE WEIGHTED AVERAGE OF DATA FROM 20 STATIONS. UPSTREAM BASIN VALUES ARE WEIGHTED IN RELATION TO THE AVERAGE APRIL-SEPTEMBER RUNOFF CONTRIBUTION TO COLUMBIA RIVER AT THE DALLES.
TEMPERATURE AND PRECIPITATION INDEXES
COLUMBIA RIVER BASIN
ABOVE THE DALLES, OREGON
MARCH—JULY 1971

CHART 4
DUNCAN

REGULATION OF DUNCAN
1 JULY 1970 – 31 JULY 1971



REGULATION OF ARROW
1 JULY 1970–31 JULY 1971



COLUMBIA RIVER AT BIRCHBANK
1 JULY 1970-31 JULY 1971

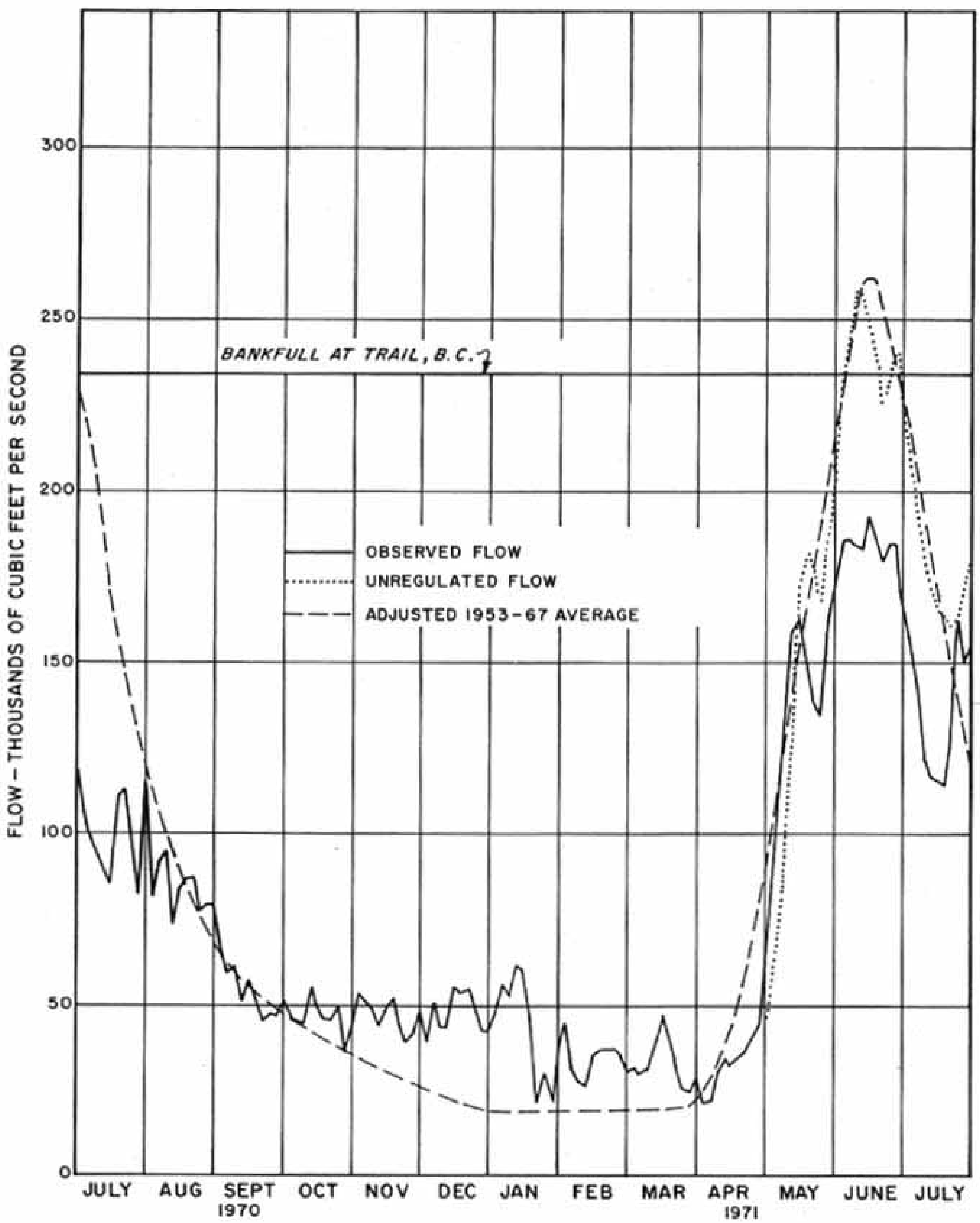


CHART 7
GRAND COULEE

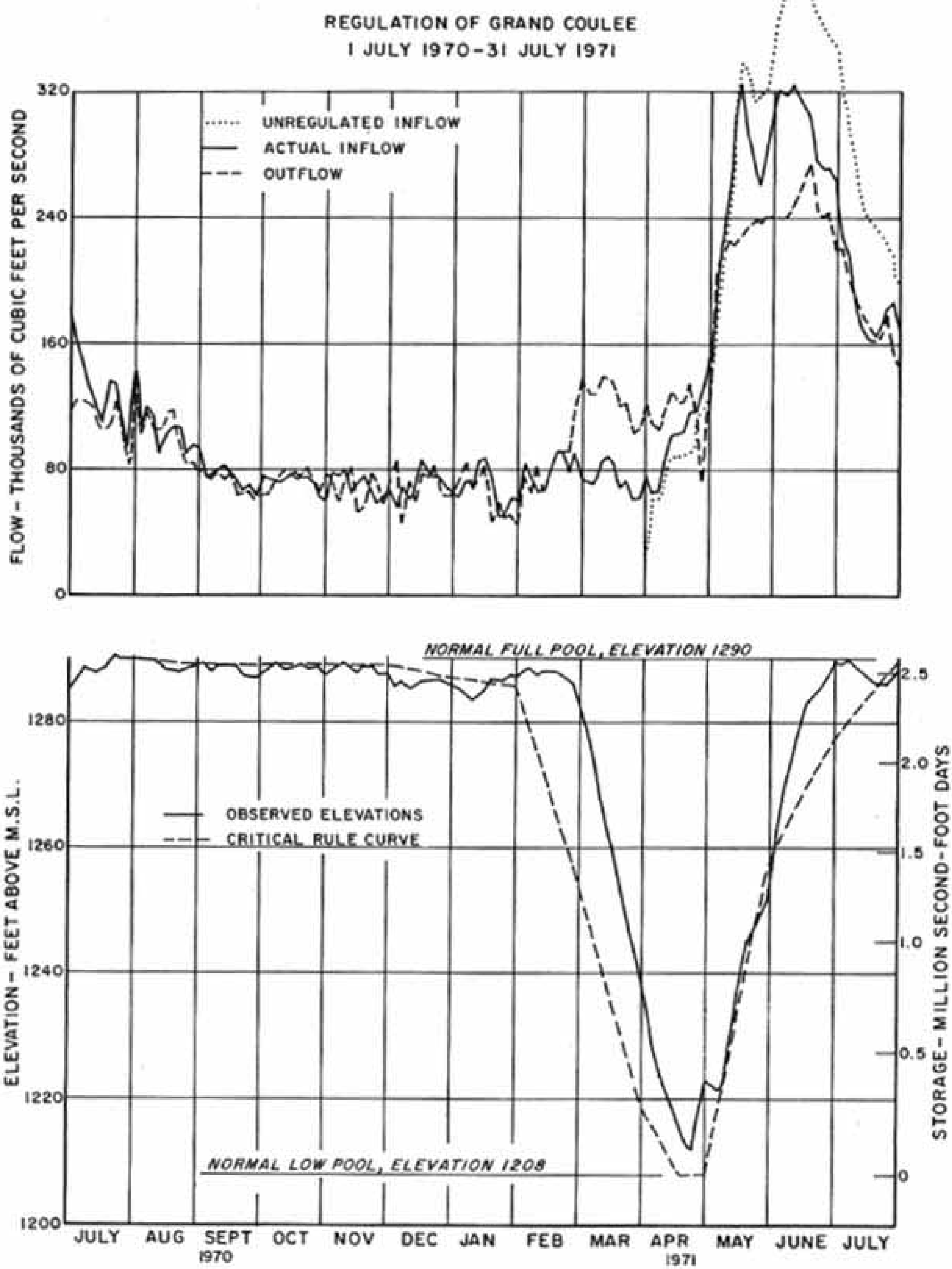
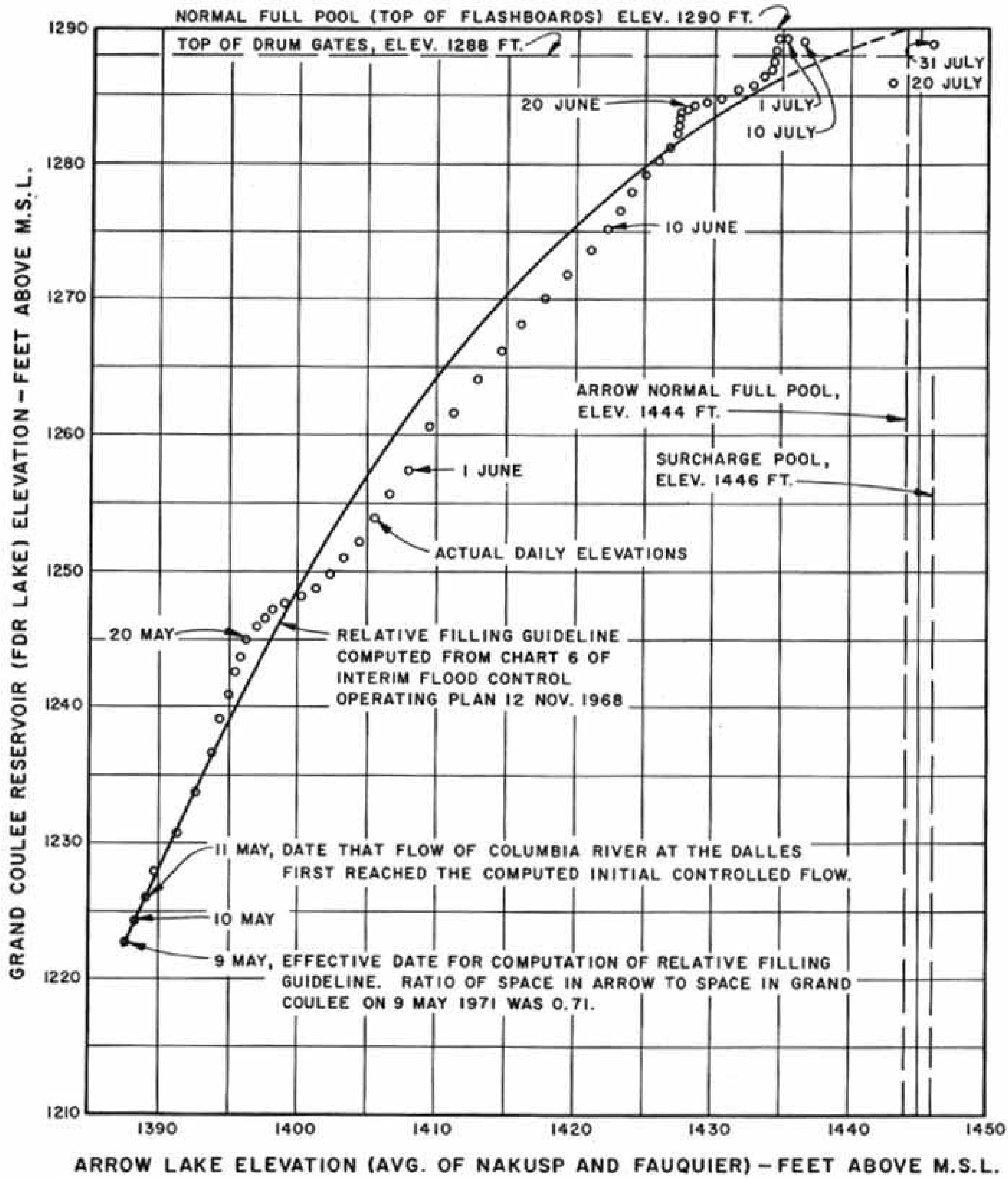
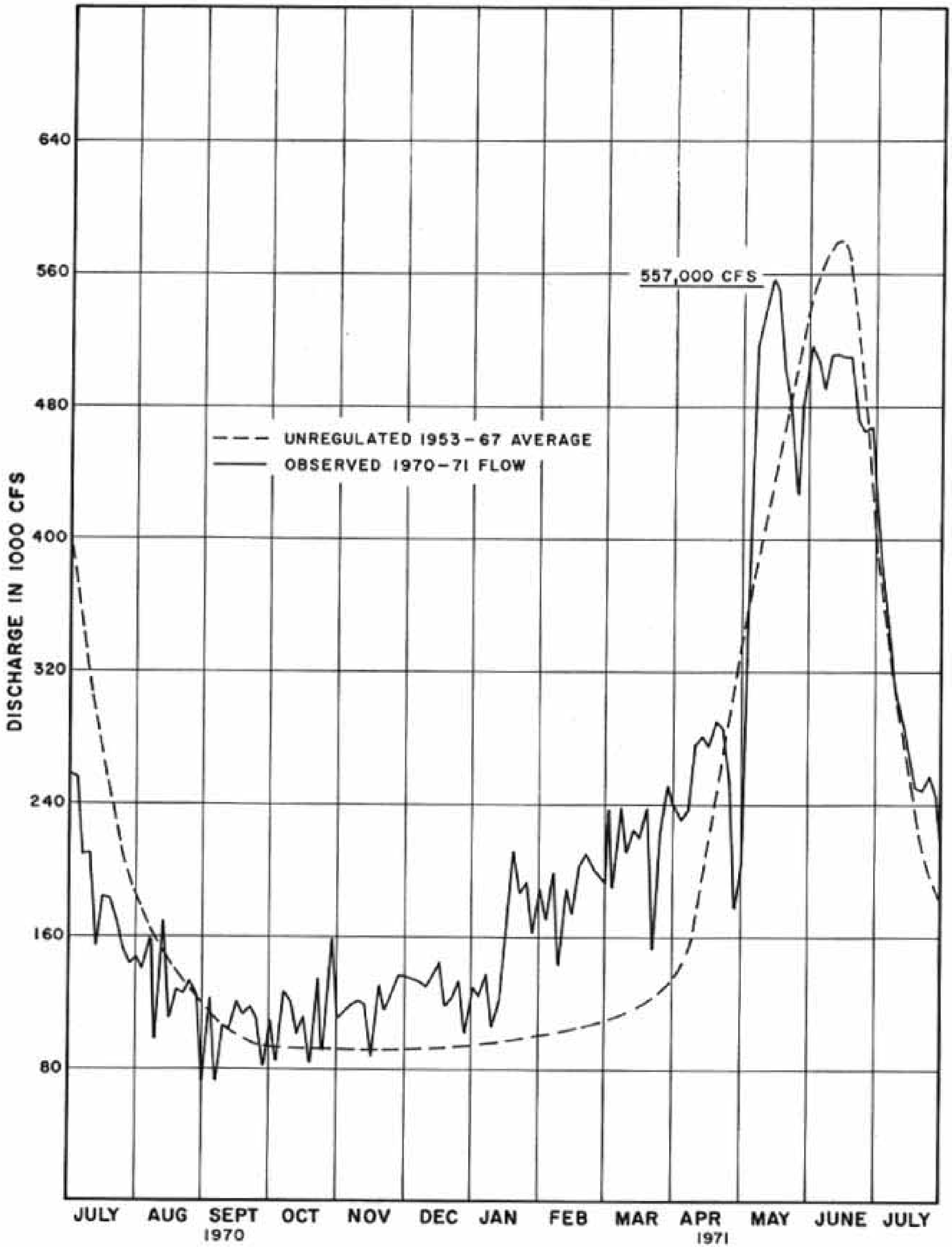


CHART 8
ARROW AND
GRAND COULEE

RELATIVE FILLING
ARROW AND GRAND COULEE



COLUMBIA RIVER AT THE DALLES
1 JULY 1970-31 JULY 1971



COLUMBIA RIVER AT THE DALLES
1 APRIL 1971 - 31 JULY 1971