REPORT ON OPERATION OF COLUMBIA RIVER TREATY PROJECTS

APRIL 1, 1967 THROUGH JULY 31, 1969

COLUMBIA RIVER TREATY OPERATING COMMITTEE

DECEMBER 1969

REPORT ON

OPERATION OF COLUMBIA RIVER

TREATY PROJECTS

1 APRIL 1967 THROUGH 31 JULY 1969

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COLUMBIA RIVER BASIN

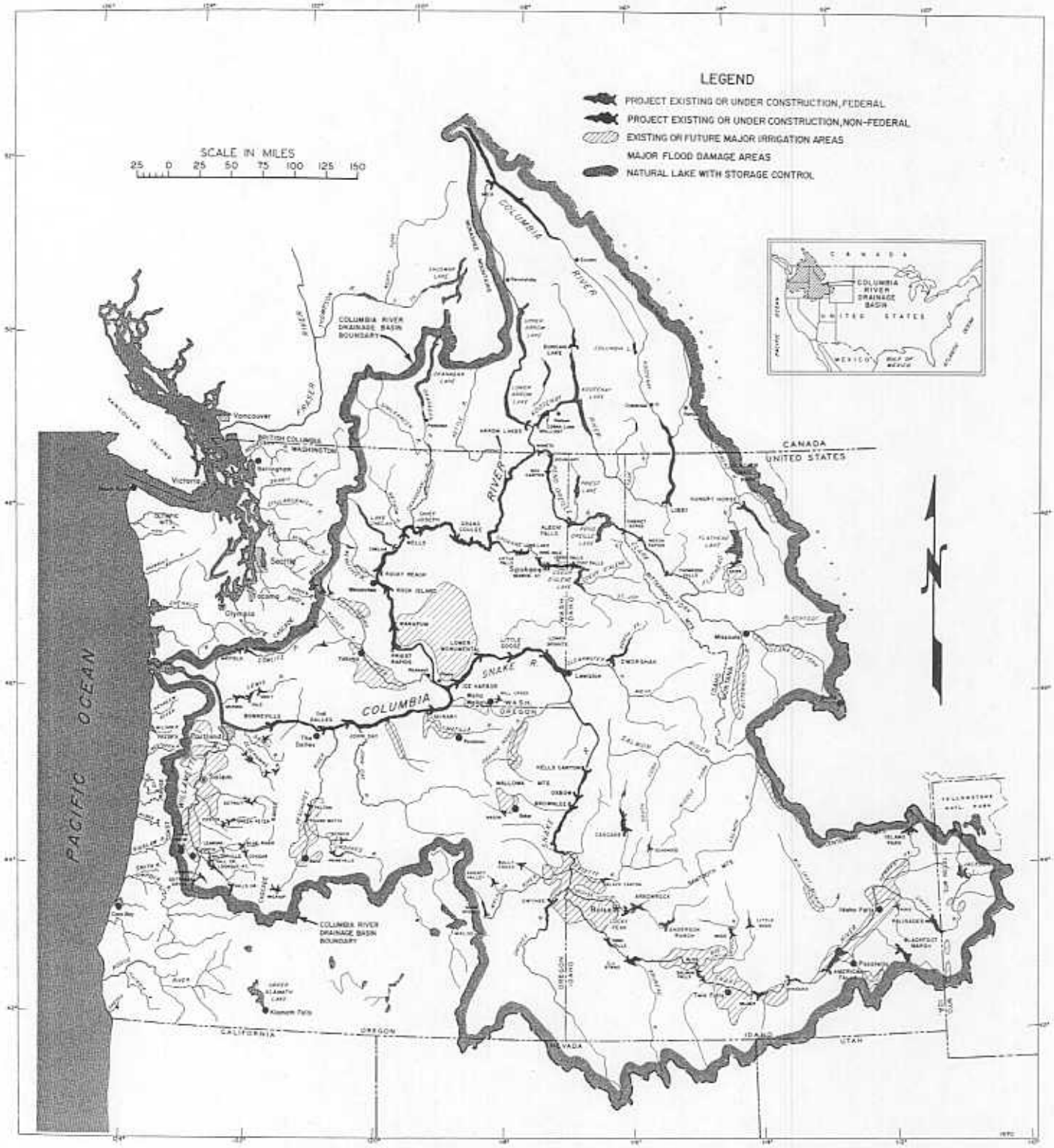

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TABLE OF CONTENTS

PHOTOGRAPHS

TABLES

CHARTS

REPORT ON

OPERATION OF COLUMBIA RIVER TREATY PROJECTS

1 APRIL 1967 THROUGH 31 JULY 1969

I. INTRODUCTION

A. Background

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 purpose of increasing hydro-electric 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 to achieve the purposes of the Columbia River Treaty. Prior to the establishment of the Operating Committee, the preparation of the operating plans and the storage operations had been carried out by the International Task Forces on Power Operating Plans and Flood Control Operating Plans, as instructed by the United States and Canadian Entities on 7 May 1965.

Under its terms of reference the Operating Committee is to prepare an annual report reviewing the preceding year's operation of Treaty storage reservoirs. This is the first such report and, therefore, it covers the period from 1 April 1967, when Duncan began operation, through 31 July 1969. 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.

B. General

The Columbia River Treaty provides for the construction and operation of a total of 15.5 million acre-feet of storage at the Duncan, Arrow and Mica projects in Canada and 5.0 million acre-feet at the Libby project in the United States.

The Treaty and associated documents also provide that the increase in hydroelectric power generation, resulting from the operation of storage developed in Canada, be divided equally between Canada and the United States. The Canadian share of the calculated increase in hydroelectric generation was sold to a group of utilities in the United States for a period of 30 years, beginning on the project completion dates stipulated by the Terms of Sale, Attachment to the Exchange of Notes, regarding the Columbia River Treaty. Duncan's initial operating date was scheduled for 1 April 1968 and Arrow's for 1 April 1969 under the Terms of Sale.

The Treaty further provides that the United States pay Canada a total of $64.4 million (U.S.) for the flood control provided by the Canadian storage reservoirs. Payments were to be made upon the commencement of operation of each of the three Canadian projects.

The Duncan and Arrow projects were both declared operational in advance of the dates established under the Terms of Sale. The Duncan project was declared operational on 31 July 1967 and the Arrow project on 10 October 1968.

The Duncan and Arrow projects were officially dedicated to the service of the people of Canada and the United States on 17 August 1967

and 9 June 1969 respectively. At the Arrow dedication ceremony the dam was named the "H. L. Keenleyside Dam", in honour of Dr. H.L. Keenleyside.

II. OPERATING CRITERIA

A. General

The Columbia River Treaty requires that the reservoirs constructed in Canada be operated pursuant to hydroelectric operating plans developed under Annex A and Article XIV.2.k. of the Treaty. A 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 Plans of 8 December 1967 and 12 November 1968, establish the general criteria of operations.

Annex A of the Treaty provides for the development of 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 immediately preceding each operating year, a Detailed Operating Plan may be developed to produce more advantageous results, through use of current estimates of loads and resources.

Early completion of both Duncan and Arrow precluded the preparation of Assured Operating Plans to cover their initial period of operation. The operation of these projects during the 1967/68 and 1968/69 operating years was accomplished under Special Operating Programs and Plans that considered the special conditions which existed.

The operating year for the Columbia River System, as used in this report, is 1 August through 31 July. The period within each year when flood control is the prime objective is taken as the flood control period of that operating year.

The Special Operating Programs provided the assumptions and criteria for the rules of operation and reservoir limitations for storage drawdown and refill conditions. These operating guides and criteria for their application were embodied in the Special Operating Plan developed for each period. The Programs also established the distribution of the benefits that resulted from the early operation of the Canadian reservoirs.

The Special Operating Plans established Operating Rule Curves (end-of-month reservoir elevations) for Duncan during the 1967/68 operating year and for Duncan, Arrow and the whole of Canadian storage for the 1968/69 operating year. The Operating Rule Curves provided the required refill levels as well as drawdown levels. They were derived from Critical Rule Curves, Assured Refill Curves, and Variable Refill Curves as described in the Principles and Procedures. The Upper Rule Curves were established to conform to the Flood Control Operating Plans.

B. Power Operation

The Special Operating Plans were 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 of 4 January 1965. Optimum generation in the United States was assured by the adoption, in the Special 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 any water condition, by operating within the limits of the Critical Rule Curves, Assured Refill Curves, Variable Refill Curves and the Upper Rule Curves established in the Special Operating Plans.

C. Flood Control Operation

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

The flood control operation during the drawdown period consists of evacuating and holding available, insofar as possible, 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.

Normal flood control operation of the Columbia River Treaty projects during the refill period is controlled in part by the computed initial controlled flow of the Columbia River at The Dalles. The Interim Flood Control Operating Plans provided a method of computing and updating the initial controlled flow. Table 1 gives the values computed for 1968 and 1969. Other operating rules and local criteria were utilized to prepare day-to-day streamflow forecasts for a large number of points in Canada and the United States, and establish the operations of the flood control storage. These daily flow forecasts were prepared by the Cooperative Columbia River Forecasting Unit, for periods of 30 to 45 days in advance, for both moderate and severe snow-melt sequences.

D. Implementation of Storage Operation

During the drawdown periods, the Canadian Treaty storage was operated on the basis of a regular weekly request for storage release. On behalf of their respective Entities the storage was operated by the Canadian Section of the Columbia River Treaty Operating Committee, as requested by the United States Section.

Some modifications of the regular weekly requests were made to meet special conditions. The Operating Committee consulted with West Kootenay Power and Light Company regarding the operation of Kootenay Lake prior to establishing the amounts and distribution of the Canadian storage releases. This coordination was necessary because operation of Duncan and storage in the United States upstream from Waneta Dam affects West Kootenay Power and Light Company's operation. The operation of Kootenay Lake in turn affects the downstream projects of West Kootenay Power and Light Company and projects in the United States.

The regular weekly requests for the release of stored water during the 1967/68 operating year, were directed to Duncan reservoir. During the 1968/69 operating year, when Arrow was also operational, the requests 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 between Arrow and Duncan reservoirs of the requested release.

During the periods of flood control operation the daily discharges 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 Plans and the stream flow forecasts. The Canadian Section directed the operation of the projects to produce the required daily discharges.

During the initial fill periods of both Duncan (April through July 1967) and Arrow (April through July 1968) the daily operation of the reservoirs was as directed by the Canadian Section. The operations accomplished reservoir filling without detriment to the United States system generation, harm to the safety of the project or infringement on reservoir freeboards.

III. STORAGE OPERATIONS

A. General

The storage operation of the Treaty reservoirs resulting from the Special Operating Plans and other operating requirements are shown on Charts 1 and 2. Chart 1 shows the inflows, the storage elevations and the discharges from Duncan for the period 1 April 1967 through 31 July 1969. Chart 2 shows the same information for Arrow for the period 1 April 1968 through 31 July 1969. Also shown on these charts are some of the operating guides.

B. Duncan Operation

1. Initial Fill Period, 1 April through 31 July 1967

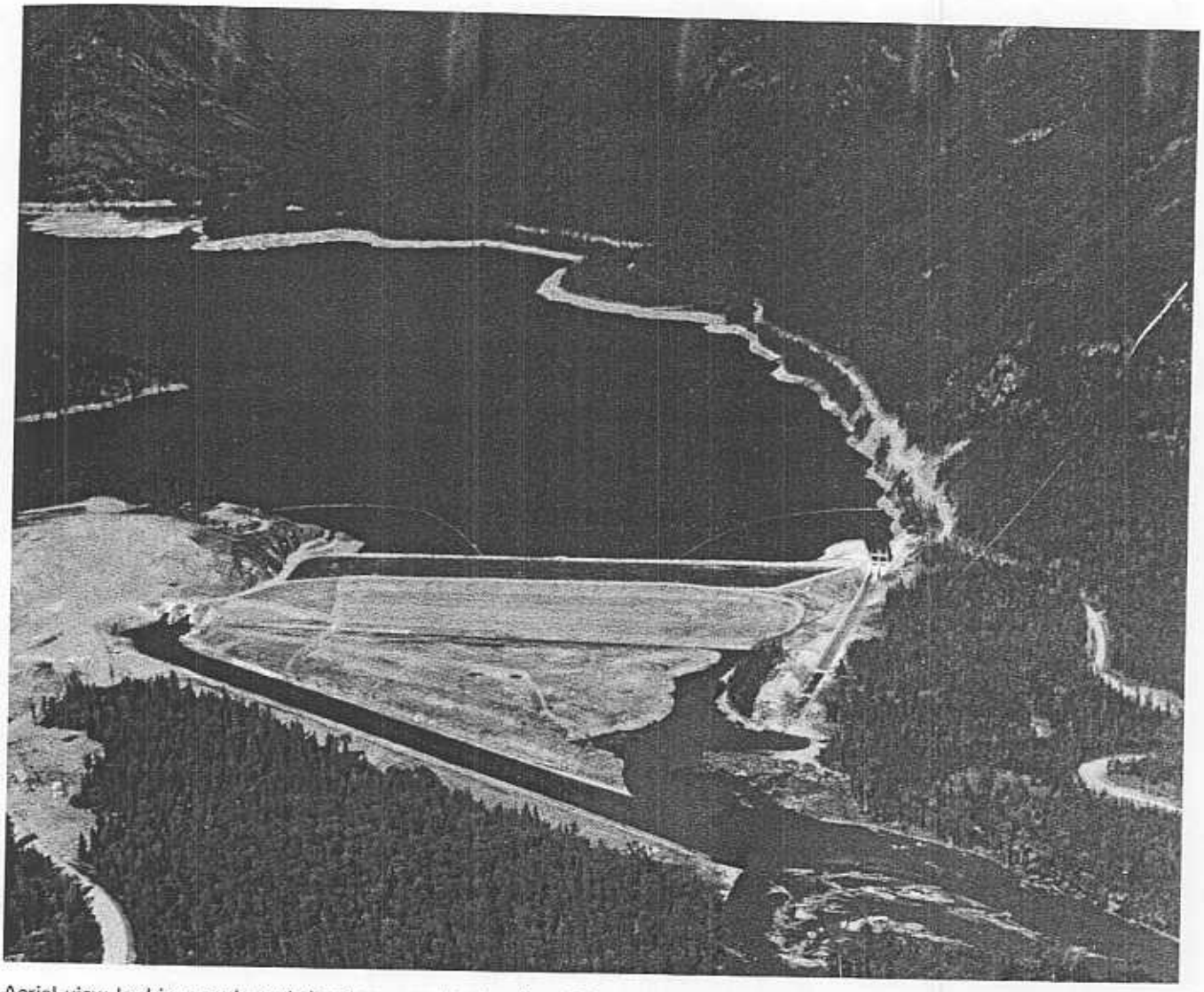
The early completion and filling of Duncan was complicated by the possibility of extreme settlement in the dam's foundation, caused by fully loading the structure one year prior to its planned completion date. To achieve the benefits of the storage one year early the Canadian Entity decided to attempt a controlled reservoir fill. If adverse effects had occured it would have been necessary to release all the water stored.

Under the Special Operating Program of 14 March 1967, the Duncan discharge was controlled and filling commenced on 29 April 1967 under the direction of the Canadian Entity. As shown on Chart 1 the filling was suspended for short periods to inspect the dam and measure settlement. Inspections were made at elevations 1803, 1860 and 1870 feet. No adverse affects were noted and the reservoir reached normal full pool elevation of 1892 feet on 25 July 1967.

2. 1967/68 Operating Year

As shown on Chart 1, the Duncan reservoir full pool elevation of 1892 feet was maintained until draft of water for downstream power generation was commenced on 23 September 1967. The draft continued until 22 October 1967 when, with Duncan reservoir at elevation 1875 feet, the occurrence of high inflows in the lower Columbia River made further draft from the Duncan reservoir unusable. Draft resumed on 26 November 1967 and continued until 4 February 1968, when the Duncan reservoir had reached elevation

DUNCAN PROJECT



Aerial view looking northward showing completed project. The release control tunnels are at the left and spillway at right. The reservoir is nearly empty.

B.C. Hydro Photograph

1811 feet. After two weeks pause the lake was drafted further to elevation 1804.8 feet on 2 March 1968.

From 3 March to 6 April discharge was reduced to the minimum allowable to store water which would have spilled in the lower Columbia River. This resulted in an elevation of 1810.8 feet on 6 April. Release of this water commenced on 7 April and by 16 April 1968 the reservoir reached its minimum elevation of 1800 feet.

Beginning 1 January 1968, forecasts of volume inflow to Duncan were made for the periods from the first of each month through 31 July 1968. Based upon these forecasts the Variable Refill Curves were determined. As shown on Chart 4, the 1968 Variable Refill Curves for Duncan ranged below the Assured Refill Curve from a minimum of 3.5 feet on 31 January to a maximum of 19.7 feet on 30 April 1968.

The April volume runoff forecast for Duncan for April through August 1968 was 2.24 million acre-feet(1.13 million second-foot-days) as shown on Table 2. With this forecast the Interim Flood Control Plan required that 1.27 million acre-feet of flood control storage space be evacuated and maintained at Duncan for use in controlling the summer peak of 1968.

As indicated in Table 2, the seasonal volume runoff forecast prepared as of 1 April 1968 for the Columbia River at The Dalles, was 84.0 million acre-feet(42.3 million second-foot-days). Table 1 shows the computed initial controlled flow to be 380,000 cubic feet per second.

As shown on Chart 1, inflow was passed through the Duncan project, with the reservoir at elevation 1800 feet, from 16 April until 11 May 1968. On 11 May, by agreement of the Operating Committee the discharge was reduced to 1000 cubic feet per second and filling of the reservoir commenced. Filling at this rate continued until 2 June, at which time it was agreed on the basis of streamflow simulations, that there was no threat of filling Duncan reservoir prior to the time of the summer peak in either the United States or Canada. Accordingly, filling at the maximum rate began on 2 June 1968. Discharges larger than minimum discharge were commenced on 12 July as the reservoir approached full pool level. The reservoir reached normal full pool level of elevation 1892 feet on 19 July 1968.

3. 1968/69 Operating Year

In the fall months of 1968, high natural streamflows made the release of Duncan storage unnecessary until 2 December 1968. Draft commenced for downstream power production and flood control storage evacuation at that time, and continued until 23 December with the reservoir at elevation 1869.5 feet. After a brief pause draft was resumed and continued until 2 February 1969 with the reservoir at elevation 1834.5 feet. On 1 March draft resumed and the reservoir was lowered to its Upper Rule Curve elevation of 1807.5 feet by 20 March 1969. Since the additional water below elevation 1807.5 feet was not required for power generation, the reservoir was not drafted below this elevation in 1968-69. As shown on Chart 5, the elevation of Duncan exceeded its Upper Rule Curve as

was agreed by the Entities in a letter from the Canadian Entity to the United States Entity dated 31 March 1969, (Reference No. 9).

The 1969 Variable Refill Curves for Duncan ranged below the Assured Refill curve from a maximum of 21.2 feet on 29 February 1969, to a minimum of 4.6 feet on 30 June 1969, as shown on Chart 5.

Table 2 shows the April volume runoff forecast for Duncan for April through August 1969 was 2.10 million acre-feet(1.06 million second-foot days). This volume forecast required 1.27 million acre-feet of flood control storage space be evacuated at Duncan, which results in a reservoir elevation of 1807.5 feet.

As indicated in Table 2, the seasonal volume runoff forecast, prepared as of 1 April 1969 for the Columbia River at The Dalles, was 108.0 million acre-feet (54.4 million second-foot days). Table 1 shows the computed initial controlled flow to be 470,000 cubic feet per second and this normally would have been the criteria for the commencement and level of control for flood control operations. However, in accordance with a request from the U.S. Bureau of Reclamation, the Grand Coulee discharge was restricted to 205,000 cubic feet per second or less until 12 June by operation of upstream storage. As shown on Chart 10, this special operation resulted in discharges at The Dalles which were less than the computed initial controlled flow throughout the entire filling period.

As shown on Charts 1 and 5, the Duncan discharge was reduced to 1000 cfs. in late April 1969 and maintained constant until 16 May, when it was reduced to 100 cfs. by agreement. The inflow

in May and June varied from about 3000 cubic feet per second to 16,000 cubic feet per second, so the reservoir filled rapidly. In early July, as it approached full pool elevation of 1892 feet the discharge was gradually increased about 10,000 cubic feet per second for a short period. Elevation 1892 feet was first reached on 10 July 1969 after which the discharge was adjusted to approximately equal the inflow.

Chart 5 compares the actual elevations of Duncan reservoir with the Upper and Critical Rule Curves and the Assured and Variable Refill Curves for 1969. As shown, the actual lake elevation was above the refill rule curves during the refill season, except that the actual elevation was below the Assured Refill Curve during part of May.

C. Arrow Operation

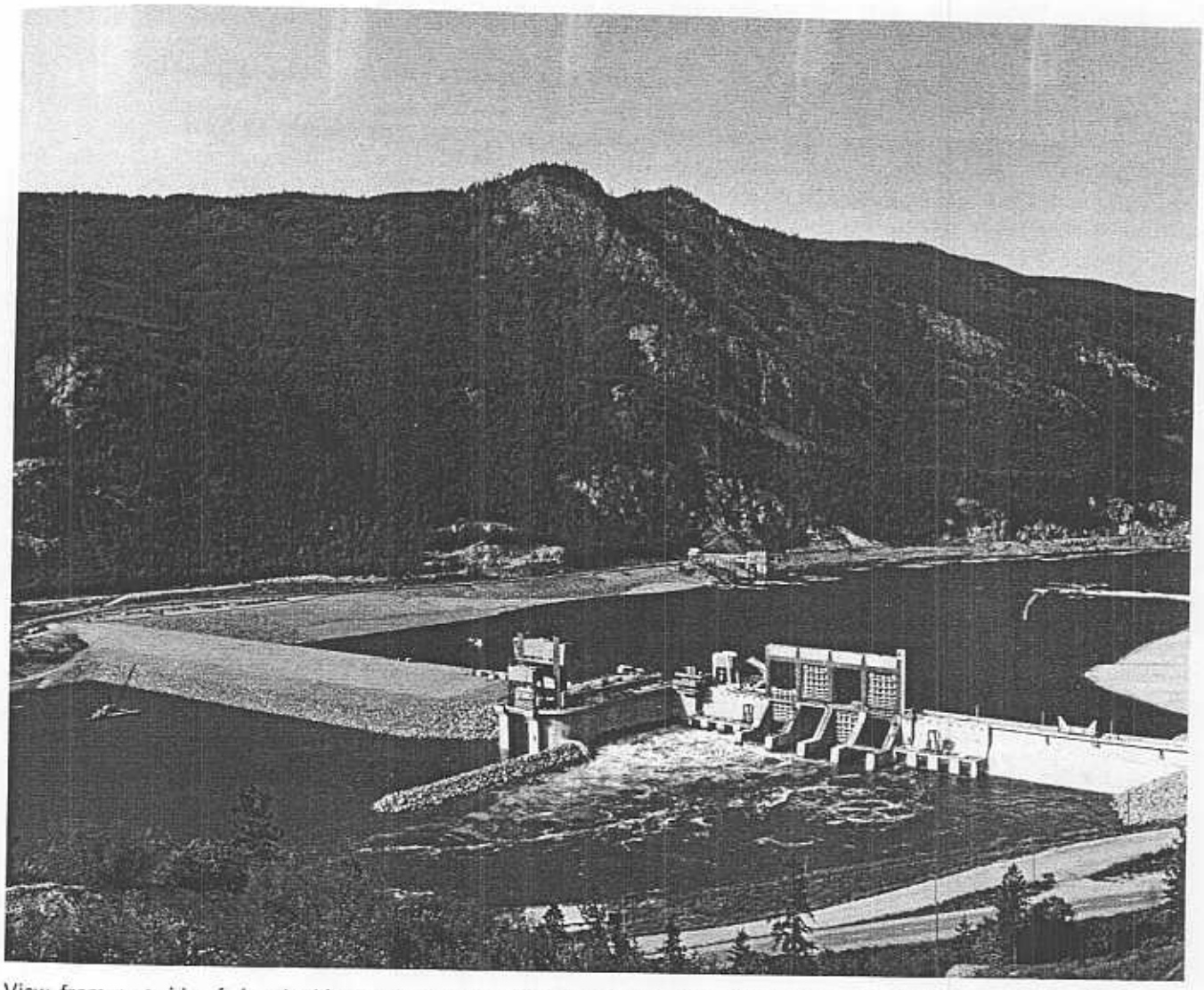
1. Initial Fill Period, 1 April through 31 July 1968

The operation of the Arrow reservoir during this period was governed by two considerations:

a. The desire to store water to elevation 1404 feet and thus make available to the United States and Canada the power generation benefits available from this volume of water.

b. The necessity to not exceed elevation 1404 feet which would result in disruption of work within the reservoir area. The completion of the reservoir preparation work had been scheduled for 31 July 1969.

ARROW PROJECT



View from east side of river looking across dam during initial filling. The earth fill is to the left, the navigation lock in the center and the concrete release control structure at the right bank.

B.C. Hydro Photograph

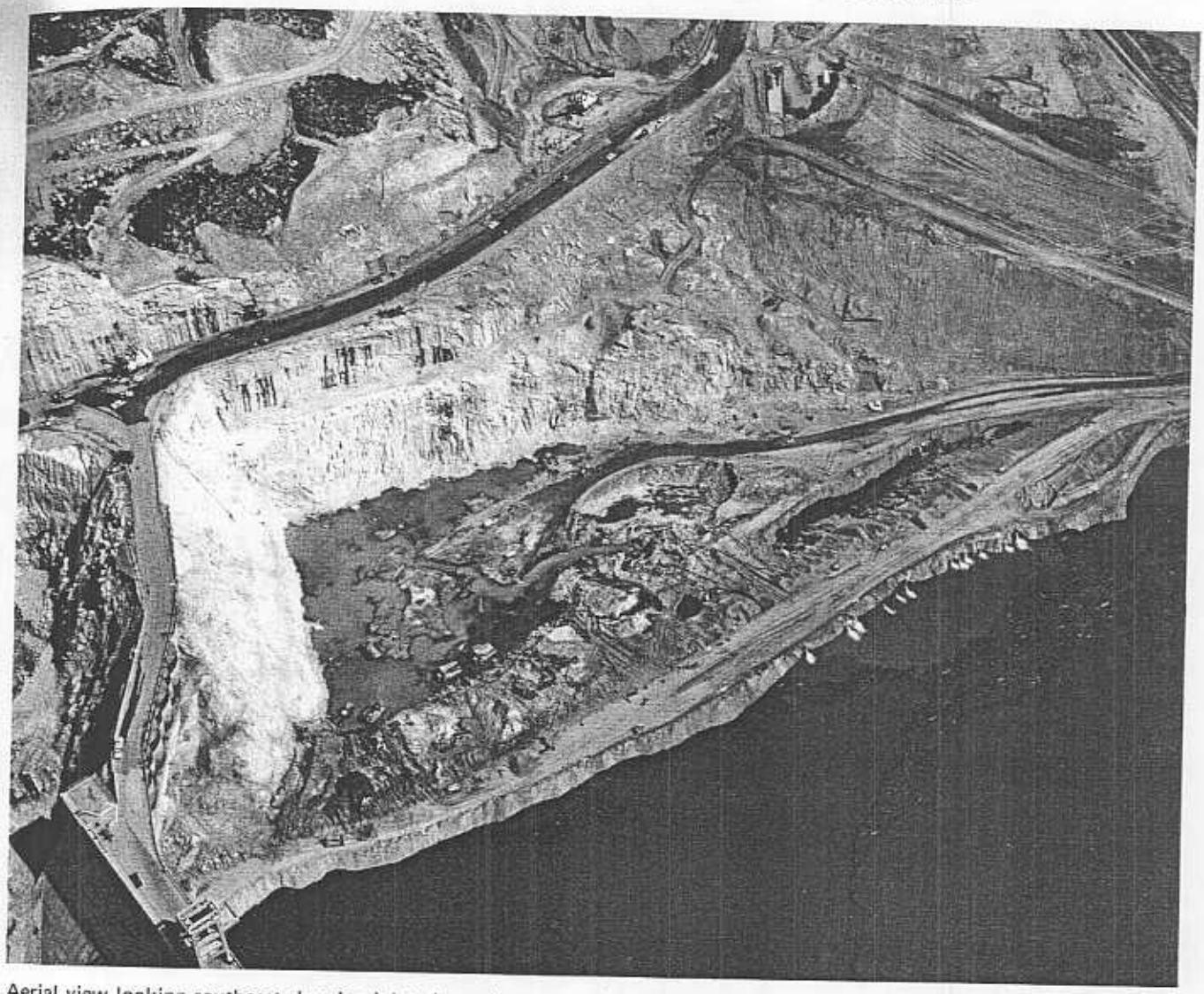
The early completion of Arrow Dam was scheduled for October 1968, well after the flows had receded from summer peaks and surplus water would not be available for storing. Since rollways and gate installations in the sluiceways were not complete, it was necessary to employ temporary measures in the form of stoplogs and temporary gates, to allow partial filling to a reservoir elevation of 1404 feet, before 31 July 1968.

In order to ensure meeting the schedule of an October completion for the Arrow project, one sluiceway overflow section had been poured prior to the summer high flows. The remaining three sluiceway sections were used to discharge the river flow until the reservoir exceeded elevation 1394 feet when all sluiceways could be used. On 26 June 1968, 10-foot deep stoplogs, which remained completely submerged and thus had little effect on the discharge capacity were placed in the three uncompleted sluiceways. The flows remained high, delaying the placing of the remaining stoplogs until 17 July 1968. The temporary gates were placed on 18 July. Discharge control for placing of downstream stoplogs and pool filling commenced on 19 July. The pool was raised to elevation 1404 feet on 31 July 1969. The operation of the temporary stoplogs and gates to obtain the partial storage was completely successful.

2. 1968/69 Operating Year

High natural streamflows occurred during the fall and early winter months of 1968 and there was no need for the release of

GRAND COULEE DAM THIRD POWERHOUSE EXCAVATION



Aerial view looking southeast showing inlet channel upstream from Grand Coulee Dam excavated to elevation: 1110. Taken during record drawdown of Lake Roosevelt.

U.S. Bureau of Reclamation Photograph

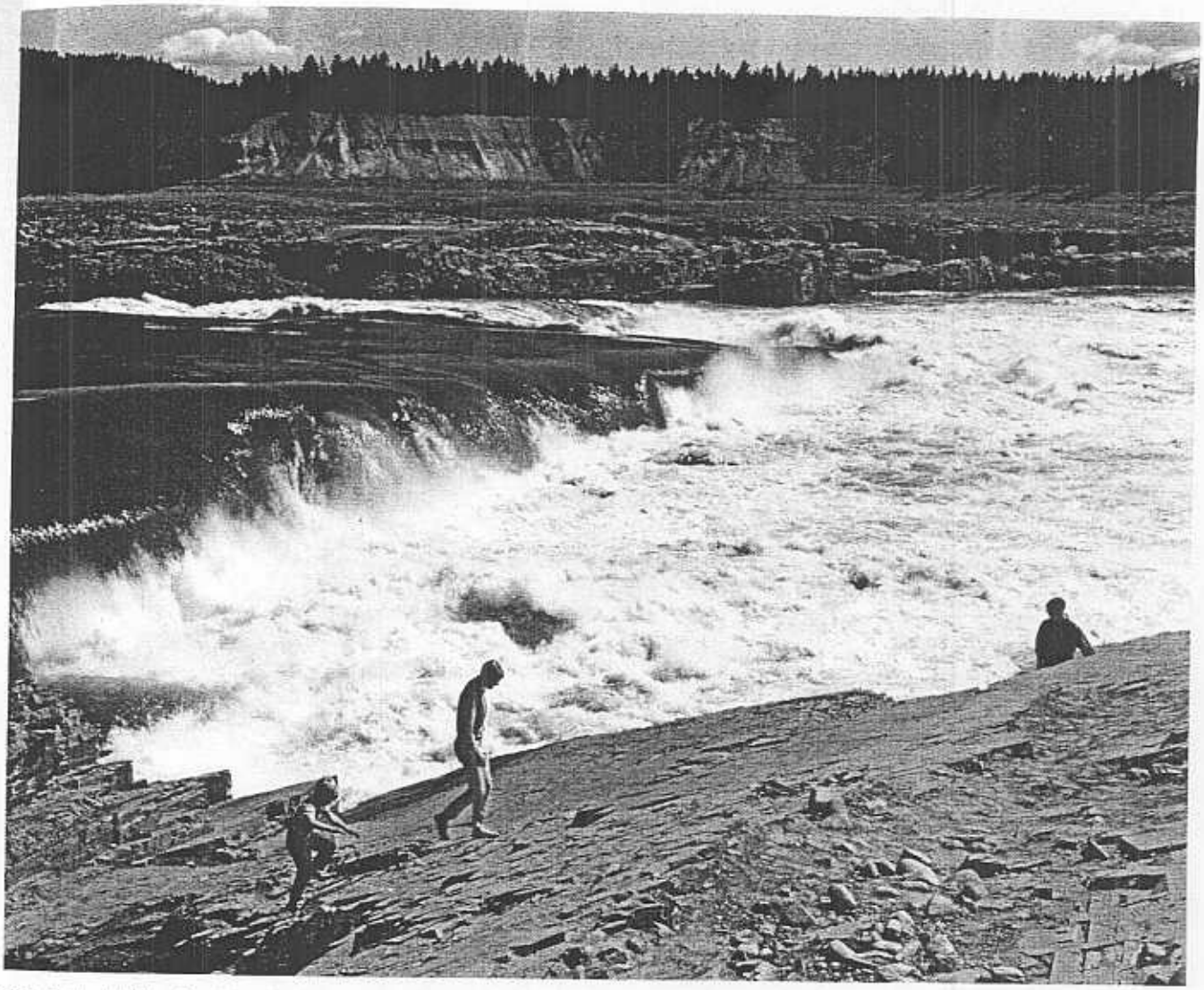
water from Arrow until well into the usual draft period. As shown on Chart 2, the Arrow reservoir was controlled, as closely as possible, at elevation 1404 feet until 23 December 1968 at which time draft commenced for power production in the United States. Draft continued, at varying rates, until 4 March 1969, by which time the reservoir reached elevation 1389.0 feet. Draft resumed on 20 March and continued until 18 April, at which date the reservoir reached a low elevation of 1381.4 feet.

Until Mica Reservoir becomes operational, Arrow is an annual refill reservoir; that is, there is adequate inflow every year to insure refilling from the lowest to the highest operating levels. For this reason the computation of Variable Refill Curves for Arrow is not required until Mica Reservoir is in operation.

The Seasonal Volume Runoff Forecast for the Columbia River at The Dalles, for the period 1 April to 31 August 1969, was 108.0 million acre-feet (54.4 million second-foot days). This amount requires, under the Interim Flood Control Plan, the total 7.14 million acre-feet(3.60 million second-foot days) of flood control storage space be evacuated and maintained at Arrow, to the extent physically possible, until storing for flood control operations are commenced. This volume of storage space requires that the Lower Arrow Lake be drafted to elevation 1377 feet.

Due to the draft, as shown on Chart 3, of F. D. Roosevelt Lake below elevation 1160 feet for construction of the Grand Coulee third powerhouse, it was agreed by the Entities in their

KETTLE FALLS DURING DEEP DRAFT OF LAKE ROOSEVELT



The Falls, hidden in Lake Roosevelt for 28 years, were visible for a two week period when the Lake was drawn down to allow work on the Grand Coulee Third Powerhouse.

U.S. Bureau of Reclamation Photograph

letter of 31 March 1969, that it would not be necessary to supply the full 7.1 million acre-feet of flood control storage at Arrow. Under this agreement the elevation of Arrow exceeded the Upper Rule Curve. Control of Arrow discharge began on 18 April. During late April and early May the Arrow discharge was maintained between 5000 and 10,000 cfs. to prevent F.D. Roosevelt Lake from rising above 1170 feet, the maximum elevation the cofferdam protecting the work area could safely withstand. The unusually low discharge caused Arrow to rise rapidly as shown on Chart 2. This interfered with crews working in the reservoir area and reservoir preparation was not completed during 1969. It has been agreed that if physically possible, Arrow will be maintained near elevation 1377 feet as measured at the Fauguier Gage during the month of March 1970, to allow completion of this work.

Upon completion of the work in the Grand Coulee forebay in mid-May 1969, the Arrow discharge was increased to about 90,000 cubic feet per second to attain a better balance of flood control storage space between Arrow and Grand Coulee. The resulting rapid rise of F. D. Roosevelt Lake permitted pumping into Banks Lake with a more normal head and also increased the generating capacity of Grand Coulee. Near the end of May, after the Grand Coulee forebay rose above elevation 1240 feet, the Arrow discharge was reduced to about 45,000 cfs. until 4 June. It was then increased in a series of steps in June to retain storage space for possible late high flows. Discharge reached a maximum of 127,500 cubic feet per second on 28 June.

Arrow was raised to normal full pool, elevation 1444 feet on 26 July 1969, when it was reasonably certain that there was little remaining snowmelt flood potential upstream.

IV. DOWNSTREAM EFFECTS OF STORAGE OPERATION

A. Flood Control

Chart 6 shows the observed and, where available, the computed preproject flow of the Columbia River at Birchbank, British Columbia, for the period 1 April 1967 through 31 July 1969. It also shows the 1953-67 monthly mean flows. The preproject flow was computed allowing for the effects of natural storage in Kootenay, Arrow and Duncan Lakes.

Chart 7 shows the observed flow for the period 1 April 1967 through 31 July 1969 and the 1953-67 monthly mean flow of the Columbia River at The Dalles, Oregon. Charts 8, 9 and 10 illustrate the estimated effects of the operation of Duncan and Arrow in reducing the discharge of the lower Columbia River at Bonneville Dam, during the 1967, 1968, and 1969 highwater seasons.

1. 1967 Flood Period

Duncan reduced the peak stage of Kootenay Lake by an estimated two feet and of Kootenai River in the Bonners Ferry-Creston Flats area by 0.6 feet. On the main stem Columbia River the reduction provided by Duncan was 1.2 feet at Trail, B. C. and 0.4 feet at Vancouver, Washington.

2. 1968 Flood Period

Duncan reduced the peak stage of both Kootenay Lake and the Columbia River at Trail by an estimated 1.1 feet. Operation of the Columbia Basin system of reservoirs reduced the peak discharge of the Columbia River at The Dalles to 415,000 cubic feet per second; a reduction of approximately 130,000 cubic feet per second. The corresponding reduction in peak stage at Vancouver, Washington, was about 5 feet. Duncan contributed about 10 percent of the total effective storage in the reservoir system during the period of control of the lower Columbia River.

3. 1969 Flood Period

Duncan reduced the peak stage of Kootenay Lake by an estimated 1.4 feet, and the combination of Arrow and Duncan reduced the peak stage of the Columbia River at Trail by an estimated 6 feet. Operation of the Columbia Basin system of reservoirs reduced the peak discharge of the Columbia River at The Dalles to 435,000 cubic feet per second; a reduction of 180,000 cubic feet per second. The corresponding reduction in peak stage at Vancouver, Washington, was about 6 feet. Arrow contributed about 23 percent and Duncan about 4 percent of the total effective storage during the period of control of the lower Columbia River.

B. Power

1. Benefits: 1 April 1967 through 31 March 1968.

The Canadian share of downstream power benefits due to the early completion of Duncan, after allowance for 5 percent trans-

mission losses, was established as 95 average megawatts delivered at the Canadian-United States border. There was no capacity benefit since there was no assurance that full storage could be achieved. However, the Entities agreed that the Canadian share would be delivered at Blaine, Washington, at rates up to 180 megawatts, to the extent that facilities and operating limitations would permit.

The United States Pacific Northwest Coordinated System firm load-resource balance, including Arrow and Duncan storage regulation, showed about 364 average megawatts of firm energy load carrying capability in excess of estimated firm loads during the draft period 1 September 1967 through 15 April 1968. Reservoir rule curves were established to make the surplus firm energy available for secondary energy loads in September and October 1967 in the event critical water conditions were experienced. The potential secondary energy market was about 1000 average megawatts. Although better than median-month level streamflows occurred on the main stem of the Columbia in all months of the draft period except December 1967 and April 1968, the 637 average megawatts anticipated from the Hanford steam plant was unavailable during the period 28 August through 30 December 1967 due to a labour strike. Storage above Operating Rule Curve was completely drafted by 27 September 1967 and secondary energy deliveries from the Federal system was curtailed from that date until 18 October.

After 18 October favourable streamflows enabled full service to be made to area loads for the remainder of the year.

2. Benefits: 1 April 1968 through 31 July 1969

The Canadian share of downstream power benefits due to the early completion of Arrow, after allowance for 5 percent transmission losses, was established as 158 megawatts of firm capacity and 86 average megawatts of energy delivered at the Canadian-United States border. Subsequently the Entities agreed upon a mutually advantageous capacity-energy exchange arrangement and that the Canadian share would be delivered at Blaine in weekly amounts as scheduled by the Canadian Entity within the agreed limits. The amounts agreed were 102 average megawatts at a maximum rate of 158 megawatts during the period 1 April 1968 through 31 October 1968 and 86 average megawatts at a maximum rate of 110 megawatts during the period 1 November 1968 through 31 March 1969. At times the delivery of the Canadian share was made at rates greater than agreed to enable reduction in deliveries during planned service interruptions. No additional transmission charges were assessed for deliveries at the higher rates.

The Canadian share of downstream power benefits attributable to Duncan were delivered under the provisions of the Columbia Storage Power Exchange in accordance with the Terms of Sale, Attachment to Exchange of Notes. C.S.P.E. energy deliveries

during the period 1 April 1968 through 31 March 1969 were 108.9 average megawatts at rates up to 184.1 megawatts. On 1 April 1969, with the commencement of Arrow's operation under the Terms of Sale, these deliveries were increased to 549.7 average megawatts at rates up to 941.6 megawatts.

The United States Pacific Northwest Coordinated Systems firm load resource balance showed about 100 average megawatts. firm energy in excess of estimated firm loads during the draft period of 15 August 1968 through 15 April 1969. The potential secondary energy market was about 1200 average megawatts. Favourable streamflows supplemented by the release of storage above assured reservoir refill curves, provided sufficient energy to meet the total energy load requirements during the year. However, due to insufficient peaking capacity, it was necessary to curtail secondary energy deliveries over the peak load hours of several days during extreme cold periods in December and January. It was also necessary at times to spill water past Grand Coulee to provide water for generation at downstream plants during heavy load periods.

C. Other Benefits

The operations of Arrow and Duncan greatly facilitated the third powerhouse construction at Grand Coulee Dam in the spring of 1969. Had the Treaty projects not been available to control the river flow during critical periods, the construction program would have been delayed a year.

REFERENCES

The following documents governed the operation of the Columbia Treaty Projects during the period 1 April 1967 through 31 July 1969.

1. "Principles and Procedures for the Preparation and Use of Hydroelectric Operating Plans for Canadian Treaty Storage", dated 25 July 1967.
2. "Special Operating Program for the Duncan Reservoir for the Period 30 April 1967 through 31 March 1968", dated 14 March 1967.
3. "Operating Program for Duncan Reservoir During the Period 31 July 1967 through 31 March 1968", dated 19 July 1967.
4. "Special Operating Plan for Duncan Reservoir During the Period 1 August 1967 through 31 July 1968", dated 5 December 1967.
5. "Interim Flood Control Operating Plan for Duncan Reservoir - 1967-68", dated 8 December 1967.
6. "Special Operating Program for Canadian Storage During the Period 1 April 1968 through 30 June 1968", dated 26 February 1968.
7. "Special Operating Plan for Canadian Storage During the Period 1 August 1968 through 31 July 1969", dated 27 August 1968.
8. "Interim Flood Control Operating Plan for Duncan and Arrow Reservoirs", dated 12 November 1968.
9. "Letter of 31 March 1969 from Canadian Entity to United States Entity".

TABLES

TABLE 1

INITIAL CONTROLLED FLOW
COLUMBIA RIVER AT THE DALLES

I. UPSTREAM STORAGE CORRECTIONS (KAF)

PROJECT	1968 FLOOD 4 Jun	1969 FLOOD 12 May
ARROW	5,000	4,947
DUNCAN	1,043	1,182
HUNGRY HORSE	625	1,382
FLATHEAD LAKE	349	500
NOXON	113	184
PEND OREILLE	354	436
GRAND COULEE	2,749	7,083
BROWNLEE	63	490
JOHN DAY	339	482
	10,635	16,686
USE	10,600	16,700

II. FORECAST OF CORRECTED RUNOFF VOLUME (KAF), COLUMBIA RIVER AT THE DALLES

	4 Jun	12 May
Date - 31 Aug Volume Runoff	60,800	84,900
Less Upstream Storage Correction	10,600	16,700
Corrected Residual Runoff	50,200	68,200

III. ADJUSTED MEAN DAILY DISCHARGE (KCFS) AT THE DALLES

	4 Jun	12 May
Observed Regulated Flow at The Dalles	301	414
Adjustment for Category IV Projects	69	111
Adjusted Mean Daily Discharge	370	525

IV. INITIAL CONTROLLED FLOW (KCFS)

	4 Jun	12 May
From Chart 1 Interim Flood Control Plan (interpolated for date and using Corrected Residual Runoff Volume)	380	470

TABLE 2

SEASONAL VOLUME RUNOFF FORECASTS

THOUSANDS OF ACRE-FEET

Forecast Date - 1st of:	DUNCAN LAKE INFLOW		ARROW LAKE INFLOW		UNREGULATED RUNOFF COLUMBIA RIVER AT THE DALLES, OREGON
	Most Probable 1 Apr - 31 Aug	95% Probable Date - 31 Jul	Most Probable 1 Apr - 31 Aug	95% Probable Date 31 Jul	Most Probable 1 Apr - 31 Aug
			1967		
Jan					101,000
Feb	Forecast		Forecast		113,000
Mar					111,000
Apr	Not		Not		113,000
May					111,000
Jun	Required		Required		-
Jul					105,000
ACTUAL					104,000
			1968		
Jan	1994	1366			75,000
Feb	2060	1424	Forecast		79,000
Mar	2055	1399			85,000
Apr	2241	1580	Not		84,000
May	2243	1545			82,000
Jun	2310	1268	Required		-
Jul					-
ACTUAL	2133				82,000
			1969		
Jan	2085	1491	23,675	19582	101,000
Feb	2132	1573	23,400	19025	116,000
Mar	2136	1569	23,252	18576	114,000
Apr	2099	1529	22,907	17899	108,000
May	2187	1486	24,092	16985	115,000
Jun	2225	1088	24,521	15732	114,000
Jul					117,000
ACTUAL	2047		24,016		104,000

CHARTS

Chart 1 - Regulation of Duncan Reservoir - April 1967 through July 1969

Chart 2 - Regulation of Arrow Reservoir - April 1968 through July 1969

Chart 3 - Regulation of Grand Coulee Reservoir - April 1967 through July 1969

Chart 4 - Operating Guides and Actual Regulation; Duncan - 1 January through 31 July 1968

Chart 5 - Operating Guides and Actual Regulation; Duncan - 1 January through 31 July 1969

Chart 6 - Columbia River at Birchbank April 1967 through July 1969

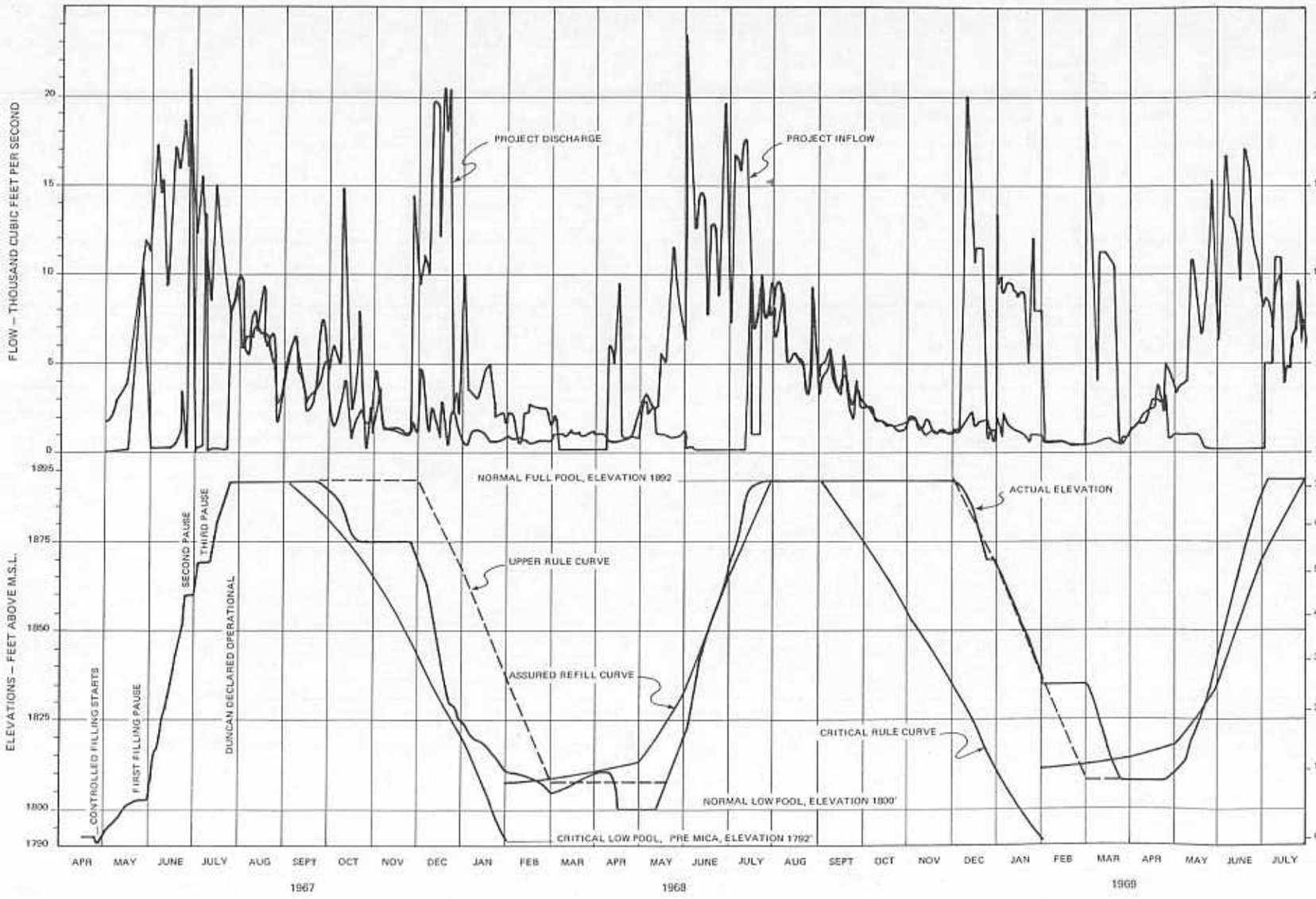
Chart 7 - Columbia River at The Dalles April 1967 through July 1969

Chart 8 - Columbia River at Bonneville Dam 1967 Flood Regulation

Chart 9 - Columbia River at Bonneville Dam 1968 Flood Regulation

Chart 10 - Columbia River at Bonneville Dam 1969 Flood Regulation

CHART 1



NOTES:

— *PROJECT INFLOW*
— *PROJECT DISCHARGE*

— *OBSERVED RESERVOIR ELEVATION*
— *CRITICAL RULE CURVE*
— *ASSURED REFILL CURVE*
—·— *UPPER RULE CURVE*

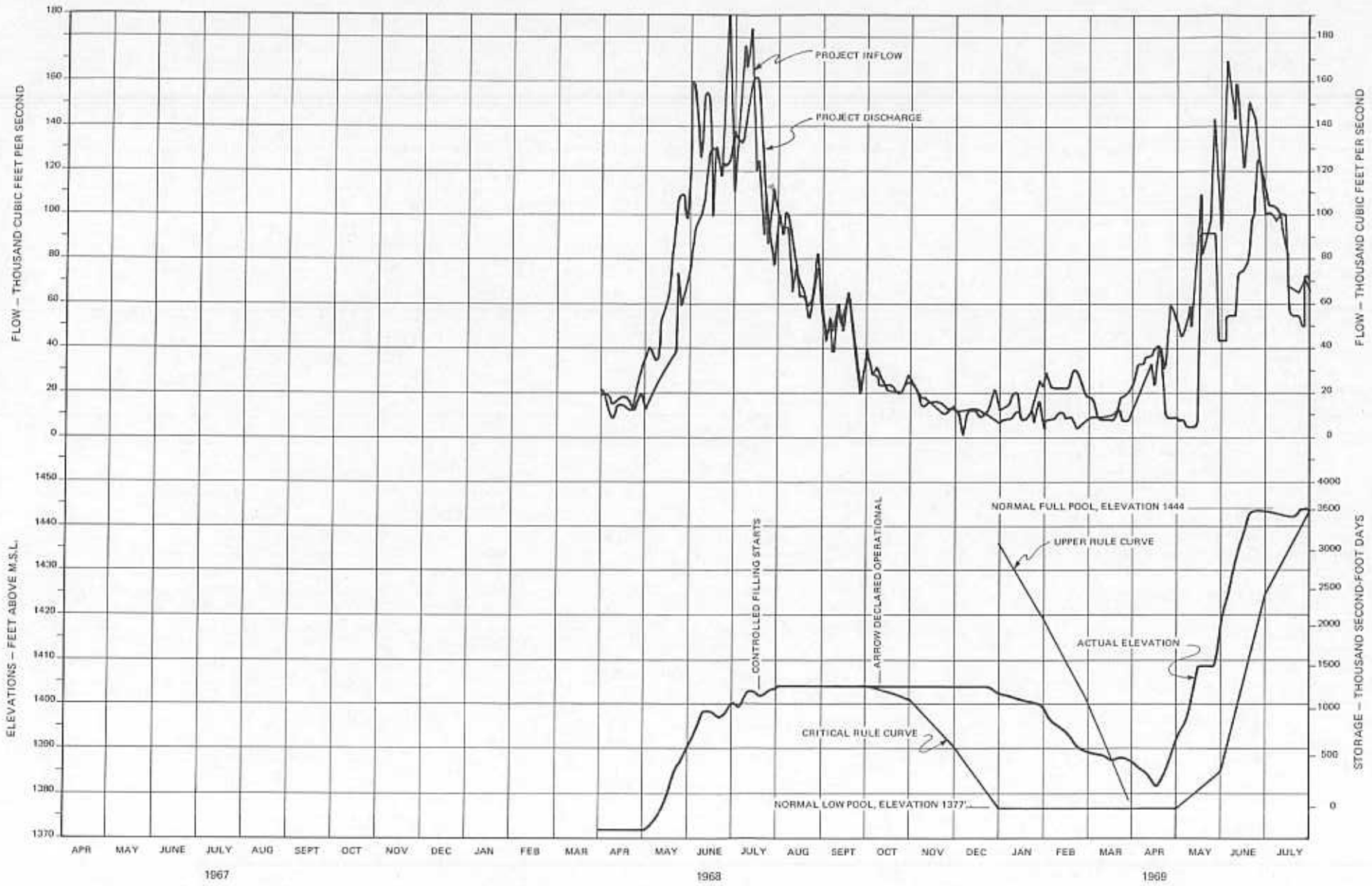
COLUMBIA RIVER TREATY

REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68; 1968/69

REGULATION OF DUNCAN
RESERVOIR APR 1967 – JULY 1969

DEC 1969

CHART 2



NOTES:

— *PROJECT INFLOW*
— *PROJECT DISCHARGE*

— *OBSERVED RESERVOIR ELEVATION*
— *CRITICAL RULE CURVE*
— *UPPER RULE CURVE*

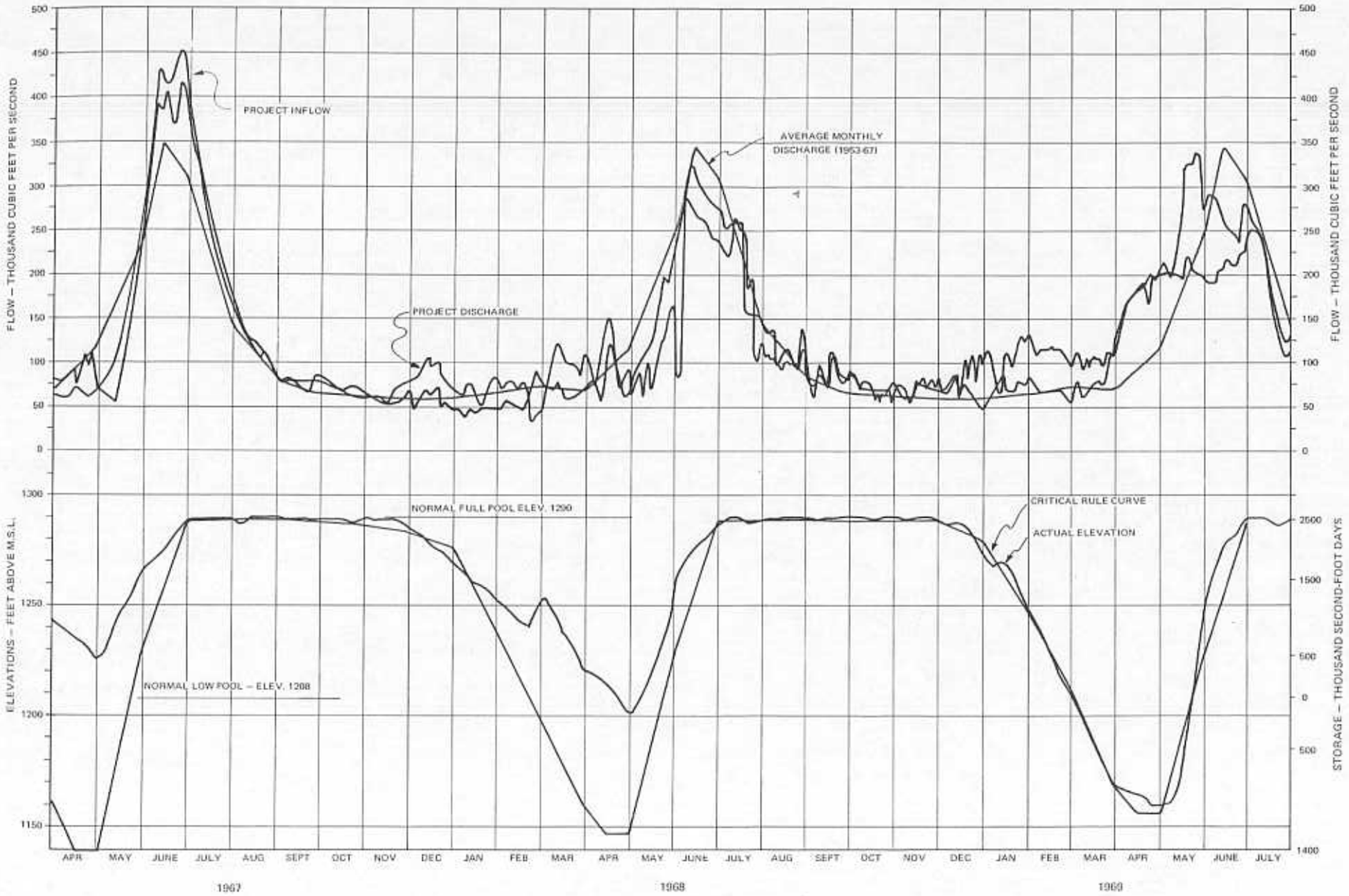
COLUMBIA RIVER TREATY

REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68; 1968/69

REGULATION OF ARROW
RESERVOIR APR 1968 - JULY 1969

DEC 1969

CHART 3



NOTES:

— *PROJECT INFLOW*

— *PROJECT DISCHARGE*

— *1953-67 AVERAGE MONTHLY DISCHARGE*

— *OBSERVED RESERVOIR ELEVATION*

— *CRITICAL RULE CURVE*

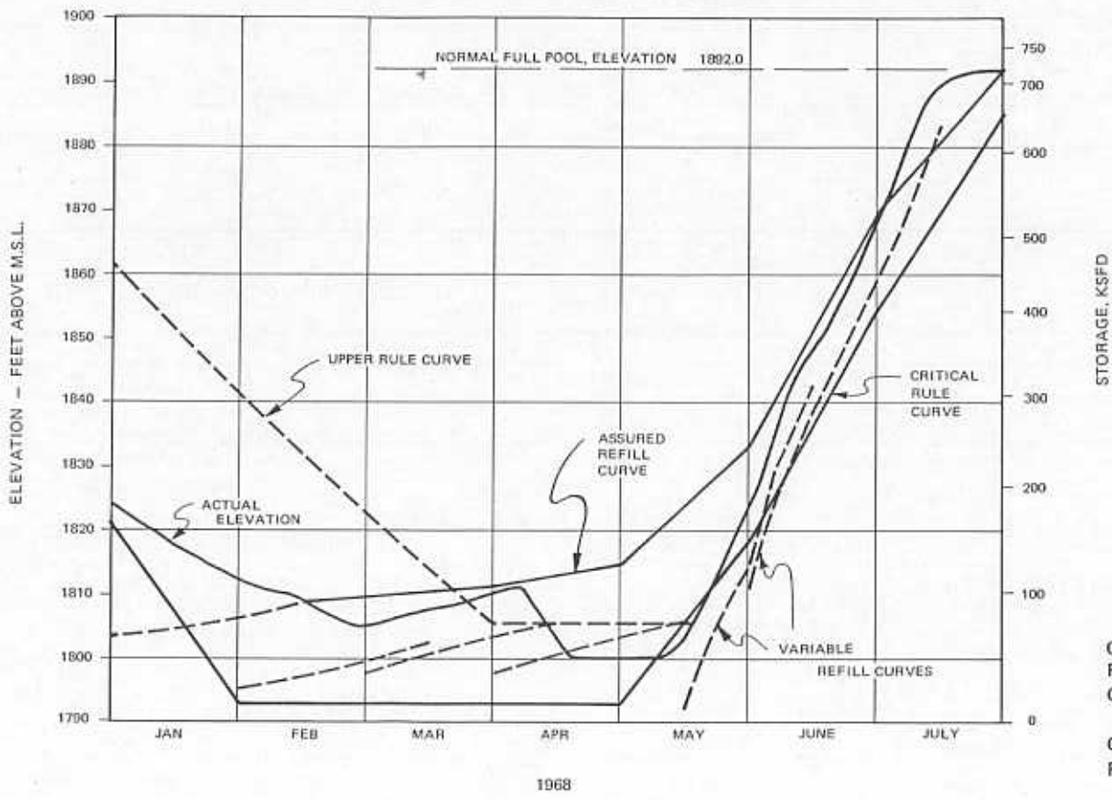
COLUMBIA RIVER TREATY

REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68; 1968/69

REGULATION OF GRAND
COULEE RESERVOIR – APR 1967 - JULY 1969

DEC 1969

CHART 4



NOTES:

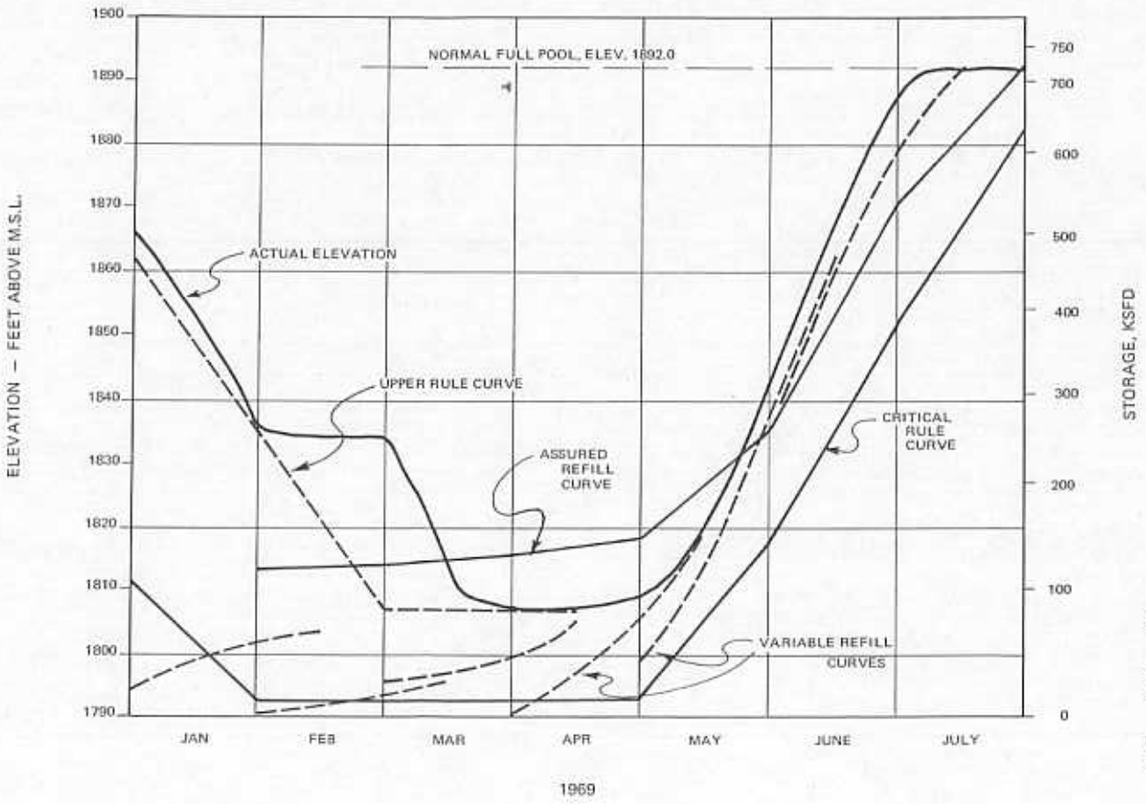
- *OBSERVED RESERVOIR ELEVATION*
- *CRITICAL RULE CURVE*
- *ASSURED REFILL CURVE*
- *VARIABLE REFILL CURVE*
- *UPPER RULE CURVE*

COLUMBIA RIVER TREATY
REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68; 1968/69

OPERATING GUIDES AND ACTUAL
REGULATION: DUNCAN 1 JAN - 31 JULY 1968

DEC 1969

CHART 5



NOTES:

- *OBSERVED RESERVOIR ELEVATION*
- *CRITICAL RULE CURVE*
- *ASSURED REFILL CURVE*
- *VARIABLE REFILL CURVE*
- *UPPER RULE CURVE*

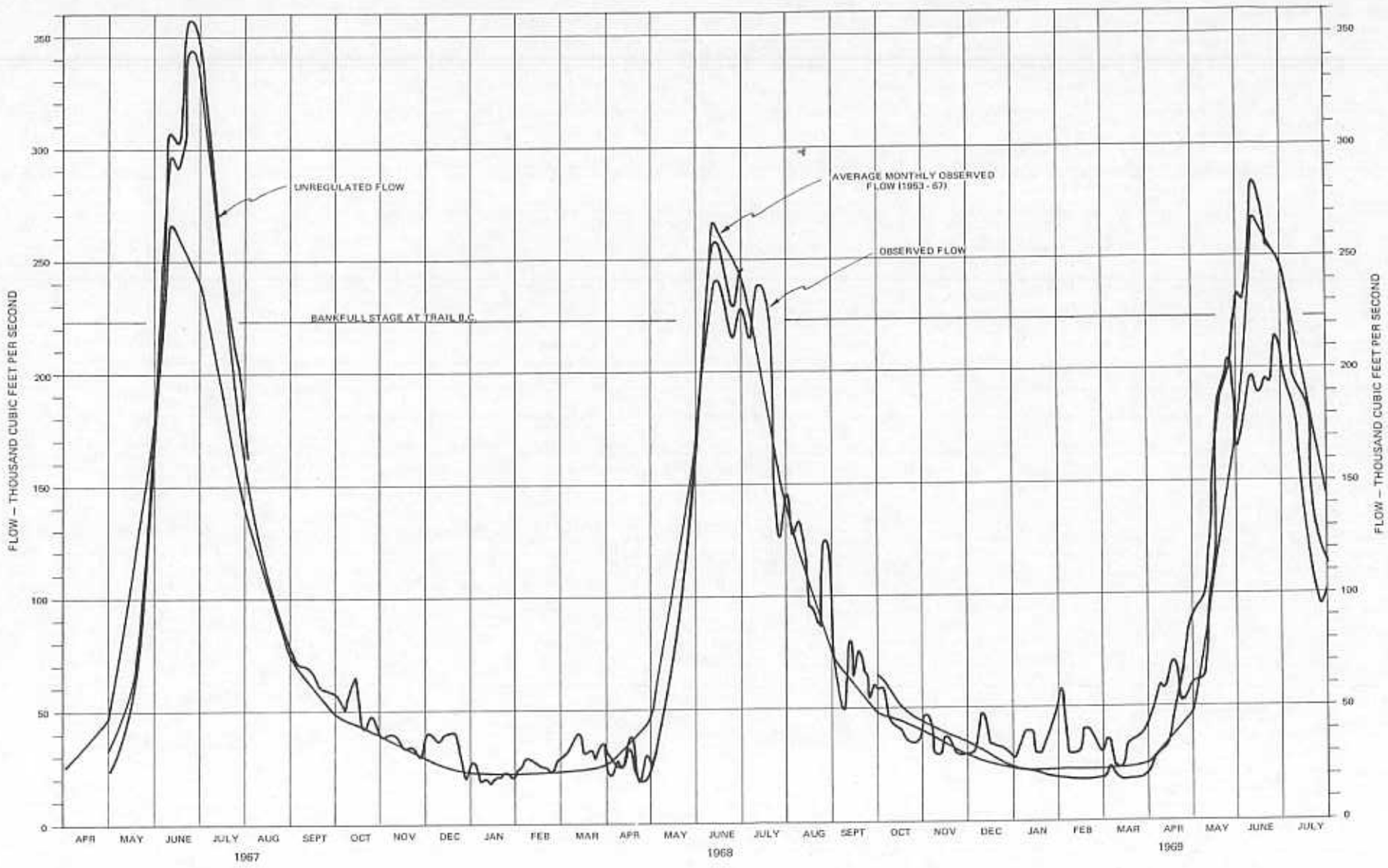
COLUMBIA RIVER TREATY

REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68; 1968/69

OPERATING GUIDES AND ACTUAL REGULATION; DUNCAN 1 JAN - 31 JULY 1969

DEC 1969

CHART 6



— *OBSERVED FLOW*
— *UNREGULATED FLOW*
— *1953-67 AVERAGE MONTHLY OBSERVED FLOW*

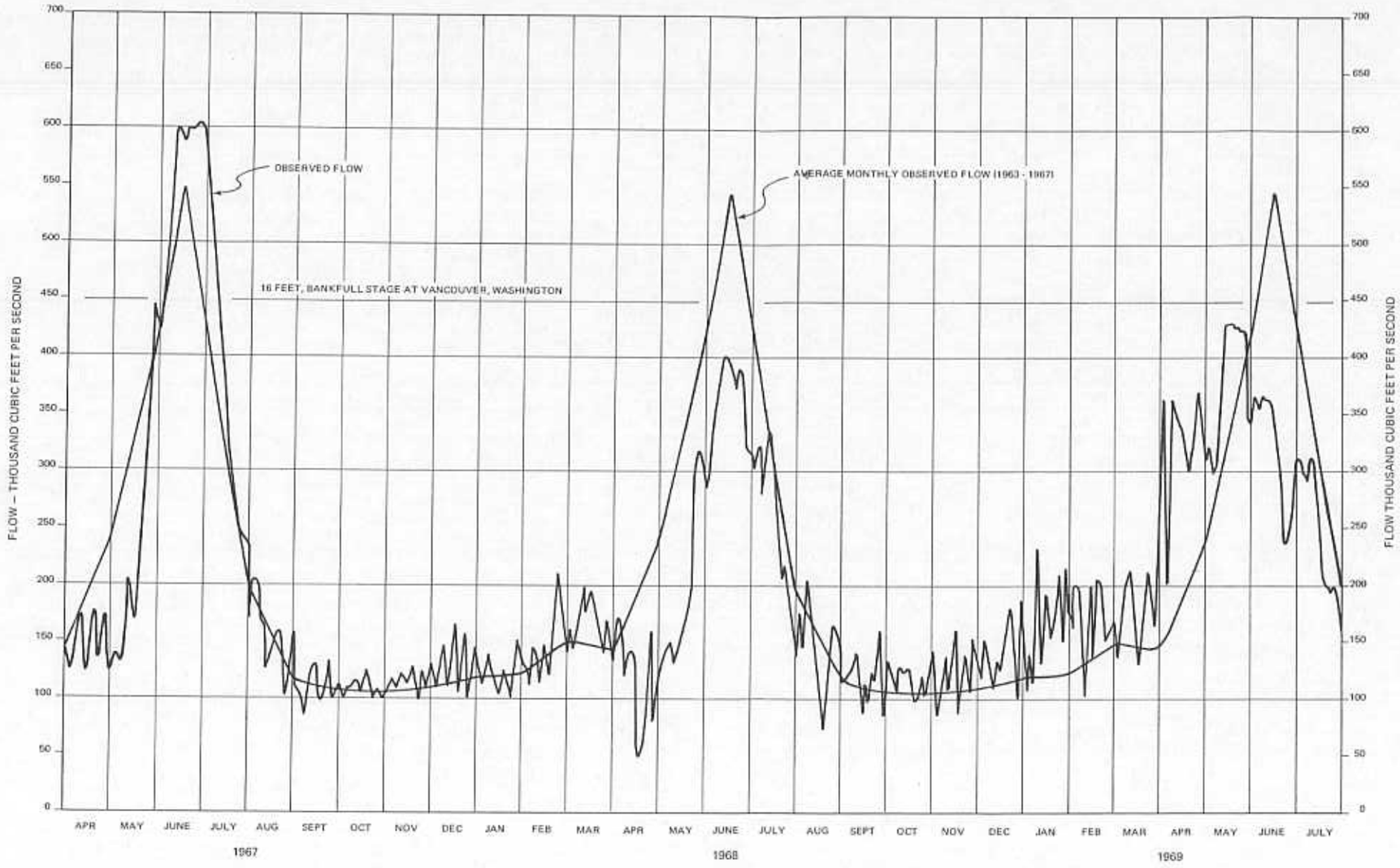
COLUMBIA RIVER TREATY

REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68; 1968/69

COLUMBIA RIVER AT
BIRCHBANK – APR 1967 - JULY 1969

DEC 1969

CHART 7



NOTES:

— *OBSERVED FLOW*
— *1953 - 67 AVERAGE MONTHLY OBSERVED FLOW*

COLUMBIA RIVER TREATY

REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68; 1968/69

COLUMBIA RIVER AT
THE DALLES APR. 1967 – JULY 1969

DEC 1969

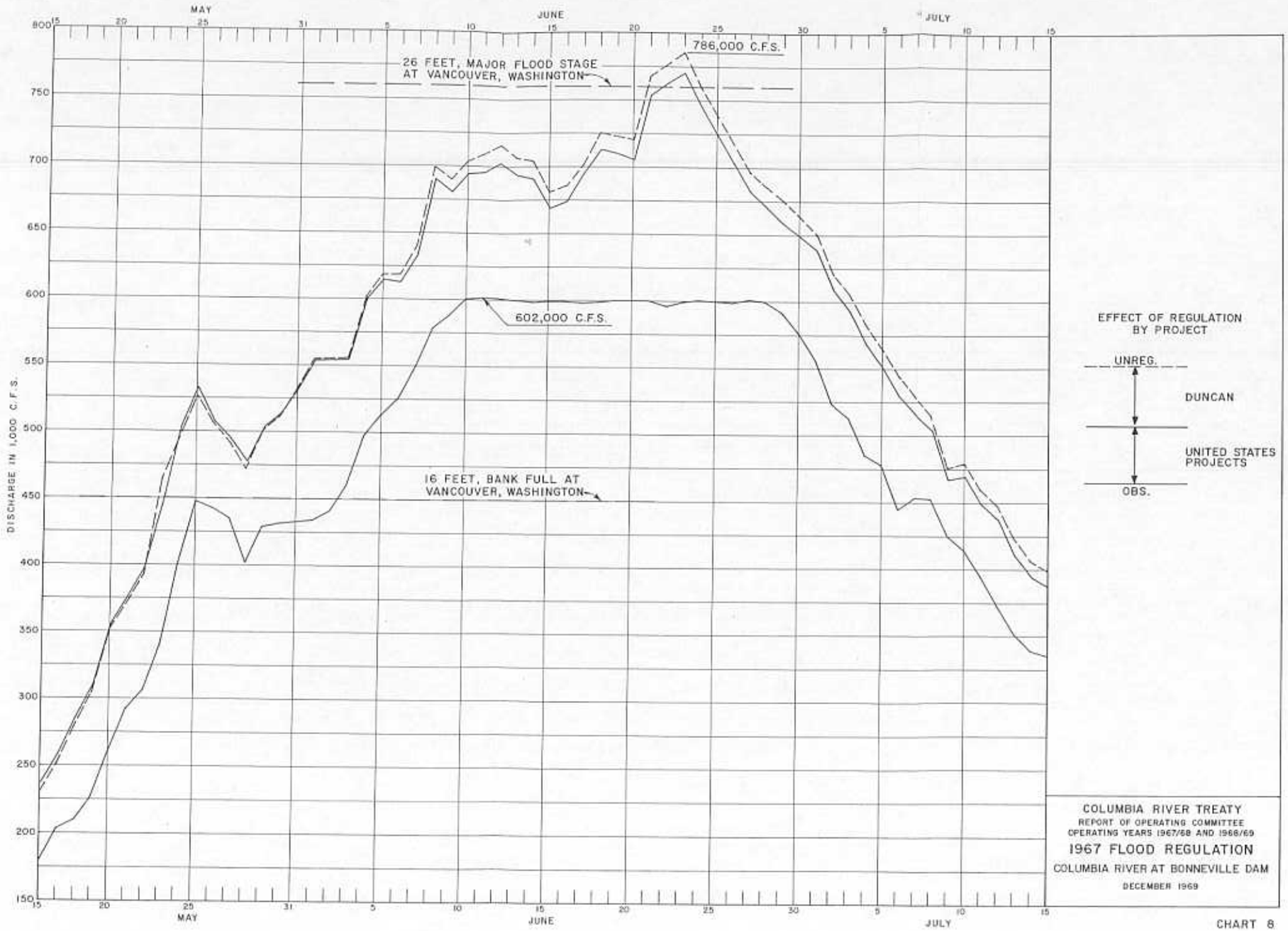
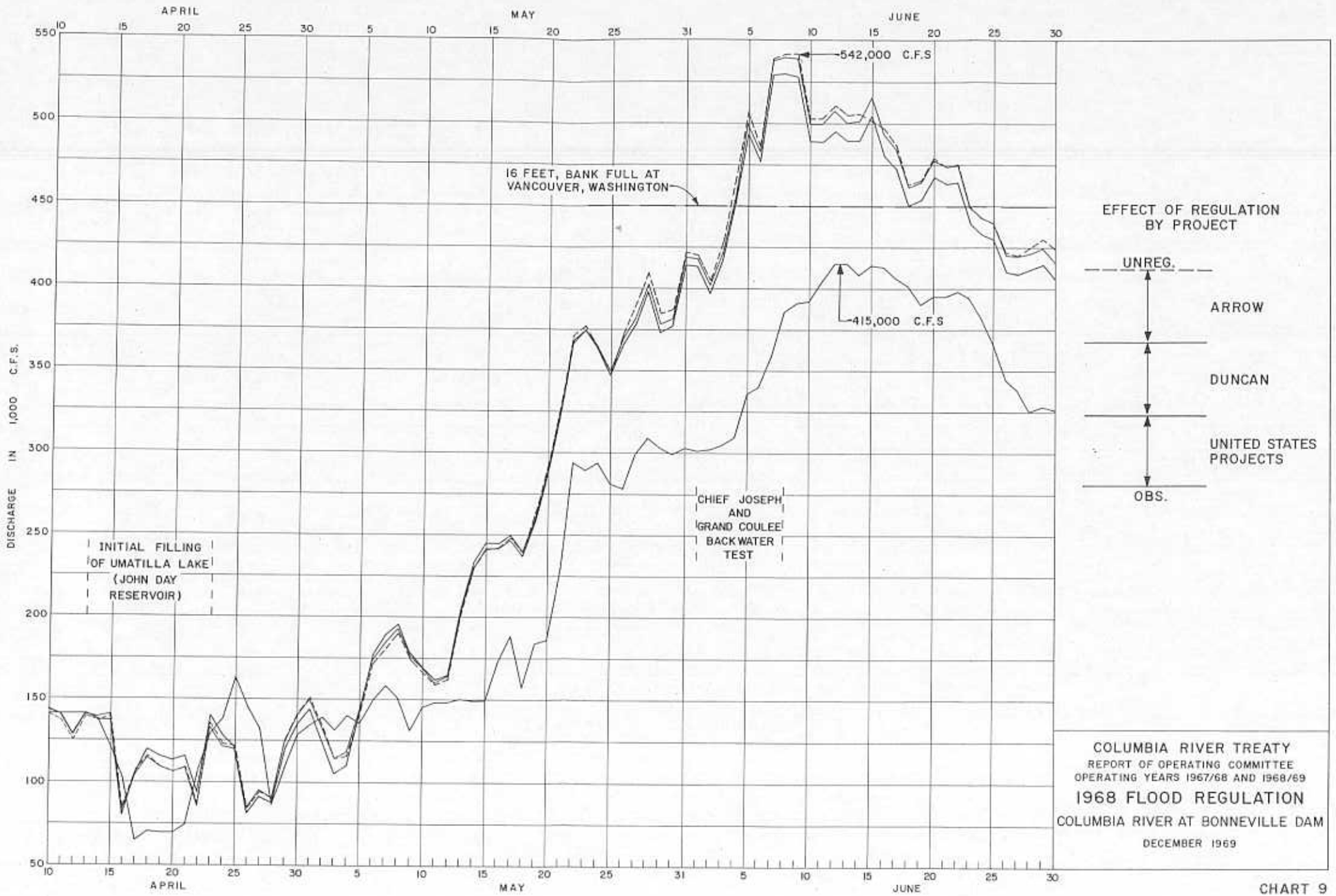

MAY
JUNE
JULY
786,000 C.F.S.
26 FEET, MAJOR FLOOD STAGE AT VANCOUVER, WASHINGTON
602,000 C.F.S.
16 FEET, BANK FULL AT VANCOUVER, WASHINGTON
DISCHARGE IN 1,000 C.F.S.
800
750
700
650
600
550
500
450
400
350
300
250
200
150
EFFECT OF REGULATION BY PROJECT
UNREG.
DUNCAN
UNITED STATES PROJECTS
OBS.
COLUMBIA RIVER TREATY
REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68 AND 1968/69
1967 FLOOD REGULATION
COLUMBIA RIVER AT BONNEVILLE DAM
DECEMBER 1969

CHART 8



COLUMBIA RIVER TREATY

REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68 AND 1968/69

1968 FLOOD REGULATION

COLUMBIA RIVER AT BONNEVILLE DAM

DECEMBER 1969

CHART 9

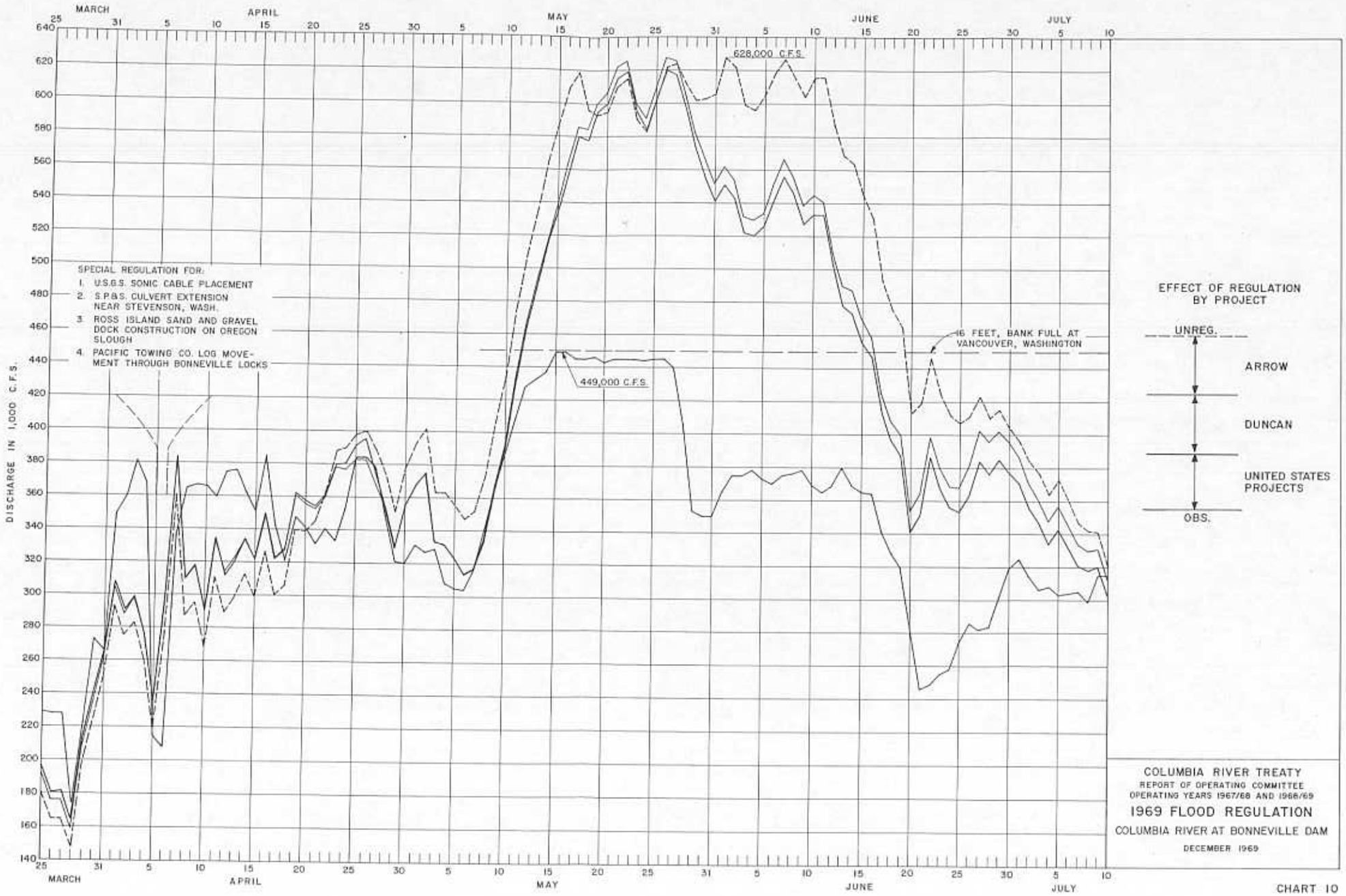

MARCH
APRIL
MAY
JUNE
JULY
DISCHARGE IN 1,000 C.F.S.
628,000 C.F.S.
449,000 C.F.S.
16 FEET, BANK FULL AT VANCOUVER, WASHINGTON
SPECIAL REGULATION FOR:
1. U.S.G.S. SONIC CABLE PLACEMENT
2. S.P.&S. CULVERT EXTENSION NEAR STEVENSON, WASH.
3. ROSS ISLAND SAND AND GRAVEL DOCK CONSTRUCTION ON OREGON SLOUGH
4. PACIFIC TOWING CO. LOG MOVEMENT THROUGH BONNEVILLE LOCKS
EFFECT OF REGULATION BY PROJECT
UNREG.
ARROW
DUNCAN
UNITED STATES PROJECTS
OBS.
COLUMBIA RIVER TREATY
REPORT OF OPERATING COMMITTEE
OPERATING YEARS 1967/68 AND 1968/69
1969 FLOOD REGULATION
COLUMBIA RIVER AT BONNEVILLE DAM
DECEMBER 1969

CHART 10