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INLAND WATERS BRANCH

The Effects of the W.A.C. Bennett Dam on Downstream Levels and Flows

A. COULSON
R.J. ADAMCYK

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DEPARTMENT OF ENERGY,
MINES AND RESOURCES

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A. COULSON AND R.J. ADAMCYK

INLAND WATERS BRANCH
DEPARTMENT OF ENERGY, MINES AND RESOURCES
OTTAWA, CANADA, 1969

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Preface

Construction of the W.A.C. Bennett Dam on the Peace River in British Columbia was completed in 1968 as an integral part of the Province's power development program. The filling of the reservoir (Williston Lake) behind the dam began in December 1967, in advance of the dam's completion.

This report summarizes the effects that the dam is expected to have on levels and flows in the Mackenzie River basin once the power development is in full operation and the estimated effects of the partial filling of the reservoir during 1968.

The findings in this report are interpretations based on somewhat limited basic streamflow and water level data available at the end of 1968 and, therefore, are subject to change as more information becomes available.

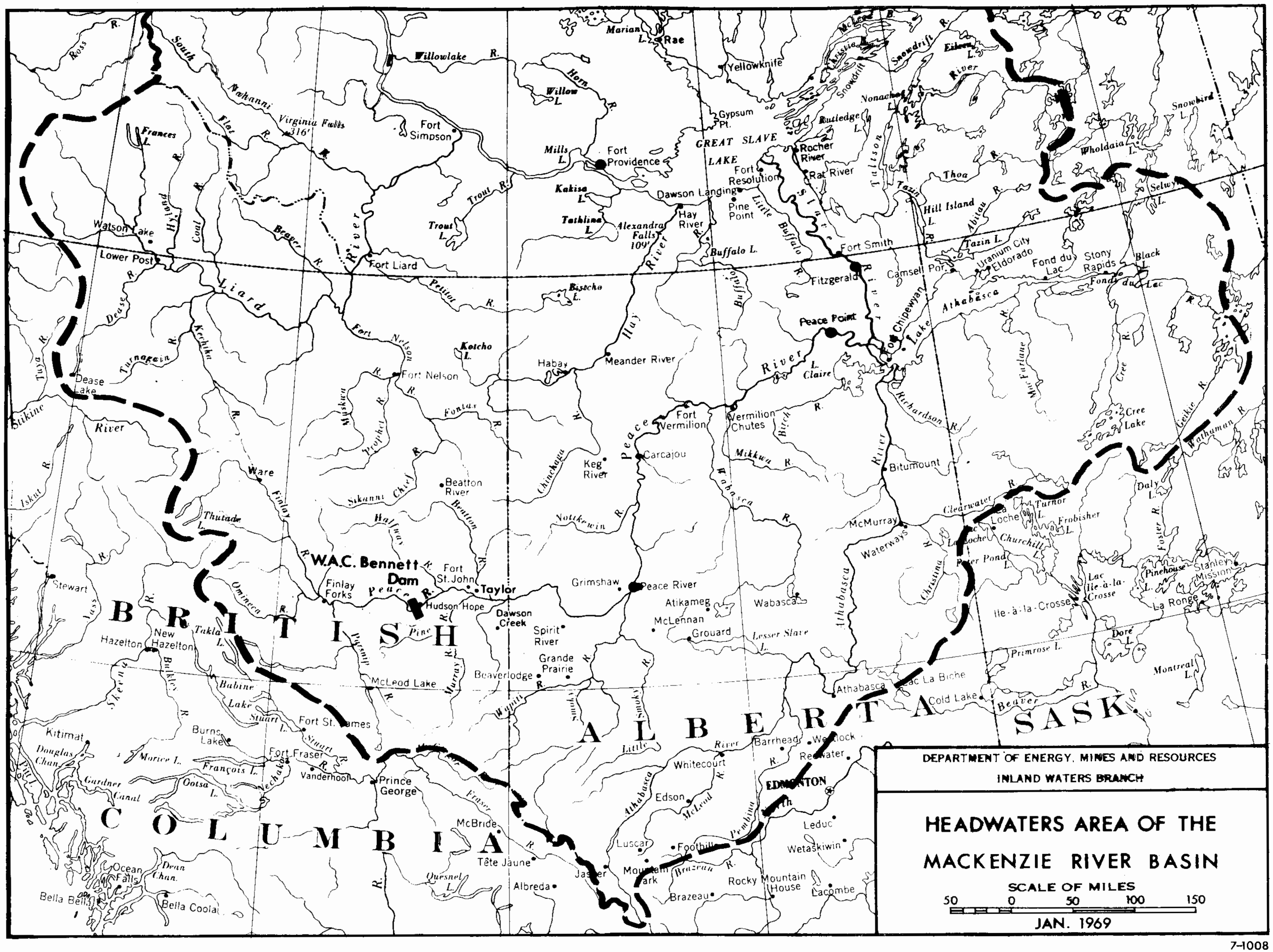

DEPARTMENT OF ENERGY, MINES AND RESOURCES
INLAND WATERS BRANCH
HEADWATERS AREA OF THE
MACKENZIE RIVER BASIN
SCALE OF MILES
50 0 50 100 150
JAN. 1969
7-1008
BRITISH COLUMBIA
ALBERTA
SASK.
GREAT SLAVE LAKE
W.A.C. Bennett Dam
Peace Point
EDMONTON
Yellowknife
Rae
Fort Providence
Fort Simpson
Fort Liard
Fort Nelson
Fort Smith
Fort Chipewyan
Fort Resolution
Hay River
Fort Vermilion
Peace River
McMurray
Hudson Hope
Fort St. John
Taylor
Dawson Creek
Grande Prairie
Prince George
Jasper
Watson Lake
Lower Post
Dease Lake
Finlay Forks
Uranium City
Virginia Falls 316'
Alexandra Falls 109'
Lake Athabasca
Peace River
Liard
Slave River
Athabasca
Hay River
Fort Nelson R.
Nahanni
Finlay
Parsnip
Smoky
Wapiti
Clearwater
Fraser
Stikine River
Skeena

Figure 1.

The Effects of the W.A.C. Bennett Dam on Downstream Levels and Flows

A. COULSON AND R.J. ADAMCYK

INTRODUCTION

On December 21, 1962, the British Columbia Comptroller of Water Rights issued a conditional water licence to the British Columbia Hydro and Power Authority authorizing the construction of a storage dam, powerhouse and associated works on the Peace River.

Construction of the main dam on a reach of river about 11 air miles upstream from Hudson Hope, began in 1963. In ensuing years, rock and earth fill were placed in record time and the dam, rising some 645 feet above bedrock and with a crest length of 2,850 feet, was completed in 1968.

The filling of the reservoir began in December 1967. On December 12, the water elevation in the reservoir area was 1,725 feet. By the end of October 1968, the reservoir level had risen to 2,080 feet, corresponding to a reservoir content of 22,367,000 acre-feet, or about 40 percent of the normal maximum capacity of 56,685,000 acre-feet. As is to be expected, the storing of water in Williston Lake is reducing the flows and levels downstream on the Peace River. The level of Lake Athabasca is also affected because high levels on the Peace River have a backwater effect which causes water from the Peace River to be diverted into Lake Athabasca; during such high flow periods, the entire inflow into Lake Athabasca is stored in the lake until the Peace River level falls below the level of the lake. It is evident, therefore, that a reduction in the natural level of the Peace River will reduce the natural inflow into Lake Athabasca and consequently lower the level of the lake.

While the reservoir is filling, the combined reductions of flow in the Peace River and of water stored in Lake Athabasca will affect downstream regime, including flow in the Slave River, the level of Great Slave Lake and flow in the Mackenzie River.

Once the reservoir is filled and the powerhouse is in full operation, the total annual flow in the Peace River will be essentially the same as would have occurred under natural conditions; the regime will not return to the "pre-dam" normal, however, since the widely varying flows of former years are expected to be superseded by a constant release of about 36,000 cfs from the reservoir, leading to permanent regime changes in the flows of the Slave and Mackenzie Rivers and in the levels of Lake Athabasca and Great Slave Lake.

FILLING THE RESERVOIR

The mean inflow to the reservoir is about 36,000 cfs, equivalent to 26,000,000 acre-feet per year. At that rate, the reservoir could be filled by the spring of 1970, assuming average runoff conditions and retention of all inflow to the reservoir. However, the conditional water licence stipulates minimum flows in the River near Taylor or near Hudson Hope; these minimum releases, together with the releases for power generation which began in 1968, should extend the filling period beyond the spring of 1970. It is possible that the reservoir could reach maximum elevation during 1970 if inflows are above average in the intervening period; with average inflows, however, it is unlikely to be filled until 1971 or 1972.

MINIMUM RELEASES FROM THE RESERVOIR

The Conditional Water Licence No. 27722 issued by the Province of British Columbia on December 21, 1962, stated that the minimum flows to be maintained by releases of water from the reservoir would be as follows:

December 1 to March 31 - Calculated natural inflows to the reservoir.

April 1 to July 15 - 10,000 cfs or the natural flow, whichever is the lesser, as measured near Taylor.

July 16 to September 15 - 10,000 cfs, as measured near Hudson Hope.

September 16 to November 30 - 10,000 cfs or the natural flow, whichever is the lesser, as measured near Taylor.

Provided also that a flow of not less than 1,000 cfs shall be released from the dam at all times.

These conditions were twice modified in 1968. On July 15, 1968, the British Columbia Comptroller of Water Rights authorized a minimum release of 1,000 cfs for the period July 16, 1968 to September 30, 1968. On November 15, 1968, a minimum flow of 10,000 cfs at Taylor or the natural flow, whichever is the lesser, was authorized for the period December 1, 1968, to March 31, 1969.

INSTALLATION OF GENERATING UNITS

Eight units are planned for installation in the powerhouse before the end of 1972, and two other units may be added later. Units 1, 2 and 3 were placed on line in 1968, the first two on September 9, and the third on September 11. Units 4 and 5 are scheduled for service in 1969, on June 1 and July 1, respectively. Unit 6 is expected to be on line on September 1, 1971 and units 7 and 8 by September 1972.

The full-gate discharge of each unit will be 7,000 cfs at maximum head, but while the reservoir is filling, the discharge will be less at the lower head available. During December 1968, the combined flow through the three units was about 12,000 cfs, but as additional units are added, the maximum flows will increase and are expected to be about 19,000 cfs during the summer months and about 26,000 cfs during the winter.

The maximum flow with all units installed will likely be 40,000 cfs.

EFFECTS OF STORING WATER IN 1968

In the spring and summer of 1968, natural runoff in the Mackenzie Basin was fairly low. For instance, the estimated natural runoff of the Slave River from April to September, 1968, would normally be exceeded in seven out of ten years. Ordinarily, this would have resulted in river and lake stages somewhat below average in 1968. However, stages were much lower than average because water was being stored in Williston Lake.

Figure 2 shows, graphically, estimates of the natural levels or flows that would have occurred at points on the Peace River, Lake Athabasca, the Slave River, Great Slave Lake and the Mackenzie River had storing of water in Williston Lake not taken place. Also shown for comparison purposes are the recorded regulated levels or flows that actually occurred.

The storing of water in Williston Lake during the spring of 1968 reduced the natural peak flow of the Peace River at Hudson Hope from 195,000 cfs to 10,000 cfs. This resulted in a reduction in peak stage of about five feet at Peace River and of about seven feet at Peace Point; the peak level of Lake Athabasca and the peak stage of Slave River were reduced by about three feet and two feet, respectively.

The reduction in the amount of water in storage was least on Great Slave Lake where the peak level was reduced by about 0.6 foot, resulting in a reduction in peak outflow from Great Slave Lake of about 35,000 cfs.

PERMANENT REGIME CHANGES

The power plant associated with the W.A.C. Bennett Dam is to be used as a base load plant and, therefore, it may be assumed that there will be a constant release of about 36,000 cfs once the powerhouse is in full operation. It is possible that considerable spill may occur in years of excessive runoff, but it is probable that such spill would coincide with the natural flood peak, resulting in peak flow downstream from the dam no greater than would have occurred under "pre-dam" conditions.

When in full operation, the reservoir's effect on the Mackenzie Basin will be to reduce spring high water levels and flows and to increase winter low water levels and flows. However, the magnitude of the effects will vary, depending on whether the natural runoff in a particular year is high, low or average. In order to assess the magnitude of the effects, Tables 1 and 2 have been prepared to show the estimated levels or flows at selected points in the basin under natural regime and under regulated regime respectively. The Tables contain estimates of the annual means, and of both the high water peaks and low water minimums through the full range of probabilities.

Permanent changes in regime at any desired probability level may be determined by comparing Tables 1 and 2. Table 3 gives a general idea of the magnitude of the permanent changes by comparing median values (0.50 probability in Tables 1 and 2) of peak or minimum levels or flows. In Table 3 the natural regime is denoted by "N", the regulated regime by "R" and the change in regime by "C".

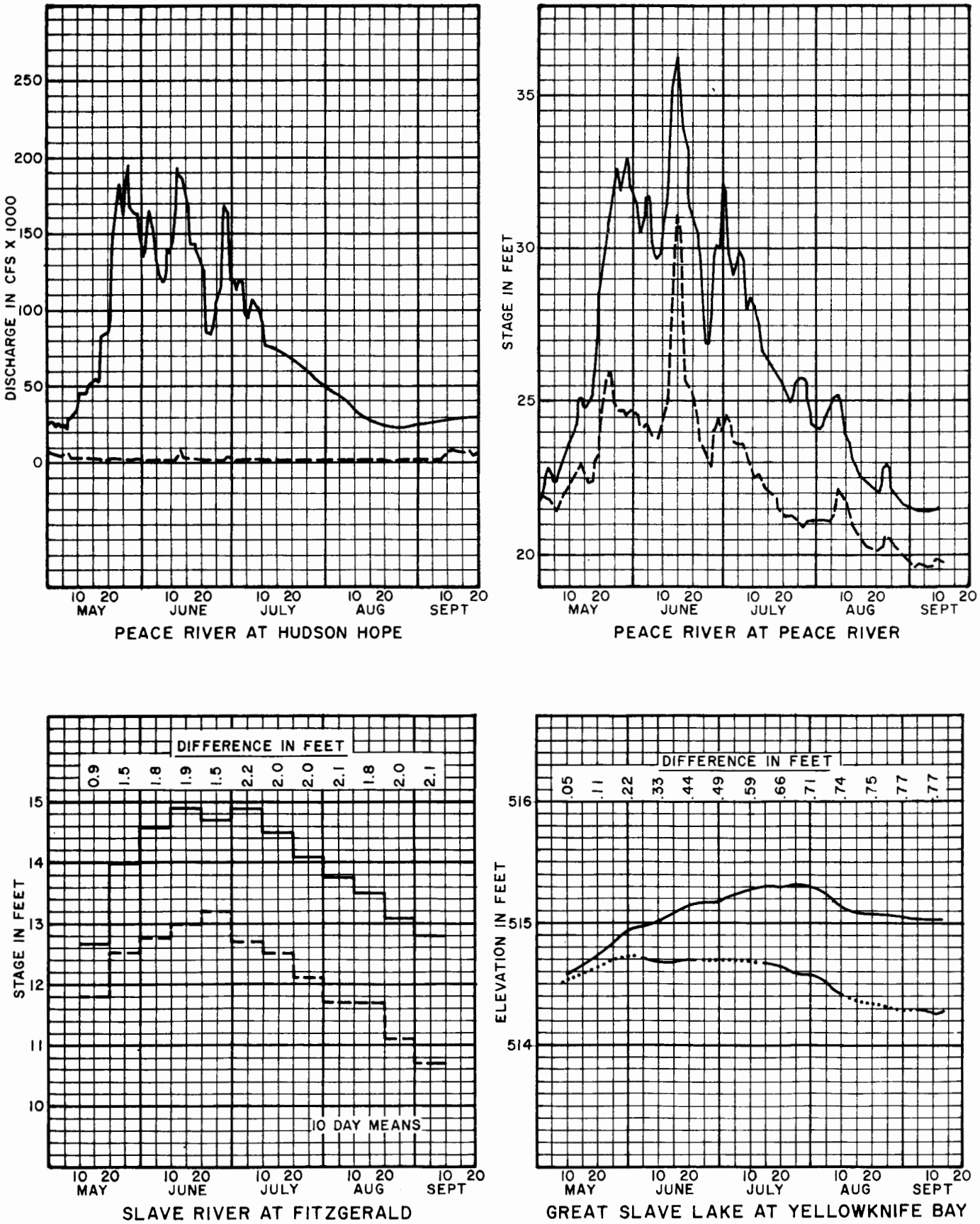
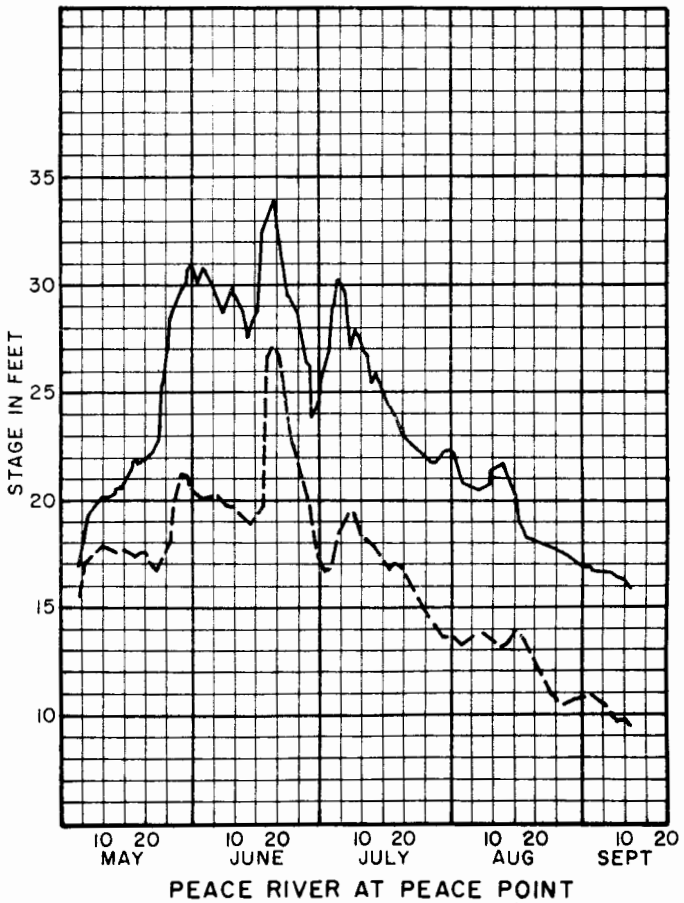
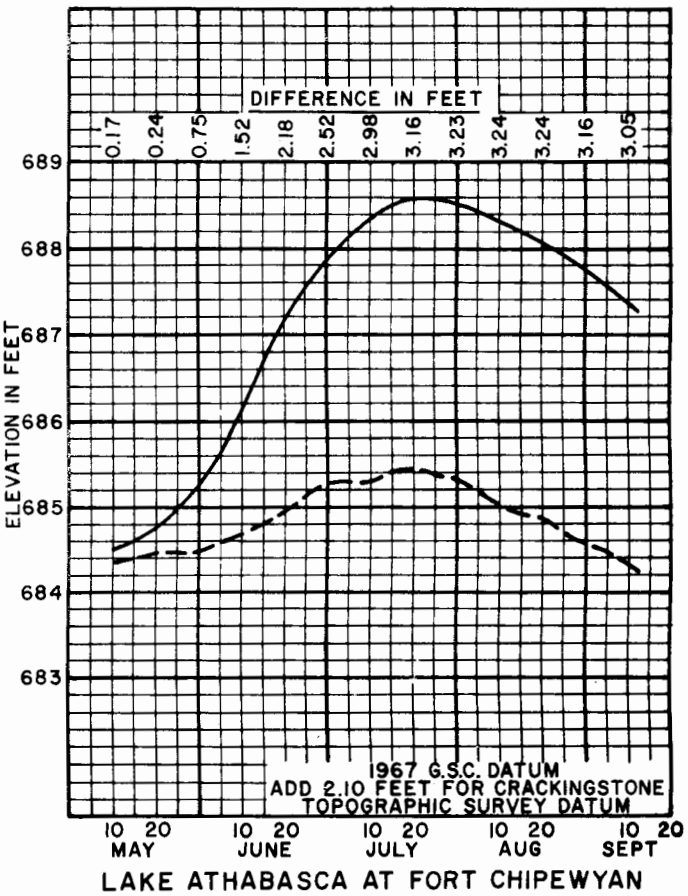
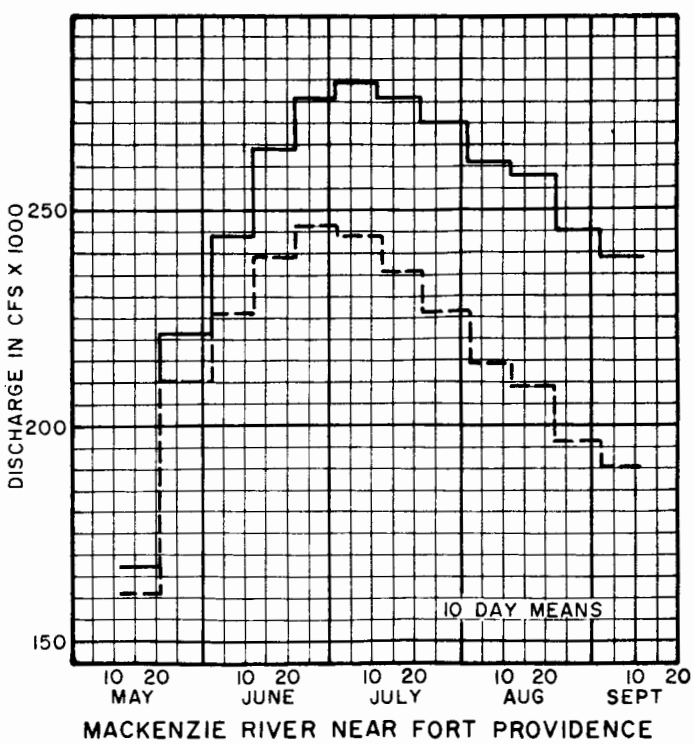

DISCHARGE IN CFS X 1000
250
200
150
100
50
0
10 20 MAY
10 20 JUNE
10 20 JULY
10 20 AUG
10 20 SEPT
PEACE RIVER AT HUDSON HOPE
STAGE IN FEET
35
30
25
20
10 20 MAY
10 20 JUNE
10 20 JULY
10 20 AUG
10 20 SEPT
PEACE RIVER AT PEACE RIVER
DIFFERENCE IN FEET
0.9 1.5 1.8 1.9 1.5 2.2 2.0 2.0 2.1 1.8 2.0 2.1
STAGE IN FEET
15
14
13
12
11
10
10 DAY MEANS
10 20 MAY
10 20 JUNE
10 20 JULY
10 20 AUG
10 20 SEPT
SLAVE RIVER AT FITZGERALD
DIFFERENCE IN FEET
.05 .11 .22 .33 .44 .49 .59 .66 .71 .74 .75 .77 .77
ELEVATION IN FEET
516
515
514
10 20 MAY
10 20 JUNE
10 20 JULY
10 20 AUG
10 20 SEPT
GREAT SLAVE LAKE AT YELLOWKNIFE BAY

Figure 2.







DEPARTMENT OF ENERGY, MINES AND RESOURCES
INLAND WATERS BRANCH
ENGINEERING HYDROLOGY SECTION
JANUARY 24, 1969

THE 1968 EFFECTS OF STORAGE AT THE W.A.C. BENNET DAM

for

the Spring and Summer Seasons

at

Specific Points in the Mackenzie Basin

LEGEND

- Regulated (Recorded)
- Natural (Estimated)
- Regulated (Estimated)

Figure 2 (cont'd)

TABLE I

MACKENZIE BASIN NATURAL REGIME

			PEACE RIVER AT PEACE RIVER (C.F.S.) X = 5 DAYS	PEACE RIVER AT PEACE POINT (C.F.S.) X = 5 DAYS	LAKE ATHABASCA[1] AT FORT CHIPEWYAN (FEET) X = 10 DAYS	SLAVE RIVER AT FITZGERALD (C.F.S.) X = 10 DAYS	GREAT SLAVE[2] LAKE AT YELLOWKNIFE BAY (FEET) X = 10 DAYS	MACKENZIE RIVER NEAR FORT PROVIDENCE (C.F.S.) X = 10 DAYS
HIGH WATER	PROBABILITY OF AN ANNUAL PEAK X DAY MEAN GREATER THAN	.05	510,000	413,000	692.4	299,000	516.2	333,000
		.10	465,000	397,000	691.8	295,000	516.0	320,000
		.25	405,000	370,000	690.7	286,000	515.8	307,000
		.50	346,000	345,000	689.5	271,000	515.5	288,000
		.75	297,000	320,000	688.4	245,000	515.2	269,000
		.90	260,000	300,000	687.5	230,000	515.0	256,000
		.95	237,000	290,000	686.9	221,000	514.8	243,000
LOW WATER	PROBABILITY OF AN ANNUAL MINIMUM X DAY MEAN LESS THAN	.05	6,400	9,400	682.1	16,000	512.8	54,000
		.10	7,000	10,000	682.4	19,000	513.0	58,000
		.25	7,600	10,800	682.8	25,000	513.4	64,000
		.50	8,400	11,900	683.2	34,000	513.8	71,000
		.75	9,200	12,700	683.7	46,000	514.2	80,000
		.90	10,000	13,500	684.1	61,000	514.5	88,000
		.95	10,400	14,000	684.3	72,000	514.6	93,000
ANNUAL MEAN			63,400	72,000	685.7	131,000	514.5	162,000

1. GEODETIC SURVEY DATUM (1967), ADD 2.10 FEET FOR CRACKINGSTONE TOPOGRAPHIC SURVEY DATUM

2. APPROXIMATE GEODETIC SURVEY DATUM

TABLE 2

MACKENZIE BASIN REGULATED REGIME								
			PEACE RIVER AT PEACE RIVER	PEACE RIVER AT PEACE POINT	LAKE ATHABASCA AT FORT CHIPEWYAN [1]	SLAVE RIVER AT FITZGERALD	GREAT SLAVE LAKE AT YELLOWKNIFE BAY [2]	MACKENZIE RIVER NEAR FORT PROVIDENCE
			(C.F.S.) X = 5 DAYS	(C.F.S.) X = 5 DAYS	(FEET) X = 10 DAYS	(C.F.S.) X = 10 DAYS	(FEET) X = 10 DAYS	(C.F.S.) X = 10 DAYS
HIGH WATER	PROBABILITY OF AN ANNUAL PEAK X DAY MEAN GREATER THAN	.05	360,000	310,000	690.2	251,000	515.7	301,000
		.10	320,000	290,000	689.8	241,000	515.5	288,000
		.25	265,000	260,000	688.9	226,000	515.3	275,000
		.50	214,000	233,000	687.7	209,000	515.0	256,000
		.75	172,000	207,000	686.6	192,000	514.7	237,000
		.90	141,000	186,000	685.7	177,000	514.5	224,000
		.95	126,000	175,000	685.3	170,000	514.3	211,000
LOW WATER	PROBABILITY OF AN ANNUAL MINIMUM X DAY MEAN LESS THAN	.05	36,900	39,700	682.3	38,000	513.0	67,000
		.10	37,000	40,300	682.6	41,000	513.2	70,000
		.25	37,200	40,500	683.0	47,000	513.5	77,000
		.50	37,500	41,000	683.5	56,000	513.8	84,000
		.75	37,800	41,300	684.0	68,000	514.2	92,000
		.90	38,000	41,700	684.4	83,000	514.5	100,000
		.95	38,100	41,800	684.6	94,000	514.6	105,000
ANNUAL MEAN			63,400	72,000	685.2	131,000	514.4	162,000

1. GEODETIC SURVEY DATUM (1967), ADD 2.10 FEET FOR CRACKINGSTONE TOPOGRAPHIC SURVEY DATUM

2. APPROXIMATE GEODETIC SURVEY DATUM

TABLE 3

MACKENZIE BASIN PERMANENT REGIME CHANGES								
			PEACE RIVER AT PEACE RIVER	PEACE RIVER AT PEACE POINT	LAKE ATHABASCA[1] AT FORT CHIPEWYAN	SLAVE RIVER AT FITZGERALD	GREAT SLAVE[2] LAKE AT YELLOWKNIFE BAY	MACKENZIE RIVER NEAR FORT PROVIDENCE
			(C.F.S.) X = 5 DAYS	(C.F.S.) X = 5 DAYS	(FEET) X = 10 DAYS	(C.F.S.) X = 10 DAYS	(FEET) X = 10 DAYS	(C.F.S.) X = 10 DAYS
MEDIAN VALUES	ANNUAL PEAK X DAY MEAN	N	346,000	345,000	689.5	271,000	515.5	288,000
		R	214,000	233,000	687.7	209,000	515.0	256,000
		C	-132,000	-112,000	-1.8	-62,000	-0.5	-32,000
	ANNUAL MINIMUM X DAY MEAN	N	8,400	11,900	683.2	34,000	513.8	71,000
		R	37,500	41,000	683.5	56,000	513.8	84,000
		C	+29,100	+29,100	+0.3	+22,000	0.0	+13,000

1. GEODETIC SURVEY DATUM (1967)

2. APPROXIMATE GEODETIC SURVEY DATUM

To illustrate the use of Table 3, it will be seen that in a median year, the maximum level of Lake Athabasca will be reduced by 1.8 feet and the minimum level increased by 0.3 foot. By referring to Tables 1 and 2, it will be seen that the maximum level would be reduced by 2.2 feet in a high year and by 1.6 feet in a low year. Similarly, the minimum level would be increased by 0.3 foot in a high year and by 0.2 foot in a low year.

Certain facts that show up on Figure 2 and Table 1 are worth noting. It can be seen that high peak flows on the Peace River at Peace River are greater than at Peace Point, even though the drainage areas are 72,000 square miles and 113,000 square miles, respectively. This is due to attenuation of the flood peak by channel storage as the peak travels downstream. Also, the peak flow of the Slave River at Fitzgerald under natural regime is considerably less than the peak flow of the Peace River at Peace Point because a significant part of the Peace River flow is diverted into Lake Athabasca until the peak on the Peace River has passed. To a lesser extent, the same is true under regulated regime, showing that some Peace River water will still be diverted into Lake Athabasca.

It should also be noted that there is a consistent relation between the level of Great Slave Lake and the flow of the Mackenzie River during high water, but this relation does not hold during low water because ice restricts the outflow channel capacity. Thus, at any given lake elevation, winter outflow to the Mackenzie River may be less than half the open-water outflow. Also, the minimum flow in the Mackenzie River does not necessarily occur at the same time as the minimum elevation of Great Slave Lake. The lowest flows usually occur in May, while the lowest lake elevation may occur in November before the start of ice formation at the outlet to the Mackenzie River.

SUMMARY

Construction of the W.A.C. Bennett Dam on the Peace River has caused and will continue to cause changes in the regime of the Peace River, Lake Athabasca, the Slave River, Great Slave Lake and the Mackenzie River.

The effects will be most severe during the period when the reservoir is being filled but, because of increasing releases for power generation, the flows from the reservoir during 1969 and later should not be as restricted as in 1968.

Once the powerhouse is in full operation, the overall effects promise to be beneficial because of reductions in flood peaks and increases in low flows.

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