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DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES

WATER RESOURCES BRANCH

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REPORT

on

HYDRO-ELECTRIC POWER RESOURCES

of the

PORCUPINE, PEEL, AND RAT RIVER REGION

YUKON AND NORTHWEST TERRITORIES

Vancouver, B.C.

April 1965

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SECTION 1 - SUMMARY

The studies incorporated in this report may be regarded as a preliminary assessment of the major possibilities for hydro-electric power development in the Porcupine, Peel, and Rat River region. Although the scope of the investigations did not permit compilation of some of the basic data necessary to definitely establish the technical and economic feasibility of projects, the designs, estimates, and power evaluations were carried out in sufficient detail to provide a reasonable indication of the magnitude of the hydro-electric power potential of the region and their costs of development.

1. Diversion Plan

The studies show that development of the maximum hydro-electric power potential of the region would involve the diversion of waters of the Porcupine and Peel Rivers to generating plants on the Rat River. This plan would provide about 1.1 million kw of prime power.

The proposed diversion system could be developed in five stages. The initial stage, consisting of a storage and power project on the Porcupine River at the Bell site, would cost an estimated \$95,000,000. It would produce about 590 million kwh of firm energy annually at a cost of about 10 mills

per kwh at site. When the final stage has been completed, the cumulative capital cost would amount to almost \$1,000,000,000 and would produce 10 billion kwh of firm energy annually at an average cost of about 6 mills per kwh at site.

The first four stages would involve only waters of the Porcupine River. With storage developed at two reservoirs on the Porcupine for regulation and diversion to supply two powerplants located on the Rat River, an estimated 660,000 kw of prime power would be made available. At the fifth or ultimate stage, more flow would be supplied to the Rat River plants by diversion from the Peel River to produce an additional 490,000 kw of prime power.

The total estimated capital cost of the system before the addition of Peel River water would be about \$550,000,000. Waters of the Porcupine River would produce in the system about 5.7 billion kwh of firm energy annually at an average cost of about $5\frac{1}{2}$ mills per kwh at site.

The capital cost attributable to the development of the Peel River increment would be an estimated \$450,000,000. Waters of the Peel River would produce in the diversion system about 4.3 billion kwh of firm energy annually at an average cost of about 6 mills per kwh at site.

2. Non-Diversion Plans

If the water resources of the region were not to be used in diversion development, then the studies would consider projects on the Porcupine and Peel Rivers only. Sites on the Rat River would not warrant consideration for independent development.

In a non-diversion plan, the water resources of the Porcupine River in Canada could be developed by two storage and power projects located at the Bell and Porcupine Canyon sites. The system would be capable of generating about 175,000 kw of prime power, or the equivalent of 1.5 billion kwh of firm power annually at an average unit cost of about 7½ mills per kwh at site. The total capital costs of the two projects would be about \$180,000,000.

Thus, the development of the water resources of the Porcupine River by diversion would result in almost a four-fold increase in average annual firm-energy production over the non-diversion plan; that is, an increase in annual firm-energy production from 1.5 billion kwh in the non-diversion plan to 5.7 billion kwh in the diversion plan.

The studies contained in this report on the possibilities for hydro-electric power development in the Peel River basin without diversion are incomplete. Three sites were examined on the Peel River which could be used to develop

the hydro-electric power potential of the river, but additional hydrologic data would be required, before a useful appraisal could be made of their combined capabilities. Therefore, at the present stage of the studies, it is not possible to indicate which plan of development, diversion or non-diversion, would accomplish greater utilization of the water resources of the Peel River basin.

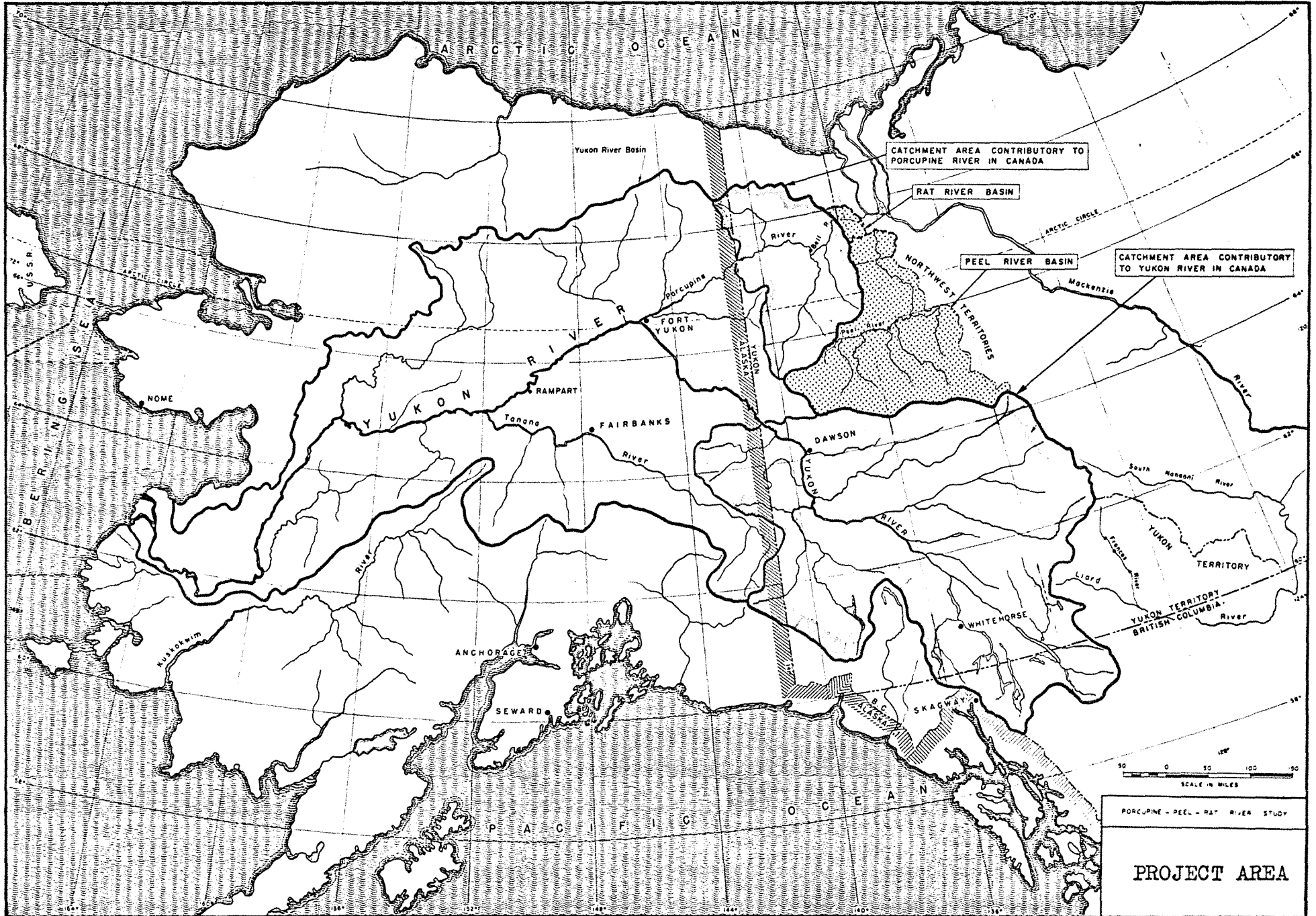
A preliminary appraisal was made of a storage project at the Aberdeen Falls site on the Peel River in conjunction with a run-of-river project downstream at the Bonnet Plume site. Projects in such a system, developed to produce about 310,000 kw of prime power, would cost \$290,000,000. It would produce 2.7 billion kwh of firm energy annually at an average cost of about $6\frac{1}{2}$ mills per kwh at site.

SECTION 2 - INTRODUCTION

The Water Resources Branch of the Department of Northern Affairs and National Resources has undertaken surveys and investigations in the Yukon River basin in Canada to provide an inventory of the hydro-electric power resources of the region.

The Yukon River is an international stream. Its basin occupies an area of 330,000 square miles, including about a third of the State of Alaska, over half the Yukon Territory, and a small area in the northwest corner of British Columbia. The Canadian portion of the basin covers some 127,000 square miles, and is divided by the Ogilvie Mountains into two drainage areas. The southern region, with a catchment area of about 113,000 square miles, is drained by the main stem of the Yukon River, while the northern region, with a catchment area of some 24,000 square miles, is drained mainly by the Porcupine River. The Porcupine River joins the main stem of the Yukon River at Fort Yukon in Alaska. (See Plate 1.)

The results of investigations into the hydro-electric power possibilities of the southern region of the basin were presented in the Water Resources Branch report entitled "Yukon River Basin Report", dated December 1962.



PORCUPINE - PEEL - RAT RIVER STUDY

PROJECT AREA

The report was prepared by the British Columbia and Yukon District office of the Water Resources Branch.

The present report is concerned with hydro-electric power possibilities in the northern region; that is, the region drained by the Porcupine River in Canada. In addition, since attractive opportunities are available in the region for diversion developments, the investigation was expanded to include the contiguous areas drained by the Peel and Rat Rivers which form part of the Mackenzie River system. The areal extent, geographic location, and relative position of the Porcupine, Peel, and Rat River region with respect to the southern region previously investigated are shown on Plate 1.

1. Purposes of the Report

The main purposes of the investigations and studies undertaken for the report were:

- (a) to compile an inventory of the potential hydro-electric power resources of the Porcupine, Peel, and Rat River region; and
- (b) to provide an estimate of the cost of developing this potential.

2. Scope of the Investigations and Studies

The investigations and studies were concentrated on the appraisal of the major possibilities for the development

of hydro-electric power in the Porcupine, Peel, and Rat River region. Other possible water uses, such as navigation, fisheries and wildlife, were not investigated.

Field Investigations. Preliminary field examinations were made in the summers of 1962 and 1963 involving aerial reconnaissance and ground surveys. The Porcupine, Peel, and Rat Rivers, and their major tributaries, were examined their entire lengths by air and, in part, by boat. Streamflow gauging stations were established at strategic locations in the region. Ground surveys were conducted at the major damsites. The surveys included topographical and geological mapping, and a limited geophysical appraisal of subsurface conditions by the seismic method. Surveys were also carried out to obtain river profiles of the main stem of the Porcupine, Peel, and Rat Rivers. In addition, barometric surveys were undertaken to provide information relating to storage capabilities of potential reservoir sites.

Office Studies. The office studies covered the following aspects. Hydrologic studies were made to derive estimates of streamflow and flood potential at the various project sites. Power outputs and storage requirements were examined on the basis of the streamflow estimates and information relating to site characteristics. Preliminary designs and cost estimates were prepared for each of the major

development sites. Several of the projects were considered both for independent development and as elements of a system plan.

The investigations and studies were preliminary in nature. The suitability of sites was assessed on the basis of surface indications only, supplemented in part by a limited geophysical appraisal. The full determination of the engineering and economic feasibility of the projects would require subsurface exploration at the sites by drilling and power-marketing studies. Intensive research into the construction and operation of structures under permafrost conditions would have to be carried out. An expanded program for the collection of data on meteorology and runoff would be required.

3. The Report

The report presents a diversion plan which would incorporate many of the potential storage and power sites in the Porcupine, Peel and Rat River area into an integrated hydro-electric power system. The proposed system of reservoirs and hydro-electric installations was designed to produce maximum feasible utilization of the available flow and head in the region. Several other combinations of storage and power sites were studied and are also outlined in the report.

In addition, the report presents a non-diversion plan for developing the hydro-electric power potential of the region, assuming no diversion of water to adjacent river basins.

Elements included in the diversion and non-diversion plans are listed in Tables 2 and 4, respectively, together with summaries of estimated project costs and power outputs.

Although the scope of the investigations did not permit compilation of data essential to a complete and detailed analysis of the many projects investigated, the designs, estimates and power evaluations are in sufficient detail to provide a reasonable indication of the magnitude of the hydro-electric power potential of the region and their costs of power production.

4. Organization of Studies

This report was prepared under the general administrative supervision of the Director of the Water Resources Branch, Department of Northern Affairs and National Resources. The investigations and studies were undertaken by the British Columbia-Yukon District office under the direction of H.T. Ramsden, District Engineer. The work was carried out by the Rivers Investigation Section under the supervision of W.Q. Chin, P.Eng., with the assistance of A.L. Ellis and A.G. Smith.

Examination and geological mapping of the damsites was carried out by E.B. Owen, Geological Survey of Canada, Department of Mines and Technical Surveys.

Spirit levelling and barometric surveys were carried out along the Porcupine, Peel, and Rat Rivers to establish vertical controls for reservoir mapping. This work, together with the compilation of maps of reservoir areas and diversion routes by aerial photogrammetric methods, was undertaken by the Topographical Survey Division, Surveys and Mapping Branch, Department of Mines and Technical Surveys, Ottawa.

Special air photography was taken in the region to supplement existing aerial coverage.

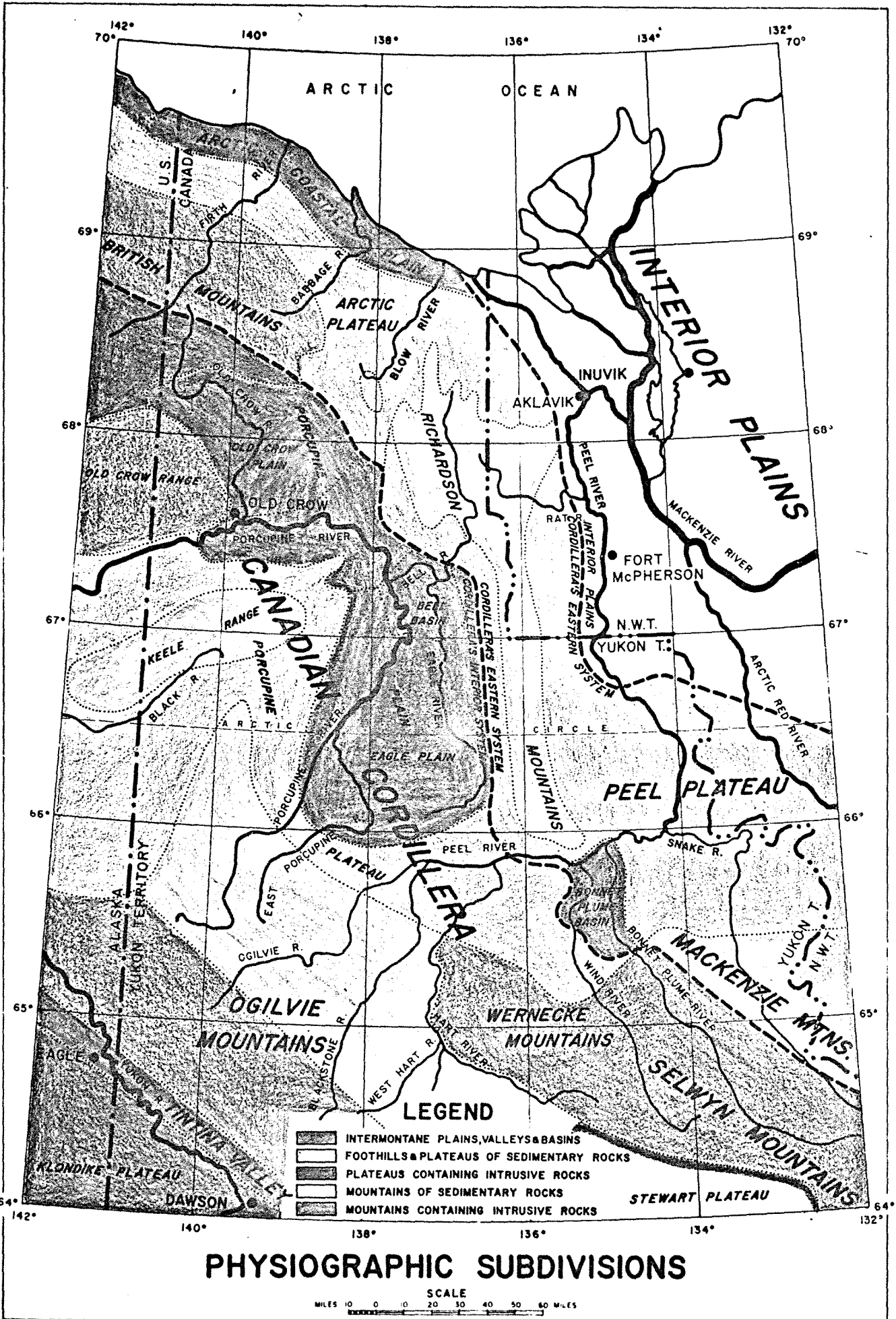
SECTION 3 - DESCRIPTION OF THE REGION

1. Location and Extent

The region under consideration in this report is shown on Plates 1 and 6. It covers some 53,000 square miles, and includes the areas drained by the Porcupine, Peel, and Rat Rivers in Canada. Except for the Rat River basin and a small portion of the Peel River basin, both of which lie in the Northwest Territories, the region is located mainly in the northern part of the Yukon Territory. About 21,000 square miles or 40% of the total area lies north of the Arctic Circle.

2. Physiography

General. The Porcupine, Peel, and Rat River area lies within the physiographic region known as the North American Cordillera. (Plate 2.) Much of the area is an intermontane region of uplands, plateaus and lowlands. The divides and drainage pattern of the three river basins are determined largely by the many mountain groups which encircle and pierce the region. On the north the British Mountains form the divide between the Arctic drainage and the Porcupine drainage. Along the southern limits of the region, the Ogilvie and Selwyn Mountains form the divide between the Peel River



system and the Yukon River system. To the east the Richardson Mountains penetrate the region in a north-south direction for 200 miles to form part of the divide between the Porcupine River basin and that of the Rat and Peel River basins.

An important feature of the divide along the Richardson Mountains is the existence of two relatively low passes which afford attractive possibilities for trans-basin diversion of water. Eagle Pass, located on the divide between the Porcupine and Peel Rivers, near the head of the Eagle River at Palmer Lake, has an elevation of 1,260 feet. McDougall Pass, located on the divide between the Porcupine and Rat Rivers at Summit Lake near the head of the Bell River, has an elevation of about 1,040 feet.

Glaciation and Permafrost. The western portion of the region, embracing the Porcupine River basin and the upper reaches of the Peel River basin, has not been subjected to glaciation except for local alpine type. Pleistocene glaciation appeared to have terminated on the eastern slopes of the Richardson Mountains. No glaciers and icefields now exist in the region although the region is everywhere underlain by permafrost.

Seismic Activities. The region may be subject to earthquakes, but little or no information is available on seismic activities in this area. Most of the major damaging

shocks, however, have occurred southwest of this region, in Alaska along the Pacific-rim area of the Aleutian Islands and the Alaska Range.

3. Streams

Porcupine River. The Porcupine River in Canada drains an area of 23,500 square miles. The river rises in the Ogilvie Mountains at an elevation of about 6,000 feet, and follows a general northeasterly course in the Yukon Territory for about 230 miles to its junction with the Bell River. The Porcupine River then continues in a northwesterly and westerly direction for a distance of 140 miles to enter Alaska at the 141st west meridian. The bed of the river at the international boundary is at an elevation of about 720 feet. In Alaska the river flows in a southwesterly direction for about 175 miles to its junction with the Yukon River near Fort Yukon. The proposed Rampart Canyon project on the Yukon River in Alaska would flood about 150 miles of the lower reach of the Porcupine River. The main tributaries in the Canadian portion of the basin are the Bell and Old Crow Rivers, which flow directly into the Porcupine River, and the Eagle River, which is tributary to the Bell River.

During the high-water season, the Porcupine River is navigable by shallow-draught boats up to and beyond the

junction of the Bell River. Commercial navigation is carried out on the lower reach of the river to supply the Indian settlement of Old Crow, Y.T.

Peel River. The Peel River starts in the Yukon Territory at the confluence of the Ogilvie and Blackstone Rivers, and flows eastward for 120 miles to meet the Snake River. It then continues in a northerly course for 147 miles to Fort McPherson in the Northwest Territories. At this point the Peel River has a drainage area of 28,600 square miles. North of Fort McPherson, the Peel River flows through a many-channel delta to join the Mackenzie River. The main stem of the Peel River has a total drop of about 1,250 feet from its headwaters at the junction of the Ogilvie and Blackstone Rivers to its mouth on the Mackenzie River. In addition to the Ogilvie and Blackstone Rivers, which rise in the Ogilvie Mountains, the other principal tributaries of the Peel River are the Wind and Bonnet Plume Rivers, which drain the Selwyn Mountains, and the Snake River, which has its headwaters in both the Selwyn and Mackenzie Mountains. The Rat River, together with many small streams, originates in the eastern slopes of the Richardson Mountains to drain directly into the Peel River.

In the high-water season, the Peel River is navigable by small river craft along the lower 230-mile reach of the river up to the foot of Aberdeen Falls.

Rat River. The Rat River, located in the Northwest Territories, has its source in the Richardson Mountains and flows eastward from McDougall Pass in a 75-mile course to join the Peel River near Fort McPherson. The river has a drainage area of about 900 square miles, and a total fall of about 1,000 feet from McDougall Pass to its junction with the Peel River.

4. Climate

The Porcupine, Peel, and Rat River area is characterized by long, cold winters and relatively warm summers. Much of the area is semi-arid. During the winter months precipitation falls mainly in the form of snow. In the summer, precipitation is of the light, showery type caused by the northward extension of low-pressure systems which produce occasional cloudbursts. Precipitation varies widely throughout the basin. The greatest precipitation occurs in the mountainous areas of the south and west where the low-pressure systems moving inland from the North Pacific induce frequent frontal and orographic activities.

One of the striking characteristics of the area, in common with all regions of high latitude, is the varying length of the period of daylight. During the months of May, June, and July, there is almost continuous daylight. In the

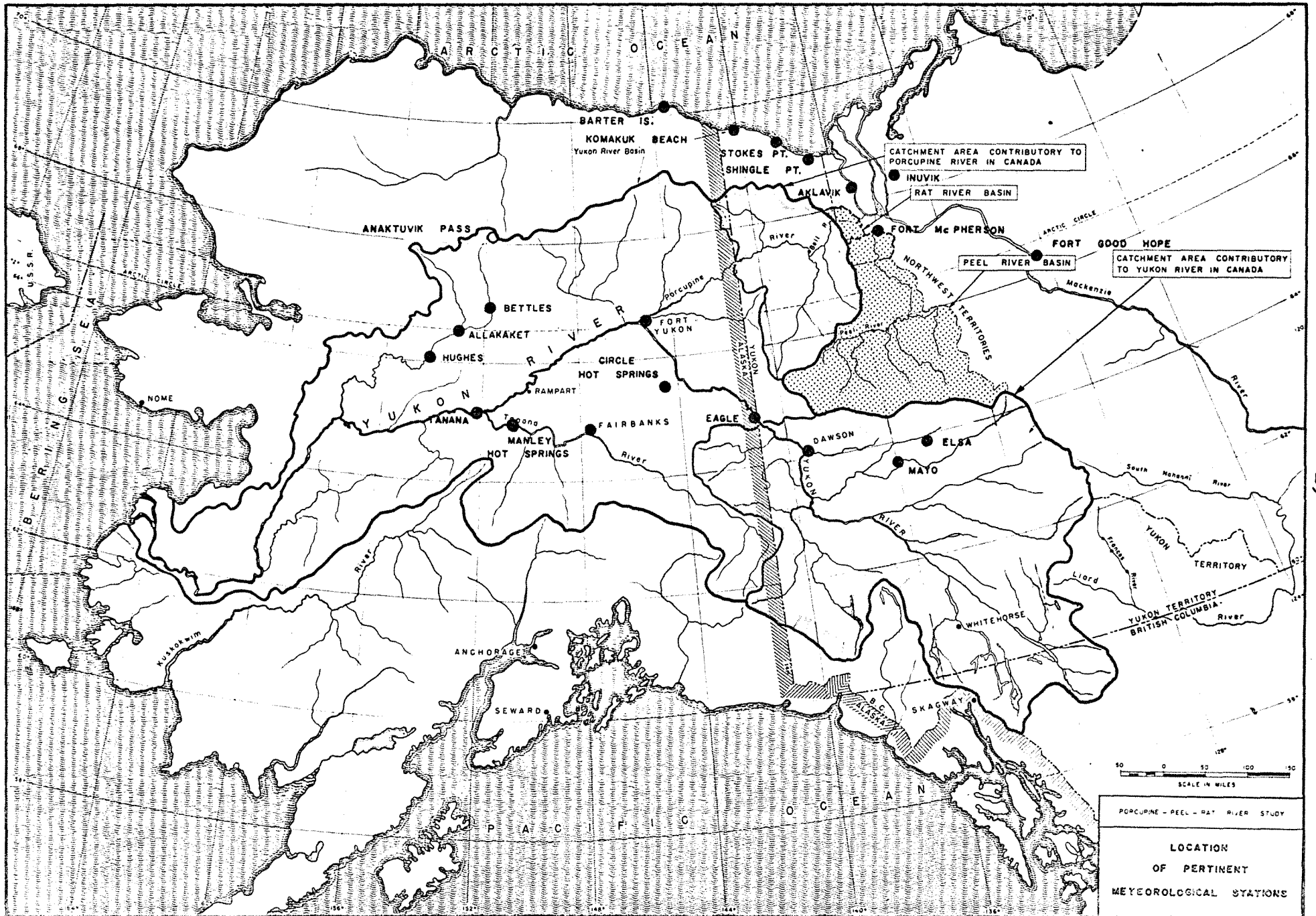
winter months the period of daylight is very short. In mid-winter the sun does not rise above the horizon.

At present there are no meteorological stations located in the region except for the station at Fort McPherson on the eastern edge of the area. Intermittent climatological observations were started at Old Crow, Y.T., in 1951, but were discontinued in 1956. Locations of climatological stations in areas adjacent to the region are shown on Plate 3.

5. Economic Development

The region is still at a pioneer stage of development without any road access at the present time. The population in the region is estimated to be less than 300 persons, of which approximately 200 are located at the Indian settlement of Old Crow, Y.T., and the remainder at Fort McPherson, N.W.T. Most of the native population are self-employed in fishing, hunting, and trapping. The majority have no stable year-round means of livelihood.

During recent years the region has been the scene of extensive explorations for oil and gas. Also considerable interest and explorations have been centred on a vast iron deposit in the Snake River area of the Peel River basin.



PORCUPINE - PEEL - RAT RIVER STUDY
 LOCATION
 OF PERTINENT
 METEOROLOGICAL STATIONS

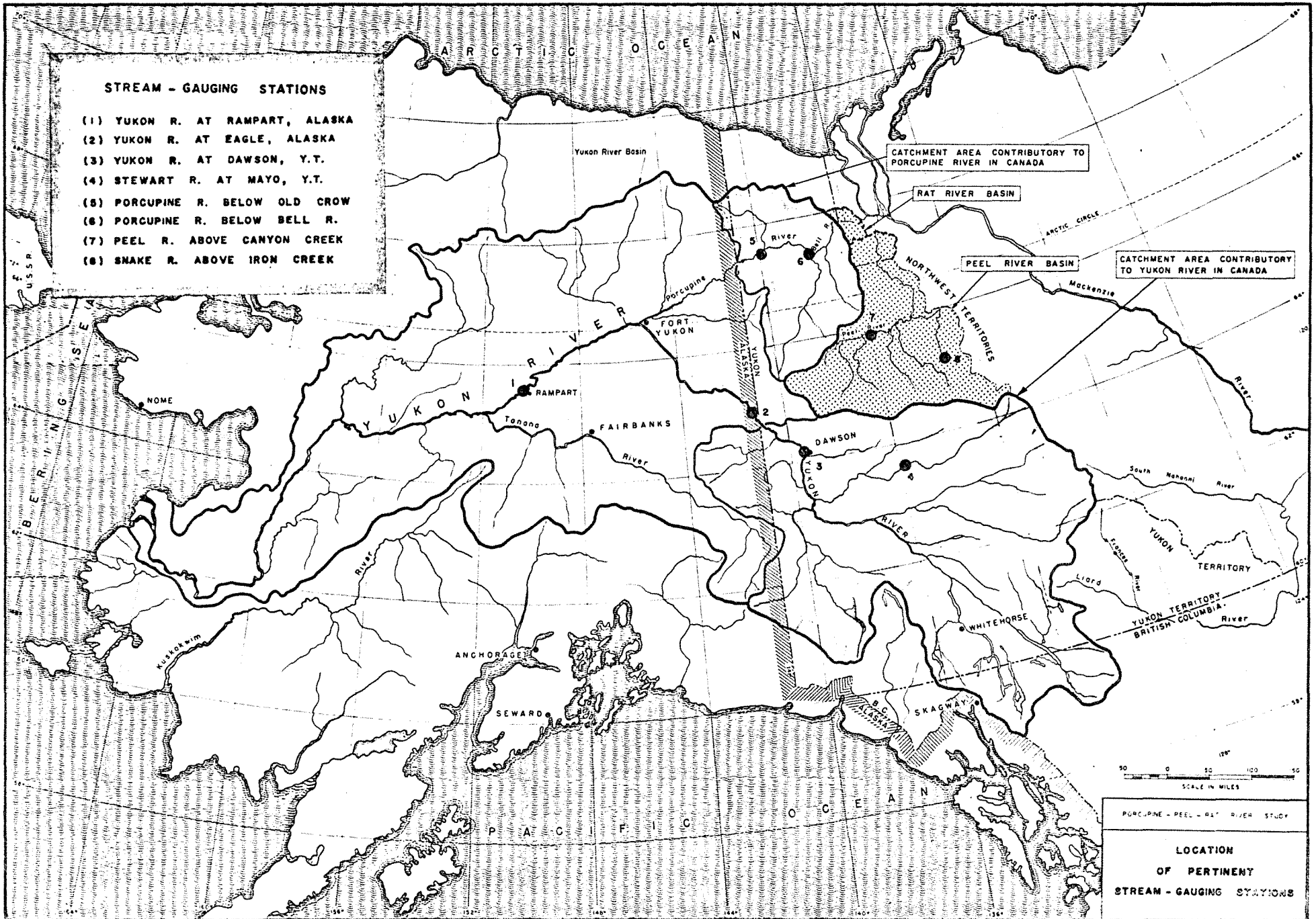
SECTION 4 - WATER RESOURCES

1. Hydrometric Records

Collection of basic hydrologic data in the region was initiated in recent years. A total of four gauging stations are presently in operation. Two gauging stations on the Porcupine River, one near Old Crow, Y.T., and the second below the junction of the Bell River, were established in the summer of 1961 and the fall of 1963, respectively. The third gauging station, on the Peel River about 10 miles upstream from Aberdeen Falls, was established in the summer of 1961. The fourth gauging station, located on the upper reach of the Snake River, was established in the fall of 1963 as a result of the recent interest and activities connected with the iron deposits of the area. No gauging station was established on the Rat River because of its small drainage contribution to the region and because of the difficult and high cost of access. Locations of gauging stations in and adjacent to the region are shown on Plate 4.

2. Runoff Characteristics

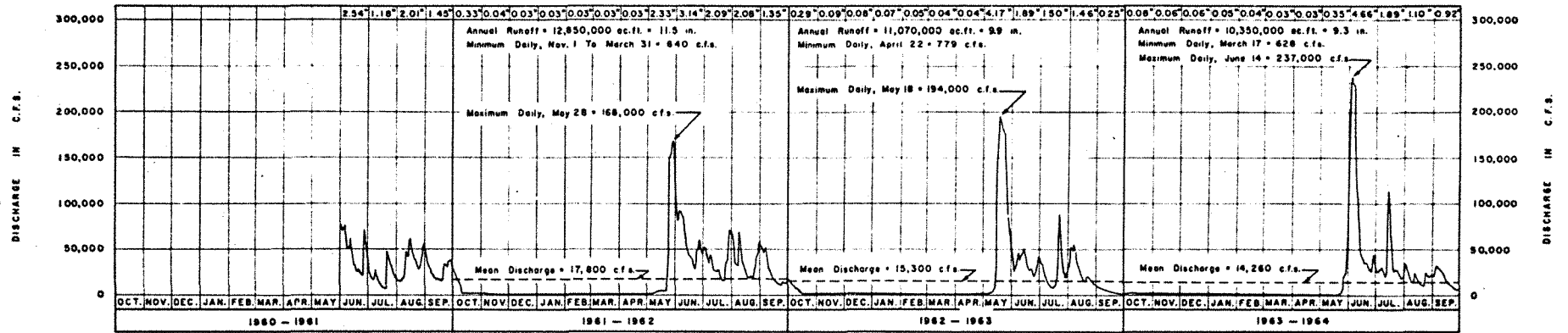
Most of the winter precipitation is retained in the region as snow. Consequently, a large part of the annual runoff occurs during the snowmelt period, which usually begins



about mid-May and ends by about mid-June. It is estimated that about 50% of the annual runoff occurs in the two-month period of May and June. And, because of the relatively short summers, about 90% of the annual runoff is concentrated into the five-month period from May to September.

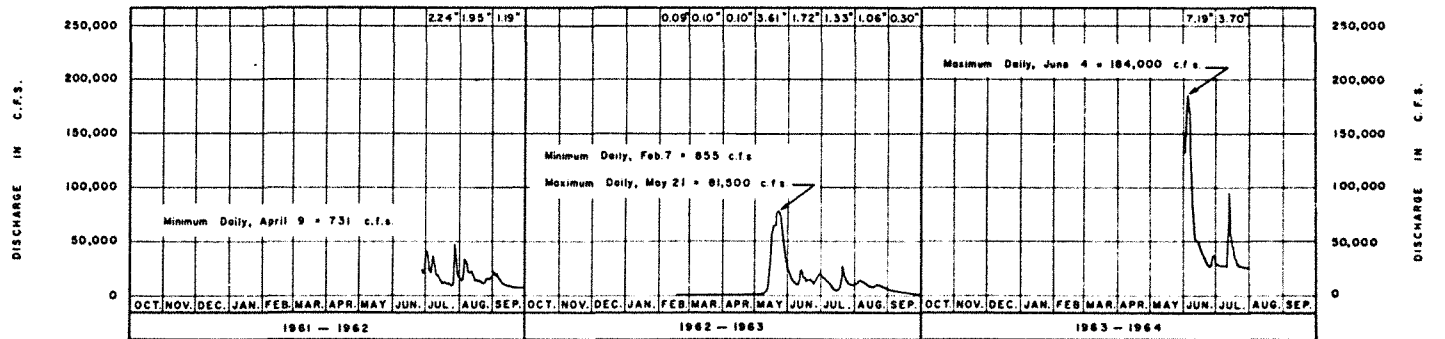
Runoff in the winter months is very low. Beginning in late September, freezing weather quickly reduces runoff to the point where streamflow is believed to be sustained mainly by ground-water discharge. The extreme variability of streamflow can be seen in the records of the Porcupine River at Old Crow, Y.T., for 1964. A peak flow of 237,000 cfs was recorded on June 14 of that year, which is 377 times the low winter flow of 628 cfs recorded in the same year. (Plate 5.)

On the main streams the peak flow for the year usually occurs within one or two weeks of breakup, with snowmelt providing the major portion of the flood runoff. On the smaller streams peak flow may result from heavy summer rainstorms. Since most of the region is underlain with permafrost, the infiltration losses are at a minimum, and runoff following rainstorms is very rapid. This condition causes extreme fluctuations in the summer hydrographs of streamflows. Prolonged rainstorms over a wide area can produce high flood flows in the region at any time in the summer months. Conversely, prolonged drought after the snowmelt period can produce near-minimum flows in the summer months.



PORCUPINE RIVER AT OLD CROW, YUKON TERRITORY

DRAINAGE AREA = 20,900 SQ. MILES



PEEL RIVER ABOVE CANYON CREEK, YUKON TERRITORY

DRAINAGE AREA = 10,200 SQ. MILES

PORCUPINE - PEEL - RAT RIVER STUDY

DAILY DISCHARGE HYDROGRAPHS

3. Water Supply

Because of the short period that gauging stations have been in operation in the region, the records available could not be taken as representative of the normal runoff pattern in the area. From an examination of climatic records of stations adjacent to the region, it would appear that greater-than-normal precipitation occurred in the region in the three years that streamflow records have been collected. This condition undoubtedly generated greater-than-normal runoff during the period.

In order to provide a longer and more representative period for power-output analysis, annual and monthly volumes of flow at project sites were synthesized to cover an eight-year period from 1955 to 1963. (See Plate 6 for location of projects.)

The synthesized flows were derived from an analysis of precipitation records and streamflow records at stations located in adjacent regions. First, isohyetal maps of annual precipitation were developed based on precipitation data from climatological stations throughout Alaska, Yukon Territory, and adjacent areas of the Northwest Territories. In developing the isohyetal maps for the region, considerations were given to elevation of terrain and location of storm paths to estimate possible frontal and orographic effects. Secondly, annual runoff was computed for

the drainage area contributing inflow to the Yukon River between the stream-gauging stations at Eagle and Rampart. (The Porcupine River basin in Canada contributes about 26% of the total drainage area between the two gauging stations.) Thirdly, correlation was made of the computed annual runoff and the estimated annual precipitation for the area between the gauging stations at Eagle and Rampart. Finally, these correlations, together with the isohyetal maps of precipitation, provided the basis for estimating the annual runoff from the various sub-areas for each of the eight years.

The preliminary studies indicated the following average distribution of runoff from the region during the eight-year period from 1955 to 1963. (See Table 1.)

TABLE 1 - DISTRIBUTION OF RUNOFF

Basin	Drainage Area	Estimated Runoff - 8-Year Average - 1955 to 1963								
		October - April			May - September			Average Water-Year		
	sq.mi.	maf	cfs	inches	maf	cfs	inches	maf	cfs	inches
Porcupine River at Porcupine Canyon Site	22,500	0.7	1,800	0.6	8.1	27,000	6.7	8.9	12,300	7.3
Porcupine River at Bell Site	13,900	0.5	1,200	0.7	5.4	18,000	7.3	5.9	8,200	8.0
Peel River at Aberdeen Falls Site	10,200	0.8	1,900	1.4	5.1	17,000	9.4	5.9	8,200	10.8
Porcupine River at Old Crow, Y.T.	20,900	Recorded Runoff - 3-Year Average - 1961 to 1964								
		0.6	1,400	0.5	10.8	36,000	9.7	11.4	15,800	10.2

SECTION 5 - PLANS OF DEVELOPMENT

1. General

Storage is the key to power development on streams with wide variations in natural flow, such as the Porcupine and Peel Rivers. Storage on the Peel River would be expensive to develop but, fortunately, attractive storage sites are available along the Porcupine River in Canada which could effectively control 100% of the flow and would involve development of only moderate-sized structures.

Moreover, the natural topographic features of the region lend themselves to diversion developments which could utilize, on the Rat River in Canada, a greater total head than would be possible on the natural river courses of the Porcupine and Peel Rivers themselves.

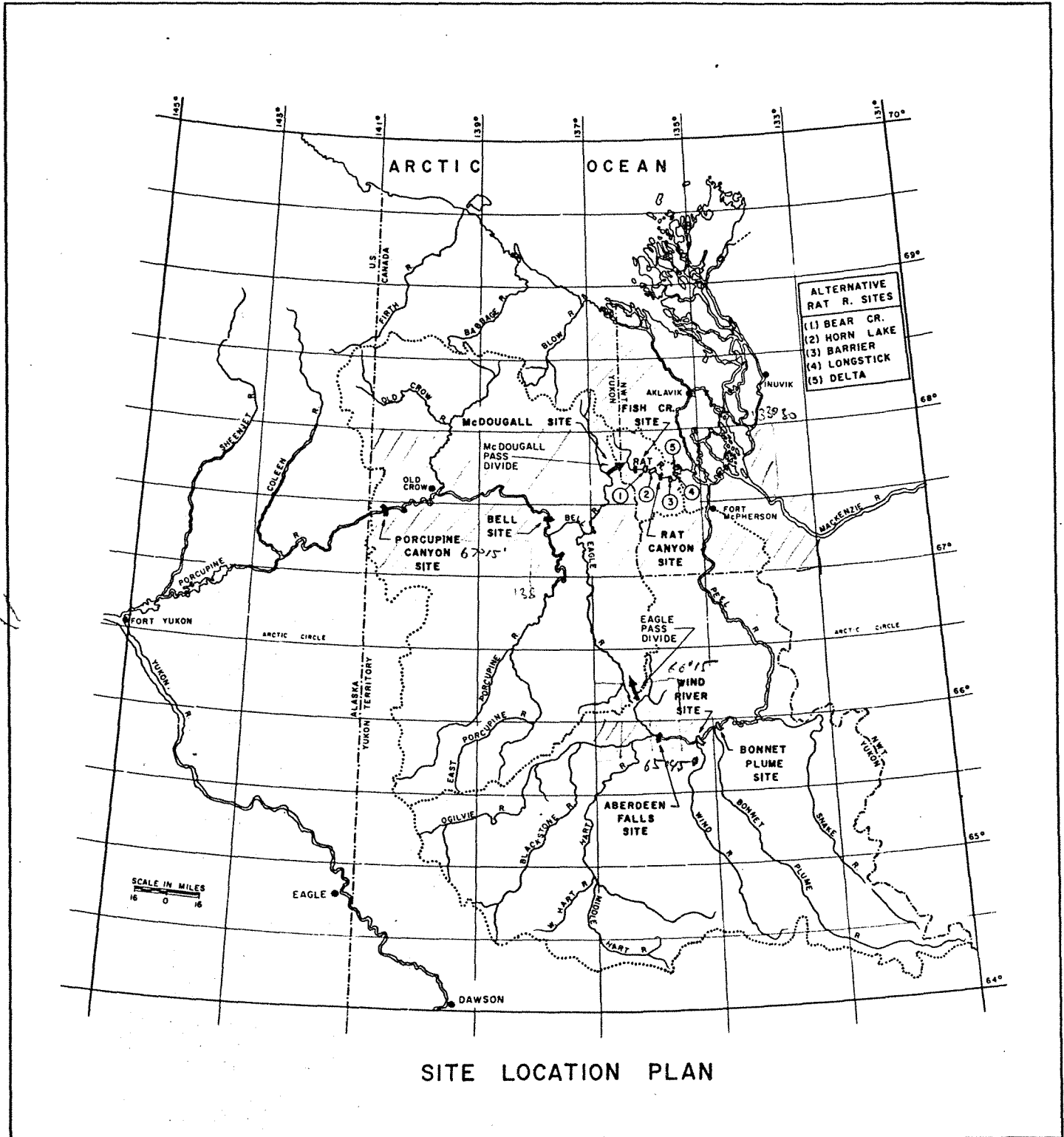
Because of these possibilities, the investigations that were carried out to evaluate the hydro-electric power potential of the region considered two general plans of development: a diversion plan, in which Porcupine and Peel River water would be diverted for development of power on the Rat River; and a non-diversion plan, in which the water of the Porcupine and Peel Rivers would be utilized within their own basins, without any portion diverted elsewhere.

The locations of the projects included in both the diversion and non-diversion plans are shown on Plate 6. Details of the various plans are discussed in the ensuing paragraphs.

2. Basic Assumptions

Site Selection and Project Layouts. In the selection of sites for structures, areas with considerable thickness of permanently frozen overburden were to be avoided where possible. Bedrock foundations were to be considered essential for powerhouse, spillways, concrete dams, as well as earth or rockfill dams of any appreciable height. Where earth or rockfill dams had to be founded on permanently frozen overburden, only low-head structures would be considered and special treatment would be provided to ensure safety of the structures. Such treatment might consist of either controlled thawing and consolidation prior to construction, or complete prevention of thawing by insulation, or even the use of mechanical refrigeration.

Water Supply and Storage Requirements. There are possibilities for the development of reservoirs of enormous capacities at the Bell and the Porcupine Canyon sites on the Porcupine River. The storage capacity that could be provided



SITE LOCATION PLAN

economically is governed by the amount of water available for filling the reservoirs. In order to obtain conservative estimates of the water supply and storage requirements, the following assumptions were made:

- (a) even with the enormous storage capacity available at several of the reservoir sites for 100% regulation of river flows, the firm regulated flows used for power-output computation not to exceed 90% of the estimated average flows at the project sites after deducting evaporation losses from reservoirs;
- (b) storage requirements to produce firm regulated flow to be increased by a 20% factor to insure against the possible occurrence of a drier cycle than that used in the studies.

Power. In selecting the size of power installations for plant designs and cost estimates, a plant factor of 65% was used throughout the studies, as was done in earlier reports, in order to evaluate all the projects on the same basis. The plant factor is based on an assumed 75% load factor and a 10% reserve capacity. In computing power outputs, overall plant efficiencies of 87% were assumed.

Cost. The estimates of construction costs were escalated from 1964 price levels in the Pacific Northwest to reflect the higher costs of construction in this remote northern region of the Yukon and Northwest Territories. Although located far from existing highway routes, the major potential power sites would be accessible by river routes. While restricted to a four-month period during the summer,

the rivers would offer a means of moving bulky materials to the sites during open-water season at less cost than by other transportation. Such access was taken into consideration in the cost estimates.

In deriving annual costs, an interest rate of 5% and an amortization period of 50 years were assumed. Annual operation, maintenance and interim replacement charges were included.

Sequence of Development. The present studies are basically an inventory of the major possibilities for hydroelectric power development in the region. The timing of construction of the elements in each of the plans studied would depend upon the demand for energy and the rate at which the demand grows. Such a market study is not available and clearly beyond the scope of this report. However, a sequence of staged development is presented in the studies to provide an indication of the contribution that each project would add to a system on an incremental basis. In determining the unit cost of power production, it was assumed that all the firm energy that could be produced by the projects would be salable.

3. Diversion Plan

The diversion plan, at ultimate development, would consist of five major projects, two of which would be located

on the Porcupine River for storage and diversion purposes, two located on the Rat River for the development of head for power generation, and one located on the Peel River for diversion only. These projects are listed below, and their locations are shown on Plate 6. Profiles of the system are shown on Plate 7. Other pertinent data are summarized on Tables 2 and 3.

Porcupine River

- Bell-McDougall Project - diversion, pumping, storage, and peaking development
- Porcupine Canyon Project - diversion and storage development

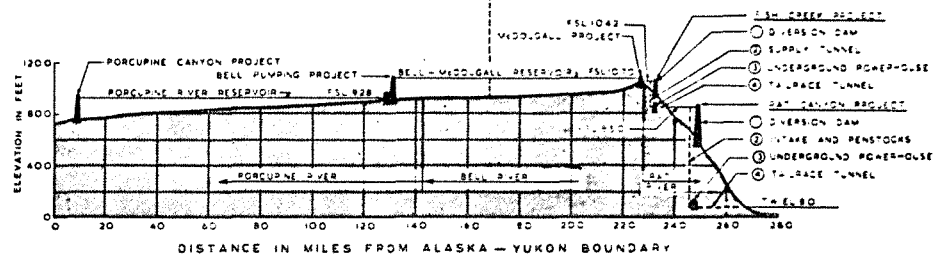
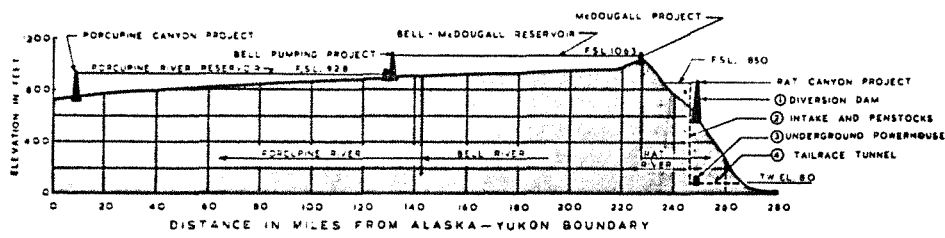
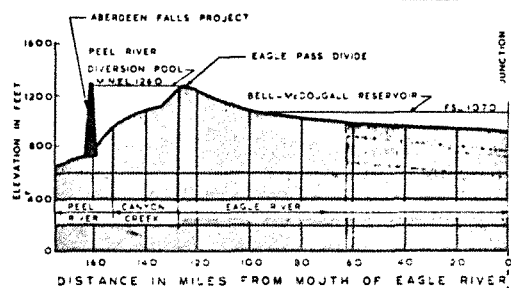
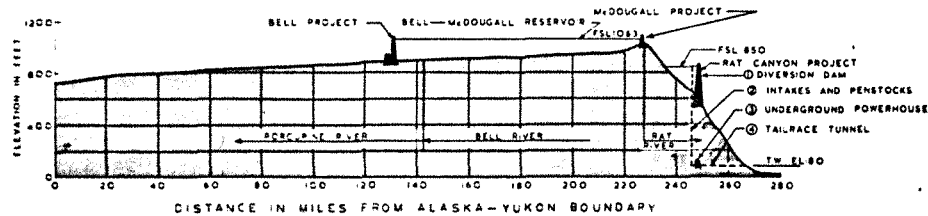
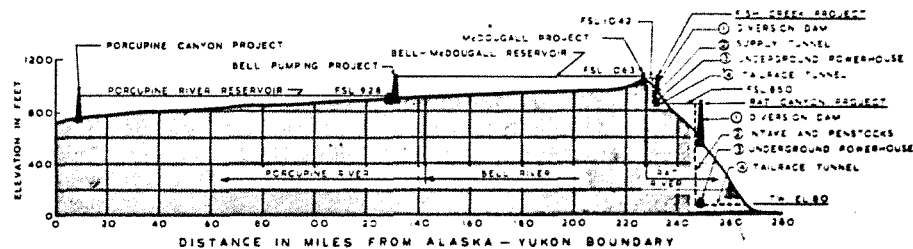
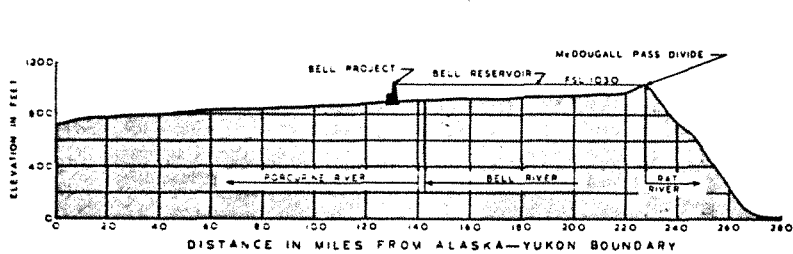
Rat River

- Fish Creek Project - run-of-river power development
- Rat Canyon Project - run-of-river power development

Peel River

- Aberdeen Falls Project - diversion development

The total active storage capacity of the system would be 13.3 million acre-feet. The development would involve an average annual diversion of 10,400 cfs from the Porcupine River and 7,200 cfs from the Peel River, to provide a total regulated flow of 17,600 cfs for power generation at the Rat River plants. With a total installed capacity of two million kw, the system would be capable of producing a net output of about 10.2 billion kwh of firm energy annually, equivalent to an average delivery



PROFILES OF PROPOSED SYSTEM DEVELOPMENT

DIVERSION PLAN

TABLE 2
DIVERSION PLAN.
SUMMARY OF COST AND OUTPUT DATA

	STAGE OF DEVELOPMENT	LOCATION	PURPOSE	ESTIMATED CAPITAL COST		ESTIMATED ANNUAL COST		AVERAGE REGULATED FLOW CFS	AVERAGE H.K KW/CFS	ANNUAL FIRM OUTPUT AND ANNUAL PUMPING REQUIREMENTS MW-YR	NET ANNUAL FIRM ENERGY OUTPUT		AT-SITE POWER COST				
				INCREMENT	CUMULATIVE	INCREMENT	CUMULATIVE				INCREMENT	CUMULATIVE	INCR.	CUM.			
				\$	\$	\$	\$				MW-YR	KWHx10 ⁶	MW-YR	KWHx10 ⁶	MILLS/KWH	MILLS/KWH	
PORCUPINE DIVERSION	1	Bell Site Project (Pump - Turbines)	Porcupine River	Storage And Power Generation	94,836,000	94,836,000	5,705,000	5,705,000	7,100	9.10	67.1	67.1	588	67.1	588	9.7	9.7
	2	Add Bell-McDougall Reservoir	Porcupine River	Diversion, Storage, And Peaking	37,055,000		2,221,000		6,900	0.00							
		Add Rat Canyon Project (4 Units)	Rat River	Power Generation	188,200,000		11,123,000		6,900	55.97	386.2						
		Sub-Totals			220,255,000	320,091,000	13,344,000	19,049,000			386.2	319.1	2,795	386.2	3,383	4.7	5.6
	3	Add Porcupine Canyon Reservoir	Porcupine River	Diversion And Storage	69,220,000		4,097,000		3,500	0.00							
		Activate Bell Pumping (Pump - Turbines)	Porcupine River	Diversion, Pumping, And Peaking					3,500	15.03	-52.6						
		Add 2 Units At Rat Canyon Project	Rat River	Power Generation	27,732,000		1,768,000		3,500	54.90	192.2						
		Sub-Totals			96,952,000	417,043,000	5,865,000	24,914,000			139.6	132.2	1,158	518.4	4,541	5.1	5.5
	4	Add Fish Creek "Tunnel" Project	Rat River	Power Generation	128,801,000	545,844,000	7,744,000	32,658,000	10,400	13.24	137.7	137.7	1,206	656.1	5,747	6.4	5.7
	PEEL DIVERSION	5	Add Aberdeen Falls Project	Peel River	Diversion	269,746,000		15,363,000									
Add Additional 6' Of Storage To Bell-McDougall Reservoir			Porcupine River	Regulation Of Peel River Water													
Add Second Powerplant At Fish Creek "Tunnel" Project			Rat River	Power Generation	68,204,000		4,181,000		7,200	13.39	96.4						
Add Second Powerplant At Rat Canyon Project			Rat River	Power Generation	112,242,000		6,783,000		7,200	54.78	394.4						
Sub-Totals				450,192,000	996,036,000	26,327,000	58,985,000			490.8	489.1	2,428	1,145.2	10,031	6.1	5.9	

Notes

- Includes A Reduction Of 7.4 MW-YR In The Stage 2 Output Of The Rat Canyon Project Due To An Increase In Tailwater Level As A Result Of Greater Diversion From The Porcupine River
- Includes A Reduction Of 1.7 MW-YR Due To Increased Pumping Head At The Bell Site Pumping Plant

TABLE 3
PROJECT DATA FOR DIVERSION PLAN

STAGE	PROJECTS	STREAM	POOL ELEVATION		AVERAGE TAIL - WATER ELEV.	STORAGE		HEAD			No. OF UNITS	GENERATORS UNIT RATING	PLANT CAPACITY	HYDRAULIC CAPABILITY AT RATED HEAD	NOMINAL PRIME OUTPUT
			MAX.	MIN.		TOTAL	USABLE	MAX.	MIN.	RATED					
			FEET	FEET	ACRE FEET	ACRE FEET	FEET	FEET	FEET	K.V.A					
1	Bell	Porcupine	1,030	1,008	890	15,052,000	5,652,000	140	118	135	3	37,700	107,000	11,500	67.1
2	Bell-McDougall	Porcupine	1,063	1,050	890	27,305,000	5,402,000			135	3		107,000		
	Rat Canyon	Rat	850		94			770	738	704	4	158,000	600,000	12,200	386.2
Sub Total						27,305,000	5,402,000						707,000		
3	Bell-McDougall	Porcupine	1,063	1,050	918	27,305,000	5,402,000			140.5 ¹	3 ²		107,000		52.6 ³
	Rat Canyon	Rat	850		109			770	682.5	704	6	158,000	900,000	15,200	571.0
	Porcupine Canyon	Porcupine	928	900		13,057,000	4,771,000								
Sub Total						40,362,000	10,173,000						1,007,000		518.4
4	Bell-McDougall	Porcupine	1,063	1,050	918	27,305,000	5,402,000			140.5 ¹	3 ²		107,000		52.6 ³
	Rat Canyon	Rat	850		109			770	682.5	704	6	158,000	900,000	15,200	571.0
	Porcupine Canyon	Porcupine	928	900		13,057,000	4,771,000								
	Fish Creek	Rat	1,042		865			192	131	151.5	4	61,500	234,000	16,500	137.7
Sub Total						40,362,000	10,173,000						1,241,000		656.1
5	Bell-McDougall	Porcupine	1,070	1,050	918	30,456,000	8,553,000			145 ¹	3 ²		107,000		54.3 ³
	Rat Canyon	Rat	850		110			770	680	704	10	158,000	1,500,000	27,200	965.4
	Porcupine Canyon	Porcupine	928	900		13,057,000	4,771,000								
	Fish Creek	Rat	1,042		865			192	131	151.5 172.5	7	61,500 54,500	389,000	25,100	234.1
	Aberdeen Falls	Peel	1,295	1,260											
Sub Total						43,513,000	13,324,000						1,996,000		1,145.2

- 1 Average Pumping Head
- 2 Units Used For Pumping And Spare Peaking Generation
- 3 Pumping Power Input

rate of 1.1 million kw. At a load factor of 75%, the firm-power capability of the system would be about 1.5 million kw.

The total capital cost of the projects, at 1964 price levels, was estimated to be about \$996,000,000. The average cost of firm-energy production with full development would be about 5.9 mills per kwh at site.

The development of the diversion plan could be accomplished by stages. The five stages in the proposed sequence of development are outlined below, followed by a short description of each project.

Stage 1 - Construction of Bell Storage and Power Project

The first stage would consist of the development of a storage and power project at the Bell site on the Porcupine River about 12 miles downstream from the mouth of the Bell River. Provisions would be made in the design of this project for enlargement to facilitate future diversion developments. Reversible pump-turbines would be installed to be used initially for power generation and, at later stages, for diversion pumping and peaking purposes. The estimated capital cost of the first-stage project is about \$95,000,000, of which about \$13,000,000 represents sunk cost for future expansion.

With 5.6 million acre-feet of active storage for cyclical regulation, an average firm-power draft of 7,100 cfs

would be available at the project. Operating under an average head of 132 feet, the project could generate about 67,000 kw of prime power, or the equivalent of 590 million kwh of firm energy annually, at an estimated average cost of about 9.7 mills per kwh at site.

Stage 2 - Construction of Bell-McDougall Storage and Diversion Project

and Rat Canyon Power Project

This phase would constitute the beginning of diversion development. The Bell project would now be raised in height to develop, in conjunction with a dam on the divide at the McDougall Pass site, a reservoir for storage and diversion. Water from the Porcupine River would be released through regulating works at the McDougall Pass structure to supply a powerplant at the Rat Canyon site on the Rat River about 23 miles downstream from the divide. During this stage, the power installations at the Bell project would be relegated temporarily for use as a peaking and reserve plant.

With a larger surface area on the reservoir, and consequent greater evaporation losses, the estimated firm-power draft available from the Porcupine River would be reduced from 7,100 cfs in the first stage to 6,900 cfs at the second stage. The water would be utilized at the Rat Canyon project by an underground powerhouse, in conjunction with a system of tunnels, to develop a gross head of about 770 feet. The

project could generate about 390,000 kw of prime power, or the equivalent of 3.4 billion kwh of firm energy annually. At the second phase of development, the average system cost of energy production is estimated to be about 5.6 mills per kwh at site.

Stage 3 - Construction of Porcupine Canyon Storage and Diversion Project

The third phase of development would consist of increasing the water supply to the Rat Canyon powerplant. This would be accomplished by constructing a second reservoir on the Porcupine River. A dam on the Porcupine Canyon site, located about eight miles upstream from the international boundary, would create a pool extending upstream to the toe of the Bell project. This reservoir would regulate the inflow to the Porcupine River between the Bell site and the Porcupine Canyon site. The installation at the Bell project would now be activated as a pumping plant to carry an average regulated flow of 3,500 cfs from the Porcupine Canyon reservoir, over the Bell site dam, and into the Bell-McDougall reservoir, at an average lift of about 140 feet.

With an average flow of 3,500 cfs obtained by pumping from the Porcupine Canyon reservoir, and 6,900 cfs available from inflow to the Bell-McDougall reservoir, a total regulated flow of 10,400 cfs would be supplied to the Rat Canyon powerplant. Additional generating facilities would be installed

in the underground station at the Rat Canyon project to utilize the increased flow.

At the third phase of development, the Rat Canyon project could generate about 570,000 kw of prime power or the equivalent of 5.0 billion kwh of firm energy annually. Of this, about 460 million kwh of energy annually would be used to satisfy the pumping requirements of the Bell pumping plant. The average system cost of producing a net output of 4.5 billion kwh annually at the third stage is estimated to be about 5.5 mills per kwh at site.

Stage 4 - Construction of Fish Creek Power Project

The fourth phase would complete the development of all the available head on the Rat River. The Fish Creek site, located about eight miles downstream from the divide, would be utilized to develop the remaining head of 192 feet upstream of the Rat Canyon pool. Using a system of tunnels in conjunction with an underground powerhouse, the Fish Creek project would make possible the production of an additional 138,000 kw of prime power. It would bring the total estimated net output of the system, after deducting for pumping requirements, to 656,000 kw of prime power, or the equivalent of 5.7 billion kwh of firm energy annually. At the fourth stage, the estimated average system cost of firm-energy production is about 5.7 mills per kwh at site.

Stage 5 - Construction of Aberdeen Falls Diversion Project

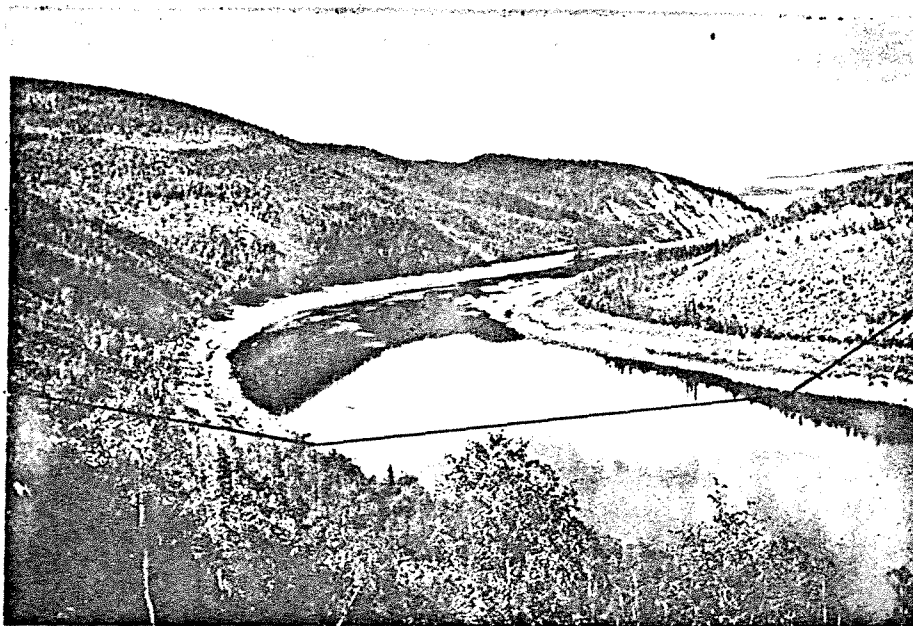
The fifth and ultimate stage of development would consist of increasing the water supply to the Fish Creek and Rat Canyon powerplants by the addition of water from the Peel River. A 560-foot-high dam on the Peel River at Aberdeen Falls would divert the unregulated flow of the Peel River across the divide at Eagle Pass into the Bell-McDougall reservoir, following the valley of the Eagle River.

The active storage capacity of the Bell-McDougall reservoir would be increased from 5.4 million acre-feet to 8.6 million acre-feet to accommodate an average unregulated inflow of 7,200 cfs diverted from the Peel River.

A total regulated flow of 17,600 cfs would then be supplied to the Rat River powerplants. To utilize the augmented flow, additional generating facilities would be installed at both the Fish Creek and Rat Canyon projects. The ultimate system would then be capable of producing a net output of about 1.1 million kw of prime power, or the equivalent of 10.0 billion kwh of firm energy annually. The average cost of firm-energy production at full development is estimated to be about 5.9 mills per kwh at site.

Bell Project. The Bell site is located on the Porcupine River about 12 miles downstream from the mouth of the Bell River. The project would be a combined storage and power

BELL SITE



LOOKING DOWNSTREAM

development. This project was selected as the first step in the development program principally because of its strategic location as the key project in the proposed diversion plan. However, the project would be a logical first choice from other considerations such as cost of initial development, length of time of construction, and quantity of power made available. The first project would have to stand alone for some time as an independent power producer until increased power demand would warrant system expansion.

The project would be constructed initially to a full-pool elevation of 1,030 feet, allowing about 10 feet of freeboard on the divide at McDougall Pass. In the event of a major flood, the Pass would serve as an emergency floodway. About 5.6 million acre-feet of active storage would be developed for cyclical regulation to provide an average firm-power draft of 7,100 cfs. Reversible pump-turbines would be installed, to be used initially for power generation with a total rated capacity of 107,000 kw and, at later stages, for diversion pumping with a total pumping capability of 8,000 cfs under 145 feet of pumping head. Throughout the later stages, the installations would also be available for peaking and reserve capacity.

A concrete-gravity structure about 180 feet high, with a crest length of 1,250 feet, was used in the preliminary cost estimates for the project. Provisions would be made in

the design for future enlargement to accommodate a higher pool elevation in connection with diversion developments. At the full-pool elevation of 1,030 feet, the reservoir would inundate about 300,000 acres of virgin territory. The flooding would affect some land on which oil and gas-exploration leases are held. The estimated capital cost of the project is \$95,000,000, of which \$13,000,000 represents sunk costs for future expansion.

Bell-McDougall Project. The Bell-McDougall project would be essentially an enlargement of the Bell project that has been previously described. The dam at the Bell site, together with a dam at the McDougall Pass site on the divide between the Porcupine River basin and the Rat River basin, would create a huge reservoir for both storage and diversion. Control works would be located at the McDougall Pass structure to provide regulated releases to the Rat River powerplants. Assuming staged development, the reversible pump-turbines installed at the Bell project would serve eventually as a pumping plant to lift water from the Porcupine Canyon storage and diversion development into the Bell-McDougall reservoir, and would also be available for peaking and reserve capacity at all stages.

The elevation of the proposed pool and the volume of active storage required would depend on the stage of development considered. In the early stages, before Peel River diversion, a normal full-pool elevation of 1,063 feet with

13 feet of drawdown would provide an active storage of 5.4 million acre-feet, sufficient for complete cyclical regulation of the inflow to the Porcupine River above the Bell site. Whereas, with the addition of Peel River water, 8.6 million acre-feet would be required at the Bell-McDougall reservoir for cyclical regulation. To provide for the eventual use of a greater amount of active storage, the studies assumed that the containing structures forming the Bell-McDougall reservoir would be constructed initially with at least 22 feet of freeboard. Therefore, to increase the active storage from 5.4 to 8.6 million acre-feet would simply involve the raising of the normal operating full-pool level from 1,063 to 1,070 feet, providing a reduced freeboard of at least 15 feet. At 1,070 feet the reservoir would flood about 472,000 acres of uninhabited wilderness and would involve additional land on which oil and gas-exploration leases are held.

The structure at the McDougall Pass site would be a rockfill dam some 88 feet high and 2,600 feet long at the crest. The dam would be constructed across the east end of Summit Lake, where it is assumed that overburden underlying the lake is presently unfrozen and would permit conventional type of rockfill construction. Control works would be located in the rock abutment of the north bank. The capital cost of the structure is estimated at \$19,700,000.

The capital cost of the additions to the first-stage Bell project, which would involve raising the structure by about 30 feet and modifications to the spillway, is estimated at \$17,300,000. The combined capital costs of the additions to the Bell project and the control structure at McDougall Pass would be \$37,000,000. (Plates 15 to 21 inclusive.)

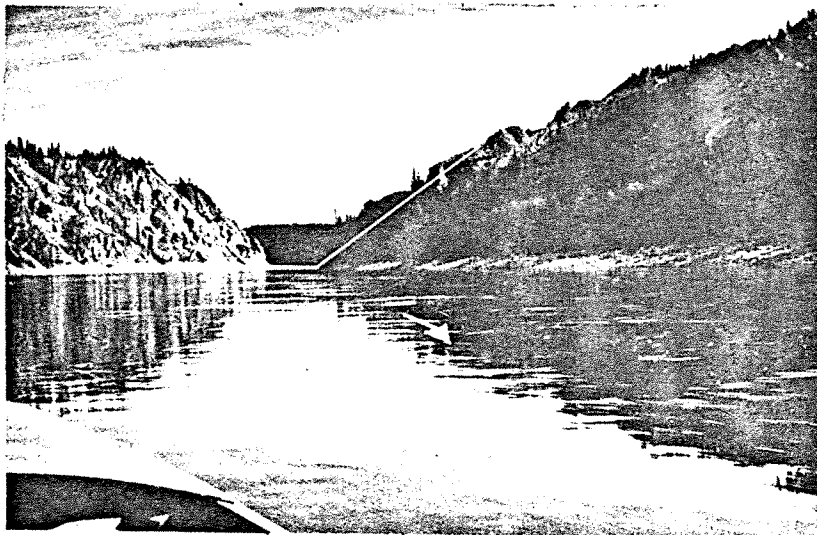
Porcupine Canyon Project. The Porcupine Canyon site is located on the Porcupine River about eight miles upstream from the international boundary. The project would be developed for storage and diversion. The inflow to the Porcupine River below the Bell site would be regulated in the Porcupine Canyon reservoir to be pumped more or less at a uniform rate into the Bell-McDougall reservoir for diversion into the Rat River.

An active storage volume of 4.8 million acre-feet would be used for cyclical regulation to divert an average flow of 3,500 cfs. At both the normal full-pool level of 928 feet and the minimum level of 900 feet, the reservoir would be backed up to the Bell site, where the pumphouse and appurtenant works would be located.

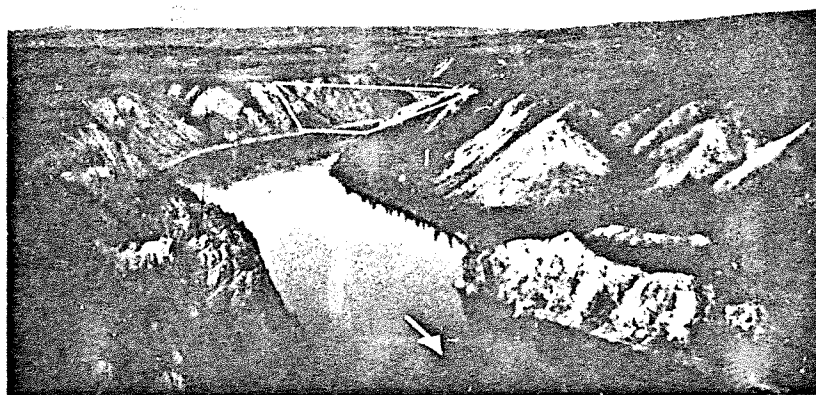
While either a concrete or rockfill structure could be used at the Porcupine Canyon site, for the purpose of this report the estimates were based on a concrete-gravity structure about 270 feet high with a crest length of 1,050 feet.

PORCUPINE CANYON SITE

PORCUPINE RIVER



LOOKING UPSTREAM



LOOKING UPSTREAM

The reservoir would flood about 200,000 acres including the Indian community of Old Crow, Y.T., and some land on which oil and gas-exploration leases are held. The capital cost of the project, excluding the pumping facilities at the Bell project, is estimated to be about \$69,000,000. (Plates 22, 23, and 24.)

Rat Canyon Project. The Rat Canyon site is located on the Rat River in the Northwest Territories, about 23 miles downstream from the divide at McDougall Pass. The project would be constructed as a run-of-river plant for power generation, utilizing water diverted from the Porcupine and Peel Rivers.

A rockfill dam about 330 feet high with a crest length of about 980 feet would develop the site to its physical limit, with the pool elevation set at 850 feet.

Power would be generated in an underground powerhouse of the Swedish type and would involve tailrace tunnels about seven miles long. The project would develop a gross head of about 770 feet with the tailrace tunnels discharging into the lower reach of the Rat River at an elevation of about 80 feet.

Construction of the power facilities would be phased so that at each stage sufficient plant capacity would be installed to accommodate the available firm regulated flow.

In the initial phase of development, with an installed capacity of 600,000 kw, the estimated capital cost of the project is \$188,000,000. The cumulative capital cost of the project at ultimate development, with a total installed capacity of 1,500,000 kw, would amount to an estimated \$328,000,000. (Plates 25 to 28 inclusive.)

Fish Creek Project. The Fish Creek site is located on the Rat River immediately below the mouth of Fish Creek and about eight miles downstream from the divide at McDougall Pass. The project would be a run-of-river power development, utilizing water diverted from the Porcupine and Peel Rivers.

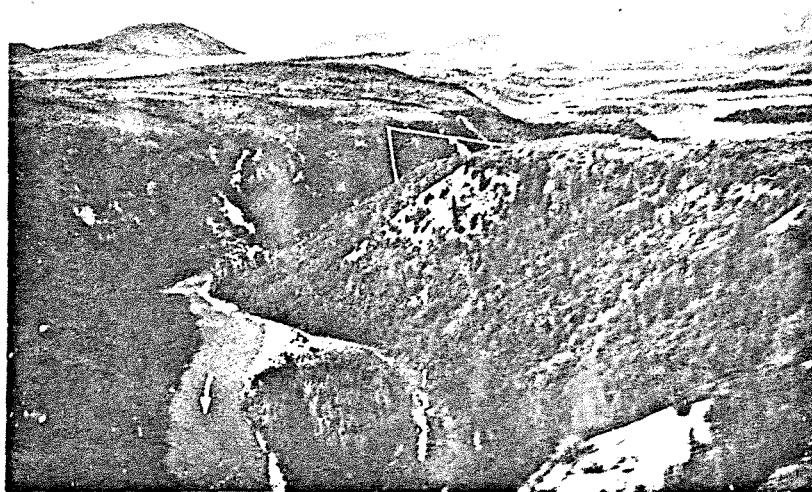
An earthfill dam about 120 feet high with a crest length of 4,500 feet would create a pool with a surface elevation of 1,042 feet, backing up to the toe of the control dam at McDougall Pass. The dam would be founded, in part, on permanently frozen overburden, and would require special engineering studies to determine the best treatment to ensure the safety of the structure.

Power would be generated in an underground powerhouse to develop, in one step, the entire head of 192 feet between the pool elevation of 1,042 feet at the Fish Creek project and the pool elevation of 850 feet at the Rat Canyon project downstream. Water would be delivered to the underground powerhouse through supply tunnels about three miles

RAT RIVER SITES



FISH CREEK SITE
LOOKING DOWNSTREAM



RAT CANYON SITE
LOOKING UPSTREAM

long, and would be discharged into the Rat Canyon pool through tailrace tunnels about one-half mile long.

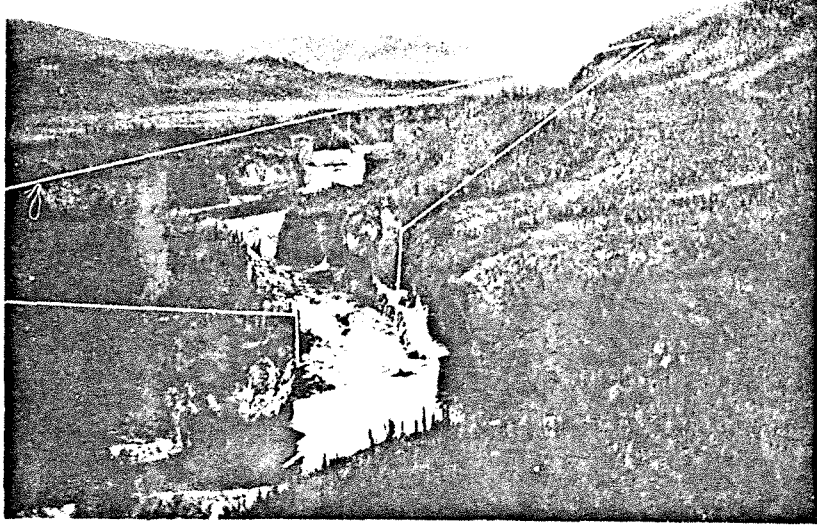
Construction of the power facilities would be phased so that at each stage sufficient plant capacity would be installed to accommodate the available firm regulated flow. In the initial phase of development, with an installed capacity of 234,000 kw, the estimated capital cost of the project is \$129,000,000. The cumulative capital cost of the project at ultimate development, with a total installed capacity of 389,000 kw, would amount to an estimated \$197,000,000. (Plates 29, 30, and 31.)

Aberdeen Falls Project. The Aberdeen Falls site is located on the Peel River about 13 miles upstream from the mouth of the Wind River. In the diversion plan, the Aberdeen Falls project would be used principally as a diversion structure. No power installations and no regulatory storage, except for flood-surge purposes, would be developed at the project.

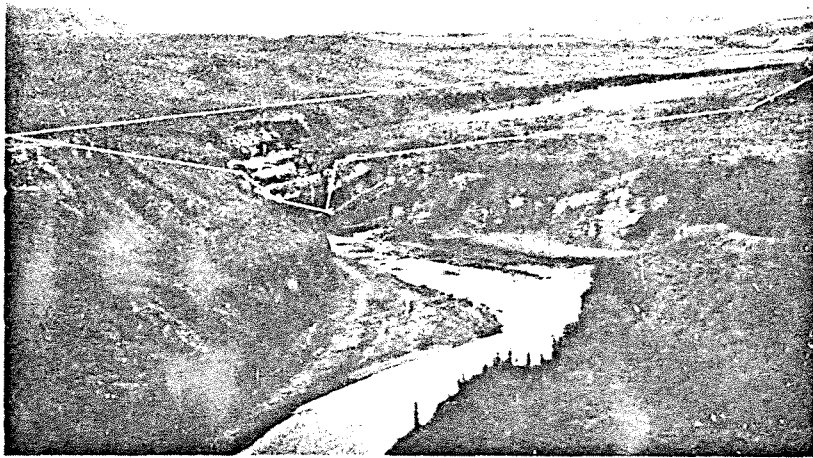
A 560-foot-high dam at the Aberdeen Falls site would raise the water level of the Peel River to a minimum elevation of 1,260 feet to permit the flow to be diverted over the divide at Eagle Pass into the Bell-McDougall reservoir, following the valley of the Eagle River. Cyclical storage would be provided at the Bell-McDougall reservoir for regulating the inflow from the Peel River for release to the Rat River powerplants.

ABERDEEN FALLS SITE

PEEL RIVER



LOOKING DOWNSTREAM



LOOKING UPSTREAM

While either a concrete or a rockfill structure could be considered for this site, for the purpose of this report a rockfill dam was used in the preliminary layout. The estimated capital cost of the project is \$270,000,000. (Plates 32, 33, and 34.)

4. Alternative Diversion Plans Examined

Many alternatives are available in planning the diversion system to utilize the water resources of the region for hydro-electric power development. The reservoirs and dams required for streamflow regulation, diversion, and power generation may be developed by projects at several alternative locations. Dams of different heights are possible at some sites, which would provide greatly different reservoir capacities and head utilization, and would result in additional alternatives. Several of the combinations of storage and power sites that were examined are outlined in the following paragraphs.

Porcupine Canyon-McDougall Reservoir. The means of regulating and diverting the flow of the Porcupine River in Canada to powerplants on the Rat River could be accomplished by a dam at the Porcupine Canyon site together with a control structure at the McDougall site. At a full-pool elevation of 1,055 feet, the reservoir would have a total storage capacity of some 150,000,000 acre-feet.

Preliminary studies have shown that such a large reservoir would be impractical. It would take the entire flow of the Porcupine River in Canada about 15 years to fill the reservoir before diversion could be accomplished. During this long filling period, the system would not be able to provide any financial returns to offset annual charges against the structures.

Bell-Fish Creek Reservoir. This reservoir could be developed for storage to serve the same purpose as the Bell-McDougall reservoir in the selected plan of diversion development. However, the control structure located at the Fish Creek site would incorporate a plant for power generation incidental to the discharge of stored water down the Rat River. The total average generating head in a system containing the Bell-Fish Creek project would be about 20 feet greater than that of the selected plan.

Preference was given in the selected plan to a project at the McDougall site for two reasons. First, a dam at the McDougall site would be much lower in cost than an initial project at the Fish Creek site and, consequently, would be more adaptable to staged development. Secondly, although the Bell-Fish Creek proposal would provide for slightly greater total-head utilization, the increase in head would be developed at the expense of a higher dam at the Fish Creek site. And, since part of the structure would be founded on permanently

frozen overburden, a higher dam would add to the difficulties in foundation preparation and permafrost control. Therefore, in the selected plan of development, a lower dam was proposed for the Fish Creek site as a run-of-river power project at a subsequent and more opportune stage of development.

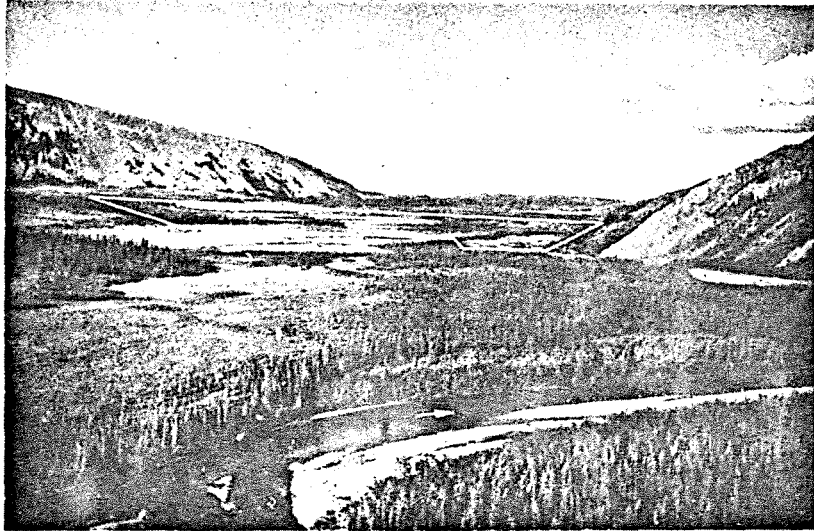
Alternative Run of River Projects on the Rat River.

A total of seven sites were examined on the Rat River; namely, Fish Creek site, Bear Creek site, Horn Lake site, Rat Canyon site, Barrier site, Longstick site, and Delta site, listed in downstream order.

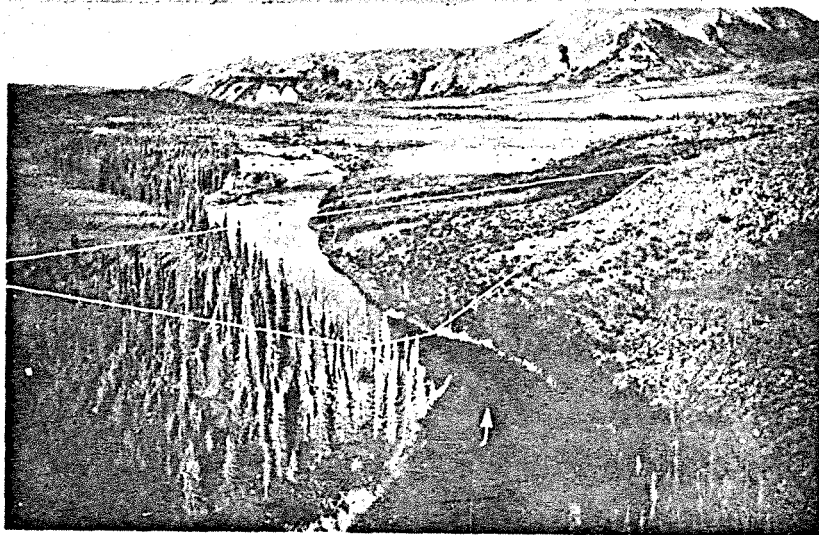
The 960 feet of head available on the Rat River, from an elevation of 1,040 feet at the divide to the water level of 80 feet at the lowest site on the Rat River, could be developed using a combination of some or all of the above-mentioned sites. However, only at the Rat Canyon site is bedrock believed to be available throughout the site area at relatively shallow depth. At all other sites, rock is available on the abutments for control works and powerplants, but bedrock in the valley is believed to be buried beneath considerable depth of overburden. Much of the overburden is in a permanently frozen state which would require costly treatment in the construction of dams.

Consideration was given to the use of a series of low-head, run-of-river projects at the Fish Creek, Bear Creek,

RAT RIVER SITES



HORN LAKE SITE
LOOKING DOWNSTREAM



BEAR CREEK SITE
LOOKING DOWNSTREAM

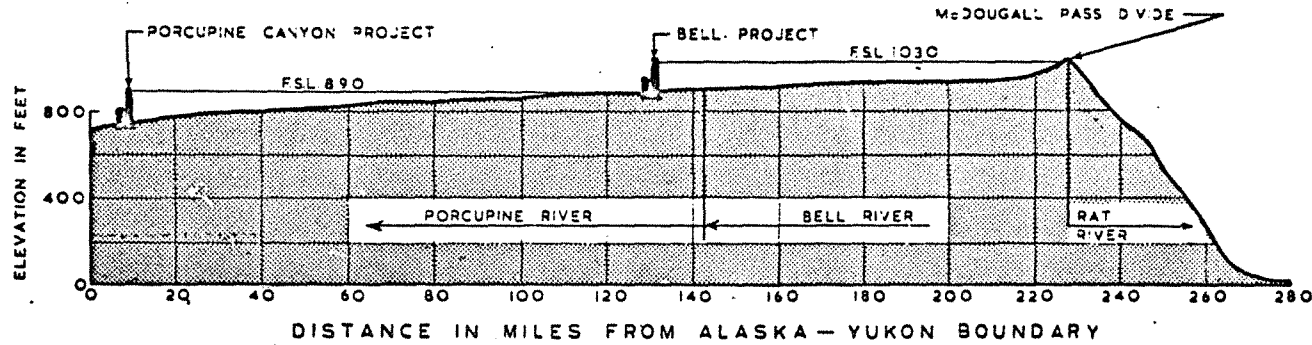
and Horn Lake sites. Studies and cost estimates were carried out for projects at these sites, based on the use of earthfill dams with upstream insulation and other special treatment to prevent thawing of the foundation and to maintain a high level of permafrost table under the dam. But, in view of the fact that very little precedent and experience are available for construction of dams on permanently frozen overburden, the selected plan proposed in this report has reduced as much as possible the need to locate dams on such foundations.

5. Non-Diversion Plans

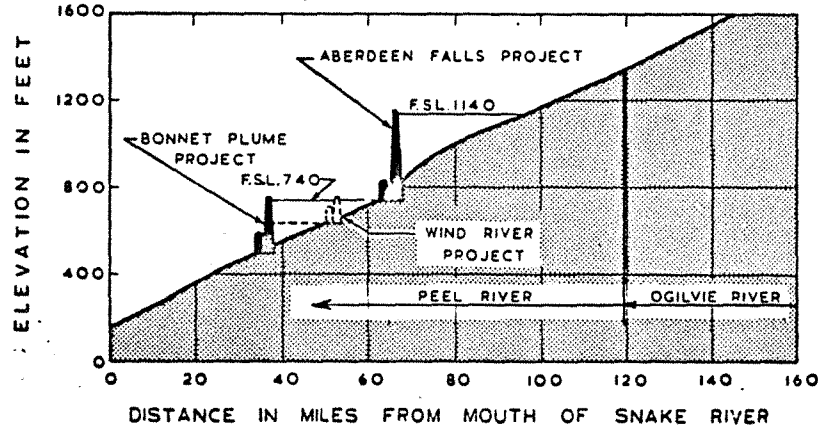
Without diversion, the studies of the hydro-electric power potential of the region were confined to projects on the Porcupine and Peel Rivers. Sites on the Rat River would not warrant consideration because of small water supply and lack of storage possibilities.

The proposed plans for non-diversion development of the Porcupine and Peel Rivers are outlined below. Locations of projects are shown on Plate 6, and profiles of proposed plans of development are shown on Plate 13. Other pertinent data are summarized on Tables 4 and 5.

Porcupine River System. Two alternative programs were open for consideration: first, development utilizing, as a unit, a 170-foot-high dam at the Bell site, and a



PORCUPINE RIVER SYSTEM



PEEL RIVER SYSTEM

PROFILES SHOWING PROPOSED DEVELOPMENTS IN NON-DIVERSION PLANS

TABLE 4

NON - DIVERSION PLANS

SUMMARY OF COST AND OUTPUT DATA

DEVELOPMENT	LOCATION	PURPOSE	ESTIMATED CAPITAL COST		ESTIMATED ANNUAL COST		AVERAGE REGULATED FLOW C.F.S.	AVERAGE H.K. KW/C.F.S.	ANNUAL FIRM ENERGY OUTPUT				AT - SITE POWER COST	
			INCREMENT	CUMULATIVE	INCREMENT	CUMULATIVE			INCREMENT		CUMULATIVE		INCRE.	CUM.
			\$	\$	\$	\$			MW-YR	KWHx10 ⁶	MW-YR	KWHx10 ⁶	MILLS/KWH	MILLS/KWH
PORCUPINE RIVER SYSTEM														
Bell Site Project	Porcupine River	Storage And Power Generation	82,345,000	82,345,000	5,082,000	5,082,000	7,100	9.78	69.4	608	69.4	608	8.4	8.4
Porcupine Canyon Project	Porcupine River	Storage And Power Generation	96,863,000	179,208,000	6,024,000	11,106,000	10,300	10.22	105.3	922	174.7	1,530	6.5	7.3
PEEL RIVER SYSTEM														
Aberdeen Falls Project	Peel River	Storage And Power Generation	204,856,000	204,856,000	12,148,000	12,148,000	7,200	26.29	189.3	1,658	189.3	1,658	7.3	7.3
Bonnet Plume Project	Peel River	Power Generation	86,275,000	291,131,000	5,298,000	17,446,000	7,200	17.04	122.7	1,075	312.0	2,733	4.9	6.4

470.339M

4.263 GWh

- 57a -

TABLE 5

PROJECT DATA FOR NON-DIVERSION PLANS

PROJECT	STREAM	POOL		AVERAGE TAIL- WATER ELEV.	STORAGE		HEAD			No. OF UNITS	GENERATORS UNIT RATING K.V.A	PLANT CAPACITY K.W	HYDRAULIC CAPABILITY AT RATED HEAD C.F.S	NOMINAL PRIME OUTPUT M.W
		MAX. ELEV.	MIN. ELEV.		TOTAL	USABLE	MAX.	MIN.	RATED					
		Feet	Feet	Feet	Acre Feet	Acre Feet	Feet	Feet	Feet					
PORCUPINE RIVER SYSTEM														
Bell	Porcupine	1,030	1,008	890	15,052,000	5,652,000	140	118	131	3	40,500	114,000	12,600	69.4
Porcupine Canyon	Porcupine	890	856	740	6,973,000	3,539,000	150	116	136	4	49,500	188,000	20,300	105.3
PEEL RIVER SYSTEM														
Aberdeen Falls	Peel	1,140	1,010	740	3,323,000	2,913,000	400	270	353	4	118,000	448,000	18,500	189.3
Bonnet Plume	Peel	740		510			250		228	2	94,200	198,000	11,500	122.7

200-foot-high dam at the Porcupine Canyon site, which together would provide for complete regulation of the river; and, secondly, development of the entire reach in a single step utilizing a dam some 340 feet high at the Porcupine Canyon site.

A high Porcupine Canyon project would permit greater use of the water resources, since the entire runoff in the Porcupine River basin in Canada would flow over the head created at this project. On the other hand, the pool created by this project would have a surface area of some 2,700 square miles, from which evaporation losses would just about nullify any head advantage it would have over the Bell-Porcupine Canyon combination. Tentative studies indicated a net gain in prime-power output of less than 20 mw with the use of a high Porcupine Canyon project instead of the two lower projects.

In a final analysis, the over-riding consideration would be to select a system which could be developed in stages to meet the growth in load demand, and at the same time, would keep the initial capital costs and construction period to a minimum. The studies indicated that these objectives could best be met by selecting the Bell project for initial development, followed by a low Porcupine Canyon project. Consequently, such a system was used in the present report to permit a more realistic appraisal of power output and costs.

The total active storage capacity in the Bell-Porcupine Canyon system would be 9 million acre-feet. With a total installed capacity of 300,000 kw, the system would be capable of generating about 174,000 kw of prime power, or the equivalent of 1.5 billion kwh of firm energy annually. The average system cost of energy production is estimated to be about 7.3 mills per kwh at site.

Stage 1 - Bell Project, a combined storage and power development

The project would be constructed to a full-pool elevation of 1,030 feet to provide 5.6 million acre-feet of active storage. With a firm-power draft of 7,100 cfs, and operating under an average head of 132 feet, the project would be capable of generating about 69,000 kw of prime power, or the equivalent of 608 million kwh of firm energy annually. With an installed capacity of 110,000 kw, the capital cost of the project is estimated to be \$82,000,000. The average cost of firm-energy production in this initial stage of development would be about 8.4 mills per kwh at site.

Stage 2 - Porcupine Canyon Project, a combined storage and power development

The project would be developed to a full-pool elevation of 890 feet so as not to encroach on the tailwater of the Bell project upstream. Regulation at the Bell project,

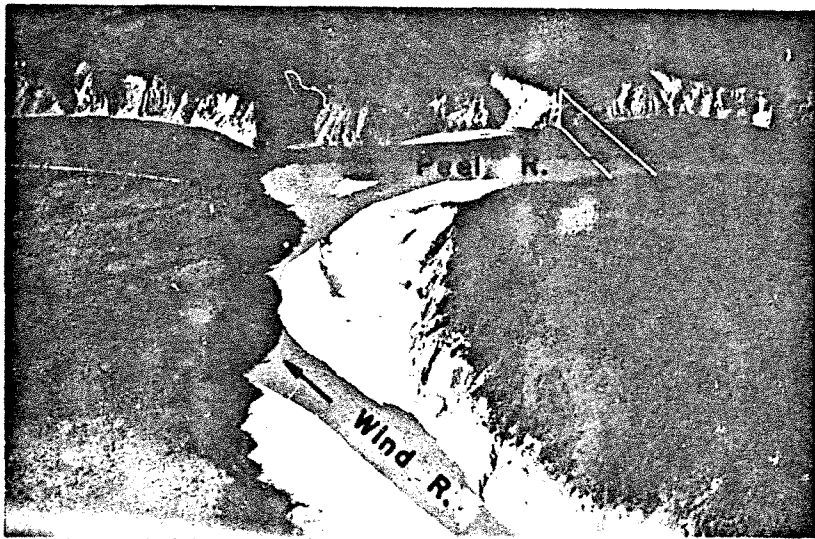
together with 3.4 million acre-feet of active storage at the Porcupine Canyon reservoir, would make available a firm regulated flow of 10,300 cfs for power generation. With an installed capacity of 190,000 kw operating under an average head of 138 feet, the project would be capable of generating about 105,000 kw of prime power, or the equivalent of 922 million kwh of firm energy annually. The capital cost of the project is estimated to be \$97,000,000. The cost of firm-energy production for the Stage 2 increment would be about 6.6 mills per kwh at site. The average system generation cost, therefore, would be about 7.3 mills per kwh at site.

Peel River System. Three sites were examined on the Peel River which could be used to develop the hydro-electric power potential of the river. At all three sites, the river flows through narrow rock-lined gorges where bedrock is believed to occur in the riverbed at relatively shallow depths. These sites are listed below in downstream order, and their locations indicated on Plate 6.

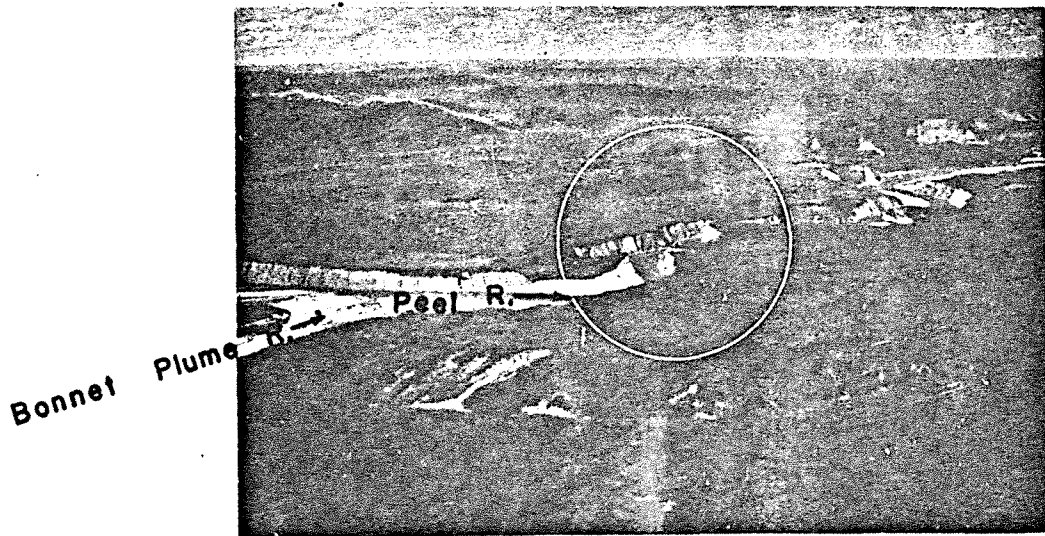
- Aberdeen Falls site - possible development as a combined storage and power project
- Wind River site - possible development as a run-of-river power project
- Bonnet Plume site - possible development as a run-of-river power project

Storage capacity on the Peel River would be expensive to develop because of steep river gradients and generally

PEEL RIVER SITES



WIND RIVER SITE
LOOKING TOWARDS LEFT ABUTMENT



BONNET PLUME SITE
LOOKING DOWNSTREAM

narrow valleys. Favourable topography for construction of a high dam on the Peel River to create appreciable storage volume for streamflow regulation is found only at the Aberdeen Falls site. However, below the Aberdeen Falls site, the Wind and Bonnet Plume Rivers, with a combined drainage area of some 9,000 square miles, would contribute substantial inflow to the Peel River. Unfortunately, downstream projects at either the Wind River or the Bonnet Plume sites would not develop any significant amount of storage to control the highly fluctuating inflow from these tributaries. Consequently, in order to make the most effective use of the available water supply, a storage development at the Aberdeen Falls project would have to be large enough to firm up generation at these downstream plants.

In view of the fact that hydrologic data is not presently available for the area contributory to the Wind and Bonnet Plume Rivers, no attempt was made to estimate the capabilities of projects on the Peel River in system operation.

From the above discussion, it is obvious that the initial step in the development of hydro-electric power on the Peel River would have to be a combined storage and power project at the Aberdeen Falls site. The economic height for the project is not so apparent. As an initial project, the structure would have to stand alone for some time as an independent power producer. The economics and costs of initial development

would depend on conditions of operation and the load demand which, in turn, would determine what amount of storage and head should be utilized.

(a) Aberdeen Falls Project. For the purpose of this report, the study of the Aberdeen Falls project was based on the arbitrary use of the top one-third of the reservoir for streamflow regulation to provide a firm regulated flow equivalent to 90% of the estimated mean flow of the river at the project site.

At a full-pool level of 1,140 feet, the top one-third of the reservoir would contain 2,900,000 acre-feet of usable storage. This amount of storage would be adequate for cyclic regulation to yield an average firm regulated flow of about 7,200 cfs. At an average head of 355 feet, the project would be capable of generating 190,000 kw of prime power, or the equivalent of about 1.7 billion kwh of firm energy annually.

While either a concrete or rockfill structure could be developed at the Aberdeen Falls site, in this study the estimate was based on a concrete-gravity structure about 415 feet high. With an installed capacity of 450,000 kw, the capital cost of the project would be about \$205,000,000. The average cost of firm-energy production is estimated to be about 7.3 mills per kwh at site.

(b) Bonnet Plume Project. A study was made of the Bonnet Plume project to develop in one step a gross head of 230 feet, backing water up to the tailwater of the Aberdeen Falls project. This study was based entirely on regulated releases from an upstream project at Aberdeen Falls. No provisions were made in the estimates for the utilization of uncontrolled inflow from the Wind and Bonnet Plume Rivers. Such an estimate was made at this time merely to obtain a rough approximation of the capabilities of the site.

A concrete-gravity structure about 270 feet high would create a pool with a surface elevation of 740 feet. Operating as a run-of-river plant with an average regulated flow of 7,200 cfs, the Bonnet Plume project would be capable of generating 122,000 kw of prime power, or the equivalent of 1.1 billion kwh of firm energy annually. The total installed capacity of the project would be 198,000 kw and the estimated capital cost of the project is \$86,000,000. The average cost of firm energy from the Bonnet Plume increment would be about 5 mills per kwh at site. The average system generation cost including the Aberdeen Falls project would be about 6½ mills per kwh at site.

It is possible by system operation to increase the power output of the Bonnet Plume project through the use of storage and power generation at the Aberdeen Falls project to firm up generation from the uncontrolled inflows of the Wind

and Bonnet Plume Rivers. Alternatively, it might be more advantageous to provide electrical co-ordination with a system on the Porcupine River, utilizing the vast and relatively cheap storage available in that basin for firming purposes. However, such considerations have not received detailed study in this report.

6. Comparison of Plans

Porcupine River System. The development of the water resources of the Porcupine River by diversion to the Rat River would result in almost a four-fold increase in annual firm-energy output over the non-diversion plan. In the absence of diversion, the projects on the Porcupine River in Canada would be capable of generating about 1.5 billion kwh of firm energy annually; and, with diversion, the water from the Porcupine River basin in Canada could be utilized by projects on the Rat River to develop about 5.7 billion kwh of firm energy annually.

Peel River System. Under the diversion plan, the Peel River would be added only at the ultimate stage of the program after complete development of the Porcupine-Rat River system. It would not be worth while diverting Peel River flow until the water could be used through the entire head developed on the Rat River.

On the other hand, early development of the Peel River system in a non-diversion plan would present a problem of providing a project small enough to match up with initial market requirements. The regime of the river and the topography of the basin are such that the necessary storage could be obtained only by the construction of a large structure at the Aberdeen Falls site.

At the present stage of the studies, it is not possible to indicate which plan of development, diversion or non-diversion, would accomplish greater utilization of the water resources of the Peel River basin. Certainly, water diverted to the Rat River would be utilized over a greater head than that possible of development on the Peel River itself. Such diversion, however, would reduce appreciably the volume of flow on the Peel River at the Wind and Bonnet Plume sites and would, accordingly, reduce the usefulness of these sites for power development. In view of the large inflow from the Wind and Bonnet Plume Rivers, it is conceivable that, by electrical co-ordination with other power sources for firming purposes, a non-diversion system on the Peel River could produce as much power as by diversion development. Further studies would be required to provide a more definitive appreciation of such a proposal.

SECTION 6 - DISCUSSIONS

The results of investigations and studies of the hydro-electric power potential of the Porcupine, Peel, and Rat River region undertaken for this report have been presented in the way of an inventory to indicate the possibilities available for development when needed. No attempt was made to deal with such aspects as the potential market for hydro-electric power generated in the region, power transmission, and the economics of water power versus thermal power. Although detailed considerations of such factors are beyond the scope of the present investigation, a general discussion of these factors would be appropriate to round out the study.

1. Potential Market

No significant development has taken place in the region to date which would present a potential market for a sizable block of power. Power requirements at nearby settlements of Old Crow, Y.T., and Fort McPherson, Aklavik, and Inuvik in the Northwest Territories are small and do not constitute a potential power market of any consequence.

Knowledge of the mineral resources of the region is still limited. Recently a major iron-ore deposit was found

in the Snake River area of the Peel River basin. This discovery may prove to be economically attractive for a development requiring a substantial amount of power for processing purposes. A transmission line of less than 200 miles long could deliver power from projects on the Porcupine or Rat River to a processing area located in the immediate vicinity of the iron-ore deposits.

2. Power Transmission.

The terrain in the Porcupine, Peel, and Rat River region would not present any difficult problem in transmission-line design and in providing suitable right-of-way for transmission routes. The entire region is virtually uninhabited, and tree growth is sparse, requiring little or no clearing of right-of-way.

As a rough approximation, the average cost of transmitting power from projects in this region to a load centre located some 200 miles away may be taken to be about 2 mills per kwh. In the initial stage, the cost would be much higher because transmission facilities would not be fully utilized until system development is well advanced.

3. Alternative Sources of Power

A common yardstick for appraising the economics of hydro-electric power generation is to compare the costs with alternative thermal-electric generation.

Although mineral fuels such as coal, gas and oil are known to occur in the region, no comprehensive data are available as to the size of their occurrence. In the past few years extensive exploration programs have been undertaken in the region by several oil companies in their search for petroleum deposits. To date, four test wells have been drilled in the area. Although shows of gas and oil were believed to have been found in some wells, their potential is still unknown. Therefore, at the present time, to provide a valid comparison of thermal alternative to hydro-electric power generation, the costs of large-scale thermal-electric generation would have to be based on the assumption that fuel would be imported into the region.

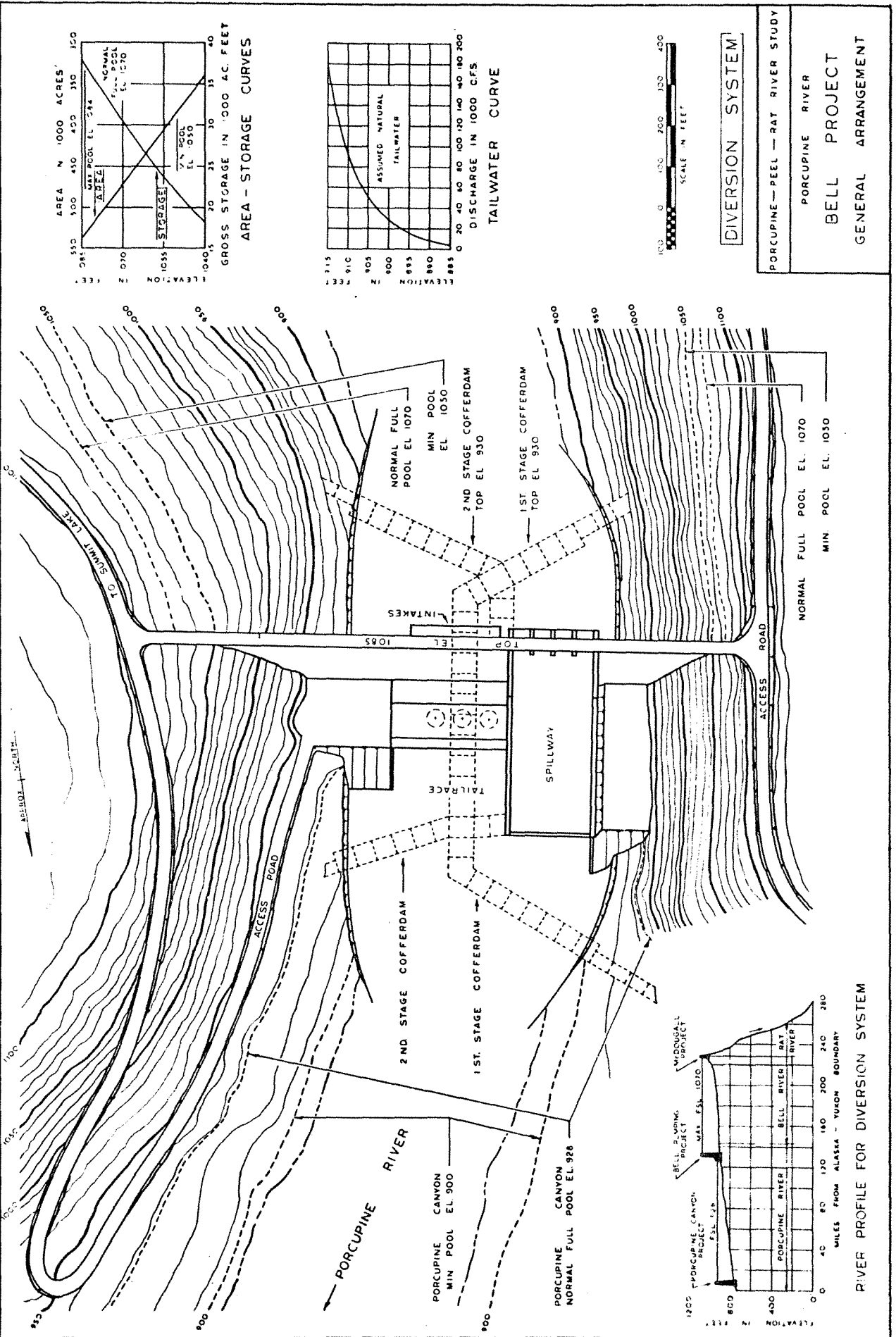
Statistics of operating utilities in Alaska show that the cost of power from fuel-burning plants ranges from 17 mills per kwh in southeast Alaska to nearly 50 mills per kwh in outlying areas of the interior part of the state. 1/ In Canada, power from thermal-electric plants is marketed at

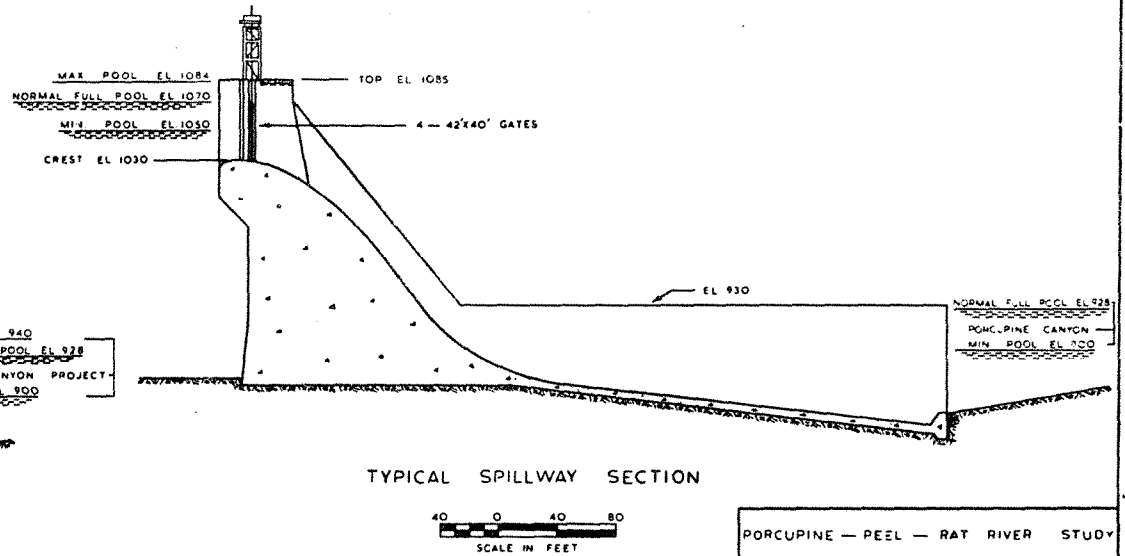
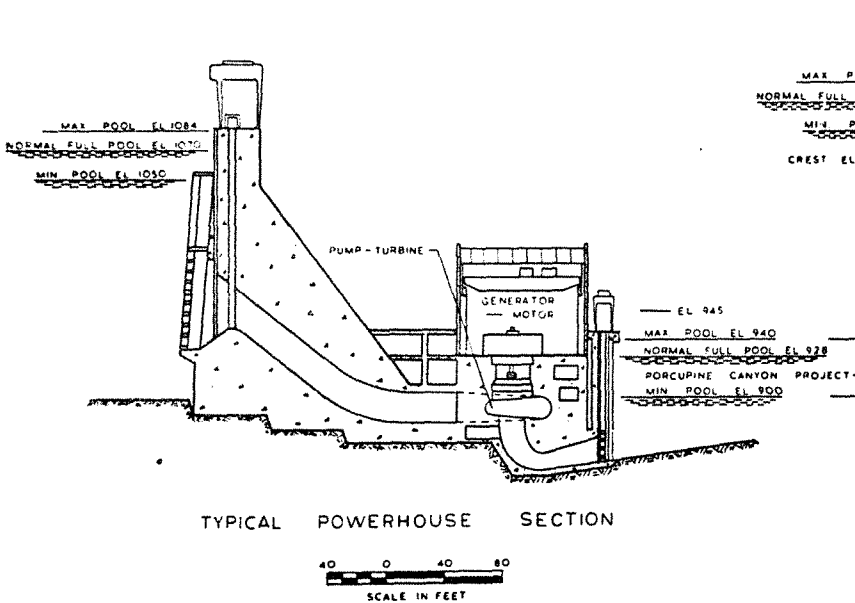
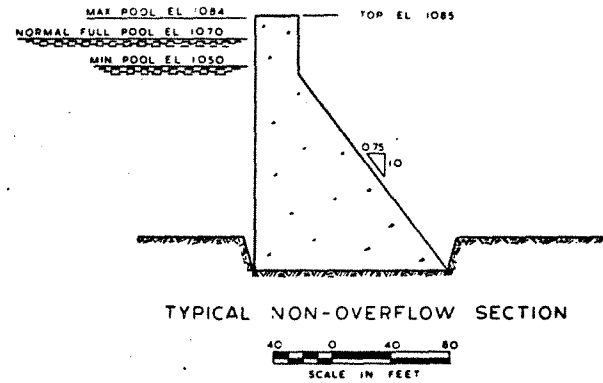
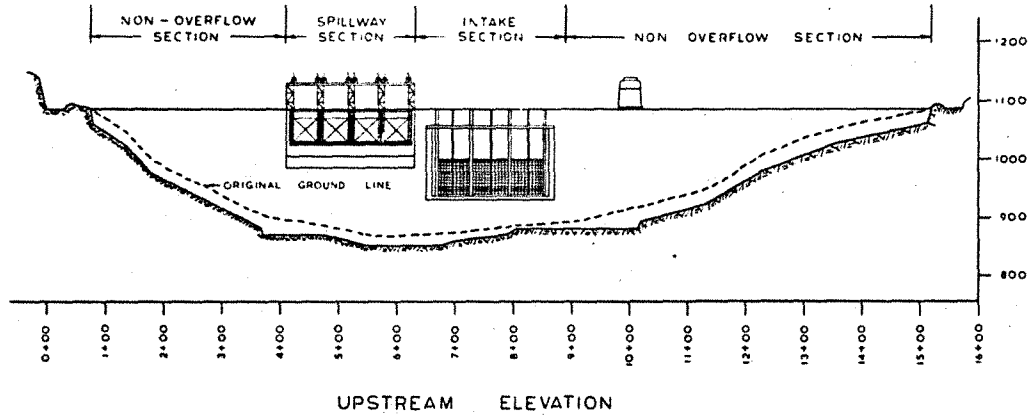
1 United States Department of the Interior, Rampart Project, Alaska, Market for Power and Effect of Project on Natural Resources, Juneau, Alaska, January 1965.

Inuvik and Fort Simpson, N.W.T., for about 55 and 65 mills per kwh, respectively. Power from hydro-electric plants ranges in costs from about 7 mills per kwh for the Snare River plant in the Northwest Territories to about 12 mills per kwh for the Whitehorse Rapids and Mayo plants in the Yukon Territory.

It would appear, therefore, that the cost of power from hydro-electric projects in the Porcupine, Peel, and Rat River region would compare favourably with present power costs in the north.

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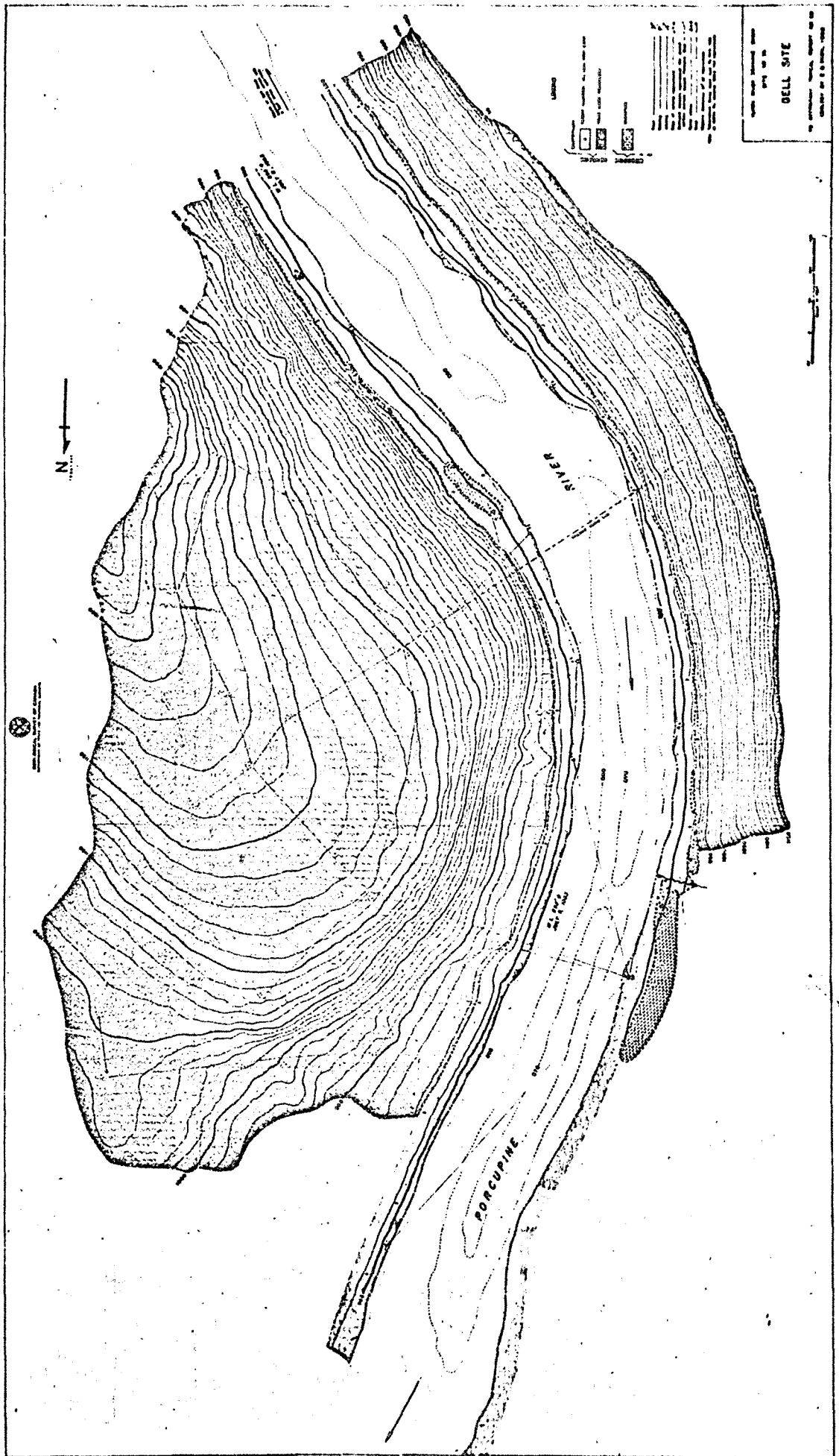


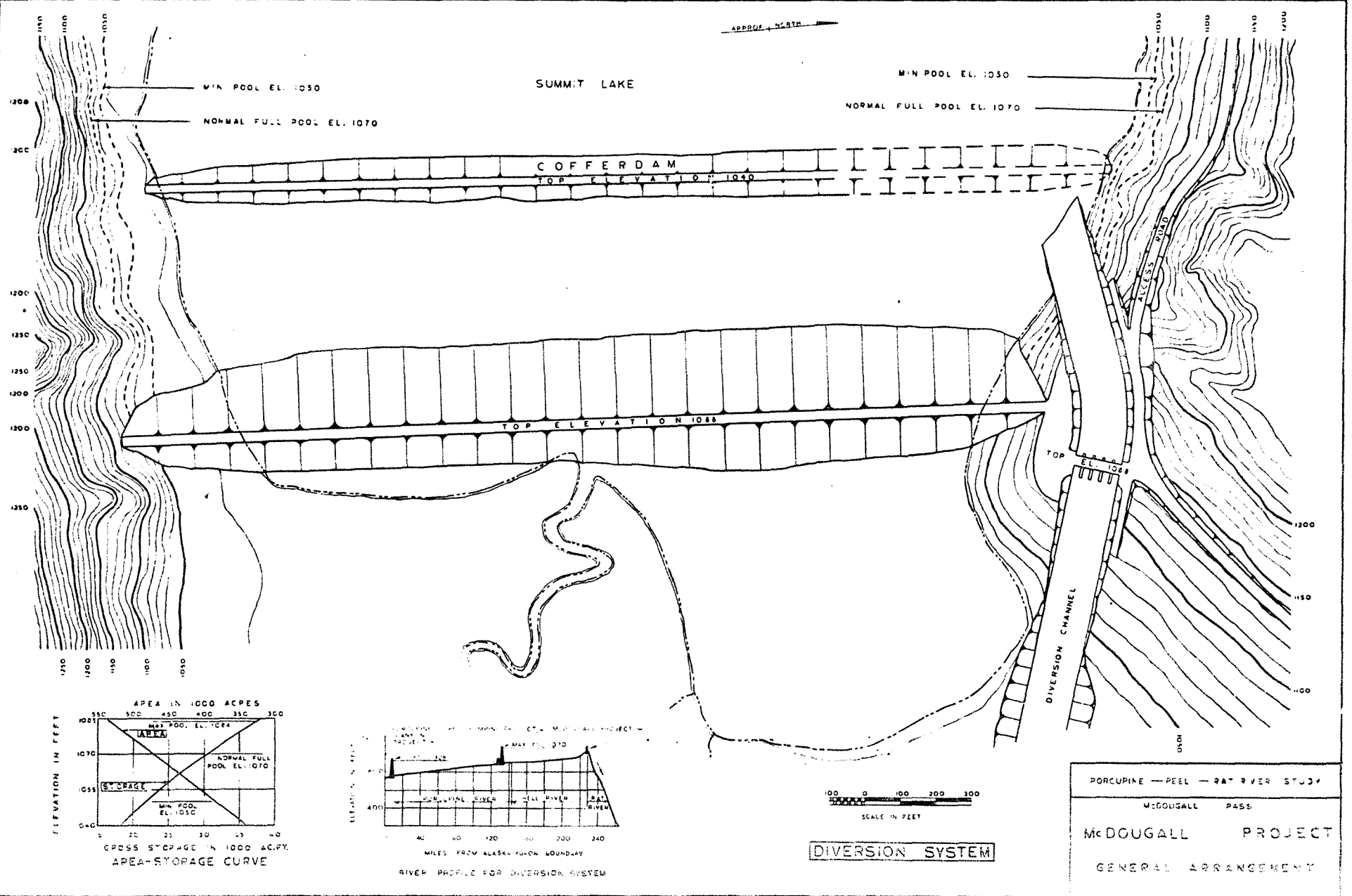


PORCUPINE - PEEL - RAT RIVER STUDY
 PORCUPINE RIVER
BELL PROJECT
 SECTIONS AND ELEVATIONS

DIVERSION SYSTEM

D I A T C 17

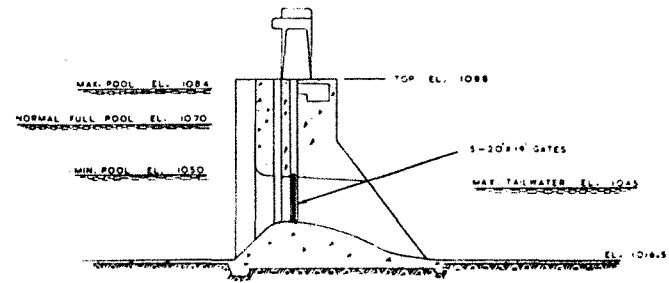




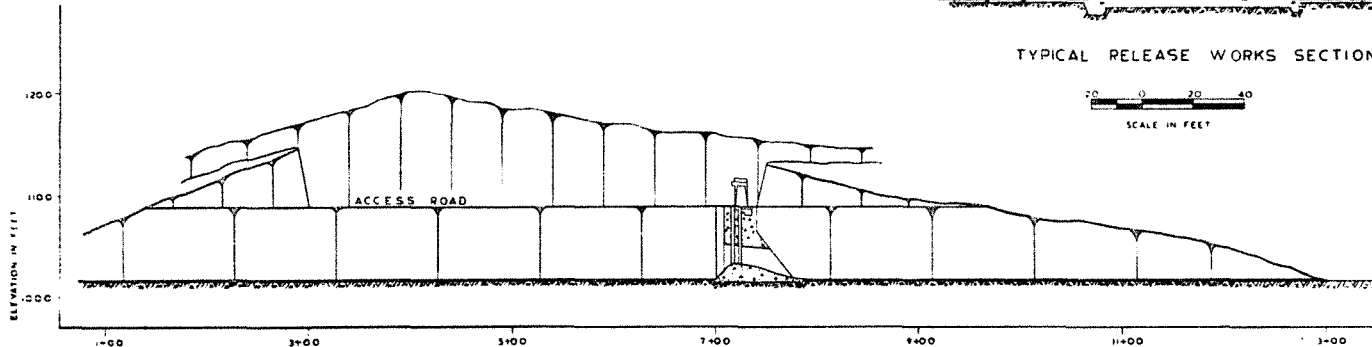
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TYPICAL EMBANKMENT SECTION



TYPICAL RELEASE WORKS SECTION



PROFILE DEVELOPED ALONG CENTER LINE OF DIVERSION CHANNEL

PORCUPINE - PEEL - RAT RIVER STUDY

MCDUGALL PASS

MCDUGALL PROJECT

SECTIONS AND ELEVATIONS

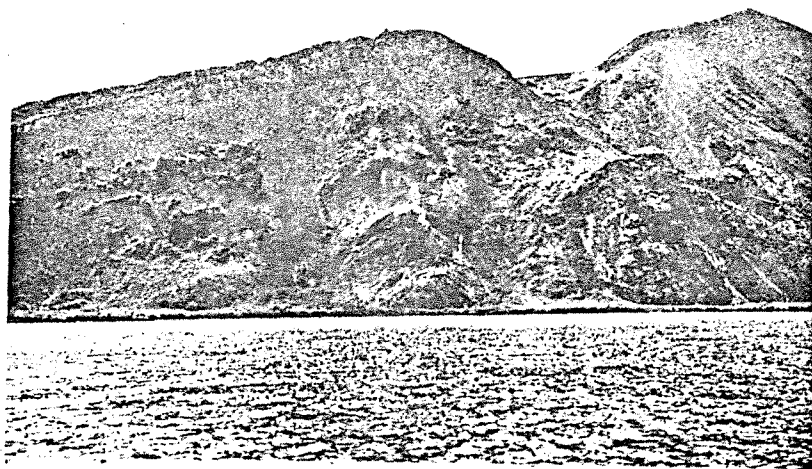
DIVERSION SYSTEM

- 11 -

McDOUGALL SITE

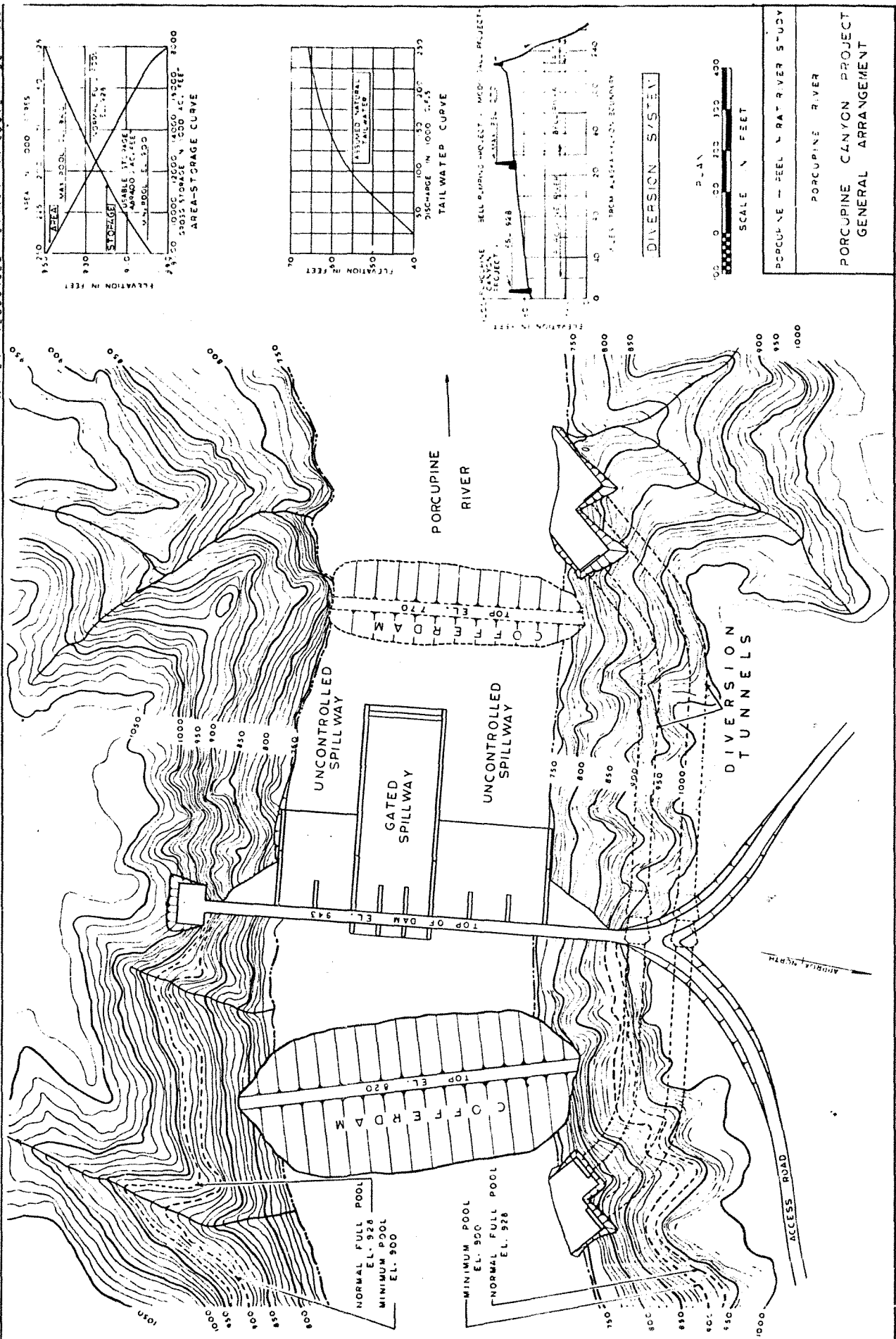


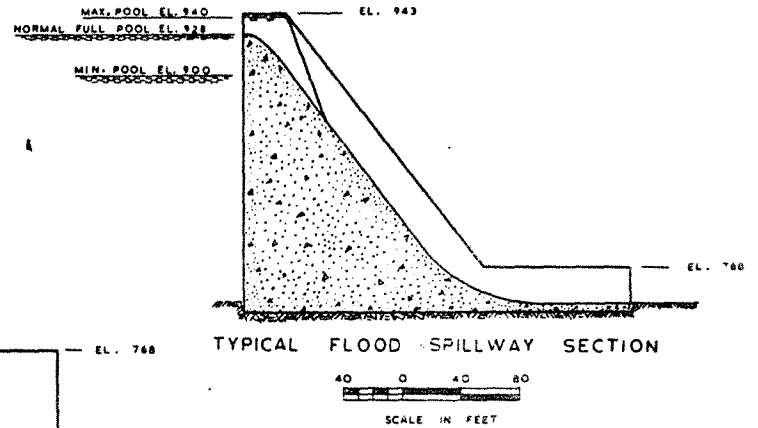
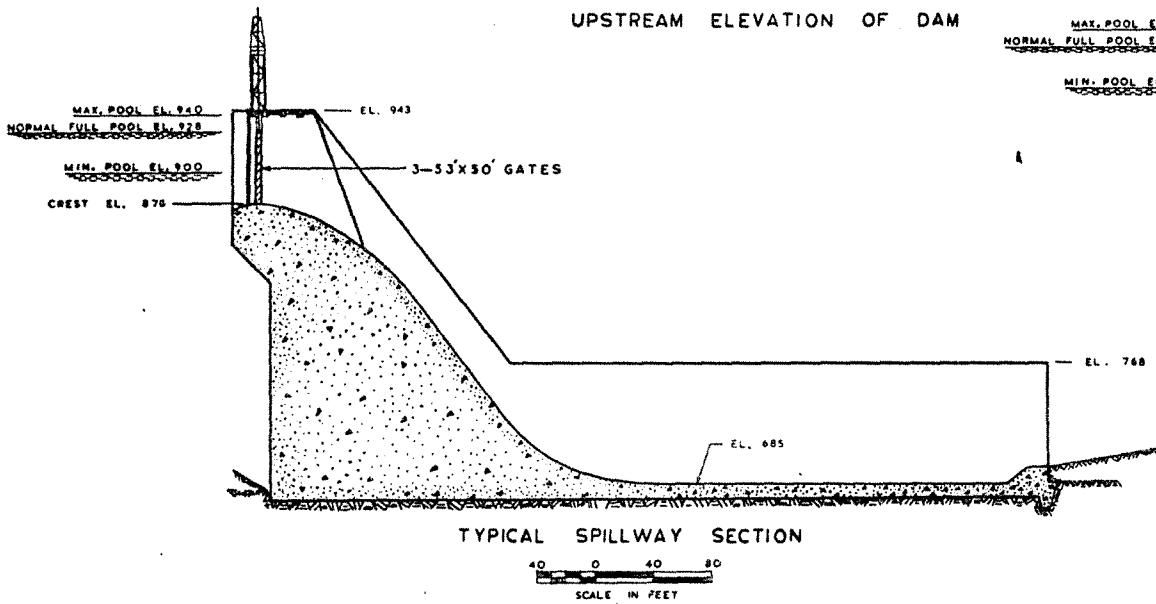
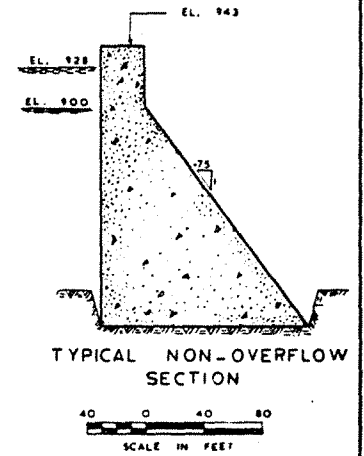
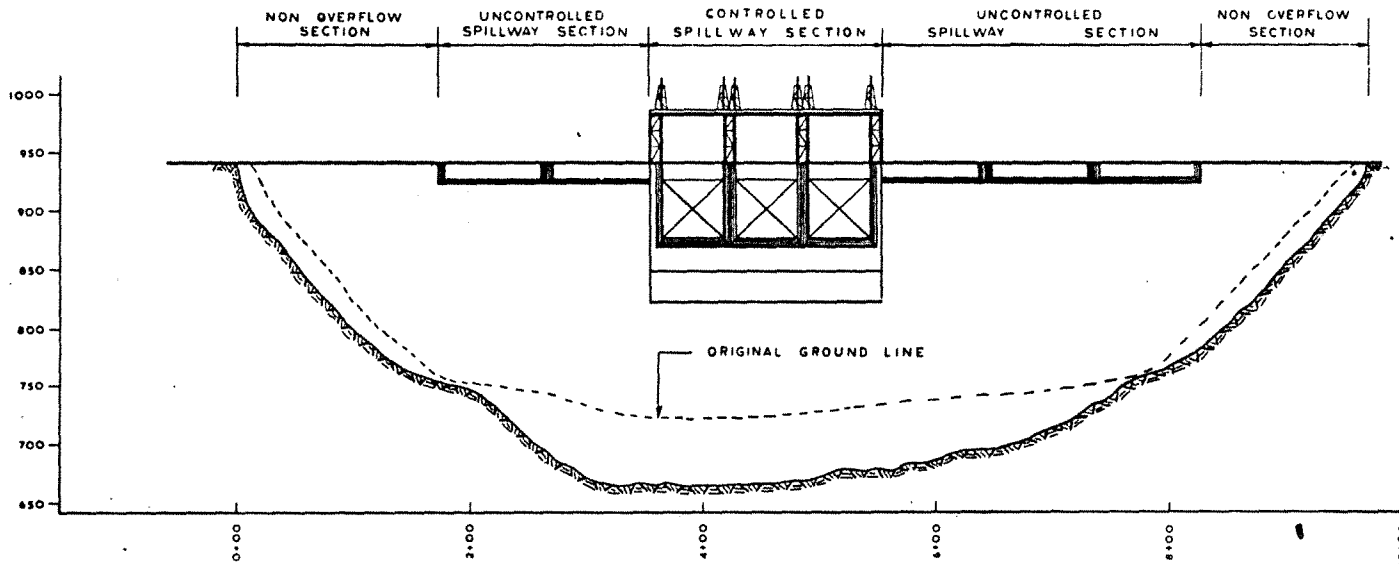
NORTH ABUTMENT



SOUTH ABUTMENT

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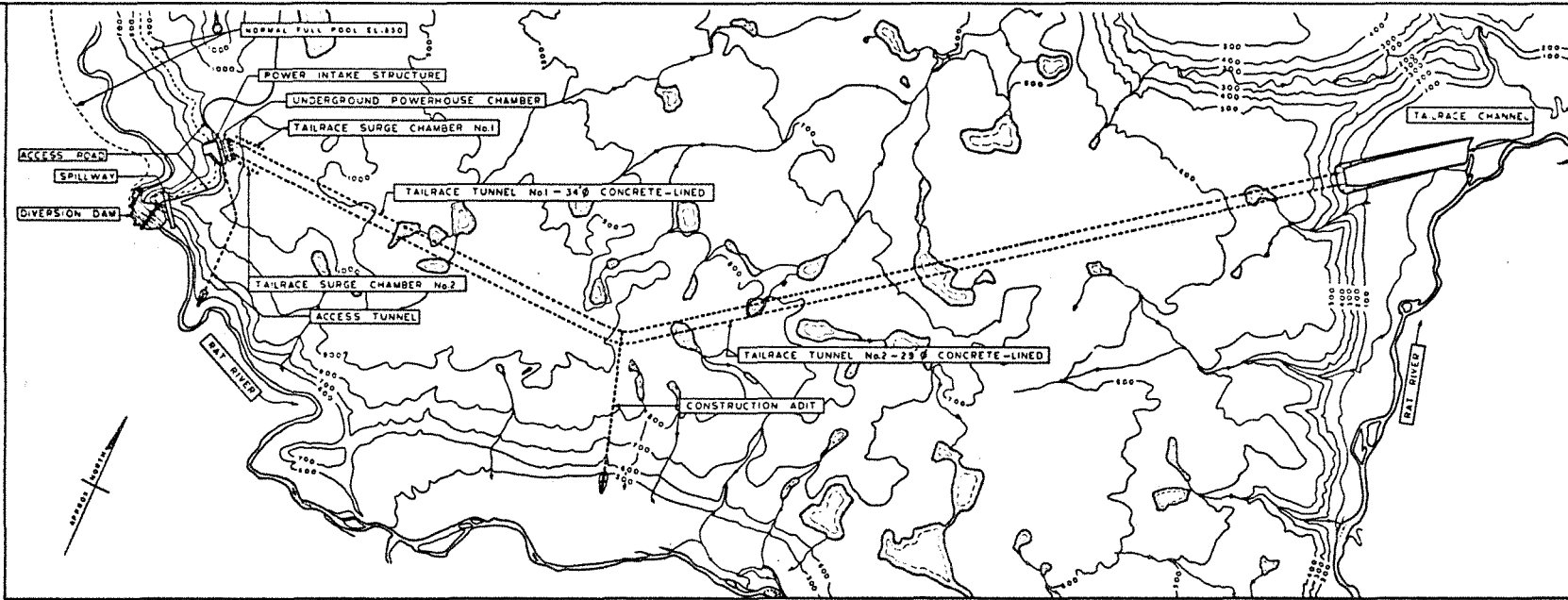
PORCUPINE - PEEL - RAT RIVER STUDY

PORCUPINE RIVER

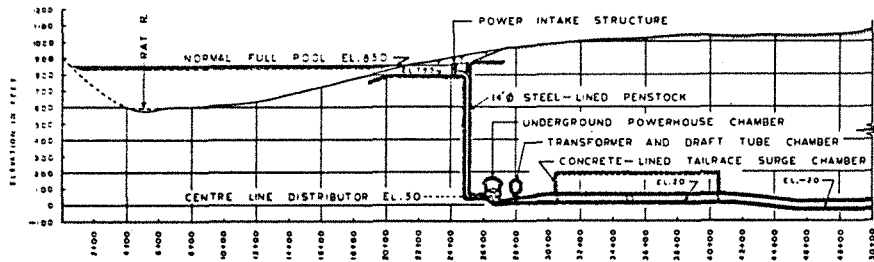
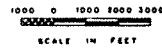
PORCUPINE CANYON PROJECT

SECTIONS AND ELEVATIONS

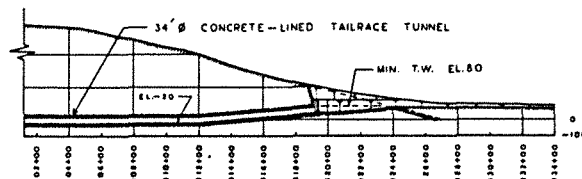
DIVERSION SYSTEM



GENERAL PLAN



DEVELOPED PROFILE OF POWER FACILITIES



DIVERSION SYSTEM

PORCUPINE - PEEL - RAT RIVER STUDY

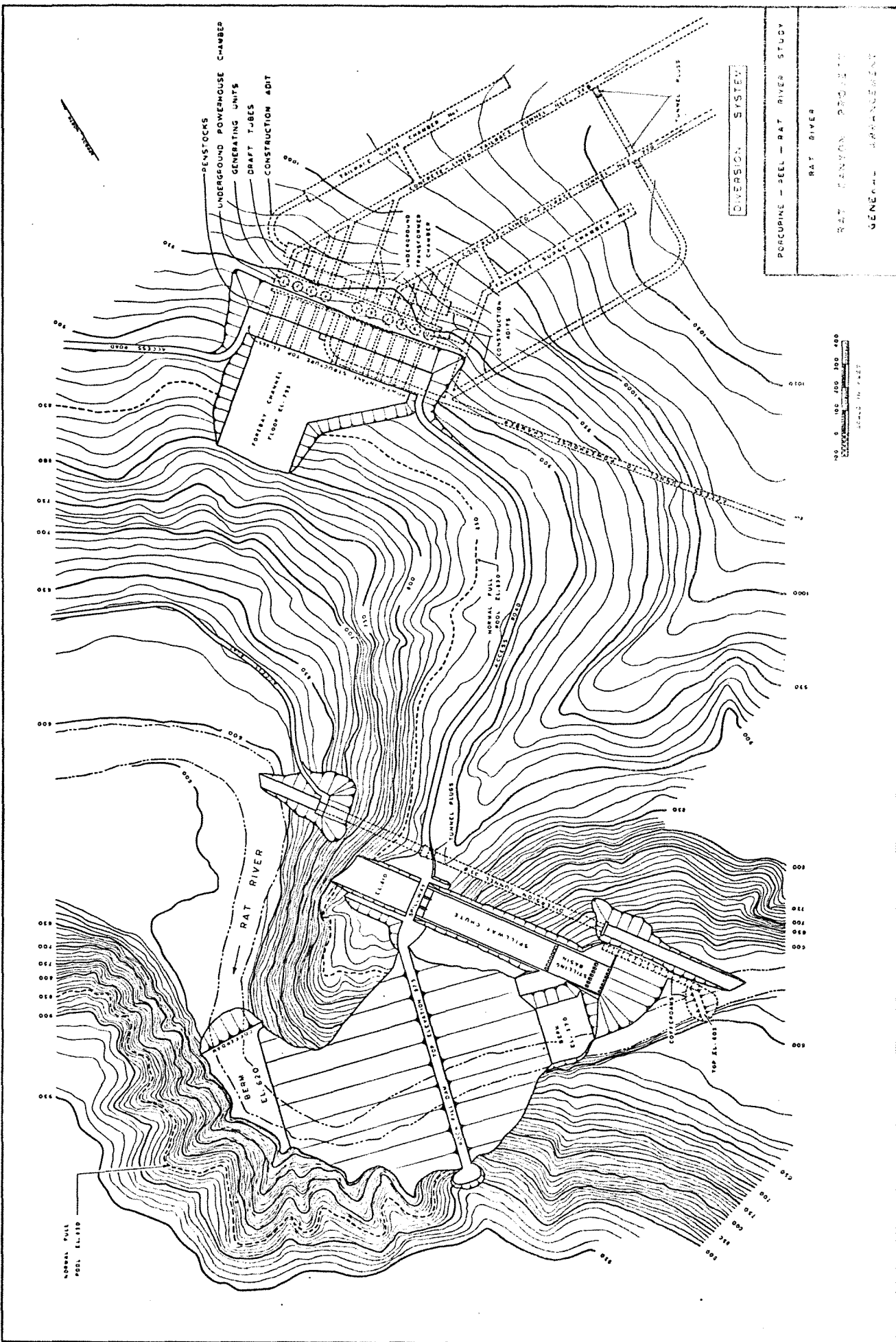
RAT RIVER

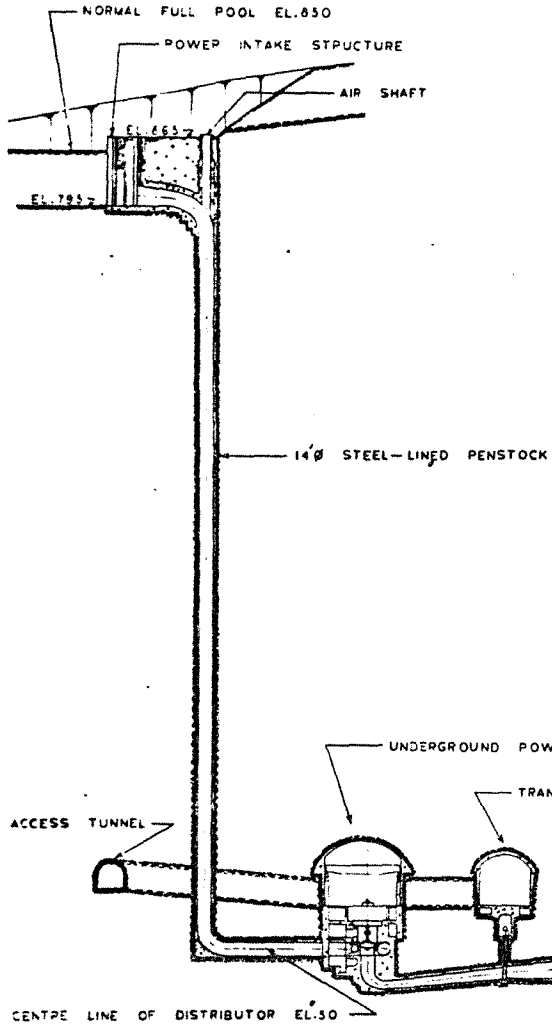
RAT CANYON PROJECT

GENERAL PLAN AND PROFILE

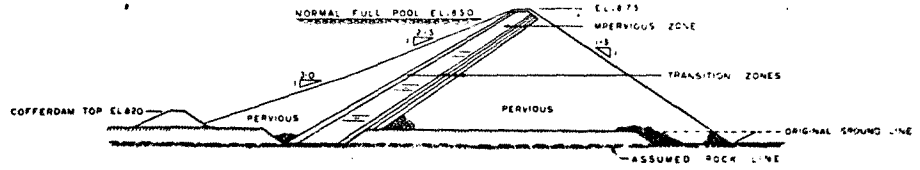
WATER RESOURCES BRANCH VANCOUVER B C 1963

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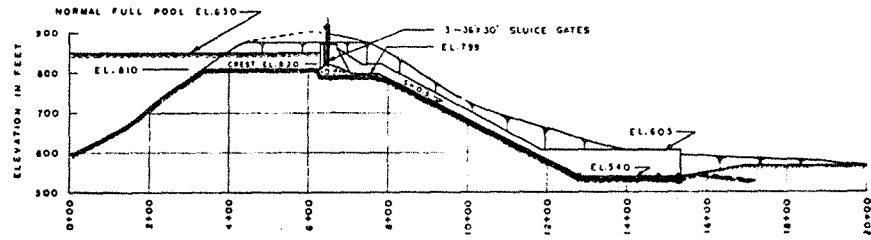
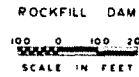




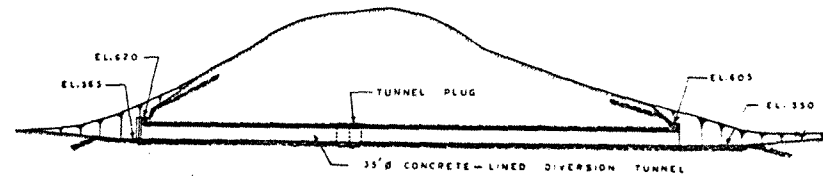
TYPICAL INTAKE AND POWERHOUSE SECTION



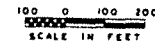
MAXIMUM EMBANKMENT SECTION



PROFILE OF SPILLWAY

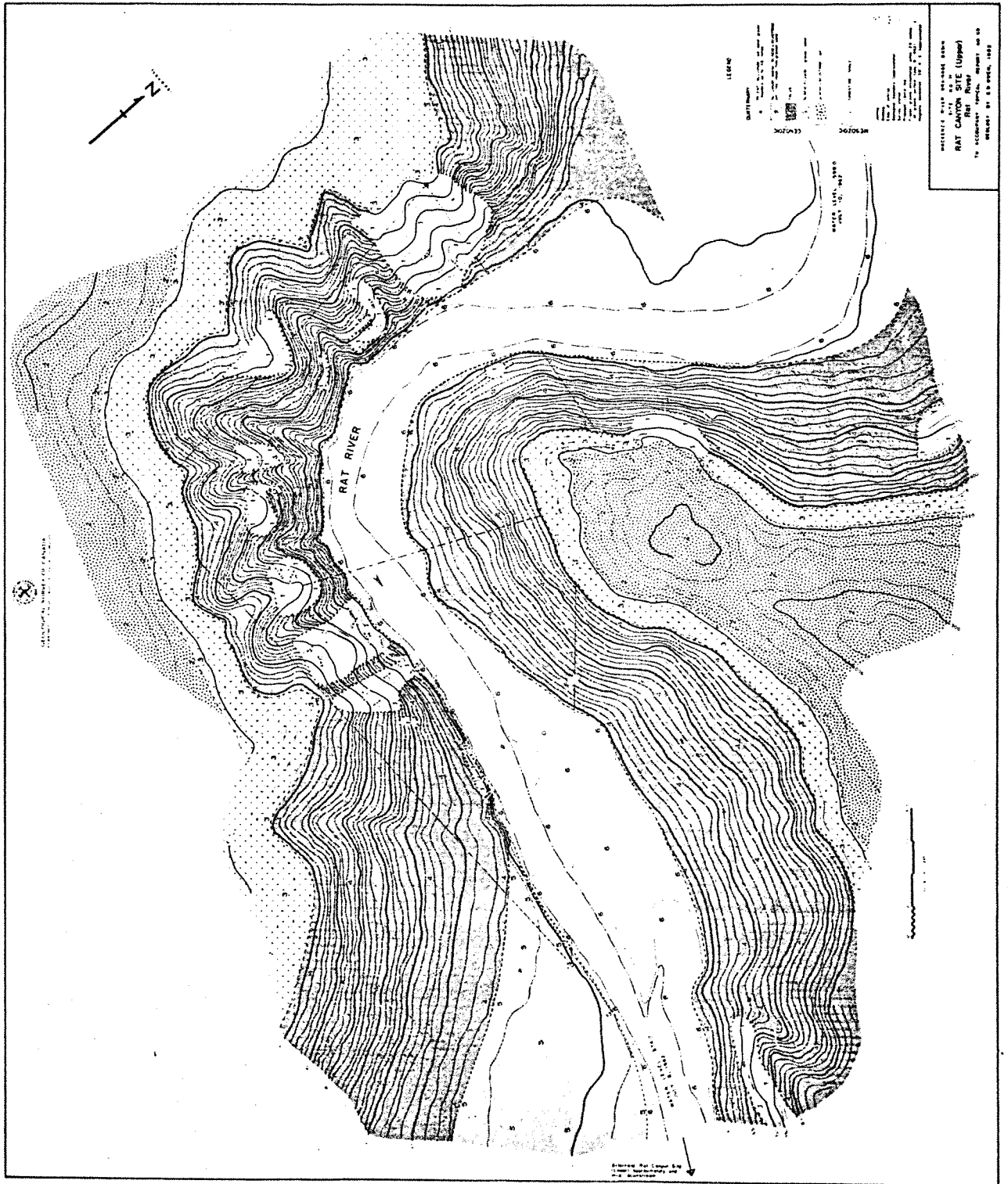


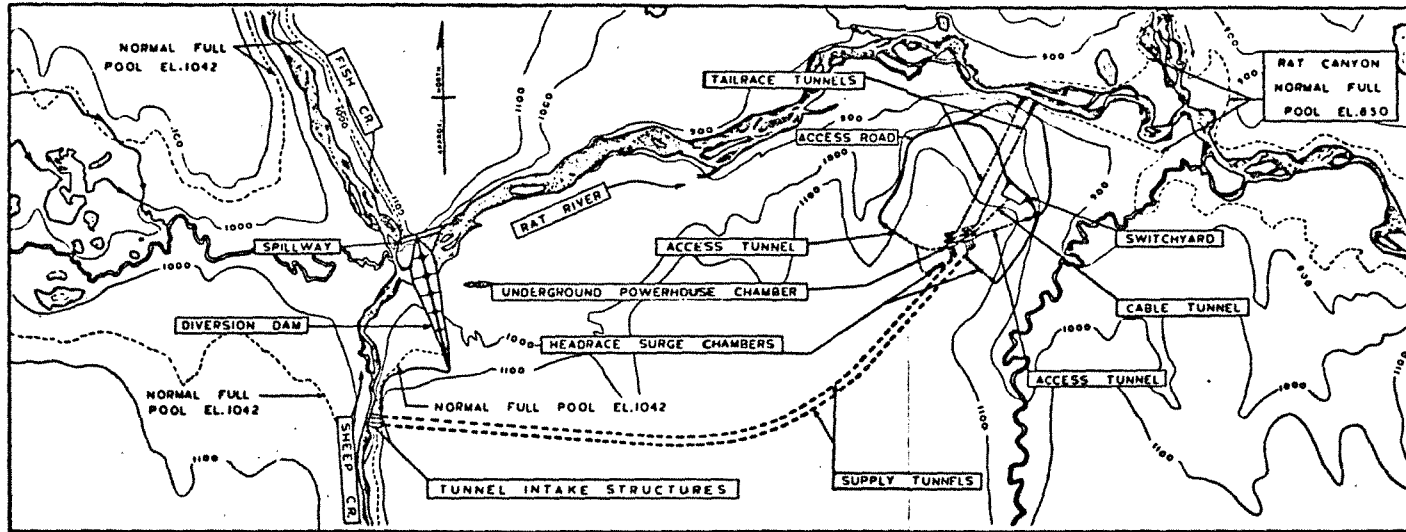
PROFILE OF DIVERSION TUNNEL



<p>PORCUPINE-PEEL-RAT RIVER STUDY</p> <p>RAT RIVER</p> <p>RAT CANYON PROJECT</p> <p>SECTIONS AND ELEVATIONS</p>

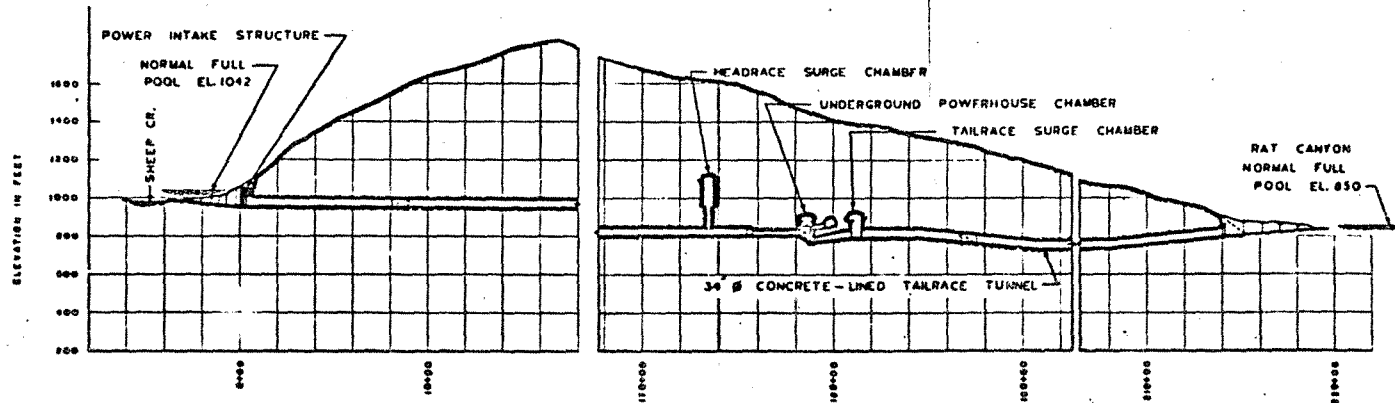
DIVERSION SYSTEM





GENERAL PLAN

1000 0 1000 2000 3000
SCALE IN FEET



DEVELOPED PROFILE OF POWER FACILITIES

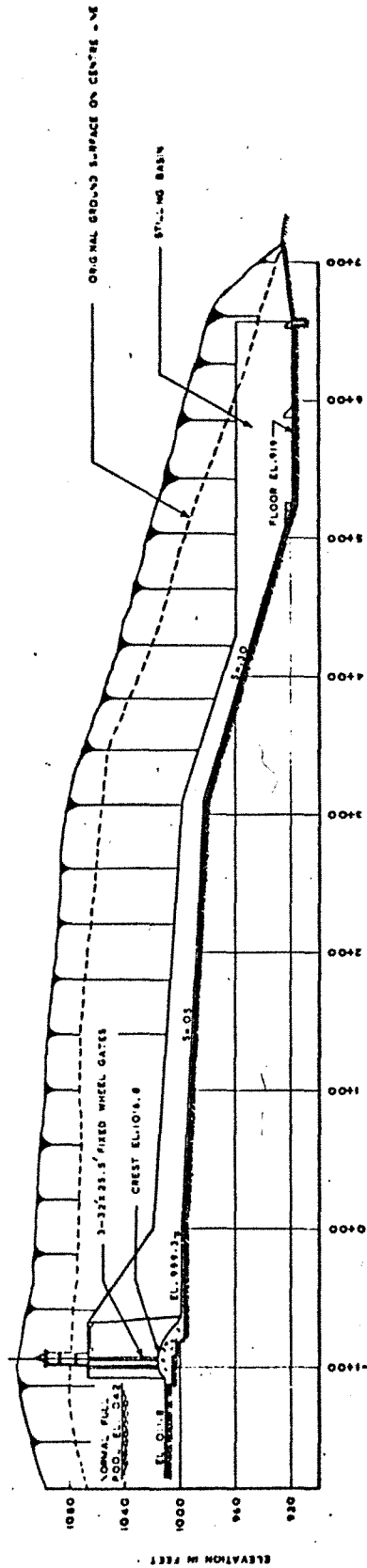
PORCUPINE - PEEL - RAT RIVER STUDY

RAT RIVER

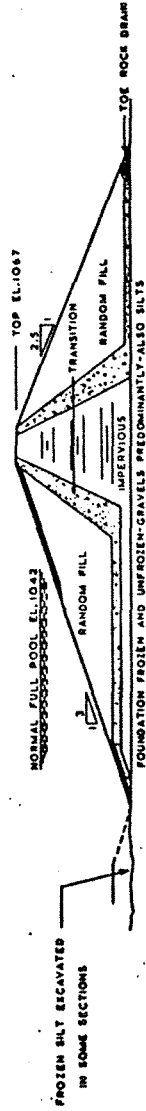
FISH CREEK PROJECT

GENERAL PLAN AND PROFILE

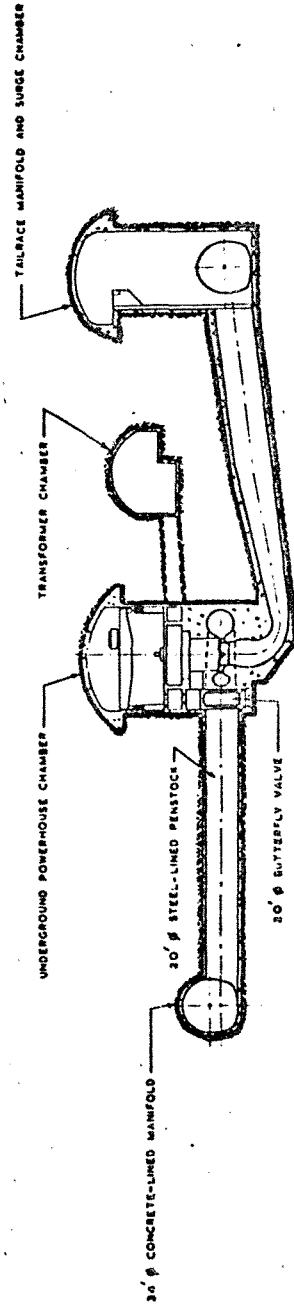
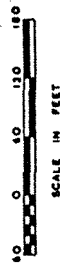
DIVERSION SYSTEM



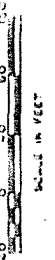
PROFILE OF SPILLWAY



MAXIMUM EMBANKMENT SECTION



SECTION THROUGH POWER CHAMBER



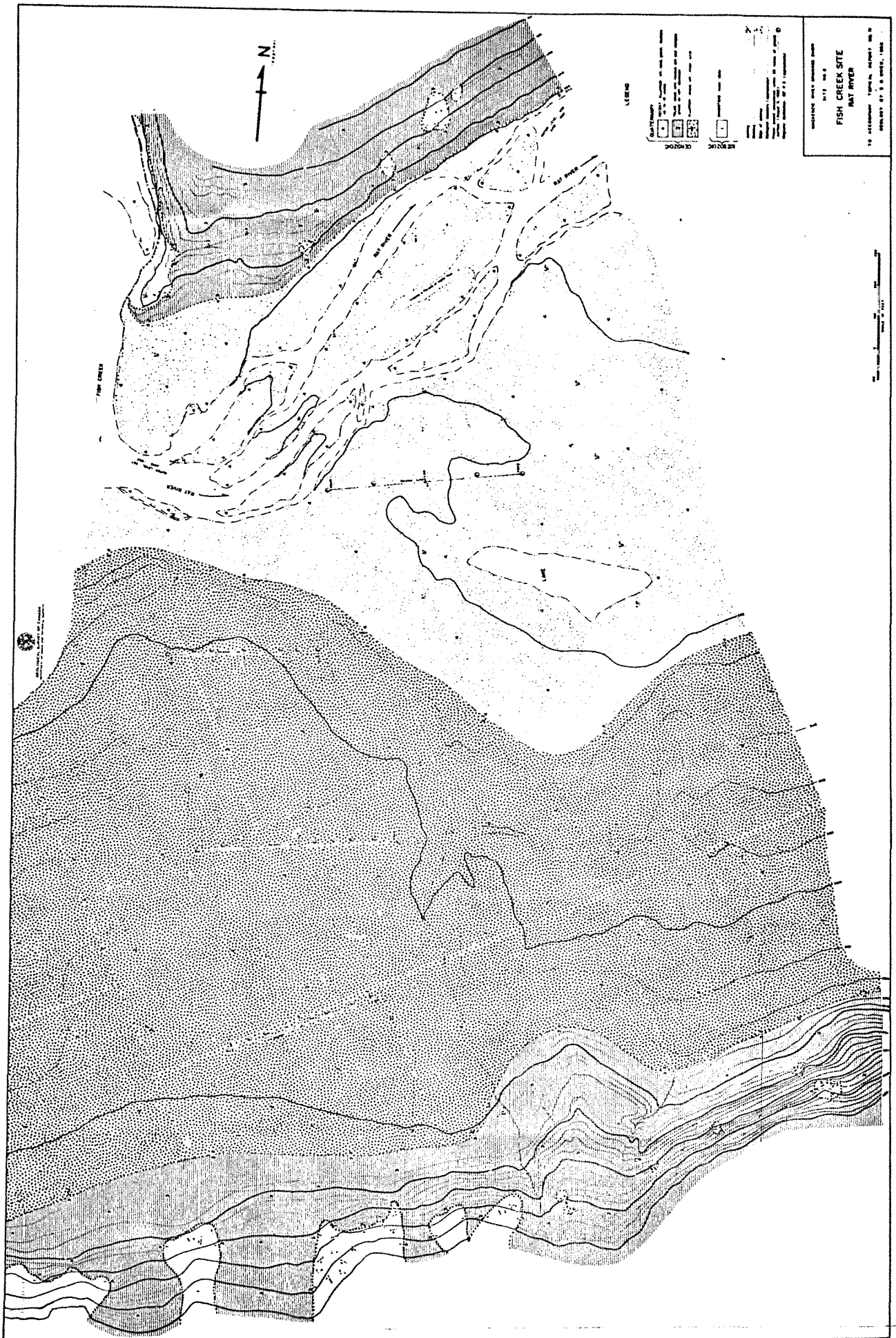
DIVERSION SYSTEM

PORCUPINE — PEEL — RAY RIVER STUDY

RAY RIVER

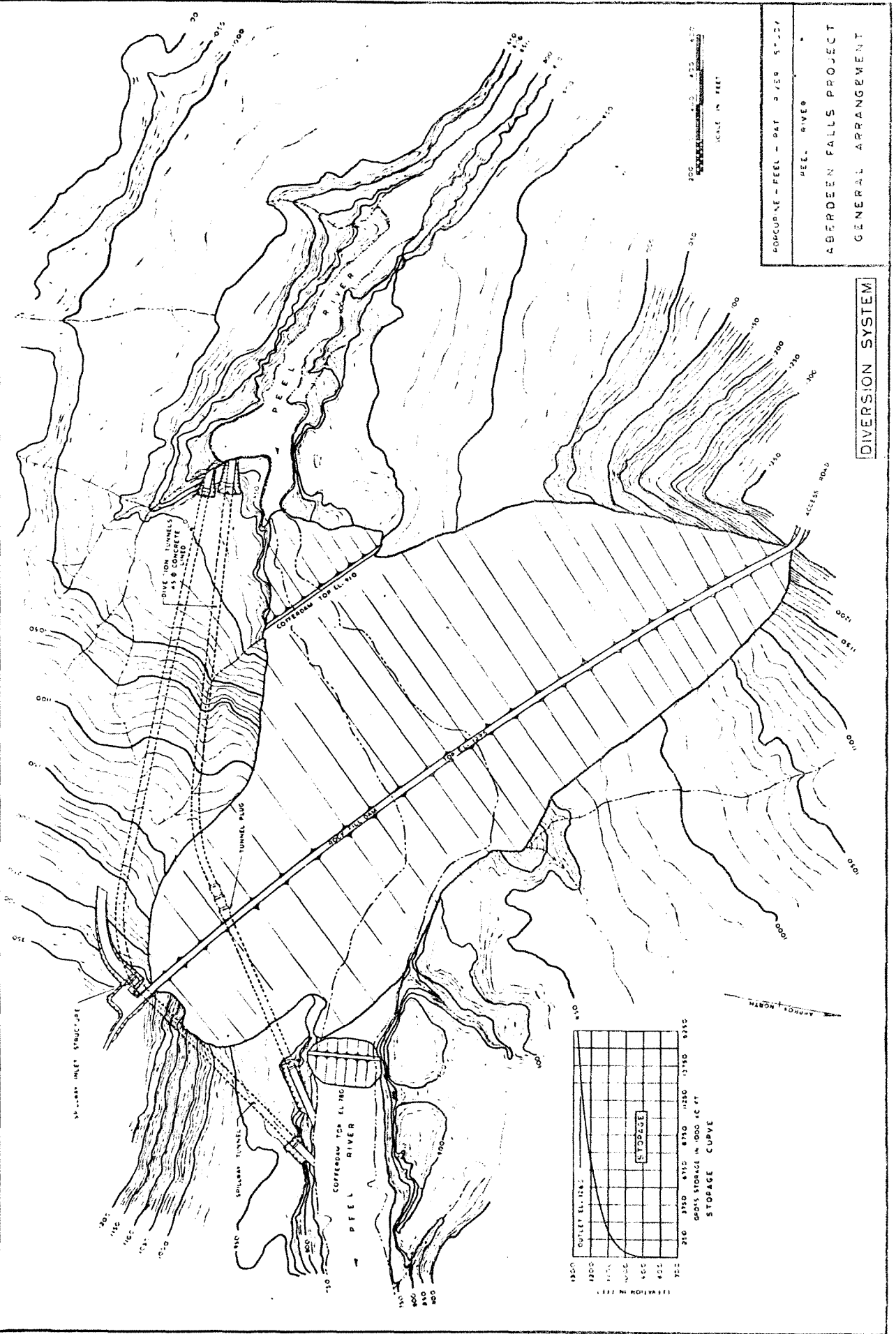
FISH CREEK PROJECT

SECTIONS AND ELEVATIONS



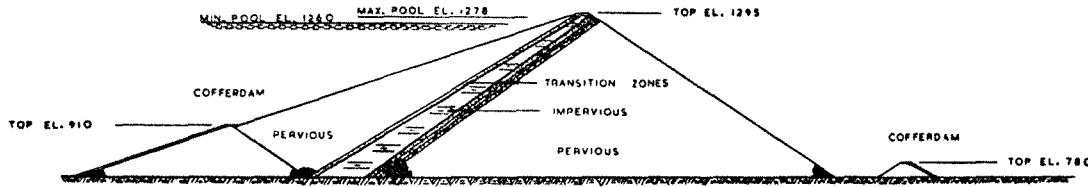
WATER RESOURCES BRANCH - VANCOUVER B.C. 361

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES

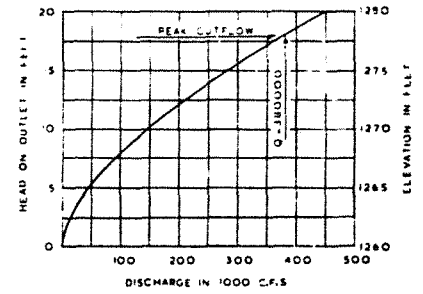


COMPILED BY - PEEL - DAT 3 FEB 5-57
 PEEL RIVER
 ABERDEEN FALLS PROJECT
 GENERAL ARRANGEMENT

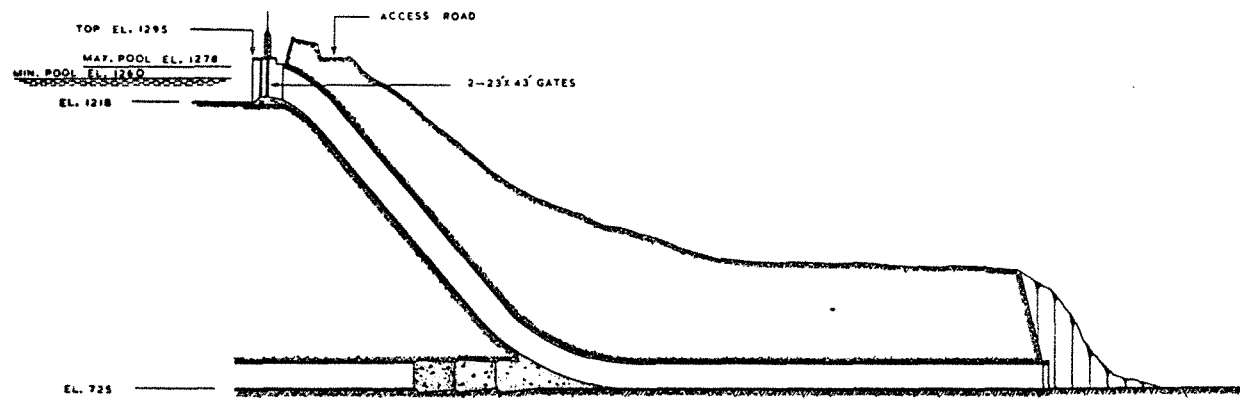
DIVERSION SYSTEM



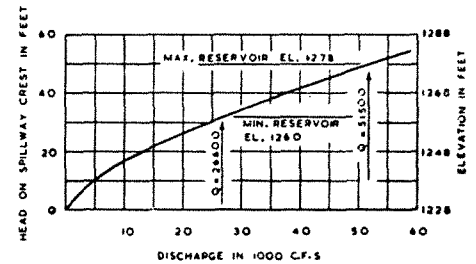
MAXIMUM ROCK FILL SECTION



OUTLET RATING CURVE



SPILLWAY SECTION



SPILLWAY RATING CURVE

PORCUPINE - PEEL - RAT RIVER STUDY

PEEL RIVER

ABERDEEN FALLS PROJECT

SECTIONS AND ELEVATIONS

DIVERSION SYSTEM

