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DEPARTMENT OF THE INTERIOR

INFORMATION SERVICE

GEOLOGICAL SURVEY

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FOUR POTENTIAL WATERPOWER SITES INVESTIGATED NEAR SEWARD, ALASKA

Four prospective sites for waterpower development on the Kenai Peninsula near Seward, Alaska, have been investigated by scientists and engineers of the Geological Survey and pronounced "potentially useful," according to Secretary of the Interior Douglas McKay.

Field examinations have been made of the geology of dam sites, reservoir sites, and probable diversion tunnel routes for power development for Grant, Ptarmigan, Cooper, and Crescent Lakes. These lakes are in the Kenai Mountains roughly 25 to 40 miles north of Seward.

The report has been prepared by Arthur Johnson and is available in Survey files for public inspection. It describes the physical and climatic characteristics of the area that relate to power development and states that because the sites are located in areas of severe winter temperatures (30 to 40 degrees below zero Fahrenheit during most winters), "This climatic feature must be given due consideration in the design of the various structures required for power development."

Streamflow records available for evaluating the potential power, cover a 7-year period for Grant and Ptarmigan Creeks and a 5-year period for Cooper and Crescent Creeks. They show a pronounced variation throughout the year as well as from one year to the next. Therefore reservoir storage to equalize flow is a prime requisite for power development.

All four lakes provide favorable opportunities for such storage. Relatively inexpensive dams ranging in height from 20 to 50 feet can be built at the lake outlets. Water can be conveyed from storage sites to the power sites through pipelines or tunnels of reasonable lengths, utilizing a fall of approximately 250 feet for Grant Lake, 345 feet for Ptarmigan Lake, 745 feet for Cooper Lake, and 1,000 feet for Crescent Lake.

The total estimated potential power for the four lakes is 11,000 kilowatts for 90 percent of the time and 14,000 kilowatts for 50 percent of the time.

Copies of Mr. Johnson's paper entitled "Preliminary report on the potential waterpower of Grant, Ptarmigan, Cooper and Crescent Lakes on the Kenai Peninsula near Seward, Alaska," are available for public inspection at the following offices of the Geological Survey: Library, Room 1033 General Services Administration Bldg., Washington, D. C.; in California at 4 Homewood Place, Menlo Park, and Room 724 Appraisers Bldg., San Francisco; Room 244 Federal Bldg., Tacoma, Washington; and in Alaska in Room 117, Federal Bldg., Juneau, Room 210 Glover Bldg., Anchorage, Geological Survey Office, Palmer, and Brooks Memorial Mines Bldg., at College.

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P.N. 84212

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Preliminary report on

THE POTENTIAL WATERPOWER OF GRANT, PTARMIGAN, COOPER AND CRESCENT LAKES ON THE KENAI PENINSULA, NEAR SEWARD, ALASKA

By
Arthur Johnson
June 1955

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ABSTRACT

Grant, Ptarmigan, Cooper, and Crescent Lakes, located in the Kenai Mountains in the upper portion of the Kenai River Basin, approximately 25 miles to the north of Seward, present favorable opportunities for the development of waterpower. Grant and Ptarmigan Lakes can be made readily accessible by roads from the Seward-Anchorage Highway which in this area practically parallels the Alaska Railroad; and Cooper and Crescent Lakes by access roads from the Sterling Highway.

Geologic conditions are favorable for the construction of the various elements of a power development although some special problems may be encountered.

The power sites are located in areas of severe winter temperatures, -30° to -40° or less in most winters. This climatic feature must be given due consideration in the design of the various structures required for a power development.

Streamflow records are available for a 7-year period for Grant and Ptarmigan Creeks and for a 5-year period for Cooper and Crescent Creeks. Only short and incomplete records of precipitation are available in the area of the power sites but records have been kept at Seward for 30 years. The precipitation at Seward during the periods for which streamflow records are available was, in general, less than average. It seems reasonable that similar conditions would prevail over the upper Kenai Basin. Consequently, the available streamflow records cover a period of less than average precipitation and estimates of potential power based on these figures probably are on the conservative side. Only regulated flow is considered in this report.

Each of the four lakes is a favorable storage site. Adequate capacity for complete regulation of the flow on a year-to-year basis or over a period of several years can be obtained by the construction of dams ranging in height from 20 to 50 feet. Water from the reservoirs can be conveyed to the powerhouses through conduits, tunnels, or pipelines of reasonable length.

The total estimated potential power for the four lakes is 11,000 kilowatts for 90 percent of the time and 14,000 kilowatts for 50 percent of the time.

Transmission line distances to Seward range from 22 miles for the Ptarmigan Lake power site to as much as 50 miles for the Cooper Lake power site that would be located on the Kenai River. The transmission line distance to Anchorage will approximate 100 miles, depending on the route selected.

INTRODUCTION

Purpose and Scope

This report is made to evaluate the waterpower potential of Grant, Ptarmigan, Cooper, and Crescent Lakes in order to classify the lands adjacent to these lakes as to their waterpower values. The report considers the available topographic map data, streamflow records, climatic records, and other pertinent information in arriving at estimates of the potential power.

A general plan of development is shown for each lake as a means of arriving at the potential power as well as indicating the construction that would be required to develop it. It is recognized that when the various sites are developed the final plans may not follow the general plans outlined herein. The objective of the report is to show the potential power available whereas considerations at the time of actual development may show that the fullest possible development may not necessarily be the best one to follow. The analysis of potential waterpower in this report considers only the use of regulated flow as the flow from each of the lakes is so low for such a long period of each year that development based on natural flow would not be justified.

Maps and Aerial Photographs

The four lakes under consideration are shown on the following topographic quadrangles:

Seward. Reconnaissance series, scale 1:250,000.
Contour interval 200 feet.

Seward. B-6, B-7, B-8, C-6, C-7, C-8, scale 1:63,360.
Contour interval 100 feet.

Maps are also available for each of the four lakes on a scale of 1:24,000 with a 10- or 20-foot contour interval. These maps include underwater contours and detailed maps of the dam site at the lake outlets. The dam site maps are on a scale of 1:4800 (1 inch = 400 feet) or 1:2400 (1 inch = 200 feet). These maps are published under the following titles and are included as plates 1, 2, 3, and 4 in this report.

Plan and Profile
Grant Creek and Grant Lake, Alaska
Dam Site

Plan
Ptarmigan Lake near Seward, Alaska
Dam Site

Plan
Cooper Lake, Alaska
Dam Site

Plan
Crescent Lake near Seward, Alaska
Dam Site

Aerial photographs were obtained of the area by the Army Map Service in 1951. The photographs covering the lakes and adjacent area are listed below:

Lake	Symbol	Mission	Roll	Exposures
Grant	51-AM-1	509	3	440, 441, 464, 465
	50-M-6	373	24	301, 302
Ptarmigan	51-AM-1	509	3	442, 443, 462, 463
	50-M-6	371	20	344, 345
		373	24	303, 304
Cooper	51-AM-1	509	2	219, 220, 221, 222
			3	349, 350
	50-M	371	19	140, 141, 142
Crescent	51-AM-1	509	3	345, 346, 347, 348
				392, 393, 394, 395

The negatives for the above photographs are on file with the Geological Survey, Denver Federal Center, Denver, Colorado.

Acknowledgments

Personnel of the U. S. Forest Service located at the Kenai Lake Ranger Station were most cooperative in making equipment available to the field parties making the surveys on the lakes as well as giving much helpful information on trails and other local conditions.

GEOGRAPHY

The four lakes considered in this report are located in the Kenai Mountains, 22 to 26 miles generally north of Seward (see fig. 1) and are all tributary to the upper part of the Kenai River Basin. Each lake empties into a creek of the same name.

Grant Lake

The Grant Lake Basin has an area of 43.5 square miles and is the largest of the four basins considered in this report. The lake itself is six miles long and has an area of 2.45 square miles or 5.6 percent of the area of the basin. For the first two miles from the outlet the axis of the lake trends a little to east of north and then makes practically a right-angle bend and trends just south of east from the bend to the head. The maximum width is slightly over one-half mile. About a half mile upstream from the bend mentioned above there is an island leaving only narrow channels about 75 feet wide between either side of the island and the lake shores. The channel between the island and the north shore of the lake had a depth of only three feet and the channel to the south of the island a depth of 18 feet at the time of the field survey. Soundings were made in the lower 1 1/2 miles of the lake and depths of well over 200 feet were observed.

A depth of 196 feet was observed at a point 0.3 mile from the lake outlet (see plate 1). The shore line is steep throughout. The only comparatively flat area adjacent to the lake is the valley bottom just upstream from the head of the lake. The lower two-mile section of the lake roughly parallels the north-south trending valley of Upper and Lower Trail Lakes and is separated from that valley by a ridge which varies in width from 3/4 to 1 1/4 miles. For the first 1 1/2 miles north of the Grant Lake outlet the elevation of this ridge is below 1,000 feet. Its topography is quite irregular and a saddle one mile north of the lake outlet falls to elevation 743 feet which is only 43 feet higher than the lake level. The trail from Moose Pass to Grant Lake goes through this saddle. North and east of the saddle the ridge rises rapidly and the maximum elevation in the basin, 5,883 feet, is on the saddle north of Grant Lake. Elevations above 5,000 feet are reached at a number of points along the boundary of this drainage basin. The distribution of area with respect to elevation is shown in table 2.

Grant Creek below the lake is only 1.1 miles in length and flows into the short section of Trail River between Upper and Lower Trail Lakes.

According to the Seward B-6, B-7, C-6, and C-7 quadrangles there are nine distinct glaciers in the basin with a combined area of 5.3 square miles or 12 percent of the area of the basin at the lake outlet.

There is a fairly good foot trail from the railroad bridge over Upper Trail Lake at Moose Pass to Grant Lake, reaching the west shore of the lake at a point one mile north of the outlet. The Alaska Railroad and the Seward-Anchorage Highway make Grant Lake readily accessible.

Ptarmigan Lake

The Ptarmigan Lake Basin has an area of 29.9 square miles. The lake is 3 1/2 miles long and has a maximum width of one-half mile. The axis of the trends slightly south of east. The shores are steep and the only comparatively flat area adjacent to the lake is the valley bottom at the head of the lake. The steep shores extend well below lake level as shown by the underwater contours (see plate 2). The maximum observed depth was 234 feet. Ptarmigan Creek, the outflowing stream from the lake, is 3 1/4 miles long and flows into Kenai Lake one-fourth mile south of the Kenai Lake Ranger Station which is five miles north of the upper end of Kenai Lake.

There are eight glaciers in the Ptarmigan Lake Basin with an aggregate area of 2.6 square miles.

The maximum elevation in the basin, 6,210 feet, is along the divide between it and the Victor Creek Basin to the south. The elevation along the basin boundary is above 6,000 feet at this point only but a considerable part of it is above 5,000 feet in elevation. There is a comparatively low divide southeast of the lake, 1,900 to 2,000 feet in elevation, between the Ptarmigan Lake Basin and the Snow River Basin.

The distribution of area with respect to elevation is shown in table 2.

The Alaska Railroad and the Seward-Anchorage Highway cross Ptarmigan Creek within one-fourth mile of the mouth. There is a fairly good foot trail from the station of Falls on the railroad to the lake. This trail follows the north shore of the lake to its upper end and apparently continues beyond the lake into Paradise Valley in the Snow River Basin.

Cooper Lake

The Cooper Lake Basin has an area of 31.6 square miles. The lake is six miles long with a maximum width of one mile near the upper end. It has a minimum width of less than 500 feet at a point 1 1/2 miles from the outlet. The lake flows into Cooper Creek, which has a length of 4 3/4 miles and empties into the Kenai River two miles downstream from Cooper Landing at the outlet of Kenai Lake. The general direction of both the lake and the creek is southeast-northwest. The shores of the lake are steep except near the head of the lake where the adjoining area is comparatively flat. The steep slopes continue well below lake level as shown by the underwater contours on the map of Cooper Lake (see plate 3). In the section from the lake outlet to the constriction mentioned above the maximum depth was about 70 feet. Upstream from the constriction depths of more than 200 feet are soon reached. Depths in excess of 400 feet were found in the wide section of the lake about 1 1/2 miles from the upper end.

The area draining into Cooper Lake could be increased by diversion of the flow from about 8.5 square miles of Stetson Creek. This would increase the present drainage area of 31.6 square miles above the lake outlet to 40.1 square miles, or 27 percent. Stetson Creek is a tributary of Cooper Creek, joining it at a point 1 1/2 miles downstream from the outlet of Cooper Lake. The point of diversion on Stetson Creek would be about one-half mile upstream from the mouth and the necessary diversion canal would be about 1 1/2 miles long.

The highest point in the basin is Cooper Mountain, elevation 5,270 feet, on the ridge between the Cooper Lake Basin and the Russian River Basin to the southwest. This is the only point along the boundary of the basin that is more than 5,000 feet in elevation. There is a low divide or saddle between the upper end of Cooper Lake and Upper Russion Lake five miles to the southwest. The low point in this saddle is slightly less than 1,300 feet in elevation. There is also a low divide or saddle between the upper end of Cooper Lake and Kenai Lake two miles to the northeast. The low point in this saddle also is between the 1200 and 1300-foot contours but apparently slightly lower than the pass to Upper Russian Lake.

The distribution of area with respect to elevation is shown in table 2.

It is of interest to note that the area of Cooper Lake, 3.17 square miles, is 10 percent of the area of the entire basin.

There are, as shown on the Seward B-8 topographic quadrangle, seven small glaciers in the basin with an aggregate area of 0.8 square mile. This quadrangle also shows a foot trail from Upper Russian Lake to Kenai Lake going through the two saddles mentioned above and passing by the upper end of Cooper Lake.

Any development on Cooper Lake would require the construction of a road to the lake. One general route would be up the valley of Cooper Creek and the road would be about five miles in length. Another would be an approach from Kenai Lake through the saddle previously mentioned. Although the lakes are only 2 miles apart across this saddle, to connect with the Sterling Highway near Cooper Landing would require approximately an additional eight miles of highway along the southwest shore of Kenai Lake and to connect with the Seward-Anchorage Highway just south of the head of Kenai Lake would require 15 miles of road following the south and west shores of Kenai Lake.

Crescent Lake

The Crescent Lake drainage basin has an area of 21.2 square miles. The lake, as the name implies, is crescent-shaped with the points of the crescent pointing northward. The lake is six miles long and has a maximum width of one-half mile. The lake area, 2.14 square miles, is 10 percent of the area of the basin, the same as for Cooper Lake. The lake empties into Crescent Creek, a tributary of Quartz Creek which in turn flows into Kenai Lake four miles upstream from the lake outlet. Crescent Creek has a length of six miles. The original road to Kenai Lake was on the east side of Quartz Creek and crossed Crescent Creek one-half mile above the mouth but the new road is located on the opposite side of Quartz Creek and does not cross Crescent Creek.

The entire shore of the lake is steep. In general, the steep slopes continue well below the lake level as shown by the underwater contours (see plate 4). There is a shallow area around two small islands 2 1/2 miles from the outlet. Depths around the upper island are less than 15 feet. The maximum depth observed in random soundings was 291 feet. Slightly greater depths may exist but it seems doubtful that these would be much over 300 feet. The maximum observed depth was about two miles from the head of the lake.

The highest point in the basin, 5,320 feet, is on the divide between the drainage into Crescent Lake and Crescent Creek, and is about midway between the two points of the crescent or the ends of the lake. Two other points along the boundary of the basin exceed 5,000 feet in elevation. These are on the ridge between the upper segment of Crescent Lake and Kenai Lake. There is a low divide or saddle between Crescent Lake and Kenai Lake. The low point in this saddle is between 1,800 and 1,900 feet in elevation. At the narrowest part of this saddle the distance between the lakes is 2 3/4 miles. There is also a low divide or saddle between the upper end of Crescent Lake and Moose Creek which drains into Upper Trail Lake. There is a small lake, Carter Lake, which drains into Moon Creek, located in this saddle. This lake is three-fourths mile long and one-fourth mile wide with the long dimension slightly east of north. It is separated from Crescent Lake by a distance of one-half mile. The elevation of Carter Lake is 1,486 feet or 32 feet higher than the elevation of Crescent Lake. The dividing ridge between Carter Lake and Crescent Lake is at about an elevation of 1,490 feet. In view of this topographic condition there is practically no "upper basin" so that almost the entire drainage into Crescent Lake is from the sides.

The distribution of area with respect to elevation is shown in table 2.

The drainage which normally enters the Carter Lake Basin could readily be diverted into Crescent Lake by breaching the narrow divide at the head of Carter Lake to such a depth that there would be no outflow through the regular lake outlet. The Carter Lake Basin has an area of 1.7 square miles. The drainage from a small basin, with an area of 1.1 square miles, that drains into Crescent Creek about 1,000 feet downstream from the lake outlet, could also be readily diverted into Crescent Lake. These two additional areas, with a total of 2.8 square miles, would increase the area tributary to Crescent Lake to 24.0 square miles or 77 percent of the area at the gaging station on Crescent Creek.

Any development on Crescent Lake would require road construction. One route would be from the existing old road to Kenai Lake up the Crescent Creek Valley to the lake outlet. Such a road would be about six miles long. The upper end of the lake is 2 1/2 miles in a straight line from the Seward-Anchorage Highway just west of the upper end of Upper Trail Lake. There is practically a 1,000-foot difference in elevation in the first mile of this distance. The length of road required to reach the head of Crescent Lake would therefore be considerably longer than the 2 1/2-mile straight-line distance in order to keep within permissible grades.

There is a foot trail from a point on the north shore of Kenai Lake five miles west of the Kenai Lake Ranger Station leading to Crescent Lake through the saddle between the two lakes. This trail reaches Crescent Lake on the south shore 2 1/2 miles from the head of the lake. This trail was in fair condition in 1951 when the lake was mapped.

The four lakes considered in this report are readily accessible by amphibious planes during the open-water season and by ski-equipped planes during the winter months.

Data relative to elevation and area of the four lakes are summarized in table 1.

Table 1.--Elevations and areas relating to Grant, Ptarmigan, Cooper, and Crescent Lakes, Alaska

Lake	Elevation (feet)	Area of lake (sq mi)	Drainage area (sq mi)	
			At lake outlet	At gaging station
Grant	700	2.45	43.5	43.7
Ptarmigan	755	0.99	29.5	32.4
Cooper	1,168	3.20	31.6	31.6
Crescent	1,454	2.14	21.2	31.3

Table 2.--Relation of area with respect to elevation for Grant, Ptarmigan, Cooper, and Crescent Creeks, Alaska

Elevation below	Grant Creek		Ptarmigan Creek		Cooper Creek		Crescent Creek	
	Area (sq mi)	Percent of total area a/	Area (sq mi)	Percent of total area a/	Area (sq mi)	Percent of total area a/	Area (sq mi)	Percent of total area a/
1,000 feet	5.7	13.0	4.7	14.5	-	-	0.4	1.3
2,000 feet	13.6	31.2	12.1	37.4	14.2	45.0	10.8	34.5
3,000 feet	23.4	53.5	18.9	58.3	22.1	70.0	18.8	60.0
4,000 feet	34.8	79.6	26.6	82.0	29.6	93.6	26.4	84.3

a/ Area at gagins stations.

GEOLOGY

A field examination of the geology of the dam sites, reservoir sites, and probable diversion tunnel routes for power development from the four lakes considered in this report was made during the 1952 field season. The resulting report entitled "Geologic investigations of proposed power sites at Cooper, Grant, Ptarmigan, and Crescent Lakes, Alaska," by George Plafker, was released to open file November 3, 1954. It is available for public inspection at the following offices of the Geological Survey: Library, Room 1033, General Services Administration Building, Washington, D. C.; 4 Homewood Place, Menlo Park, California; Room 724, Appriasers Building, San Francisco, California; Room 117, Federal Building, Juneau, Alaska; Brooks Memorial Mines Building, College, Alaska; and Room 210, E. F. Glover Building, Anchorage, Alaska. It is also available at the Territorial Department of Mines, Juneau, Alaska. Further reference will be made to this report in the discussion of the individual power sites.

CLIMATE

The climatic features that are of primary concern in the evaluation of waterpower potential are temperature and precipitation. No weather records have been obtained within the four lake basins under consideration. Short and incomplete records of precipitation are available at three nearby stations, Moose Pass, Cooper Landing, and Naptowne. The first two are in the immediate vicinity of the lake basins and the winter temperature records at these stations are of particular interest in relation to the power sites. The record at Naptowne is of interest in giving information on conditions in the Kenai lowlands which lie west of the lake area. The longest period of record available near the area under study is at Seward at the head of Resurrection Bay for which the record extends from 1908 to the present. This record is not complete as one or more monthly values are lacking in several years and data for several complete years are not available. The precipitation record, including seasonal snowfall, is given in table 3. A review of this table shows that there are 30 years during the period for which the annual record is complete. The precipitation records for Moose Pass, Cooper Landing, and Naptowne are shown in table 4. Table 3 also includes the seasonal snowfall at Seward, recording a seasonal mean of 68.7 inches. Using the value of 10" snowfall as equivalent to 1 inch of precipitation, snowfall would account for about 10 percent of the precipitation at Seward. In view of the higher elevation and colder temperatures over the lake basins a larger proportion of the annual precipitation would occur as snow than at Seward. This is verified by the runoff records for the lake basins. Annual values for snowfall are not available at either Moose Pass or Cooper Landing.

The available temperature records at Moose Pass, Cooper Landing, and Naptowne are shown in table 5, together with the record at Seward since 1941. From this table it is seen that the monthly mean temperatures at Moose Pass and Cooper Landing are quite comparable but are appreciably lower than at Seward during the winter months, October to March. The summer temperatures are comparable with those at Seward. The temperatures at Naptowne are slightly lower than those at Cooper Landing or Moose Pass. The available annual minimum temperatures at Seward, Moose Pass, Cooper Landing, and Kenai are shown in table 6. This record indicates that the winter minimums at Moose and Cooper Landing will generally be at least 15°F to 20°F lower than the minimums at Seward. This is of particular significance as the conditions at Moose Pass and Cooper Landing are representative of the conditions at the powerhouse locations that are discussed in this report. Winter temperatures in the power site areas will be from -20°F to -30°F practically every winter and temperatures of -40°F to -50°F can be expected in some years.

Although conditions in the lake basins are not directly comparable with conditions at Seward the general pattern should be somewhat similar. The precipitation is concentrated in the winter months. In general, the 4-month period, September through December, has one-half of the annual average. October is usually the month of greatest precipitation and June the least. The three-month period, May through July, accounts for only one-eighth of the annual average precipitation. Summer temperatures in the vicinity of the lakes are much the same as at Seward whereas the winter temperatures are considerably lower.

Table 3.--Monthly and annual precipitation and seasonal snowfall, in inches, at Seward, Alaska

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Calendar year	Water year a/	Percent of mean annual b/	Seasonal snowfall c/
1908	-	10.43	2.35	4.00	1.63	0.45	3.25	6.34	4.29	9.73	20.99	12.38	-	-	-	-
1909	0.52	0.47	3.72	3.03	4.47	4.39	0.72	3.71	3.66	8.92	0.37	12.80	46.78	67.79	0.99	55.5
1910	3.32	4.52	2.50	0.55	1.43	2.59	2.15	2.45	7.12	5.72	1.55	4.91	38.81	-	-	70.0
1911	1.45	5.67	2.30	4.12	2.66	2.95	1.89	2.55	3.25	9.30	4.96	-	-	-	-	63.0
1912	-	-	5.77	4.29	8.39	0.53	3.10	13.04	13.91	9.29	9.84	9.89	-	-	-	-
1913	2.76	3.52	3.37	6.24	2.68	0.05	4.82	2.90	10.83	8.78	4.13	5.83	55.91	66.19	0.96	84.0
1914	4.03	6.69	2.36	1.59	2.64	6.81	1.67	7.93	3.79	11.09	4.55	7.80	60.95	56.25	0.82	-
1915	7.09	3.73	9.67	11.96	0.10	1.71	0.94	12.71	9.46	2.82	6.24	4.99	71.42	80.81	1.17	-
1916	0.32	7.66	1.63	3.44	6.68	5.53	1.21	5.97	9.54	14.13	12.89	4.21	73.21	56.03	0.81	-
1917	-	-	-	0.88	2.02	1.45	3.94	5.87	18.35	-	4.97	-	-	-	-	-
1918	-	1.00	0.49	3.36	1.30	1.14	1.98	6.64	26.35	16.41	6.41	13.95	-	-	-	-
1919	7.85	4.38	1.74	2.73	1.52	1.13	2.04	10.12	12.77	7.70	1.32	5.90	59.20	80.45	1.17	122.0
1920	3.95	6.10	0.20	0.70	0.67	2.79	4.88	8.05	2.73	9.93	5.90	4.24	50.14	44.99	0.65	29.5
1921	2.70	2.66	2.40	6.73	1.19	0.61	2.45	3.38	15.28	13.40	2.39	7.85	61.04	57.47	0.84	-
1922	4.41	1.21	1.31	7.74	3.81	1.64	4.38	8.49	1.86	14.89	9.17	4.49	63.12	58.21	0.85	-
1923	1.55	4.51	2.57	4.96	0.98	5.69	2.47	2.04	16.04	33.17	6.20	5.38	85.56	69.36	1.01	-
1924	6.71	9.92	8.18	5.20	1.70	0.90	5.45	4.20	11.75	4.92	9.52	1.83	70.28	98.76	1.44	-
1925	1.23	1.47	2.01	2.37	-	-	-	-	-	-	-	-	-	-	-	-
1926	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1927	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1928	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1929	-	-	-	3.18	5.39	0.88	4.19	2.70	9.81	15.77	13.84	2.19	-	-	-	-
1930	1.86	2.42	7.53	3.53	3.20	1.12	3.38	6.32	5.62	4.68	12.76	14.44	66.86	66.78	0.97	-
1931	14.02	9.91	5.08	3.61	3.79	2.61	4.38	3.54	8.47	12.07	15.87	2.00	85.35	87.29	1.27	-
1932	-	2.65	1.73	4.28	4.64	3.45	1.13	7.63	4.73	9.84	1.56	3.67	-	-	-	-
1933	2.06	2.50	3.99	5.18	4.19	3.44	0.69	8.82	6.95	3.84	8.46	0.00	50.08	52.85	0.77	-
1934	5.33	8.67	3.91	10.10	6.58	1.71	1.64	7.62	12.15	15.15	2.96	17.22	93.04	70.01	1.02	58.1
1935	4.50	13.34	5.85	4.36	2.85	0.52	6.81	2.91	12.78	10.41	2.70	6.91	73.94	89.25	1.30	87.6

Table 3.--Continued

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Calendar year	Water year a/	Percent of mean annual b/	Seasonal snowfall c/
1936	12.16	0.71	1.19	1.29	8.35	0.17	2.15	5.85	5.76	16.63	14.85	3.16	72.27	57.65	0.84	46.1
1937	3.64	0.35	3.59	3.39	3.72	4.67	2.29	2.11	12.50	10.45	-	5.29	-	70.90	1.03	46.2
1938	6.58	8.17	1.50	6.08	5.03	6.49	2.52	-	-	-	-	-	-	-	-	-
1939	-	-	5.43	6.51	1.57	1.22	4.17	11.38	6.45	6.87	5.57	9.81	-	-	-	-
1940	12.07	2.83	5.54	8.62	3.02	1.31	2.14	10.71	18.69	14.85	6.43	5.86	92.07	87.18	1.27	47.6
1941	2.48	14.55	12.12	13.91	4.60	2.98	5.50	0.78	4.70	3.47	2.27	11.17	78.53	88.76	1.29	64.1
1942	8.22	10.40	6.64	5.00	1.12	3.83	3.61	10.49	7.91	7.18	0.94	1.01	66.35	74.13	1.08	66.8
1943	2.68	6.77	1.68	4.49	2.22	3.38	3.58	3.62	15.19	11.34	18.33	18.25	91.53	52.74	0.77	99.1
1944	11.33	6.18	1.97	1.09	7.00	1.58	4.83	11.44	8.05	12.20	7.43	6.25	79.35	101.39	1.47	87.5
1945	12.13	10.99	3.07	1.38	2.24	1.93	2.23	8.13	6.55	15.81	2.17	4.78	71.41	74.53	1.08	65.5
1946	5.59	6.20	3.23	3.40	4.87	1.25	0.88	4.62	5.42	11.73	4.37	2.93	54.49	58.22	0.85	91.1
1947	3.01	6.40	7.16	1.79	6.64	2.87	2.38	4.95	10.77	7.73	12.61	8.73	75.04	65.00	0.95	-
1948	12.52	4.83	1.38	0.00	3.72	-	4.36	1.05	9.49	13.48	4.46	1.61	-	-	-	-
1949	4.66	0.64	6.10	3.67	1.78	2.05	1.04	5.61	13.21	8.13	10.90	4.65	62.44	58.31	0.85	-
1950	1.18	0.92	3.03	-	5.54	3.77	1.38	4.82	15.83	3.96	0.32	6.12	-	-	-	-
1951	3.27	3.81	2.63	4.66	2.60	2.87	0.88	3.02	12.82	5.12	4.88	2.57	49.13	46.96	0.68	-
1952	1.76	3.77	3.13	4.74	1.74	1.41	5.28	4.44	3.96	21.65	19.23	15.08	86.19	42.80	0.62	-
1953	2.16	15.97	2.08	7.63	0.80	0.60	1.12	5.64	8.87	10.13	6.40	7.76	69.16	100.83	1.46	-
1954	4.92	3.54	5.81	0.40	2.45	0.71	4.02	2.73	2.86	-	-	-	-	51.73	0.75	-
No. of values	37	40	42	43	43	42	43	42	42	40	40	39	30	31	-	18
Mean	5.03	5.51	3.76	4.33	3.34	2.31	2.88	5.89	9.54	10.82	7.27	6.85	68.46	68.83	-	68.7
Percent of mean annual	7.4	8.2	5.6	6.4	5.0	3.4	4.3	8.7	14.1	16.0	10.8	10.1	-	-	-	-
Maximum	14.02	15.97	12.12	13.91	8.39	6.81	6.81	13.04	26.35	33.17	20.99	18.25	93.04	101.39	-	122.0
Minimum	0.32	0.35	0.20	0.00	0.10	0.05	0.69	0.78	1.86	2.82	0.32	0.00	38.81	42.80	-	29.5

a/ October 1 to September 30.
b/ For water years.
c/ July 1 to June 30.

Table 4.--Monthly and annual precipitation in inches at Moose Pass, Cooper Landing, and Naptowne, Alaska

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Calendar year	Water year a/
Moose Pass														
1952					0.42	0.41	1.85			9.32 a/	11.87	10.97		
1953	0.63	13.18	2.32	3.84	1.29	0.68	0.84	3.06	2.96	5.51	1.29	2.25	37.85	
1954	1.67	2.33		0.11						8.83				
Cooper Landing														
1941									0.84	1.28	0.35	1.48		
1942	1.31	1.79	0.97	0.59	0.37	0.50	2.28		2.92	3.55				
1943	1.28	1.02	0.35		0.47	1.07	1.93			3.90	4.79			
1944			3.08	0.59		1.20	3.45	5.24						
1945			1.88											
1948						0.72								
1952				1.42	0.45	0.71	1.66	1.04	3.36	5.88	7.08			
1953			0.65	0.23	1.54	0.65	1.17	4.38	2.74	3.44	0.89	2.34		
1954	1.39	2.34		T	0.28	0.69	2.01	2.15	1.81	2.97	1.10			
Naptowne														
1951	0.88	0.83	0.19	1.13	0.39	2.11	1.96	2.17	4.73	0.80	0.89	0.91	16.99	
1952	1.48	0.45	1.34	0.69	0.48	0.76	2.74	1.95	1.78	1.76	2.48	1.85	17.76	14.27
1953	0.32	1.12	0.30	0.05	0.99	0.95	0.89	2.78	2.37	1.58	0.32	1.51	13.18	15.86
1954	0.57	0.17	1.65	T	0.12	0.46	3.53	1.84	1.66					13.41

a/ Includes August and September.
T. Trace.

Table 5.--Monthly and annual mean temperatures, °F, at Seward, Moose Pass, Cooper Landing and Naptowne, Alaska

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
							Seward						
1941	26.6	32.9	35.2	40.6	45.8	52.4	51.8	58.0	52.1	42.6	26.2	27.1	40.9
1942	30.8	35.0	30.4	39.8	49.0	51.6	56.2	55.1	53.0	41.4	26.8	12.7	40.2
1943	19.6	26.8	32.0	38.8	46.8	52.6	55.2	54.9	47.8	40.7	34.6	30.5	40.0
1944	26.5	32.8	30.5	36.0	43.8	53.0	55.7	57.6	49.5	40.8	33.0	28.8	40.7
1945	33.2	30.4	31.8	36.7	44.5	52.0	55.8	54.1	50.2	39.4	25.8	28.4	40.2
1946	27.4	28.5	25.8	35.4	43.6	54.0	57.6	53.8	49.7	41.2	28.9	18.0	38.7
1947	13.0	28.6	34.8	38.3	43.5	50.5	58.6	57.4	49.2	41.2	36.1	32.2	40.3
1948	28.2	24.1	28.2	40.0	45.2	-	54.4	55.6	48.4	38.9	25.5	19.4	-
1949	24.8	20.8	34.6	35.8	44.2	50.5	54.4	56.5	50.6	41.1	34.7	21.3	39.1
1950	25.6	19.8	34.5	37.2	43.0	50.9	54.7	57.9	48.7	39.3	24.5	24.4	38.4
1951	18.4	26.2	24.0	37.4	44.4	49.2	60.0	55.7	50.1	38.2	33.3	23.9	38.4
1952	18.9	28.9	31.0	35.4	43.5	51.6	54.8	56.7	50.5	41.7	36.5	28.4	39.8
1953	21.4	27.9	29.3	38.6	44.6	55.8	58.2	56.0	48.7	38.1	32.0	29.6	40.0
1954	24.7	18.1	-	36.9	45.1	51.7	56.5	55.4	51.9	-	-	-	-
							Moose Pass						
1941	-	-	-	-	-	-	-	59.3	48.8	37.8	16.6	19.2	-
1942	27.0	32.3	25.2	36.8	47.6	52.8	61.4	58.7	51.6	41.7	18.9	-6.2	37.3
1943	5.6	18.2	24.2	35.9	48.8	59.4	59.1	-	45.2	37.0	32.0	-	-
1951	-	-	-	-	-	-	-	-	-	-	-	-	-
1952				30.7 a/	40.7	51.4	55.7 a/	-	-	38.1 a/	34.4	20.9	-
1953	11.5	20.4	18.4	33.9 a/	43.4 a/	55.1 a/	57.5 a/	54.4 a/	45.4 a/	33.6 a/	23.5 a/	18.6 a/	34.7
1954	6.4 a/	2.5 a/	-	28.0 a/	-	-	-	-	45.2 a/	-	-	-	-

FIG 1. INDEX MAP OF KENAI PENINSULA, ALASKA, SHOWING LOCATION OF GRANT, PTARMIGAN, COOPER AND CRESCENT LAKES

Table 5.--Continued

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						Cooper Landing							
1941									47.0	34.2	18.0	19.1	
1942	27.7	33.2	26.7	37.7	48.2	50.0	51.1	52.6	47.6	36.8	14.4	- 0.2	35.5
1943	4.3	21.6	25.1	35.5	45.4	54.6	54.4	52.0	45.6	38.2	32.0	29.2	36.5
1944	-	30.6	25.4	33.8	44.6	53.8	56.2	55.6	46.6	36.2	-	26.8	-
1945	-	-	28.0	32.6	43.2	51.2	54.7	-	44.0	-	-	-	-
1952	-	-	-	32.9	41.3	50.9	55.1	54.1	45.7	37.1	32.2	22.1	-
1953	10.8	22.2	22.7	36.8	44.0	55.1	57.1	53.7 a/	44.2	30.8	22.4	21.1	35.1
1954	11.0	4.3	-	32.4	46.8	52.3	55.7	55.8 a/	47.4	-	-	-	-
						Naptowne							
1951	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	- 2.9	19.0	22.2	30.8	39.9	49.4	54.8	52.7	45.2	37.3	31.5	17.7	33.1
1953	6.1	20.4	19.0	36.4	43.3	55.2	56.8	54.3	45.4	32.5	15.8	14.3	33.3
1954	3.4	0.7	-	29.6	45.6	51.3	54.3	53.7	46.8	-	-	-	-

a/ Record incomplete, 1 to 9 days missing.

Table 6.-- Annual minimum temperatures, °F, at Seward, Moose Pass, Cooper Landing, Naptowne and Kenai, Alaska

Year	Annual minimum temperatures °F				
	Seward	Moose Pass	Cooper Landing	Naptowne	Kenai
1940	+ 1				
1941	+ 1				
1942	- 5	- 37	- 23		
1943	- 12	- 48	- 32		
1944	- 10				- 35
1945					- 33
1946	- 7				- 29
1947	- 17				- 48
1948	- 1				- 28
1949	- 6				- 36
1950	0				- 29
1951	- 10			- 48	- 42
1952	- 5			- 51	- 40
1953	- 2	- 27	- 19	- 33	- 25
1954 a/	- 6	- 39	- 33	- 40	- 34

a/ For period January 1 - November 30.

FACTORS AFFECTING HYDRAULIC STRUCTURES

The severe winter temperatures, -20°F or lower in most winters, with some years as low as -40°F to -50°F, and the resultant ice conditions must be considered in the design of dams, spillways, intake and tailrace structures, pipelines, and penstocks. The over-all range in temperatures from possible maximums approaching 100°F to minimums of -50°F, or lower must be considered in the design of transmission lines.

Flood conditions may result from rapid melting of snow or heavy rains. The annual maximum stages as a rule result from the melting of the snow and will in general occur at a time when reservoir stages would be low. The heavy rains are most likely to come at time when reservoirs are at or near maximum stages. The probable maximum discharge from either snow melt or heavy rains must be considered in the design of spillways.

The disposal or passing of debris that may accumulate in the reservoirs from heavy rains or from avalanches must also be considered in the design of spillways and intake structures. The possible occurrence of avalanches should be carefully considered in the location of the various structures related to a power development.

This area is similar to the Coast Ranges of California in frequency and magnitude of earthquake shocks (Plafker). Shallow focus earthquakes have been recorded with magnitudes as high as 6.9 on the Gutenberg-Richter scale (U.S.C. & G.S. 1950). The effect of possible earthquakes must therefore be considered in the design of the required structures.

WATER SUPPLY

A few miscellaneous streamflow measurements were made on Grant, Ptarmigan, and Cooper Creeks in 1913. A record of discharge was obtained for the Kenai River at a point 3 or 4 miles downstream from the outlet of Kenai Lake from August 1913 through January 1914. No further records were obtained in this area until May 1947 when a gaging station was established on the Kenai River at the outlet of Kenai Lake and has been in operation since then. Records were started on the four streams which drain the four lakes under consideration as follows:

Grant Creek	October 1947
Ptarmigan Creek	May 1947
Cooper Creek	August 1949
Crescent Creek	July 1949

The records are complete from the dates indicated but all contain periods of estimated values, particularly during the winter months. The records at present are considered provisional and subject to revision. Whatever revisions may be made in these records will not be likely to have an appreciable effect on the power estimates in this report.

The runoff at all four stations was exceptionally high for 1953. The precipitation at Seward for this year was 47 percent above average. In the 30 years of precipitation record at Seward only two other years, 1924 and 1944, had correspondingly high values. These were 44 and 48 percent, respectively, above the average. On the assumption that the variations in runoff from the lake basins are comparable to the variations in precipitation at Seward and the further assumption that the 30-year precipitation record at Seward is representative of long-period occurrences, then runoff comparable to the values in 1953 could be expected on an average of about 1 year in 10. This ratio of course cannot be taken too literally but on the other hand runoff values such as recorded in 1953 should be considered accordingly in studies of required storage capacities and estimates of potential power. Where favorable storage opportunities exist the excessive runoff of years like 1953 can be used for hold-over storage to augment the flow in years of low runoff.

The precipitation at Seward, in percent of average, for the years for which streamflow records are available was as follows:

Year	Percent
1948	86 a/
1949	85
1950	75 a/
1951	68
1952	62
1953	147
1954	75

The means for certain period combinations are shown below:

Period	Mean Percentage
1948 - 1954	85
1948 - 1954, excluding 1953	75
1950 - 1954	85
1950 - 1954, excluding 1953	70

The records for Grant and Ptarmigan Creeks cover the 7-year period 1948-1954 and for Cooper and Crescent Creeks the 5-year period 1950-1954. This indicates that the period of available streamflow records represents a period of somewhat less than average precipitation. If 1953, which was a year of excessive precipitation, were not considered then the remaining years would represent a period in which the precipitation was only about 75 percent of the average. Power estimates based on the available streamflow records will therefore be on the conservative side.

The monthly mean and annual mean values of discharge for the four streams above mentioned are given in table 7. Reference to this table shows that the variation in discharge throughout the year is similar at all stations. In general terms two-thirds of the annual runoff occurs in one-third of the year, the four-month period, June through September. Only 5 to 10 percent of the annual runoff occurs during the four-month period, January through April. June and July are invariably the months of greatest runoff, this two-month period accounting for about 40 percent of the annual total. February and March are the months of least runoff, accounting for only 3 or 4 percent of the annual total. This variation in flow distribution throughout the year clearly shows the need for storage in order to equalize the streamflow.

Any development on these streams based on natural flow is considered impracticable. Consequently, a determination of the distribution of natural flow with respect to time (duration curves) has not been made. The following discussion is aimed only at determining the amount of regulated flow that could be obtained assuming that adequate storage capacity could be provided or the flow attainable with some specified maximum storage capacity. These determinations have been based on the study of a mass curve of the measured or estimated discharge from each of the four lakes. In the

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a/ Annual value of precipitation based on estimated value for one month during the year.

Table 7.--Monthly and annual discharge in second-feet, runoff in acre-feet and depth in inches, for Grant, Ptarmigan, Cooper and Crescent Creeks, Alaska

Year	Discharge in second-feet													Runoff	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual	Acre-feet	Depth in inches
Grant Creek near Moose Pass, Alaska (Drainage area 43.7 square miles)															
1948	262	200	116	32.4	24.1	16.4	27.1	244	493	556	385	162	211	153,000	65.6
1949	259	89.8	25.9	15.0	12.4	14.8	17.1	137	409	474	323	446	186	134,900	57.9
1950	194	197	71.3	37.2	21.1	18.3	26.1	117	446	521	481	338	207	149,600	64.2
1951	101	33.3	21.0	19.1	15.5	13.6	27.3	124	325	518	376	505	174	126,100	54.1
1952	87.8	51.5	30.4	18.5	16.5	15.7	14.5	66.1	375	540	379	259	155	112,600	48.3
1953	327	256	138	57.2	44.5	30.4	63.8	300	922	705	511	327	308	223,100	95.7
1954	257	69.1	39.7	32.1	33.3	28.4	29.7	173	409	420	384	201	174	126,000	54.1
Mean	213	128	63.2	30.2	23.9	19.7	29.4	166	483	533	406	320	202	146,400	62.8
Maximum	327	256	138	57.2	44.5	30.4	63.8	300	922	705	511	505	308	223,100	95.7
Minimum	87.8	33.3	21.0	15.0	12.4	13.6	14.5	66.1	325	420	323	162	155	112,600	48.3

Table 7.--Continued

Year	Discharge in second-feet													Runoff	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual	Acre-feet	Depth in inches
Ptarmigan Creek near Lowing, Alaska (Drainage area 32.4 square miles)															
1947	-	-	-	-	-	-	-	74.6	220	247	189	135	-	-	-
1948	144	137	87.1	23.2	17.0	13.2	29.7	139	301	331	219	113	130	94,340	54.6
1949	144	71.1	24.9	14.0	11.4	13.7	16.2	93.8	276	334	233	265	125	90,750	52.5
1950	120	157	55.6	30.0	17.0	14.8	21.5	95.7	245	268	258	220	126	91,020	52.7
1951	66.0	30.3	16.5	12.4	10.0	9.5	19.7	79.3	155	251	162	245	88.5	64,050	37.1
1952	71.5	44.5	24.9	13.5	12.0	10.4	9.5	31.4	162	232	172	110	74.7	54,230	31.4
1953	198	185	85.5	41.5	28.8	20.0	33.0	158	511	382	238	148	170	122,800	71.1
1954	155	49.3	32.0	23.0	19.0	12.0	19.6	94.2	205	202	199	106	93.5	67,680	39.2
Mean	128	96.3	46.6	22.5	16.5	13.4	21.3	95.7	259	281	209	168	115	83,550	48.4
Maximum	198	185	87.1	41.5	28.8	20.0	33.0	158	511	382	258	265	170	122,800	71.1
Minimum	66.0	30.3	16.5	12.4	10.0	9.5	9.5	31.4	155	202	162	106	74.7	54,230	31.4

Table 7.--Continued

Year	Discharge in second-feet													Runoff	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual	Acre-feet	Depth in inches
							Cooper Creek near Cooper Landing, Alaska (Drainage area 31.6 square miles)								
1949	-	-	-	-	-	-	-	-	-	-	129	131	-	-	-
1950	102	130	44.5	22.6	12.1	9.1	12.0	58.7	188	182	134	155	87.9	63,620	37.7
1951	73.3	31.2	20.0	18.0	15.5	13.3	23.0	71.5	146	144	77.2	153	65.6	47,480	28.2
1952	66.6	55.0	22.2	13.5	13.0	12.5	11.5	34.9	138	181	107	69.3	60.5	43,920	26.0
1953	208	186	74.8	47.7	45.5	31.4	26.4	137	408	336	183	125	151	109,500	64.9
1954	132	46.9	32.2	25.0	24.2	17.0	12.7	96.6	196	169	136	72.8	80.5	58,270	34.5
Mean	116	89.8	38.7	25.4	22.1	16.7	17.1	79.7	215	202	128	118	89.1	64,560	38.3
Maximum	208	186	74.8	47.7	45.5	31.4	26.4	137	408	336	183	155	151	109,500	64.9
Minimum	66.6	31.2	20.0	13.5	12.1	9.1	11.5	34.9	138	144	77.2	69.3	60.5	43,920	26.0

Table 7.--Continued

Year	Discharge in second-feet													Runoff	
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual	Acre-feet	Depth in inched
	Crescent Creek near Cooper Landing, Alaska (Drainage area 31.3 square miles)														
1949	-	-	-	-	-	-	-	-	-	-	102	101	-	-	-
1950	89.7	109	54.5	29.9	16.8	14.4	15.2	46.7	148	111	63.5	117	68.0	49,250	29.5
1951	48.5	28.0	18.5	16.5	14.5	12.0	20.0	66.2	120	103	59.8	118	52.1	37,750	22.6
1952	58.0	44.0	18.4	12.5	12.0	12.0	10.5	33.2	132	126	81.9	64.7	50.5	36,680	22.0
1953	156	168	71.0	34.0	41.6	29.9	27.2	121	359	270	122	93.0	125	90,210	54.0
1954	99.4	46.1	26.0	15.0	10.2	3.0	16.0	83.5	139	106	100	59.2	59.0	42,670	25.6
Mean	90.3	79.0	37.7	21.6	19.0	14.3	17.8	70.1	180	143	88.2	92.2	70.9	51,310	30.7
Maxi-mum	156	168	71.0	34.0	41.6	29.9	27.2	121	359	270	122	118	125	90,210	54.0
Mini-mum	48.5	28.0	18.4	12.5	10.2	3.0	10.5	33.2	120	103	59.8	59.2	50.5	36,680	22.0

following discussion it has been assumed that the entire flow from the lakes would be used for power generation. This would mean that except in rare instances there would be no outflow from the lakes into their outlet streams and the only flow in them would be from the tributary areas downstream from the lake outlet. Certain considerations such as the needs for fish life may require that some water be released from the lakes in order to maintain adequate flows in the streams. This would decrease the amount of water that would actually be available for power generation. As pointed out in a previous paragraph, the available streamflow records cover a period of less than average precipitation and over a long period the values of streamflow would tend to be larger than those used in this report. The two foregoing considerations would tend to balance each other. Consequently, the values of regulated streamflow, as arrived at in the following paragraphs, are believed to give a fairly reliable indication of what can reasonably be expected over a long period.

The possible effects of evaporation are not considered in this report. As far as known no factual data for evaporation in the study area are available. In view of the climatic characteristics the amount of evaporation would not be large. The areas of the reservoir sites under consideration will not be much greater than the original lake areas so very little additional "evaporation opportunity" will result. Whatever evaporation loss occurs from the existing lakes is reflected in the available gaging station records. All factors considered, any adjustment due to evaporation would be an unwarranted refinement not justified by the available data.

Grant Creek

Streamflow records are available from October 1947 through September 1954, a 7-year period. The gaging station is located near the mouth of Grant Creek, about 3/4 mile downstream from the outlet of Grant Lake. The area at the gaging station is only 1 or 2 percent greater than at the lake outlet. The runoff at the lake outlet is therefore considered as being the same as at the gaging station. During the period of record the extremes of discharge varied from a maximum of 2,290 cfs to a minimum of 11 cfs, the daily extremes from 2,190 to 11, and the monthly extremes from 922 to 12 cfs. The annual mean flows varied from a minimum of 155 cfs in 1952 to a maximum of 308 cfs in 1953. The latter, however, was a year of exceptionally heavy runoff. The precipitation at Seward for this year was 47 percent above normal. Disregarding 1953, the average discharge for the other six years was 185 cfs.

The regulated flow available from Grant Lake for the period of record, assuming sufficient storage capacity for year-to-year regulation, is summarized as follows:

Period		Storage required for year-to-year regulation (acre-feet)	Available mean flow for period (cfs)
October 1, 1947	- October 31, 1947	0	262 a/
November 1, 1947	- October 31, 1948	50,000	210
November 1, 1948	- October 31, 1949	57,000	180
November 1, 1949	- September 30, 1950	57,000	207
October 1, 1950	- September 31, 1951	62,000	174
October 1, 1951	- November 30, 1952	65,000	174
December 1, 1952	- August 31, 1953	75,000	310
September 1, 1953	- September 30, 1953	0	308 a/
October 1, 1953	- October 31, 1953	0	257 a/
November 1, 1953	- August 31, 1954	45,000	163
September 1, 1954	- September 30, 1954	0	201 a/

The foregoing tabulation indicates that a maximum storage capacity of 75,000 acre-feet would have been required for complete year-to-year regulation. As will be explained later, capacity of the Grant Lake reservoir site in excess of about 67,000 acre-feet may not be practicable due to topographic conditions. Considering this figure as the maximum capacity available some water would have been wasted during August 1953. With this exception the available storage capacity would make year-to-year regulation possible. The regulated flow, based on the above data, would be 172 cfs 90 percent of the time and 190 cfs 50 percent of the time. Values of 170 and 190 cfs for 90 percent and 50 percent of the time are being assumed for the discharge from Grant Lake.

Ptarmigan Creek

Streamflow records are available from May 1947 through September 1954. The gaging station is located about one-fourth mile upstream from the mouth of Ptarmigan Creek. The area at the outlet of Ptarmigan Lake, 29.9 square miles, is 92 percent of the area at the gaging station. In view of the higher elevations of the drainage area above the lake the runoff per square mile into the lake would be somewhat greater than for the area between the lake and the gaging station. Consequently, the discharge from the lake would be greater than the 92 percent relation that a straight drainage area ratio would indicate. For this report the discharge at the lake outlet has been assumed as being the same as that observed at the gaging station.

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a/ Natural flow.

The average discharge for the 7-year period of record was 115 cfs, varying from a minimum of 75 cfs in 1952 to a maximum of 170 cfs in 1953. The latter year was a year of exceptionally high discharge. If the year 1953 were disregarded the average for the other 6 years would have been 106 cfs. The monthly means varied from a minimum of 9.5 to a maximum of 382 cfs. The maximum mean daily discharge was 914 cfs and the maximum peak discharge was 980 cfs, both on June 29, 1953.

The regulated flow that could have been obtained during the period of record is tabulated below.

Period			Storage required for year-to-year regulation (acre-feet)	Available mean flow for period (cfs)
October 1, 1947	-	August 31, 1948	28,000	132
September 1, 1948	-	November 30, 1949	40,000	126
December 1, 1949	-	September 30, 1950	30,000	123
October 1, 1950	-	November 30, 1952	30,000	90
December 1, 1952	-	October 31, 1953	38,000	164
November 1, 1953	-	September 30, 1954	24,000	88

The above table shows that year-to-year regulation could have been attained with a maximum storage capacity of 40,000 acre-feet. This would have provided flows of 90 and 125 cfs for 90 and 50 percent of the time. To utilize all of the flow over the 3-year period, October 1, 1950 through October 31, 1953, would have required a maximum storage capacity of 58,000 acre-feet and would have resulted in flows of 108 and 121 cfs for 90 and 50 percent of the time. The figures available for year-to-year regulation have been assumed for the power estimates in this report, viz., 90 and 125 cfs for 90 and 50 percent of the time.

Cooper Creek

The gaging station on Cooper Creek is located at the outlet of Cooper Lake and therefore provides an actual record of the lake discharge. Records are available from August 1949 through September 1954. The average discharge for the 5 complete years of record was 89.1 cfs, varying from a minimum annual of 60.5 cfs in 1952 to a maximum annual of 151 cfs in 1953. The monthly means varied from a minimum of 9.1 cfs to a maximum of 408 cfs. The maximum peak discharge was 695 cfs and the maximum daily mean was 689 cfs, both of which occurred on June 29, 1953. The regulated flow that could have been attained during the period of record is shown in the following tabulation.

Period		Storage required for year-to-year regulation (acre-feet)	Available mean flow for period (cfs)
October 1, 1949	- October 31, 1949	-	102 a/
November 1, 1949	- November 30, 1949	-	130 a/
December 1, 1949	- September 30, 1950	20,000	82
October 1, 1950	- September 30, 1951	16,000	66
October 1, 1951	- Novwmber 30, 1952	24,000	80
December 1, 1952	- August 31, 1953	30,000	130
September 1, 1953	- September 30, 1953	-	125 a/
October 1, 1953	- October 31, 1953	-	132 a/
November 1, 1953	- September 30, 1954	18,000	76

The foregoing tabulation shows that year-to-year regulation could have been attained with a maximum storage capacity of 30,000 acre-feet. This would have resulted in regulated flows of 71 and 81 cfs for 90 and 50 percent of the time. Values of 70 and 80 cfs are being assumed for the power estimates in this report.

As explained under the section on Geography (page 6), the flow from Stetson Creek could readily be diverted into Cooper Lake, thus increasing the area draining into the lake by 27 percent. Assuming that the runoff characteristics for the Stetson Creek Basin are similar to those for the Cooper Lake Basin, the flow available for power generation would be increased 27 percent by this diversion. The figures then become 90 and 103 cfs for 90 and 50 percent of the time. For this report values of 90 and 100 cfs are assumed for this alternative plan.

Crescent Creek

The gaging station on Crescent Creek is located one-fourth mile upstream from the mouth of the creek and 5 3/4 miles downstream from the outlet of Crescent Lake. Records are available from August 1949 through September 1954. The area at the gaging station is 31.3 square miles and at the outlet of Crescent Lake 21.2 square miles or 68 percent of the area at the gaging station. As explained under the section on Geography, the drainage from the Carter Lake Basin adjacent to the head of the Crescent Lake Basin and the drainage from a small tributary basin adjacent to the lower end of the lake could readily be diverted into Crescent Lake. The addition of the Carter Lake drainage area would increase the area tributary to Crescent Lake to 22.9 square miles or 73 percent of the area at the gaging station. Including the basin near the lake outlet would bring the total to 24.0 square miles or 77 percent of the area at the gaging station. It seems quite probable that any development on Crescent Lake would take advantage of the possibility of the diversion from Carter Lake and possibly also the diversion near the lake outlet. In view of this fact the discharge at the outlet of Crescent Lake has been assumed to be equivalent to 75 percent of that at the gaging station on Crescent Creek. Runoff estimates based on this assumption should give fairly reliable figures to use regardless of which of the three alternative plans are followed in development.

The average discharge at the gage for the 5 years of record was 70.9 cfs. This varied from a minimum of 50.5 cfs in 1952 to a maximum of 125 cfs in 1953. Using a 75-percent factor the corresponding values at the lake outlet become 53.2 cfs for mean flow, 37.9 cfs for the minimum, and 93.8 cfs for the maximum.

A mass curve for the discharge at the lake outlet, using monthly values of 75 percent of the observed values at the gaging station was plotted and used in determining the regulated flows as well as the storage capacity required to attain them. These are tabulated below.

Period			Storage required for year-to-year regulation (acre-feet)	Resulting flow attainable (cfs)
October 1, 1949	-	November 30, 1949	-	74 a/
December 1, 1949	-	September 30, 1950	8,500	46
October 1, 1950	-	November 30, 1951	9,000	39
December 1, 1951	-	December 31, 1952	14,000	52
January 1, 1953	-	August 31, 1953	17,000	94
September 1, 1953	-	October 31, 1953	-	72 a/
November 1, 1953	-	September 30, 1954	9,500	41

The foregoing tabulation shows that year-to-year regulation could have been attained with a maximum storage capacity of 17,000 acre-feet. The resulting regulated flows would have been 40 and 49 cfs for 90 and 50 percent of the time. Values of 40 and 50 cfs are being assumed for the power estimates.

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a/ Natural flow.

Summary

The estimated regulated flows for the four lakes are summarized below.

Lake	Estimated discharge in cfs: 90 percent of time (Q90)	Estimated discharge in cfs: 50 percent of time (Q50)
Grant	170	190
Ptarmigan	90	125
Cooper (lake discharge only)	70	80
(with diversion from Stetson Creek)	90	100
Crescent	40	50

The difference in flow between the four lakes is due not only to the differences in the areas of the respective drainage basins but also to the difference in the unit runoff per square mile. This is shown in table 8. From this it is noted that Grant Creek has the largest yield and the other three creeks progressively less. Considering the 5-year period, 1950-1954, for which records are available at all the stations, comparison with Grant Creek records shows that the runoff per square mile from Ptarmigan Creek was three-fourths, from Cooper Creek three-fifths, and from Crescent Creek one-half of that from Grant Creek. The variation is emphasized by the fact that the four basins fall within a rectangular area extending about 30 miles east and west and 15 miles north and south.

Table 8 also includes the precipitation at Seward and a comparison of the runoff from the basins for the years of record with this precipitation. Although relationships vary from year to year there is a fairly good general agreement among the variations in precipitation and the runoff from the four basins. For example, the 1953 precipitation at Seward was more than double the value for 1952. The 1953 runoff from each basin was also more than double the 1952 value. It is of interest to note that the runoff from Grant Creek in general is inclined to be greater than the precipitation at Seward. The runoff depth in inches for Ptarmigan Creek approximates four-fifths, for Cooper Creek two-thirds, and Crescent one-half of the precipitation at Seward. The pronounced variation in precipitation over the four basins, as indicated by the values for depth of runoff, is no doubt due to orographic conditions and their effects on storm paths and precipitation.

STREAM REGULATION

Favorable opportunities exist for the development of storage on each of the four lakes under consideration. Reference to the summary of areas, table 1, shows that the area of each lake is an appreciable percentage of the area of the drainage basin above the lake outlet. In view of this relation storage for complete equalization of the streamflow throughout the year or over a period of several years can be attained by the construction of dams of low to moderate height at the outlets of each of the four lakes. A discussion of each of the four sites follows. The area and capacity values for each of the four lakes is shown in table 9.

The Grant Lake, Ptarmigan Lake, Cooper Lake, and Crescent Lake reservoir sites and dam sites are shown on plates 1, 2, 3, and 4, respectively.

Grant Lake Reservoir Site

The development of storage on Grant Lake could be accomplished by the construction of a dam at the lake outlet to raise the lake level or by tapping the lake with a tunnel to draw it below its natural level. In the first mile upstream from the outlet the lake has depths of as much as 200 feet. At the island about 2 1/2 miles from the lake outlet, just east of the right-angle bend in the lake, the depths are shallow. In the channel between the island and the north shore the depth is only three feet and in the channel between the island and the south shore 18 feet, corresponding to elevations of 697 and 682 feet at the time of the field survey. If storage were to be developed by lowering the lake below its natrual level, excavation would be necessary to obtain sufficient depth in the channel between the island and the shore. The depths in the lower end of the lake would readily permit a diversion at a sufficient depth to obtain necessary storage. However, such a plan of development would result in a mean head of about 20 percent less than under a plan of storage development by the construction of a dam at the lake outlet. In this report storage development by lowering the lake is therefore not considered.

The maximum reservoir elevation or flow line for Grant Lake is limited to an elevation of about 740 feet by the saddle in the ridge between Grant Lake and Upper Trail Lake one mile north of the outlet of Grant Lake. The low point in this saddle is at elevation 743 feet. A reservoir elevation exceeding 740 feet would require a dike or auxiliary dam in this saddle. The estimated capacity at elevation 740 feet is 67,000 acre-feet. As pointed out under Water Supply, this capacity would have been adequate to attain year-to-year regulation for all years except one during the 7-year period of record, 1948-1954. The maximum storage required during one period, December 1, 1952 through August 31, 1953, was 75,000 acre-feet, equivalent to a maximum elevation of 745 feet, or two feet higher than the low point of the saddle. A capacity of 75,000 acre-feet or even more could therefore be readily attained by the construction of a low dike in the saddle along with a slight increase in the height of the dam at the lake outlet. For the purpose of this report a maximum reservoir elevation of 740 feet is assumed, equivalent to a capacity of 67,000 acre-feet.

Table 8.--Comparison of runoff, depth in inches, for Grant, Ptarmigan, Cooper, and Crescent Creeks with precipitation at Seward, Alaska

Year a/	Precipitation at Seward inches	Grant Creek		Ptarmigan Creek		Cooper Creek		Crescent Creek	
		Runoff depth in inches	Percent of precipitation at Seward	Runoff depth in inches	Percent of precipitation at Seward	Runoff depth in inches	Percent of precipitation at Seward	Runoff depth in inches	Percent of precipitation at Seward
1948	59.28 b/	65.5	110.0	54.5	92.0	-	-	-	-
1949	58.31	57.8	98.7	52.5	90.0	-	-	-	-
1950	51.56 b/	64.0	124.0	52.6	102.0	37.8	73.5	29.5	57.3
1951	46.96	54.1	115.2	37.1	79.0	28.2	60.1	22.6	48.2
1952	42.80	48.0	112.0	31.4	73.5	26.0	60.7	22.0	51.5
1953	100.83	95.5	94.3	71.0	70.5	64.9	64.4	54.0	53.6
1954	51.73	54.0	104.3	39.2	75.9	34.6	67.0	25.6	49.6

a/ Oct. 1--Sept. 30 for both precipitation and runoff.
b/ Includes estimated value for one month.

Table 9.--Area and capacity of reservoir sites

Elevation of water surface (feet)	Area (acres)	Capacity (acre-feet) Above lake level	Capacity (acre-feet) Below lake level
Grant Lake Reservoir Site			
700	1570 a/	0	-
720	1670 b/	32,400	-
740	1780 b/ c/	66,900	-
760	1910 b/	103,800	-
800	2240 a/	-	-
Ptarmigan Lake Reservoir Site			
600	323	-	72,500
620	359	-	65,600
640	388	-	58,200
660	421	-	50,100
680	464	-	41,200
700	517	-	31,400
720	556	-	20,700
740	592	-	9,200
755	636	0	0
760	725	3,400	-
780	877	19,400	-
800	1030	38,500	-
820	1120	60,000	-
Cooper Lake Reservoir Site			
1100	1500	-	119,600
1120	1660	-	88,000
1140	1800	-	53,400
1160	1940	-	16,000
1168	2050	0	0
1180	2290	26,000	-
1200	2610	75,000	-
1220	2010	131,200	-
1240	3280	194,100	-

Table 9.--Continued

Elevation of water surface (feet)	Area (acres)	Capacity (acre-feet) Above lake level	Below lake level
Crescent Lake Reservoir Site			
1340	465	-	96,200
1360	619	-	85,400
1380	716	-	72,000
1400	818	-	56,600
1420	950	-	39,600
1440	1170	-	17,800
1454	1370	0	0
1460	1460	8,500	-
1480	1640	39,500	-
1500	1940 d/	75,300	-

a/ Measured on Seward B-6 and B-7 topographic quadrangles.
b/ Interpolated values.
c/ Reservoir elevation above 740 would require auxiliary dam across saddle in ridge between Grant Lake and Upper Trail Lake.
d/ Assuming auxiliary dam at outlet of Carter Lake.

Ptarmigan Lake Reservoir Site

The development of the Ptarmigan Lake reservoir site could be accomplished by the construction of a dam at the lake outlet to raise the lake above its natural elevation or by drawing the lake below its natural elevation by the construction of appropriate diversion works. As in the case of Grant Lake, the latter method would result in an average head of 15 to 20 percent less than in the former case. In the illustrative scheme of development used in this report construction of a dam at the lake outlet is assumed.

A storage capacity of 40,000 acre-feet would have made possible complete regulation on a year-to-year basis during the 7-year period, 1948-1954, for which streamflow records are available. Reference to table 9 shows that a capacity of 40,000 acre-feet would require a dam that would raise the lake level 47 feet or to the 802-foot elevation. As seen from the map of the Ptarmigan Lake dam site, plate 2, there is a saddle 300 feet southwest of the lake outlet, the low point of which is between the 800- and 810-foot contour. With a maximum reservoir elevation of 802 feet as suggested above, a small dam or dike might be required in this saddle and would, of course, be required for a reservoir elevation much above 802 feet. This saddle could be used as the spillway location, thereby returning any overflow water to the creek at a point well below the dam. There is also a saddle located 400 feet northeast of the lake outlet, the controlling elevation of which is not much above the 810-foot contour. A reservoir elevation approaching 810 feet would require consideration of a dike in this saddle.

As stated above, a storage capacity of 40,000 acre-feet would require raising the lake level 47 feet. The lake would have to be lowered 72 feet below its normal level to obtain this same capacity. The lake attains a depth of over 150 feet within one-half mile of the outlet so that conditions are favorable for diverting the lake well below its natural elevation.

Cooper Lake Reservoir Site

Cooper Lake has an area equal to 10 percent of the area of its drainage basin. Consequently an appreciable storage capacity can be attained by a relatively small change in lake level. As shown in the section on Water Supply, complete regulation during the 5-year period of record, 1950-1954, could have been attained with a storage capacity of 30,000 acre-feet. This capacity would require raising the lake 14 feet above or lowering it 16 feet below its natural level. The average reservoir elevation in the former case would be 1,175 feet and in the latter 1,160 feet. A difference of 15 feet represents only 2 percent of the total head available between Cooper Lake and Kenai Lake. In view of the small size of dam that would be required the illustrative scheme for power development used in this report is based on the construction of a dam at the lake outlet to develop the requisite storage capacity. If Stetson Creek is diverted into Cooper Lake the additional storage capacity could be obtained with only an additional four- or five-foot increase in the maximum reservoir elevation. It is estimated that raising the lake level 20 feet would provide sufficient capacity to fully accommodate the diversion from Stetson Creek.

Crescent Lake Reservoir Site

Crescent Lake, like Cooper Lake, has an area equivalent to 10 percent of the area of its drainage basin. Consequently, the requisite storage capacity can be attained with a comparatively small change in lake level. The analysis of the streamflow shows that a maximum storage capacity of 17,000 acre-feet would have been required for year-to-year regulation during the 5-year period of record, 1950-1954. This could be attained by raising the lake 12 feet or lowering it 14 feet below its natural elevation.

Although the necessary storage capacity could be attained by the construction of a dam to raise the lake level only 12 feet the construction of a somewhat higher dam would facilitate the diversion of the water from Crescent Lake to a powerhouse site on Moose Creek just upstream from its mouth at Upper Trail Lake. As previously explained, there is a low divide between the drainage into Crescent Lake and Carter Lake, the latter flowing into Moose Creek. Carter Lake is at an elevation of 1,486 feet and the divide is at an elevation of about 1,490 feet. By cutting through the narrow ridge between Carter Lake and Crescent Lake and building a dam at the outlet of Crescent Lake to raise its elevation to 1,496 feet or 10 feet above the elevation of Carter Lake, and with the construction of a small dam and appropriate headworks at the outlet of Carter Lake for a pipeline and penstock, diversion of water from Crescent Lake to a powerhouse on Moose Creek could readily be accomplished. The dam at the Crescent Lake outlet with a maximum reservoir elevation of 1,496 feet and allowing five feet for freeboard, would need to be 47 feet in height. The above plan is assumed in the illustrative scheme of development. The usable storage capacity in the 10-foot range between 1,486 and 1,496 would be 18,000 acre-feet.

WATERPOWER

Developed Power Sites

There are no developed waterpower sites within the four basins considered in this report. Plans for development on each of the four lakes are under active consideration as is evidenced by the applications listed below that have been submitted to the Federal Power Commission.

Lake	Project No.	Applicant	Remarks
Grant	2129	Grant Lake Electric Power Company	Preliminary permit issued January 1954
Ptarmigan	2156	City of Seward	Preliminary permit issued December 1954
Cooper	2170	Chugach Electric Association	Application for preliminary permit filed October 1954
Crescent	2171	City of Seward	Application for preliminary permit filed October 1954

A preliminary permit from the Federal Power Commission gives the applicant the exclusive right to conduct surveys and investigations and make plans for development. These permits are issued for a specific period, usually three years. Before actual development can be undertaken a license must be issued by the Federal Power Commission.

Undeveloped Power Sites

The development of the potential power from the four lakes can be accomplished in one stage for each lake. The possible plans of development outlined below are used as a means of evaluating the potential power. The objective of this section is to point out in general terms possible schemes of development and the potential power that could be made available. It is recognized that when actual development occurs the final plan may vary considerably from that outlined herein. However, the basic factors of water supply, available head, and storage possibilities will remain essentially the same except for possible changes in the estimates of water supply that may occur when records for additional years are obtained.

As pointed out in the preceding section on Stream Regulation, storage at each of the four reservoir sites could be developed by the construction of a dam at the lake outlet to raise the lake level above its natural elevation or by tapping the lake at sufficient depth and drawing the lake below its natural elevation. The illustrative plans presented in this report contemplate the construction of a dam at the lake outlet in each case. For Grant Lake and Ptarmigan Lake development of storage by drawing the lake below its natural level would result in a substantial decrease in the available head that could be developed and a corresponding decrease in the available power as compared with raising the lake by the construction of a dam. In the case of Cooper Lake and Crescent Lake, the difference in the head that could be utilized is only a matter of two or three percent between the two methods. In the case of Crescent Lake, however, there are definite advantages to be gained by the construction of a dam at the lake outlet as will subsequently be explained.

The four power sites are described below. The estimated waterpower potential of the sites with related data are shown in table 10.

In the following descriptions the statements regarding the geologic conditions at dam sites or along tunnel routes are based on the report previously mentioned under the section on Geology. This report should be referred to for more detail about the geologic conditions and their relationship to and effects upon probable plans of development.

In the matter of tunnels and pipelines, the intakes would have to be sufficiently below the minimum reservoir elevation to provide an adequate water seal and would be subject to a hydrostatic pressure equivalent to this depth and the variation in reservoir elevations. The gradients for any tunnels considered would be comparatively flat as in all cases, with the possible exception of Grant Lake, the minimum size of tunnel that can be conveniently driven would have a larger area than would be required by hydraulic considerations. Any pipelines would likely have a steeper gradient than a tunnel. In view of the low winter temperatures it may be advisable to have pipelines covered to sufficient depth to minimize freezing. So doing would also minimize the possibilities of damage from avalanches. For these same reasons it may be advisable to give consideration to locating the penstocks underground.

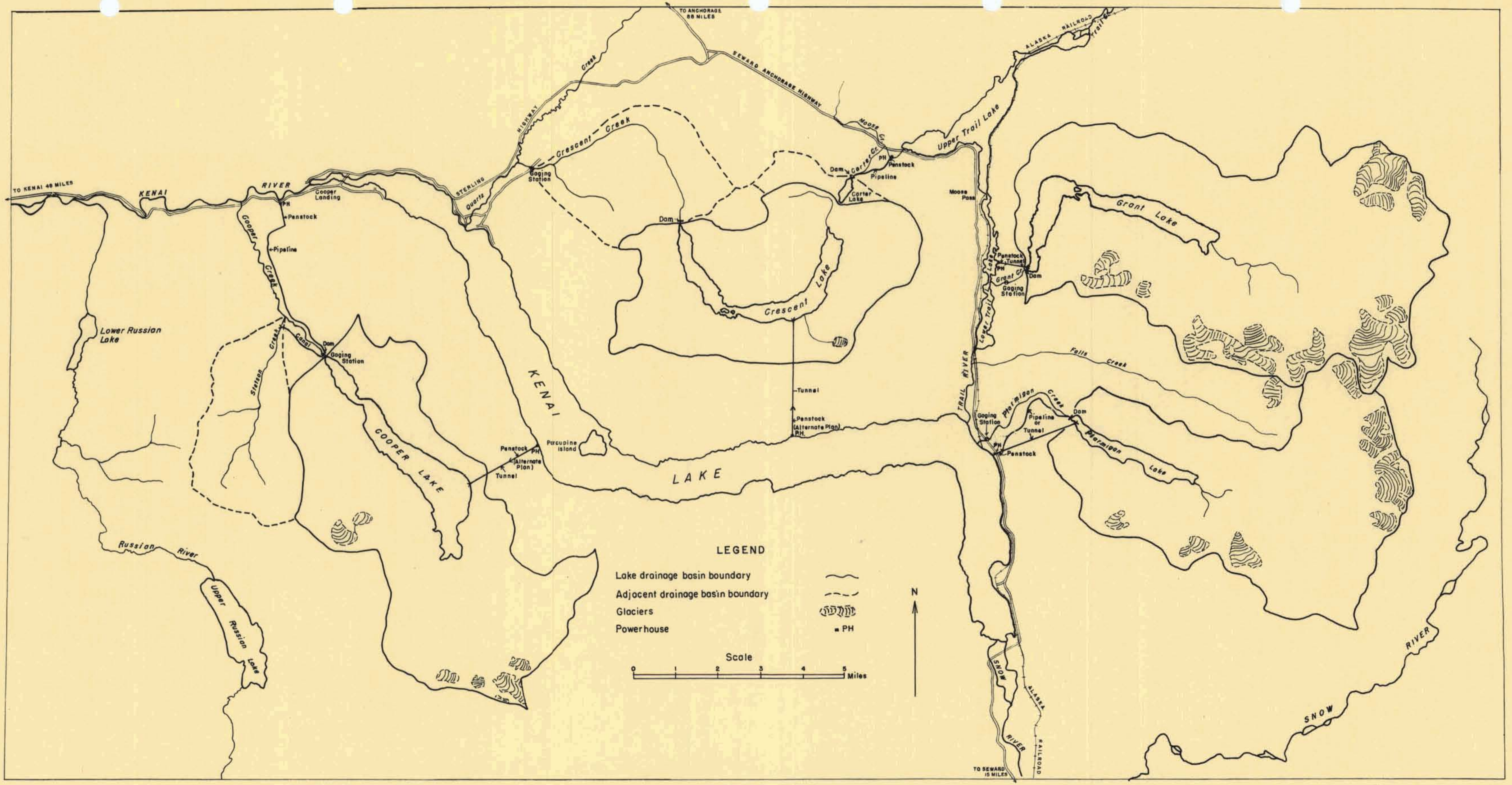

FIGURE 2. ILLUSTRATIVE PLANS OF WATERPOWER DEVELOPMENT FOR GRANT, PTARMIGAN, COOPER AND CRESCENT LAKES

Tailrace elevations have been assumed to be the same as for the lake or stream on which the powerhouse is located. Whether or not this is attainable will depend on type of design selected. In the power estimates in this report the available head has been considered as the difference between the estimated mean reservoir elevation and the tailrace elevation as above referred to.

Grant Lake Power Site

The development of power from Grant Lake would require the construction of a dam at the lake outlet and conveyance of the water to one of several possible powerhouse sites on the east shore of Upper Trail Lake. In this report a dam with a maximum reservoir elevation of 740 feet, 40 feet above normal lake elevation, is assumed. With a five-foot freeboard such a dam would have a height of 45 feet above normal lake elevation and a crest length of approximately 550 feet. The exact length will depend on the actual location selected but will be between 500 and 600 feet.

A dam with a maximum reservoir elevation higher than 740 feet would require an auxiliary dam or dike in the saddle in the ridge between Grant Lake and Upper Trail Lake located one mile north of the outlet of Grant Lake. The controlling elevation in this saddle is 743 feet. This saddle could serve as a location for the spillway. If the maximum reservoir elevation were limited to 740 feet some excavation would be required. With a higher reservoir elevation the spillway structure could also serve as the auxiliary dam. A spillway could also be incorporated as part of the main dam.

The dam site area is underlain by a uniformly dipping sequence of interbedded slate, sandy slate and graywacke. These rocks, particularly the graywacke, are suitable as a foundation for either a concrete or rock fill dam of the height required at this site, about 50 feet.

Water from the reservoir would be conveyed by a pipeline or tunnel to a powerhouse site at one of several possible locations along the east shore of Upper Trail Lake. If a pipeline were used it would follow the right bank of Grant Creek for about one-half mile and then swing away to the north for about one-half mile to the head of the penstock leading to a powerhouse site in the cove a half mile northeast of the mouth of Grant Creek. The penstock would have a length of 700 to 800 feet. Part of the pipeline route along Grant Creek would be through a canyon with very steep walls where construction and maintenance would be difficult (see plate 1).

The elevation of Upper Trail Lake is 472 feet which is considered the tailrace elevation for the powerhouse. The head would vary from a minimum of 228 feet to a maximum of 268 feet with an estimated mean head of 249 feet.

There are several possible tunnel routes that could be considered, varying in length from about 2,700 feet to about 3,700 feet, each terminating in a penstock 700 to 800 feet in length. The shortest tunnel route, 2,700 feet, would divert from a point just upstream from the dam at the lake outlet and lead to the same powerhouse site mentioned above for the pipeline. This same powerhouse site could also be reached by a tunnel diverting from the lake in the small embayment one-half mile north of the lake outlet. A tunnel originating at the same point, and about 3,500 feet in length, could lead to a powerhouse site in the cove on the east shore of Upper Trail Lake one mile above its outlet. Two other tunnel routes could be used for this alternative powerhouse site. One would divert from Grant Lake in the small embayment 0.8 mile north of the lake outlet and would have an approximate length of 3,300 feet. The other route would originate in the embayment 1.1 mile north of the lake outlet and would have an approximate length of 3,700 feet. The final selection of a tunnel route would be dictated primarily by the geologic conditions that would be encountered rather than by the actual length of the route.

The ridge between Grant Lake and Upper Trail Lake is underlain by interbedded slate and graywacke. The strike of both bedding and cleavage is generally between N and N 10°E. The bedrock for the most part appears to be uniformly fresh, sound, and tight. The most favorable alignment for a tunnel would be at right angles to the bedding strike or almost due west.

The minimum size of tunnel that could be conveniently driven would probably be adequate for the volume of water to be carried with velocities conforming to accepted design standards. The potential power would be essentially the same for any of the suggested tunnel routes. The potential power with the diversion by pipeline would be slightly less than for the tunnel diversion due to greater length and less favorable hydraulic characteristics. The regulated flow from Grant Lake has been estimated as 170 and 190 cfs for 90 and 50 percent of the time, respectively. The corresponding power values with the plan of development outlined would be 2,880 and 3,220 kilowatts.

The transmission line from either of the above sites could follow the Seward-Anchorage Highway. The distance from this site to Seward is 27 miles.

The proximity of Grant Lake to the Alaska Railroad and the Seward-Anchorage Highway makes the location for the several structures that would be required readily accessible.

Ptarmigan Lake Power Site

The plans of development for Ptarmigan Lake would be similar to those for Grant Lake. A dam would be built at the lake outlet to raise the lake to a maximum elevation of 802 feet or 47 feet above normal lake level.

Allowing for a five-foot freeboard, the dam would have a height of 52 feet above lake level. Immediately below the lake outlet there is a narrow canyon so that a dam 50 feet high would have a crest length of only 100 feet (see plate 2).

As previously explained in the section on Stream Regulation, there is a saddle located 300 feet southwest and also one located 400 feet northeast of the lake outlet. The controlling elevation in the first is between the 800- and 810-foot contours and in the second between the 810- and 820-foot contours, apparently not very much above the 810-foot contour. With a maximum reservoir elevation of 802 feet a small auxiliary dam or dike might be required in the saddle first mentioned. The spillway could also be located in this saddle and could be incorporated as part of the auxiliary dam. This spillway location would return any excess flow to the creek well downstream from the dam. If the maximum reservoir elevation approached the 810-foot elevation consideration would also have to be given to the second saddle mentioned.

The dam site is underlain by slate that contains minor amounts of graywacke in lenses less than two inches thick. The slate is fine-grained, well consolidated, and blue-black to black in color. The rock is well suited as the foundation for a concrete or rock fill dam of the height considered, about 50 feet. The profile of the stream valley and soundness of the foundation are such that an arch dam could be considered at this site.

The powerhouse would be located on the shore of Kenai Lake one-half mile southeast of the mouth of Ptarmigan Creek and three-fourths mile southeast of the Kenai Lake Ranger Station. The elevation of Kenai Lake is 436 feet which is considered as the tailrace elevation for this powerhouse. The head would vary from 319 to 366 feet, with an estimated mean head of 345 feet. Water would be brought from the reservoir to the penstock leading to the powerhouse either through a pipeline following the left bank of Ptarmigan Creek or through a tunnel. The pipeline would have a length of 2.5 miles and the tunnel 1.9 miles. The diversion point for the tunnel could be located at some point along the southwest shore of the lake in the first half mile upstream from the lake outlet and the length to the penstock leading to the powerhouse site would remain close to the 1.9 miles above indicated. Most of the ridge between Ptarmigan Creek and Kenai Lake is underlain by well consolidated dark slate. Near Kenai Lake the slate is interbedded with thick beds of hard, massive graywacke. The bedrock along most of the tunnel alignment would probably be relatively sound and tight. Some closely jointed or faulted zones may be encountered. The penstock would be in practically the same location in either plan and would have a length of 1,000 feet or less. The tunnel diversion would tend to give slightly greater power values than the pipeline diversion due to the more favorable characteristics of shorter length and less friction loss as a tunnel would likely have a greater cross sectional area than a pipeline. The tunnel plan would be preferable to the pipeline from the standpoint of operation and maintenance although the initial cost of the tunnel plan would probably be greater than for the pipeline. The relative merits of the two plans would require a detailed analysis which is beyond the scope of this report. The regulated flow from Ptarmigan Lake has been estimated as 90 and 125 cfs for 90 and 50 percent of the time. The corresponding power values are 2,110 and 2,930 kilowatts.

The transmission line route from the powerhouse could follow along or near the Seward-Anchorage Highway. The distance to Seward would be 22 miles.

Ptarmigan Lake, like Grant Lake, is also readily accessible from the Alaska Railroad and the Seward-Anchorage Highway.

Cooper Lake Power Site

The plan of development outlined herein would consist of a dam at the lake outlet to develop the necessary storage capacity. Such a dam would only have to raise the lake level 14 feet to provide the requisite storage to regulate the flow from Cooper Lake. However, as explained under Water Supply it appears possible to divert the flow from Stetson Creek into the Cooper Lake reservoir and by so doing increase the flow available for power production approximately 25 percent. In order to provide for this additional volume as well as to provide some additional capacity over the amount indicated by the records now available a dam 25 feet high with a maximum reservoir elevation 20 feet above normal lake elevation has been assumed for this report.

The geologic conditions within the area in which the dam would be located are quite variable and the type of dam to be constructed would depend on the exact location selected along with further investigation of the geologic conditions. In order to give a general picture of the size of the dam required two tentative locations will be discussed (see plate 3).

The first location considered is 800 feet downstream from the lake outlet. The stream elevation at this point is 1,158 feet or 10 feet lower than the lake level. The maximum reservoir elevation would be 1,188 feet and the crest of the dam would be at elevation 1,193 feet. The dam would have a height of 35 feet above the stream elevation and a crest length of 325 feet. From the information now available it appears that an earth fill dam might be considered for this site with adequate cut-off provisions for both the foundation and abutments.

The second location is about 2,400 feet downstream from the lake outlet. At this point the stream elevation is 1,125 feet. With a maximum reservoir elevation of 1,188 feet and allowing a 5-foot freeboard the dam would have a height of 68 feet above stream elevation. The crest length would be approximately 250 feet. This narrow gorge is in graywacke and may provide a suitable site for a concrete or rock fill type of dam. It might even be suitable for an arch type of dam.

Topographic conditions throughout the dam site area do not permit the location of a spillway in a nearby saddle well removed from the dam, as was the case for Grant Lake and ptarmigan Lake. The spillway would have to be incorporated as part of the dam or immediately adjacent to it on either bank.

As above mentioned, it may be advantageous to divert the flow from Stetson Creek into Cooper Lake and thus increase the water available for power generation. This diversion would require a canal about 1 1/2 miles long with sufficient capacity to carry the entire flow from Stetson Creek during periods of maximum discharge. During the period of record the maximum peak discharge at the outlet of Cooper Lake was 695 cfs. Based on drainage area ratio the corresponding maximum on Stetson Creek would have been 188 cfs. A canal capacity in the order of magnitude of 200 cfs or more would therefore be required to take advantage of the entire discharge from Stetson Creek.

There are two possible locations for a powerhouse for the development of Cooper Lake. One location would be on the west shore of Kenai Lake, almost opposite Porcupine Island, 9 1/4 miles southeast of the outlet of Kenai Lake at Cooper Landing. At this point the shortest distance between the shore lines of Cooper Lake and Kenai Lake is 1.8 miles. This location would require a tunnel 1 -1/4 miles in length and a penstock about 4,000 feet in length to convey the water from the reservoir to the powerhouse. The tunnel would divert from Cooper Lake at a point about 1 3/4 miles from the head of the lake, near where the shore line changes from a north-south to a northwest-southeast direction. The tunnel route would be through the saddle between Cooper and Kenai Lakes on a course of about N 70°E. The tunnel would be through well consolidated, blue-black to black slate and hard, gray or black graywacke. The transmission line route from the powerhouse location would depend on where the power was to be used. If the market area were Seward and vicinity the route would most likely follow the south and west shore of Kenai Lake until the Seward-Anchorage Highway is reached near the head of Kenai Lake, a distance of 15 1/2 miles. From this point to Seward the distance is 17 miles, so the over-all distance from the powerhouse to Seward would be between 32 and 33 miles. Another route would follow the west and south shore of Kenai Lake to the highway bridge three-fourths mile east of Cooper Landing, a distance of 8 1/2 miles, and then follow the highway to the point where the power would be used.

The other location for the powerhouse would be on the south or left bank of the Kenai River at a point three-fourths mile east of the mouth of Cooper Creek and three-fourths mile west of Cooper Landing. Water would be conveyed from the reservoir to the powerhouse through a pipeline about 3 3/4 miles in length following the right side of the Cooper Creek Valley to the penstock which would be about 3,500 feet in length. This location has the advantage of being on an existing highway. The over-all length of the conduit from the lake to this site is 4 1/2 miles, as compared with a length of two miles for the powerhouse site on Kenai Lake and consequently the net head would be slightly less. The final choice as to which of the two locations is preferable will require a detailed study to evaluate and compare the various considerations, some of which cannot be fully evaluated until time of actual development is at hand. Both schemes of development are included in the illustrative plans shown in figure 2. The plan with the powerhouse location on Kenai Lake has been shown as an alternative plan.

With the powerhouse located on the Kenai River the tailrace elevation would be essentially the same as the elevation of Kenai Lake, 436 feet. The mean head is estimated as 746 feet.

The estimated regulated flow from Cooper Lake is 70 and 80 cfs for 90 and 50 percent of the time. The corresponding power values are 3,550 and 4,060 kilowatts. Including the diversion from Stetson Creek these values would be 4,570 and 5,070 kilowatts.

Crescent Lake Power Site

There are two general plans for the development of power from Crescent Lake, both of which contemplate the construction of a dam at the outlet of Crescent Lake to develop the necessary storage capacity. Although raising the lake level 12 feet will provide the necessary storage capacity the illustrative plan herein proposed contemplates a dam to raise the lake 42 feet so as to provide a simpler method of conveying the water from the reservoir to the powerhouse. The difference in the two plans of development is in the location of the powerhouse.

In one case the powerhouse would be located on the north shore of Kenai Lake, 4 1/2 miles east of Porcupine Island and 5 miles west of the Kenai Lake Ranger Station. Water would be brought from the reservoir through a tunnel 2.0 miles in length to the penstock which would have a length of 4,000 feet. The tunnel would divert from the south side of Crescent Lake at a point one-third mile east of the trail to Kenai Lake and would have a north-south direction. This location and alignment of the tunnel along with the penstock takes advantage of the shortest distance between the two lakes, 2 3/4 miles. The tunnel length would be about two miles with the penstock three-fourths mile in length. The bedrock in the tunnel area is a slate interbedded with lenses of graywacke. The tunnel route above outlined would pass through some unconsolidated material for a short distance near Crescent Lake. An alternate location about 4,000 feet to the west would encounter less unconsolidated material and have more favorable rock conditions as well. Its length would be slightly longer, approximately five percent.

The most likely transmission line route would follow the north shore of Kenai Lake five miles, cross the Trail River, and then reach the Seward-Anchorage Highway at a point near the Kenai Lake Ranger Station 23 miles from Seward.

The other powerhouse location would be on Moose Creek, one-fourth mile upstream from its mouth at Upper Trail Lake, and along the Seward-Anchorage Highway, 37 miles from Seward. In this plan advantage would be taken of the topography to reduce the length of conduit required to bring water from the reservoir to the powerhouse (see plate 4). In this plan the dam at the outlet of Crescent Lake would be built so as to provide a maximum lake level of 1,496 feet or 42 feet above normal lake level. The dam would be 500 to 600 feet downstream from the lake outlet and would have a crest elevation of 1,501 and a crest length of 1,000 feet. The low divide between the head of Carter Lake and Crescent Lake would be cut down to the elevation of Carter Lake, 1,486 feet. This divide is only 5 to 10 feet higher than Carter Lake. A dam would be built at the outlet of Carter Lake with the maximum flow line of 1,496 above mentioned or 10 feet higher than the level of Carter Lake. Such a dam would be 15 feet above normal lake level. There is a small saddle 800 feet west of the outlet of Carter Lake. The exact elevation in this saddle is not known but appears to be well below the 1500-foot contour and somewhat above the elevation of Carter Lake, 1,486 feet. A small dam or dike would be required in this saddle. The Crescent Lake reservoir would thus be formed by two dams, one at the outlet of Crescent Lake and the other at the outlet of Carter Lake, with a small auxiliary dam or dike in the saddle above mentioned. The dam at the outlet of Carter Lake could also serve as the headworks for the pipeline and penstock leading to the powerhouse. The pipeline would have a length of three-fourths mile and the penstock 2,000 feet. In view of being more readily accessible and the lesser conduit requirements, the powerhouse location on Moose Creek is considered preferable to the one on Kenai Lake.

In the foregoing plan the tailrace elevation for the powerhouse is considered as being the same as the elevation of Upper Trail Lake, 472 feet. The estimated mean head is 1,019 feet. The estimated regulated flow from Crescent Lake is 40 and 50 cfs for 90 and 50 percent of the time. The corresponding values for power are 2,770 and 3,460 kilowatts.

The plans as above outlined assume favorable geologic conditions at the dam site at the Crescent Lake outlet as well as at the Carter Lake outlet. As the dam at the latter location will only raise the water 10 feet it is believed that whatever unfavorable geologic conditions might exist there can be readily overcome. The foundation material at the dam site at the outlet of Crescent Lake consists of unconsolidated stream and fluvioglacial deposits which may extend to a depth of as much as 50 feet or more. This material has adequate physical characteristics to support a low earth fill dam of proper design. However, from the surface indications this material appears quire permeable so that seepage may be a critical factor in determining the suitability of this site. Further investigations must be made to determine its geologic feasibility.

Topographic conditions are favorable for the location of a spillway around either end of the dam that would empty into the channel well below it.

In the event that geologic conditions are such that the construction of a dam at the outlet of Crescent Lake is not feasible the plan of development of drawing the lake below its natural level can be considered as an alternative. With a powerhouse location on Kenai Lake the diversion conditions would remain essentially the same as previously described. With a powerhouse location on Moose Creek the diversion would require a tunnel almost two miles in length. The penstock would be essentially the same as in the previous plan with a length of approximately 2,000 feet. The tunnel would be in slate and graywacke throughout the entire length. This rock is relatively sound and tight. The above tunnel would have practically the same length as the tunnel to Kenai Lake but the geologic conditions along its route are considered more favorable. The proximity to the Seward-Anchorage Highway also makes it more readily accessible. All factors considered, it appears that a powerhouse location on Moose Creek along the Seward-Anchorage Highway is the most favorable plan for the development of Crescent Lake whether the required storage capacity is developed by the building of dams as above outlined or by drawing the lake below its natural elevation.

In the plan of drawing the lake below its natural level the mean reservoir elevation would be 1,448 feet whereas if a dam could be built at the outlet of Crescent Lake so as to have a maximum reservoir elevation of 10 feet above Carter Lake the mean reservoir elevation would be 1,491 feet, or 43 feet greater. The tailrace elevation for a powerhouse on Moose Creek would be 472 feet, the elevation of Upper Trail Lake. The heads under the two schemes of development would be 976 and 1,019 feet, or a difference of about 4 percent which would also be the difference in the power available.

SUMMARY

The potential power available from the four lakes discussed following the plans of development outlined is summarized in table 10. The power estimates are based on the formula

$$P = (0.068)(Q)(H) \text{ in which}$$

P = power in kilowatts
Q = flow in cubic feet per second
H = gross head in feet.

The constant, 0.068, gives an over-all efficiency of 80 percent.

Table 10.--Estimated potential waterpower and related data for Grant, Ptarmigan, Cooper, and Crescent Lakes power sites, Alaska

Power Site	Elevations in feet				Flow in cfs		Power in kilowatts	
	Maximum reservoir	Estimated mean reservoir	Tailrace	Head	90 percent of time Q90	50 percent of time Q50	90 precent of time	50 percent of time
Grant Lake	740	721	472	249	170	190	2,880	3,220
Ptarmigan Lake	802	781	436	345	90	125	2,110	2,930
Cooper Lake (with flow from Cooper Lake only)	1,188	1,182	436	746	70	80	3,550	4,060
(with diversion from Stetson Creek)					90	100	4,570	5,070
Crescent Lake (with dam and powerhouse on Moose Creek)	1,496	1,491	472	1,019	40	50	2,770	3,460
(without dam and powerhouse on Moose Creek)	1,454	1,448	472	976	40	50	2,660	3,320
(without dam and powerhouse on Kenai Lake)	1,454	1,448	436	1,012	40	50	2,750	3,440