Geologic Reconnaissance of a Proposed Powersite on the Maksoutof River near Sitka, Southeastern Alaska

GEOLOGICAL SURVEY BULLETIN 1211-F

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By ALEXANDER A. WANEK

GEOLOGY OF WATERPOWER SITES IN ALASKA

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A feasibility study of geologic conditions at a proposed powersite on the Maksoutof River near Sitka, Alaska

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1975

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress Cataloging in Publication Data
Wanek, Alexander A. 1916–
Geologic reconnaissance of a proposed powersite on the Maksoutof River near Sitka southeastern Alaska.
(Geology of waterpower sites in Alaska) (Geological Survey Bulletin 1211–F)
Bibliography: p.
Supt. of Docs. no.: I 19.3:1211–F
1. Geology–Alaska–Baranof Island. 2. Dams–Baranof Island.
I. Title. II. Series. III. Series: United States Geological Survey Bulletin 1211–F.
QE75.B9 no. 1211–F [QE84.B36] 557.3′08s 75–619058 [627′.82′097982]

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington, D. C. 20402
Stock Number 024-001-02645-7

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GEOLOGIC RECONNAISSANCE OF A PROPOSED POWERSITE ON THE MAKSOUTOF RIVER NEAR SITKA, SOUTHEASTERN ALASKA

By ALEXANDER A. WANEK

ABSTRACT

The proposed Maksoutof River hydroelectric project to supply power to Sitka, Alaska, is about 40 miles (64 km) south of Sitka on the west side of Baranof Island. The coastal and interior regions are uninhabited and inaccessible except by boat, fixed-wing aircraft, or foot travel.

The southwestern part of Baranof Island is rugged and mountainous and contains many fiords that penetrate deep into the interior. The altitude of the summit areas is generally less than 4,000 feet (1,200 m). The Maksoutof River flows southwestward into Sandy Bay and drains a basin of approximately 32.7 square miles (85 km^2) containing several lakes that have waterpower potential.

The damsites are in areas that are seismically active. Major faults, such as the Peril Strait fault and the Chatham Strait fault on the north and east sides of Baranof Island, are known to have been active since the Tertiary Period.

The rocks of Baranof Island, which range in age from Paleozoic (?) to Mesozoic, are tightly folded and lie in broad belts that are regionally metamorphosed. The structural belts trend northwest, except locally, where they strike north and northeast. The southern part of Baranof Island is underlain by metamorphic rocks of Triassic to Cretaceous age that are intruded by dioritic rocks probably related to the Coast Range batholith. The lineaments on Baranof Island trend northwest; some lineaments have been interpreted as the surface expression of major faults or shear zones.

The waterpower development would be a single-purpose hydroelectric project on the Maksoutof River. Dams at the outlets of Maksoutof and Khvostof Lakes would provide a combined water storage of 100,000 acre-feet (123 x 10^6 m^3) in the reservoirs. Controlled releases would be made into Maksoutof Lake from Khvostof Lake.

The proposed Khvostof Lake damsite is about 100 feet (30 m) downstream from the lake outlet in a steep-walled canyon cut in graywacke of Late Jurassic and Early Cretaceous age. At places the graywacke is cataclastically foliated and metamorphosed to semischist and hornfels. The rocks strike northwest and have a steep homoclinal dip to the east. The prominent joint systems strike north to northeast and have steep dips. No faulting was observed at the damsite. Several saddles, or notches, near abutments of the damsite contain an undetermined thickness of alluvium and will require concrete dikes. The proposed damsite is suitable for a concrete dam but may require grouting to seal zones of closely spaced joints. Leakage at the damsite should be minimal. Concrete saddle dams will be required along the north shore of Khvostof Lake to prevent leakage from

the reservoir into Plotnikof Lake. The reservoir of Khvostof and Rezanof Lakes is underlain by hard dense graywacke that strikes northwest and dips steeply east. The rocks are strongly deformed, and at places the silicified bedrock may indicate zones of fracture or faulting. Construction material may be available from deposits in the reservoir and the alluvial delta below the damsite. Landslides on the southeast side of Rezanof Lake and the northeast side of Khvostof Lake may be potential hazards to the dam.

The proposed damsite at Maksoutof Lake is about 200 feet (60 m) downstream from the lake outlet. The damsite is underlain by hard dense graywacke; the abutments are competent to take the thrust of a concrete dam. No faulting was observed at the damsite, but the lineament 2,000 feet (600 m) downstream may be the surface expression of a fault or shear zone. The proposed damsite or an alternate damsite farther downstream is suitable for a concrete dam. The alternate damsite may be more favorable because the dam would be anchored in massive, less weathered bedrock and would require minimal grouting in open joints. The reservoir is underlain by graywacke that is fractured, siliceous and slightly mineralized. Jointing is well defined in the massive graywacke. No major faulting was observed in the reservoir, but the presence of fractured graywacke at places indicates some movement along joints or possible shear zones. Unconsolidated deposits consist of alluvium, colluvium, and landslide debris. Construction material may be available in deposits at the southeast end of Maksoutof Lake or in the delta where the Maksoutof River flows into the lake. An avalanche area that may be a hazard to the dam is along the north shore of the southeastern part of Maksoutof Lake.

The damsites are more suitable for concrete dams than for earthfill dams. The foundations and abutments are hard semischistose graywacke and hornfels that provide adequate bearing capacity and minimal slip. Leakage is restricted to joints normal to the dam axis and can be controlled by grouting. The dams would be short and have narrow foundations. Materials are not available in sufficient quantities for construction of earthfill dams.

The tunnel route extends from the outlet of Maksoutof Lake southwest to Sandy Bay. The bedrock is graywacke similar to that at the Maksoutof Lake damsite. The tunnel might require lining where it would penetrate a possible shear zone 1,400 feet (420 m) from the powerhouse. The powerhouse site is on an alluvial fan near the head of Sandy Bay; the installations may be subject to landslide hazards.

INTRODUCTION

The proposed Maksoutof River hydroelectric project on Baranof Island, southeastern Alaska, would supply power to Sitka, Alaska. At the request of the Branch of Waterpower Classification, Conservation Division, reconnaissance geologic investigations were made at two proposed damsites on Khvostof Lake and Maksoutof Lake during September 1967. Geologic examinations were also made of the reservoir areas, a possible tunnel and penstock route, and the powerhouse site at Sandy Bay. Transportation to the powersites was by fixed-wing float aircraft; geologic mapping was done by boat and foot traverse.

The powersite is about 40 miles (64 km) south of Sitka on the west side of Baranof Island at about lat 56°30′00′′N. and long 134°57′30′′W. (fig. 1). The coastal and interior regions south of Sitka are uninhabited except by commercial fishermen and by people who use the few cabins on fly-in lakes provided for sportsmen by the U.S. Forest Service. There are no established trails, and walking is difficult along the game trails which parallel the rivers and lakeshores.

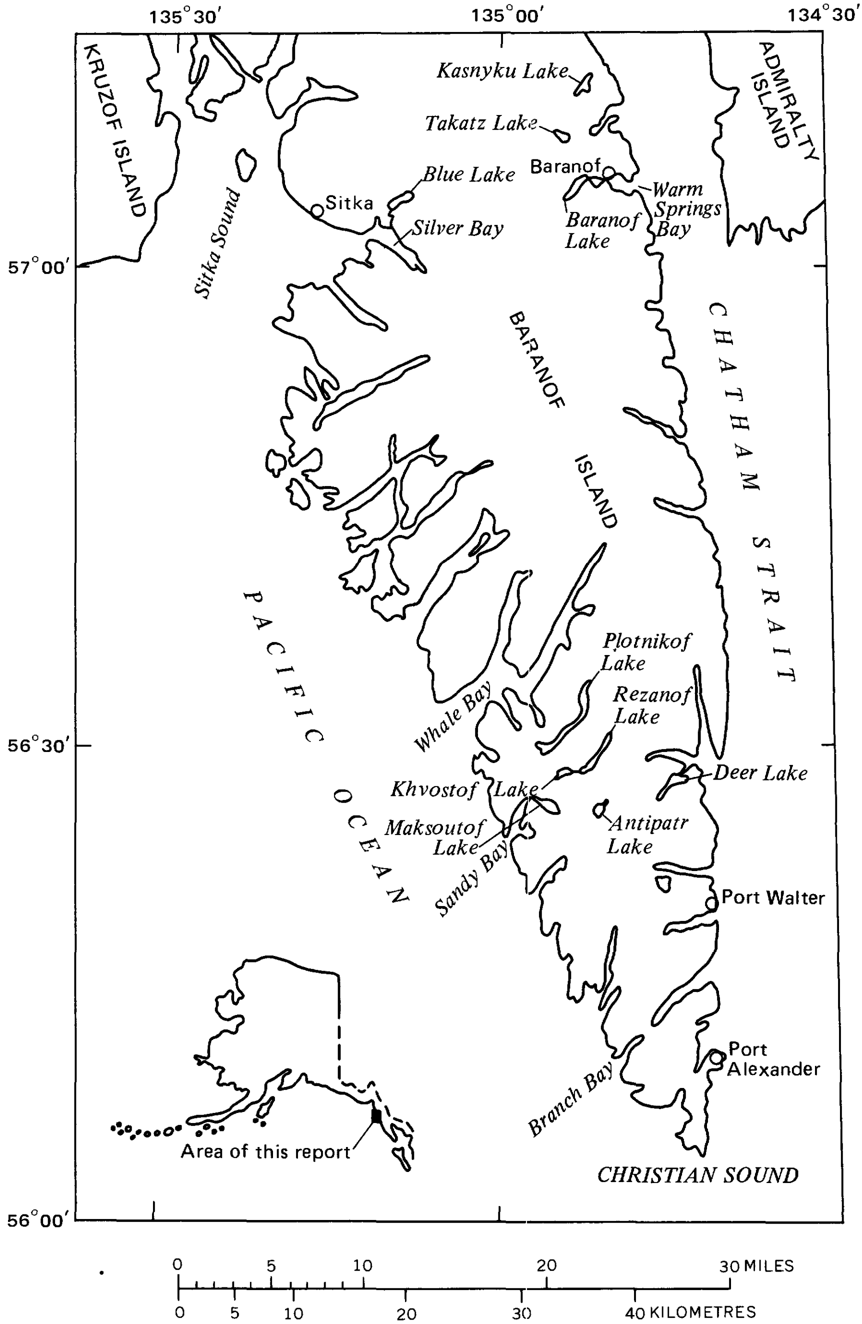

FIGURE 1.—Index map showing area studied for the proposed Maksoutof River powersite, southeastern Alaska.

Sitka (population 3,370 in 1970) is the nearest city; the Greater Sitka Borough population was 6,109 in 1970. The waterpower potential and the vast timber resources within the area provided numerous possibilities for economic development.

The powersite is shown on the U.S. Geological Survey Port Alexander 1:250,000-scale reconnaissance topographic map, the Port Alexander (C–3, B–3, and B–4) 1:63,360-scale topographic quadrangle maps, and the Maksoutof River 1:24,000- and 1:2,400-scale river-survey maps. The areas are included in the U.S. Navy aerial photographs SEA 124-012 through 015 and SEA 121-059 through 061, taken September 1948, scale approximately 1:40,000 at sea level.

Areal photographs were used for geologic mapping and to determine the general structural features in the mapped area and the adjacent areas. Observations were made at the abutments of the damsites and at many localities within the reservoir, along the tunnel route, and at the powerhouse site. Samples of the bedrock were taken for petrographic and chemical analyses.

The author acknowledges the logistical support by the Branch of Waterpower Classification, the provision of cabins and boats within the area by the U.S. Forest Service, and the able field assistance of Richard Carter.

TOPOGRAPHY AND DRAINAGE

Baranof Island is within the Chilkat-Baranof Mountains section of the Pacific Border Ranges province (Wahrhaftig, 1965). The southwestern part of Baranof Island is extremely mountainous and contains many northeast-trending fiords that penetrate deep into the interior. The fiords merge with steep-sided U-shaped valleys that contain long narrow lakes. Some of the large streams flow through a series of connecting hanging valleys that contain lakes left by glaciers. The streams flow over cliffs in spectacular falls, some as much as several hundred feet high. The altitude of the summit areas is generally less than 4,000 feet (1,200 m). The altitude of the highest peak at the head of Rezanof Lake is approximately 3,600 feet (1,080 m). Several small glaciers and snowfields are in cirques at the higher altitudes.

The Maksoutof River drains an extensive lake system and flows southwestward into Sandy Bay (fig. 2). The drainage basin contains seven lakes that have waterpower potential. Maksoutof Lake (formerly called Lonieof Lake) is at the altitude of 547 feet (164 m) and has an area of approximately 450 acres (1.8 km^2, or 182 ha); Rezanof Lake at the altitude of 730 feet (222 m) has an area of approximately 1,025 acres (4.1 km^2, or 415 ha). Two small unnamed lakes lie between Khvostof and Maksoutof Lakes. The Antipatr Lake basin contains three lakes, of which two drain into Maksoutof Lake, and the third and largest, Antipatr Lake, drains into Snipe Bay. The flow from the outlet of Antipatr

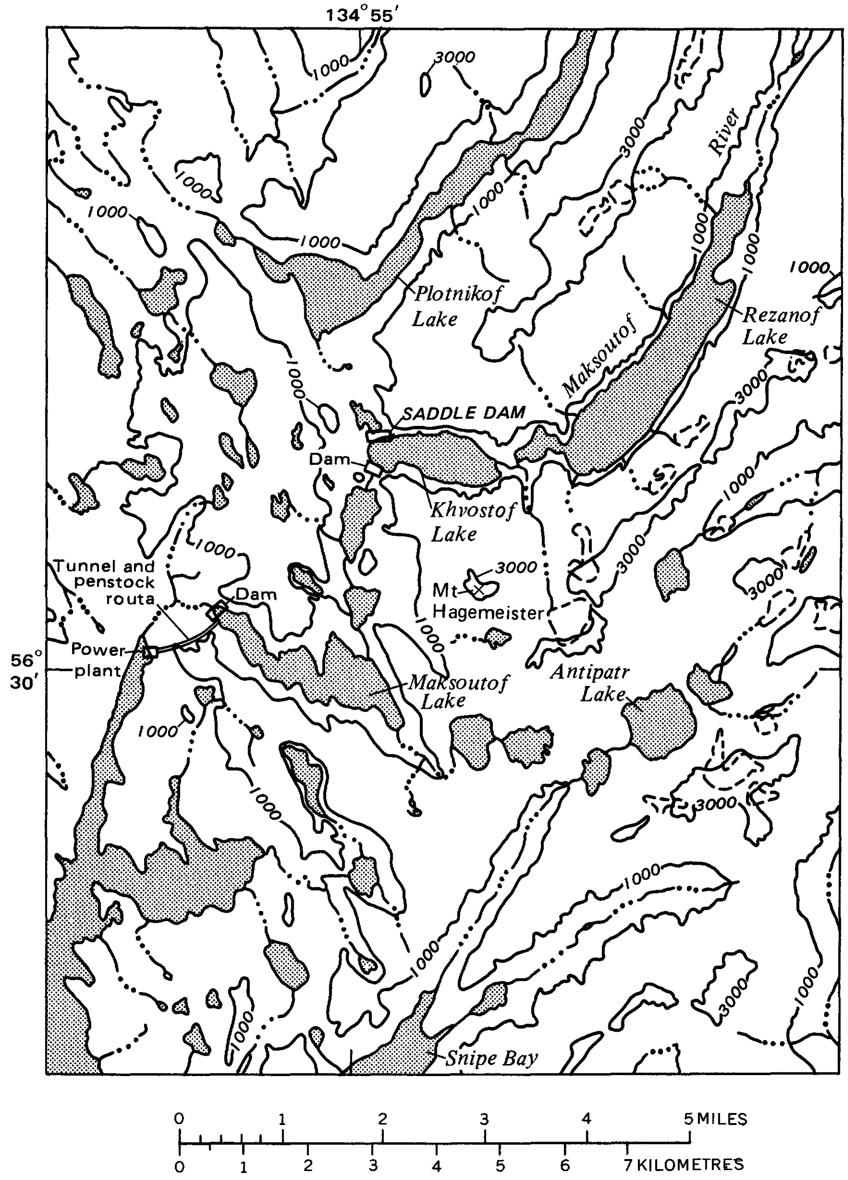

FIGURE 2.—Maksoutof River waterpower development plan.

Lake could be diverted into Maksoutof Lake. The total area draining to the outlet of Maksoutof Lake would be 32.7 square miles (85 km^2). Discharge measurements made by the U.S. Geological Survey on May 30, 1930, at the mouth of the Maksoutof River, indicated a flow of about 400 cubic feet per second (12 m^3/s). Geological Survey records for the

Maksoutof River from June 1951 to September 1956 show an average flow rate of 403 cubic feet per second (12.09 m^3/s; 291,800 acre-ft per year).

CLIMATE AND VEGETATION

The climate of southeastern Alaska is characterized by mild winters, cool summers, and large amounts of precipitation. The amount of precipitation increases progressively from June, one of the drier months, to a peak in October. The heaviest snowfall occurs during December, January, and February. Average monthly and mean annual temperature and precipitation for the period 1922–52 at Sitka (U.S. Weather Bureau, 1958, p. 20, 27) are summarized below:

Month	Temperature (°F)	Temperature (°C)	Precipitation (in.)	Precipitation (cm)
January	31.7	0.2	8.76	22.25
February	34.1	1.2	6.55	16.64
March	36.5	2.5	7.37	18.72
April	41.3	5.2	5.52	14.02
May	46.6	8.1	4.47	11.35
June	51.3	10.7	3.28	8.33
July	54.8	12.7	4.92	12.50
August	55.5	13.1	7.23	18.36
September	51.7	10.9	12.09	30.71
October	45.8	7.7	14.68	37.29
November	38.2	3.4	12.02	30.53
December	35.4	1.9	9.41	23.90
Mean annual	43.6	6.4	96.30	240.75

U.S. Weather Bureau records for a period of 17 years (1936-52) at Little Port Walter, 12 miles (19 km) southeast of the powersite on the east side of the island, show an annual precipitation of about 222.47 inches (556.18 cm). Over the same period the weather station at Baranof town reported an annual precipitation of 151.68 inches (379.20 cm).

The forest cover extends from sea level to an altitude of about 2,000 feet (600 m). Spruce, hemlock, and cedar are the most abundant conifers and generally grow in dense stands. A species of pine is present locally but is not abundant. Thickets of alder, devilsclub, and berry bushes form almost impassable barriers on talus slopes and along streams and alluvial fans. Bedrock above timberline is generally covered by a growth of grass, lichen, and heather. The area is within the Tongass National Forest.

PREVIOUS INVESTIGATIONS

One of the earliest reconnaissance geologic studies of Baranof Island was made in 1895 and 1896 by Becker (1898, p. 78–80) when he examined the geology near Sitka and described the gold lodes of Silver

Bay. Members of the Harriman Alaska Expedition (Emerson, 1904) briefly studied the rocks and mineral prospects near Sitka and Silver Bay. Wright and Wright (1905) made the first general geologic investigations from Taku Inlet to Sitka by way of Peril Strait, where they studied the geology of Silver Bay and the west coastal region of Baranof Island. The Wrights (1908) studied the rocks of western Baranof Island and those near Juneau and concluded that the areas were geologically analogous. The regional geology from Peril Strait to Silver Bay and the mineral deposits of the Sitka mining district are described by Knopf (1912). The waterpower sites in southeastern Alaska are described in a report to the Federal Power Commission and U.S. Forest Service (1947). Twenhofel (1951) studied the geology of the Blue Lake damsite near Sitka, Alaska. Soward (1961) made feasibility studies of proposed powersites at Baranof and Carbon Lakes, Baranof Island. Berg and Hinckley (1963) studied in detail the geology in the northern part of Baranof Island. Loney, Pomeroy, Brew, and Muffler (1964) made a stratigraphic and structural study to provide a basis for geologic mapping of Baranof Island. Wanek and Callahan (1969) investigated the geologic feasibility of proposed powersites at Deer and Kasnyku Lakes, Baranof Island. Callahan (1970) investigated a possible powersite at Takatz Creek on the east side of Baranof Island.

REGIONAL GEOLOGY

The geology of Baranof Island was described by Knopf (1912), Berg and Hinckley (1963), and Loney, Pomeroy, Brew, and Muffler (1964). In brief, the sedimentary rocks are probably Paleozoic to Cretaceous in age, lie in broad structural belts that trend northwest across northern Baranof Island, and are intruded by igneous rocks that range in composition from diorite to tonalite. Berg and Hinckley (1963) mapped a thick sequence of slate, graywacke, and conglomerate named the Sitka Group for exposures in the vicinity of Sitka, in a discontinuous belt along the southwest side of Chichagof and Baranof Islands. These rocks now classified as a formation, the Sitka Graywacke, crop out from old Sitka southeastward to Silver Bay and form parts of many of the islands near Sitka. They are also the predominant rock types in the area of damsite investigations.

Many prominent northwest-trending lineaments are in the northern part of Baranof Island. Twenhofel and Sainsbury (1958) interpreted these lineaments as the surface expression of major faults that are part of a system of fractures subparalleling the coastal ranges and the North Pacific Coast of British Columbia and Alaska. Loney, Pomeroy, Brew, and Muffler (1964) believed that many of the conspicuous linear features on Baranof Island reflect joint systems. The northeast-trending lineaments and the fiords underlying Whale, Sandy, and Snipe Bays and inlets on the west coast of Baranof Island are believed by the author to indicate joint systems.

GLACIATION

The most intensive glaciation on Baranof Island occurred during Pleistocene time, when the great Cordilleran ice sheet covered the island to an altitude of about 3,000 feet (900 m) (Coulter and others, 1965). Below this altitude valleys and ridges show glacial smoothing and rounding, whereas above this altitude peaks are serrated and precipitous as a result of late alpine glaciation. Some high cirques contain remnant glaciers. The ice flowed southwest from the high interior valleys to the coast and coalesced into piedmont glaciers. The movement of the ice along the coast eroded the bedrock in the direction of foliation and minor joint systems.

The parallelism of the many ice-scoured northeast-trending lineaments along the west coast indicates that dominant joints and possibly some faulting controlled the trend of these linear features. South of Whale Bay many lakes and valleys near the coast are oriented northwest and seem to diverge from the strike of the northeast-trending joint systems. This may be due to the modifying influence of foliation and joints of less widespread systems.

EARTHQUAKE HISTORY

The damsites are located in areas that are seismically active. Major faults, such as the Peril Strait fault and the Chatham Strait fault on the north and east sides of Baranof Island, are known to have been active since the Tertiary Period. Between 1843 and 1956, as many as 18 earthquakes that had an estimated intensity of 5 or more on the modified Mercalli scale (Heck, 1958) were reported in southeastern Alaska. The presence of active faults within areas of recorded seismic activity makes it imperative that the location of dams and appurtenant works be chosen carefully. All structures must be designed for adequate protection against earthquakes and possible tsunamis.

WATERPOWER DEVELOPMENT

The waterpower development would be a single-purpose hydroelectric project on the Maksoutof River, Baranof Island (fig. 2), to supply power to the Sitka area. The Maksoutof River connects five lakes before discharging into Sandy Bay. Two of the lakes, Maksoutof and Khvostof, would be used as storage reservoirs. A dam 97 feet (29 m) high at the outlet of Khvostof Lake would raise the water surface of Khvostof Lake and the connecting Rezanof Lake to an altitude of 780 feet (234 m) and would provide 72,100 acre-feet (88.9×10^6 m^3) of water storage. Controlled releases would be made into Maksoutof Lake.

A dam 84 feet (25.2 m) high below the outlet of Maksoutof Lake would raise the water-surface altitude to 600 feet (180 m) and would provide 27,900 acre-feet (34.4×10^6 m^3) of storage in the reservoir. This storage combined with that in Khvostof Lake would provide about 92.5 percent regulation of the flow from Maksoutof Lake. A pressure tunnel and penstock having a combined length of 4,080 feet (1,224 m) would convey water from Kaksoutof Lake to a powerplant at the head of Sandy Bay. The powerplant would have an installed capacity of 24,400 kilowatts operating at an average annual plant factor of 55 percent and through an average head of 514 feet (154.2 m). A 115,000-volt transmission line about 61 miles (98 km) long would deliver project power to a substation in Sitka.

KHVOSTOF LAKE–REZANOF LAKE

Rezanof Lake is the uppermost in the chain of lakes drained by the Maksoutof River (pl. 1). Water from Rezanof Lake flows for about 1,000 feet (300 m) in a channel cut on bedrock and in alluvium before emptying into Khvostof Lake. The lakes occupy the upper end of a long east-northeast-trending glacial valley. The troughlike character of the valley, the rounded landforms, and the presence of freshly ice scoured bedrock surfaces suggest glaciation within Holocene time.

Rezanof Lake is 3.4 miles (5.4 km) long and as much as 0.6 mile (0.96 km) wide but narrows to about 0.3 mile (0.48 km) at each end. The water surface altitude was 730 feet (219 m) on July 30, 1967. No soundings were made in the lake. The valley walls above Rezanof Lake rise in steep smooth surfaces to an altitude of about 3,000 feet (900 m), the approximate level once occupied by the glacial ice, and in serrated spines to the summit areas at altitudes between 3,000 and 4,000 feet (900–1200 m). Vegetation is sparse on the east side of the valley and clings precariously to the ice-scoured surface. Landslide scars are common. Rezanof Lake heads in an marshy flat-floored valley several miles long that is covered by heavy undergrowths of alder and devilsclub. The lower slopes of the valley locally consist of coalescing talus cones. The narrow flood plain at the lower end of Rezanof Lake was formed by deposits laid down by the large stream flowing from the south into the lake outlet. The stream heads in a small glacier east of Mount Hagemeister (fig. 2). A Forest Service cabin is near the outlet of Rezanof Lake.

Khvostof Lake is roughly oval shaped and is approximately 1.4 miles (2.24 km) long and nearly 0.5 mile (0.8 km) wide. It had a water-surface altitude of 708 feet (212 m) on July 29, 1967, and is 485 feet (146 m) deep according to soundings made by the U.S. Geological Survey. Khvostof Lake occupies the lower part of the troughlike valley, where the valley turns west from the interior mountains to the coastal foothills. The topography along the upper part of the lake is similar to that near Rezanof Lake. The damsite at the outlet of Khvostof Lake is in the coastal foothills, which were once covered by glacial ice moving south. The orientation of lake basins and valleys in a northwest-southeast direction and the rounded hills of nearly similar altitudes are characteristic of ice erosion. A low divide separates Khvostof Lake from Plotnikof Lake, which lies about 1 mile (1.6 km) to the north. A pond with a water-surface altitude of 755 feet (227 m) occupies much of the area north of the divide and drains into the watershed of Plotnikof Lake (fig. 2).

The outlet from Khvostof Lake is cut in bedrock, and the river flows at a steep gradient through a narrow canyon about 400 feet (120 m) long; a waterfall is at the lower end, where the river flows into a small unnamed lake. East of the canyon the ground surface rises steeply up a narrow ridge to the top of Mount Hagemeister at the altitude of 3,225 feet (968 m). West of the canyon the ground surface rises to the summit of a rounded hill at the altitude of about 1,000 feet (300 m) and drops into a saddle area draining into Khvostof Lake. The river flows south through two small lake basins in a distance of 2 miles (3.2 km) and discharges into Maksoutof Lake.

GEOLOGY

BEDROCK

The rocks in this area comprise the Sitka Graywacke of Late Jurassic and Early Cretaceous age (Loney and others, 1964). In many places the graywacke is cataclastically foliated and metamorphosed to semischists and slates. In general, the metamorphic rocks are a monotonous sequence of interbedded fine- to medium-grained schistose graywacke and hornfels. The graywacke is arkosic, thick bedded to massive, and generally dark gray; crossbedding is characteristic in the massive graywacke.

The argillite and shaly graywacke are metamorphosed to hard dense fine-grained brittle hornfels. These rocks appear solid on freshly exposed surfaces but weather into small fragments. The hornfels are dark, thin bedded, and siliceous and weather dark brown. Quartz and quartz calcite veins fill many fractures, and druse is common in the fractures and joints. Very little sulfide mineralization occurs in the silicified zones. The presence of the mineral assemblage biotite-albite-quartz in the hornfels indicates that these rocks were derived by dynamothermal metamorphism (Loney and others, 1964). Late biotite possible suggests subsequent thermal metamorphism.

The Sitka Graywacke exposed along the southeast shore of Rezanof Lake consists of low-grade metamorphic rock in which relict sedimentary textures and structure are locally preserved (Loney and others, 1964). These rocks grade into the metamorphic rock types present in the lower part of the reservoir and should be impervious to leakage in the reservoir area.

The rocks in the reservoir area trend northwest and dip steeply to the east. They are strongly deformed, as evidenced by druse in silicified fractures at many places. Whether or not the fractures represent shear zones in the bedrock is uncertain. The fractures do not appear oriented to any linear topographic feature that may indicate faulting. It is believed that the northwest-trending structure in the graywacke resulted from northeast-southwest compression and that the metamorphic rocks were later subjected to thermal metamorphism by the intrusion of two major granitic complexes in the southeastern part of Baranof Island.

UNCONSOLIDATED DEPOSITS

The unconsolidated sediments within the damsite and reservoir areas consist of alluvium, colluvium, talus, and landslide deposits. The three main deposits of coarse sand and gravel in the area are in the flood plain at the head of Rezanof Lake, the flood plain in the divide area between Rezanof and Khvostof Lakes, and the delta below the damsite where the river flows into the upper unnamed lake.

The delta at the head of Rezanof Lake contains the largest deposits of gravel. The materials range in size from silt to coarse gravel. Much of the finer sediments are interbedded with waterlaid beds of cobbles and talus; the deposits grade laterally into the talus and landslide detritus that is enroaching on the flood plain from the adjacent uplands and may be suitable construction material. Finer material occurs in fore-set beds of sediments along the front of the delta. The thickness of the gravel deposits is believed to be in excess of 40 feet (12 m). The extent of the deposits is shown on plate 1, a 1:24,000-scale map.

The next largest available deposit of gravel is in the divide area between Khvostof and Rezanof Lakes. The large stream draining into the river below the outlet of the lake has formed a large delta in Rezanof Lake. The river flowing from the outlet has reworked the sediments and deposited them on the flood plain above Khvostof Lake. The gravel deposits vary from coarse sand to cobbles and are interbedded with deposits of talus. The alluvial flat where the Forest Service cabin is located seems to be the best locality for the excavation of construction material. The deposits are as much as 30 feet (9 m) thick and may have considerable lateral extent. The flood plain below the outlet is narrow, and the presence of bedrock at places in the channel indicates that the gravel deposits are thin along the river.

The delta at the head of the unnamed lake below the Khvostof Lake damsite consists of deposits of silt, coarse gravel, and talus. Fine sand is deposited in the lake bottom here and also near the outlets in Rezanof and Khvostof Lakes. However, these deposits are small and may be inadequate for construction material.

Other materials occur in the landslide deposits bordering the reservoir. The deposits are small and are formed below avalanche chutes in the bedrock; the largest occurs at the head of Rezanof Lake. The talus ranges in size from small boulders to blocks as much as 8 feet (2.4 m) in diameter. The landsliding is recent but does not appear to be a potential hazard. One exception is along the east side of Rezanof Lake, where the precipitous slope shows fresh ice scour on the bedrock. The vegetation clings precariously to the slope, and large areas of the bedrock have been denuded of surficial material by landslides or snowslides. This area can be a potential hazard at those places where the jointing is very pronounced and the bedrock is subject to severe weathering.

STRUCTURE

The beds in the Sitka Graywacke consistently strike northwest. The rocks have a steep homoclinal dip to the northeast, and locally some beds may be overturned. Foliation is more distinct in argillite or shaly graywacke than in massive graywacke and seems to be parallel to the bedding. In many places the rocks are fractured and silicified. The steep or vertical beds and slaty cleavage indicate strong deformation. Small folds are not apparent in the area possibly because of the competency of massive graywacke. Well-defined jointing is characteristic. The most conspicuous joints strike north to northeast and dip steeply; minor joint sets strike east-west and dip moderately.

The rocks strike N. 20°–70° W. and dip 55°–82° NE. Locally some beds dip steeply southeast. The attitude of the beds seems related to the large northwest-trending lineaments on the northeast and southwest sides of Baranof Island that are believed the surface traces of major faults (Twenhofel and Sainsbury, 1958).

No faults were observed in the mapped area. Locally, evidence for small-scale faulting may be suggested by fractured and highly silicified graywacke. Berg and Hinckley (1963) believed that the major structural features are probably due to regional metamorphism related to intrusion by granitic complexes in the southeastern part of Baranof Island.

DAMSITE

The proposed damsite is about 100 feet (30 m) downstream from the outlet of Khvostof Lake (pl. 1*B*, section *A*-*A*′). The river channel is 30-40 feet (9-12 m) wide and is cut in graywacke. There, the canyon walls rise steeply 100—300 feet (30—90 m) above the river level and would be adequate to support a concrete arch-type dam. The lower slopes of the abutments are covered by landslide detritus, possibly as much as 15–20 feet (4.5–6 m) deep. The upper part of the right abutment is a vertical cliff rising to an altitude of 1,000 feet (300 m). The left abutment is a northeast-trending ridge whose summit consists of 2 small knolls at the approximate altitude of 840 feet (252 m).

A deep saddle that trends parallel to the outlet separates the left abutment from the vertical cliff to the east. The highest point in the saddle is at an altitude of 802 feet (240.6 m). The saddle may represent a former channel cut by water draining from a glacier lake at a once higher level. A dominant joint set strikes northeast through the saddle and may have influenced erosion of the bedrock. The saddle is filled to a depth of 30–40 feet (9–12 m) with large talus blocks derived from the adjacent canyon walls. Much of the material is very coarse and possibly too permeable to be grouted. A saddle dam (pl. 1*B*, section *C*–*C*′) about 110 feet (33 m) long at a crest altitude of 830 feet (249 m) would be necessary to prevent leakage from the reservoir. The foundation for the saddle dam must be excavated to bedrock.

Another saddle area northwest of the right abutment was examined to determine the presence of unconsolidated deposits of gravel that might cause excessive leakage from the reservoir. The abutment extends north in a narrow ridge that separates the shallow, poorly drained basin from Khvostof Lake. The ridge, which is above the altitude of 800 feet (240 m), is cut at several places by small streams that flow east into the lake. Hard fine-grained graywacke crops out in small knolls and ridges in the saddle area. Surficial deposits, such as peat, mudflows, and some gravel beds, overlie the bedrock at a depth of several feet and at places to as much as 10 feet (3 m). The controlling altitude in the saddle just west of the right abutment is approximately 850 feet (255 m). The area is underlain by bedrock which in outcrops appears impermeable. Leakage from the reservoir should not be excessive except possibly through some joint sets that may be open at depth.

An alternate damsite (pl. 1*B*, section *B*—*B*′) is about 300 feet (90 m) below the Khvostof Lake outlet and approximately 150 feet (45 m) below the proposed damsite. The topography and the geology are nearly the same at both damsites. Graywacke is exposed in the right abutment and channel section, and the foundation for the dam would require minimum excavation. The left abutment would require excavation of the talus material to a possible depth of 10–20 feet (3–6 m). The graywacke at this site appears more massive and shows less tendency to weather into small fragments.

If the water storage capacity for the reservoir is to be increased it may be more economical to construct a dam at the alternate site. The dam would be shorter in length than a dam constructed upstream. A dam about 240 feet (72 m) long, with a crest altitude of 810 feet (243 m), would obtain a maximum regulated water storage.

RESERVOIR SITE

A dam at the outlet of Khvostof Lake (pl. 1) will raise the water surface of Khvostof and Rezanof Lakes to the altitude of 780 feet (234 m) and will form a reservoir about 5.7 miles (9 km) miles long and 0.6 mile (0.96 km) wide. The increased storage capacity will not appreciably increase the reservoir area, except for the alluvial flat at the head of Rezanof Lake and the divide area between Rezanof and Khvostof Lakes. The flood plain above Rezanof Lake consists of corase alluvial deposits of cobbles, pebbles, and gravel interstratified with slide detritus. The talus encroaches on the flood plain in coalescing fan deposits. A raise in the water level of the reservoir will inundate the base of these fans and may cause some subaqueous sliding. Similarly, the divide area between Khvostof and Rezanof Lake is in part an alluvial fan formed by the large stream draining the small basin east of Mount Hagemeister. The coarse boulder and gravel deposits have been reworked by water flowing from Rezanof Lake and deposited along the flood plain above Khvostof Lake. The surficial deposits may be as much as 10 feet (3 m) thick. Graywacke crops out along the river channel and in the ridges near the flood plain.

Bedrock is exposed in nearly continuous outcrops along the shoreline of the lakes. Most of the geologic mapping was done on Khvostof Lake and the lower part of Rezanof Lake. As judged from the air reconnaissance along the upper part of Rezanof Lake, the bedrock seems to be hard lineated schistose and slaty graywacke.

The principal rocks in the reservoir are arkosic graywacke interbedded with lesser amounts of argillite, shaly graywacke, and hornfels. The graywacke is massive and hard and has well-defined jointing. Sedimentary structures, such as graded bedding and small-scale crossbedding, are common.

The many linear topographic features on the ground and those observed on the aerial photographs appear to parallel the foliation or major joint sets in the bedrock. One large linear topographic feature that trends northwest across the upper part of Rezanof Lake may be the surface expression of a fault. It coincides with the contact of the lineated schistose Sitka Graywacke and the Sitka Graywacke. However, the foliation in the bedrock at either end of Rezanof Lake is parallel to this lineament, and, possibly, the planar surfaces along the contact between different rock types were easily eroded. Several lineaments along the north shore of Khvostof Lake trend northwest and appear parallel to the foliation. At these places considerable fracturing and silicification of the bedrock are common; the graywacke is hard and appears to be impervious. The foliation is well defined and persists in a northwest-trending direction. In the vicinity of Khvostof Lake, the foliation strikes N. 25°–45° W. and dips 80°–90° NE.

At places the dominant joint sets appear to parallel or subparallel the northwest-trending topographic linear features. These joint sets strike N. 10°–40° W. and dip 45°–90° SW. Less widespread joint sets strike N. 25°–70° E. and dip 30°–40° NW. Locally, where jointing in the graywacke is very conspicuous, the bedrock is badly weathered. In a narrow divide, such as the area between Khvostof and Plotnikof Lakes, the pronounced jointing may cause some leakage and will require grouting. No faulting was observed on the ground in the reservoir area; the lineaments are believed to be formed along dominant joint sets or foliation.

KHVOSTOF LAKE SADDLE DAMSITE

The low divide between Khvostof and Plotnikof Lakes is underlain by graywacke that has lithologies similar to the bedrock at the damsite. The topographic features, such as ridges and basins in the saddle area, are oriented northwest and probably were controlled by joint systems and foliation. The exposed bedrock shows evidence of recent ice scour, and the rounded elongated ridges are also characteristic of glaciation. The many small basins present probably resulted from plucking of the bedrock along planar surfaces by the moving ice. The divide is poorly drained and contains numerous bogs, marshes, and lakes. A large pond at the altitude of 755 feet (227 m; pl. 1*C*) drains northward into watershed of Plotnikof Lake. The pond is separated from Khvostof Lake by an east-trending ridge that is cut by a number of northwest-trending saddles. Hornfels and graywacke are exposed in small knolls and knobs in the ridge and along both sides of the large pond. Colluvium consisting of mudflows and thin deposits of gravel as much as 4 feet (1.2 m) thick covers areas between the exposed bedrock.

Locally, jointing is pronounced in the graywacke. Some linear features are eroded along the foliation which strikes N. 40°–50° W. and dips 60°–90° NE. A dominant joint set strikes N. 45° W. and is vertical. A less widespread joint set strikes N. 40°–70° E. and dips 40°–90° NW. At several localities along the ridge the bedrock is fractured and highly silicified; quartz druse is common in the graywacke. Some of the outcrops, especially in small knolls, are deeply weathered. The bedrock at the saddle damsites should be excavated to sufficient depth to prevent leakage through possible open joints. The surficial deposits overlying the bedrock are thin and should not permit leakage.

A minimum of four auxiliary dams (pl. 1*C*, section *A*–*A* ′), must be constructed in the series of small saddles along the north shore of Khvostof Lake is the maximum water surface in the reservoir is to be above the altitude of 780 feet (234 m). A reservoir with a maximum water surface at an altitude of 802 feet (241 m) would require dams that range in length from 20 feet (6 m) to as much as 300 feet (90 m) at places where they are combined to cross closely spaced saddles. The height of the dams would range from 20 feet (6 m) to as much as 50 feet (15 m).

An alternate saddle damsite north of the ridge is across the two prongs of the large pond at the altitude of 755 feet (227 m). This damsite is underlain by graywacke and would require only two dams (pl. 1*C*, section *B–B* ′) to hold the regulated water storage in the reservoir. The dams would be 100 and 130 feet (90 and 39 m) long, respectively, and about 50–60 feet (15–18 m) high. The foundation would be in bedrock, and leakage through the joint sets should be minimal.

MAKSOUTOF LAKE

Maksoutof Lake is the lowermost lake drained by the Maksoutof River (pl. 1*A*). It occupies an irregularly shaped northwest-trending basin in the western part of the coastal foothills about 0.75 mile (1.2 km) from Sandy Bay. The area is rugged and cut by deep gorges, one of which contains the lower basin of the Maksoutof River. The river flows at a steep gradient northwest from the outlet of Maksoutof Lake for about 600 feet (180 m) and plunges over a cliff in spectacular falls nearly 250 feet (75 m) high. Below the falls the canyon trends west to the confluence with a tributary canyon and then southwest to tidewater.

Maksoutof Lake is approximately 2.2 miles (3.5 km) long and 0.6 mile (0.96 km) wide and had a water-surface altitude of 548 feet (164 m) on July 16, 1967. The upper part of the lake is 369 feet (111 m) deep, and the lake bottom is 179 feet (54 m) above mean sea level. The two small unnamed lakes between the Khvostof Lake damsite and Maksoutof Lake have water-surface altitudes of 567 and 632 feet (170 and 190 m), respectively. A U.S. Forest Service cabin is on the alluvial flat where the Maksoutof River discharges into Maksoutof Lake.

GEOLOGY

BEDROCK

Massive schistose graywacke interbedded with shaly graywacke and hornfels crops out along the lakeshore and the Maksoutof River below the outlet. The rock is dark gray and brownish gray, hard, dense, and siliceous. Foliation in the graywacke strikes northwest and is parallel or subparallel to the bedding; the beds dip steeply to the east. Jointing is conspicuous, and at places the graywacke is deeply weathered. Locally, the hornfels appears fractured and contains abundant quartz and calcite druse and vugs. The bedrock appears impervious and should permit minimal leakage from the reservoir.

UNCONSOLIDATED DEPOSITS

Gravel deposits occur at places in the reservoir area. The delta formed at the southeast end of Maksoutof Lake by the stream draining the Antipatr chain of lakes offers the best source for construction material. The unconsolidated material consists of deposits of coarse gravel interbedded with beds of cobbles and slide detritus; some beds consist of fine sand and silt. The flood plain is narrow, and the gravel beds grade laterally into the talus deposits that are on the lower slopes of the valley. The gravel deposits extend up the valley, but their areal distribution and their thickness were not determined. Some sand and silt are deposited in the shallow water of the lake.

Alluvial deposits that may be suitable for construction material occur in the delta where the Maksoutof River flows into Maksoutof Lake. The small delta extends upstream in a narrow flood plain to the outlet of the lower unnamed lake. Most of the deposits appear to be very coarse gravel and boulders and contain much fragmentary material derived from slide deposits in the adjacent slopes. Some finer gravel may be in fore-set beds along the front of the delta. The outcrops of bedrock in and along the flood plain indicate that the gravel deposits may be thin.

Colluvium occurs at places in thin deposits of peat, soil, mudflows, gravel, and slide detritus. The deposits are in areas that are poorly drained and where the boundaries of the interbedded deposits are gradational.

Avalanche deposits are formed at the base of rock chutes cut in steep cliffs or in continuous talus aprons along the lower slopes of the cliffs. The deposits consist of slide detritus ranging in size from small fragments to large blocks of graywacke. Most of the slides appear stabilized and should not present any hazard in the reservoir.

One locality along the north shore in the southeastern part of Maksoutof Lake may be a potential slide hazard. The graywacke is exposed in steep cliffs which rise 300–400 feet (90–120 m) above the water surface. Foliation and joints in the bedrock structure have contributed to the weathering of the graywacke. The slides that have resulted from spalling of rock from the overhanging cliffs consists of large blocks, some as large as houses. The upper part of the lake is studded with islands of slide material. Landsliding at this locality could create wave conditions in the reservoir that might be destructive to the dam.

STRUCTURE

The dominant structure in the bedrock consists of northeast-dipping beds that have a persistent northwest trend. The foliation or bedding strikes N. 30°–45° W. and dips 50°–60° NE., generally, with some dips as much as 65° NE. Several joint sets are present, but no set is dominant. A strong joint set strikes N. 40°–60° E. and dips 57°–82° NW. A less widespread joint set strikes N. 45°–50° E. and dips 50°–78° SE. A minor joint set strikes east-west and dips 20° N. to 75° S. Many of the major joint sets are normal to the channel and should not cause excessive leakage. Where fine-grained rock is exposed, as in the right abutment, jointing and cleavage are generally pronounced, and the rock is deeply weathered. At such localities grouting may be required to make the rock impermeable. No faulting was observed at the damsite. A topographic linear feature about 2,200 feet (660 m) below the damsite trends northwest and may be the surface expression of a shear zone. The shear zone has been eroded into a steep-walled basin along the Maksoutof River, on which the east wall forms the fall line.

DAMSITE

A favorable location for the dam is 200 feet (60 m) downstream from the outlet of Maksoutof Lake, where the channel is about 60 feet (18 m) wide (pl. 1*A*, section *A–A* ′). The right abutment is an east-trending ridge that rises steeply to an altitude of 650 feet (195 m). The ridge narrows eastward and extends into the lake. The upper part of the abutment is a vertical cliff that rises to altitudes of 630–650 feet (189–195 m); the lower slopes are covered by talus deposits 5–15 feet (1.5–4.5 m) thick. The right abutment and the river channel are underlain by impervious graywacke. A shallow basin that drains east into Maksoutof Lake separates the right abutment from the upland area to the north where the bedrock is overlain by thin colluvial deposits. The controlling altitude in the higher part of the shallow basin is about 636 feet (194 m).

The left abutment is near the west end of an elongated ridge. The ground surface rises abruptly from the river channel to an altitude of 660 feet (198 m) and then flattens in a shallow saddle that drains through a short canyon into the river just below the damsite. Above the saddle the ground surface rises steeply to the summit at an altitude of 1,500 feet (450 m). The lower slopes of the left abutment are covered by talus deposits about 10 feet (3 m) thick that overlie graywacke.

The canyon is V-shaped—narrow at the channel and about 140 feet (42 m) wide at the altitude of 600 feet (180 m), the proposed crest height of the dam. Bedrock is exposed in the channel and in the cliffs above the altitude of 570 feet (171 m) on either abutment. A short distance downstream from the damsite, the ground surface drops several hundred feet in a series of vertical cliffs into the lower basin of the Maksoutof River.

An alternate damsite (*B–B* ′, fig. 3B) is about 100 feet (30 m) downstream from the proposed site; the topographic and geologic conditions are similar. The advantage of the alternate damsite is that the dam would be anchored in massive bedrock with more wallrock in the abutments, whereas the left abutment at the proposed damsite is a projecting ridge where bedrock is more deeply weathered and would require grouting to prevent excessive leakage through open joint sets. The disadvantage of the alternate damsite is that it would require a dam about 200 feet (60 m) long at the crest altitude of 600 feet (180 m), compared with one 140 feet long (42 m) at the damsite upstream.

RESERVOIR SITE

The reservoir area (pl. 1, 1:24,000-scale map) at a maximum controlled water-surface altitude of 600 feet (180 m) would extend upstream about 1 mile (1.6 km) below the Khvostof Lake damsite. The lower of the two unnamed lakes would be within the reservoir.

The exposed bedrock within the reservoir is interbedded schistose graywacke and hornfels and is similar in lithology to bedrock at the damsite. Some of the topographic linear features that trend north or northwest across the reservoir may be possible surface expressions of shear zones or fractures along which some movement has occurred. No major faulting was observed in the outcrops examined.

The foliation or bedding in the graywacke strikes N. 20°–50° W. and dips 50°–70° NE. The bedrock at one locality half a mile southwest of the Khvostof Lake damsite appears to be much fractured, and the foliation strikes N. 70°W. and dips 60°N. This deviation in foliation may indicate the presence of minor faults or undulations in the bedrock. Jointing is pronounced in the massive graywacke. A strong joint set strikes N. 20°–50°E. and dips 47°–76°NW.; another joint set strikes N. 30°–50° E. and dips 62°–90° SE. A less widespread joint set strikes N. 60°–80° W. and dips 80°–90° N. The proposed reservoir area in underlain by bedrock that appears impermeable and should permit minimal leakage from the reservoir.

CONSTRUCTION MATERIAL

Sand and gravel deposits suitable for construction material are present within the powersite (pl. 1, 1:24,000-scale map). For the Khvostof Lake–Rezanof Lake damsite, available deposits occur at the head of Rezanof Lake, the flood plain in the interdivide area between these lakes, and the alluvial delta below the damsite. The deposits range from silt to very coarse gravel and cobbles, all homogeneous, and should be a good source of concrete aggregate.

The metamorphic rocks from which the deposits are derived are siliceous, and the compressive strength of the more massive graywacke may approach that of the hardest sandstone. The talus deposits along the shoreline of the lakes can be a source of concrete aggregate suitable for crushing. They contain materials or minerals whose chemical composition is such that corrosive action would be minimized if the material were used as concrete aggregate.

Gravel deposits at the southeast end of Maksoutof Lake are possible construction material. The deposits range from sand to cobbles and grade laterally into talus, but their thickness and extent have not been determined. They are homogeneous and have been derived from graywacke that is siliceous and suitable for construction material. The talus deposits near the damsite can be crushed into fine material for concrete aggregate. The deposits in the small delta formed where the Maksoutof River flows into Maksoutof Lake may be too small to be of use.

TUNNEL AND PENSTOCK ROUTE

A proposed tunnel route was examined along a line from the outlet of Maksoutof Lake southwest to Sandy Bay. The rocks along this route are interbedded schistose graywacke, argillite, and hornfels similar to the bedrock exposed near the damsite in the reservoir. The general structural trend in northwest, and the beds or foliation dip steeply east. The strike of the foliation ranges from N. 25°–40° W., and the dips range from 52°–71° NE.; jointing is well defined. A strong joint set strikes N. 75°–80° E. and dips 76°–80° N. A minor joint set strikes N. 80° W. and dips 50° S.

A large lineament that trends northwest across the canyon below the lower falls in the Maksoutof River can be traced to the south on the aerial photographs for several miles. The deep basin subsequently eroded along the lineament suggests that it may be a shear zone. Possibly the foliation or bedding in the bedrock may have influenced the orientation of the lineament.

The tunnel would penetrate massive graywacke along most of the tunnel route; the interbeds of argillite or hornfels are also impervious bedrock. At places the finer grained rocks show pronounced cleavage that near major joints might cause leakage and require lining of the tunnel. The lineament below the damsite reflects a shear zone in the bedrock; the tunnel would require concrete lining where it penetrated this zone. All the outcrops examined are hard dense bedrock that appears suitable for tunnel construction.

The proposed tunnel route (fig. 2; pl. 1, 1:24,000-scale map) would trend southwest 1,500 feet (450 m) and then west for 1,700 feet (510 m) to Sandy Bay. A penstock about 800 feet (240 m) long with a head of 570 feet (171 m) would convey the water to the powerhouse site at tidewater. The basin along the lineament has been eroded to a depth which would expose a tunnel if it were driven directly southwest from the powersite. The tunnel route was directed farther south from the damsite so that a greater thickness of rock cover would be sustained where the tunnel crosses the lineament. The lineament may be underlain by deep fracture zones or open joints that might cause excessive leakage. The ground altitudes along the tunnel and penstock route might also be in error because topographic contouring by photogrammetric methods is in many places done on the tops of trees in rain-forest environments. Therefore, it might be better to drive a tunnel under deeper rock cover and eliminate the problem of excessive leakage beneath the basin.

POWERHOUSE SITE

A suitable site for a powerhouse installation may be near the head of Sandy Bay (pl. 1, 1:24:000-scale map). An alluvial fan extends south for several hundred yards along the east side of Sandy Bay from the sharp point in the terrace where bedrock is exposed. The bedrock is similar to the rocks exposed along the tunnel route. The ground surface in a distance of 300 feet (90 m) rises about 50 feet (15 m) from the water level to the base of vertical cliffs which trend southeast. At places the cliffs rise to altitudes of 500–800 feet (150–240 m), and their lower slopes are covered by landslide detritus. Power installations on the terrace may be subject to landslide hazards.

The alluvial fan extends eastward about 1,500 feet (450 m) up a canyon to the base of the cliffs. Possible sites for large installations may be along the edge of the fan where the bedrock is exposed or where the alluvial deposits are believed to be thin. Exploratory drilling at places along the periphery of the alluvial fan will ascertain the proximity of bedrock to the surface. The power installations must be constructed on bedrock to prevent their destruction by the compaction of the alluvial fill resulting from possible earthquakes.

CONCLUSIONS AND RECOMMENDATIONS

The damsites are feasible for concrete dams. At both sites the abutments seem capable of taking the thrust of an arch-type dam. The bedrock is massive hard semischistose graywacke and hornfels. The rocks appear impermeable at the damsites and reservoirs, except at places where the outcrops are narrow and are subjected to deep weathering. Grouting may be required at the damsites where a strong joint system is normal to the axis of the dam or in zones of deep weathering adjacent to the dam. The saddle in the left abutment of the Khvostof Lake damsite must be grouted to prevent seepage through the bedrock between the dam and the former channel. The bedrock ridge between Khvostof and Plotnikof Lakes seems to be impervious to seepage.

Some of the northwest-trending lineaments in the Maksoutof Lake reservoir area probably reflect the trend of foliation or subparallel joint sets. At places, the fractured silicified rocks may be evidence of shear zones. No major faulting was observed in the powersite.

The maximum controlled water-surface altitudes must be below the controlling altitudes of saddle areas to prevent leakage. Saddles that contain deep alluvial fill should be excavated to bedrock and diked by concrete dams. Major landslides that may cause waves destructive to the dams could occur at the southeast side of Rezanof Lake and along the northeast side of Maksoutof Lake. Construction material for the dam is available in the gravel deposits within the reservoirs.

The tunnel route is in graywacke and will not require concrete lining, except possibly where dominant open joints or fractures are penetrated in the subsurface as they are in the shear zone below the powersite. The power installations should be constructed at sites away from landslide hazards.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1975—677-311/51