Chakachamna Hydroelectric Alternative for the Railbelt Region of Alaska

Volume XIV

Ebasco Services Incorporated

August 1982

Prepared for the Office of the Governor
State of Alaska
Division of Policy Development and Planning
and the Governor's Policy Review Committee
under Contract 2311204417

Battelle
Pacific Northwest Laboratories

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The major portion of this report was prepared by the Bellevue, Washington, and Newport Beach, California, offices of Ebasco Services Incorporated. Their work includes the Introduction, Technical Description, Environmental and Engineering Siting Constraints, Environmental and Socioeconomic Considerations and Institutional Considerations. Capital cost estimates were prepared by S. J. Groves and Sons of Redmond, Washington, and reviewed by the Ebasco cost estimating department in New York City. Cost of energy estimates were prepared by Battelle, Pacific Northwest Laboratories of Richland, Washington.

PREFACE

The state of Alaska, Office of the Governor, commissioned Battelle, Pacific Northwest Laboratories (Battelle-Northwest) to perform a Railbelt Electric Power Alternatives Study. The primary objective of this study was to develop and analyze long-range plans for electrical energy development for the Railbelt Region (see Volume I). These plans will be used as the basis for recommendations to the Governor and Legislature for Railbelt electric power development, including whether Alaska should concentrate its efforts on development of the hydroelectric potential of the Susitna River or pursue other electric power alternatives.

Substantial hydro resources exist in the Railbelt Region. Many of these resources could be developed with conventional (~15 MW installed capacity or larger) hydroelectric plants. Several sites have the potential to provide power at first-year costs competitive with thermal alternatives and have the added benefit of long-term resistance to effects of inflation. However, high capital investment costs render many sites noncompetitive with alternative sources of power.

Environmentally, hydroelectric options are advantageous because they produce no atmospheric pollution or solid waste. However, environmental disadvantages may include the destruction and transformation of habitat in the area of the reservoir, destruction of wilderness value and recreational opportunities, and negative impacts on downstream and anadromous fisheries.

Based on environmental and economic considerations, the Chakachamna hydroelectric project was among several hydroelectric projects selected as possible alternatives to the Upper Susitna project. An individual study of the Chakachamna project was commissioned for several reasons. First, the prospective capacity and energy production of the Chakachamna project would be greater than for any of the other selected alternatives to the Upper Susitna project, yet not so large as to result in underutilization of the facility. Second, preliminary estimates of the cost of energy from the Chakachamna project appeared to be very favorable, partly because it would be a lake-tap project and no dam would be required. Finally, because it would be a lake-tap project, it appeared that the potential environmental effects of the project would be moderate compared to other alternatives. This report, Volume XIV of a series of seventeen reports, documents the findings of this study.

Other power-generating alternatives selected for in-depth study included pulverized coal steam-electric power plants, natural gas-fired combined-cycle power plants, the Browne hydroelectric project, large wind energy conversion systems and coal-gasification combined-cycle power plants. These alternatives are examined in the following reports:

Ebasco Services, Inc. 1982. Coal-Fired Steam-Electric Power Plant Alternatives for the Railbelt Region of Alaska. Prepared by Ebasco Services Incorporated and Battelle, Pacific Northwest Laboratories for the Office of the Governor, State of Alaska, Juneau, Alaska.

Ebasco Services, Inc. 1982. Natural Gas-Fired Combined-Cycle Power Plant Alternative for the Railbelt Region of Alaska. Prepared by Ebasco Services Incorporated and Battelle, Pacific Northwest Laboratories for the Office of the Governor, State of Alaska, Juneau, Alaska.

Ebasco Services, Inc. 1982. Browne Hydroelectric Alternative for the Railbelt Region of Alaska. Prepared by Ebasco Services Incorporated and Battelle, Pacific Northwest Laboratories for the Office of the Governor, State of Alaska, Juneau, Alaska.

Ebasco Services, Inc. 1982. Wind Energy Alternative for the Railbelt Region of Alaska. Prepared by Ebasco Services Incorporated and Battelle, Pacific Northwest Laboratories for the Office of the Governor, State of Alaska, Juneau, Alaska.

Ebasco Services, Inc. 1982. Coal-Gasification Combined-Cycle Power Plant Alternative for the Railbelt Region of Alaska. Prepared by Ebasco Services Incorporated and Battelle, Pacific Northwest Laboratories for the Office of the Governor, State of Alaska, Juneau, Alaska.

During the course of this study, the Alaska Power Administration commenced a full-scale feasibility study of the Chakachamna hydroelectric project, at a considerably greater level of effort than the present study. In the feasibility study, initial analyses of project configuration resulted in the selection of a configuration differing from that selected for the present study. The configuration selected for the Bechtel feasibility study would be of 330 MW installed capacity, with an annual average energy production of 1570 GWh as compared to the 480-MW installed capacity project discussed in this report. Flow would be maintained in the Chakachatna River to support the native anadromous fishery, resulting in a reduction in energy production and a need for less intalled capacity. Further information on the Bechtel feasibility study is provided in Section 7.0 of this study.

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SUMMARY

Numerous sites showing potential for hydroelectric development have been identified in the Railbelt Region of Alaska. Many, however, appear at this time to be uneconomic due to high capital costs, or appear to have the potential for unacceptably severe environmental impacts. Among the sites of sufficient size to be of interest in the context of a Railbelt-wide electric power planning and that present potentially competitive economic characteristics and acceptable environmental impacts is the proposed lake-tap project at Chakachamna Lake, located about 85 miles west of Anchorage.

The proposed Chakachamna hydroelectric project would be a lake-tap hydroelectric development consisting of an intake structure at Chakachamna Lake, a transmountain pressure tunnel, approximately 10.8 miles in length, a surge tank, a vertical shaft to the powerhouse elevation, penstocks and a powerhouse discharging to the McArthur River. The installed capacity of the design examined in this report would be 480 MW.

Power from the project would be transmitted at 230 kV, approximately 55 miles to the existing transmission corridor of the Chugach Electric Association Beluga Station, and thence to Anchorage along the common corridor. The estimated annual average energy production would be 1892 GWh and the estimated annual firm energy production would be 1869 GWh.

Cost estimates for the proposed project indicate an overnight capital cost of approximately $2100/kW, with operation and maintenance costs of 3.75 $/kW/yr. Assuming a 1991 in-service date, levelized busbar energy costs are estimated to be 25.5 mills/kWh (January 1982 dollars).

Approximately 9-1/2 years would be required for project completion, including preconstruction studies, licensing, design, construction and startup. A 60-month construction period would be required. Under this schedule, the earliest in-service date, assuming a mid-1982 authorization to proceed, would be late-1991.

Environmental effects of the Chakachamna project could range from modest to locally severe, depending upon project design and operation, the magnitude

of the anadromous fisheries of the Chakachatna and McArthur Rivers and the impact of project operation on downstream fisheries. Principal potential environmental impacts include destruction of the existing sockeye run into Chakachamna Lake from the Chakachatna River; disturbance of the downstream Chinook and pink salmon fisheries of the Chakachatna and McArthur Rivers; disturbance of resident fisheries of Chakachatna and McArthur Rivers; terrestrial habitat changes due to dewatering of the Chakachatna River, drawdown of Chakachamna Lake and flow increases in the lower McArthur River; effects of vehicular access to the Chakachatna and McArthur River valleys and to Chakachamna Lake; and effects of the construction work force on local communities. Destruction of the Chakachatna sockeye run could be alleviated by alternative project design and operational procedures allowing maintenance of Chakachatna flow during migration periods and control of lake level to facilitate spawning.

Physical features of the site that may pose potentially severe engineering constraints include the general seismicity of the project area, potential faulting in the vicinity of the pressure tunnel, proximity of the Mt. Spurr Volcano and effects of Chakachatna River dewatering upon Barrier Glacier, which controls the outlet to Chakachamna Lake. Provisions for these engineering conditions, as they are currently understood, have been incorporated into the proposed project design. Field investigation of site characteristics, particularly the geologic conditions along the route of the pressure tunnel, will be required, however, prior to arriving at a final project design.

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

The proposed Chakachamna project is a transmountain diversion and hydroelectric power development project (refer to Figure 1.1). Chakachamna Lake, located about 85 air miles west of the City of Anchorage, would be utilized as a storage reservoir. Water would be conveyed through a pressure tunnel and penstock to a power plant located on the McArthur River at latitude 61°05'N, longitude 152°11'W. The power output would be transmitted to Anchorage, the principal outlet for the sale of electrical energy to the Railbelt Region. The installed capacity of the project would be 480 MW.

The advantages of the project may be categorized both generically, as related to hydro power, and on a site-specific level. In a generic sense, the pertinent advantages of hydro power include zero fuel costs, maturity of technology, simplicity, reliability, and quick responsiveness of the generating equipment. The Chakachamna site is considered to be advantageous from cost, project size and environmental standpoints. A study of alternate non-Susitna hydro generating sources in Alaska identified a total of 91 potential sites. Of the 91 sites, 10 were selected for more detailed development and cost estimates (Acres American, Inc. 1981). From this study, Chakachamna was ranked as having the lowest economic cost of energy, and therefore represents a potentially attractive alternative to the Susitna project from an economic standpoint. The prospective size (480 MW installed capacity, 1923 GWh average annual energy) is desirable in the context of the existing size of the Railbelt electric power system. The project would be of sufficient size to allow displacement of more expensive thermal generation (especially if the Anchorage-Fairbanks electrical intertie is completed as proposed) yet is not so large as to result in underutilization.

Environmentally, the principal impact would be disruption of the flow of the Chakachatna River with resulting impact on the anadromous fishery of this stream. The facility could be operated, however, to maintain streamflow during critical migration periods. As the project is of the lake-tap variety, impacts of reservoir construction would be absent.

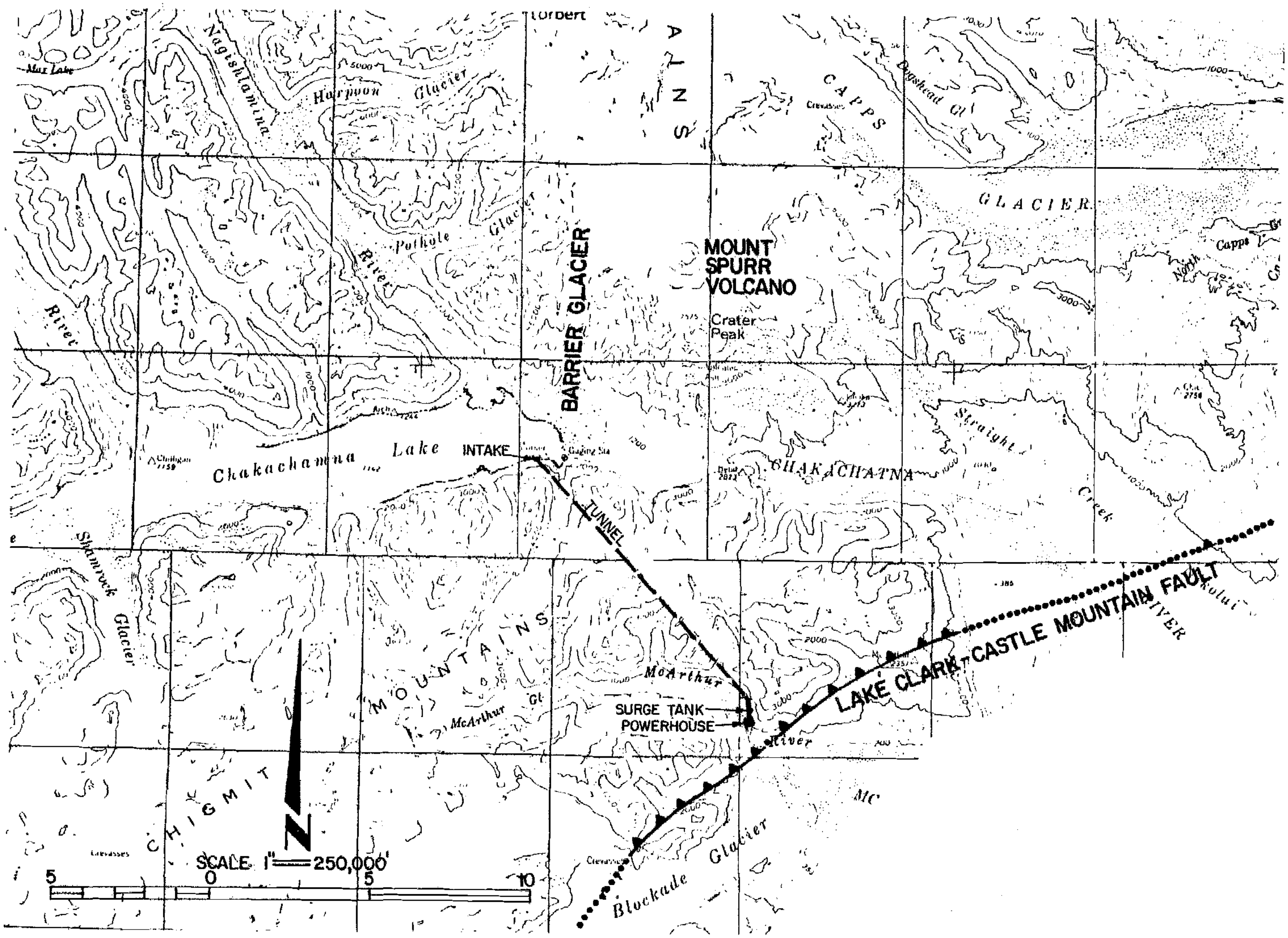


FIGURE 1.1. General Site Plan and Geologic Features

The project site, however, possesses certain disadvantages. Geologically, the Lake Clark-Castle Mountain fault zone, a seismically active fault, lies about 11 miles east of Chakachamna Lake (see Figure 1.1) and very close to the site of the proposed powerhouse. This fault may affect the stability of the Chakachamna storage reservoir, especially with regard to the Barrier Glacier ice-moraine dam that forms the downstream boundary of the reservoir. Approximately 5 miles to the northeast of Chakachamna Lake is the 11,070-foot-high Mount Spurr, an active volcano. Ash falls and mud slides resulting from an eruption of Mount Spurr may seriously impair the operation of the Chakachamna reservoir as well as the integrity of the Barrier Glacier ice-moraine dam. Also, there is uncertainty about the composition of this ice-moraine dam and the possible effect that the proposed reservoir operation might have on future movement of the glacier tongue, especially if it proved to be active at its downstream extremity that presently forms the left bank of the Chakachatna River as it leaves Chakachamna Lake.

Logistically, the location of the project presents some further disadvantages. Due to the remoteness of the project, a considerable amount of road construction and communication and transmission facilities would have to be provided.

These disadvantages, both geologic and logistic, are discussed in more detail in the following sections.

As an alternative to the selected transmountain diversion scheme, consideration was given to constructing a dam across the Chakachatna River 6 miles below the outlet of Chakachamna Lake, and developing the head along the river itself for power. This alternative was, however, subsequently abandoned because of difficulties associated with constructing the dam, which were recognized during an Ebasco site reconnaissance visit. The foundation, and especially the left abutment geologic conditions, are unfavorable for constructing a dam anywhere along the upper Chakachatna River. Also, the high seismic design factor due to the close proximity of the Lake Clark-Castle Mountain fault zone may seriously impair the stability of a dam built in this area.

2.0 SITE DESCRIPTION

2.1 SITE

2.1.1 Geology, Seismology, and Volcanism

The water storage reservoir for the project, Chakachamna Lake, is a glacier-formed lake surrounded by mountains that are part of the Alaska Range near the Cook Inlet Lowlands. The mountains surrounding the lake rise to above 5,000 feet elevation and support many active glaciers, one of which dams the Chakachatna River at the outlet of the lake. The region is both seismically and volcanically active, with major northerly-dipping thrust of strike-slip faults paralleling Cook Inlet, and a line of active volcanoes landward of the faults. The dominant geologic features of the site area are as follows:

- About 60 miles to the east of Chakachamna Lake, the Lake Clark-Castle Mountain fault zone, a 350± mile-long fault, is known to have offset Holocene sediments, and Recent sediments dated to between 260 and 1800 years ago. This fault passes within approximately 11 miles of Chakachamna Lake and a preliminary estimate of the potential magnitude of a seismic event along this feature is 7+. The potential for seismic activity generally increases as one proceeds southward along the fault.

- An active volcano, Mount Spurr, is located about 5 miles to the northeast of Barrier Glacier. This volcano erupted ash in 1953 and caused a mudslide that temporarily dammed the Chakachatna River 6 miles downstream of the lake outlet. Similar mudflows could conceivably alter the nature of the ice-moraine dam that forms Chakachamna Lake, render inservicable the intake structure to the power tunnel, and otherwise affect the feasibility or useful life of the project.

- Lake Chakachamna is formed by a natural dam at its eastern end, consisting of glacial morainal deposits from the still active Barrier Glacier. This glacier is an active alpine-type ice stream that descends the southwest slope of Mount Spurr and spreads into an expanded fan-shaped tongue for a distance of 2 miles across the Chakachatna River valley. This results in a confinement of nearly a 1 mile reach of the Chakachatna River into a narrow channel at the base of the steep mountainside on the south side of the valley. However, during the last 30 years, evidence points toward a trend of slow recession and shrinkage of the glacier. The exception to this trend is the advancement of one ice lobe on the glacier that is believed to be the result of Mount Spurr's 1953 eruption. With the development of the Chakachamna powersite and the resulting long periods of lake drawdown, the erosive effects of the existing Chakachatna River on the Barrier Glacier will be diminished. It is believed that this may result in the advancement of Barrier Glacier and closure of the short gap to the north of the mountainside where the river currently flows.

Surperficial deposits in this area include gravels, sands, and silts that form river deltas and beach deposits at the entrances of the Nagishlamina, Chilligan, and Neacola Rivers. A large glacial moraine is present at the base of More Glacier. The streams that feed Lake Chakachamna are all laden with sediment. The sediment is primarily "rock-flour" of glacial origin, and much of it seems to stay in suspension even after it reaches the calm waters of the lake. There are no firm data available as to the rate of accumulation of sediment in the lake, but the abrupt "leveling off" of the lake bottom at depths below 240 feet is an indication of a considerable accumulation of sediment.

Aerial photographs of this region show a series of parallel lineaments that trend roughly NW-SE. These features are quite evident in the field, and seem to extend for some distance. They are nearly vertical, and close examination shows severe fracturing and pulverization in the fault or fracture zone. A tunnel from Lake Chakachamna to the McArthur River Valley would roughly parallel the strike of these features.

Tunnels and related structures would be excavated in granitic rocks as indicated on existing geologic maps of the region. These maps show that the alignment would cross a zone of contact between granitics of two different periods of intrusion. Older greenstones outcrop directly to the north of Chakachatna River and these same rocks could conceivably outcrop along the tunnel route. Site inspections have shown generally favorable geologic conditions for tunnel portals where steep faces of relatively fresh rock are exposed. The powerhouse would be located 11 miles south of the lake on the McArthur River, between the floodplain and an active talus slope.

2.1.2 Hydrology

The entire drainage area contains lofty, rugged mountains with numerous large glaciers in the valleys and perpetual ice fields in the higher elevations. These glaciers and ice fields comprise 20 percent of the 1,120 square miles of drainage area. Mountain peaks are in the range of 6,000 to 10,000 feet in elevation, with the highest peak being Mount Torbert at elevation 10,600. Mount Spurr, an active volcano just outside the drainage area, rises to elevation 11,070 feet. Merrill Pass lies 18 miles to the west of Chakachamna Lake at an elevation of about 3,100 feet.

The generally southeastern exposure of the drainage area receives moisture from the storms moving inland through Cook Inlet. The principal streams contributing to Chakachamna Lake are the Neacola and Chilligan Rivers, each about 24 miles in length. Other streams include the Nagishlamina and the Igitna. Three of these streams terminate in Kenibuna Lake located directly to the west of Chakachamna Lake. Kenibuna Lake, in turn, empties into Chakachamna Lake. All streams except for the Chilligan River originate in glaciers.

The U.S. Geological Survey established a recording stream gaging station on the Chakachatna River at the outlet of the lake on June 14, 1959. This station, identified by the U.S. Geological Survey as "Chakachatna River near Tyonek, Alaska," was in continuous operation until 1972. A tabulation of the monthly historical discharges at this gage is shown in Table 2.1. The average monthly discharge for the 13-year period of record (extending from water year 1960 through water year 1972) is 3651 cfs. The monthly discharges recorded at

TABLE 2.1. Average Monthly Discharge at Outlet of Lake Chakachamna (cfs)[a]

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960	2022	992	658	504	381	325	250	1483	6368	10500	10300	4364
1961	1800	1116	882	817	780	544	394	876	5673	12090	12330	6989
1962	2638	1200	730	690	630	540	470	620	5222	13000	11060	6904
1963	1827	1144	744	553	387	361	332	748	3441	12640	12240	7737
1964	2768	1384	1007	618	436	424	370	471	6287	10590	12030	5654
1965	2026	1090	852	620	449	360	350	525	2117	10020	13810	10260
1966	4072	1180	650	480	400	350	350	615	5995	10040	10310	7145
1967	3790	1100	820	600	500	430	380	935	6616	14380	16610	7333
1968	2939	1565	947	626	535	490	511	1695	6190	12580	12170	4369
1969	1552	939	723	639	550	500	533	1033	6548	13100	8416	3347
1970	3098	1822	1066	705	568	550	625	1285	4893	9960	8884	3587
1971	2201	1247	829	532	467	467	692	2381	10930	14470	16710	4513
1972	1351	902	726	585	484	446	481	906	4294	12860	12750	6995

(a) From USGS Gage No. 15294500 - Chakachatna River near Tyonek.

this gage have been used as monthly reservoir inflows in the power operation studies for the project and serve as a basis for the estimates of power output and reservoir fluctuation. As discussed in Section 2.6.2, using the recorded lake discharges to also approximate reservoir inflow values introduces some error into the results of the reservoir operation studies for very wet or dry hydrologic periods. More detailed feasibility analyses should therefore utilize derived reservoir inflows for the power operation studies, computed by adjusting the recorded discharge by the effect of storage in the lake.

2.2 PLANT

2.2.1 Overview

Lake Chakachamna would be utilized as the storage reservoir for the project. Water would be conveyed from this reservoir via a 26-foot-diameter, 10.8-mile-long rock tunnel and a 26-foot-diameter vertical shaft, to the steel penstocks, and ultimately to the powerhouse. The powerhouse would be located on the McArthur River, approximately 25 miles upstream of the mouth of the river at Cook Inlet. The average net operating head for the project is estimated to be 867 feet. The major civil works are shown in plan and section in Figures 2.1 and 2.2, respectively. A summary of the principal project features is shown in Table 2.2.

The total installed plant capacity of 480 MW would be developed by four 120-MW reaction turbine-generators. The annual firm power output of the project is estimated to be 1,869,000,000 kilowatt hours.

The transmission of power would be over a 230-kV double-circuit line, approximately 115 miles in length and terminating at a substation near Anchorage. One transmission corridor alternate as well as the preferred route are shown in Figure 2.3.

Due to the remoteness of the project, approximately 40 miles of access roads will be required. The access road layout is also shown in Figure 2.3.

TABLE 2.2. Chakachamna Hydroelectric Project Summary of Project Features

Adit Tunnels	11,300 lineal feet 30 ft diameter 5 percent steel sets (W 12 x 65) 10 percent shotcreted and rockbolted (10-ft bolts)
Power Tunnel	57,000 lineal feet 26 ft diameter - circular cross section 10 percent concrete lined (1.5 ft) with steel sets (W 8 x 31 to W 10 x 49) 20 percent shotcrete lined (4 in.) and rockbolted (10-ft bolts) 70 percent unlined
Power Shaft	685 lineal feet, 26 ft diameter 5 percent steel set supported (W 8 x 31) 20 percent rockbolted (10-ft bolts) 10 percent shotcreted (4 in.)
Gate Shaft	500 lineal feet 20 ft diameter concrete lined (1.5 ft) for entire length
Spillway Tunnel	13,200 lineal feet 30 ft diameter 10 percent steel sets (W 12 x 65) 20 percent shotcreted (4 in.) over rockbolts (10-ft bolts) 80 percent unlined
Surge Tank	70 ft diameter, 400 ft high 50 percent rockbolted (15 ft bolts) 30 percent 2 ft concrete lined, 60 percent unlined
Steel Penstocks	1-18.5 ft diameter, 700 lineal feet 4-8.5 ft diameter, 100 lineal feet
Powerhouse	480 MW installed capacity
Francis Turbines	4 - 166,000 hp, 867 ft net design head
Generators	4 - 133,300 kVa, 300 rpm at 0.9 pf
Outside Powerhouse	dimensions: width: 120 ft length: 320 ft height: 120 ft

Switchyard dimensions: 300 ft x 100 ft

Tailrace Channel: width = 200 ft
depth = 20 ft
length = 1000 ft

Access Roads: 40 miles; 2 single span bridges near Lake Chakachamna

Transmission Lines: 115 miles, 230 kV
55 miles of new corridor
60 miles adjacent to existing corridor

2.2.2 Reservoir

The reservoir is anticipated to have a normal maximum water surface elevation of 1127 feet. At this elevation, the length of the lake is about 15 miles and the surface area is 15,250 acres. It is estimated that a total of 4,150,000 acre-feet of volume exists in the lake below elevation 1127. The lowest elevation obtained from soundings is 762 feet. Operation studies indicate that approximately 2,080,000 acre-feet of storage in the lake would be utilized for regulation of power releases.

The reservoir would be operated to store as much runoff as possible during the summer months when runoff is high. Regulated flows would be released for power generation throughout the year. Normally, runoff would fill the lake from mid-May to October. Any flood flows would spill from the lake into the Chakachatna River through a natural spillway at elevation 1127 feet. This natural outlet is located at the east end of Lake Chakachamna. Beginning in October the lake would be drawn down gradually during the winter months, reaching minimum elevation in mid-May, when the cycle would start again. The results of reservoir operation studies performed for the project indicate that during an average hydrological year the lake would be drawn down to a minimum level of elevation 1019 in May with the average reservoir level for the entire year being elevation 1076. The minimum reservoir level determined in the operation studies was elevation 968, which occurred only once during the period of hydrologic record.

An emergency spillway outlet has been included in the conceptual layout of the project in addition to the natural spillway that presently exists at the east end of Chakachamna Lake. The justification for including the emergency spillway outlet is based on the difficulty of predicting, with certainty, the future movements of the Barrier Glacier, especially when essentially all of the runoff into the lake becomes diverted for the production of power. Significant future glacier movement could cause it to completely seal off the only natural lake outlet. The uncertainties associated with the movements of this glacier and the need for additional studies are discussed in more detail in Section 4.2 of this report.

This concern is further emphasized by the USGS-1972 Water Resources Data for Alaska report, which describes the occurrence of a maximum lake discharge of 470,000 cfs. This flow was not measured at the outlet gauge, but was estimated through the observations of high water marks of the flood downstream of the lake. A flood of this magnitude would indicate that at some time in the past the glacier did, in fact, move sufficiently to close off the natural lake outlet. This would have subsequently resulted in a lake buildup that ultimately overtopped and then quickly eroded the glacier.

For estimating purposes, a 30-foot-diameter, 2.5-mile-long emergency spillway tunnel located in the right abutment of the lake outlet has been indicated (see Figure 2.1). The actual required diameter may vary somewhat from 30 feet but this would have to be determined through detailed hydrologic studies. This tunnel would have an invert elevation of approximately 1130 at the upstream end and would slope gradually to its outlet on the Chakachatna River. The upstream portal of this tunnel would be located in the steep granite face on the right bank of the outlet, roughly 500 feet south of the natural river channel at the outlet. For estimating purposes, it is assumed that the tunnel would be unlined for approximately 80 percent of its length.

A reconnaissance level estimate of the 100-year sediment inflow to the lake has been determined as 1,350,000 acre-feet (USBR 1962). Of this total, only about 70,000 acre-feet would be deposited in the active conservation space. This is roughly three percent of the active storage capacity and is therefore considered insignificant. Also, the annual loss due to evaporation is estimated to be not more than one-half foot for a full reservoir. At elevation 1127 feet this would amount to an insigificant 7250 acre-feet per year, or 0.3 percent of the active storage capacity.

The intake structure to the power tunnel would lie within the south bank of Lake Chakachamna, approximately 1 mile west of the lake outlet. This location would place the portal within a steep granite slope. During construction, the connection at the intake to the tunnel would be formed by blasting a plug of rock. Subsequently, loose rock might be removed from the intake by divers, but a concrete structure would not be built upstream of the gate shaft. The invert (lower lip of intake) would be at an approximate elevation of 916 feet. It would be provided with a coarse trashrack, which would be installed by divers. The purpose of this trashrack would be to prevent large logs from entering the tunnel.

A gate shaft would be located in the power tunnel approximately 500 feet downstream of the intake portal. This gate shaft would rise from the tunnel line to above the water surface of Lake Chakachamna where an entrance structure would be constructed at an elevation of 1400 feet. The shaft would contain two fixed-wheel gates, 30 feet high by 13 feet wide. These gates would normally function as remotely controlled service gates and would be used to close the tunnel only for dewatering and inspection. The gates could also be closed by remote control during an emergency.

The shaft would also contain auxiliary gates immediately upstream of the intake gates that would be closed during maintenance work on the main intake gate. Finally, the shaft would contain a fine trashrack designed to withhold all debris that may pass the coarse trashrack at the intake.

2.2.3 Tunnel, Surge Tank, and Penstock

Plan and section views of the water conductors are shown in Figures 2.1 and 2.2, respectively. Not shown in these figures, but immediately upstream of the surge tank, would be a 100-foot-long rock trap, formed by deepening the tunnel to create a long shallow basin 3 feet deep. Rock pieces that enter the tunnel would settle into this trap and not be carried into the turbines.

As discussed previously, the major portion of the power tunnel would be 26 feet in diameter and 10.8 miles long. The average flow in this main tunnel would be 3650 cfs.

From a site reconnaissance level interpretation of geologic conditions, as well as a review of available literature, it is felt that the rock is sufficiently competent to allow the main tunnel to be unlined along most of its route. It is estimated that approximately 10 percent of the tunnel would require a reinforced concrete lining with steel sets. This lining would probably be required at the inlet portal, for short distances along the tunnel and at the tunnel-surge tank intersection. A minimal amount of shotcrete and rockbolting (approximately an additional 20 percent) has also been assumed, to allow for jointing and changes in rock types. Lining and reinforcing at the entrance portal would be accomplished subaqueously.

A 70-foot-diameter, 400-foot-high surge tank would be located at the downstream end of the main tunnel. The assumed lining and support requirements for the surge tank are shown in Table 2.2.

Emerging downwards from the surge tank would be a 26-foot-diameter vertical shaft. For estimating purposes, it is assumed that this shaft would be unlined for approximately 90 percent of its length with supports and minimal shotcrete lining as defined in Table 2.2. Lower down, an 18.5-foot-diameter steel penstock would bifurcate into smaller 8.5-foot-diameter penstocks, which would connect to the powerhouse.

Construction access to the water conductors would be via the 20-foot-diameter gate shaft, located approximately 500 feet south of the entrance portal, as well as by access from the powerhouse excavation. Additional access would be provided by two construction access tunnels. One access tunnel, 6000 feet long, would intersect the main power tunnel approximately 6.7 miles downstream from the inlet portal. A second tunnel, 5300 feet long, would provide access to the surge tank from the southeast. These construction features are illustrated in Figure 2.1.

2.2.4 Power Plant

The powerhouse would be a semi-outdoor surface installation, located on the north bank of the McArthur River about 25 miles upstream of the mouth of the McArthur River on Cook Inlet. It will set into a side hill excavation and will be anchored to the rock slope to provide additional resistance against seismic forces. The structure would be reinforced concrete, and would be approximately 120 feet wide, 320 feet long, and 120 feet high (see Figures 2.4 and 2.5). It would contain four unit bays and a service bay. The unit bays would house four vertical Francis turbines, each with an output of 166,000 horsepower under a net head of 869 feet, resulting in a total installed plant capacity of 480,000 kW. The total plant discharge under these conditions would be about 7800 cfs. Generators would be umbrella-type, operating at a speed of 300 rpm. Turbine shutoff valves (either butterfly or spherical valves) capable of operating under emergency shutdown, would guard each unit.

Two main 260 MVA three-phase transformers would transform the voltage from 13 kV to 230 kV transmission voltage. A two bay, one and a half breaker switchyard, containing six breakers and measuring approximately 300 feet long by 100 feet wide, would be located adjacent to the powerhouse.

A tailrace channel with an average width of 200 feet would be excavated to the natural river channel from the downstream end of the powerhouse draft tubes. Draft tube gates would be serviced by a monorail hoist. The average tailwater elevation is estimated to be elevation 185 feet.

2.3 TRANSMISSION SYSTEM

Previous studies of the Chakachamna project have considered various alternatives for transmission line routes from the powerhouse to Anchorage. The 1962 Bureau of Reclamation Status Report (USBR 1962) on the Chakachamna project proposed 113.5 miles of 230-kV transmission lines with 1.5 miles of submarine cables to be used to cross Cook Inlet near Anchorage. A 138-kV line, presently being upgraded to 230 kV, now exists from Anchorage to the Beluga Station of the Chugach Electric Association. The station is located about 40 miles east of the Chakachamna powerhouse. This transmission line is owned and operated by the Chugach Electric Association. Therefore, only about 55 miles of new transmission line corridor have to be developed to extend from the Chakachamna powerhouse to the Beluga Station. Any additional transmission line required to deliver power from the Chakachamna Project to Anchorage will likely utilize the corridor of the existing Chugach line.

Two possible routes (A and B) for the transmission line segment from the Chakachamna power plant to the Beluga Station have been established through an evaluation of topographic and geologic maps of the region. These routes are shown in Figure 2.3. Route A is slightly longer than Route B by about 2 miles; however, foundation conditions appear to be more favorable for the longer Route A and therefore Route A is recommended.

Basically, an overhead line will start in the switchyard close to the powerhouse and head eastward just above the flood plain of the McArthur River for approximately 7 miles. At this point Routes A and B differ. Route A turns in a northerly direction for 2 miles, paralleling the eastern edge of the Tordrillo Mountains before heading north eastward 5 miles to a crossing of the Chakachatna River. Route B takes a more direct path to the Chakachatna River, approximately 6 miles across low lands and swampy terrain. The preferred transmission corridor (Route A) will closely parallel the plant access road right-of-way, as shown in Figure 2.3.

The transmission lines will then cross the Chakachatna River near its confluence with Straight Creek. The crossing will be above ground and in close proximity with an existing access road bridge crossing. From the Chakachatna River crossing the transmission corridor will parallel an existing road for approximately 40 miles to the Beluga Station.

Selection of transmission line structures is based on strength requirements, terrain, and visual appearance. Towers and angle structures will be composed of tubular steel-guyed columns, 60 to 90 feet high and pin-connected to the foundation. These structures combine the necessary strength with an inconspicuous appearance and will be economical to construct in rugged terrain due to their unique anchoring methods. The ruling span for most of the line would be 1000 feet. Approximately 10 percent of the structures will be founded on rock and will require anchors to accommodate the uplift forces. Ninety percent of the towers will be founded on deep soil deposits possessing an active freeze-thaw zone. Steel H-pile foundations will be required for these soil-supported structures.

2.4 SITE SERVICES

Site access will consist of an access road to the powerhouse as well as an access road to the power tunnel intake (see Figure 2.3). A total of about 40 miles of road will be required to connect the site facilities with an existing road crossing the Chakachatna River at its confluence with Straight Creek. No pipeline, air, or waterway access will be required. During construction, electric power will be brought into the site from the nearby

Beluga Station. Living facilities during construction will be provided by either a trailer park-type arrangement, or by temporary housing at the powerhouse location and tunnel inlet.

2.5 CONSTRUCTION

2.5.1 General Construction Methods

The feature of primary importance and uniqueness, from a construction point of view, is the 10.8-mile-long power tunnel. For the purpose of this project evaluation, it is assumed that the tunnel will be excavated using two tunnel-boring machines (TBMs), each working 3 shifts per day. It is felt that this will result in the most expeditious performance of the work while minimizing tunnel lining requirements, tunnel diameter, work crews, and excavation spoil.

Both TBMs will start from the central construction adit (see Figure 2.1) and excavate in opposite directions towards the ends of the tunnel. The upstream machine will excavate to within approximately 50 feet of the tunnel outlet and then be dismantled in the tunnel. It would subsequently be removed via the gate shaft shown in Figure 2.1. The tunnel will have to be locally widened in the area where the machine is to be dismantled to provide access. The last upstream 50 feet of the tunnel will be excavated by conventional drilling and blasting after the entire tunnel is completed and the powerhouse is nearly complete.

The second TBM will work downstream towards the surge tank. It would subsequently be removed from the tunnel via the access adit that enters the surge tank area shown in Figure 2.1.

All other rock excavation, e.g., for the surge tank, vertical shaft, penstocks, emergency spillway, and bifurcations, as well as the powerhouse and tailrace open cuts, and all construction adits, will be performed using conventional drilling and blasting methods. It is envisioned that this additional excavation (with the exception of the central adit) will be performed concurrently with the main tunnel excavation.

The powerhouse will be conventional in size and location, and should therefore not require any unusual construction methods or techniques. The only special consideration is the harsh winter climate, which will shorten the powerhouse construction year by approximately 4 months, particularly during its earlier stages of construction. To compensate for this, extended work shifts may be utilized in the summer months.

The transmission corridor is quite lengthy, utilization of the existing Beluga corridor notwithstanding. In excess of 100 miles of transmission lines will have to be provided; however, access will not be a problem. The corridor will parallel existing or newly constructed roads. It is estimated that several work crews can be utilized concurrently to erect the transmission facilities from several locations.

2.5.2 Construction Schedule

A complete project schedule from preliminary field studies through licensing, design, construction, startup testing, and commercial operation is presented in Figure 2.6. The schedule is broken down by major project activities versus calendar months; month zero representing July 1 of the base year.

From the start of work authorization at month zero it is estimated that approximately 18 months will be required to perform the preliminary field and office work necessary to support the conceptual engineering and licensing efforts. Part of this work will consist of performing field surveying and mapping, as well as preliminary geotechnical, hydrologic, and environmental studies. These efforts will utilize existing published information, as well as data gathered through preliminary-level field work.

Conceptual engineering will be performed concurrently with the field studies and will identify and evaluate possible alternative project layouts and features that best utilize the water resources in the Chakachatna River drainage basin. Power production analyses will consider a range of operational alternatives and installed capacities to define an optimal plant size and operation scheme. The selected plant size and operation scheme will maximize power output benefits and also incorporate any identified environmental constraints on project operation (e.g., restrictions on drawdown of Lake Chakachamna, instream flow requirements in the Chakachatna River, and restrictions to fluctuations in plant discharge into the McArthur River). Included in this level of engineering will be a more detailed development of transmission line routes, with emphasis given to routing the line clear of as many natural hazards as possible.

The above 18-month effort will terminate with the preparation and submittal of the necessary documentation for a FERC license application. For schedule estimating purposes, it is assumed that 2 years will be required for processing of the license application by the FERC. (If significant opposition to the project materializes the licensing phase may extend to as many as 4 years).

Upon submittal of the FERC license application, detailed design will commence for the power plant and conveyance systems. This will also include design of the structures and the mechanical, electrical and control systems, as well as provision of support services to assure that the work is performed with appropriate management controls and that materials are available to support project schedules. Specifically, this work will include the following:

- Preparation of detailed design criteria for use in the development of project design drawings. Design drawings will accommodate all of the construction-related activities required by the project. This includes solicitation of bids for services, construction and erection activities as well as actual construction of the tunnel, powerhouse, and transmission facilities. In addition to the detailed design drawings, the architect/engineer will prepare bills of material for supply of miscellaneous electrical, mechanical, and civil materials.

- Performance of engineering calculations required for preparation of drawings, specifications, and other pertinent data used in the design of the project, consistent with the requirements of regulatory bodies and design codes and standards.

- Preparation of technical specifications in sufficient detail to allow for project procurement and/or construction.
- Review of vendor documents and drawings for conformance to architect-engineer (AE)-prepared specifications and for confirmation of physical interfaces with related systems.
- Establishment of quality assurance requirements based on the detailed design developed on the basis of the project description, performance calculations, as well as on information provided by vendors and contractors. These requirements will serve as a basis for construction and for erection of structures, for procurement, and for installation, testing and operation of equipment.

It is estimated that 2 years will be required to carry out these design efforts from the time of formal receipt of the FERC license.

Procurement activities will run concurrently with detailed design and will consist of the following:

- Preparation of bid documents and evaluation of bids.
- Monitoring and control of procurement contracts.
- Vendor quality assurance services to assure that purchased items are supplied in accordance with the requirements of applicable procurement documents.
- Expediting services to assure the timely arrival of purchased items at the site.

Construction activities will commence in the summer about midway through the design period and will consist of the start of access road construction, connecting the site with the Chakachatna River crossing. It is estimated that construction of the entire project can be accomplished in about 5 years from the start of access road construction. As shown on the project schedule (Figure 2.6), this estimate is based on the yearly cessation of outdoor construction activities for a 3- to 4-month period during the winter months.

Indoor activities such as tunnel and penstock construction will, however, be performed throughout the year.

As discussed previously, the long tunnel is a unique construction feature of the project and could be a critical path item in the construction of the entire project. Therefore, it is assumed that work on the tunnel will be performed year-round, three shifts per day using two tunnel-boring machines simultanteously. Due to the length of the transmission line, it is also assumed that work will proceed on it from several locations simultaneously.

Startup testing of all major equipment and auxiliary appurtenances will be performed before commercial acceptance. This testing will start during the last year of powerhouse construction and will continue for a period of approximately 4 months after construction has been completed.

The total design and construction period including preconstruction field studies, design, licensing, construction and startup would be approximately 9-1/2 years. A mid-1982 authorization to proceed[a] would result in a fully operational facility about the end of 1991.

2.5.3 Construction Work Force

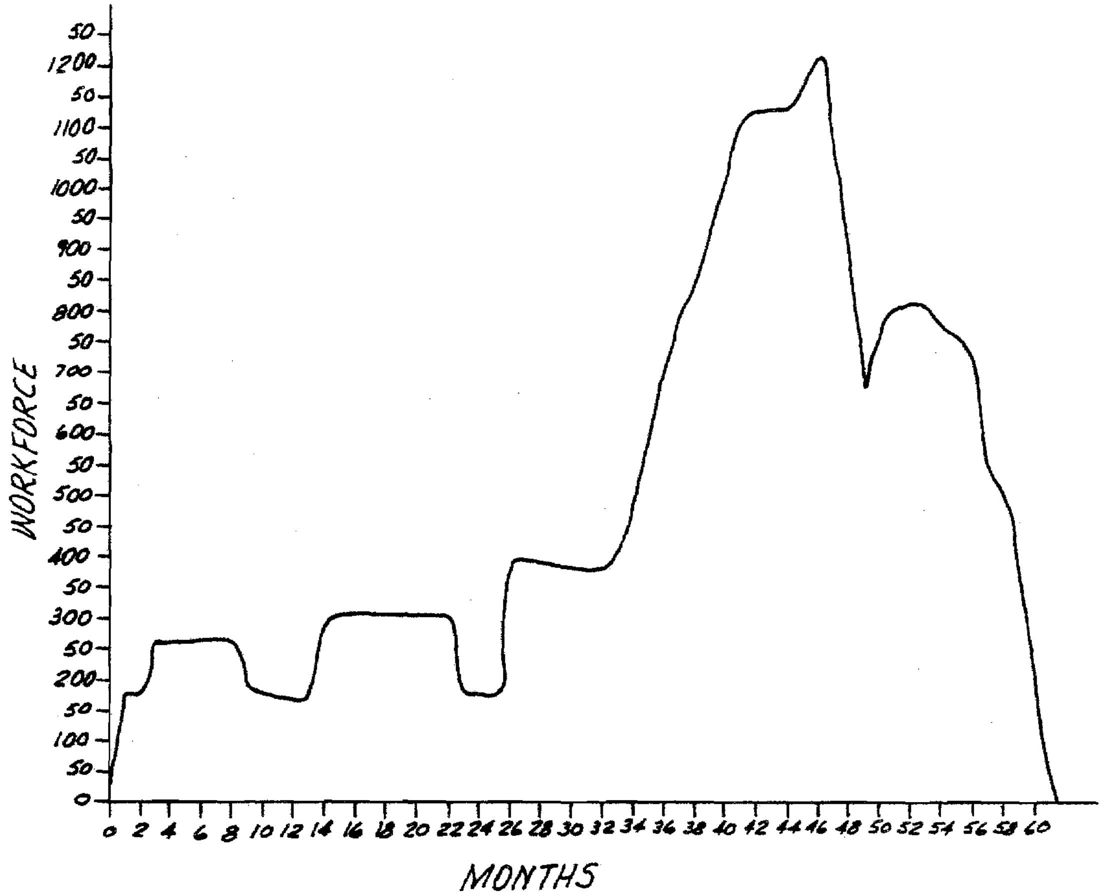
The number of workers necessary for construction of the project will vary over the approximate 5-year construction period. The distribution of this work force over the schedule is shown in Figure 2.7. Construction is estimated to peak near the end of year 3, requiring a work force of approximately 1220 personnel.

2.6 OPERATION AND MAINTENANCE

2.6.1 General Operating Procedures

The Chakachamna project will be operated as a conventional hydroelectric facility, with releases being made through the power plant on a daily basis as required to meet load demands. The project will ordinarily operate 24 hours a day, with the greatest release being made during daytime periods of peak load. During off-peak periods, the plant discharge will vary depending on

(a) Used as a basis for comparison in this series of studies.



NOTE: Does not include vendor personnel, owner personnel, A-E engineers, or transmission line construction personnel located at site.

FIGURE 2.7. Construction Work Force Requirements

local characteristics but will never fall below a minimum discharge requirement. The reservoir level would vary on a seasonal basis as a function of load characteristics and available streamflow. The details of the operating characteristics are discussed in greater detail below.

2.6.2 Operating Parameters

Forced Outage Rate

The estimated forced outage rate for the project is 1 percent.

Scheduled Outage Rate

The scheduled outage rate for the plant is estimated to be an average of 5 days per year per unit over the life of the project.

Power Output and Project Operation Characteristics

A hydropower simulation study was performed for the Chakachamna project by Acres American, Inc. (1981). This study involved utilization of a reservoir and power plant simulation model that simulated the operation of the project on a monthly basis for the 13-year period of hydrologic record. The results of this study were obtained from Acres and reviewed by Ebasco. To provide an independent check to the Acres study, Ebasco performed a similar operation study using the 13-year record of streamflow at the lake outlet as inflow. As discussed below, the assumption will introduce some error into certain study results. Several parameters used in Ebasco's simulation study were obtained directly from the Acres study. These include storage-elevation data, maximum and minimum operating storages, average tailwater level, minimum powerhouse release requirements, monthly demands, load factor, the discharge coefficient, and average overall efficiency. The results of Ebasco's operation study have been utilized herein as a basis for estimating the power output and operation characteristics of the project.

During an average hydrologic year, the reservoir level will vary between the normal maximum level of elevation 1127 feet and a minimum of elevation 1019 feet, with the average reservoir level being elevation 1076 feet. The estimated average tailwater level at the McArthur River of the powerhouse site is elevation 185 feet. The resulting average net power level (including allowance for friction losses in power conduit) is estimated to be 867 feet. Table 2.3 represents the estimated operational characteristics of the project during an average hydrologic year, showing the anticipated monthly values of generation and reservoir level. These values are obtained from the results of Ebasco's simulation study for the period of hydrologic record. The estimated average annual energy production from the project is 1,892 GWh, which corresponds to an annual plant factor of 45 percent. The firm annual energy is estimated to be 1,869 GWh.

It should be noted that utilization of the recorded outflows at Lake Chakachamna as inflows into the reservoir in the operation studies will result in some error, because the recorded outflows are subject to the natural regulatory effect of the lake. Utilizing the recorded outflows as inflows in

TABLE 2.3. Project Operation During Average Hydrologic Year

Month	Average Monthly Energy Generation (GWh)	Average End-of-Month Reservoir Elevation (ft)
October	166	1112
November	184	1102
December	207	1088
January	191	1075
February	163	1062
March	162	1047
April	140	1032
May	133	1019
June	124	1034
July	126	1075
August	137	1108
September	159	1116
Annual Average	1892	1076

the operation study will admittedly have negligible effect on the estimate of average annual energy, but the firm energy will tend to be overstated, since the actual inflows during the driest year of record would be less than the outflows recorded at the outlet of the lake. Therefore, the actual firm energy available from the project would be less than the 1,869 GWh obtained from the operation studies. Any further operation studies should use reservoir inflows that have been computed by adjusting the recorded outflows for the effect of storage in the lake.

The plant discharge into the McArthur River will vary from a maximum of approximately 8,100 cfs, under conditions of maximum reservoir level and power output, to a minimum of 1000 cfs during offpeak hours. The naturally occurring discharges from Lake Chakachamna into the Chakachatna River will be essentially eliminated.

It should be noted that the simulation study results described above are based on the assumption that all of the available inflow into Chakachamna Lake would be diverted to the powerhouse on the McArthur River, with no downstream fish release being provided in the Chakachatna River below the lake. This, of course, represents the most optimistic assumption regarding available flows for power generation. If a fishery maintenance release were provided in the Chakachatna River downstream of Chakachamna Lake, both the firm and average annual energy production from the project would be reduced. Whether the project would be feasible with a fish release requirement can only be evaluated by estimating the power output and resulting cost of power associated with the selected fish release schedule. The project construction cost estimate for such a scheme would have to include an allowance for flow control facilities at the outlet of Chakachamna Lake that would be capable of reliably releasing the desired amount of water.

2.6.3 Project Life

The economic life of the project is considered to be 50 years.

2.6.4 Operating Work Force and General Maintenance Requirements

It is anticipated that the Chakachamna project will be a remote-controlled facility and will not require resident operating personnel. Daily trips will, however, be made to the plant to perform routine maintenance and inspection. These inspections could be performed by one or two operators. Major overhauls and maintenance work will ordinarily be performed on an annual basis by a larger crew.

Although the presence of rock flour in the reservoir water may cause some additional wear to the turbine parts, major components of the generating machinery are not expected to need replacement during the life of the project. Repairs to the runner blades are likely and certain parts of the turbine may have to be replaced during the turbine life, such as bearings, wicket gates, wear rings, and face plates. Generator bearings and windings are other items that may have to be replaced during the plant life. In addition, many pieces of auxiliary or supporting equipment may have to be replaced at least once during the project life. As frequently is the case, this may, however, be caused by the equipment item having become obsolete and replacement parts not being available. Replacement is then often less costly than fabricating special parts.

3.0 COST ESTIMATES

3.1 CAPITAL COSTS

3.1.1 Construction Costs

Construction costs have been developed for the major bid line items common to hydroelectric power plants. These line item costs have been broken down into the following categories: labor and insurance, construction supplies, equipment repair and labor, equipment rental, permanent materials, and subcontracts. Results of this analysis are presented in Table 3.1. Total overnight construction cost is estimated to be $1,010 million.[a] The equivalent unit capital cost is $2104 per kilowatt.

3.1.2 Payout Schedule

A payout schedule has been developed for the entire project and is presented in Table 3.2. The payout schedule was based on a 60-month basis from start of project construction to completion.

3.1.3 Escalation

Estimates of real escalation in capital costs for the plant are presented below. These estimates were developed from projected total escalation rates

Year	Materials and Equipment (Percent)	Construction Labor (Percent)
1981	1.0	0.5
1982	1.2	1.7
1983	1.2	1.7
1984	0.7	1.3
1985	-0-	-0-
1986	-0.1	-0.1
1987	0.3	0.3
1988	0.8	0.8
1989	1.0	1.0
1990	1.1	1.1
1991	1.6	1.6
1992 - on	2.0	2.0

(a) January 1982 dollars, not including land or land rights, owner's costs or transmission costs beyond the switchyard.

TABLE 3.1. Bid Line Item Costs for Chakachamna Hydroelectric Project[a] (January 1982 Dollars)

Bid Line Item	Construction Labor and Insurance	Construction Supplies	Equipment Repair Labor	Equipment Rent	Permanent Materials	Sub-Contracts	Total Direct Cost
1. Improvements to Site	224,800	11,300	232,500	173,300	6,900		648,800
2. Earthwork and Piling	67,632,100	35,994,400	21,749,000	56,307,000	160,256,100	680,000	342,618,600
3. Concrete	29,666,200	1,201,900	4,621,900	2,973,300	17,864,400		56,327,700
4. Structural Steel and Lift Equipment	2,238,200	348,500	97,400	925,400	10,985,000		14,594,500
5. Buildings	263,400	28,800		12,000	477,000		781,200
6. Turbine Generator	6,684,000	46,000		20,000	62,000,000		68,750,000
7. Other Mechanical Equipment	362,600	23,000		9,000	1,175,000		1,569,600
8. Piping	1,966,200	40,300		20,000	3,000,000		5,026,500
9. Instrumentation	93,500	3,500		1,500	100,000		198,500
10. Electrical Equipment	2,803,600	40,300		30,000	4,500,000		7,373,900
11. Painting	201,200	17,300		10,000	125,000		353,500
12. Off-Site Facilities	9,227,700	834,700	15,500,700	11,654,600	2,438,200		39,655,900
13. Substation	670,700	23,000		15,000	2,100,000		2,808,700
14. Construction Camp Expenses	9,791,400	36,700,700					46,492,100
15. Indirect Construction Costs and Architect/Engineer Services[b]	134,277,800	22,730,500	5,201,100	2,723,000			164,932,400
SUBTOTAL	266,103,400	98,044,200	47,402,600	74,874,100	265,027,600	680,000	752,131,900
Contractor's Overhead and Profit							129,000,000
Contingencies							129,000,000
TOTAL PROJECT COST							1,010,131,900

(a) The project cost estimate was developed by S. J. Groves and Sons Company. No allowance has been made for land and land rights, client charges (owner's administration), taxes, interest during construction or transmission costs beyond the substation and switchyard.

(b) Includes $98,000,000 for engineering services and $66,932,400 for other indirect costs including construction equipment and tools, construction related buildings and services, nonmanual staff salaries, and craft payroll related costs.

TABLE 3.2. Payout Schedule for Chakachamna Hydroelectric System (January 1982 dollars)

Month	Cost per Month, Dollars	Cumulative Cost, Dollars
1.	8,165,100	8,165,100
2.	8,165,100	16,330,200
3.	10,447,900	26,778,100
4.	10,447,900	37,226,000
5.	10,447,900	47,673,900
6.	10,447,900	58,121,800
7.	10,447,900	68,569,700
8.	10,447,900	79,017,600
9.	8,165,100	87,182,700
10.	8,165,100	95,347,800
11.	8,165,100	103,512,900
12.	8,165,100	111,678,000
13.	8,165,100	119,843,100
14.	11,498,900	131,342,000
15.	11,498,900	142,840,900
16.	11,498,900	154,339,800
17.	11,498,900	165,838,700
18.	11,498,900	177,337,600
19.	11,498,900	188,836,500
20.	11,498,900	200,335,400
21.	11,498,900	211,834,300
22.	11,498,900	223,333,200
23.	8,165,100	231,498,300
24.	8,165,100	239,663,400
25.	8,165,100	247,828,500
26.	13,714,100	261,542,600
27.	13,714,100	275,256,700
28.	13,714,100	288,970,800
29.	13,478,800	302,449,600
30.	13,478,800	315,928,400
31.	13,478,800	329,407,200
32.	13,478,800	342,886,000
33.	13,478,800	356,364,800
34.	15,316,400	371,681,200
35.	13,145,000	384,826,200
36.	25,570,100	410,396,300
37.	22,427,800	432,824,100
38.	24,082,900	456,907,000
39.	24,082,900	480,989,900
40.	31,490,600	512,480,500
41.	34,680,400	547,160,900
42.	35,262,800	582,423,700
43.	35,262,800	617,686,500
44.	35,262,800	652,949,300
45.	31,859,100	684,808,400
46.	36,715,500	721,523,900
47.	31,870,500	753,394,400
48.	32,261,800	785,656,200
49.	17,572,800	803,229,000
50.	21,170,800	824,399,800
51.	21,170,800	845,570,600
52.	21,170,800	866,741,400
53.	21,170,800	887,912,200
54.	20,230,600	908,142,800
55.	20,230,600	928,373,400
56.	20,692,100	949,065,500
57.	18,463,400	967,528,900
58.	18,463,400	985,992,300
59.	14,791,700	1,000,784,000
60.	9,347,900	1,010,131,900

(including inflation) and subtracting a Gross National Product deflator series which is a measure of inflation.

3.2 OPERATION AND MAINTENANCE COSTS

3.2.1 Operation and Maintenance Costs

The annual operation and maintenance cost for the Chakachamna hydroelectric project, expressed in January 1982 dollars, is estimated to be $1.8 million (3.75 $/kW/yr). All operation and maintenance costs are assumed to be fixed costs that do not vary appreciably with the plant's kilowatt-hour output.

3.2.2 Escalation

Estimated real escalation of operation and maintenance costs is as follows:

Year	Escalation (Percent)
1981	1.5
1982	1.5
1983	1.6
1984	1.6
1985	1.7
1986	1.8
1987	1.8
1988	2.0
1989	2.0
1990	2.0
1991	2.0

3.3 COST OF ENERGY

The estimated busbar energy cost for the Chakachamna hydroelectric project is 25.5 mills per kilowatt-hour. This is a levelized lifetime cost, in January 1982 dollars, assuming a 1991 first year of commercial operation and full utilization of the average annual power output of the facility. Estimated busbar energy costs for lower capacity factors and other startup dates are shown in Figures 3.1 and 3.2. First and subsequent year energy costs and capital and O&M cost components are shown in Table 3.3. Year-of-occurrence

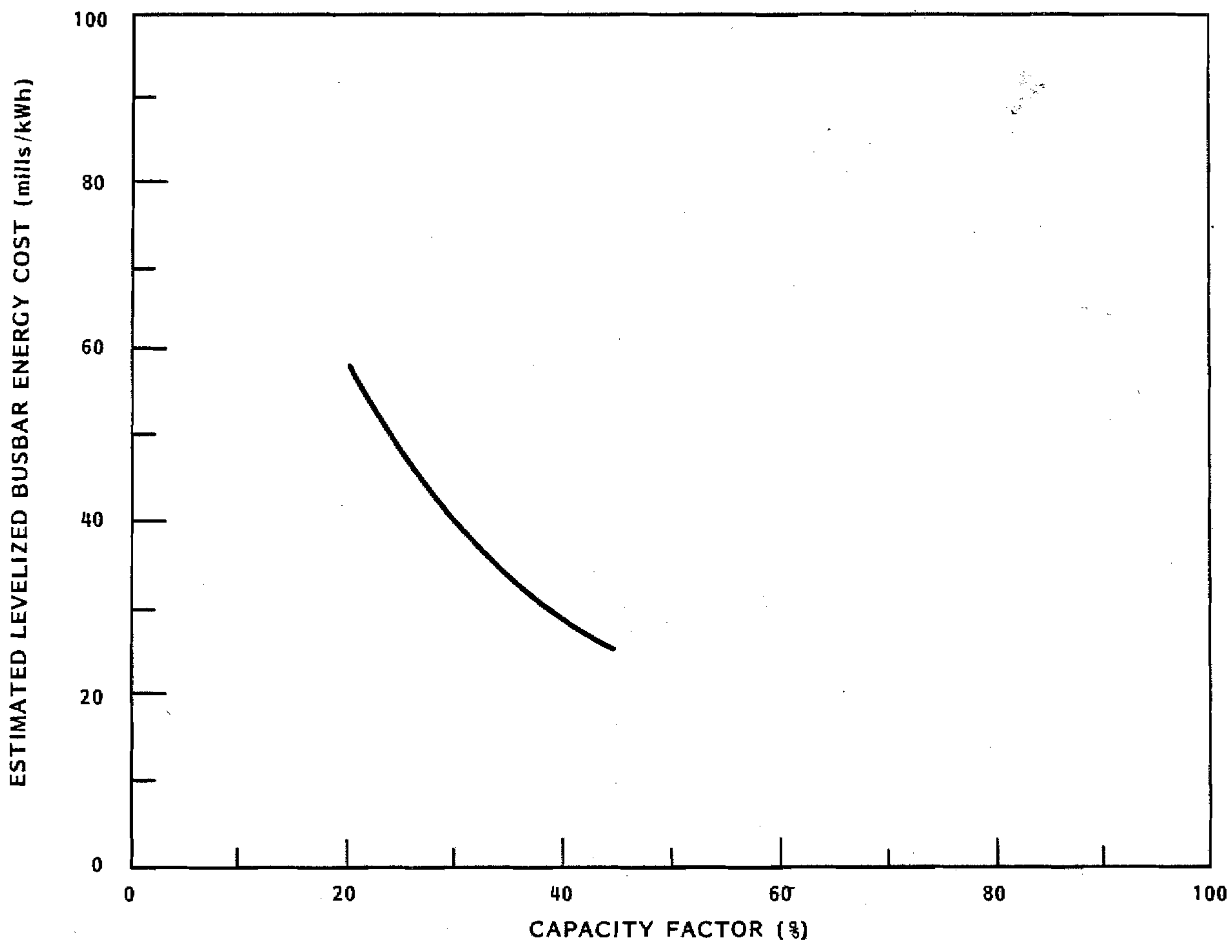


FIGURE 3.1. Cost of Energy Versus Capacity Factor (January 1982 dollars)

costs are essentially flat over the economic lifetime of the facility, since O&M costs represent a small portion of the total costs.

These costs are based on the following financial parameters:

Debt Financing	100%
Equity Financing	0%
Interest on Debt	3%
Federal Taxes	None
State Taxes	None
Bond Life	50 years
General Inflation	0%

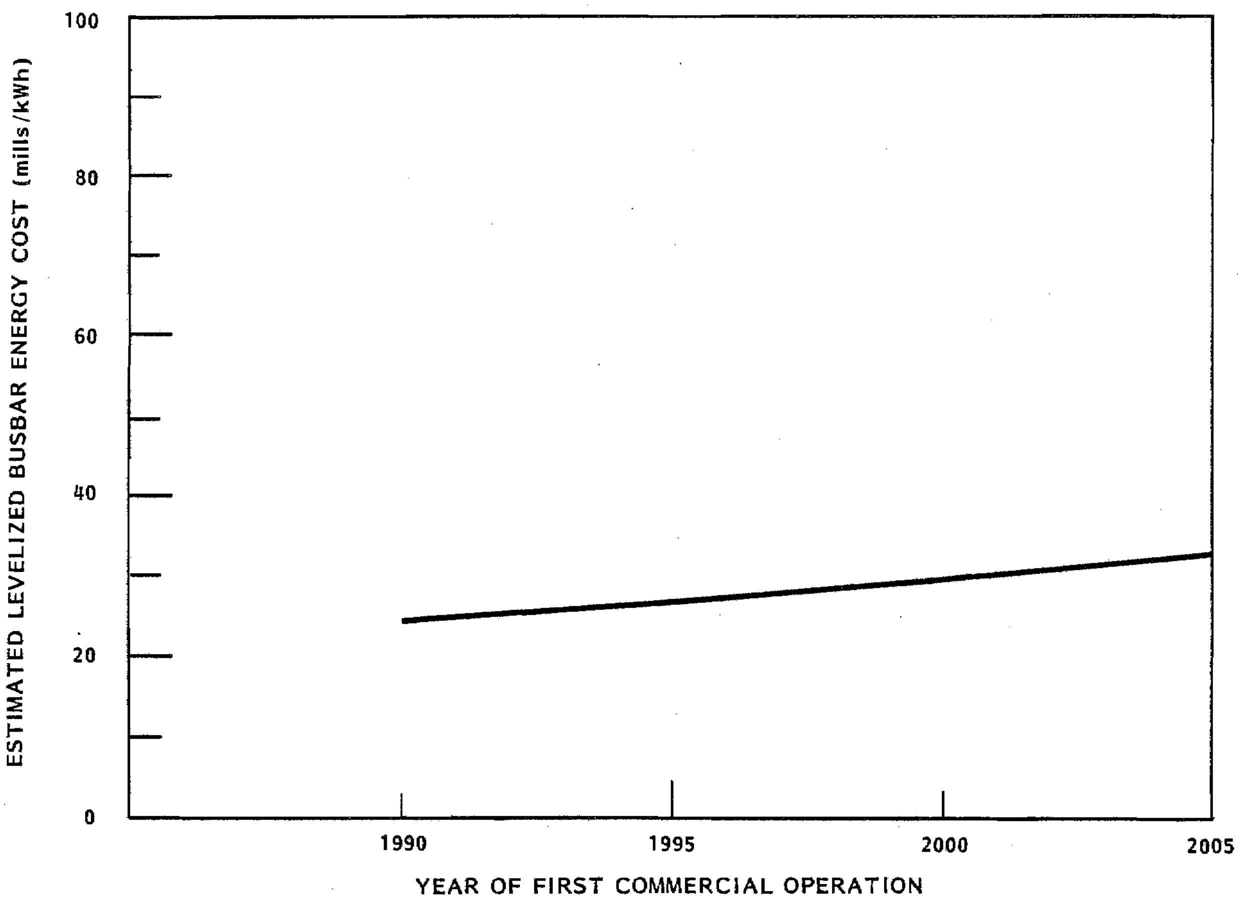


FIGURE 3.2. Cost of Energy Versus First Year of Commercial Operation (January 1982 dollars)

The escalation factors given in Section 3.1 were employed. Weighted average capital cost escalation factors were derived using a labor/material ratio of 30 percent/70 percent.

TABLE 3.3. Year-of-Occurrence Energy Costs (January 1982 dollars)

Year	Unit Capital Costs (mills/kWh)	Unit O&M Costs (mills/kWh)	Unit Total Costs (mills/kWh)[(a)]
1991	23.8	1.1	25.0
1992	23.8	1.2	25.0
1993	23.8	1.2	25.0
1994	23.8	1.2	25.0
1995	23.8	1.2	25.1
1996	23.8	1.3	25.1
1997	23.8	1.3	25.1
1998	23.8	1.3	25.1
1999	23.8	1.3	25.2
2000	23.8	1.4	25.2
2001	23.8	1.4	25.2
2002	23.8	1.4	25.2
2003	23.8	1.4	25.3
2004	23.8	1.5	25.3
2005	23.8	1.5	25.3
2006	23.8	1.5	25.4
2007	23.8	1.6	25.4
2008	23.8	1.6	25.4
2009	23.8	1.6	25.5
2010	23.8	1.6	25.5
2011	23.8	1.7	25.5
2012	23.8	1.7	25.6
2013	23.8	1.8	25.6
2014	23.8	1.8	25.6
2015	23.8	1.8	25.7
2016	23.8	1.9	25.7
2017	23.8	1.9	25.7
2018	23.8	1.9	25.8
2019	23.8	2.0	25.8
2020	23.8	2.0	25.8
2021	23.8	2.1	25.9
2022	23.8	2.1	25.9
2023	23.8	2.1	26.0
2024	23.8	2.2	26.0
2025	23.8	2.2	26.1
2026	23.8	2.3	26.1
2027	23.8	2.3	26.1
2028	23.8	2.4	26.2
2029	23.8	2.4	26.2
2030	23.8	2.4	26.3
2031	23.8	2.5	26.3
2032	23.8	2.5	26.4
2033	23.8	2.6	26.4
2034	23.8	2.7	26.5
2035	23.8	2.7	26.5
2036	23.8	2.8	26.6
2037	23.8	2.8	26.7
2038	23.8	2.9	26.7
2039	23.8	2.9	26.8
2040	23.8	3.0	26.8

(a) Rounding errors may be present.

4.0 ENVIRONMENTAL AND ENGINEERING SITING CONSTRAINTS

Council of Environmental Quality regulations implemented pursuant to the National Environmental Policy Act of 1969 require that an environmental impact statement be prepared for projects requiring licensing by a federal agency. The statement must include a discussion and evaluation of alternatives to the proposed action. This requirement is usually satisfied for hydroelectric projects through the evaluation of alternative sites (projects) and possibly through the evaluation of other energy-generating technologies. The purpose of such a siting study is to identify a preferred project and possibly viable alternative projects to supply the required amount of power. This process can contribute to reductions in project costs, through analysis of environmental and engineering siting considerations.

This section presents many of the constraints that will be evaluated during a siting study. Special attention is given to the applicability of these constraints to the location considered in this study. It should be realized that many of the constraints placed upon the development of a hydroelectric plant are regulatory in nature and therefore the discussion presented in this section is complemented by the identification of power plant licensing requirements presented in Section 6.0.

4.1 ENVIRONMENTAL SITING CONSTRAINTS

4.1.1 Water Resources

Water resource siting constraints generally center about two topics: water availability and water quality. With a hydroelectric project, there are additional locational constraints placed upon the water resource, e.g., locational suitability of the reservoir formed by the project. The Chakachamna project presents a variation in that a natural reservoir (lake) already exists, and evaluations would need to be made on impacts from changes on lake level to the local hydrology.

The dewatering of the upper portion of the Chakachatna River may preclude the project development unless this environmental cost is deemed acceptable. Alternatively, controlled discharges could be made to the Chakachatna River to support the anadromous fishery. The tailrace discharges to the McArthur River may result in water changes to this river system, which again would need to be considered in a feasibility study.

4.1.2 Air Resources

There will be no major environmental impact or siting constraints relating to air resources.

4.1.3 Aquatic and Marine Ecology

A detailed inventory of the aquatic species and habitat characteristics present in Lake Chakachamna, the Chakachatna River, and the McArthur River will need to be performed, with emphasis on andromous fish, significant benthos, and aquatic vegetation-supporting terrestrial life. Changes in the populations of these species due to the drastic changes in the hydraulic regimes must be estimated and weighed in the feasibility study, to ascertain if the project benefits outweigh potential environmental costs.

4.1.4 Terrestrial Ecology

Since habitat loss is generally considered to represent the most significant impact on wildlife, the prime study activity regarding terrestrial ecology will be an identification of important wildlife areas, especially critical habitat of threatened or endangered species. Based upon this inventory, exclusion, avoidance and preference areas for tunnel access points, access roads, and other components that do not require a specific location should be delineated and factored into the overall plant component siting process. Habitat losses due to the anticipated changes in river morphology for such important species as moose, caribou, and black bear need identification and evaluation in the feasibility study.

4.1.5 Socioeconomic Constraints

Major socioeconomic constraints center about potential land use conflicts, and community and regional socioeconomic impacts associated with project activities. Potential exclusionary land uses will include lands set aside for public purposes, areas protected and preserved by legislation (federal, state or local laws), areas related to national defense, areas in which a hydroelectric installation might preclude or not be compatible with local activities (e.g., urban areas or Indian reservations), or those areas presenting safety considerations (e.g., aircraft facilities). Avoidance areas will generally include areas of proven archeological or historical importance not under legislative protection, and prime agricultural areas.

Regarding other socioeconomic concerns, minimization of the boom/bust cycle will be a prime criterion. Through the application of criteria pertaining to community housing, population, infrastructure and labor force, this important consideration should be evaluated and preferred mitigative measures identified. Because the potential power plant area is a remote site and will likely cause significant boom/bust-related impacts on nearby small population communities (i.e., Tyonek), socioeconomic criteria will be heavily weighted in the overall site evaluation process.

4.2 ENGINEERING SITING CONSTRAINTS

The Chakachamna site has some characteristics that could constrain the development of the project. These include seismic, volcanic, glacial, and hydrologic aspects.

The Lake Clark-Castle Mountain fault passes within 11 miles of the site and is known to have been an earthquake generator. It is estimated that a potential magnitude-seven earthquake can occur along this feature. An earthquake of this size can be adequately designed for but will require more costly and massive structures. Such an earthquake might also affect the stability of the Barrier Glacier that forms Chakachamna Lake. This could cause a potential hazard downstream of the project.

The close proximity of the Lake Clark-Castle Mountain fault to the site increases the possibility that other faults may be present along the route of the power tunnel. To verify the existence of any such faulting, an aeromagnetic survey should be conducted along the power tunnel alignment. The survey should cover a distance of at least 5 miles outward along each side of the alignment. The results of the survey would be interpreted to yield magnetic contours to delineate the configuration of the various granitic rock formations along the tunnel route, as well as overburden thickness. The presence of faulting (if any) would then be determined and subsequently confirmed by local seismic refraction surveys.

Any faults confirmed would then be studied for capability by performing mineralogical dating studies at a surface expression of the faults. An alternative to the dating study is to assume that any faulting along the tunnel alignment is capable and then to statistically determine, through correlations with the Lake Clark-Castle Mountain fault movements and with area seismicity, when the next movement along the fault could be anticipated. Seismicity associated with this movement would also be determined.

Based on information currently available, it is felt that the presence of faulting along the tunnel alignment should not alone preclude the feasibility of the project. Seismic loading to the project facilities caused by this movement could be incorporated into the design. Physical constrictions in the tunnel that might develop due to movements along the fault could, if significant enough, be repaired locally. Typically, however, movements and offsets in tunnels traversing areas of high seismicity and faulting are small.

Mudslides, glowing avalanches (gases and solids flowing together in a liquid), and ash falls from an eruption of the active Mount Spurr volcano might similarly affect the stability of the Barrier Glacier, as well as the operation of the power tunnel intake and any lake outlet structure/emergency spillway that is provided. Mt. Spurr has a history of active ash eruptions, with the most recent occurring in 1953. The 1953 eruption caused mudslides that temporarily dammed the Chakachatna River for a length of several miles below Barrier Glacier. Ash falls can also be quite disruptive to the operation of the switchyard and transmission lines, causing pole fires, flashovers, and on occasion, trip-outs. Trip-outs, however, are more predominant in non-vertical insulator arrangements.

Design precautions may be taken to mitigate some of the effects that volcanic activity may have on the project. A potential ash fall depth should be considered as an added normal live load for the design of the powerhouse and any other plant facilities. Openings to the powerhouse should be kept to a minimum. Since the facility would be remote-controlled, no windows should be provided. Equipment at the intake gate should be completely enclosed. Also, protective measures should be made available for workers at the site (e.g, protective masks, air packs, etc.).

Specifications for the generating equipment should include requirements for extra-durable runner and wicket gate seals. This will extend the life of the seals against the errosive effects of volcanic ash suspended in the water. In addition, special water filters should be provided for the unit bearing lubrication systems to assure that this water remains clear.

The electrical transmission equipment will require special protective features, especially since volcanic ash may contain chemical components that, when in contact with water, will cause conducting films on the insulator surfaces. Therefore, insulators will have to be selected that have increased breakage distances and special anti-pollution shapes. In areas where ash buildup is likely to be high, which may include the switchyard and portions of the transmission line, additional preventative measures would have to be provided. Such measures include periodic lubrication of the insulators with silicone, hot-line washing of the insulators using a mobile hot-line washing truck (in the switchyard only) and, where acceptable, de-energized washing of insulators.

Mudslides and glowing avalanches previously mentioned should not affect the powerhouse area due to the protective topography between Mt. Spurr and the site. These events could, however, greatly affect Chakachamna Lake, its outlet, and the power intake. The potential of a mudslide and/or glowing avalanche filling a portion of Chakachamna Lake and inundating its outlet and/or intake would have to be studied in detail. If these occurrences proved highly probable, the entire lake-tap design concept, as it presently exists, would have to be modified. A relocation of the intake structure several miles to the west, and a corresponding increase in the tunnel length could be required. If these events are significant enough to close the lake outlet, a temporary outlet would have to be provided by channeling or some other means until the existing outlet is reopened, or a new outlet constructed.

Finally, the operating agency of the project should take practical measures to maintain a high level of awareness of the volcanic activity at Mt. Spurr. If an eruption seems certain, the operators of the project should be prepared to close the intake gates and shut down the plant on very short notice. This course of action should be implemented if the eruption is serious enough to significantly damage an operating plant, regardless of the above design considerations.

The normal course of Barrier Glacier movements that will result from withdrawing water from Chakachamna Lake may present some difficulties that will need to be investigated. For example, the mitigating effect that power production might have on the natural erosion of the glacier by the Chakachatna River may cause the glacier to form a continuous ice dam across the outlet of Chakachamna Lake. The potential problem of glacier movements will require a detailed study into the mechanics and extent of these movements.

Also related to the glacier-ice dam concern is the potential effect that a probable maximum flood (PMF) could have on the stability of the ice dam. If such potential formation of a continuous ice dam was proved to be likely, the emergency spillway would then have to be sufficiently large to accommodate the PMF.

5.0 ENVIRONMENTAL AND SOCIOECONOMIC CONSIDERATIONS

5.1 SUMMARY OF FIRST ORDER ENVIRONMENTAL IMPACTS

The construction and operation of the proposed Chakachamna hydroelectric generating facility will create changes or impacts to the land, water, and socioeconomic environments in which it is located. These impacts are directly related to various power plant characteristics that represent the primary effects of the plant on the environment. A summary of these characteristics is presented in Table 5.1. In this section, the primary effects of the proposed hydroelectric projec are analyzed and evaluated in light of existing environmental conditions to determine the significance of the impact and the need for additional mitigative measures.

5.2 ENVIRONMENTAL AND SOCIOECONOMIC EFFECTS

5.2.1 Water Resource Effects

The configuration of the hydroelectric project will have some significant, irreversible impacts on the local water resources. Diversion of the runoff into Lake Chakachamna to the MacArthur River via the proposed power tunnel will essentially eliminate discharge from the lake into Chakachatna River. In addition, under very dry hydrological conditions the lake will be subject to fluctuations in elevation of up to 160 feet. The McArthur River will experience an increase in flow, corresponding roughly to the loss in the Chakachatna River. Should the water qualities of the lake and McArthur River differ significantly, the river will experience a charge in water quality as well.

Parameters most likely to experience a change include temperature, dissolved oxygen, total dissolved gases, and suspended sediment. Adverse aquatic impacts generic to most hydroelectric power plants and potential problems with the Chakachamna project include stabilized flow patterns, armoring and scouring of stream beds, reduced bedload movement, flushing, and high-pressure discharges that could cause gas supersaturation.

TABLE 5.1. Primary Environmental Effects

Air	No first order impacts.
Water	
Diversion to McArthur River Through Plant	Average: 3660 cfs Maximum: 8100 cfs Minimum: 1000 cfs
Water Quality	To be determined in siting and feasibility studies; impacts anticipated to be changes in suspended sediment and increases in dissolved gas concentration.
Other	Fluctuation in lake level to 160 feet.
Aquatic and Marine Ecosystems	
Anadromous Fish	Probable destruction of existing sockeye salmon run under proposed operating regime. Potential impact on Chinook and pink salmon runs of lower Chakachatna and McArthur Rivers.
Other	Likely impacts on lake trout, arctic char, whitefish, rainbow trout, sculpins, blackfish and northern pike due to changes in water quality, flow regime or lake-level fluctuations.
Terrestrial Ecosystems	
Wildlife Habitat	Changes in riparian vegetation, loss of habitat at powerhouse, access road and sites.
Food Chain	Effects of changes in fish population.
Human Presence	Increased access to McArthur and Chakachatna River drainages and to Chakachamna Lake.
Rare and Endangered Species	No significant impact expected.
Land	
Plant Site	Modest (tens of acres).
Plant Access	Approximately 40 miles of road.
Transmission	Approximately 55 miles of 270-kV overhead line.
Relocations	None.
Socioeconomic	
Construction Work Force	Peak requirement of approximately 1220.
Operating Work Force	1-2 operators for daily inspection.
Relocations	None.
Land Use Changes	Loss of wilderness quality in Chakachatna and McArthur River valleys; and in valley of Chakachamna Lake.
Recreation	Loss of wilderness quality as above. Increased access to Chakachatna and McArthur River valleys and to Chakachamna Lake.
Capital Investment	65 percent within region 35 percent outside region.
Operating Investment	89 percent within region 11 percent outside region.

5.2.2 Air Resource Effects

Since the reservoir (Lake Chakachamna) already exists, there are no anticipated significant effects to the air resource or local climatology.

5.2.3 Aquatic and Marine Ecosystem Effects

Potential aquatic ecological impacts of hydropower project construction on Chakachamna Lake center on lake level fluctuations as a result of reservoir drawdown (exposure of fish spawn and elimination of spawning habitat) and possible entrainment and impingement problems (fish eggs, larvae, and food organisms) associated with diversion of lakewater through the turbines. Potential aquatic ecological impacts to the lake inlet streams may result from decreased lake access due to reservoir drawdown at certain periods of the year.

The primary inlet to the lake, the Chilligan River, serves as a spawning area for red (sockeye) salmon. Known spawning areas for Chinook (King) and pink (humpy) salmon exist in the lower tributaries of the Chakachatna and McArthur Rivers. The McArthur River will receive the tailrace flows from the project. The annual adult escapement for these species is unknown, as is their contribution to the Cook Inlet runs. Lake trout are resident within Lake Chakachama; Dolly Varden (Arctic char), whitefish, and rainbow trout are present in the lower tributaries of the Chakachatna and McArthur Rivers. Information on anadromous species, including estimates of annual escapement, are not available for these drainage areas. Non-salmonid fish species that probably occur within project area waters include sculpins, blackfish, and northern pike. It is highly likely that all of the above species will be disturbed.

Aquatic impacts on the Chakachatna and McArthur Rivers will be the most severe due to potential changes in existing flow regimes. For example, the design will essentially dewater the upper Chakachatna River and divert the lake outflow via a tunnel to the McArthur River. This operating scenario would most likely eliminate anadromous fish access to the upper Chakachatna River and Chakachamna Lake and will alter the existing flow regimes and chemical makeup of the McArthur River, thus potentially altering fish production in that river as well.

It is possible that sockeye salmon runs blocked from entering Lake Chakachamna via the Chakachatna River would enter the McArthur River, homing to Chakachamna Lake water discharged at the powerhouse.

A thorough study of the numbers and species of fish and their habitat requirements will be needed to assess potential mitigative measures for any losses due to project construction and operation. Depending on the results of this study, several types of mitigative measures could be used to offset any projected losses. These measures include: 1) maintenance of acceptable streamflows (e.g., in Chakachatna River) based on instream flow analyses; 2) trapping and transporting of both upstream and downstream migrants past project facilities; 3) screening of the intake; 4) fish passage facilities around dewatered areas; 5) spawning channels; 6) new hatcheries at a number of potential locations; and 7) indirect enhancement to commercial and recreational fisheries by enhancing resources in nearby rivers. Each alternative measure will have to be weighed against cost and effectiveness in determining the final one to be used.

5.2.4 Terrestrial Ecosystem Effects

The primary potential wildlife impacts of hydroelectric development in the project area will be from river level fluctuations and habitat loss. River level fluctuation may change the character of the riparian vegetation that is used by moose in the winter and marshes that are used by waterfowl during the spring, summer, and fall. Changes in the river level may also affect the fish populations utilized by brown and black bear and habitat used by beaver. Unexpected drawdown will expose beaver inhabiting lodges to predation.

In addition to these impacts, hydroelectric facilities and access roads will eliminate some wildlife habitat and open up the project area to increased hunting pressure. While increased hunting is detrimental to some populations, it is beneficial to others, and it provides additional hunting opportunity to Alaskans. Increased access and the associated use by people will also create more poaching and human/bear conflicts. Project design will impact wildlife in two river drainages. However, wildlife impacts resulting from alteration of Lake Chakachamna are expected to be small.

5.2.5 Socioeconomic Effects

The construction and operation of a large hydroelectric plant has a high potential to cause a boom/bust cycle, causing significant impact on community infrastructure. The site is located at or near communities with a population of less than 500. Peak construction crew requirements of approximately 1220 workers will be necessary for construction. In some of these remote communities, the population could more than quadruple. The installation of a construction camp would not mitigate the impacts on the social and economic structure of a community.

The expenditures that flow out of the region account for investment in equipment and supervisory personnel. For this large-scale project, a larger proportion of the expenditures can be attributed to the civil costs. Approximately 35 percent of an investment in the project will be made outside the Railbelt Region, while 65 percent will be made within the Railbelt. The breakdown of operating and maintenance expenditures for a hydroelectric project will be approximately 11 percent spent outside the Railbelt and 89 percent spent within the region.

6.0 INSTITUTIONAL CONSIDERATIONS

This section presents an inventory of major federal, state of Alaska, and local environmental regulatory requirements that would be associated with the development of a 480-MW hydroelectric power plant at Chakachamna Lake. The inventory is divided into three subsections, setting forth federal, state, and local environmental requirements.

6.1 FEDERAL REQUIREMENTS

The Chakachamna hydro project may be exempt from the National Pollutant Discharge Elimination System (NPDES) permitting program that is operated for Alaska by the EPA pursuant to Section 402 of the Clean Water Act. The NPDES permit is required for discharges from a "point source." As this term is defined (40 CFR 122.3) it is unclear whether this project would include a point source discharge into navigable waters, as EPA generally does not issue NPDES permits to hydroelectric projects if water merely passes through a turbine from the reservoir to the receiving waters. However, an NPDES permit will likely be required if during construction of a dam, water is discharged from settling basins, or if floor drains, sanitary systems, etc. are discharged during operation. This issue can only be resolved with the development of additional information regarding project design.

The most important permit applicable to a hydroelectric project that could have a substantial impact upon the licensing schedule is the license that must be obtained for construction of a water power project of more than 2000 horsepower installed-capacity. These licenses are issued by the Federal Energy Regulatory Commission (FERC) as required by the Federal Power Act (16 USC 792-828c). FERC issues these licenses according to the regulations in 18 CFR 4.

An application for a FERC license for a new project is quite complicated, requiring the preparation of seven exhibits (18 CFR 4.41). (These regulations are presently under review. The format may be changed significantly.) Among these is a requirement that the applicant show evidence of compliance with requirements of state laws with respect to water appropriation and use of water for power production (18 CFR 4.41 Exhibit D). This is accomplished by showing that state permits have been obtained, and that the state has certified that water quality will be maintained as is required by section 301 of the Clean Water Act. As a result, submission of a complete FERC permit cannot occur prior to receipt of the prerequisite permits and certifications. Furthermore, the FERC review process for application approval is lengthy even after a prospective permittee has exerted considerable time and energy in submitting all requisite documentation.

Licensing of a hydroelectric project in Alaska could be completed, barring any major difficulties in obtaining a FERC permit, in 42 months. The critical element in the schedule will be the FERC permit, which FERC cannot approve before the applicant has submitted its environmental report (18 CFR 4.41 Exhibit) and state water use permits. This schedule assumes that all necessary environmental monitoring can be completed in 12 months. As climatic conditions in Alaska could impede the collection of necessary field data, the licensing schedule could be delayed. Note also that NEPA compliance, including EIS preparation, for a hydroelectric project is generally the responsibility of FERC. In the scoping sessions between federal agencies and the applicant, FERC is generally selected as the lead agency for a hydro power project. These and other federal requirements are summarized in Table 6.1.

6.2 STATE REQUIREMENTS

In addition to the FERC permit, a hydroelectric project will be subject to some specialized permits required in Alaska, such as the dam permit and water use permit issued by the Alaska Department of Natural Resources and the permit to interfere with salmon spawning streams and waters issued by the Alaska Department of Environmental Conservation. The state of Alaska also imposes special requirements upon some projects if the project site is located on lands that have been reserved by the state requirements restricting use of land (due to preservation of the land by state government or native Alaskans) under one of several special programs. The state requirements are summarized in Table 6.2.

TABLE 6.1. Federal Regulatory Requirements

Agency	Requirement	Scope	Statute or Authority
Environmental Protection Agency	National Pollutant Discharge Elimination System	Discharges to Water	38 USC 1251 et seq.; section 1342
U S Army Corps of Engineers	Construction Activity in Navigable Water	Construction in Water	33 USC 401 et seq.; section 403
	Discharge of Dredged or Fill Material	Discharges to Water	33 USC 1251 et seq.; section 1342
Federal Energy Regulatory Commission	Environmental Impact Statement	All Impacts	42 USC 4332 section 102
	License for Major New Hydropower Project	Construction of Hydropower Project	16 USC 792 et seq.
National Marine Fisheries Service/ Fish and Wildlife Service	Threatened or Endangered Species Review	Air, Water, Land	16 USC 1531 et seq.
Advisory Council on Historic Preservation	Determination that Site is not Archeologically Significant	Land Use	16 USC 402 aa et seq.
	Determination that Site Does Not Infringe on Federal Landmarks	Land Use	16 USC 416 et seq.
All Federal Agencies	Executive Order No. 11990	Development in Wetlands	
	Executive Order No. 11988	Development in Floodplains	

TABLE 6.2. State Regulatory Requirements

Agency	Requirement	Scope	Statute or Authority
Alaska Department of Environmental Conservation	State Certificate that Discharges Comply with CWA and State Water Quality Requirements	Discharges to Water	33 USC 1257 et seq.; section 1341
	Solid Waste Disposal Permit	Solid Waste	Alaska Statute 46.03.100
	Permit to Interfere With Salmon Spawning Streams and Waters	Construction in Water	Alaska Statute
Alaska Department of Natural Resources	Water Use Permit	Appropriation of Water	Alaska Statute 46.15.030-185
	Rights-of-Way Easement	Right of Way on State Lands	11 Alaska Administrative Code 58.200
	Dam Permit	Construction of Dam 10 Feet High or More	Alaska Statute
Alaska Office of the Governor	Coastal Use Permit	Land Use	Alaska Statute 46.40
Alaska Department of Fish and Game	Anadromous Fish Protection Permit	Fish Protection	Alaska Statute 16.05.870
	Critical Habitat Permit	Fish and Game Protection	Alaska Statute 16.20.220 and .260
	Fishways for Obstruction to Fish Passage	Fish Protection	Alaska Statute

6.3 LOCAL REQUIREMENTS

The Chakachamna hydroelectric project will be located in the Kenai Peninsula Borough on Cook Inlet, and will be subject to the permitting and zoning restrictions imposed by the borough. In addition, the Kenai Peninsula Borough has a solid waste disposal program to which the project may be subject. Borough regulations require that the plans for any construction in the borough must be approved by borough authorities before construction can begin.

7.0 ONGOING PROJECT STUDIES

Bechtel Civil and Minerals, Inc. is currently performing under contract to the Alaska Power Authority a detailed feasibility analysis of the Chakachamna hydroelectric project (Bechtel 1981). This work commenced in the fall of 1981 and is scheduled for completion late in 1982. Bechtel submitted a letter report to the Power Authority dated November 23, 1981, which described studies of alternative development schemes for the project.

Four alternative project layouts were identified in Bechtel's report, with estimates of power output and construction costs provided for each. Two alternatives, identified as Alternatives A and B, involve diverting the basin flow from Lake Chakachamna via a pressure tunnel to a powerhouse on the McArthur River. Alternative A would divert all of the inflow to the powerhouse, while Alternative B would provide a downstream fish release to the Chakachatna River, thus reducing the amount of flow available to the power plant. Alternatives C and D involve developing the head along the Chakachatna River itself, by means of a pressure tunnel and powerhouse. Alternative C would provide a nominal downstream fish release, while Alternative D would provide no fish release. None of the four alternatives include a dam in the proposed layout and all would utilize a lake tap-type intake structure. A tabulation of the cost estimate and power output potential from each alternative as presented in Bechtel's report is shown in Table 7.1.

Subsequent to receipt of Bechtel's report, Ebasco was verbally advised by Bechtel that as a result of discussions with the Power Authority, a decision was made to adopt Alternative B for further study. Ebasco was also advised that the cost estimate presented in the report had been revised to reflect an allowance of $50 million for fish passage facilities. The total project cost has been revised to $1.45 billion, with the total cost of energy estimated to be 43.6 mills/kWh.

Of the four alternatives identified in Bechtel's report, Alternative A most closely resembles the scheme shown by Ebasco in this report. Both schemes involve diversion of all Chakachamna Lake inflow to the McArthur River, with

TABLE 7.1. Project Development Alternatives Identified by Bechtel[a]

Item	Development Alternative/Powerhouse Location			
	A McArthur River	B McArthur River	C Chakachatna River	D Chakachatna River
Installed Capacity (MW)	400	330	300	300
Firm Annual Generation (GWh)	1665.5	1374.1	1249.2	1249.2
Capital Costs ($ billions)[b]	1.5	1.4	1.6	1.6
Annual Costs ($ millions)[c]	59.9	55.9	63.9	63.9
Net Cost of Energy (mills/kWh)	35.9	40.7	51.1	51.1
Allowance for O and M (mills/kWh)	1.5	1.5	1.5	1.5
Total Cost of Energy (mills/kWh)	37.4	42.2	52.6	52.6

(a) From letter report on Chakachamna Hydroelectric Project Development Studies by Bechtel Civil and Minerals, Inc., November 23, 1981, Alaska Power Authority.
(b) January 1982 price level, includes interest during construction at 3 percent per annum.
(c) Equal to 3.99 percent of capital cost, includes interest, amortization and insurance for 50 year project life.

no fish release allowance. While a detailed comparison of the project layouts, cost estimates and power output prepared by Bechtel and Ebasco is beyond the scope and purpose of this report, certain general observations are discussed below.

The two project layouts are generally similar. Both include a lake tap, gate shaft, pressure tunnel, surge tank, penstock, a four-unit powerhouse, a switchyard, access roads, and a transmission line. The only significant differences between the two schemes are: a) Bechtel's Alternative A proposes an underground powerhouse with a tailrace surge chamber and tailrace tunnel, while Ebasco layout includes a surface-type powerhouse with a tailrace channel, and

b) Ebasco's layout includes a spillway tunnel at the lake outlet, while Bechtel's layout does not. Our assumption of a surface-type powerhouse is based on available mapping and a brief site visit to the general vicinity of the powerhouse. With this information, we see no apparent reason that a surface powerhouse could not be constructed, and we have included this type of powerhouse in our conceptual layout because it is generally more economical than construction of an underground powerhouse, as the Bechtel report also acknowledges. Inclusion of a spillway tunnel at the lake outlet was considered prudent in view of the uncertainty of the action of Barrier Glacier during the life of the project and the influence of the glacier on passage of flood flows through the natural outlet of the lake.

Certain differences are also present between Bechtel's Alternative A and the Ebasco layout in the estimates of installed capacity, power output, and operational characteristics. Bechtel's scheme indicates an installed capacity of 400 MW and an estimated annual firm energy production of 1753 GWh (before transmission and station service losses). Ebasco has selected an installed capacity of 480 MW (the same as that shown in the Acres American, Inc. (1981) Development Selection Report) and has estimated the average annual energy to be 1982 GWh (before transmission and station service losses). While a detailed investigation of the reasons for these differences was not undertaken, certain reasons can be readily identified.

The reservoir inflows utilized in Bechtel's power studies have been developed by adjusting the recorded discharges at the outlet of the lake to reflect the effect of the storage in the lake. The scope of the Ebasco study being much more limited, such extensive in-house data adjustment has not been included and the lake outflows readily available as gaging station records have been taken to also directly represent the basin inflows. This less sophisticated approach will have the effect of slightly overstating the actual available inflow during dry years and understating the inflow during wet years. The long-term average available inflow should, however, be essentially the same for the two methods. The average annual inflow for the period of record used by Bechtel (calendar year 1960 through 1970) was 3,547 cfs, while the average inflow used by Ebasco was 3,651 cfs for the hydrological period of water year 1961 through 1972. The average discharge for the entire period for the USGS gage at the lake outlet was 3,646 cfs.

The active storage utilized in Bechtel's proposed scheme lies between elevations 1128 and 1028, which corresponds to 1,526,000 acre-feet. The active storage used in the operation proposed by Ebasco is 2,080,000 acre-feet, between elevations 1127 and 968. The greater amount of active storage should make little difference in the estimates of average annual energy, but it will have the benefit of providing a larger proportion of firm energy, everything else being equal.

Minor differences also exist between the two schemes in tunnel diameter and assumed tailwater elevation. Considering the scope of this study and the early stage of Bechtel's study as represented in their letter report of November 23, 1981, the differences between the layouts and power output estimates of the two schemes are not substantial.

8.0 REFERENCES

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