ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA
CHAKACHAMNA HYDROELECTRIC PROJECT

INTERIM REPORT

NOVEMBER 30, 1981

Bechtel Civil & Minerals, Inc. - San Francisco   Job 14879

ALASKA POWER AUTHORITY

ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

INTERIM REPORT

NOVEMBER 30, 1981

Bechtel Civil & Minerals, Inc. - San Francisco   Job 14879

ALASKA POWER AUTHORITY

ANCHORAGE ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

INTERIM REPORT NOVEMBER 30, 1981

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1-1
2.0	SUMMARY	2-1
	2.1 Project Layout Studies	2-1
	2.2 Geological Studies	2-3
	2.3 Environmental Studies	2-4
	2.4 Economic Evaluation	2-9
	2.5 Technical Evaluation and Discussion	2-9
3.0	PROJECT DEVELOPMENT STUDIES	3-1
	3.1 Regulatory Storage	3-1
	3.2 Chakachatna Dam	3-2
	3.3 McArthur Tunnel Development	3-5
	3.3.1 Alternative A	3-5
	3.3.2 Alternative B	3-8
	3.4 Chakachatna Tunnel Development	3-9
	3.4.1 Alternative C	3-9
	3.4.2 Alternative D	3-11
	3.5 Transmission Line and Submarine Cable	3-12
	3.6 References	3-13
4.0	HYDROLOGICAL AND POWER STUDIES	4-1
	4.1 Introduction	4-1
	4.2 Historical Data	4-2
	4.3 Derived Lake Inflows	4-3
	4.4 Power Studies	4-4
	4.5 Results	4-10
	4.6 Variations in Lake Water Level	4-11

				Page
5.0	GEOLOGIC INVESTIGATIONS			
	5.1	Scope of Geologic Investigations		5-1
		5.1.1	Technical Tasks	5-1
		5.1.2	Schedule	5-7
	5.2	Quaternary Geology		5-9
		5.2.1	Glaciers and Glacial Geology	5-10
		5.2.2	Mt. Spurr Volcano	5-34
		5.2.3	Slope Conditions	5-45
	5.3	Seismic Geology		5-50
		5.3.1	Tectonic Setting	5-50
		5.3.2	Historic Seismicity	5-52
		5.3.3	Fault Investigations	5-57
	5.4	References		5-75
6.0	ENVIRONMENTAL STUDIES			6-1
	6.1	Study Area		6-2
	6.2	Environmental Hydrology		6-4
		6.2.1	Background	6-4
		6.2.2	Study Objectives and Methodology	6-6
		6.2.3	Results and Discussion	6-16
		6.2.4	Conclusions	6-27
	6.3	Aquatic Biology		6-31
		6.3.1	Background	6-31
		6.3.2	Study Objectives and Methodology	6-32
		6.3.3	Results and Discussion	6-43
		6.3.4	Summary and Conclusions of 1981 Studies	6-67
	6.4	Terrestrial Vegetation and Wildlife		6-68
		6.4.1	Background	6-68
		6.4.2	Study Objectives and Methodology	6-69
		6.4.3	Results and Discussion	6-71
		6.4.4	Conclusions	6-84

			Page
	6.5	Human Resources	6-85
		6.5.1 Background	6-85
		6.5.2 Archaeological and Historic Resources	6-87
		6.5.3 Land Ownership and Use	6-95
		6.5.4 Recreation	6-122
		6.5.5 Socioeconomics	6-125
		6.5.6 Community Infrastructure	6-137
		6.5.7 Transportation	6-141
		6.5.8 Visual Resources	6-147
	6.6	References	6-150
7.0		EVALUATION OF ALTERNATIVES	7-1
	7.1	Engineering Evaluation	7-1
		7.1.1 General	7-1
		7.1.2 Chakachatna Dam	7-2
		7.1.3 Alternative A	7-2
		7.1.4 Alternative B	7-3
		7.1.5 Alternatives C and D	7-4
	7.2	Geological Evaluation	7-7
		7.2.1 Chakachatna Dam	7-7
		7.2.2 Alternative A	7-8
		7.2.3 Alternative B	7-9
		7.2.4 Alternatives C and D	7-10
	7.3	Environmental Evaluation	7-11
		7.3.1 Chakachatna Dam	7-11
		7.3.2 McArthur Tunnel Alternatives A and B	7-12
		7.3.3 Chakachatna Tunnel Alternatives C and D	7-16
8.0		CONSTRUCTION COSTS AND SCHEDULES	8-1
	8.1	Estimates of Cost	8-1
		8.1.1 Power Tunnel	8-3
		8.1.2 Underground Powerhouse and Associated Structures	8-5
		8.1.3 Tailrace Channel	8-6
		8.1.4 Switchyard	8-7

		Page
8.0	CONSTRUCTION COSTS AND SCHEDULES (Cont'd.)	
8.1.5	Transmission Line and Cable Crossing	8-7
8.1.6	Site Access and Development	8-7
8.2	Exclusions from Estimates	8-9
8.3	Construction Schedules	8-10
9.0	ECONOMIC EVALUATION	9-1
9.1	General	9-1
9.2	Parameters for Economic Evaluation	9-1
9.3	Cost of Power from Alternative Sources	9-2
9.3.1	General	9-2
9.3.2	Construction Cost	9-3
9.3.3	Operation and Maintenance Cost	9-4
9.3.4	Fuel Cost	9-4
9.4	Value of Hydro Generation	9-6
9.5	Economic Tunnel Sizing	9-11
9.6	Economic Tunnel Length	9-13
10.0	1982 STUDY PROGRAM	10-1
10.1	Engineering Studies	10-1
10.1.1	Hydrological Studies	10-1
10.1.2	Chakachatna Dam	10-1
10.1.3	Reservoir and Fish Passage Facilities	10-2
10.1.4	Power Intake and Tunnel	10-2
10.1.5	Underground Powerhouse Complex	10-3
10.1.6	Transmission Line and Submarine Cable Crossing	10-3
10.1.7	Access Roads and Construction Facilities	10-4
10.1.8	Cost Estimate and Construction Schedule	10-4
10.1.9	Feasibility Report and License Application	10-4
10.2	Geologic Studies	10-5
10.3	Environmental Studies	10-6
10.3.1	Environmental Hydrology	10-7
10.3.2	Aquatic Biology	10-9
10.3.3	Wildlife Biology	10-12
10.3.4	Human Resources	10-14

ALASKA POWER AUTHORITY
ANCHORAGE ALASKA
CHAKACHAMNA HYDROELECTRIC PROJECT
INTERIM REPORT NOVEMBER 30, 1981

1.0 INTRODUCTION

This report has been prepared in accordance with the terms of the August 1981 contract between Alaska Power Authority and Bechtel Civil & Minerals, Inc. in connection with services for performing a feasibility study and for preparing an application for an FERC license to construct the Chakachamna Hydroelectric Project. As its title indicates, the report is of an interim nature. It is based upon previously published information regarding the project, and on data acquired and derived during a brief study period in the fall of 1981. Its objectives are to summarize the information derived from the studies, to provide a preliminary evaluation of alternative ways of developing the power potential of the project, to define that power potential and to report on the estimated cost of construction.

Although the data collected and study period are limited by the short time base, some rather clear indications have emerged as to the manner in which it is considered that development of the project should proceed. Even though some of the present data may be subject to modification as the data base and depth of study are expanded next year, the data presented in this report are considered adequate to give realistic evaluations of the power potential of the project and its cost of construction.

For the assessment of environmental factors and geological conditions in the project area, Bechtel retained the services of Woodward-Clyde Consultants.

As may be seen by reference to Figure 1-1, Chakachamna Lake lies in the southern part of the Alaska Range of mountains about 85 miles due west of Anchorage. Its water surface lies at about elevation 1140 feet above mean sea level.

The project has been studied and reported upon several times in the past. The power potential had been estimated variously from about 100,000 kw to 200,000 kw firm capacity, depending on the degree of regulation of the outflow from Chakachamna Lake and the hydraulic head that could be developed.

Two basic alternatives can be readily identified to harness the hydraulic head for the generation of electrical energy. One is via the valley of the Chakachatna River. This river runs out of the easterly end of the lake and descends to about elevation 400 feet above sea level where the river leaves the confines of the valley and spills out onto a broad alluvial flood plain. A maximum hydrostatic head of about 740 feet could be developed via this alternative.

The other alternative is for development by diversion of the lake outflow to the valley of the McArthur River which lies to the southeast of the lake outlet. A maximum hydrostatic head of about 960 feet could be harnessed by this diversion. Various means of development by these two basic alternatives are discussed in the report on the basis of the present knowledge of the site conditions.

SUMMARY

2.0 SUMMARY

2.1 Project Layout Studies

The studies evaluated the merits of developing the power potential of the project by diversion of water southeasterly to the McArthur River via a tunnel about 10-miles long, or easterly down the Chakachatna valley either by a tunnel about 12-miles long or by a dam and tunnel development. In the Chakachatna valley, few sites, adverse foundation conditions, the need for a large capacity spillway and the nearby presence of an active volcano made it rapidly evident that the feasibility of constructing a dam there would be questionable. The main thrust of the initial studies was therefore directed toward the tunnel alternatives, with possibilities for a dam set aside until 1982.

Two alignments were studied for the McArthur tunnel. The first considered the shortest distance that gave no opportunity for an additional point of access during construction via an intermediate adit. The second alignment was about a mile longer, but gave an additional point of access, thus reducing the lengths of headings and also the time required for construction of the tunnel. Cost comparisons and economic evaluation nevertheless favored the shorter 10-mile 25-foot diameter tunnel.

The second alignment running more or less parallel to the Chakachatna River in the right (southerly) wall of the valley afforded two opportunities for intermediate access adits. These, plus the upstream and downstream portals would allow construction to proceed simultaneously in 6 headings and reduce the construction time by 18 months less than that required for the McArthur tunnel. Economic evaluation again favored a 25-foot diameter tunnel running all the way from the lake to the downstream end of the Chakachatna Valley.

If all the controlled water were used for power generation, the McArthur powerhouse could support 400 MW installed capacity, and produce average annual firm energy of 1753 GWh. The effects of making a provisional reservation of approximately 19% of the average annual inflow to the lake for instream flow requirements in the Chakachatna River were found to reduce the economic tunnel diameter to 23 feet. The installed capacity in the powerhouse would then be reduced to 330 MW and the average annual firm energy to 1446 MW.

For the Chakachatna powerhouse, diversion of all the controlled water for power generation would support an installed capacity of 300 MW with an average annual firm energy generation of 1314 GWh. Provisional reservation of approximately 0.8% of the average annual inflow to the lake for instream flow requirements in the Chakachatna River was regarded as having negligible effect on the installed capacity and average annual firm energy because that reduction is within the accuracy of the present study.

The reasoning for the smaller instream flow releases considered in this alternative is discussed in Section 2.5

2.2 Geological Studies

At the present level of study, the Quarternary Geology in the Chakachatna and McArthur Valleys has been evaluated and the seismic geology of the general area has been examined though additional work remains to be done next year. General observations as they may affect the project are as follows:

The move of ice of the Barrier Glacier toward the river may be gradually slowing. However, no material change in the effect of the glacier on the control of the Chakachamna Lake outlet is anticipated.

The condition of the Blockade Glacier facing the mouth of the McArthur Canyon also appears to be much the same as reported in the previous USGS studies.

There does not appear to be any reason to expect a dramatic change in the state of growth or recession of either of the above two glaciers in the foreseeable future.

Surface exposures on the left (northerly) side of the Chakachatna Valley consist of a heterogeneous mix of volcanic ejecta and glacial and fluvial sediments which raise serious doubts as to the feasibility of damming the Chakachatna River at this location.

The rock in the right wall of the Chakachatna Valley is granitic, and surface exposures appear to indicate that it would be suitable for tunnel construction if that form of development of the project were found to be desirable.

No rock conditions have yet been observed that would appear to rule out the feasibility of constructing a tunnel between the proposed locations of an intake structure near the outlet of Chakachamna Lake and a powerhouse site in the McArthur Valley. It must be noted, however, that in the vicinity of the proposed powerhouse location in the McArthur Canyon, the surface exposures indicate that rock quality appears to improve significantly with distance upstream from the mouth of the canyon.

The Castle Mountain fault, which is a major fault structure, falls just outside the mouth of the McArthur Canyon and must be taken into account in the seismic design criteria of any development of the project whether it be via the McArthur or Chakachatna Canyons. Other significant seismic sources are the Megathrust section of the subduction zone and the Benioff zone.

2.3 Environmental Studies

2.3.1 Hydrology

Field reconnaissances were conducted in Chakachamna Lake, several of its tributary streams, the Chakachatna and Mc Arthur Rivers. Data collected and developed are typical of glacial rivers with low flow in late winter and large glacier melt flows in July and August.

The water level in Chakachamna Lake when measured was elevation 1142 and is typical of the September lake stage records in the 12 years preceding the major flood of August 1971. A lake bottom profile was surveyed on the deltas at the mouth of the Chilligan River and near the Shamrock Glacier Rapids.

Reaches of the McArthur and Chakachatna Rivers vary from mountainous through braided and meandering streams. All except the most infrequent large floods are mostly contained within the unvegetated flood plain. Sedimentation characteristics appear to be typically those of glacial systems with very fine suspended sediments and substantial bed load transport.

2.3.2 Aquatic Biology

Field observations identified the following species in the waters of the project area:

Resident:	Rainbow trout	Arctic grayling
	Lake trout	Slimy sculpin
	Dolly Varden	Ninespine stickleback
	Round Whitefish	Threespine sticleback
	Pygmy Whitefish	
Anadromous:	Chinook salmon	Pink salmon
	Chum salmon	Sockeye salmon
	Coho salmon	Dolly Varden

Some of the streams flowing into Chakachamna Lake contain large areas used by spawning sockeye salmon and substantual numbers of these fish were counted in the Igitna and Chilligan Rivers. Evidence of potential sockeye spawning was noted in Chakachamna Lake. Juvenile sockeye salmon use Chakachamna and Kenibuna Lakes as nursery habitat. Lake trout, Dolly Varden, round whitefish and slimy sculpin were also found in these locations.

Side channels and tributaries of the Chakachatna and McArthur Rivers contain salmonid spawning sites and numerous fish were observed using them. These habitats are also used as juvenile rearing areas. The Noaukta Slough, a meandering reach of the Chakachatna River is used extensively as a nursery area by juvenile fishes, particularly coho and sockeye salmon. Juvenile pygmy whitefish and Dolly Varden are also abundant in the slough. The intertidal ranges of both river systems do not contain suitable habitat for salmonid spawning or juvenile rearing.

2.3.3 Terrestrial Biology

On the basis of their structural and species compositions, eight types of vegetation habitats were delineated. These range from dense alder thickets in the canyons to vast areas of coastal marsh. The riparian communities are the most prevalent varying from rivers with emergent vegetation to those with broad flood plains scattered with lichen, willow and alder.

Evaluation of wildlife communities in the project area identified seventeen species of mammals. Moose, coyote, grizzly bear and black bear ranges occur throughout the area.

Birds also are abundant, fifty-six species having been identified with the coastal marshes along Trading Bay containing the largest diversity.

None of the species of plants, mammals and birds that were found are listed as threatened or endangered although in May 1981 it was proposed that the tule white-fronted goose, which feeds and nests in the area, be considered for threatened or endangered status.

2.3.4 Human Resources

These studies were organized into the following six elements:

- Archaeological and historical resources
- Land ownership and use
- Recreational resources
- Socioeconomic characteristics
- Transportation
- Visual resources

Many contacts were made with both state and federal agencies and Native organizations, as well as a limited reconnaissance of the project area.

No known cultural sites have been identified and the field reconnaissance indicates that the proposed sites for the power intake and powerhouses have a low potential for cultural sites.

Land owners in the area comprise federal, state, and borough agencies, Native corporations and private parties. Land use is related to resource extraction (timber, oil and gas), subsistence and the rural residential Village of Tyonek.

Recreational activity takes place, but with the exception of Trading Bay State Game Refuge, little data is available as to the extent or frequency with which the area is used.

Regional data on population, employment and income characteristics are relatively good. Employment level and occupational skill data are limited and need to be developed together with information on local employment preferences.

Transportation facilities in the area are few and small in size. There is an airstrip on the shoreline at Trading Bay and a woodchip loading pier near Tyonek. Several miles of logging roads exist between Tyonek and the mouth of the Chakachatna Valley. The Chakachatna River is bridged near its confluence with Straight Creek. here is no permanent road between the project area and any part of the Alaska road system.

The project area's scenic characteristics and proximity with BLM lands, Lake Clark National Park and the Trading Bay State Game Refuge make visual resource management a significant concern.

2.4 Economic Evaluation

The studies demonstrate that the project offers an economically viable source of energy in comparison with the 55.6 mills/KWh which is the estimated cost of equivalent energy from a coal fired plant, apparently the most competitive alternative source. Taking that figure as the value of energy, the Chakachamna Hydroelectric Project could begin producing 400 MW at 50% load factor (1752 GWh) in 1990 at 37.5 mills/KWh if all stored water is used for power generation. If approximately 19 percent of the water is reserved for instream flow release to the Chakachatna River, the powerplant could still produce 330 MW (1446 GWh) at 43.5 mills/KWh, which is still significantly more economical than the coal fired alternative. In both cases above, the powerhouse would be located on the McArthur River. A powerhouse on the Chakachatna River as described in the report is barely competitive with the alternative coal fired source of energy.

2.5 Technical Evaluation and Discussion

At this stage of the feasibility study several alternative methods of developing the project have been identified and reviewed. Based on the analyses performed, the more viable alternatives have been identified for further study in 1982.

2.5.1 Chakachatna Dam Alternative

The construction of a dam in the Chakachatna River canyon approximately 6 miles downstream from the lake outlet, does not appear to be a reasonable alternative. While the site is topographically suitable, the foundation conditions in the river valley and left abutment are poor as mentioned earlier in Section 2.2. Furthermore, its environmental impact specifically on the fisheries resource will be significant although provision of fish passage facilities could mitigate this impact to a certain extent.

2.5.2 McArthur Tunnel Alternatives A and B

Diversion of flow from Chakachamna Lake to the McArthur valley to develop a head of approximately 900 feet has been identified as the most advantageous as far as energy production at reasonable cost is concerned.

The geologic conditions for the various project facilities including intake, power tunnel, and powerhouse appear to be favorable based on the limited 1981 field reconnaissances. No insurmountable engineering problems appear to exist in development of the project.

Alternative A, in which essentially all stored water would be diverted from Chakachamna Lake for power production purposes could deliver 1664 GWh of firm energy per year to Anchorage and provide 400 MW of peaking capacity. Cost of energy is estimated to be 37.5 mills per kWh. However, since the flow of the Chakachatna River below the lake outlet would be adversely affected, the existing anadromous fishery resource which uses the river to gain entry to the lake and its tributaries for spawning, would be lost. In addition the fish which spawn in the lower Chakachatna River would also be impacted due to the much reduced river flow. For this reason Alternative B has been developed, with essentially the same project arrangement except that approximately 19 percent of the average annual flow into Chakachamna Lake would be released into the Chakachatna River below the lake outlet to maintain the fishery resource. Because of the smaller flow available for power production, the installed capacity of the project would be reduced to 330 MW and the firm energy delivered to Anchorage would be 1374 GWh per year. The estimated cost of energy is 43.5 mills per KWh. Obviously, the long term environmental impacts of the project in this Alternative B are significantly reduced in comparison to Alternative A, since the river flow is maintained, albeit at a reduced amount.

2.5.3 Chakachatna Tunnel Alternatives C and D

An alternative to the development of this hydroelectric resource by diversion of flows from Chakachamna Lake to the McArthur River is by constructing a tunnel through the right wall of the Chakachatna valley and locating the powerhouse near the downstream end of the valley. The general layout of the project would be similar to that of Alternatives A and B for a slightly longer power tunnel.

The geologic conditions for the various project features including intake, power tunnel, and powerhouse appear to be favorable and very similar to those of Alternatives A and B. Similarly no insurmountable engineering problems appear to exist in development of the project

Alternative C, in which essentially all stored water is diverted from Chakachamna Lake for power production, could deliver 1248 GWh of firm energy per year to Anchorage and provide 300 MW of peaking capability. Cost of energy is estimated to be 52.5 mills per KWh. While the riverflow in the Chakachatna River below the powerhouse at the end of the canyon will not be substantially affected, the fact that no releases are provided into the river at the lake outlet will cause a substantial impact on the anadromous fish which normally enter the lake and pass through it to the upstream tributaries. Alternative D was therefore proposed in which a release of 30 cfs is maintained at the lake outlet to facilitate fish passage through the canyon section into the lake. In either of Alternatives C or D the environmental impact would be limited to the Chakachatna River as opposed to Alternatives A and B in which both the Chakachatna and McArthur Rivers would be affected. Since the instream flow release for Alternative D is less than 1% of the total available flow, the power production of Alternative D can be regarded as being the same as those of Alternative C at this level of study (300 MW peaking capability, 1248 GWh of firm energy delivered to Anchorage). Cost of power from Alternative D is 54.5 mills per KWh.

The cost of energy from Alternative D is 25% greater than that for Alternative B and is close to the cost of alternative coal-fired resources. Therefore, it is planned that studies of the project to be performed in 1982 will concentrate on the McArthur River alternatives.

PROJECT DEVELOPMENT STUDIES

3.0 PROJECT DEVELOPMENT STUDIES

3.1 Regulatory Storage

The existing stream flow records show a wide seasonal variation in discharge from Chakachamna Lake with 91 percent occurring from May 1 through October 31 and 9 percent from November 1 through April 30 when peak electrical demands occur. The storage volume required to regulate the flow has been reported to be in the order of 1.6 million acre-feet (USBR, 1962). The elevation of the river bed at the lake outlet has been reported as 1127-1128 feet (Giles, 1967). This elevation is thought to have varied according to the amounts and sizes of solid materials deposited in the river bed each year by the melting toe of the glacier, and the magnitude of the annual peak outflow from the lake that is available to erode the solid materials away and restore the river channel.

The above-mentioned volume of regulatory storage can be developed by drawing down the lake by 113 feet to elevation 1014. It could also be obtained by raising the lake 83 feet to a normal maximum operating water surface of elevation 1210 and this would have the advantage of increasing the hydraulic head available for development. Previous studies of the project have discredited the possibility of locating a control structure at the lake outlet because its left abutment would have lain on the toe of the Barrier Glacier. This is equally true today, and it is concurred that there is no case for a control structure at the lake outlet. According to USGS measurements taken between 1961 and 1966, the glacier advanced several feet per year at measuring stations located about 100-150 feet from the river bank near the lake outlet. Although no new measurements have been taken in the present studies, the ice obviously undergoes considerable movement as further discussed in Section 5.2 of this report.

Furthermore, the Barrier Glacier ice thickness was measured in 1981 by the USGS using radar techniques. The data has not yet been published but verbal communication with the USGS staff has indicated that the ice depth is probably 500-600 feet in the lower moraine covered part of the glacier near the lake outlet. Thus it would appear that the outlet channel from the lake may be a small gravel and boulder lined notch in a deep bed of moving ice that does not provide a suitable foundation for a permanent structure.

3.2 Chakachatna Dam

The possibility of gaining both storage and head by means of a dam on the Chakachatna River was first posed in 1950 by Arthur Johnson (Johnson, 1950) who identified, though was unable to inspect, a potential dam site about 6 miles downstream from the lake outlet. Three years later, during the 1953 eruption of Mount Spurr, a mud flow descended the volcano slopes and temporarily blocked the river at this location, backing it up for about 4-miles until it overtopped the debris dam. At this location, the river today is still backed up almost 2 miles despite the occurrence of the August 1971 lake breakout flood estimated to have peaked at about 470,000 cubic feet per second (Lamke, 1972). This flow is about twenty times larger than the maximum daily discharge that occurred during the 1959-1972 period of record.

Examination of aerial photographs taken after the 1953 eruption between 1954 and 1981 indicate that subsequent mud flows, though of smaller magnitude, may have occurred but probably did not reach the river. The source of this activity has been Crater Peak, an active volcanic crater on the southerly flank of Mount Spurr. It lies directly above and in close proximity to the postulated dam site and thus poses serious questions on the safety of this site for construction of any form of dam. At this location, generally from about 6-miles to 7-miles downstream from the lake outlet, the river is confined within a canyon. Both upstream and downstream, the valley substantially widens and does not appear to offer any topographically feasible sites for locating a dam.

Within the canyon section itself, conditions are rather unfavorable for siting a dam. Bedrock is exposed on the right abutment, making this the most likely site for a spillway, but the rock surface dips at about 40-degrees toward the river channel. At this location, the peak discharge of the probable maximum flood calculated according to conventional procedures would be in the order of 100,000 cubic feet per second. The flood of record however, is estimated to have peaked at about 470,000 cubic feet per second (Lamke, 1972). It was apparently caused by a sudden release of stored water from Chakachamna Lake when a part of the toe of the Barrier Glacier, that was constricting the outlet channel, was eroded away. Since the repetition of such an event would still be possible in the future, even if a dam were constructed so that its reservoir water level exceeded that of the present lake level, the discharge capacity of a spillway at this location would apparently have to be at least equal to the 470,000 cubic feet per second flood of record. The crest length of such a spillway would have to be several hundred feet and siting it on the steeply dipping right abutment rock surface would be difficult and very costly. It is clearly evident that the problems associated with designing a spillway of these proportions on such a steeply dipping rock surface are very serious indeed.

Surface examination of the left abutment conditions, as discussed in Section 5.2.3.2 of this report, indicates that they consist of deep unconsolidated volcanic materials. These would require a deep diaphragm wall or slurry trench cutoff to bedrock, or an extensive upstream foundation blanket to control seepage through the pervious materials lying on this abutment. Very high costs would also be attached to their construction.

The presence of the volcano and its potential for future eruptions accompanied by mud flows as well as pyroclastic ash flows is probably the overriding factor in discrediting the feasibility of constructing a dam in this canyon location. Consequently, pending further examination next year, this concept has been temporarily set aside from further consideration at the present stage of the studies, and the main thrust has been directed toward development by gaining regulatory storage by drawing down the lake water level and diverting water from a submerged intake in Chakachamna Lake through a tunnel to the McArthur River, or through a tunnel to the mouth of the Chakachatna Valley, as discussed in the next two sections of this report.

3.3 McArthur Tunnel Development

3.3.1 Alternative A

Initial studies have been directed toward development by means of a tunnel to the McArthur River that would maximize electrical generation without regard to release of water into the Chakachatna River for support of its fishery. Two arrangements have been studied, the first being a tunnel following an alignment about 12-miles long designated Alternative A-1 and shown in Figure 3-1. This alignment provides access for construction via an adit in the Chakachatna Valley about 3 miles downstream from the lake outlet. As discussed in Section 9.0 of this report, the tunnel would be 25-feet internal diameter and concrete lined throughout its full length.

The second tunnel studied is designated Alternative A-2 and follows a direct alignment to the McArthur Valley without an intermediate access adit as shown on Figure 3-2. As further discussed in Section 9.0 of this report, this tunnel would also be 25-feet diameter and concrete lined.

Although the tunnel for Alternative A-1 is about 1-mile longer than that for Alternative A-2, it would enable tunnel construction to proceed simultaneously in four headings thus reducing its time for construction below that required for the shorter tunnel in Alternative A-2. Nevertheless, the studies show that the economics favor the shorter tunnel and no other significant factors that would detract from it have been identified at this stage of the studies. Therefore the direct tunnel route was adopted and all further references in the report to Alternative A are for the project layout with the direct tunnel shown on Figure 3-2.

Typical sketches have been developed for the arrangement of structures at the power intake in Chakachamna Lake and these are shown on Figure 3-4 with typical sections and details on Figure 3-5. Similarly, layouts have been developed for structures located beyond the downstream end of the tunnel. These include a surge shaft, penstock, manifold, valve gallery, powerhouse, transformer gallery, access tunnel, tailrace tunnel and other associated structures as shown on Figure 3-6.

For Alternative A, the installed capacity of the powerhouse derived from the power studies discussed in Section 4.0 of this report is 400 MW. For purposes of estimating costs, the installation has been taken as four 100 MW capacity vertical shaft Francis turbine driven units.

It is to be noted that the layout sketches mentioned above and those prepared for other alternatives considered in this report must be regarded as strictly typical. They form the basis for the cost estimates discussed in Section 8.0 but will be subject to refinement and optimization as the studies proceed. For example, the lake tapping for the power intake is laid out on the basis of a single opening about 26-feet in diameter. This is a very large underwater penetration to be made under some 150-170 feet of submergence, and the combination of diameter and depth is believed to be unprecedented. In the final analysis, it may prove advisable to design for multiple smaller diameter openings. The information needed to evaluate this is not available at the present time.

In similar vein, the penstock is shown as a single inclined pressure shaft descending to a four-branched manifold at the powerhouse level with provisions for emergency closure at the upstream end. Again, this is a very large pressure shaft, but the combination of pressure and diameter is not unprecedented in sound rock. Other considerations, such as unfavorable hydraulic transients in the manifold, or operational flexibility, may support the desirability of constructing a bifurcation at the downstream end of the tunnel with two penstocks, each equipped with an upper level shutoff gate, provided to convey water to each pair of turbines in the four-unit powerhouse. Such an arrangement would cost more than the single penstock shaft.

Turbine shutoff valves are shown located in a valve chamber separated from the powerhouse itself. Optimization studies will be made during 1982 to evaluate whether these valves can be located inside the powerhouse at the turbine inlets, or whether a ring gate type installation inside the turbine spiral cases might be preferable.

The powerhouse is shown as an underground installation. This appears to be the most logical solution for development via the McArthur River because of the steep avalanche and rock slide-prone slopes of the canyon wall. For the same reason, the transformers are shown in a chamber adjacent to the powerhouse cavern. A surge chamber is shown near the upstream end of the tailrace tunnel. It may prove more advantageous for this relatively short tailrace tunnel to make it free-flowing in which case the surge chamber would not be required.

The object of the above comments is to point out some of the options that are available. The arrangement of structures shown provides for a workable installation. In the present short time frame since the study began, it is not to be regarded as the optimum or most economical. Optimization will be performed at a later date. The layout is a workable arrangement that gives a realistic basis on which to estimate the cost of constructing the project, and a separately identified contingency allowance is provided in the estimate to allow for costs higher than those foreseen at the present level of study.

3.3.2 Alternative B

This alternative considers what effect a tentative allocation of water to meet instream flow requirements in the Chakachatna River would have on the amount of energy that could be generated by Alternative A which would use all stored water for energy generation. The tentative instream flow schedule is discussed in Section **7.3.2** of this report. For diversion to the McArthur River, and reservation of water for instream flow releases, the tunnel diameter would be about 23 feet. Based on the power studies discussed in Section 4.0, the installed capacity of the powerhouse would be reduced to 330 MW. The tunnel alignment and basic layout of structures generally is the same as that shown for Alternative A in Figure 3-2. The diameters of hydraulic conduits and the dimensions of the 330 MW powerhouse would be smaller than for the 400 MW powerhouse in Alternative A and appropriate allowances for these are made in the cost estimates.

The actual manner in which water would be released to the Chakachatna River is not presently identified. In any plan of development that includes the provision of an adit 3 miles downstream from the lake outlet, as mentioned in Section 3.3.1 above, the adit would be a convenient point of release for the water. This, however, would not replenish any flow in the first 3 miles of the river, and nor would it keep the lake outlet open for either upstream or downstream passage of fish. In fact, keeping the lake outlet open bears every indication of being a very difficult problem to solve, and from a practical point of view may not be readily soluble unless the operating range of lake level is kept within narrow limits. That of course would adversely affect the amount of energy that could be generated by the project and possibly even destroy its viability. Due to the presence of the glacier at the lake outlet, it would appear that any fish passage facility would have to be constructed inside a tunnel in the right bank which is a massive rock mountainside. Since no plan for such a facility has been developed at this stage of the studies, a provisional allowance of $50 million is shown in the estimate for fish passage facilities.

3.4 Chakachatna Tunnel Development

3.4.1 Alternative C

The initial studies of this Alternative focused on development of the power potential by means of a tunnel roughly paralleling the Chakachatna River without release of water for instream flow requirements between the lake outlet and the powerhouse where the water diverted for power generation would be returned to the river. The tunnel alignment is shown on Figure 3-3.

This alignment offers two convenient locations for intermediate access adits during construction. The first is about 3 miles downstream from the lake outlet in the same location as discussed in Section 3.3.1 above for Alternative A. The second adit location is about 7 miles downstream from the lake outlet. The total tunnel length in this arrangement is about 12 miles and the adits would make it possible for construction of the tunnel to proceed simultaneously in six different headings.

The arrangement of the power intake is essentially the same and in the same location as for Alternative A as shown on Figures 3-4 and 3-5. The tunnel is also 25-feet internal diameter, concrete lined, and penetrates the mountains in the right wall of the Chakachatna Valley. The arrangement for the surge shaft, penstock, valve gallery, powerhouse and associated structures is similar to that for development via diversion to the McArthur River but is modified to fit the topography and lower head. The layout is shown on Figure 3-7. The head that can be developed in Alternative C is roughly 200 feet less than in Alternatives A and B and the installed capacity in the powerhouse is only 300 MW as determined from the power studies discussed in Section 4.0 of this report.

For purposes of estimating the present costs of construction, the powerhouse is taken as being located underground. If economy can be attained by locating it outside on the ground surface, this will be optimized in subsequent studies. Comments made in Section 3.3.1 regarding the layout sketches for the McArthur powerhouse in Alternative A apply equally to the powerhouse and associated structures for the Chakachatna powerhouse considered in Alternative C.

3.4.2 Alternative D

Studies of this Alternative take account of the effect on electrical generation of reserving water to meet instream flow requirements in the Chakachatna River. The tentative water release schedule is less than that considered for development by power diversions to the McArthur River as discussed in Section 7.1.5 of this report. The reason for this is that in the lower reaches of the river, downstream from the proposed powerhouse location, the river flow will include those waters that were diverted for electrical generation. These lower reaches of the river are probably more important to the fishery than the reach of the river between the lake outlet and the proposed powerhouse location. This probability is suggested, though not fully confirmed, by observations made of fish runs during the 1981 field studies. These have indicated that the Chakachatna River, between the lake outlet and the proposed location of the powerhouse, serves primarily as a travel corridor for fish passing through the lake to spawning areas further upstream. The river itself, in this reach does not appear to offer much in the way of suitable spawning and juvenile rearing habitat. On the other hand, significant numbers of fish and spawning areas were observed in the lower reaches of the river downstream from the proposed powerhouse location. Consequently, the tentative instream flow releases are small when compared with those considered for development via power diversions to the McArthur River, as discussed in Section 7.1.5 of this report. The tunnel diameter for development of the power potential via the Chakachatna tunnel with provision for instream flow releases, is 25-feet, the same as that mentioned in Section 3.3.1 above without such releases. The installed capacity in the powerhouse also remains the same at 300 MW. The layout sketches shown in Figures 3-3 and 3-7 for Alternative C are equally applicable to Alternative D as are the comments set forth in Section 3.3.0 regarding the layout sketches for development via the McArthur River.

3.5 Transmission Line and Submarine Cable

At the present stage of the project development studies, no specific evaluation has been made of transmission line routing. Whether development should proceed via the proposed McArthur or Chakachatna powerhouse locations, it is assumed for the purposes of the cost estimates that the transmission lines would run from a switchyard in the vicinity of either powerhouse site to a location in the vicinity of the existing Chugach Electric Association's Beluga powerplant. The general routing of the proposed lines is shown on Figure 3-8. At Beluga, an interconnection could be made through an appropriate switching facility with the existing Beluga transmission lines if a mutually acceptable arrangement could be negotiated with the owners of those lines. This would enhance reliability of the total system, but for purposes of this report no such interconnection has been assumed.

Beyond Beluga, it is assumed for purposes of the estimate, that the new transmission lines for the Chakachatna or McArthur powerhouses would parallel the existing transmission corridor to a terminal on the westerly side of Knik Arm and cross that waterway by submarine cables to a terminal on the Anchorage side. Beyond that point, no costs are included in the estimates for any further required power transmission installations.

In the four alternatives thus far considered, the cost estimates are based on power transmission via a pair of 230 KV single circuit lines with capacity matching the peaking capability of the respective power plants. Optimization studies to determine whether transmission should be effected in that manner or by a single line of double circuit towers are planned to be performed during 1982.

3.6 References

Giles, Gordon C., April 1967.
Barrier Glacier Investigations and Observations in Connection with Water Power Studies. USGS rough draft report.

Jackson, Bruce L., March 1961. Potential Water Power of Lake Chakachamna, Alaska. USGS open file report.

Johnson, Arthur, January 1950. Report on Reconnaissance of Lake Chakachamna, Alaska, USGS.

Lamke, Robert, March 1972, Floods of the Summer of 1971 in South-Central, Alaska. USGS open file report.

United States Bureau of Reclamation, 1952. Reconnaissance Report on the Potential Development of Water Resources in the Territory of Alaska.

United States Bureau of Reclamation, 1962. Chakachamna Project, Alaska. Status Report.

United States Department of the Army, Corps of Engineers, 1950. Survey Report on Harbors and Rivers in Alaska. Interim Report No. 2, Cook Inlet and Tributaries.

HYDROLOGICAL AND POWER STUDIES

4.0 HYDROLOGICAL AND POWER STUDIES

4.1 Introduction

River flow records from a gaging station are usually accepted as an indicator of future runoff from a drainage basin and the longer the period of record is, the more reliable it will be in forecasting future runoff. In the case of Chakachamna Lake, the records of a gage located near the lake outlet cover only a relatively short period of time from June 1959 to September 1972. Furthermore, some gaps that occurred during the above period further reduce its continuity to a period dating from June 1959 to August 1971.

There are no records of the inflow to Chakachamna Lake, and since that information is needed to perform reservoir operation and power studies, the inflows were calculated for the continuous period of record by reverse routing the outflows and making appropriate adjustments for changes in lake water levels.

Continuing efforts are being made to extend the hydrological data base by statistical correlation with records from other stations. An encouraging relationship has emerged but was not ready in time to be used for this interim report. Consequently, the inflows derived from the existing records have been used in the studies to determine the power generating potential of the water resource in the Chakachamna basin.

4.2 Historical Data

Hydrometeorological data from several stations in the Cook Inlet Basin are being used for the derivation and extension of estimated lake inflow records. Streamflow records include the following furnished by U.S. Geological Survey:

Station No.	Description
15294500	Chakachatna River near Tyonek (the lake outlet gage)
15284000	Matanuska River near Palmer
15284300	Skwentna River near Skwentna
15292000	Susitna River at Gold Creek

Gaging Station No. 15294500 above is located on the right bank of the Chakachatna River close to the outlet of Chakachamna Lake. The gage records extend for 13 years and 5 months from May 21, 1959 to September 30, 1972. The gage however, was rendered inoperative by a lake outbreak flood on August 12, 1971 and the records between that date and June 20, 1972 are estimated rather than recorded flows. Thus, the true period of record only extends from May 21, 1959 to August 12, 1971 and from June 20, 1972 to September 30, 1972. Furthermore, during that period, several of the winter month flows are estimated figures because of icing conditions and instrument failure. This however, is not considered to be a serious concern, because only 11% of the average annual flow has occurred in the seven months from November through May.

In addition to the streamflow data, records of the water surface elevation at Station No. 15294500 were also obtained from USGS files.

Meteorological data consist of daily temperature and precipitation data furnished by National Oceanic and Atimospheric Administration, National Climatic Center, Ashville, N.C. for the following stations:

Kenai
Anchorage
Sparrevohn

The locations of all stations mentioned above are indicated on Figure 4-1. A bar chart showing the periods of record at these stations is plotted on Figure 4-2.

4.3 Derived Lake Inflows

Chakachamna Lake with its surface area of about 26-square miles regulates the runoff from its drainage basin to a moderate extent. In order to derive a record of inflows to the lake, the regulatory efforts of the lake were removed from the outflow records by a reverse routing procedure which is basically a water balance computation using the classic continuity equation set forth below:

$$I_t - O_t = \Delta s$$

Where

I_t is the inflow volume during month t
O_t is the outflow volume during month t
Δ_s is the change in lake storage during month t

For all practical considerations, the Chakachatna River near Tyonek gage is, in effect, located at the lake outlet and field observations confirmed that its height closely represents the lake water surface elevation. Hence, it was assumed for the reverse routing computations that the two were the same. Evaporation, seepage and other losses of water from the lake were assumed to be small and effectively compensated for by direct precipitation onto the lake surface, the latter being otherwise ignored.

The lake stage-storage curve used in the computations is shown on Figure 4-3. This is based on data measured by the USGS and recorded on maps Chakachatna River and Chakachmna Lake Sheets 1 and 2 dated 1960.

The average monthly inflows were calculated for the period June 1, 1959 through July 31, 1971. The eleven calendar years from January 1, 1960 to December 31, 1970 were used as the basis for power studies and the inflows for this period are listed in Table 4-1 from which it may be noted that the mean annual inflow was 3,547 cubic feet per second.

4.4 Power Studies

Using the derived lake inflows mentioned above, powerplant operation studies were performed to determine the firm and secondary energy, the power flows and the fluctuations in the water surface elevation of Chakachamna Lake for a range of installed capacities in each of the four alternative forms of project development described in Section 3.0 of this report. The studies were made by means of a computer program that performs sequential routing of the derived monthly inflows while satisfying power demands, the tentative in-stream flow requirements, and physical system constraints. Power demands are in accordance with a plant load factor of 0.5 and the monthly variations in peak demand listed in Table 4-2. As advised by APA, these have the same values as those being used in the evaluation of sources of power alternative to that of the Chakachamna Hydroelectric Project.

The in-stream flow requirements, listed in Table 4-3, represent provisional minimum monthly flows to be released into the Chakachatna River near the lake outlet as further discussed in Sections 7.3.2 and 7.3.3 of this report.

The physical system constraints, set forth in Table 4-4, are the overall plant efficiency, tailwater elevation and head loss coefficient for the hydraulic conduits.

The power studies were performed in such manner that water was drafted from lake storage whenever the monthly inflows were insufficient to meet the power demand. On the assumption that spill, or discharge of water from the lake into the Chakachatna River in excess of the tentative instream flow requirements would occur from the natural lake outlet whenever the lake water level exceeded elevation 1,128 feet, the amount of secondary energy that could be generated was also calculated. The secondary energy, is that which can be generated by plant capacity in excess of that needed to meet the load carrying capability, using water which otherwise would have spilled.

TABLE 4-1

DERIVED INFLOWS TO CHAKACHAMNA LAKE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
	Flow in cubic feet per second												
1960	400.	307.	267.	393.	3637.	6837.	11209.	9337.	3145.	1439.	799.	870.	3220.
1961	877.	589.	470.	346.	1881.	7983.	12808.	10899.	6225.	1586.	843.	696.	3767.
1962	633.	541.	471.	470.	1265.	7925.	13149.	10411.	5542.	1197.	863.	613.	3590.
1963	498.	357.	315.	337.	1801.	4735.	13249.	12208.	5847.	2056.	930.	710.	3587.
1964	364.	435.	332.	477.	1830.	8093.	10700.	11798.	4246.	1245.	909.	662.	3424.
1965	419.	219.	337.	398.	1286.	3490.	13046.	10516.	10802.	2114.	597.	466.	3641.
1966	388.	336.	350.	410.	1893.	8072.	10303.	9974.	6608.	1953.	910.	313.	3459.
1967	531.	449.	384.	880.	2030.	8761.	14931.	15695.	6191.	2040.	1215.	571.	4473.
1968	534.	510.	467.	630.	2996.	7808.	13117.	11257.	2793.	976.	689.	612.	3532.
1969	465.	486.	500.	652.	1948.	9271.	12510.	7297.	2793.	3057.	1215.	541.	3396.
1970	497.	504.	550.	899.	2265.	6789.	10360.	7986.	2734.	1359.	742.	460.	2929.
Mean	511.	430.	404.	536.	2076.	7251.	12307.	10671.	5175.	1729.	883.	592.	3547.

TABLE 4-2

MONTHLY PEAK POWER DEMANDS USED IN POWER STUDIES

MONTH	MONTHLY PEAK DEMAND (Percent of Annual Peak Demand)
January	92
February	87
March	78
April	70
May	64
June	62
July	61
August	64
September	70
October	80
November	92
December	100

Source: Susitna Hydroelectric Project Development Selection Report Appendix D, Table D.1 (Second Draft, July 1981)

TABLE 4-3

PROVISIONAL MINIMUM RELEASES FOR INSTREAM FLOW IN CHAKACHATNA RIVER DOWNSTREAM FROM CHAKACHAMNA LAKE OUTLET FOR USE IN POWER STUDIES

MONTH	MC ARTHUR TUNNEL DEVELOPMENT ALTERNATIVE B (CFS)*	CHAKACHATNA TUNNEL DEVELOPMENT ALTERNATIVE D (CFS)
January	365	30
February	343	30
March	345	30
April	536	30
May	1,094	30
June	1,094	30
July	1,094	30
August	1,094	30
September	1,094	30
October	365	30
November	365	30
December	360	30

*Use the average monthly inflow to the lake (CFS) or the figure listed whichever has the lower value.

TABLE 4-4

POWERPLANT SYSTEM CONSTRAINTS FOR ALTERNATIVE PROJECT DEVELOPMENTS

ALTERNATIVE	PLANT EFFICIENCY (%)	AVERAGE TAILWATER ELEVATION (FT.)	HEAD LOSS IN HYDRAULIC CONDUITS (FT.)
A	85	210	$0.0000024 \times Q^2$
B	85	210	$0.0000024 \times Q^2$
C	85	400	$0.0000028 \times Q^2$
D	85	400	$0.0000028 \times Q^2$

Note: Q = Flow in cubic feet per second.

For each of the alternatives considered for development of the project, a range of installed powerplant capacities was tested in order to determine what installed capacity would make the most use of all water available for power generation without drawing the lake level below a given minimum elevation. This was tentatively taken as 1,014 feet which is about 114 feet drawdown below the reported outlet channel invert elevation. The lake was assumed to be full at the beginning of each run.

4.5 Results

The results of the power studies listed in Table 4-5 show that, on the basis of the 11 years of record, and with the parameters used in the studies, the optimum development via the McArthur Tunnel could support a powerplant of 400 MW installed capacity when all controlled water is used for power generation as in Alternative A. At 50% plant factor, this provides an average annual 1,752 GWh of firm energy. The provisional instream flow reservations for Alternative B discussed in Section 7.3.2 of this report represent about 19% of the average annual flow in the Chakachatna River during the period of record. If that amount of water is reserved for instream flow, then the installed capacity of powerplant that could be justified in development of the project via the McArthur River would be reduced almost proportionately to 330 MW and the firm average annual energy would be 1446 GWh.

For development via the Chakachatna tunnel, the optimum development using all controlled water for power generation, Alternative C, would have an installed capacity of 300 MW and the firm annual average energy is 1314 GWh at 50% plant factor. The provisional minimum instream flow reservations in Alternative D discussed in Section 7.3.3 of this report represent less than 1% of the average annual flow during the period of record. Thus the installed capacity and firm energy in Alternative D for practical purposes would remain the same. There would however be about 15% reduction in the amount of secondary energy that could be generated.

4.6 Variations in Lake Water Level

The variations in lake water surface elevation calculated at the end of the month during the course of the power studies for each of the four alternatives and cases listed in Table 4-5 are plotted for ease of reference on Figure 4-4 for Alternatives A and B, and on Figure 4-5 for Alternatives C and D.

TABLE 4-5

POWER STUDIES SUMMARY

Development Alternative	Installed Capacity (MW)	Average Annual Energy Firm (GWh)	Surplus (GWh)	Average Annual Flow Power Diversion (CFS)	Provisional Instream (CFS)	Spill (CFS)
A	400	1752	153	3322	0	225
B	330	1446	124	2701	679	167
C	300	1314	139	3230	0	317
D	300	1314	130	3239	30	278

Note: Period of record January 1, 1960 to December 31, 1970
Average annual inflow to Chakachamna Lake 3547 cfs (2.6 million AF)
Alternatives A & B - Development via McArthur tunnel
Alternatives C & D - Development via Chakachatna tunnel

Power diversion flows are the flows needed to meet firm energy requirements. Spill is the difference between average annual inflow to Chakachamna Lake (3547 CFS) and the sum of power diversion plus provisional instream flows. Part of the spill can be used for the generation of surplus energy.

GEOLOGIC INVESTIGATIONS

5.0 GEOLOGIC INVESTIGATIONS

5.1 Scope of Geologic Investigations

5.1.1 Technical Tasks

The scope of the geologic investigations planned for the Chakachamna Hydroelectric Project Feasibility Study includes five technical tasks:

(1) Quaternary geology,

(2) Seismic geology,

(3) Tunnel alignment and powerplant site geology,

(4) Construction materials geology, and

(5) Road and transmission line geology.

These tasks were identified and scopes defined so that, upon completion of the investigations, the information needed to assess the potential impact of a range of geologic factors on the feasibility of the proposed project will be available. If the Chakachamna Project is judged to be feasible, additional geologic investigations will be required in order to provide the detailed information appropriate for actual design.

At the feasibility level, it is appropriate to gather information regarding the general character of the geologic environment in and around the project area, with particular attention to geologic hazards and the geology of specific facilities siting locations. The Chakachamna

Project, as presently conceived, is unlikely to include facilities such as dams that would increase the risks associated with geologic hazards that are naturally present in the project area. The geologic tasks were planned in recognition of the above and were designed to focus on geologic factors that may influence the technical feasibility, the operating reliability, and/or the cost of the proposed project.

The work on the geology tasks began in August 1981 but the majority of the work will take place in 1982. This interim report includes a summary of the work planned for the geologic investigations (Section 5.1.1) and the schedule for each geology task (Section 5.1.2), summaries of the work completed for the Quaternary geology (Section 5.2) and seismic geology (Section 5.3) tasks, and some preliminary commentary on geologic conditions in the project area included in Section 7.0. The commentary and any tentative conclusions presented here are subject to revision as the project work continues.

5.1.1.1 Quaternary Geology

The Quaternary geology task was designed to include an assessment of the glaciers and glacial history of the Chakachamna Lake area, an investigation of the Mt. Spurr and associated volcanic centers, and a study of the slope conditions near sites proposed for project facilities.

A study of the glaciers was judged to be appropriate because:

(1) movement of the terminus of Barrier Glacier influences the water level in Chakachamna Lake;

(2) the possibility that changes in the terminal position of Blockade Glacier could alter the drainage at the mouth of the McArthur River Canyon; and

(3) questions regarding the influence of other glaciers in the study area on the size and hydrologic balance of Chakachamna Lake.

In addition, knowledge of the ages of geomorphic surfaces is important to the assessment of possible seismic hazards and such knowledge depends on an understanding of the glacial geology.

The simple presence of Mt. Spurr, an active volcano, at the eastern end of Chakachamna Lake provides a clear rationale for investigating the volcanic history and potential volcanic hazards of the project area. Of particular interest is the possibility that lava flows or volcanic mudflows (a possibility increased by the glacier ice on Mt. Spurr) could enter the lake and produce large waves, an increase in lake level, and/or a change in conditions at the lake outlet or on the upper reaches of the river. In addition, the possible impact of a dark, heat-absorbing layer of volcanic ejecta on the glaciers' mass balance, and thus the lake's hydrologic balance is of interest.

Chakachamna Lake, Chakachatna River Canyon, and McArthur River Canyon are all bordered by steep slopes that may be subject to a variety of types of slope failure. A large landslide into the lake could change the usable volume of water stored in the lake and could alter conditions at the proposed lake tap and at the natural outlet from the lake. Potential outlet portal and surface powerhouse sites in the river canyons are all on or immediately adjacent to steep slopes. Both the integrity of and access to these facilities could be impaired in the event of landslide and rockfall activity.

Because of the concerns indicated above, the Quaternary geology task was designed to investigate the timing and size of past glacial fluctuations, the frequency and type of volcanic activity, and the slope conditions in order to provide an estimate of possible future events that could influence the costs and operating performance of the proposed hydroelectric project. In addition, this task should provide information regarding the possibility of the project destabilizing the lake outlet by producing or allowing changes in Barrier Glacier, thereby increasing the flood hazard.

5.1.1.2 Seismic Geology

The seismic geology of the Chakachamna Lake area is of interest because southern Alaska is one of the most seismically active areas in the world. Potential seismic hazards of direct concern to the proposed hydroelectric project include surface faulting, ground shaking, seismically-induced slope failure, lake seiche, and liquefaction. Specifically, the seismic geology task was designed to investigate the possibility of active faults in the immediate vicinity of the proposed facilities, to access the location and activity of regional faults (e.g., Castle Mountain, Bruin Bay), and to estimate the type and intensity of seismic hazards that may be associated with these faults and with the subduction zone.

The seismic geology investigations were planned to maximize the use of existing information by following a sequence of subtasks that become increasingly site specific as the work proceeds. The primary elements in the sequence are:

- o literature review
- o remote sensing imagery analysis
- o field reconnaissance
- o low-sun-angle air photo acquisition and analysis
- o detailed field studies

The data produced by the above sequence is required to assess directly the surface faulting hazard and for input to the probabilistic assessment of ground motion parameters.

In order to develop approximate ground motion spectra for the various elements of the project, existing ground motion information developed for other projects in southern Alaska will be reviewed and modified, as appropriate. A simplified evaluation of the liquefaction potential of the transmission line alignment is also planned.

5.1.1.3 Tunnel Alignment and Powerplant Site Geology

The scope of work for this task was based on the need to assess the feasibility of constructing a lake tap in Chakachamna Lake, a long tunnel, and a powerhouse as the primary components of the proposed hydroelectric development. Because of the steep mountainous terrain above the tunnel alignment, the tunnel feasibility study was planned around the mapping of bedrock exposures in the mountains and production of a strip map; drilling will be limited to the powerhouse site during the feasibility investigations. The strip map will focus on those bedrock characteristics that determine the technical and economic feasibility of tunnelling. Geophysical techniques will be used to assess the lake bottom bedrock and sediment characteristics at and near the proposed lake tap and subsurface conditions at the proposed powerhouse site.

All reasonably possible surface powerplant and outlet portal sites are on or adjacent to high, steep slopes. Hazards such as landslides, rockfalls, and avalanches, which are a particular concern in seismically active areas, will also be assessed during the feasibility study.

5.1.1.4 Construction Materials Geology

The proposed Chakachamna Hydroelectric Project will, if constructed, require aggregate for concrete, road construction, and construction of the transmission line. In addition, boulder rip-rap may be required at the outlet portal and outfall from the powerhouse. This task was planned to yield information about potential aggregate sources at the powerhouse-outlet portal site, along the road, and along the transmission line alignment.

5.1.1.5 Road and Transmission Line Geology

Geologic considerations will be important in the assessment of the road and transmission line routes. This task was designed to use aerial photograph analysis and reconnaisdance-level field studies in order to provide information on the general character of the alignments. The task plans recognized the need to give particular attention to river crossings, which may be subject to large floods, and to wetland areas where special construction techniques may be required.

5.1.2 Schedule

Because 1981 field work could not begin until late August and because the details of some of the geologic field work are appropriately a function of the decisions reached during other, non-geologic tasks, the 1981 geologic field program was limited.

5.1.2.1 Quaternary Geology

All of the Quaternary geology field studies were either of a regional nature or directed at targets that would not vary as a function of final configuration of the project facilities. Therefore, it was possible to complete the field work planned for this task. Some additional review of unpublished data, such as that held by the U.S. Geological Survey in Fairbanks, and discussions with geologists who have worked in the Chakachamna area remain to be completed. Although several important implications with respect to the proposed hydroelectric project have been identified and some tentative conclusions may be drawn, additional analyses and discussions are needed before the conclusions can be finalized.

5.1.2.2 Seismic Geology

As discussed in Section 5.1.1.2, the seismic geology task is designed around a sequence of investigations, each of which builds on the preceding ones. Because of this characteristic, the seismic geology task demands a certain amount of elapsed time and cannot be speeded up by adding additional staff.

During 1981 it was possible to complete the literature review, analysis of existing remote sensing imagery, field reconnaissance, and the acquisition and initial analysis of the low-sun-angle aerial photography. The detailed field studies and ground motion assessment will be conducted in 1982.

5.1.2.3 Tunnel Alignment and Powerplant Site Geology

No field investigations were conducted for this task in 1981 because the various tunnel alignment locations and configurations to be studied were not identified prior to completion of the 1981 field season. All of the geologic and geophysical investigations planned for this task will be completed in 1982.

5.1.2.4 Construction Materials Geology

The work for this task will be conducted in 1982.

5.1.2.5 Road and Transmission Line Geology

The work for this task will be conducted in 1982.

5.2 Quaternary Geology

The Quaternary, approximately the last 2 million years of geologic time, is commonly subdivided into the Pleistocene and the Holocene (most recent 10,000 years). Although the Pleistocene is generally equated to the glacial age and the Holocene with post-glacial time, such a distinction is less clear in southern Alaska where the mountains still contain extensive glaciers.

The Quaternary was a time of extreme and varied geologic activity in southern Alaska. In addition to the extensive glacial activity and associated phenomena, the Quaternary was also a time of mountain building and volcanic activity. The products of these and other geologic processes that were active during the Quaternary, and are still active today, are broadly present in the Chakachamna Lake area. Although the geologic investigations for this feasibility study consider a broad range of topics that fall under the general heading of Quaternary geology, this task was planned to address three specific topics:

(1) glaciers and glacial geology;

(2) Mt. Spurr volcano; and

(3) slope conditions.

In addition, the seismic geology task (Section 5.3) is designed to focus on Quaternary and historic fault activity and seismicity and is highly dependent on an understanding of the glacial history of the area for temporal data.

For the Quaternary geology task of the Chakachamna feasibility study, field work consisted of a twelve-day reconnaissance during which all three primary topics of interest (above) were studied. When combined with information available in the open literature and that gained through interpretation of aerial photography, the field reconnaissance provides a basis for assessing the potential impact of the glaciers, volcano, and slope conditions on the proposed hydroelectric project.

5.2.1 Glaciers and Glacial Geology

5.2.1.1 Regional Glacial Geologic History

At one time or another during the Quaternary, glaciers covered approximately half of Alaska (Pewe, 1975). Previous investigations have demonstrated that the Cook Inlet region has had a complex history of multiple glaciation (Miller and Dobrovolny, 1959; Williams and Ferrians, 1961; Karlstrcm, 1964; Karlstrom and others, 1964; Trainer and Waller, 1965; Pewe and others, 1965; Schmoll and others, 1972). The current understanding of the region's glacial history is based on interpretation of the morphostratigraphic record in association with relative and absolute age dating and other Quaternary studies. The complex history is recorded in glacial, fluvial, lacustrine, marine, and eolian sediments that have been studied primarily in their surface exposures where they can be associated with specific landforms. Although more recent work has lead to modification and refinement of Karlstrom's (1964) history of glaciation in the Cook Inlet region, that work still provides a good general overview and, except where noted, serves as the basis for the following summary.

On at least five separate occasions during the Quaternary, the glaciers in the mountains that surround Cook Inlet have expanded onto the Cook Inlet lowlands where they coalesced to cover much or all of the lowland with ice. Evidence for the two oldest recognized glaciations (Mt. Susitna, Caribou Hills) consists dominantly of erratic boulders and scattered remanants of till at high elevation sites around the margins of the lowland. Evidence for the next glaciation, the Eklutna, includes moraines and till sheets that demonstrate the coalescence of ice from various source areas to form a Cook Inlet piedmont glacier. The available evidence suggests several thousand feet of ice covered virtually all of the Cook Inlet lowland during these early glaciations.

The next two glaciations, the Knik and the Naptowne, correspond to the Early Wisconsin and Late Wisconsin glaciations of the midwestern United States, respectively. Thus, the Naptowne glaciation of the Cook Inlet region correlates, in general, with the Donnely (Pewe, 1975) and McKinley Park (TenBrink and Ritter, 1980; TenBrink and Waythomas, in preparation) glaciations reported from two areas on the north side of the Alaska Range. During the Knik and Naptowne glaciations ice again advanced onto the Cook Inlet lowland, but the ice did not completely cover the lowland as it apparently did during the earlier glaciations. Even at the glacial maxima, portions of the lowland were ice free; such areas were commonly the sites of large ice-dammed lakes that have been studied in some detail (Miller and Dobrovolny, 1959; Karlstrom, 1964).

The maximum ice advance during the Naptowne glaciation is recorded by distinct end moraine complexes located near the mouths of the major valleys that drain the Alaska Range and by moraines on the Kenai lowland. The moraines on the Kenai lowland are of particular interest because they were, at least in part, formed by the Trading Bay ice lobe, which originated in the Chakachatna-McArthur rivers area and advanced across Cook Inlet at the time of the Naptowne maximum. Karlstrom (1964) reported on these features on the Kenai lowland in some detail.

Karlstrom (1964) used a combination of radiocarbon dates and relative-age dating techniques to develop a chronology for the Cook Inlet glaciations. According to Karlstrom, the Naptowne glaciation continued, although with decreasing intensity, past the Pleistocene-Holocene boundary (generally taken as being near 10,000 years before present [ybp]), through the Climatic Optimum, to the beginning of Neoglaciation (see Porter and Denton, 1967). Recent work on the north side of the Alaska Range has produced a well-dated chronology for the McKinley Park glaciation (TenBrink and Ritter, 1980; TenBrink and Waythomas, in preparation). That chronology shows major stadial events at:

(1) 25,000-17,000 ybp (maximum advance at about 20,000 ybp);

(2) 15,000-13,500 ybp;

(3) 12,800-11,800 ybp; and

(4) 10,500-9,500 ybp.

Recognizing the differences in ice extent and other factors between the Cook Inlet region and the north side of the Alaska Range, the TenBrink chronology is probably reflective of the timing of the primary Naptowne stadial events. Dates from the Cook Inlet region proper have yet to yield such a clear picture, probably because of the greater complexity of the conditions and thus the record there.

Following the Naptowne glaciation (about 9,500 ybp by TenBrink's chronology, as late as 3,500 ybp according to Karlstrom, 9164), glacial advances in the Cook Inlet region have been limited to rather small-scale fluctuations that have extended only up to a few miles beyond present glacier termini. Karlstrom (1964) referred to these Neoglacial advances as the Alaskan glaciation, which he divided into two distinct periods of advance (Tustumena and Tunnel) and further subdivided into three and two short-term episodes, respectively. According to Karlstrom (1964) these Neoglacial events range in age from approximately 3,500 ybp to historic fluctuations of the last several decades.

Two points of particular interest regarding Neoglaciation in Alaska emerged from the literature review:

(1) the idea that "... the youngest major advance typically was the most extensive of the Neoglaciation" (Porter and Denton, 1967, p. 187), and

(2) Karlstrom's (1964) suggestion that, at least in the mountains around the margins of the Cook Inlet region, there was no distinct hiatus between the last small Naptowne readvance and the first Neoglacial advance.

These points will be addressed in the following section.

5.2.1.2 Project Area Glacial Geologic History

The reconnaissance-level investigations conducted for the Chakachamna feasibility study confirm the general picture for the project area presented by Karlstrom (1964). The area examined during the field reconnaissance is indicated on Figure 5-1. Although a rather broad area was included in the study area, most of the field work took place in the Chakachamna Lake basin, along the Chakachatna River, and on the southern slopes of Mt. Spurr.

Most of he study area was covered by glacier ice during the maximum stand of the Naptowne-age glaciers. Based on Karlstrom's (1964) work, it would appear that only high, steep slopes and local elevated areas were not covered by Naptowne ice. Within the area examined in the field, the upper limit of Naptowne ice is generally clearly defined, particularly in the area between Capps Glacier and Blockade Glacier, at and east of the range front (Figure 5-1). In this area lateral moraines produced during the maximum stand of Naptowne ice (25,000-17,000 ybp) are distinct and traceable for long distances; younger Naptowne lateral and terminal moraines are also present. The largest area that was not buried by Naptowne ice and which was observed during field reconnaissance is located high on the gentle slopes east of Mt. Spurr, between Capps Glacier and Straight Creek. The two older surfaces (Knik and [?] Eklutna) observed in this area (Figure 5-1) correspond well to the ideas presented by Karlstrom (1964).

Not only are moraines marking the Naptowne maximum present, but a large number of moraines produced during subsequent stadial advances or recessional stillstands are also present. These features demonstrate that even at the Naptowne maximum, ice from Capps Glacier and other glaciers to the north did not coalesce with ice coming from the Chakachatna canyon, except possibly near the coast. The Chakachatna ice and that issuing from the McArthur River Canyon and Blockade Glacier did join, however, to produce Karlstrom's (1964) Trading Bay ice lobe. That ice lobe covered the alluvial flat that, at the coast, extends from Granite Point to West Foreland. From the present coast, the Trading Bay lobe (according to Karlstrom, 1964) extended across Cook Inlet to the Kenai lowland.

The complex of moraines located between Blockade Glacier and the Chakachatna River area allow one to trace the slow retreat of Naptowne ice. As the Trading Bay lobe retreated westward across the inlet and then across the Trading Bay alluvial flats to the mountain front, separate ice streams became distinct. As the Naptowne ice continued to retreat up the Chakachatna Canyon more and more individual glaciers became distinct from one another. For example, Brogan Glacier (informal name, Figure 5-1), separated from the Chakachatna River by a low volcanic ridge, produced a recessional sequence that is independent of that formed by ice in the Chakachatna canyon. Such a sequence of features is less distinct or absent for the other glaciers between Brogan Glacier and Barrier Glacier.

Within the Chakachamna Lake basin, the evidence of Naptowne and older glaciations is largely in the form of erosional features and scattered boulders. Naptowne-age till apparently occurs only in isolated pockets within the lake basin and its major tributary valleys. The Naptowne-age surfaces in the basin are mantled with a sequence of volcanic ashes that averages two to three feet in thickness. The solids are typically developed on these volcanics rather than on the underlying glacially-scoured granitic bedrock or till.

In contrast to the erosional topography that characterizes the Naptowne and older surfaces within the Chakachamna Lake basin, Neoglacial activity produced prominent moraines and outwash fans. Neoglacial features were examined at or near the termini of the following glaciers;

(1) all glaciers along the south shore of the lake from Shamrock Glacier to the lake outlet;

(2) Barrier Glacier;

(3) Pothole and Harpoon Glaciers, where they enter the Nagishlamina River Valley;

(4) all of the glaciers that flow to the south, southeast, and east from the Mt. Spurr highland (Alice Glacier to Triumvirate Glacier, Figure 5-1); and

(5) Blockade Glacier.

The Neoglacial history of several of these glaciers is discussed in more detail in Sections 5.2.1.3 through 5.2.1.5. The Neoglacial record is of particular importance to an assessment of possible glacier fluctuations over the next several decades.

Returning to the two points raised at the end of Section 5.2.1.1:

(1) In most cases observed in the study area, it appears that the latest Neoglacial advance was as extensive or more extensive than earlier Neoglacial advances. This is in agreement with the Porter and Denton (1967) general conclusion for southern Alaska.

(2) Karlstrom's (1964) chronology suggested a continuous sequence of decreasing glacial advances leading from Naptowne to Neoglacial time. In most parts of the study area it was not possible to assess this suggestion. However, the morainal sequence produced by Brogan Glacier (Figure 5-1) and the difference in the topographic characteristics of those moraines suggest that there was little, if any, hiatus between the youngest Naptowne moraine and the oldest Neoglacial moraine.

5.2.1.3 Barrier Glacier

Barrier Glacier originates in the snow and ice field high on the slopes of Mt. Spurr. From there it flows down a steep, ice-carved canyon to the shore of Chakachamna Lake where its piedmont lobe forms the eastern end of the lake (Figure 5-2). Barrier Glacier is of particular interest to this feasibility study because the glacier forms the eastern end of the lake and influences the size and character of the outlet from the lake.

Barrier Glacier was described by Capps (1935) in his report on the southern Alaska Range and was considered in several reports on the hydroelectric potential of Chakachamna Lake (Johnson, 1950; Jackson, 1961; Bureau of Reclamation, 1962). Giles (1967) conducted a detailed investigation of the terminal zone of Barrier Glacier. Most recently, the U.S.G.S. investigated Barrier Glacier as a part of a volcanic hazards assessment program at Mt. Spurr (Miller, personal communication, 1981).

Giles' (1967) investigation of Barrier Glacier was the most comprehensive to date and was specifically designed to assess the possible impact of the glacier on hydroelectric development of Chakachamna Lake, and vice versa. That work, which took place between 1961 and 1966, included mapping of the lake outlet area and measurements of horizontal and vertical movement and of ablation on various portions of the glacier. Those measurements indicated that:

(1) horizontal movement is in the range of 316 to 125 ft/yr on the debris-free ice and 28 to 1 ft/yr on the debris-covered lobe of ice that forms the southernmost component of the glacier's piedmont lobe complex; and

(2) surface elevation changes were generally small (+0.8 to -2.9 ft/yr), but ablation on the relatively debris-free ice averaged about 35 ft/yr in the terminal zone.

Giles (1967) identified five ice lobes, two on the debris-covered ice and three on the exposed ice, in the terminal zone of Barrier Glacier. Examination of color infrared aerial photographs for the current study suggests that he defined topographic, but not necessarily glaciologically-functional lobes or ice streams. For example, on the debris-covered portion of the piedmont zone, Giles identified two lobes on the basis of a deep drainage that cuts across that zone. On the air photos it is clear that the drainage in question parallels and then trends oblique to the curvilinear flow features preserved in the debris mantle. The drainage does not appear to mark the boundary between two ice streams.

Giles (1967) concluded that the level of Chakachamna Lake is controlled by Barrier Glacier, specifically by one 900-ft wide portion of debris-covered ice along the river; that zone reportedly advances southward, into the river channel, at a rate of about 25 ft/yr. Although the rate of ice movement was apparently relatively constant throughout the year, the low stream discharge in the winter allows the glacier to encroach on the channel but the ice is eroded back during the summer. Thus, Giles suggested that there is metastable equilibrium in the annual cycle. The annual cycle appears to be superimposed on a longer-term change such as that suggested by Giles' measurements.

Observations made during analysis of the color infrared (CIR) aerial photographs and during the 1981 field reconnaissance lead to general agreement with the conclusions produced by previous investigations. Nonetheless, the CIR air photos and extensive aerial and ground-based observations have allowed for the development of several apparently new concepts regarding Barrier Glacier; those new ideas may be summarized as follows:

(1) All of the moraines associated with Barrier Glacier are the products of late Neoglacial advances of the glacier and subsequent retreat. The large, sharp-crested moraines that bound the glacier complex on the eastern and a portion of the western margin (Figure 5-2A) mark the location of the ice limit as recently as a few hundred years ago (maximum estimate) and perhaps as recently as the early to middle part of this century. Cottonwood trees, which are the largest and among the oldest of the trees on the distal side of the moraine are approximately 300 to 350 years old based on tree ring counts on cores collected during the 1981 field work (location of trees on Figure 5-2A). Those dates provide an upper limit age estimate. The vegetation-free character of the proximal side of the moraine and the extremely sharp crest suggest on even more youthful ice stand.

(2) When Barrier Glacier stood at the outermost moraine (no. 1 above), the terminal piedmont lobe was larger than that now present and probably included a portion that floated on the lake; the present river channel south of the glacier could not have existed in anything near its present form at that time. The extent of the piedmont lobe, as suggested here, is based on interpretation of the flow features preserved on the debris-mantled portion of the terminal lobe and the projected continuation of the outermost moraine (no. 1 above).

(3) The most recent advance of Barrier Glacier did not reach the outermost moraine. It appears that the flow of ice was deflected westward by pre-existing ice and ice-covered moraine at the point where the glacier begins to form a piedmont lobe. This pulse was responsible for the vegetation-free zone of till that mantles the ice adjacent to the debris-free ice and for the large moraines that stand above the delta at the northeast corner of the lake.

(4) The presently active portion of Barrier Glacier has the same basic flow pattern as that described in no. 3, above, but the terminus appears to be retreating. The flow of ice is deflected westward as it exits the canyon through which the glacier descends the slopes of Mt. Spurr. The flow pattern is clearly visible on and in the debris-free ice and is further demonstrated by the distribution of the distinct belt of volcanic debris present along the eastern margin of the glacier.

(5) All of the above may be combined to suggest that the large debris-mantled (ice-cored) lobe that forms the most distal portion of the glacier complex, and which borders the river, is now, at least in large part, decoupled from the active portion of the glacier. This interpretation in turn suggests that the movements measured by Giles (1967) are due to adjustments within the largely independent debris-mantled lobe and to secondary effects transmitted to and through this lobe by the active ice upslope.

(6) In spite of the fact that disintegration of the debris-mantled lobe is extremely active locally, the lobe appears to be generally stable because remanant flow features are still preserved on its surface. The debris cover shifts through time, thickening and thinning at any given location as topographic inversion takes place due to melting of the ice and slumping and water reworking of the sediment. It appears that the rate of melting varies as a function of the thickness of the debris cover, with a thick cover insulating the ice and a thin cover producing accelerated melting. Removal of the covering sediment along the edge of the river leads to slumping and exposure of ice to melt-producing conditions. Thus the distal portion of the debris-mantled lobe that borders the river is one site of accelerated melting. Other areas of accelerated melting are concentrated along drainages that have developed within the chaotic ice-disintegration topography.

(7) There is no ice now exposed along the lake shore or around the lake outlet, at the head of the Chakachatna River, as was the case as recently as a few decades ago (Giles, 1969). These areas are rather uniformly vegetated and the debris mantle over the ice appears to be relatively thick compared to areas where accelerated melting is taking place. These areas appear to be reasonable models of what to expect when melting of the ice and the associated sorting and readjustment of the overlying debris have produced a debris cover thick enough to insulate the ice.

(8) If the debris-mantled ice lobe is functionally decoupled from the active ice, as suggested above, the move of ice toward the river is likely to gradually slow in the near future. The Giles' (1967) data suggest that this slowing may be underway; the 1971 flood on the Chakachatna suggests that the ice movement is still occasionally rapid enough to constrict the river channel, however. Nonetheless, it appears likely that, barring a dramatic or catastrophic event, the degrading portion of the ice lobe along the river will slowly stabilize to a condition similar to that along the lake shore. This will probably lead to a channel configuration somewhat wider than at present but the channel floor elevation is unlikely to change significantly. This scenario assumes that the discharge will remain relatively similar to that today. If discharge increases, than a channel deepening, as suggested by Giles (1967), may occur. If discharge decreases, the available data suggest that the outlet channel is likely to become more

narrow and perhaps more shallow as the debris-covered ice continues to stabilize.

(9) Over the long term the possible changes along the uppermost reaches of the Chakachatna River, where the lake level is controlled, are potentially more varied and more difficult to predict. One reason for this is that the longer time frame (i.e., centuries vs. decades) provides an increased probability for both dramatic (e.g., marked warming or cooling of the climate) and catastrophic (e.g., large volcanic eruption) events. In this regard, it should be noted that Barrier Glacier and the lake outlet appear to be within the zone of greatest potential impact from eruptions of Mt. Spurr volcano (see Section 5.2.2).

Post and Mayo (1971) listed Chakachamna Lake as one of Alaska's glacier-dammed lakes that can produce outburst floods. They rated the flood hazard from the lake as "very low" unless the glacier advances strongly. The 1971 flood on the Chakachatna (Lamke, 1972) was attributed to lateral erosion of the glacier terminus at the lake outlet. This flood may have, in fact, been triggered by waters from an outburst flood at Pothole Glacier, a surging glacier (Post, 1969) in the Nagishlamina River Valley (Section 5.2.1.5).

5.2.1.4 Blockade Glacier

Blockade Glacier (Figure 5-1) originates in a very large snow and ice field (essentially a mountain ice cap), high in the Chigmit Mountains south of Chakachamna Lake. This same ice cap area is also the source of several of the glaciers that flow to the south shore of Chakachamna Lake (e.g., Shamrock, Dana, and Sugiura Glaciers; Figure 5-1). Blockade Glacier flows southward out of the high mountains into a long linear valley, which trends NE&SW and which is apparently fault controlled (Section 5.3). Once in the linear valley, Blockade Glacier flows both to the northeast and to the southwest. The southwestern brach terminates in Blockade Lake, which is one of Alaska's glacier-dammed lakes that is a source of outburst floods (Post and Mayo, 1971). The northeastern branch of the glacier terminates near the mouth of the McArthur River Canyon and melt water from the glacier drains to the McArthur River.

Blockade Glacier is of specific interest to the Chakachamna feasibility study because one of its branches does terminate so near the mouth of the McArthur River Canyon, and a likely site for the powerhouse for the hydroelectric project is in the lower portions of the canyon (Section 3.0). Changing conditions at the northeastern terminus of Blockade Glacier could conceivably change the drainage of the McArthur River to a degree that may influence conditions in the canyon, i.e., at the proposed powerhouse sites in the canyon.

Blockade Glacier has not been the subject of previous detailed studies such as those for Barrier Glacier (Section 5.2.1.3). Observations made during the 1981 field reconnaissance covered the lower-elevation portions of the source area and both terminal zones, but were concentrated around the northeastern terminus, near the McArthur River.

At its northeastern terminus Blockade Glacier is over two miles wide. Over about half of that width (the northern half) the glacier terminates in a complex of melt water lakes and ponds that are dammed between the ice and Neoglacial moraines. The melt water from the lake system drains to the McArthur River via one large and one small river that join and then flow into the McArthur about 2.5 miles downstream from the mouth of the McArthur River Canyon. A complex of recently abandoned melt water channels formerly carried flow to the McArthur at the canyon mouth. A small advance of the ice front would reinstitute drainage in these now dry channels.

Melt water issuing from the southern half of the ice front flows to the McArthur River in braided streams that cross a broad outwash plain. Whereas the northern portion of the terminus is very linear, the southern portion includes a distinct lobe of ice that is more than a half mile wide and protrudes beyond the general ice front by more than three-quarters of a mile. Another notable characteristic of this zone is that the Neoglacial moraines, which are so prominent to the north, have been completely eroded away by melt water along the southern margin of the glacier.

On the basis of the above observations and the report that Blockade Lake produces outburst floods (Post and Mayo, 1971), it appears that the distinct features in the southern portion of the northeast terminal zone are present because this is the area where the outburst floods exit the glacier front. The broad outwash plain and the removal of the Neoglacial moraines are probably both due to the floods; the vegetation-free (i.e., active) outwash plain is much larger than the size of the melt water streams would suggest. The distinct lobe of ice that protrudes beyond the general front of the glacier probably marks the location of the sub-ice channel through which the outburst floods escape.

The outermost Neoglacial moraines present near the northeastern terminus lie about three-quarters of a mile beyond the ice front. With the exception of the distinct ice lobe, the general form of the ice front is mirrored in the shape of the Neoglacial terminal moraines. The outermost end moraine, which stands in the range of 20 to 40 ft above the surrounding outwash plain (distal) and ground moraine (proximal), is in the form of a continuous low ridge with a gently rounded crest. Three or four less distinct and less continuous recessional moraines are present between the ice and the Neoglacial maximum moraines. Distinct glacial fluting is present in the till in this area.

The Neoglacial end moraine can be traced to a distinct, sharp-crested Neoglacial lateral moraine that is essentially continuously present along the glacier margins well up into the source area for Blockade Glacier. The proximal side of the lateral moraine is steep and vegetation-free, suggesting ice recession in the very recent past. The crest of the lateral moraine stands about 40 or 50 ft (estimate based on observations from the helicopter) above the ice along the lower portions of the glacier.

A readvance of Blockade Glacier's northeastern terminus on the order of one-quarter to one-half a mile would reestablish drainage through the abandoned channels near the mouth of the McArthur River Canyon. Such a change is unlikely to significantly impact conditions within the canyon but would disrupt facilities (e.g., roads) on the south side of the McArthur River, immediately outside the mouth of the canyon. The glacier will have to advance about three-quarters of a mile before conditions in the canyon are likely to be seriously affected. An advance of a mile and a half would essentially dam the mouth of the canyon and would flood a major portion of the lower reaches of the canyon, including the sites under consideration for the powerhouse. Such a glacier-dammed lake would likely produce outburst floods.

There is no evidence that any of the Neoglacial advances of Blockade Glacier were extensive enough to dam the McArthur River Canyon. The outmost of the Noeglacial moraines lies at least one-quarter of a mile short of the point where ice-damming of the canyon would begin, however. Outwash fans on the distal side of the moraine may have produced minor ponding in the lowermost reaches observed in the field and on the color infrared air photos suggest that the last time that Blockade Glacier may have dammed the McArthur Canyon was in late Naptowne time, approximately 10,000 years or more ago.

The only reasonable mechanism that could produce an advance of Blockade Glacier that would be rapid enough to impact on the proposed hydroelectric project is a glacier surge; a surging glacier could easily advance a mile or more within a period of a few decades. Evidence for surges in the recent past might include an advancing glacier front in an area where glaciers are generally in recession and/or distorted medial moraines or longitudinal dirt bands on the glacier surface (Post, 1969; Post and Mayo, 1971). It is clear that Blockade

Glacier's recent history has been one of recession as is the case for all other glaciers examined during the 1981 field reconnaissance. There are many distinct longitudinal dirt bands and small medial moraines visible on the surface of Blockade Glacier. If one or more of the individual ice streams that comprise Blockade Glacier had recently surged, such activity should be reflected in contortions in the dirt bands and medial moraines. Visible deformation of the surface features on the glacier is very subtle and not suggestive of recent surging of even individual ice streams in the glacier. Thus, there is no evidence of a general surge of Blockade Glacier in the recent past.

In summary, it appears that Blockade Glacier began to withdraw from its Neoglacial maximum within the last few hundred years. At that maximum stand, melt water drainage joined the McArthur River at the canyon mouth and outwash may have produced some ponding and sediment aggradation in the lower reaches of he canyon, but the glacier was not extensive enough to have dammed the canyon. Surging is the most reasonable mechanism that could produce a future advance large enough and rapid enough to impact on the proposed powerhouse sites in the McArthur Canyon. No evidence suggestive of surging of Blockade Glacier was identified during this study.

Currently, melt water is carried away from the canyon mouth. Even markedly accelerated melt water production from Blockade Glacier is unlikely to change this condition or to have a negative impact on the proposed hydroelectric project.

5.2.1.5 Other Glaciers

In order to get a reasonably broad-based sense of the glacial record and history of recent glacier behavior in the Cakachamna Lake region, the field reconnaissance included aerial and ground-based observations of a number of the glaciers in the region in addition to Barrier and Blockade Glaciers. Those glaciers included:

(1) Shamrock Glacier, Dana Glacier, Sugiura Glacier, and First Point Glacier along the south shore of Chakachamna Lake (see figure 5-1 for locations);

(2) Harpoon Glacier and Pothole Glacier in the Nagishlamina River Valley;

(3) Alice Glacier, Crater Peak Glacier, and Brogan Glacier on the slopes of Mt. Spurr, above the Chakachatna River;

(4) Capps Glacier and Triumvirate Glacier on the eastern slopes of Mt. Spurr; and

(5) McArthur Glacier in the McArthur River valley.

Post (1969) surveyed glaciers throughout western North America in an effort to identify surging glaciers. Four of his total of 204 surging glaciers for all of western North America are in The Chakachamna study area (Figure 5-1). Three, including Pothole Glacier and Harpoon Glacier, are located in the Nagishlamina River Valley, tributary to Chakachamna Lake, and one, Capps Glacier, is on the eastern slope of Mt. Spurr. Surface features indicative of surging are clearly visible on the color infrared aerial photographs used in this feasibility study and were observed during field reconnaissance.

Specific observations pertinent to an understanding of the glacial history of the area and the feasibility study include:

(1) All of the glaciers listed above appear to have only recently withdrawn from prominent Neoglacial moraines, which in most (if not all) cases mark the Neoglacial maximum advance positions of the glaciers. These moraines and younger recessional deposits are generally ice-cored for those glaciers in groups 1 through 3 (above), but have little or no ice core in groups 4 and 5, which terminate at slightly lower elevations.

(2) Ponding and sudden draining of the impoundment upstream of the Pothole Glacier (a surging glacier) end moraine complex in the Nagishlamina River valley may be an episodic phenomena that can produce flooding in the lower portions of that valley and thus a pronounced influx of water into Chakachamna Lake. Published topographic maps (compiled in 1962) show a small lake upstream of the end moraine, which with the exception of a narrow channel along the western valley wall, completely blocks the Nagishlamina River Valley. That lake is no longer present but there is clear evidence for its presence and the presence of an even larger lake in the recent past. Features on the floor of the lower Nagishlamina River Valley suggest recent passage of a large flood. Such a sudden influx of water into

Chakachamna Lake could produce significant changes at the outlet from the lake. It may be that the 1971 flood on the Chakachatna River (U.S.G.S., 1972) was triggered by such an event, the stage having been set by the slow increase in the level of Chakachamna Lake in the years prior to the flood (Giles, 1967).

(3) Only glaciers south and east, and in the immediate vicinity at Crater Peak on Mt. Spurr retain any evidence of a significant cover of volcanic ejecta from the 1953 eruption of Crater Peak. On both Crater Peak Glacier and Brogan Glacier (see Figure 5-1) the ice in the terminal zone is buried by a thick cover of coarse ejecta. The volcanic mantle, where present, appears to be generally thick enough to insulate the underlying ice. The ejecta cover on Alice Glacier is surprisingly limited. Areas where the volcanic cover formerly existed, but was thin enough so that its presence accelerated melting, have probably largely been swept clean by the melt-water. In any case, the only areas where there is now evidence that the dark volcanic mantle has or is producing more rapid melting is on the margins of the thickly covered zones on the two cited glaciers.

(4) Highly contorted medial moraines on Capps Glacier, Pothole Glacier, and Harpoon Glacier suggest that several of the individual ice streams that comprise those glaciers have surged in the recent past. No comparable features were observed on any of the other glaciers in the Chakachamna study area.

5.2.1.6 Implications with Respect to the Proposed Hydroelectric Project

Implications derived from the assessment of the glaciers in the Chakachamna Lake area, with respect to specific project development alternatives, are included in Section 7.2. General implications, not directly tied to any specific design alternative, may be summarized as follows:

(1) In the absence of the proposed hydroelectric project, the terminus of Barrier Glacier is likely to continue to exist in a state of dynamic equilibrium with the Chakachatna River and to produce small-scale changes in lake level through time; the terminal fluctuations are likely to slow and decrease in size in the future, leading to a more stable condition at the lake outlet.

(2) If development of the hydroelectric project or natural phenomena dam the Chakachatna River Valley and flood the terminus of Barrier Glacier, the rate of disintegration is likely to increase. If the level of the lake is raised, the rate of calving on Shamrock Glacier is likely to increase.

(3) If hydroelectric development lowers the lake level, the debris-covered ice of Barrier Glacier is likely to encroach on and decrease the size of the river channel; a subsequent rise in lake level could yield conditions conducive to an outburst flood from the lake. A lowering of the level of Chakahamna Lake will also cause the short rivers that carry water from Kenibuna Lake and Shamrock Lake into

Chakachamna Lake to incise their channels, thereby lowering the levels of those upstream lakes over time.

(4) There is no evidence to suggest that Blockade Glacier will have an adverse impact on the proposed hydroelectric project or that the project will have any effect on Blockade Glacier.

(5) Glacier damming of the Nagishlamina River Valley may result in outburst floods that influence conditions at the outlet from Chakachamna Lake.

(6) With the exception of Shamrock Glacier, the terminus of which may be affected by the lake level, there is no evidence to suggest that the proposed project will influence the glaciers (other than Barrier Glacier) in the Chakachatna-Chakachamna Valley. Changes in the mass balance of the glaciers will influence the hydrologic balance of the lake-river system, however.

5.2.2 Mt. Spurr Volcano

5.2.2.1 Alaska Peninsula-Aleutian Island Volcanic Arc

Mt. Spurr is an active volcano that rises to an elevation above 11,000 ft at the eastern end of Chakachamna Lake. Mt. Spurr is generally reported to be the northernmost of a chain of at least 80 volcanoes that extends for a distance of about 1,500 miles through the Aleutian Islands and along the Alaska Peninsula; recent work has identified another volcano about 20 miles north of Mt. Spurr (Miller, personal communication, 1981). Like Mt.

Spurr, about half of the known volcanoes in the Aleutian Islands-Alaska Peninsula group have been historically active.

The volcanoes of this group are aligned in a long arc that follows a zone of structural uplift (Hunt, 1967), and that lies immediately north of the subduction zone the northern edge of the Pacific Plate. The volcanoes on the Alaska Peninsula developed on a basement complex of Tertiary and pre-Tertiary igneous, sedimentary, and metasedimentary rocks the pre-volcanic rocks are poorly exposed in the Aleutian Islands. At the northern end of the chain, such as at Mt. Spurr, the volcanoes developed on top of a pre-existing topographic high. Mt. Spurr is the highest of the volcanoes in the group and the summit elevations generally decrease to the south and west.

The Alaska Peninsula-Aleutian Islands volcanic chain is, in many ways, similar to the group of volcanoes in the Cascade mountains of northern California, Oregon, Washington, and southern British Columbia. In general, both groups of volcanoes developed in already mountainous areas, both consist of volcanoes that developed during the Quaternary and include historically active volcanoes. In both areas the volcanic rocks encompass a range of compositions but are dominantly andesitic, and both groups contain a variety of volcanic forms. The Alaskan volcanoes include low, broad shield volcanoes, steep volcanic cones, calderas, and volcanic domes. Much of the present volcanic morphology developed in late- and post-glacial time.

5.2.2.2 Mt. Spurr

Capps (1935, p. 69-70) reported, "The mass of which the highest peak is called Mt. Spurr consists of a great outer crater, now breached by the alleys of several glaciers that flow radially from it, and a central core within the older crater, the highest peak of the mountain, from vents near the top of which steam sometimes still issues. One small subsidiary crater, now occupied by a small glacier, was recognized on the south rim of the old, outer crater."

Subsequent work has shown that Capps' observations were, in part, in error. The error is specifically related to the suggestion that the peaks and ridges that surround the summit of Mt. Spurr mark the rim of a large, old volcanic crater. Why Capps had this impression is clear because as one approaches the mountain from the east or southeast, the view strongly suggests a very large crater; such a view has suggested to many geologists that Capps was correct in his observations. It is only when one gets up on the mountain, an opportunity made practical by the helicopter, that it becomes clear that most of the "crater rim" consists of granitic and not volcanic rocks. The most recent and comprehensive report on the distribution of lithologies present on Mt. Spurr is found in Magoon and others (1976). The U.S. Geological Survey plans to issue an open file report on Mt. Spurr in 1982 (Miller, personal communication, 1981).

Field work aimed at assessing the potential impact of volcanic activity from Mt. Spurr on the proposed hydroelectric development at Chakachamna Lake was concentrated in the area bounded by the Nagishlamina River on the west, the Chakachatna River on the south, a north-south line east of the mountain front on the east, and the Harpoon Glacier-Capps Glacier alignment on the north (Figure 5-1). Most of the observations at the higher elevations were from the helicopter; landing locations high on Mt. Spurr are few and far between and many of the steep slopes are inaccessible to other than airborne observations. It was possible to make numerous surface observations in the Nagishlamina River and Chakachatna River valleys and on the slopes below 3,000 ft elevation to the south and southeast of the summit of Mt. Spurr.

Observations made during the 1981 reconnaissance indicate that the Quaternary volcanics of Mt. Spurr, with the exception of airfall deposits, are largely confined to a broad wedge-shaped area bounded generally by Barrier Glacier, Brogan Glacier, and the Chakachatna River (Figures 5-1 and 5-2); the distribution of Quaternary volcanics north of the summit, in areas that do not drain to the Chakachamna-Chakachatna basin, was not investigated.

The bedrock along the western margin of Barrier Glacier is dominantly granite. The only exception observed during the field reconnaissance, which focused at elevations below about 5,000 ft, was an area where the granite is capped by lava flows (Figure 5-2). East of Barrier Glacier the slopes above about 2,000 ft consist of interstratified lava flows and proclastics, which are exposed in cross section. The slopes of Mt. Spurr in this area are not the product of triginal volcanic deposition but are erosional features. Thus, it is clear that the volcanics once extended farther to the south and southwest into what is now the Chakachamna Lake basin and

Chakachatna River Valley. The lower slopes immediately east of Barrier Glacier and south of Mt. Spurr consist of a broad alluvial fan complex.

Between Alice Glacier and the mountain front, the upper slopes of Mt. Spurr, where not buried by glacier ice or Neoglacial deposits, expose interbedded lava flows (often with columnar jointing), pyroclastic units, and volcaniclastic sediments. As is the case near Barrier Glacier, most of the slopes in this area are steep, often near vertical erosional features that expose the volcanic sequence in cross-section. The primary exception to this is found on and adjacent to Crater Peak where some of the slopes are original depositional features.

Crater Peak was the site of the most recent eruption of Mt. Spurr. That eruption, which took place in July, 1953, was described by Juhle and Coulter (1955). The 1953 eruption produced an ash cloud that was observed as far east as Valdez, 100 miles from the volcano; the distribution of ejecta on Mt. Spurr demonstrates that virtually all of the airborne material traveled eastward with the prevailing winds. The thick debris cover on Crater Peak and Brogan Glaciers (Figure 5-2) is largely the product of this eruption.

Any lava that issued from Crater Peak in 1953 was limited to the slopes of the steep-sided cone. The eruption did produce a debris flow, which began at the south side of the crater where volcanic debris mixed with water from the glacier that reportedly occupied the crater (Capps, 1935) and the outer slopes of the cone began to move downslope toward the Chakachatna River. The debris flow, which was probably more a flood than a debris flow initially, eroded a deep canyon along the eastern margin of Alice Glacier, through the Neoglacial moraine complex at the terminus of Alice Glacier, and through older volcanics and alluvium adjacent to the Chakachatna River. When it reached the Chakachatna River, the debris flow dammed the river and produced a small lake that extended upstream to the vicinity of Barrier Glacier. The dam was subsequently partially breached, lowering the impoundment in the Chakachatna Valley to its present level. Evidence for the high water level includes tributary fan-deltas graded to a level above the current water level and a "bath tub ring" of sediment and little or no vegetation along the southern valley wall.

East of the 1953 debris flow, the Chakachatna River flows through a narrow canyon within the broader valley bounded by the upper slopes of Mt. Spurr on the north and the granitic Chigmit Mountains on the south. The southern wall of the canyon (and valley, as whole) consists of glacially-scoured granitic bedrock. With the exception of remnant deposits of the 1953 debris flow that are present against the granitic bedrock (Figure 5-2), the 1981 reconnaissance yielded no evidence of volcanic or volcaniclastic rocks on the southern wall of the Chakachatna Valley. The northern wall of the Chakachatna Canyon exposes a complex of highly weathered (altered ?) andesitic lava flows, pyroclastics, volcaniclastic sediments, outwash, and in one location, what appears to be an old (pre-Naptowne) till.

Although the general late-Quaternary history of the Chakachatna River Valley is reasonably clear, the details of that history are very complex and would reguire an extensive field program to unravel. The observations made during the 1981 reconnaissance suggest the following:

(1) Late-Tertiary and/or early-Quaternary volcanic activity at Mt. Spurr built a thick pile of lava flows, proclastics, and volcaniclastic sediments on top of a granitic mountain mass of some considerable relief.

(2) Interspersed volcanic and glacial activity occurred during the Pleistocene, with alternating periods of erosion and deposition. The width of the valley at Chakachamna Lake is maintained downstream to the area of Alice Glacier (Figure 5-2). From that point to the mountain front, where the same broad valley form seems to reappear, the overall valley is plugged by a complex of volcanic (and glacial) deposits. This, along with the volcanic cliffs high on the slopes of Mt. Spurr, suggests that volcanics once largely filled what is now the Chakachatna Valley, that glaciers then eroded a broad, U-shaped valley (such as is still present in the lake basin), and that subsequent volcanic activity produced the bulk of the deposits that form the valley "plug".

(3) The age of the volcanics in the "plug" is not clear. Some of the characteristics of the basal volcanic rocks exposed along the river suggest some antiquity. For example, many lava flows are so deeply weathered (or altered ?) that the rocks disintegrate in one's hand. These volcanics appear

to be overlain by outwash and may be interbedded with till, which is also deeply weathered (altered?). These and other features suggest that at least some of the volcanics in this area were deposited in pre-Naptowne time. Glacial deposits, including moraines, a large area of kame and kettle deposits,and glacier-marginal lake deposits interpreted to be a late-Naptowne age overlie portions of the volcanic valley plug. [See Section 7.2 for discussion of implications with respect to a dam in the Chakachatna Canyon.]

In contrast, it is difficult to understand how the apparently easily eroded volcanics in this area survived the Naptowne-age glaciers that filled the Chakachatna Valley and were large enough to extend across Cook Inlet (Karlstrom, 1964). In addition, there are many landforms, such as volcanic pinnacles, that clearly are post glacial as they could not have survived being overriden by glacier ice. Such landforms demand the removal of several tens of feet of volcanics over large areas.

Although the evidence is conflicting and an unambiguous interpretation difficult, it does appear that much of the volcanic valley plug is of pre-Naptowne age. The basis for this conclusion is most clearly documented by the presence of outwash on top of volcanics, a sequence exposed at several sites in the canyon. The outwash is capped by a three-to-four foot thick cap of volcanic ash (many discrete depositional units) as is typical of Naptowne-age surfaces in the area. Just how these volcanics survived the Naptowne glaciation is not clear.

(4) Following the withdrawal of the Naptowne ice from the Chakachatna River Valley, Holocene volcanic activity, glacial activity, and fluvial and slope processes have produced the present landscape. Most, if not all of the present inner canyon, through which the Chakachatna River flows, appears to be the product of Holocene downcutting by the river.

Given that many of the details of the Quaternary history of Mt. Spurr are not well understood, it is nonetheless clear that Mt. Spurr is an active volcano that may produce lava flows, pyroclastics, and volcaniclastic sediments in the immediate vicinity within the life of the project. Airfall deposits can be expected to influence a larger area. Considering the size and type of volcanic events for which there is evidence at Mt. Spurr and the present topography, the area of interest to the proposed hydroelectric project most likely to be affected is the area between Barrier Glacier and the 1953 debris flow. The topography of the valley plug volcanics appears to afford some, but certainly not total protection to the canyon portion of the river valley; an example of this "protection" is provided by a second debris flow produced in 1953 that was prevented from reaching the river by intervening topography on the valley "plug".

The types of volcanic event judged to be most likely to impact the Chakachatna River Valley in the near future are:

(1) 1953-type debris flows which could inundate a portion of the valley and re-dam the river,

(2) lava flows, which could enter and dam the valley, and

(3) large floods that would be produced by the melting of glacier ice during an eruption.

Post and Mayo (1971) suggested that melting of glacier ice on Mt. Spurr during volcanic activity may present a serious hazard. Significant direct impact on Barrier Glacier would demand a summit eruption that included the flow of hot volcanics at least into the upper reaches of the glacier on the development of a new eruptive center (such as Crater Peak) west of the present summit. Of course the character of the volcanoes in the Aleutian Island-Alaska Peninsula chain make it clear that a very large event (i.e., a Mt. St. Helens--or even a Crater Lake-type event) is possible at Mt. Spurr; such an event has a very low annual probabilty of occurrence at any given site, however.

5.2.2.3 Implications with Respect to the Proposed Hydroelectric Project

The potential impact of Mt. Spurr on the proposed hydroelectric project will, in part, vary as a function of the project design (see Section 7.2), but some potential will always exist because of the location of Mt. Spurr relative to Chakachamna Lake and the Chakachatna River. The amount of negative impact on the project is clearly a function of the size of volcanic event considered; larger events, which would have the greatest potential for adverse impact, are, in general, less likely to occur than smaller volcanic events. Some general possibilities that might be associated with low- to medium-intensity events (such as a Crater Peak event or slightly larger) include:

(1) Damming of the Chakachatna River by lava or debris flows, with the most likely site being in the vicinity of the 1953 debris dam. Flooding of the terminus of Barrier Glacier may increase the rate of ice melt and possibly alter the configuration of the current lake outlet. Any project facilities on the valley floor of the upper valley would be buried by the flow and/or flooded.

(2) Flooding of the Chakachatna River Valley as a result of the melting of glacier ice on Mt. Spurr during an eruption. Project facilities near or on the valley floor would be flooded.

(3) Accelerating the retreat of Barrier Glacier due to the flow of hot volcanic debris onto the glacier. In the extreme, Barrier Glacier could be eliminated if enough hot material flowed onto the ice. A less dramatic scenario could include destabilization of the lake outlet due to accelerated melting in the terminal zone of Barrier Glacier. In contrast, a large lava flow at the present site of Barrier Glacier could replace the glacier as the eastern margin of the lake, providing a more stable dam than that provided by Barrier Glacier.

Each of the design alternatives (Section 3.0) includes a lake tap in the zone between the lake outlet and First Point Glacier. Although it is generally true that a site farther from Mt. Spurr is less likely to be subject to volcanic hazards than a site closer to the volcano, there is no apparent reason to favor one particular site in the proposed zone over any other site in that zone. A large eruptive event, apparently substantially larger than any of the Holocene events on Mt. Spurr, would be required before the proposed lake tap site would be directly threatened by an eruption of Mt. Spurr.

5.2.3 Slope Conditions

The Chigmit Mountains, south of Chakachamna Lake and the Chakachatna River, and the Tordrillo Mountains, to the north, contain many steep slopes and near-vertical cliffs. This landscape is largely the product of multiple glaciation during the Quaternary, including Neoglaciation which continues in the area today. The proposed hydroelectric project is likely to include facilities in the Chakachamna Lake basin and either or both of the McArthur and Chakachatna River valleys. Any above-ground facilities in these areas will be on or immediately adjacent to steep slopes, and thus subject to any slope processes that may be active in the area. Because of this fact, the 1981 field reconnaissance included observations of slope conditions in the areas of interest. Field work scheduled for 1982 will include detailed assessment of bedrock characteristics, such as joint orientations, that influence slope conditions.

5.2.3.1 Chakachamna Lake Area

Chakachamna Lake sits in a glacially overdeepened basin that is generally bordered by steep slopes of granitic bedrock that was scoured during Naptowne and earlier glaciations. Locally, such as along the southern valley wall west of Dana Glacier (Figure 5-2), distinct bedrock benches are present. In other areas, the slopes rise, with only minor variation in slope, from the lake level to the surrounding peaks. All principal valleys along the southern side of the lake presently contain glaciers. The principal valleys tributary to the north side of the lake, the Chilligan and Nagishlamina, are larger than those on the south side of the lake and are currently essentially ice-free, although their present form is clearly the product of glacial erosion.

No evidence of large-scale slope failures of the slopes in the Chakachamna Lake basin was observed during the 1981 field reconnaissance. Most of the slopes are glacially-scoured bedrock and are essentially free of loose rock debris, although talus is locally present. The orientation of joint sets in the granitic bedrock varies somewhat from area to area. In many areas a near horizontal out-of-slope joint set is present, but it tends to be poorly expressed relative to more steeply-dipping joints. Field work indicates that this and cross-cutting joints have formed boulder-size pieces and small slabs that produce rockfall as the only common type of slope failure for which any evidence was found. This condition is apparently most pronounced along the southern valley wall, between Sugiura Glacier and the lake outlet.

5.2.3.2 Chakachatna River Valley

The Chakachatna River, from its origin at Chakachamna Lake to the mountain front, flows through a valley that is rather variable in its form and characteristics along its length and from side to side. Throughout the valley, the south side consists of steep glaciated granitic bedrock slopes that rise essentially continuously from the river to the adjacent mountain peaks. All major tributary valleys on the southern valley wall, many of which are hanging alleys, now contain glaciers. The comments regarding slope conditions on the slopes above the lake (Section 5.2.3.1) apply to the southern wall of the Chakachatna River Valley.

The north side of the valley differs from the south side in virtually every conceivable way. On this side bedrock is volcanic, and glacial and fluvial sediments are also present. In the westernmost portion of the valley, the river is bordered by the Barrier Glacier moraine and alluvial fans; steep volcanic slopes above the alluvial fans are subject to rockfall activity. Between Alice Glacier (the area of the 1953 debris flow) and the valley mouth, the river flows through a narrow canyon, the north side of which consists of a variety of interbedded volcanics, glacial deposits, and fluvial sediments (Figure 5-2). The north canyon wall has been the site of several landslides that range in size from small slumps to large rotational slides. Such activity is likely to continue in the future. Its impact will most frequently be limited to the diversion of the main river course away from the north canyon wall; there are several examples of this now present in the canyon. A large landslide, which appears to be unlikely given the height of the slopes, could completely dam the canyon; partial damming with temporary ponding appears to be a more likely possibility.

Volcanic activity on Mt. Spurr could directly influence conditions along the Chakachatna River (Section 5.2.2), or could, by slowly altering conditions along the north wall of the canyon, have a secondary impact on the valley.

5.2.3.3 McArthur River Canyon

The McArthur River Canyon is a narrow, steep-walled glaciated valley. A possible powerhouse site has been identified along the north wall of the canyon (Section 3.0) and the following comments specifically refer to the north wall of the McArthur River Canyon. The valley walls, which consist of granitic bedrock, expose a complex of cross-cutting joint sets and shear zones. The character and dominant orientations of the joints and shears vary along the length of the canyon and the character of the slopes also varies, apparently in direct response.

Except near the canyon mouth, there is no evidence of large-scale slope failure and rockfall is the dominant slope process. Between the terminus of McArthur Glacier and Misty Valley (Figure 5-1) the joint sets are of a character and orientation such that rockfall has been active and the bedrock on the lower slopes on the north valley wall are uniformly buried beneath a thick talus. The vegetation on the talus suggests that the bulk of talus development took place some time soon after deglaciation and rockfall has been less active recently. The slopes between Misty and Gash Valleys (Figure 5-1) consist of glacially-scoured bedrock that is essentially talus free, suggesting little or no rockfall in this area.

From Gash Valley to the canyon mouth, the granitic bedrock appears to become progressively more intensely jointed and sheared and thus more subject to rockfall and small-scale slumping. Talus mantles the lower slopes in much of this area. A large fault zone (Section 5.3) is present at the canyon mouth. The fault has produced intense shearing over a broad zone that is now subject to intense erosion and is the site of several landslides.

5.2.3.4 Implications with Respect to the Proposed Hydroelectric Project

As is the case for volcanic hazards, there is no apparent reason with respect to slope conditions to favor one site over any other in the zone between the lake outlet and First Point Glacier for the lake tap. Rockfall appears to be the only potential slope hazard in that zone; there was no evidence observed in the field to suggest other types of slope failure.

As indicated on Figure 5-9, the Castle Mountain fault (Section 5.3), which is a major fault, crosses the McArthur River just outside the canyon mouth where the granitic bedrock has been badly shattered by fault movement. Surface examination reveals that the rock quality progressively improves with distance upstream from the canyon mouth and the best quality rock lies between Gash Valley and Misty Valley (Figure 5-1), beginning about 1-1/2 miles upstream from the powerhouse location presently shown on the drawings. This location is based on economic considerations alone, without taking account of the higher excavations costs that would be associated with the poorer quality rock. A critical evaluation of the rock conditions in this area will be included in the 1982 studies and a site will be selected for drilling a deep core hole.

A powerhouse site at or immediately outside the canyon mouth, as has been considered in other studies, is likely to be in the fault zone and subject to fault rupture as well as high ground motions. In addition, facilities outside the canyon will be in Tertiary sedimentary rocks and glacial deposits, not granite.

5.3 Seismic Geology

5.3.1 Tectonic Setting

The active faulting, seismicity, and volcanism of southern Alaska are products of the regional tectonic setting. The primary cause of the faulting and seismic activity is the stress imposed on the region by the relative motion of the Pacific lithospheric plate relative to the North American plate along their common boundary (Figure 5-3). The Pacific plate is moving northward relative to the North American plate at a rate of about 2.4 inches/year (Woodward-Clyde Consultants, 1981 and references therein). The relative motion between the plates is expressed as three styles of deformation. Along the Alaska Panhandle and eastern margins of the Gulf of Alaska, the movement between plates is expressed primarily by high-angle strike-slip faults. Along the northern margins of the Gulf of Alaska, including the Cook Inlet area, and the central and western portions of the Aleutian Islands, the relative motion between the plates is expressed by the underthrusting of the Pacific plate beneath the North American plate. At the eastern end of the Aleutian Islands, the relative plate motion is expressed by a complex transition zone of oblique thrust faulting.

The Chakachamna Lake area is located in the region where the interplate motion is producing underthrusting of the Pacific plate beneath the North American plate. This underthrusting results primarily in compressional deformation, which causes folds, high-angle reverse faults, and thrust faults to develop in the overlying crust. The boundary between the plates where underthrusting occurs is a northwestward-dipping megathrust fault or subduction zone. The Aleutian Trench, which marks the surface expression of this subduction zone, is located on the ocean floor approximately 270 miles south of the Chakachamna Lake area. The orientation of the subduction zone, which may be subdivided into the megathrust and Benioff zone (Woodward-Clyde Consultants, 1981), is inferred at depth to be along a broad inclined band of seismicity that dips northwest from the Aleutian Trench.

The close relationship between the subduction zone and the structures within the overlying crust introduces important implications regarding the effect of the tectonic setting on the Ghakachamna Lake Project. The subduction zone represents a source of major earthquakes near the site. Faults in the overlying crust, which may be subsidiary to the subduction zone at depth, are sources of local earthquakes and they may present a potential hazard for surface fault rupture. This is of special concern because the Castle Mountain, Bruin Bay, and several other smaller faults have been mapped near to the Chakachamna Lake Hydroelectric Project area (Detterman and others, 1976; Magoon and others, 1978). Future activity on these faults may have a more profound affect on the seismic design of the project structures than the underlying subduction zone because of their closer proximity to proposed project site locations.

5.3.2 Historic Seismicity

5.3.2.1 Regional Seismicity

Southern Alaska is one of the most seismicially active regions in the world. A number of great earthquakes (Richter surface wave magnitude Ms 8 or greater) and large earthquakes (greater than Mx 7) have been recorded during historic time. These earthquakes have primarily occurred along the interplate boundary between the Pacific and North American plates, from the Alaskan panhandle to Prince William Sound and along the Kenai and Alaska Peninsulas to the Aleutian Islands. Among the recorded earthquakes are three great earthquakes that occurred in September 1899 near Yakutat Bay, with estimated magnitudes Ms of 8.5, 8.4, and 8.1 (Thatcher and Plafker, 1977). Ground deformation was extensive and vertical offsets ranged up to 47 ft. (Tarr and Martin, 1912); these are among the largest known displacements attributable to earthquakes. Large parts of the plate boundary were reuptured by these three earthquakes and by twelve others that occurred between 1897 and 1907; these included a magnitude Ms 8.1 event on 1 October 1900 southwest of Kodiak Island (Tarr and Martin, 1912; McCann and others, 1980) and a nearby magnitude Ms 8.3 earthquake on 2 June 1903, near 57° north latitude, 156° west longitude (Richter, 1958).

A similar series of major earthquakes occurred along the plate boundary between 1938 and 1964. Among these earth uakes were the 1958 Lituya Bay earthquake (Ms 7.7) and the 1972 Sitka earthquake (Ms 7.6), both of which occurred along the Fairweather fault system in southeast Alaska; and the 1964 Prince William Sound earthquake

(Ms 8.5), which ruptured the plate boundary over a wide area from Cordova to southwest of Kodiak Island and which produced up to 39 ft. of displacement (Hastie and Savage, 1970). Figure 5-4 shows the aftershock zones of these and other major earthquakes in southern Alaska and the Aleutian Islands. The main earthquakes and aftershocks are inferred to have ruptured the plate boundary in the encircled areas.

Three zones along the plate boundary which have not ruptured in the last 80 years have been identified as "seismic gaps" (Sykes, 1971). These zones are located near Cape Yakataga, in the vicinity of the Shumagin Island, and near the western tip of the Aleutian Chain as shown in Figure 5-4. The Yakataga seismic gap is of particular interest to the project because of its proximity to the site region. The rupture zone of a major earthquake filling this gap has the potential to extend along the subduction zone to the north and northwest of the coastal portion of the gap near Yakataga Bay.

5.3.2.2 Historic Seismicity of the Project Study Area

The historic seismicity within 90 miles of the project area, approximately centered on the east end of Chakachamna Lake, is shown in Figures 5-5, 5-6, and 5-7. The earthquake locations are based on the Hypocenter Data File prepared by NOAA (National Oceanic and Atmospheric Administration, 1981). The Hypocenter Data File includes earthquake data from the U.S. Geological Survey and other sources and represents a fairly uniform data set in terms of quality and completeness since about 1964.

Based on Figures 5-5, 5-6, and 5-7 and data available in the open literature, the seismicity of the project area is primarily associated with four principal sources: the subduction zone, which is divided into two segments--the Megathrust and Benioff zone (Woodward-Clyde Consultants, 1981,; Lahr and Stephen, 1981); the crustal or shallow seismic zone within the North American Plate; and moderate to shallow depth seismicity associated with volcanic activity. The seismic sources are briefly discussed below in terms of their earthquake potential.

The Megathrust zone is a major source of seismic activity that results primarily from the interplate stress accumulation and release along a gently inclined boundary between the Pacific and North American plates. This zone is the source area of many of the large to great earthquakes, include the Ms 8.5 1964 Prince William Sound earthquake, which ruptured along the inclined plate boundary from the eastern Gulf of Alaska to the vicinity of Kodiak Island. The maximum magnitude for an earthquake event along the Megathrust zone is estimated to be Ms 8.5 (Woodward-Clyde Consultants, 1980, 1981).

The Benioff zone portion of the subduction zone is believed to be restricted to the upper part of the descending Pacific plte, which lies beneath the North American plate in southern Alaska. This zone is the source of smaller magnitude and more continuous earthquake activity relative to the Megathrust zone. No earthquakes larger than about Ms 7.5 are known to occur along the Benioff zone and therefore, a maximum magnitude earthquake of Ms 7.5 is estimated for this zone (Woodward-Clyde Consultants, 1981).

The primary source of earthquakes in the crustal or shallow seismic zone is movement along faults or other structures due to the adjustment of stresses in the crust. As shown in Figure 5-7, the historic seismicity of the crustal zone within a large part of the project study area is low. The data base used to compile the historic seismicity of the crustal zone for this study has no recorded earthquakes in the vicinity of Chakachamna Lake.

The majority of the recorded earthquakes shown in Figure 5-7 are located along the eastern and southern margins of the project study area. Most of these events have not been correlated or associated with any known crustal structures, with the possible exception of one event that is associated with the Castle Mountain fault. As discussed in Section 5.3.3.3, the Castle Mountain fault is one of the two major faults present in the project study area. It passes within a mile or less of the proposed project facilities in the McArthur River drainage and within 11 miles of the proposed facilities at Chakachamna Lake. Evidence for displacment of Holocene deposits has been reported in the Susitna lowlands, in the vicinity of the Susitna River (Detterman and others, 1976a). Although a number of recorded earthquakes are located along the trend of the Castle Mountain fault (Figure 5-7), only one event, an Ms 7 earthquake in 1933, has been associated with the fault (Woodward-Clyde Consultants, 1980b). A maximum magnitude earthquake of Ms 7.5 has been estimated for the Castle Mountain fault (Woodward-Clyde Consultants, 1981).

Further studies (planned for 1982) are needed to assess the possible association of other historic earthquakes shown in Figure 5-7 with candidate significant features identified in the fault investigation phase of the project study.

Because of the proximity of the project site to active volcanoes of the Aleutian Islands-Alaska Peninsula volcanic chain, including Mt. Spurr which is located immediately northeast of the Chakachamna Lake, volcanic-induced earthquakes are considered a potential seismic source. Active volcanism can produce small-to-moderate magnitude earthquakes at moderate-to-shallow depths due to the movement of magma or local adjustments of the earth's crust.

Occasionally, severe volcanic activity such as phreatic explosions or explosive caldera collapses may be accompanied by significant earthquake events. Because such large volcanic events are rare, there is little data from which to estimate earthquake magnitudes that may be associated with them. However, because of the similarities in characteristics of the Mount St. Helens volcano to those of the Aleutian chain (including Mt. Spurr), it is reasonable to assume that earthquakes associated with the recent Mount St. Helens eruption of May 1980 may also occur during future volcanic activity of Mt. Spurr and others in the Aleutian chain. The largest earthquake associated with the Mount St. Helens explosive eruption that occurred on 18 May 1980 had a magnitude of 5.0. Numerous smaller earthquakes with magnitudes ranging from 3 to 4 were recorded during the period preceding trhe violent rupture of Mount St. Helens (U.S. Geological Survey, 1980).

As part of a volcanic hazard monitoring program, the U.S. Geological Survey has been operating several seismograph stations in the vicinity of Mt. Spurr to assess its activity. Data acquired by these stations are not presently available but will be released in 1982 as an Open-File Report (Lahr, J. C., personal communication, 1981).

5.3.3 Fault Investigation

5.3.3.1 Approach

The objectives of the Chakachamna Lake Hydroelectric Project seismic geology task are:

(1) to identify and evaluate significant faults within the project study area that may represent a potential surface rupture hazard to project facilities and

(2) to make a preliminary evaluation of the ground motions (ground shaking) to which proposed project facilities may be subjected during earthquakes. In order to meet the specific task objectives and to provide a general assessment of the seismic hazards in the project area, the seismic geology study was designed and conducted in a series of sequential phases (Figure 5-8).

5.3.3.2 Work to Date

The study phases reported here include review of available literature, analysis of remotely sensed data, aerial field reconnaissance, and acquisition of low-sun-angle aerial photographs.

Information of a geologic, geomorphic, and seismologic nature available in the open literature was evaluated to identify previously reported faults and lineaments that may be fault related within the project study area. Geologists presently working in the area or familiar with the study area were also contacted. The locations of all faults and lineaments derived from the literature review and discussions with other geologists were plotted on 1:250,000-scale topographic maps.

Lineaments interpreted to be fault related were also derived from the analysis of high-altitude color-infrared (CIR) aerial photographs (scale 1:60,000) and Landsat imagery (scale 1:250,000) of the study area outlined by the 30-mile diameter circle on Figure 5-9. These lineaments were initially plotted (with brief annotation) on clear mylar overlays attached to the photographs and images on which they were observed. The lineaments were then transferred and plotted on the 1:250,000-scale topographic maps. The faults and lineaments identified from the review of the available literature and interpretation of CIR photographs and landsat imagery comprise a preliminary inventory of faults and lineaments within the study area.

The faults and lineaments in the preliminary inventory were then screened on the basis of a one-third length length-distance criterion to select those faults and lineaments within the study area that potentially could produce surface rupture at sites proposed for facilities. The length-distance criterion specifies a minimum length for a fault or lineament and a minimum distance from the project site for a fault or lineament to be retained for further study. For example, a fault or lineament that trends toward the project site and has an observed length of 10 miles would be selected for further study if it was less than 30 miles from the project site. A fault or lineament with the same trend and same length, but at a distance of greater than 30 miles from the project site would not be selected for further study.

The one-third length-distance criterion used is based on the empirical data that suggest that fault rupture rarely occurs along the full length of a fault (except for very short faults) during an earthquake (Slemmons, 1977, 1980). The length-distance criterion also takes into account

(1) the possibility of surface rupture within or near to the project site occurring on faults that may be identified only in areas remote from the project site, but which in actuality may extend undetected to the project site, and

(2) the fact that at greater distances from the project site, only onger faults would have the potential of producing rupture at the site.

Regional faults in southern Alaska that are known or inferred to be active but are distant from the project study area were not evaluated for surface rupture potential. These faults, because of their activity, were considered to be potential seismic sources and therefore were evaluated in terms of their potential for causing significant ground motions at the project site.

The faults and lineaments selected for further study on the basis of the length-distance criterion or because they appeared to be potential sources of significant ground shaking were transferred to 1:63,360-scale topographic maps for use during the aerial reconnaissance phase. During the aerial reconnaissance, the faults were examined for evidence (geologic features, and geomorphic expression) that would suggest whether or not youthful activity has occurred. The lineaments were examined to assess:

(1) whether they are or are not faults, and

(2) if they are not faults, what is their origin. For those lineaments that were interpreted to be faults or fault-related, further examination was made to look for evidence that would be suggestive of youthful activity.

After the aerial reconnaissance evaluation of the faults and lineaments, each feature was classified into one of three categories:

(1) a candidate significant feature;

(2) a non-significant feature; or

(3) an indeterminate feature.

Candidate significant features are those that at some point along their length, exhibit geologic morphologic, or vegetational expressions and characteristics that provide a strong suggestion of youthful fault activity. Non-significant features are those, which on the basis of the aerial reconnaissance, apparently do not possess geologic, morphologic, or vegetational characteristics and/or expressions suggestive of youthful fault activity; it was possible to identify non-fault-related origins for many features in this category. Indeterminate features are those lineaments that posses some geologic, morphologic, or vegetational characteristics or expressions that suggest the lineament may be a fault or fault-related feature with the possibility of youthful activity, but for which the evidence is not now compelling.

5.3.3.3 Candidate Significant Features

The candidate significant and indeterminate features identified during the first four phases of this task will require further study in order to evaluate their potential hazard to the proposed project facilities. These features occur in three principal areas, which are designated Areas A, B, and C (Figure 5-9) and are discussed in the following sections. The features presented in each area are discussed in terms of their proximity and orientation with respect to the nearest proposed project facility, previous mapping or published studies in which they have been identified, their expression on CIR photographs, and observations made during the aerial reconnaissance phase of the study.

Area A

Area A is bounded by Mt. Spurr and the Chakachatna River and Chakachamna Lake and Capps Glacier (Figure 5-9). Two candidate significant features, SU 56 and CU 50, and two indeterminate features, CU 52 and SU 150, are located within this area.

Feature CU 50 is a curvilinar fault that trends roughly east-west and extends from the mouth of the Nagishlamina River to Alice Glacier, a distance of about 5 miles. The western end of the feature is approximately 2 miles north of the lake outlet. CU 50 was initially identified on CIR photographs and is characterized by the alignment of:

(1) linear slope breaks and steps on ridges that project southward from Mt. Spurr, east of Barrier Glacier, with

(2) a linear drainage and depression across highly weathered granitic rocks west of Barrier Glacier.

During the aerial reconnaissance, disturbed bedded volcanic flows and tuffs were observed on the sides of canyons where crossed by the feature east of Barrier Glacier. These volcanic rocks are mapped as primarily being of Tertiary age, but locally may be of Quaternary age (Magoon and others, 1976). The possibility of the disturbed volcanic rocks being of Quaternary age suggests that CU 50 may be a youthful fault. The dense vegetation west of Barrier Glacier prohibited close examination of the fault in the granitic terrain.

CU 50 is classified as a candidate significant feature on the basis of its close proximity to proposed project facility sites and because it appears to displace volcanic rocks that may be Quaternary in age.

Feature CU 52 is a composite feature that consists of a fault mapped by Barnes (1966) and prominent morphological features observed on CIR photographs. The feature tends N63°E and extends along the mountain front from Capps

Glacier to Crater Peak Glacier, a distance of about 7.5 miles (Figure 5-9). The southwestern end of this feature is approximately 8 miles from the outlet of Chakachamna Lake. Along the northeastern portion of CU 52, from Capps Glacier to Brogan Glacier, the feature is defined by a fault that separates Tertiary granitic rocks from sedimentary rocks of the Tertiary West Foreland formation (Magoon and others, 1976). The southwestern segment, from Brogan Glacier to the Crater Peak Glacier, which extends the mapped fault a distance of 3 miles, was identified on the basis of aligned linear breaks in slope, drainages, and lithologic contrasts. During the field reconnaissance, a displaced volcanic flow was observed at the southwest end of the feature. Over most of its length, the fault was observed to be primarily exposed in bedrock terrain; youthful lateral moraines crossed by the fault did not appear to be affected.

This fault is considered to be a candidate significant feature because of its prominent expression in the Tertiary sedimentary and volcanic rocks crossed by the fault and because of its close proximity to the proposed project facilities. In addition, the fault may extend farther to the west along the mountain front than was observed on the CIR photographs or during the brief reconnaissance. If such is the case, it may connect with feature CU 50.

Feature SU 56 consists of two segments, a fault and a lineament. The combined feature trends N78°E and can be traced from the toe of Barrier Glacier to the edge of the mesa like area between the Chakachatna River and Capps Glacier, a distance of about 11 miles (Figure 5-9). The western extent of the fault segment is unknown, but if the lineament segment, defined by a linear depression across the toe of Barrier Glacier is associated with the fault, it may extend into and along the south side of Chakachamna Lake, very near the proposed lake tap.

SU 56 was recognized on the CIR photographs on the basis of the alignment of morphologic and vegetation features: a linear depression across the piedmont lobe of Barrier Glacier; a narrow linear vegetation alignment across the alluvial fan east of and adjacent to Barrier Glacier; small subtle scarps between Alice and Crater Peak Glaciers; and a prominent scarp and possibly a displaced volcanic flow between Crater Peak and Brogan Glaciers. During the field reconnaissance, all of the characteristics observed on the CIR photographs could be recognized with the exception of the vegetation alignment east of Barrier Glacier. At two locations along the feature, between Alice and Brogan Glaciers, displaced volcanic flows and tuffs were observed. At both localities the sense of displacement was down on the south side relative to the north side. The amount of displacement could not be measured due to the rugged terrain at the two locations. At the eastern end of the fault, near Brogan Glacier, the fault is on trend and appears to connect with one of seven faults observed in ridges along the eastside of Brogan Glacier where Barnes (1966) mapped two prominent bedrock faults.

Feature SU 56 is classified as a candidate significant feature because:

(1) it displaces volcanic rocks that may be of Quaternary age;

(2) the linear depression across the toe of Barrier Glacier is on trend with the fault; and

(3) the westward projection of the feature would pass very close to the proposed project facilities along the south side of Chakachamna Lake.

Feature SU 150 is composed of a series of parallel west-to-northwest-trending faults mapped by Barnes (1966). These faults are located on the Southwest side of the mesa-like area between Brogan and Capps Glacier, approximately 12 miles east of the outlet of Chakachamna Lake (Figure 5-9). These faults are exposed east of Brogan Glacier along a nearly vertical canyon wall that is deeply eroded into Tertiary sedimentary rocks mapped as the West Foreland formation (Magoon and others, 1976).

During the aerial reconnaissance, five additonal faults were observed along the wall of the canyon, south of the two faults mapped by Barnes (1966). Displacement on these faults, as well as on the two mapped by Barnes (1966), appears to be on the order of a few feet to a few tens of feet, with the south side up relative to the north side. An exception to this is the southernmost fault, on which the displacement appears to be relatively up on the north side. During the aerial reconnaissance, the faults could not be traced for any appreciable distance beyond their approximate length of 2 miles mapped by Barnes (1966). The southernmost fault, which is on trend with Feature SU 56, is probably an extension of that feature.

The series of faults associated with Feature SU 150 are included in this report as candidate significant features because of the probable connection of the southernmost fault in the series with Feature SU 56, which consists of morphologic features that are suggestive of youthful fault activity.

Area B

Area B includes the Castle Mountain fault and several parallel lineaments (SU 49, SU 84, and CU 56, Figure 5-9). The Castle Mountain fault is one of the major regional faults in southern Alaska. It trends northeast-southwest and extends from the Copper River basin to the Lake Clark area, a distance of approximately 310 miles (Beikman, 1980). The Castle Mountain fault crosses the mouth of the McArthur River Canyon near Blockade Glacier. The Castle Mountain fault is reported to be an oblique right-lateral fault with the north side up relative to the south side (Grantz, 1966; Detterman and others, 1974, 1976a, b).

The Castle Mountain fault is a prominent feature for most of its mapped length. The segment northeast of the Susitna River is defined by a series of linear scarps and prominent vegetation alignments in the Susitna Lowlands and lithologic contrast in the Talkeetna Mountains (Woodward-Clyde Consultants, 1980; Detterman and others, 1974, 1976a). Between the Susitna and Chakachatna Rivers, the fault is less prominent but is marked by a series of slope breaks, scarps, sag ponds, lithologic contrasts, and locally steeply dipping, sheared sedimentary rocks that are generally flat to gently dipping away from the fault (Schmoll and others, 1981;

Barnes, 1966). Southwest of the Chakachatna River, toward the Lake Clark area, the Castle Mountain fault is well defined and expressed by the alignment of slope breaks, saddles, benches, lithologic contrasts between plutonic and sedimentary rocks, shear zones, and a prominent topographic trench through the Alaska-Aleutian Range Batholith (Detterman and others, 1976b).

Displacement on the Castle Mountain fault has been occurring since about the end of Mesozoic time (Grantz, 1966). The maximum amount of vertical displacement is about 1.9 miles or more (Kelley 1963; Grantz, 1966). The maximum amount of right-lateral displacement is estimated by Grantz (1966) to have been several tens of miles along the eastern traces of the fault. Detterman and others (1967 a,b) cited 10 miles as the total amount of right-lateral displacment that has occurred along the eastern portion of the fault and about 3 miles as the maximum amount of right-lateral displacement that has occurred along the western portion, in the Lake Clark area.

Evidence of Holocene displacement has only been observed and documented along a portion of the Castle Mountain fault in the Susitna Lowland (Detterman and others, 1974, 1976a). During their investigation, Detterman and others (1974) found evidence suggesting that 7.5 ft. of dip-slip movement has occurred within the last 225 to 1,700 years. The amount of horizontal displacement related to this event is not know. However, Detterman and others (1974) cited 23 ft. of apparent right-lateral displacement of a sand ridge crossed by the fault. Bruhn (1979), based on two trench excavations, reported 3.0 to 3.6 ft. of dip-slip displacement, with the north side up relative to the south side, along predominately steeply south-dipping fault traces. He also reported 7.9 ft. of right-lateral displacement of a river terrace near one of the trench locations.

On the CIR photographs, the Castle Mountain fault is readily recognizable on the basis of the alignment of linear morphologic and vegetation features. The most notable features were observed in areas where bedrock is exposed at the surface and include: the prominent slope break that occurs along the southside of Mount Susitna and Lone Ridge; the prominent bench across the end of the Chigmit Mountains, between the McArthur and Chakachatna Rivers; and the alignment of glacial valleys in the Alaska Range, one of which is occupied by Blockade Glacier. In areas covered by glacial deposits, the expression of the Castle Mountain is more subtle and is dominantly an alignment of linear drainages, depressions, elongated mounds, and vegetation contrasts and alignments.

Based on interpretation of the CIR photographs and aerial reconnaissance observations, three lineaments (SU 49 and portions of SU 84 and CU 56) are believed to be traces or splays of the Castle Mountain fault. Lineament SU 49 is approximately 4 miles long, trends northeast, and is on line with the segment of the fault mapped between Lone Ridge and Mount Susitna (Figure 5-9). SU 49 was identified on the basis of the alignment of linear drainages and saddles on a southeast-trending ridge with a vegetation contrast in the Chakachatna River flood plain and by a possible right-lateral affect or the east facing escarpment along the west side of the Chakachatna River.

Lineament SU 84 partially coincides with the mapped trace of the Castle Mountain fault southwest of Lone Ridge. At the Chuitna River, the mapped trace of the Castle Mountain fault bends slightly to the north (Figure 5-9) whereas lineament SU 84 continues in a more southwesterly direction. Features along SU 84 that make it suspect are the alignment of an elongate mound on trend with steeply dipping sedimentary rocks exposed along the banks of the Chuitna River and the eroded reentrant along the high bluff on the northeast side of the Chakachatna River (Nikolai escarpment).

Lineament CU 56 is located east of Lone Ridge; it trends N70°E, is 7 miles long, and is an echelon to the mapped trend of the Castle Mountain fault. CU 56 was identified on the CIR photographs on the basis of the alignment of linear drainages and depressions and vegetation contrasts and alignments. During the aerial reconnaissance, a broad zone of deformed sedimentary rocks was observed on the location where CU 56 crosses the Beluga River. This locality coincides with a zone of steeply dipping sedimentary rocks mapped by Barnes (1966).

Area C

Area C is located south to southeast of the proposed project facilities sites, along the southeastern side of the Chigmit Mountains between the North Fork Big River and McArthur River (Figure 5-9). Three prominent northeast trending parallel features, SU 16, SU 22, and SU 23, are located in this area. SU 16 is an inferred fault that transverses both granitic bedrock and glacial deposits. SU 22 and SU 23 are primarily confined to the granitic bedrock terrain.

Feature SU 16 is the longest of the three northeast-southwest trending features located in Area C. This feature extends from approximately the intersection of the McArthur and Kustatan Rivers southwestward across a broad bench and along the northeast trending segment of the North Fork Big River, a distance of about 25 miles (Figure 5-9). SU 16 may extend even farther to the west if it follows a very linear glacial valley that is aligned with the northeast trending segment of the North Fork Big River. The northern end of SU 16 approaches to within 10 miles of the proposed project facilities in McArthur River area.

SU 16 was identified on the CIR photographs and aerial reconnaissance on the basis of the alignment of elongate low hills, linear depressions, vegetation contrasts, prominent slope breaks, and a lithologic contrast that form the broad bench like area between the North Fork Big River and Kustatan Rivers. The southwestern segment of the fracture is defined by the alignment of a linear portion of the North Fork Big River and a linear glacial valley north of Double Peak. During the aerial reconnaissance, no distinctive evidence, such as displaced lithologic units or bedding or scarps, was observed to confirm that SU 16 is actually a fault. Nonetheless, morphologic features that were observed do suggest that SU 16 is a fault and that it may be a youthful fault.

SU 16 is included in this report as a candidate significant fault because the morphologic features observed on the CIR photographs and during the aerial reconnaissance strongly suggest that it is a fault and may be a youthful fault.

Features SU 22 and SU 23 (Figure 5-9) are both northeast trending linear to curvilinear faults that parallel one another at a distance of about one mile. Feature SU 22 can be traced from about the McArthur River southwestward to Black Peak, a distance of about 16 miles. Feature SU 23 is approximately 8 miles in length and extends from Blacksand Creek southwestward to the north Fork Big River area. The northeastern ends of the two features (SU 22 and SU 23) approach to within 8 miles of proposed project facility sites in the McArthur River area. Both features were recognized on CIR photographs and are defined by the alignment of prominent linear troughs that are partially occupied by small lakes and ponds, scarps, slope breaks, benches, and saddles.

During the aerial reconnaissance, the two features could be readily traced across bedrock terrain (mapped as Jurassic to Cretaceous-Tertiary granitic rock; Magoon and others, 1976) on the basis of their morphologic features. Slicken-sided and polished surfaces were observed at several of the scarps and slope break localities examined; sheared zones were also observed during the reconnaissance. The southwestern portions of both features are located in very rugged terrain and are poorly defined due to the highly jointed granitic rocks that are present along this segment.

At the northern end, in the vicinity of Blacksand Creek, SU 23 appears to splay out with one trace trending toward SU 22 and one trace trending toward SU 16 (Figure 5-9). SU 22 also appears to die out in the vicinity of Blacksand Creek, although there was a subtle tonal alignment observed on the CIR photographs on the north side of the creek that suggests it may extend across Blacksand Creek toward the McArthur River.

SU 22 and SU 23 are included as candidate significant features because their prominent expression suggests that they are major structures and that they may be associated with SU 16 which is considered a fault with possible youthful activity.

Area D

Area D (Figure 5-9) includes the Bruin Bay fault, which is one of the major regional faults in southern Alaska. The Bruin Bay fault is a northeast-trending, moderate-to-steeply-northwest-dipping reverse fault that extends along the northwest side of the Cook Inlet from near Mount Susitna to Bechalaf Lake, a distance of about 320 miles (Detterman and others, 1976b). The fault approaches as close as approximately 30 miles south to southwest of the proposed project facilities at Chakachamna Lake and approximately 20 miles of the project facilities in the McArthur River.

The northern segment of the Bruin Bay fault, from about the Drift River area to Mount Susitna, is projected beneath surficial deposits from its last bedrock exposure north of Katchin Creek. The projection is based on a prominent linear depression across Kustatan Ridge, alignment of linear lakes and depressions in the lowland area west and north of Tyonek, and highly disturbed and faulted Teritiary sedimentary rocks along the Chuitna and Beluga River (Detterman and others, 1976b; Magoon and others, 1976; Schmoll and others, 1981). To the south of Katchin Creek, where the fault is exposed in bedrock areas, the trace of the fault is commonly marked by a zone of crushed rock a few to several hundred meters wide and saddles or notches (Detterman and others, 1976b).

The sense of displacement along the fault is reverse with the north side up relative to the south side (Magoon and others, 1976; Detterman and others, 1976b). Detterman and Hartsock (1966) reported left-lateral displacement of 6 miles or less has occurred along the fault in the Iniskin-Tuxedni region, southwest of the study area. The youngest unit reported displaced by the Bruin Bay fault is the Tertiary sedimentary Beluga formation (Magoon and others, 1976). No displacement of Holocene surficial deposits between Katchin Creek and the probable junction of the fault with Castle Mountain fault near Mt. Susitna has been observed or documented (Detterman and others 1976b; Detterman, personal communication, 1981).

During the analysis of the CIR photographs, several subtle to prominent discontinuous lineaments were identified along the projected trend of the Bruin Bay fault across the McArthur and Chakachatna River flood plains near the Cook Inlet, and along the lowland area west of Tyonek. The lineaments were examined during the aerial reconnaissance and no displacement or disturbed Holocene deposits were observed. Several of the lineaments, however, did coincide with disturbed or faulted sedimentary rocks of the Beluga formation exposed along the Chuitna and Beluga Rivers. Further work is needed to assess whether the glacial and/or fluvial deposits overlying the sedimentary bedrock have been faulted or disturbed.

Although no evidence has been observed or reported that would indicate youthful fault activity along the Bruin Bay fault, several of the lineaments observed on the CIR photographs are suggestive of youthful fault activity. On the basis of the lineaments along the projected trace of the Bruin Bay fault, and the fact that the fault is suspected to intersect with the Castle Mountain fault, the Bruin Bay fault is considered for this report to be a candidate significant feature.

5.3.3.3 Implications with Respect to the Proposed Hydroelectric Project

Based on the results of the work to date a preliminary assessment can be made regarding the potential surface faulting hazards and seismic sources of ground motion (shaking) with respect to the proposed project site.

(1) Within the study area, faults and lineaments in four areas have been identified for further evaluation in order to assess and better understand their potential effect on project considerations. For example, if feature SU 56 is an active fault, its trend is toward the area proposed for the lake tap and the extent and activity of this feature clearly require evaluation. Several of these features may prove to be capable of producing earthquakes, thus both ground shaking and surface rupture in the project area.

(2) The Castle Mountain fault is located along the southeast side of the Chigmit Mountains at the mouth of McArthur Canyon. Although no displacements of Holocene deposits have been observed or reported for the segment of the Castle Mountain fault between the Susitna River and the Lake Clark area, the fault is considered an active fault on the basis of the reported displacement of Holocene deposits east of the project area in the vicinity of the Susitna River.

(3) Based on a review of the available literature and detailed studies conducted for major projects in southern Alaska there are three potential seismic sources that may have an effect on the project site. These include: the subduction zone, which consists of the Megathrust and Benioff zone; crustal seismic zone; and severe volcanic activity. The Castle Mountain fault (crustal seismic source) and the Megathrust segment of the subduction zone are expected to be the most critical to the project with respect to levels of peak ground acceleration, duration of strong shaking, and development of response spectra.

5.4 References

Barnes, F. F., 1966, Geology and coal resources of the Beluga-Yentna Region, Alaska: U.S. Geological Survey Bulletin 1202-C, 54 p.

Beikman, H. M., compiler, 1974, Preliminary geologic map of the southeast quadrant of Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-612, scale 1:1,000,000.

Beikman, H. M., compiler, 1980, Geologic map of Alaska: U.S. Geological Survey, scale 1:2,500,000.

Bruhn, R. L., 1979, Holocene displacement measured by trenching the Castle Mountain fault near Houston, Alaska: Alaska Division of Geological and Geophysical Surveys, Geological Report 61, 4 p.

Bureau of Reclamation, Chakachamna Project Alaska - Status report March, 1962: Bureau of Reclamation, Alaska District Office, Juneau, Alaska, unpublished report, 21 p.

Capps, S. R., 1935, The southern Alaska Range: U.S. Geological Survey Bulletin 862, 101 p.

Detterman, R. L., and Hartsock, J. K., 1966, Geology of the Iniskin-Tuxedni Region, Alaska: U.S. Geological Survey Professional Paper 512, 78 p.

Detterman, R. L., Plafker, G. Hudson T., Tysdal, R. G., and Pavoni, N. 1974, Surface geology and Holocene breaks along the Susitna segment of the Castle Mountain fault, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-618, scale 1:24,000.

Detterman, R. L., Plafker, G., Tysdal, R. G., and Hudson, T., 1976a, Geology and surface features along part of the Talkeetna segment of the Castle Mountain-Caribou fault system, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-738, scale 1:63,360.

Detterman, R. L., Hudson, T., Plafker, G., Tysdal, R. G., and Hoare, J. M., 1976b, Reconnaissance geologic map along the Bruin Bay and Lake Clark faults in Kenai and Tyonek quadrangles, Alaska: U. S. Geological Survey Open-File Report 76-477, 4 p., scale 1:250,000.

Giles, G. C., 1967, Barrier Glacier investigations and observations in connection with waterpower studies: U.S. Geological Survey, unpublished report, 61 p.

Grantz, Arthur, 1966, Strike-slip faults in Alaska: U.S. Geological Survey Open-File Report, 82 p.

Hastie, L. M., and Savage, J. C., 1970, A dislocation model for the Alaska earthquake: Bulletin of the Seismological Society of America, v. 60, p. 1389-1392.

Hunt, C. B., 1967, Physiography of the United States: W. H. Freeman and Co., San Francisco, 480 p.

Jackson, B. L., 1961, Potential waterpower of Lake Chakachamna, Alaska: U. S. Geological Survey Open-File Report, 20 p.

Johnson, A., 1950, Report on reconnaissance of Lake Chakachamna (sic), Alaska: U. S. Geological Survey Open-File Report, 8 p. plus plates.

Juhle, W., and Coulter, H., 1955, The Mt. Spurr eruption, July 9, 1953: Transactions, American Geophysical Union, v. 36, no. 2, p. 199-202.

Karlstrom, T. V., 1964, Quaternary geology of the Kenai lowland and glacial history of the Cook Inlet region, Alaska: U. S. Geological Survey Professional Paper 443, 69 p.

Karlstrom, T. V., Coulter, H. W., Jernald, A. T., Williams, J. R., Hopkins, D. M., Drewes, H., Huller, E. H., and Candon, W. H., 1964, Surficial Geology of Alaska: U. S. Geological Survey Miscellaneous Geologic Investigation Map I-557, scale 1:1,584,000.

Kelley, T. E., 1963, Geology and hydrocarbons in Cook Inlet Basin, Alaska, in Childs, D. E., and Beebe, B. W., eds., Backbone of the Americas Symposium: American Association of Petroleum Geologists Memoir 2, p. 278-296.

Lahr, J. C., and Stephens, C. D., 1981, Review of earthquake activity and current status of seismic monitoring in the region of the Bradley Lake Hydroelectric Project: U. S. Geologica, Survey Report, prepared for the Department of the Army, Alaska District, Corpos of Engineers, 21 p.

Lamke, R. D., 1972, Floods of the summer of 1971 in southcentral Alaska: U. S. Geological Survey, Water Resources Division, Alaska District, Open-File Report, p. 30-31.

Magoon, L. B., Adkison, W. L., and Egbert, R. M., 1976, Map showing geology, Wildcat Wells, Tertiary plant fossil localities, K-Ar age dates, and petroleum operations, Cook Inlet area, Alaska: U. S. Geological Survey Map I-1019, scale 1:250,000.

McCann, W. R., Perez, O. J., and Sykes, L. R., 1980, Yakataga Gap, Alaska: Seismic history and earthquake potential: Science, v. 207, p. 1309-1314.

Miller, R. D., and Dobrovolny, E., 1959, Surficial geology of Anchorage and vicinity, Alaska: U. S. Geological Survey Bulletin 1093, 128 p.

National Oceanic and Atmospheric Administration, 1981, Hypocenter Data File Period of Coverage 1929 to 1980: Environmental Data Services, Boulder, Colorado.

Pewe, T. L. Hopkins, D. M., and Giddings, J. L., 1965, The Quaternary geology and archeology of Alaska: in Wright, H. E. and Frey, D. G., eds., The Quaternary of the United States, Princeton University Press, Princeton, p. 355-374.

Pewe, T. L., 1975, Quaternary geology of Alaska: U.S. Geological Survey Professional Paper 835, 145 p.

Plafker, G., 1969, Tectonics of the March 27, 1964, Alaska Earthquakes: U. S. Geological Survey Professional Paper 543-I, 74 p.

Porter, S. C., and Denton, G. H., 1967, Chronology of Neoglaciation in the North American cordillera: American Journal of Science, v. 265, p. 177-210.

Post, A., 1969, Distribution of surging glaciers in western North America: Journal of Glaciology, v. 8, no. 53, p. 229-240.

Post, A., and Mayo, L. R., 1971, Glacier dammed lakes and outburst floods in Alaska: U. S. Geological Survey Hydrologic Investigations Atlas HA-455.

Richter, C. F., 1958, Elementary seismology: San Francisco, Freeman Press, 768 p.

Schmoll, H. R., Szabo, B. J., Rubin, M., and Dobrovolny, E., 1972, Radiometric dating of marine shells from the Bootlegger Cove clay, Anchorage area, Alaska: Bulletin, Geological Society of America, v. 83, p. 1107-1114.

Schmoll, H. R., Yehle, L. A., Gardner, C. A., 1981, Preliminary geologic map of the Congahbuna area, Cook Inlet Region, Alaska: U. S. Geological Survey Open-File Report 81-429, 8 p.

Schmoll, H. R., Pasch, A. D., Chleborad, A. F., Yehle, L. A., and Gardner, C. A., in press, Reconnaissance engineering geology of the Beluga Coal resources area, south-central Alaska, in Rao, P. D., ed., Focus on Alaska's Coal '80, Conference, Fairbanks, Alaska, Proceedings: Fairbanks, University of Alaska, School of Mineral Industry MIRL Report No. 47.

Slemmons, D. B., 1977, State-of-the-art for assessing earthquake hazards in the United States; Part 6: Faults and earthquake magnitude with Appendix on geomorphic features of active fault zones: U. S. Army Engineering Waterways Experiment Station, Vicksburg, Contract No. DACW 39-C-0009, 120 p.

Slemmons, D. B., 1980, Letter to R. E. Jackson, Nuclear Regulatory Commission, dated 5 November 1980 and errata, dated 4 December 1980, in San Onofre Nuclear Generating Stations Units 2 and 3, Safety Evaluation Report, NUREG-0712, Appendix E, p. E1-E28.

Sykes, L. R., 1971, Aftershock zones of great earthquakes, seismicity gaps, and earthquake prediction for Alaska and the Aleutians: Journal of Geophysical Research, v. 76, p. 8021-8041.

Tarr, R. S., and Martin, L., 1912, The earthquakes at Yakutat Bay, Alaska in September 1899: U. S. Geological Survey Professional Paper 69, 135 p.

TenBrink, N. W., and Ritter, D. F., 1980, Glacial chronology of the north-central Alaska Range and implications for discovery of early man sites: Geological Society of America, Abstracts with Programs, 1980, p. 534.

TenBrink, N. W., and Waythomas, C. F., in preparation, Late Wisconsin glacial chronology of the north-central Alaska Range - a regional synthesis and its implications for early man settlements.

Thatcher, W., and Plafker, G., 1977, 1899 Yakutat Bay, Alaska Earthquakes: Seismograms and Crustal Deformation (Abs.): Geological Society of America Abstracts with Programs, v. 9, p. 515.

Trainer, F. W., and Waller, R. M., 1965, Subsurface stratigraphy of glacial drift at Anchorage, Alaska: U. S. Geological Survey Professional Paper 525-D, p. D167-D174.

U. S. Geological Survey, 1980, Volcano Log: Mount St. Helens, 1980, Spall, H., (ed.), in Earthquake Information Bulletin: U. S. Geological Survey, July-August 1980, v. 12, no. 4, p. 142-149.

Williams, J. R., and Ferrinas, O. J., 1961, Late Wisconsin and recent history of the Matanuska Glacier, Alaska: Arctic, v. 14, no. 1, p. 83-90.

Woodward-Clyde Consultants, 1978, Offshore Alaska seismic exposure study: Prepared for Alaska Subarctic Operators' Committee (ASOC), March, 1978, v. 1 through 5.

Woodward-Clyde Consultants, 1979, Reconnaissance Geology, Bradley Lake Hydroelectric Project: Contract No. DACW 85-79-C-0045, Department of the Army, Alaska District, Corps of Engineers, 65 p.

Woodward-Clyde Consultants, 1980a, Seismicity Study Bradley Lake Hydroelectric Project: Contract No. DACW 85-79-C-0045 Modification P0001, Department of the Army, Alaska District, Corps of Engineers, 35 p.

Woodward-Clyde Consultants, 1980b, Interim Report on Seismic Studies for Susitna Hydroelectric Project for Acres American Incorporated: Alaska Power Authority, Susitna Hydroelectric Project, Subtask 4.01 through 4.08.

Woodward-Clyde Consultants, 1981, Draft Report Bradley Lake Hydroelectric Project Design Earthquake Study: Contract No. DACW 85-79-C-0045 Modification 0005, Department of the Army, Alaska District, Corps of Engineers, 53 p.

ENVIRONMENTAL STUDIES

6.0 ENVIRONMENTAL STUDIES

As described previously, one component of the Chakachamma Project Feasiblity Study is an environmental evaluation of the natural and human resources. To accomplish the evaluation, the environmental studies were divided into four disciplines: environmental hydrology, acquatic biology, terrestrial biology, and human resources. The objectives of this feasibility study are to:

- o obtain sufficient information on the environment of the study area to identify constraints that may be placed on the project, potentially affecting its feasibility; and

- o obtain sufficient information to prepare the required environmental exhibits for the FERC license application.

To meet these objectives a two phase program has been designed. Phase I consists of a reconnaissance-level survey conducted during the fall season of 1981. This survey provides a more thorough understanding of the study area, and hence allow a more appropriate design of 1982 Phase II studies.

During 1981, there were two reconnaissance efforts. The first overview was conducted in August by the task leaders of the biological and hydrological disciplines. The objective of the August site visit was to document the presence of sockeye salmon in the major project waters and to survey the site in preparation for the fall reconnaissance. The second investigation was carried out in mid-September and involved two weeks of field data collections. The objectives of this effort were to obtain sufficient information and understanding of the study area and its resources to allow for the design of more detailed 1982 studies and to assess, in a preliminary nature, the overall environmental assessment of the conceptual designs of the project alternatives. Coincident with the 1981 field studies were ongoing reviews of the literature and discussions with key agency and native corporation personnel.

Specific objectives and preliminary results of the 1981 environmental investigations by each discipline are presented in the following parts of this section. Preliminary conclusions are based on data obtained from agency personnel, available literature, and the limited information collected during the fall reconnaissance programs.

Preliminary assessments of anticipated environmental impacts associated with each project alternative are presented in Section 7, while descriptions of conceptual work plans for 1982 programs are presented in Chapter 10.

6.1 Environmental Study Area

The study area is located on the west side of Cook Inlet approximately 60 miles west of Anchorage (Figure 6.1). This region supports a wide variety of biological and visual resources, and is bordered by the Alaska Mountain Range on the west and Upper Cook Inlet on the east. Administration of the lands and waters of the area come under the jurisdiction of the U.S. Fish and Wildlife Service, the National Park Service, the Alaska Department of Fish and Game, the Alaska Department of Natural

Resources, and two native corporations (Cook Inlet Region and Tyonek Native). Although management of the area is complex due to the multitude of organizations responsible for the area, specific sites within the study area have specific management objectives. While the Trading Bay State Game Refuge is maintained to protect waterfowl and provide sport hunting, the Lake Clark National Park's principal objective is to maintain the ecosystem in as nearly pristine a condition as possible. Research in both areas involves documenting pristine conditions and processes, and determining the stability of the ecosystems. In contrast to refuge and park objectives, the native corporations manage their lands for high yield timber harvesting and maintenance of subsistence resources.

Between the mountains and the tidal flats in Trading Bay, the land is flat and drainage is poor. Throughout these lower elevations of the project area, the absence of relief has contributed to the formation of a continuous array of marshes, bogs, and ponds. Two major rivers transport the water from the mountains to the inlet, collect runoff from adjacent marshes and bogs, and provide both migration and spawning habitat for numerous species of resident and anadromous fish. The first of these major rivers, the McArthur, has its origin at McArthur Glacier, yet receives the majority of its water from Blockade Glacier. The second major waterway is the Chakachatna River. Originating at the outlet of Chakachamna Lake, the river flows east about 15 miles through a canyon containing almost continuous rapids and few pools. Once on the low flatlands, the Chakachatna floodplain gets substantially larger until it reaches its divergence from Noaukta Slough, after which it becomes much narrower. The Noaukta Slough carries a large proportion of the flow from the divergence as it fans out into a two mile wide tangle of interlaced channels before it joins the McArthur River. Downstream from this confluence, the McArthur flows several miles to the Chakachatna River confluence, after which it passes through marshes and tidal flats before reaching Trading Bay.

Chakachamna Lake and its tributaries, the Nagishlamina River, the Chilligan River, and Kenibuna Lake are located in the higher elevations of the study area above the Chakachatna River. As with the rest of the project area, these high elevation lands and waters support a variety of fish and wildlife. Chakachamna Lake is approximately 350 feet deep with mountains rising 3000 to 4000 feet above its steep, rocky shoreline. At the mouths of the major tributaries are large deltas, composed mainly of sand and glacial-fluvial deposits.

6.2 Environmental Hydrology

6.2.1 Background

The overall objectives of the environmental hydrology studies for the Chakachamna Hydroelectric Project are to:

- assess the impacts of flow regulation on the physical characteristics of the Chakachatna and McArthur River systems and

- provide input to the biological and socioeconomic impact analysis investigations.

Studies conducted to date for this interim report have addressed both of these objectives to a reconnaissance level.

6.2.1.1 Data Base

There have been few, if any, environmental hydrology studies conducted in the project area in relation to the development of hydropower. A number of hydrologic studies have been conducted on the Chakachatna River flow regime to evaluate the potential for hydropower using these flows; these studies were first reported in 1950 and were investigated in more detail in the 1960's. Section 4.0 of this report summarizes the current level of knowledge of the flows available for hydropower generation.

Mr. Robert D. Lamke, Chief of the Hydrology Section of the Water Resources Division of the U.S. Department of Interior Geological Survey, provided flow data and standard hydrologic analyses for use in this investigation. Hydrologic data for engineering purposes are presented in Section 4.0 of this report. Some of these analyzed data were used in the environmental hydrology evaluations.

6.2.1.2 Study Area

The study area was described in the previous section. The major areas studied during the environmental hydrology reconnaissance investigation included:

- Three areas near the mouths of the major tributaries to Chakachamna Lake; Shamrock Glacier Rapids (A, Fig.

6.2), Chilligan River (B, Fig. 6.2), and Nagishlamina River (C, Fig. 6.2).

- o Four areas along the Chakachatna River (D through G, Fig. 6.2).
- o Two areas along Middle River (F and H, Fig. 6.2).
- o Eight areas along the McArthur River (I through P, Fig. 6.2).
- o Two areas of Noaukta Slough Channels at their confluence with McArthur River (O and P, Fig. 6.2).

Other areas along the streams that may be impacted by the project were also investigated, but in less detail.

6.2.2 Study Objectives and Methodology

The specific objectives of the environmental hydrology reconnaissance study leading to this interim report were to:

- o collect sufficient quantitative and qualitative data to make a preliminary assessment of the physical impacts related to each of the project alternatives, and
- o provide input to preliminary assessments of biological and socioeconomic impacts related to each of the project alternatives

These objectives were met through a combination of field data collection and office evaluations, as described in the following sections:

6.2.2.1 Hydrology

Field Data Collection. Hydrologic field data that were collected during the two week field reconnaissance include:

- o discharge measurements,
- o lake water level survey, and
- o wetland/river level surveys.

Discharge measurements were taken at study locations D, F, G, H, I, K, L, and M (Figure 6.2) using procedures similar to those of the U.S. Geological Survey; however, for expediency during this brief reconnaissance, only about 10 measuring stations were used in each channel. A Marsh-McBirney flow meter was used to measure velocity at a depth equal to 60 percent of the full depth.

A survey was conducted at Chakachamna Lake to establish the lake surface elevation at the time of the survey. Vertical angle measurements were taken from Bench Mark MORE (on the south side of the lake mid-way along the lake) to the lake water level. A Topcon DMS-1 electronic distance measurement system was used to measure distances.

Standard differential leveling techniques were used to measure the difference between the water level in a wetland and the water level in a channel of the Noaukta Slough a short distance downstream from study area E (Figure 6.2). An approximate method using a hand level was used in study area H (Figure 6.2) to evaluate the water level difference between a wetland and Middle River.

Office Evaluations. Office evaluations were conducted to develop approximate hydrologic data at eight locations in the study area (numbered locations, Figure 6.2). Developed data include:

- o natural mean monthly flows,
- o mean annual flows for natural flow conditions,
- o natural flood flows at selected locations
- o natural low flow conditions at selected locations.

In addition, instream flow requirements for maintaining fisheries habitat were calculated on a monthly basis at the outlet of Chakachamna Lake. All office evaluations were selected to provide reasonable estimates of flow conditions for the purpose of making preliminary impact assessments.

Natural mean monthly flows were estimated from the relations shown in Table 6.1 and the following assumptions:

- o mean monthly flows per square mile based on calculated Chakachamna Lake inflows (from Section 4.0) are representative of those from mountainous areas,
- o mean monthly flows per square mile based on the 4 year average of mean monthly flows of the Chuitna River (Station 15294450) are representative of those from non-mountainous areas, and
- o proportions of flow in downstream channels at each divergence is the same as the proportion of flow in those channels at the time of the reconnaissance measurement.

Table 6.1. Relations used in calculating natural mean monthly flows at eight representative locations.

Location Number[a]	River	Relation[b]
1	Chakachatna	Q_{m1} = U.S.G.S. data for Chakachatna River near Tyonek (15294500)
2	Chakachatna	$Q_{m2} = Q_{m1} + A_{1-2} \times (B+C)/2$
3	Chakachatna	$Q_{m3} = Q_{m2} + 0.913A_{2-3} \times (B+C)/2 + 0.087\ A_{2-3} \times C$
4	Chakachatna	$Q_{m4} = 0.084\ Q_{m3} + (O\ B4\ A_{3-D} + A_{D-4}) \times C$
5	Middle	$Q_{m5} = 0.016\ Q_{m3} + (0.16\ A_{3-D} + A_{D-5}) \times C$
6	Upper McArthur	$Q_{m6} = A_6 \times B$
7	McArthur	$Q_{m7} = Q_{m6} + A_{6-7} \times B$
8	McArthur	$Q_{m8} = Q_{m7} + A_{7-8} \times C + 0.90\ Q_{m3}$

[a]See Figure 6.2 for locations

[b]Qmi = mean monthly flow for any month at location i

A_{i-j} = contributing drainage area between locations i and j; a D subscript r@presents the location of the divergence of Chakachatna and Middle Rivers

B = mean monthly flow per square mile based on calculated Chakachamna Lake inflows

C = mean monthly flow per square mile based on the 4 year average of mean monthly flow of the Chuitna River (Station 15294450)

Mean annual flows were calculated from the calculated mean monthly flows on a weighted average method; the weighting was based on the number of days in each month. For example, mean January flow would be multiplied by 31/365 to obtain the January portion of the mean annual flow.

The natural flood flows were calculated based on a regional flood frequency analysis (Lamke 1979). The drainage area, percentage of lakes and percentage of forest cover, were obtained for each location from 1,250,000 scale topographic maps; Lamke's (1979) isoline maps were used to obtain mean annual precipitation and minimum January temperature. A weighted average for these parameters was used for locations 4, 5, and 8 based on the percentage of flow carried by each channel downstream from divergences as measured during the reconnaissance.

The natural low flow conditions along the Chakachatna River were estimated using on the low flow conditions per square mile from the Chakachatna River gaging station records. The low flow analyses of the gage records were provided by the U.S. Geological Survey.

Mitigative releases for fisheries were calculated using different methods for the McArthur and Chakachatna River powerhouse alternatives. The results of these analyses are presented in Section 7. For the alternatives with the powerhouse on the McArthur River, fisheries habitat down the entire length of the Chakachatna had to be considered.

The method selected to estimate the instream flow requirements for this preliminary assessment is called the Montana Method (Tennant 1975). Several major assumptions had to be made when using the Montana Method; these include:

- that the method is valid for a complex stream system like the Chakachatna River,
- that the seasonal flow regimes postulated in the model are appropriate for south-central Alaska, and
- that the method is appropriate for the complex of anadromous and resident salmonids found in the Chakachatna River.

The instream flow requirements using this method are based on a percentage of the mean annual flow. The percentage is based on observations that the wetted perimeter of a stream (potential usable habitat) typically increases rapidly with increasing discharge up to a flow equal to 30 percent of the mean annual flow. For higher discharges, the wetted perimeter increases less rapidly. Tennant (1975) refers to minimum instantaneous flows of 30 percent of the mean annual flow as "good" flow. The method also calls for two different seasonal flow regimes, a low flow period from October through March and a higher flow period from April through September. "Fair" to "good" flows can be obtained if 10 and 30 percent of the mean annual flow is maintained during the low flow and higher flow periods, respectively. These percentages were used to estimate what instream flow needs to be maintained for the fishery resource. The natural flow during the low flow period is periodically less than the recommended flows; natural flows were assumed to be released in these situations.

The required flow for the fishery resource is different for the alternatives with the powerhouse on the Chakachatna River. For these alternatives, the dewatered section of the Chakachatna River is in the canyon; this section of river apparently provides primarily migratory habitat and relatively small amounts of spawning and rearing habitats. Thus, it was assumed that maintenance of the migratory habitat is sufficient to mitigate the major impacts of dewatering this section of stream.

It was assumed that a 30 cfs flow release would be adequate to maintain a sufficient migratory pathway between the powerhouse and the lake, possibly requiring some channelization.

6.2.2.2 Hydraulics

Field Data Collection. Hydraulic data that were collected during the field reconnaissance include:

- o stream and floodplain transects,
- o stream gradients, and
- o lake bottom profiles.

The stream and floodplain transect data were collected using one or a combination of the following methods:

- o using transit and electronic distance measuring equipment to get horizontal and vertical angles and distances to locations along the transect,
- o using discharge measurement data to represent the transect below water level, and
- o using a Raytheon DE-719B depth recorder mounted to a boat to represent the transect below water level in streams too deep or swift to wade.

Some transects consist only of the portion of the transect below water level.

Stream gradients were surveyed using a transit and electronic distance measuring equipment. Water surface profiles typically were surveyed, although bed profiles also were surveyed at the lake tributary study areas.

Lake bottom profiles were collected using a Raytheon DE 719B depth recorder. Horizontal control was provided in an approximate manner by relating to terrain features and by monitoring boat speed.

Office Evaluation. Hydraulic office evaluations were conducted to provide estimates of the following types of information:

- o hydraulic geometry (width, depth, and velocity as a function of discharge) and
- o flooding and backwater characteristics.

The hydraulic geometry as defined above was calculated using the Manning equation. Input data to the equation include channel geometry and energy gradient that were obtained from the stream and floodplain transects and water surface profiles that were measured in the field. Manning roughness coefficients were estimated by back-calculating values from discharges measured or estimated in the field and checking the reasonableness based on previous experience.

Flooding is estimated at selected transect locations by establishing the stage (water level) corresponding to the calculated flood discharge from the hydraulic geometry data. Areal extent of flooding between transects is qualitative and based on aerial photographs and field observations. Backwater characteristics in tributaries are described qualitatively based on a review of flood levels and surveyed stream gradients.

6.2.2.3 Channel Configuration and Process

Field Data Collection. Data collected during the field reconnaissance pertaining to channel configuration and process include:

- observations of channel configuration,
- observations of lateral migration activity,
- observations of sediment transport characteristics.
- stream substrate
- potential fish overwintering area location surveys, and
- fish spawning channel location surveys.

The latter two data types were collected in preparation for fish overwintering studies planned for early in 1982.

The observations of channel configuration, lateral migration activity and sediment transport characteristics were qualitative and were based on the experience of the environmental hydrologist. Stream substrate was described qualitatively and documented in some cases with photographs. The surveys conducted to establish the location of selected potential fish overwintering areas and identified fish spawning channels used a combination of transit, electronic distance measuring devices, tape, and magnetic compass. Surveys were referenced to temporary benchmarks established for this survey. The results of these surveys are not presented later in this report since they were collected only for use in later field investigations.

Office Evaluations. Channel configuration, lateral migration activity and sediment transport characteristics were qualitatively evaluated for natural stream flows. The data used to evaluate these characteristics include the hydraulic characteristics discussed previously, aerial photographs, and field observation. These preliminary evaluations were qualitative and the results are descriptive.

6.2.3 Results and Discussion

The results of this reconnaissance level investigation are preliminary. Certain assumptions have been made to enable a comparison of alternatives; these assumptions will be checked during the more detailed investigations planned for 1982.

The results of the field reconnaissance and office evaluations for the current natural conditions are presented and discussed below.

6.2.3.1 Hydrology

The locations, date, and results of discharge measurements during the fall reconnaissance are summarized in Table 6.2. Estimates of mean monthly and mean annual flows at eight representative locations in the study area are presented in Table 6.3. A comparison of measured values with mean monthly values indicates that the flow at the time of the survey generally was less than the mean for September. The flow generally was decreasing throughout the two week reconnaissance. The discharge measurements indicate that approximately 90 percent of the Chakachatna River flow goes through Noaukta Slough. The remaining 10 percent flows to the Chakachatna and Middle River divergence where approximately 84 percent of this flow remains in the Chakachatna River and 16 percent flows down Middle River. This flow distribution was assumed to remain constant through the year for the purposes of comparison in this preliminary investigation.

Calculated flood discharges at eight representative locations are summarized in Table 6.4. Also shown are results of a flood frequency analysis of the Chakachatna River gage data. It is apparent that the regional flood frequency analysis yields larger flood magnitudes than the gage values, especially at greater recurrence intervals. This may be in part due to the lack of inclusion of the lake parameter in the equation for parameter D, representing the standard deviation of the floods. Calculated values at locations 1 through 5 and 8 are affected by this discrepancy. Locations 6 and 7 are likely to be better represented by the calculated values since there are no significant lakes in their basins; these locations are most significant in the evaluation of the alternatives. Thus the discrepancy at the other sites was not resolved for this preliminary investigation.

The results of the low flow investigation are summarized in Table 6.5. Low flows were not calculated downstream from the Chakachatna River-Noautka Slough divergence due to lack of confidence in predicting the flow distribution at low flows. Low flows on the McArthur River should not be reduced by the project and thus were not calculated. The lake elevation survey resulted in an elevation of 1142 feet.

Table 6.2. Locations, date, and results of field discharge measurements during September 1981

Study[a] Area	Loc.[b]	Description	Date	Discharge
D	2	Chakachatna R. U/S of Straight Ck.	21 Sept.	5,813
D	-	Straight Ck. U/S of Chakachatna R.	21 Sept.	471
E	-	Chakachatna R. D/S of Noaukta Sl. Div.	22 Sept.	681
E	-	Noaukta Sl. D/S of Chakachatna R. Div	22 Sept.	1,285[c]
F	-	Chakachatna R. D/S of Middle R. Div.	26 Sept.	428
F	-	Middle R. D/S of Chakachatna R. Div	26 Sept.	80
G	4	Chakachatna R. U/S of McArthur R.	26 Sept.	475
H	5	Middle R. U/S of Mouth	26 Sept.	132
I	-	Upper McArthur R. U/S of Powerhouse	26 Sept.	155
J	-	Upper McArthur R. nr. Powerhouse	24 Sept.	93[c]
K	-	Upper McArthur R. D/S of Powerhouse	26 Sept.	297
L	6	Upper McArthur R.	24 Sept.	417
L	-	Upper Blockade Glacier Channel	24 Sept.	312
M	-	McArthur R. U/S of Lower Bl. Gl. Chan.	25 Sept.	696
M	-	Lower Blockade Glacier Channel	25 Sept.	514
N	-	Upper Clearwater Tributary	25 Sept.	87

[a] Study areas are illustrated on Figure 6.2

[b] Loc. is the corresponding representative location at which flow regimes have been calculated

[c] Partial measurement

Table 6.3. Estimated natural mean monthly and mean annual flows at eight representative locations.[a]

MONTH	B[b] (cfs/mi^2)	C[c] (cfs/mi^2)	Qm1[d] (cfs)	Qm2 (cfs)	Qm3 (cfs)	Qm4 (cfs)	Qm5 (cfs)	Qm6 (cfs)	Qm7 (cfs)	Qm8 (cfs)
JAN	0.45	0.78	613	670	720	69	34	24	170	830
FEB	0.39	0.63	505	550	590	57	28	21	150	690
MAR	0.37	0.53	445	490	520	50	24	20	140	620
APR	0.53	1.1	441	520	580	61	43	29	200	740
MAY	2.0	8.2	1,042	1,530	1,930	250	270	110	750	2,580
JUNE	7.0	8.8	5,875	6,630	7,220	700	370	380	2,620	9,250
JULY	11.0	2.6	11,950	12,600	13,070	1,130	290	590	4,100	15,970
AUG	9.6	1.7	12,000	12,540	12,930	1,100	260	520	3,600	15,330
SEP	4.5	4.3	6,042	6,460	6,790	620	230	240	1,690	7,870
OCT	1.5	2.8	2,468	2,670	2,830	270	130	83	570	3,160
NOV	0.77	1.6	1,206	1,320	1,410	140	69	42	290	1,580
DEC	0.52	1.2	813	890	960	93	49	28	190	1,070
MEAN ANNUAL	--	--	3,645	3,935	4,160	382	150	175	1,215	5,011

[a]See Figure 6.2 for locations

[b]B = mean monthly flow per square mile based on calculated Chakachamna Lake inflows

[c]C = mean monthly flow per square mile based on a 4 year(1976-1979) average of mean monthly flows of the Chuitna River (Station 15294450); mean annual flow not used

[d]Qmi = Estimated natural mean monthly flow at location i

Table 6.4. Natural flood flows at eight representative locations based on a regional flood frequency analysis developed by Lamke (1979).

Location[a]	A[b] (mi^2)	P[c] (in)	St[d] (%+1)	F[e] (%+1)	T[f] (F^o)	M[g]	D[g]	$Q_{1.25}$[h] (cfs)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)	Q_{25} (cfs)	Q_{50} (cfs)	Q_{100} (cfs)
1[i]	1120	-	-	-	-	-	-	13,527	15,848	19,051	21,202	23,962	26,055	28,183
1	1120	75	4	17	0	20,540.2	1.46	14,570	19,289	25,725	30,556	35,391	40,845	47,198
2	1216	75	3.7	17	+1	22,542.4	1.44	16,156	21,150	27,889	32,924	37,914	43,509	50,012
3	1289	75	3.5	18.4	+1	23,799.9	1.44	17,042	22,302	29,426	34,759	40,083	45,996	52,871
4	119	72	2.8	21.5	+2	2,453.2	1.7	1,580	2,387	3,563	4,475	5,370	6,606	8,091
5	50	55	1.4	16.5	+2	1,042	1.81	645	1,029	1,609	2,067	2,518	3,180	3,988
6	54	80	1	8.4	+2	1,758.8	1.8	1,084	1,716	2,686	3,461	4,260	5,364	6,715
7	375	77	1	11.8	+3	10,219.4	1.56	6,926	9,696	13,615	16,609	19,651	23,312	27,628
8	1551	75	2.9	16.6	+2	29,862	1.41	21,650	27,882	36,269	42,533	48,791	55,554	63,401

[a] See Figure 6.2 for location

[b] A=drainage area; values for locations 4,5, and 8 are weighted average

[c] P=mean annual precipitation; values for locations 4,5, and 8 are weighted averages

[d] St=percentage of basin containing lakes; values for locations 4,5, and 8 are weighted averages

[e] F=percentage of basin covered by forest; values for locations 4,5, and 8 are weighted averages

[f] T=mean minimum January temperature; values for locations 4,5, and 8 are weighted averages

[g] M and D are parameters calculated from the basin parameters; they are used in the flood frequency equations developed by Lamke (1979)

[h] Qi=flood discharge with recurrence interval i

i These data are from a flood frequency analysis of gage data (Station 15294500)

Surveys to establish the water level in selected wetlands in relation to the river water level indicated that the wetland levels were greater than the river levels in both cases. A wetland on the northwest side of Noaukta Slough downstream from its divergence from Chakachatna River was found on 22 September to be 1.7 ft. above the water level in the closest channel of the Slough. This difference is not surprising since (1) the wetland is on the upslope side of the river and (2) the river was dropping rapidly from its higher summer stage. The survey was not sufficient to establish whether or not the Chakachatna River supplies water to the wetland.

A similar, but more approximate, survey was conducted on the Middle River near its mouth. Wetlands are present on both sides of the river at a level about 6 ft. above the Middle River water level on 26 September at about 1100 hours. Wetlands were also present on the sloping bank of the river to nearly the river level at the time of the survey. High water evidence was present at about 4 to 5 feet above the surveyed river level. This reach of Middle River is within the range of tidal influence, but the amount of influence was not evaluated during this reconnaissance study. Although the data are not conclusive, it would appear that the wetlands may be flooded periodically by a combined river flow and high tide.

The wetlands are likely to be slow-draining and may get most of their water from snowmelt and rainfall. Data from this reconnaissance study are insufficient to establish with any certainty the water budget of these wetlands.

Table 6.5 Results of low flow investigations for three locations along Chakachatna River for each of two 6 month periods.

Low Flow Parameter	November-April Gage[a] Data (cfs/mi^2)	November-April Location[b] 1 (cfs)	November-April Location[b] 2 (cfs)	November-April Location[b] 3 (cfs)	May-October Gage[a] Data (cfs/mi^2)	May-October Location[b] 1 (cfs)	May-October Location[b] 2 (cfs)	May-October Location[b] 3 (cfs)
$7Q_{1.25}$	0.43	480	520	550	0.62	689	750	790
$7Q_2$	0.36	403	440	460	0.43	486	530	560
$7Q_5$	0.29	329	360	380	0.33	365	400	420
$7Q_{10}$	0.26	292	320	340	0.29	321	350	370
$7Q_{20}$	0.23	263	290	300	0.26	293	320	340
$7Q_{50}$	0.21	231	250	270	0.24	267	290	310
$7Q_{100}$	0.19	212	230	240	0.23	252	270	290
$30Q_{1.25}$	0.43	482	520	550	1.08	1,207	1,310	1,390
$30Q_2$	0.37	411	450	470	0.77	863	940	990
$30Q_5$	0.30	340	370	390	0.55	613	670	710
$30Q_{10}$	0.27	303	330	350	0.46	512	560	590
$30Q_{20}$	0.24	273	300	310	0.39	440	480	510
$30Q_{50}$	0.22	242	263	280	0.33	371	400	430
$30Q_{100}$	0.20	221	240	250	0.29	330	360	380

[a]Low flow frequency analyses of data from Chakachatna River gage (station 15294500)

[b]Locations are identified in Figure 6.2; location 1 corresponds to Chakachatna River gage site

4.2.3.2 Hydraulics

Plots of stream and floodplain transects in study areas D, L, and P (Figure 6.2) are presented on Figures 6.3, 6.4, and 6.5, respectively. Stages corresponding to the highest and lowest mean monthly flow values are shown on the figures to show the typical annual range in stages. The hydraulic geometry for the same three transects is shown on Figures 6.6, 6.7, and 6.8. Mean monthly flows are denoted on these figures. The flows increase due to snowmelt in May, followed by a gradual increase as the mountain snowpack continues to melt and the glaciers begin to melt. In late summer, the flows taper off gradually toward the winter low flows. As the discharges change, so does the hydraulic geometry.

The Chakachatna River exhibits a large range of stages (Figure 6.3). Winter flows would likely be only a foot or two deep in the main channel with very little or no flow in the left channel. Summer flows would inundate the bar separating the two channels and a portion of the Straight Creek floodplain as well.

The Upper McArthur River is likely to have a relatively small range of stages (Figure 6 4). Winter flows would be about a half foot deep and summer flows may be 2 to 3 feet more than that. Downstream, the McArthur River will increase in both depth and range of depth (Figure 6.5). Winter depths may be a foot or more; summer flows in the main channel may be as much as 8 feet in maximum depth with water flowing in high water channels.

Flood stages were estimated for the 10 year recurrence interval flood at the three transects discussed above and were plotted on Figures 6.3, 6.4, and 6 5. The Chakachatna would likely flood the lower floodplain of Straight Creek but will probably not flood any vegetated areas. The floods on the McArthur remained in the unvegetated portion of the floodplain at these transects; it is likely that much of the McArthur River would have similar flooding characteristics.

It was apparent at some confluences that backwater conditions have been experienced in one or both of the joining channels. The backwater profile could be traced by high water marks along the banks of McArthur River upstream of its confluence with the Lower Blockade Glacier Channel. Similar conditions likely occur at most confluences where the two joining channels have dissimilar flow regimes.

Typical examples of Chakachamna Lake bottom profiles are shown in Figures 6.9 and 6.10. Also shown on Figure 6.10 is a river survey leading into the bottom profiles. The profile show that the bottom gradually gets deeper in the offshore direction until a depth of approximately 20 feet is reached, at which time the depth increase very rapidly.

6.2.3.4 Channel Configuration and Process

The channel configuration of the Chakachatna, McArthur, and Middle Rivers and Noaukta Slough were assessed during the field and office investigations and are identified on Figure 6.2. The boundaries of the reaches are approximate. Four stream configurations were selected to represent the streams in the study area:

(1) Mountainous (Mt) - characterized by numerous, almost continuous rapids; they are usually single channeled and are often controlled in shape and location by external forces such as glacial moraines, rock outcrops, and tributary deltas.

(2) Braided (B) - characterized by numerous channels, often having different water levels; short rapids, often located at the divergence of two channels; and wide, usually unvegetated floodplains: channels tend to shift their location and configuration frequently in response to the deposition of sediment transported in from upstream.

(3) Split (S) - characterized by one to three relatively stable channels, often having different water levels, all of which carry water for much of the year.

(4) Meandering (M) - characterized by a single channel whose thalweg (deepest part) shifts from one side to the other along the length of the stream; large sand or gravel bars are typically exposed on alternating sides of the stream at low flows.

Stream reaches in the study area with mountainous configurations include the upper reaches of the Chakachatna River in Chakachatna Canyon which has almost continuous rapids and maintains mostly a single channel. The ice cored moraine of Barrier Glacier controls the upper reach; old morainal and colluvial deposits form the control of the lower reach. The McArthur River also has two mountainous configuration reaches. The upper reach is well into the headwaters of the river; control is provided by cobbles and boulders whose source is the surrounding and upvalley mountains. The lower reach is formed by the terminal moraine of Blockade Glacier. The mountainous reaches on the McArthur River are primarily single channel reaches.

Braided configuration reaches in the study area include the Chakachatna River upstream of Straight Creek, Noaukta Slough, and the Upper McArthur River. The Chakachatna River reach is very typical of a braided configuration; numerous channels flow at different water levels, the number of channels being a function of the discharge entering the reach. The Noaukta Slough configuration appears to be due more to lack of channel capacity than to excessive deposition of sediments. However, dune bedforms extended across most of the channel width in many locations indicate that heavy bedloads are transported at and above some threshhold discharge. The braided reach on the Upper McArthur River is a result of sediment deposition. It contains numerous small channels flowing at different water levels.

There are two split configuration reaches in the study area. They are located upstream and downstream of the Chakachatna River braided reach. The upper reach appears to be steeper, contains more rapids, and is likely to be less stable than the lower reach. Both reaches are nearby a braided configuration, but they appear to be much more stable than the typical braided reach.

Meandering configurations are typical of the lower reaches of the Chakachatna River and most of the McArthur and Middle Rivers. The lower Chakachatna and Middle

River reaches are very similar in appearance; both are primarily single channel with few exposed bars, even at relatively low flows. Dune bedforms were numerous and closely spaced over the full length of these reaches. The McArthur River has two channels downstream of Blockade Glacier. The north channel receives inflow from the glacier via two main channels. The north and south channels both flow mainly in a single channel meandering configuration before joining near their confluence with Noaukta Slough. The channels appear to be the most active of all channels in the study area in terms of lateral migration, from which many logs have been introduced into the floodplain. Very large sand and gravel bars are evident at low flow conditions. Large dunes in the channel provided evidence of a significant bedload transport above some threshhold discharge.

Sedimentation characteristics in the study area include:

- sediment transport characteristics and

- bed and bank material types.

Sediment transport was discussed briefly above in terms of bedforms providing evidence of bedload movement. The Chakachatna River downstream of the canyon and upstream of the Noaukta Slough divergence contained some gravel dunes as the most evident bedform; these dunes are often found at the head of a channel where it splits from another channel. All channels downstream from the Noaukta Slough divergence and all of the McArthur River downstream of Blockade Glacier had dunes formed mainly of sand sized particles.

Suspended load contains concentrations of fine "glacial flour". Sand sized particles will likely be carried in suspension by discharges greater than those at the time of the reconnaissance.

Bed and bank materials are typically gravels, cobbles, and some boulders in the Chakachatna River from the lake to the Noaukta Slough divergence and in the Upper McArthur River down to Blockade Glacier. There are some sandy sections in the braided reach of the Upper McArthur River as well. The size distribution of the bed and banks then decreases rapidly in the downstream direction to become very fine sands and silts near the mouths of the rivers.

The ice characteristics in the study area have not been investigated. It is likely that the rivers develop a full ice cover over their entire length. It is possible that aufeis develops locally within each of the braided reaches; the most likely reach for this to occur is the braided reach of a continued good source of water and the shallow channels in the reach. However, there is no strong evidence for aufeis development in these reaches.

6.2.4 Conclusions

The 1981 field reconnaissance and subsequent office evaluations have provided valuable information regarding the characteristics of the two river systems that could be impacted by the proposed Chakachamna Hydroelectric Project. Additional information will be collected on the Chakachatna and McArthur River systems prior to assessing the final impact of the project.

The 1981 field reconnaissance provided the following types of information:

- instantaneous discharges at various locations throughout the study area that provide information on flow distribution, hydraulic roughness, and channel bottom configuration,

- lake water level for comparison with historic water levels,

- wetland water levels relative to adjacent streams for evaluating wetland water sources,

- stream and floodplain transects for evaluating local water levels for a variety of discharges,

- stream water surface gradients for estimating energy gradients for hydraulic calculations,

- lake bottom profiles for evaluating the lake tributary stream gradients following draw down of the lake level,

- observations of channel configuration and processes for evaluation of the changes that could occur to the various configurations under a regulated flow condition, and

- observations of bed and bank materials for evaluating the sedimentation characteristics of the stream systems.

Although these reconnaissance level field data were not always rigorously collected nor extensive in areal coverage, they provide a valuable starting point for making preliminary impact evaluations and for planning more detailed field and office investigations.

The office evaluations of the field data provided the following results:

- Hydrologic data developed for eight representative locations through the study area were typical of glacial rivers with low flow in late winter, large glacier melt flows in July and August, and annual peaks due to fall rains; the data include:

  - mean annual flows,
  - mean monthly flows,
  - flood flows with various recurrence intervals, and
  - 7 and 30 day low flows with various recurrence intervals.

- Hydraulic geometry calculated at three representative transects illustrates that the range of width, depth, and velocity for the natural flow regime is typical of streams of this size; the annual range of stages appears to increase in the downstream direction.

- Floods on the McArthur River are likely to remain in the unvegetated floodplain for all but the most infrequent events, although most floods will likely result in substantial bank erosion; floods on the Chakachatna also will likely remain mostly in the unvegetated portion of the floodplain.

- o Backwater conditions at stream confluences are a likely condition.

- o Chakachamna Lake bathymetry indicates that a distinct break in bottom gradient occurs at a depth of approximately 20 ft at the deltas of major tributary streams; at shallower depths, the gradient is gradual and at deeper depths, the gradient is steep.

- o Chakachatna River contains reaches with the following configurations:

  - mountainous in Chakachatna Canyon,
  - braided downstream of canyon and in Noaukta Slough,

  - split in the lower part of the canyon and between the bridge and Noaukta Slough, and

  - meandering in downstream reaches.

- o McArthur River contains reaches with the following configurations:

  - mountainous in the headwaters and at the Blockade Glacier moraine,

  - braided on the Upper McArthur between the two mountainous reaches,

  - meandering through the entire lower McArthur River.

- o Sedimentation characteristics of both rivers appear to be typical of glacial systems with very fine suspended sediment sizes and substantial bed load transport.

- Ice characteristics are assumed to include development of a full ice cover and have minimal aufeis development.

The above results were based on field data, office evaluations, professional experience, and several important assumptions. The assumptions must be checked during the 1982 investigations.

6.3 Aquatic Biology

6.3.1 Background

To perform a reconnaissance level evaluation of the Chakachamna Hydroelectric Project study area resources, it was necessary first to review the literature, particularly reports of previous studies. A variety of regulatory agencies were contacted including the U.S. Fish and Wildlife Service (USFWS) and the Alaska Department of Fish and Game (ADF&G). The ADF&G, Division of Sport Fish, has conducted a number of surveys in portions of the Chakachamna Lake - Chakachatna River and McArthur River systems over the past 30 years. These surveys have included aerial observations, gill netting, electroshocking, and ground observations.

In general, these reconnaissance level surveys were primarily aimed at detecting spawning runs of salmon. However, these efforts were often hampered by turbid glacial waters. As a result, some salmon species were often unobserved.

Overall, these studies showed that all of the Pacific salmon species were present in the general vicinity of the project area (Table 6.6). However, the presence of these species was not documented at more than a few locations nor had the habitat utilization been documented.

6.3.1.1 Study Area

The study area has been generally described in previous sections. Refer to Section 6.0 and 6.1 for more detail.

The Chakachamna - Chakachatna and Chilligan River System and the McArthur River System are large complex waterbodies. The riverine systems contain braided reaches, islands, inactive floodplains, sloughs, riffles, whitewater areas, side channels, tributary streams, inputs of groundwater flow, and boulder strewn areas of high gradient. The main stems of these rivers contain glacially turbid waters, although there are also clear water tributaries present in each system.

Habitat diversity is further enhanced through substrate and water quality variability. Substrates typically range from silt and fine mud to large boulders. Water temperatures during the fall season can vary by more than 10°C, ranging from 0.25°C glacial runoff to 11°C shallow pools. Water depths also vary, with some areas of the Noaukta Slough being less than 0.5 ft. deep, while some areas in Chakachamna Lake are more than 300 ft. deep.

6.3.2 Study Objectives and Methodologies

Two reconnaissance level surveys were conducted on Chakachamna Lake, and the Chakachatna, Chilligan and McArthur Rivers during 1981. The investigations included

Table 6.6 Surveys conducted by and for Alaska Department of Fish and Game. (By date, location, method and species found)

Location and Date	Method[a]	Salmon Species					Other Species				
		Sockeye	Chinook	Coho	Chum	Pink	Dolly Varden	Rainbow Trout	Lake Trout	Round Whitefish	Slimy Sculpin
Chakachamna Lake											
9/52	Vis										
9/53	Vis *										
9/54	ES, Vis										
9/56	ES	+									
1979	GN, ES	+					+		+	+	+
Chilligan River											
9/52	ES, Vis	+									
9/53	Vis *										
8/54	ES, Vis	+									
8/55	ES, Vis	+									
Igitna River											
8/52	Vis	+									
9/52	Vis										
9/53	Vis *										
Another River											
8/52	Vis *										
Kenibuna Lake											
8/52	Vis	+									
9/53	Vis *										
Chakachatna River											
7/52	Vis *, **										
6/58											
1961	Vis, GN	+	+								

Table 6.6. Concluded.

Location and Date	Method[a]	Salmon Species: Sockeye	Chinook	Coho	Chum	Pink	Other Species: Dolly Varden	Rainbow Trout	Lake Trout	Round Whitefish	Slimy Sculpin
Straight Creek											
1958	Vis										
1973 ***	Vis		+								
1976 ***	Vis		+								
1977 ***	Vis		+								
1978 ***	Vis		+								
1981 ***	Vis		+								
McArthur River (including Swank Slough and Flat Lake)											
1959	Vis										
7/61		+		+			+				
8/61				+	+						
9/61				+						+	
West Creek											
7/61	GN, Vis	+		+		+	+	+		+	
9/61	GN, Vis						+	+			
#8 Creek											
7/61	GN, Vis	+					+	+		+	
North Fork											
7/61	Vis, GN	+					+				

[a]GN-Gill net; Vis-Visual; ES-Electroshocking
* Too muddy to observe fish
** Two beluga whales at mouth
*** Chinook salmon survey only

many of the tributary streams as well. The first reconnaissance, that was conducted on 17-18 August, consisted of aerial observations of the project area. The objectives of this reconnaissance were to assess:

- the extent of the system,
- which areas should be sampled in view of their potential to be impacted by the proposed project,
- what types of sampling gear might be used; and
- the potential logistical problems caused by the site location and topography.

The second reconnaissance, conducted from 15-28 September, involved the collection of data from the areas identified during the initial reconnaissance. This effort employed both field sampling and visual observations. The objectives of this reconnaissance were to:

- identify the major species present during autumn;
- identify critical habitats and life functions taking place in the system at the time of the study;
- provide an insight to the species composition and habitat use occurring at different times of the year;
- evaluate those species and habitats potentially vulnerable to impacts that might occur during the construction and operation of one of the proposed alternative hydroelectric facilities; and

- o evaluate the nature and extent of studies that would be necessary to assess the minimum amount of water necessary to maintain a viable salmon fishery. Due to the reconnaissance level nature of the 1981 effort, it was decided that only the fish populations in these systems would be investigated. Invertebrate work would be conducted in 1982.

6.3.2.1 August Reconnaissance

The first reconnaissance primarily relied upon visual observations, including both aerial overflights and ground-level reconnaissance. During aerial overflights, the location of spawning salmonids were observed and recorded. At selected sites, ground surveys were conducted. At these locations, carcasses were observed and identified and photographs were taken to document observations of habitat parameters. The results of this reconnaissance were used in planning the 1981 fall survey.

6.3.2.2 September Reconnaissance

Since the September reconnaissance included the sampling of a variety of habitats at various depths and under varying flow conditions, a number of different fish collecting techniques were used. Table 6.7 lists the fish collection methodologies used in each water body, while specific gear types are identified in Table 6.8. Visual observations of all major water bodies were recorded from a helicopter at altitudes between 10 and 200 ft.

Electroshocking, using backpack electroshockers, was utilized in most areas where water depths of four feet or less were encountered and conductivities were less than 2000 micromhos/cm. The electroshocker immobilizes fish enabling them to be collected. Pulsed direct current (DC) was utilized to reduce the physical damage to fish while it allowed taking advantage of galvanotaxis (the attraction of fish to the anode electrode), thus making them easier to catch with a dipnet. The relatively small range of the backpack shocker confined its use to shoreline areas and shallow open water areas. It was generally operated by one member of the field team while one or both of the other members deployed dipnets or seines. This technique was particularly effective in collecting juvenile fish that were sheltered among rocks and snags and could not be sampled with other equipment. It was also useful in fast flowing areas when used in conjunction with a seine or stationary drift net since fish could be collected from swift moving waters that would otherwise be inaccessible. Areas sampled by electroshocking, seine netting or both are shown in Figure 6.11.

A hand seine (Table 6.8) was utilized both individually and in conjunction with the electroshocker. When used in conjunction with the electro shocker, the hand seine was deployed downstream, usually in swift currents. In slower moving water the seine was moved upstream (with the ends of the seine extended) toward one member of the field team who kicked or shuffled the substrate. This gear was effective on both small and large fish in confined channel reaches and along shorelines.

Table 6.7. Collection methodologies utilized by waterbody, September 1981 reconnaissance study

Water Body	Visual Observations	Electro-shocking	Hand Seine	Beach Seine	Gill Nets	Fyke Nets	Stationary Drift Nets (Trawl)	Hoop Nets	Minnow Traps
Igitna River	X								
Kenibuna Lake	X								
Another River	X								
Chilligan River	X								
Neacola River	X								
Chakachamna Lake	X	X	X	X	X			X	X
Shamrock Lake	X								
Nagishlamina River	X	X	X	X[a]				X	X
Chakachatna River	X	X	X			X			
Straight Creek	X	X	X				X		
Straight Creek Tributary	X	X	X						
Middle River	X	X	X			X			
Noaukta Sough	X	X	X			X			
McArthur River	X	X	X			X			
McArthur River Tributary	X	X	X						
Chuitkilnachna Creek	x								

[a]At mouth of river in Lake Chakachamna

Table 6.8. Collection gear specifications September 1981 reconnaissance study.

<u>Electroshockers</u>	
Coeffelt Model BP-2 - used at 600 v	
Smith-Root Model VII - 700 v at 6 millisecond pulse duration at 60 pulses/second	
<u>Hand Seine</u>	
10 ft x 6 ft - ¼" ace mesh	
<u>Beach Seine</u>	
100 ft x 6 ft - ¼" ace mesh	
<u>Gill Nets</u>	
75 ft long, each panel 15' long x 6 ft deep Panels of nylon monofilament 3/4", 1", 1.5", 2", 2.5" bar mesh	
<u>Fyke Nets</u>	
6' x 4' double funnel ½" square mesh Long wings and leads 300 ft - 1" square mesh Short wings 50 ft - 1" square mesh	
<u>Hoop Nets</u>	
No leads - Small 34" diameter 1" stretch mesh Large 48" diameter 1-½" stretch mesh	

The stationary drift net used in this study was an otter trawl with a fine mesh liner. It was deployed in streams with high velocity currents. The streamlined shape of this net allowed it to be deployed in areas where the water currents were too swift to deploy a seine.

The beach seine was similar to the hand seine described above but of much greater length (Table 6.8). This net was only used in Chakachamna Lake. One end of the net was secured to the shore while the other end was carried out from shore by boat. As the boat moved in an arc back to shore, the bottom of the net was kept on the lake bottom, thereby surrounding a volume of water. This technique was effective, but only in those areas where the current was relatively small or nonexistent and where the shore area was shallow enough to deploy the net properly.

Experimental, 75 foot long gill nets (Table 6.8), consisting of 5 panels of 0.75, 1, 1.5, 2, and 2.5 inch bar mesh were utilized only in Chakachamna Lake. These nets were deployed perpendicular to the shore, and at the surface and bottom (Figure 6.12). The small mesh panel (0.75") was always kept on the shoreward side, where juvenile fish concentrate their activity. The nets were marked with floats and checked after 1 to 3 hours. All fish collected were measured and weighed and live fish were released. Those nets that did not catch large numbers of fish were left in place overnight.

The gill nets facilitated the collection of fish in deeper areas of the lake. By leaving the nets set overnight a more time-integrated sampling of the fish populations was possible.

Fyke nets (Table 6.8) are trap nets that are set with long leads of heavy twined mesh. Fish that encounter the leads are guided towards a series of mesh funnels that guide the fish into a trap from which they can be removed. The leads and net are held in place and oriented by steel poles driven into the bottom. The nets can be used where water is shallow enough (generally 4 feet) to allow the leads to extend from the stream bottom to the water surface, and where water currents are at a minimum.

Advantages of the fyke net include both the large areas fished and the fact that they do relatively little damage to trapped fish. These nets were set in the deep water sections of the rivers that could not be adequately sampled by other gear (Table 6.7). In the Noaukta Slough, Middle River, and Chakachatna River the wings of the nets essentially directed all fish moving upstream into the funnels. In the McArthur River one main-channel section was completely blocked by the nets.

Hoop nets were set without leads in Chakachamna Lake at each of the gillnetting sites (Table 6.8). This was done to diversify the fishing techniques utilized so that species or individuals not vulnerable to the gill nets might also be collected. This gear was relatively ineffective.

Minnow traps, made of galvanized mesh were set near the hoop nets. These traps had much smaller mesh than either the gill nets or hoop nets and were utilized to again diversify the gear and enable the collection of smaller fish such as juvenile salmonids. These were generally set among rocks or other such cover that usually provides habitat for juvenile fish.

The variety of collecting gear used prevented biasing of our collections through gear selectivity. In this manner, fish of many different life stages and in different habitats were successfully collected thus providing a more complete picture of the fish populations present at each site.

In the field, fish were measured for total length and usually weighed to the nearest ounce. Where possible, the sex of the fish was noted and whether the fish, in the case of salmonids, was a parr, smolt, juvenile or adult. Scales were taken from selected specimens. All captured adult salmon and other live fish were released at the point of collection.

Juveniles were identified in the field and released whenever possible. Specimens whose species identification could not be confirmed in the field and voucher specimens were preserved in a 10 percent formalin solution for laboratory identification.

Physical data collected in the field consisted of water temperatures measured with a YSI Model 57 temperature-oxygen meter or a Taylor mercury thermometer, and water velocities measured with a Marsh-McBirney Model 201 electromagnetic flow meter or a General Oceanics Model 2035B remotereading flow meter.

Fish specimens were identified in the laboratory using keys prepared by Hart (1975), McConnel and Snyder (1972), Morrow (1980) Scoott and Crossman (1973), Smoker (1955), Troutman (1973) and Wydoski and Whitney (1979). Habitat requirements of salmon and trout were characterized by Bailey (1969), Balon (1980), Blackett (1968), Foester (1968), Martin and Oliver (1980), Merrell (1970), Morrow (1980), Nikolskii (1961), and Scott and Crossman (1973).

6.3.3 Results and Discussion

Although a large amount of data were gathered during the two 1981 reconnaissance efforts, these data represent only the biological events occurring within the short period of time encompassed by these investigations. The occurrence and extent of biological activities during the winter, spring, and early summer, can only be hypothesized. Data that were collected include:

- Species occurrence;
- Habitat utilization;
- Critical life functions taking place; and
- Relative success of the collection gear.

The following sections summarize the results of these data.

6.3.3.1 Species Occurrence

Species occurrence is perhaps one of the most significant results of this reconnaissance. All five species of salmon occurring in Alaskan waters were found to spawn in both drainages (Table 6.9). It is unclear at this time

Table 6.9. Species list and drainage of occurrence August-September 1981.

Species		Drainage of Occurrence: Chakachatna River[1]	Drainage of Occurrence: McArthur River
pygmy whitefish	Prosopium coulteri	+	+
round whitefish	Prosopium cylindraceum	+	+
Dolly Varden	Salvelinus malma	+	+
lake trout	Salvelinus namaycush	+	
rainbow trout	Salmo gairdneri	+	+
pink salmon	Oncorhynchus gorbuscha	+	+
chum salmon	Oncorhynchus keta	+	+
coho salmon	Oncorhynchus kisutch	+	+
sockeye salmon	Oncorhynchus nerka	+	+
chinook salmon	Oncorhynchus tshawytscha	+	+
arctic grayling	Thymallus arcticus	+	
slimy sculpin	Cottus cognatus	+	+
threespine stickleback	Gasterosteus aculeatus	+	+
ninespine stickleback	Pungitius pungitius	+	+

[1] Includes Lake Chakachamna and Middle River

which species usually is most abundant, but spawning sockeye salmon were most abundant during our investigation. Lake trout appeared to occur only in Chakachamna Lake, while Dolly Varden were ubiquitous throughout both drainages. Rainbow trout appeared only in the lower portions of both drainages. Round and pygmy whitefish were found in most areas of both drainages, although pygmy whitefish were not found in Chakachamna Lake or drainages above it. Slimy sculpin were found throughout both systems and in tributary streams. Sticklebacks, however, were only found in backwater areas and among vegetation, usually in the lower reaches of the rivers. Only a single grayling was observed in a side channel in the upper Nagishlamina River and none were collected or observed at any other location. It is clear, with few exceptions, that most of the species found, occurred throughout both drainages.

The fish in this area may be classified into two primary groups, forage fish and commercial and sport fish. Forage fish in the project area include threespine stickleback, ninespine stickleback, slimy sculpin, pygmy whitefish, and round whitefish. (Morrow 1980, Scott and Crossmen 1973, Balon 1980). Although the round whitefish is probably not used as a subsistence species in these drainages it is eaten by lake trout and other species of fish. Sport and commercial fishes include pink, chum, sockeye, coho and chinook salmon, Dolly Varden, lake trout, rainbow trout, and grayling (Morrow 1980, Scott and Crossman 1973).

6.3.3.2 Habitats Utilized For Various Life Functions

A wide variety of habitats were sampled during the course of the reconnaissance studies using a diverse assemblage of sampling gear. As stated, one objective of the 1981 program was to gather a wide variety of data from a large area during a relatively short period of time, thus more attention was given to collecting qualitative rather than quantitative data, and to characterize general habitat use. Habitat utilization will be reported and discussed by waterbody or river stretch, as appropriate.

Chakachamna Lake Tributaries

The results of studies at each site sampled or observed in the Chakachamna Lake/ Chakachatna River drainage is summarized in Figure 6.13. This figure identifies habitat utilization and potential habitat utilization for salmon and trout species.

The rivers flowing into Kenibuna Lake were investigated by means of low level overflights, since the waters in the Neacola, Another and Igitna Rivers were sufficiently clear to observe fish and generally characterize the substrate. The Neacola River, at the date of the overflight, was relatively shallow with an apparent sand/ silt substrate. Large amounts of emergent vegetation were present, and although the substrate appeared to be unsuitable for salmon spawning, several adult Dolly Varden were seen from the air. It is possible that round whitefish were also present and that sockeye salmon juveniles may utilize this river.

The Another River was also overflown at relatively low altitudes in September 1981, and was found to contain a substrate composed of gravel, cobble, rubble, and boulders including some areas suitable for salmonid spawning. Although the water was clear with riffles, no sockeye salmon were observed, however, one adult Dolly Varden was observed. The stream could potentially provide habitat for adults and juveniles of stream dwelling species, such as Arctic grayling, round whitefish and slimy sculpin.

When the Igitna River was overflown, the water was somewhat clouded by glacial silt. However, it was obvious that there was a great deal of gravel substrate and large numbers of sockeye salmon were observed and redds (spawning nests) were identified.

The areas of the stream that were utilized most intensively were the side-channels and relatively shallow areas of the main channel within a few miles of Kenibuna Lake. Some of the side channels appeared clearer than the main channel possibly due to the influence of flows from clearwater tributaries or groundwater. Such streams are preferred by Sockeye (Foerster, 1968). Within the stream sections utilized by sockeye salmon, there appeared to be about 3-10 fish (including both live and dead) for each 10 feet of stream length. Sockeye carcasses were abundant and while not counted, there were probably more than 1000 fish in this general area.

Although Kenibuna Lake was too turbid for proper observation, a Dolly Varden was seen at the mouth of the Igitna River. During overflights conducted by ADF&G in 1952 (undated) sockeye salmon were seen at the west end of the lake (Table 6.6). In addition to serving as a migratory pathway for spawning sockeye salmon, the lake probably also serves as nursery habitat for juvenile sockeye salmon. The lake may also provide habitat for lake trout and kokanee since these species were collected from Chakachamna Lake. The potential also exists for salmon or lake trout to spawn along the northeast shoreline of Kenibuna Lake since a gravel-cobble substrate is present.

The Chilligan River, which discharges into the northwest end of Chakachamna Lake was overflown during both August and September 1981. Although the river waters were cloudy, large numbers of sockeye salmon were observed during both investigations. Gravel and cobble substrates were common in many parts of the river. Sockeye salmon were present in large numbers but appeared to be more abundant in side channels of the river, particularly in those with clearer water. (Figure 6.14.) More than one thousand fish were observed during each survey. During the August overflight, there appeared to be some chum salmon present in the lower part of the river, however a positive identification could not be made due to the depth and turbidity of the water. Dolly Varden may also use the Chilligan River for spawning and were observed near the banks, in shallow water. The combination of substrate, water temperature, and current found in this river meet the habitat criteria for Dolly Varden described by Blackett (1968) and Leggett (in Balon 1980).

The Nagishlamina River, which discharges into the northeast end of Chakachamna Lake was overflown in August and September. Ground observations were conducted during August and nets were used at the mouth of the river during September. The ground reconnaissance in August revealed both adult and juvenile Dolly Varden as well as one Arctic grayling in the upper reaches of the river. Dolly Varden were also observed in the areas closer to the lake (Figure 6.13). A variety of sub- strates, with large stretches of gravel and cobble that appeared suitable for spawning by a number of salmonid species were also found. The upper reaches of the river were shallower and less cloudy than areas closer to Chakachamna Lake.

A sand delta occurs at the mouth of the Nagishlamina River. This area was fished with nets during the September reconnaissance. Dolly Varden, lake trout juveniles and adults, and juvenile and ripe adult sockeye salmon were captured. In addition, one ripe kokanee male was collected. During the last day of the September 1981 reconnaissance several large gray fish were observed in the river. These may have been coho salmon or kokanee or possibly Dolly Varden. The presence of coho above the mainstem of the Chakachatna River will need to be confirmed during future studies.

Chakachamna Lake.

Chakachamna Lake is large and deep. On the average, the lake is over 300 ft. deep, with relatively steep slopes and very narrow shallow areas (U.S. Geological Survey bathymetric charts 1960). Slopes of 1:2.5 or even 1:1.1 are not uncommon in some portions of the lake and gentler slopes of 1:5 are only found at the river deltas. The water in the lake is cloudy due to glacial silts. The shoreline varies from sand deltas to gravel beaches to boulder slopes. Because the perimeter of the lake is very large, a fairly extensive shallow water habitat exists despite the narrowness of the shallow water zone found along the shoreline.

During the September investigation, five species were collected in the lake including, ripe sockeye salmon migrating along the shore of the lake, lake trout, Dolly Varden, round whitefish, and slimy sculpin (Figure 6.13).

Substrates suitable for sockeye salmon and lake trout spawning were found in several areas of Chakachamna Lake. It appeared that the sockeye were spawning along one area of gravel beach on the north shore of the lake (Figure 6.15). The substrate in this area was suitable and a large number of sockeye were milling about in the area. Although visibility prohibited observing redds, a female was observed excavating a redd. It is unclear to what extent this area is used for spawning, however, the beach area was apparently utilized as nursery habitat by juvenile sockeye salmon, lake trout, and round whitefish (Figure 6.13). Adult lake trout, round whitefish, Dolly Varden and slimy sculpins were also found in this area. The round whitefish in this area were feeding on insect larvae, and the lake trout were feeding on juvenile sockeye salmon and round whitefish.

Adult lake trout were found in all areas sampled, although they were most abundant in rocky areas, particularly those sites with large boulders. Many of the adults examined during the September 1981 investigation were sexually mature spawners. This may have influenced their distribution, since the rocky shallow water areas are used for spawning. The lake trout in these areas were also found to be actively feeding. The stomach contents of one large lake trout contained 22 sockeye salmon parr.

Dolly Varden did not appear to be as abundant as lake trout, but were found at most collection sites. Anadromous, sexually mature Dolly Varden were identified near the lake outlet, while juvenile Dolly Varden were present in many of the shallow water areas.

Several of the small streams entering the lake were surveyed and were found to contain fish. One large stream at the southern end of the lake that was fed by glacial runoff (B in figure 6.15) contained suitable substrate for salmonid spawning, however, the water temperature was too cold. (0.25°C, compared to the 7.5° - 9°C found in the lake).

Although the deeper open water areas of the lake were not sampled during this reconnaissance, information from the literature (Scott and Crossman 1973) and past studies (Russells 1979) indicate that these areas would normally be utilized by lake trout and juvenile sockeye salmon. Since the juvenile sockeye are planktivorous (Scott and Crossman 1973), they would be expected to make extensive use of the open lake waters. Due to cooler temperatures in Chakachamna Lake, lake trout would be expected to make greater use of the upper strata all year long.

Upper Chakachatna River

Waters from Chakachamna Lake discharge from an outlet at the eastern end of the lake (Figure 6.15) into the Chakachatna River. This reach of river was characterized by a steep gradient, boulders, standing waves, and whitewater. The water remains at a relatively high gradient to the base of the canyon about 14 miles east of the lake (Figure 6.13 and 6.16).

Due to the relatively swift currents and lack of cover in the upper portions of the Chakachatna River canyon, this area apparently is used only as a migratory pathway by the salmon and Dolly Varden that spawn in and above Chakachamna Lake. It is also apparent that this section is used by outmigrants, including sockeye smolt and Dolly Varden.

During August and September, sockeye salmon and chum salmon were observed spawning in side channels in the lower canyon where there was a lower velocity current than in main channels. Juvenile Dolly Varden and salmon were also found to utilize the side channels throughout the lower canyon. However, they were also found in the main channel in areas where boulders provide cover and reduced velocities.

Along the main channel of the river (Figure 6.13) Dolly Varden, pygmy whitefish and round whitefish were found in most areas. Dolly Varden appeared to be most abundant. Rainbow trout were commonly found in major channels below Straight Creek.

Substantial numbers of sockeye, chum, and pink salmon were found to spawn in side channels along the Chakachatna River considerably downstream of the canyon. The largest numbers of spawning fish were found near the confluence of Straight Creek and downstream from the Chakachatna bridge. Those areas containing spawning redds generally were side channels with suitable substrate that contained ground water flows or clearwater tributaries (Figure 6.17). Pink salmon were found in the vicinity of the Chakachatna River bridge during the August survey, however, at the beginning of the September survey, only one desiccated pink salmon carcass remained. The extent of pink salmon spawning and the presence of other spawning locations within the river are presently unknown. Chinook salmon were not observed spawning in the main channel of the river although some chinook were observed in the vicinity of the confluence of side channels with the main channel. Coho salmon were observed migrating up the Chakachatna, but the location of their spawning areas are presently unknown. Some coho probably spawn in Straight Creek, while others may spawn in the Nagishlamina River. It is unclear whether any coho spawn in side channels of the Chakachatna River. Overall, the largest numbers of spawning salmon were found in the Chakachatna near the bridge and in Straight Creek.

During the September 1981 reconnaissance, the river stage had dropped from that observed in August. During both reconnaissance trips, there were many side channels and backwater areas present, particularly below Straight Creek. Typical bank habitats varied from cobble-gravel to sandsilt. Juvenile fish were found in most areas containing a cobble-gravel substrate, while larger fish were generally found further from the banks in areas of swifter current. Migrating salmon were found to utilize the backwaters for "resting areas" during their upstream migrations.

Straight Creek

Straight Creek, a major tributary of the Chakachatna River, contains substrates that vary from sand-silt to cobble-rubble, including many areas of gravel-cobble substrates suitable for salmonid spawning. The waters are cloudy with glacial silt and visibility is very limited.

Water velocities in the creek vary. Velocities in the center of the main channel have been measured at 6 ft/sec during high flows. Side channels at the same time had velocities of between 0.6 and 1.2 ft/sec.

Collections from the side channels and backwater areas of the creek show that these areas are used extensively by juvenile salmonids, of which Dolly Varden, chinook salmon parr and pygmy whitefish are the most common. Both chinook and coho salmon have been observed migrating up Straight Creek. ADF&G recognizes Straight Creek as a chinook spawning stream.

However, it is unknown whether they spawn in the clearwater tributaries to the creek or whether some spawn in the creek itself. Chum and sockeye have also been observed migrating up Straight Creek near its mouth. Both species are also believed to spawn just outside the creek mouth, in side channels of the Chakachatna River.

Spawning sockeye, chum, pink and chinook salmon were observed in the clearwater tributary to Straight Creek (labelled A in Figure 6.17) during the August reconnaissance. Migrating coho salmon, as well as spawning chums and sockeyes were observed during the September study.

The tributary is relatively narrow compared to Straight Creek, with a main channel width of about 30 ft. The substrate is largely gravel with some sand and cobble. The banks are heavily overgrown with trees and other vegetation. There are also cutbanks throughout the area; roots, snags, and sweepers also provide significant cover in this stream. The stream contains side channels and backwaters as well as a variety of pool and riffle habitats.

Juvenile salmonids were abundant in this stream particularly chinook and Dolly Varden parr. The shallow areas around snags and tree roots appeared to be favored areas due to the lower water velocity and cover. Larger Dolly Varden and rainbow trout were found in deep, swifter moving water, and were found to be consuming both Dolly Varden and chinook salmon parr, as well as pygmy whitefish. Although neither rainbow trout spawning areas nor juveniles were found in this stream, substrate and other habitat factors necessary for spawning were present (Morrow 1980, Scott and Crossman 1973).

Lower Chakachatna River.

The lower Chakachatna River divides up into three principal outflows. These are the Middle River, the Chakachatna River and the Noaukta Slough.

This lower portion of the Chakachatna River was characterized by relatively shallow depths and slower moving water than stretches further upstream. The substrate for this section of river was primarily a sand silt mud. There were relatively few rocks present. Much of the bank area was tree lined until close to the confluence with the McArthur River.

Sampling in the upstream portion of this stretch showed that Dolly Varden were abundant, comprising 80 percent of the catch. About half of the catch of Dolly Varden were fish 10 inches or less in length. Coho salmon juveniles and rainbow trout adults were also common. The area apparently serves as both nursery and adult habitat for these species.

The Middle River flows directly to Cook Inlet. Different stretches of the Middle River were characterized by different habitat types. The upper sections of the Middle River, downstream from the division with the Chakachatna, were characterized by relatively swift currents, mixed substrates, tree-lined banks, and a highly variable channel. The substrates varied from sand-gravel, sand-silt, and gravel-cobble. Cut banks were present as well as tree roots along the banks.

While the upper reaches of the Middle River were characterized by an abundance of juvenile and adult Dolly Varden, the area also served as a nursery area for coho salmon and sockeye salmon. Parr of all three species were found in areas of low velocity and cover. The river is also used by sockeye salmon during out-migrations and by sockeye, coho and chum salmon for spawning migrations. Sockeye and chum salmon were observed in August and coho were collected during September. Rainbow trout adults were also common in the upper river. However, both pygmy and round whitefish were common throughout the area. Several small, unnamed tributaries enter the Middle River. Some of the tributaries are slow moving and represent flow from old beaver dams. Both ninespine and threespine sticklebacks were found in these areas.

In the lower stretches of the Middle River the channel became wider and slower flowing, and riparian vegetation became increasingly more marsh like as the river approached Cook Inlet. The substrate is a fine sand-silt mud (Figure 6-18) with relatively few outcroppings of rock and little bank cover. Very few fish were observed or collected in this area; the most common being sticklebacks. Only one juvenile Dolly Varden and one sockeye smolt were collected in this section. There was no evidence that this stretch was used as a nursery area. This section was also part of the migratory route of sockeye, coho and chum salmon. However, no evidence was collected that indicates that chinook salmon, pink salmon, or anadromous Dolly Varden use the Middle River as part of their migratory route.

Although intertidal spawning by both pink and chum salmon has been reported in Alaska (Bailey 1964, Bailey 1969, Merrell 1970), it was not observed in the Middle River, and since the lower Middle River does not contain suitable cobble or gravel substrates (Bailey 1969, Merrell 1970, Nikolskii 1961, Morrow 1980), neither species would be expected to spawn there.

The Noaukta Slough is an area of diverse and meandering channels, islands, pools, and substrates. The slough, as observed during the two 1981 reconnaissance trips, was considerably more complex than depicted on existing maps.

The slough included a large number of islands and flooded wooded areas.

Substrates within Noaukta Slough varied extensively with large areas of the slough characterized by soft substrates dominated by sand-silt muds, while other areas were dominated by cobble-gravel substrates. Areas in the upstream portions of the slough contained greater amounts of hard substrate than areas further downstream. Riffles were more common and velocities slightly higher in this upstream reach.

Sampling in the upstream portion of Noaukta Slough (Figure 6-17) showed that Dolly Varden were abundant, comprising 80 percent of the catch. More than half of the catch of Dolly Varden were fish 10 in. or less in length. Coho salmon juveniles and rainbow trout adults were also common. The area also apparently serves as both nursery and adult habitat for these species.

Both pygmy and round whitefishes were also present in the Slough. While the pygmy whitefish was more common than the round whitefish and was often found in areas that provided cover, round whitefish were often found in deeper, faster moving water. Since adult, migrating coho salmon were collected in the upper part of the slough near the Chakachatna River, it was apparent that the slough is part of their migratory pathway.

It was also apparent that the Noaukta Slough was a major nursery area since juvenile fish were extremely abundant in the middle and lower parts of the slough. Coho salmon parr and Dolly varden parr were the most abundant. However, juvenile pygmy whitefish and sockeye salmon parr were also common. Juvenile salmonids were found where water velocities were low and cover was sufficient. The habitats utilized included tree roots, rocky bank areas, cut banks, shallow side channels with cover, snags, and sunken trees and bushes. Both sockeye salmon parr and smolt were present in these areas and occurred in a wide range of sizes. Although sockeye fry usually migrate to a lake and reside there for one to two years before going to sea (Foerster 1968), juveniles from the Chakachatna and McArthur Rivers apparently migrate to Noaukta Slough and utilize it as a nursery area since a lake is not accessible.

Although no spawning was observed in the Slough and no redds found, there was a substantial amount of suitable substrate present. The presence of turbid water obscured observations, and only one adult sockeye salmon carcass was found in the slough. However it could have washed down from known spawning areas upstream.

McArthur River

Figure 6-19 shows habitat utilization along the McArthur River as determined by observations and collections. The upper McArthur River originates at the McArthur Glacier. The area near the head waters of the McArthur River was characterized by boulders, rubble, cobble with intermixed gravel, and a fairly high gradient. There were many riffles present and water velocities reached over 4 ft/sec in the main channel. Water temperatures were measured at 0.25°C in this area. Although several samples were taken within that portion of the upper river stretching to approximately four miles below the glacier no fish were found.

In the braided section approximately four miles downstream from the glacier, the habitat was characterized by a gravel-cobble substrate and a water temperature of 3°C. Small riffles and side channels of varying depth were located throughout this area. In addition, small clear water streams entered the river along both sides of the canyon. Fish were abundant in this section of the McArthur River. Dolly Varden adults, juveniles and parr were present in this area, however juveniles of other species were not found.

A number of species were found to use the lower part of this area for spawning. Chinook, coho, pink, sockeye and chum salmon were observed spawning in the side channels of this area. Chinook salmon were observed only during the August reconnaissance and coho only during September, but both species appeared to utilize very similar areas. Sockeye salmon were the most abundant spawning species observed in this area during the two investigations, and were found in a great variety of areas including Pond A (Figure 6.20). Coho spawners began to appear in large numbers at the end of the September reconnaissance. The peak abundance of coho spawners in the McArthur may not actually occur until later in the year (October-November).

At the conclusion of the September reconnaissance, large numbers of anadromous Dolly Varden were found in the side channels of this area. Spawning behavior exhibited by Dolly Varden in this part of the McArthur had not been observed in the earlier reconnaissance. Dolly Varden spawning likely occurs from late August to the end of November, with peak activity occurring in September and October (Morrow 1980).

Downstream from the braided section of river, juvenile salmonids representing a variety of species became more abundant. Juvenile fish found in this section of the river included Dolly Varden, coho salmon, sockeye salmon, and pygmy whitefish. Adult pygmy whitefish were also present in this area. The beaver ponds labeled A and B were utilized by both sockeye salmon and Dolly Varden. Ninespine sticklebacks were also abundant in these ponds, but were especially abundant in pond C. The substrates comprising the lower braided reach to the mouth of the canyon were increasingly dominated by sand, and other fine materials. Juvenile fish were only found along the far banks of the river in areas with a hard substrate or cover provided by vegetation. The large open sand flat areas of the main channels appeared to be devoid of fish, with the exception of occasional migrants. These migrants included adult chinook, coho, chum, pink and sockeye salmon as well as Dolly Varden.

The northern channel of the McArthur River was relatively shallow with a sand-silt substrate. Fish were generally found along the banks and in areas that provided cover. Fyke net catches in this area were smaller than at any of the other stations. The species composition was also different, with the adult fishes being dominated by pygmy whitefish and a few Dolly Varden. Juveniles in this area were also less numerous, with only juvenile coho salmon, pygmy whitefish and Dolly Varden present.

Downstream from this area, several side channels and islands were present (shown in detail in Figure 6.21, Area A). In and around these side channels and islands there was a variety of cover provided by flooded trees, snags, and cobble-rubble substrate. Fish found in these areas included coho and sockeye salmon juveniles, pygmy whitefish juveniles, and Dolly Varden parr. Adult rainbow trout, pygmy, and round whitefish were also found in these areas. Very few fish except adult round whitefish were found away from cover or the channel banks.

The southern channel of the McArthur River that originated from the Blockade Glacier was characterized by a boulder-rubble-cobble substrate. Although some of the areas in this stretch contained cobble-gravel substrate that might be suitable for salmonid spawning (Area C in Figure 6.21), water temperatures in the area were probably too low.

Further downstream, the substrate was more diverse. It contained substantial quantities of sand with occasional boulders and patches of hard substrate. Water temperatures in this area (B, Figure 6.21) were approximately 3.5°C. Sampling in area B revealed that large numbers of juvenile fish were present in shallow areas that provided cover, low water velocity and eddies. Juveniles included sockeye salmon smolt and parr, chinook salmon parr, Dolly Varden, and pygmy whitefish. No coho salmon juveniles were collected in this area.

No adult salmon were found or observed in this part of the river during either reconnaissance. It is not known at present whether any spawning occurs in the southern channel.

In the vicinity of Cook Inlet, the McArthur River substrate was generally sand-silt/mud. This part of the river is not expected to provide significant juvenile nursery habitat nor spawning areas. It is, however, a migratory pathway for the anadromous salmonids.

The McArthur River also has a number of tributary streams that serve as both spawning and nursery areas. The streams identified by the letters D through H were found to contain spawning salmonids during one or both of the reconnaissance efforts (Figure 6.21). All of the streams had clear water, a variety of riffle and pool habitats, and substrate suitable for salmonid spawning. There was also a great deal of cover along the banks provided by rubble, cut banks, and overhanging trees. Streams D and E were found to contain spawning sockeye, chum, pink and chinook salmon during August 1981. Streams G and F were also found to contain chum and chinook salmon. Clearly stream G also served as a migratory pathway for streams E and F.

Although stream E was found to serve as nursery habitat for Dolly Varden, chinook salmon and coho salmon, this was the only upper McArthur tributary stream in which a juvenile fish was collected.

Stream H was overflown during September 1981 and was found to contain at least 1000 coho salmon. The stream contained large stretches of spawning substrate and large numbers of fish were found at each bend in the stream. Local people in the Tyonek area also reported that chinook, pink, and chum salmon can be found in this stream as well as rainbow trout and Dolly Varden. The extent to which this stream may be utilized for spawning by species other than coho salmon is unknown.

Overall these tributary streams represent a major part of the spawning habitat in the McArthur River drainage and may be utilized more than the side channels of the main river.

6.3.3.3 Habitat Use

For the purpose of a preliminary assessment of habitat use, the study area was divided into 13 areas that represented areas of relatively similar habitat and/or geographic location (Figure 6 22).

A The lake tributary rivers apparently do not contain salmon spawning populations and do not appear to be widely utilized.

B The Chilligan and Igitna Rivers were the major sockeye salmon spawning areas found.

C Chakachamna Lake and Kenibuna Lake represent the major juvenile sockeye rearing lakes and nursery areas.

D The area from the outlet of Chakachamna Lake to the base of the canyon along the Chakachatna River is primarily a migratory route with some use by sockeye and chum salmon spawners, and by Dolly Varden as a nursery area.

E The Chakachatna River from the Canyon to the split with the Noaukta Slough. This area includes some moderately important sockeye and chum spawning areas. There may be some minor spawning by chinook in channels of this area. This is a major migratory route for sockeye, chinook, chum, pink and coho salmon. There is minor use of this area as nursery habitat by sockeye and coho salmon, as well as Dolly Varden.

F Straight Creek and its clearwater tributary. This is a major chinook spawning area as well as a spawning area for sockeye, chum, coho, and pink salmon. Dolly Varden and rainbow trout adults utilize this area as well. These streams serve as a nursery area for chinook, coho, and Dolly Varden. These streams are also part of the migratory routes of all five salmon species.

G The lower Chakachatna River and Middle Rivers. These areas are part of the migratory pathways for the five salmon species. Some spawning occurs in the side channels of the Chakachatna in the upper parts of this section. Chum salmon appeared to be most plentiful there, with small numbers of sockeye also present. This area appeared to be moderately important as a nursery area for coho, chinook, and sockeye salmon. Dolly Varden juveniles and adults were abundant here as well.

H The Noaukta Slough. The slough is probably a major nursery area for the McArthur and Chakachatna drainages. Coho, chinook and sockeye juveniles were abundant there, as were Dolly Varden and pygmy whitefish.

I Lower McArthur River. This area is part of the migratory pathway of the five salmonid species that spawn in the McArthur drainage or that ascend the lower Chakachatna River or Noaukta Slough to spawn in the Chakachatna River drainage. This area provided nursery habitat for juvenile sockeye, coho and Dolly Varden.

J The area adjacent to the McArthur River Canyon. This part of the river provided a migratory pathway to the upper sections of the river (L) and also served as nursery habitat for coho salmon and Dolly Varden.

K The southern channel of McArthur River originates at the Blockade Glacier and has its confluence with the northern channel near the Noaukta Slough. This area served as nursery habitat for chinook and sockeye salmon as well as for Dolly Varden. It is unknown whether migratory adult salmon use this area but it appears to be unlikely.

L Upper McArthur River. This area includes spawning habitats for chinook, coho, sockeye, chum, and pink salmon. Anadromous Dolly Varden, in addition to spawning in this habitat, utilize the middle reaches as a nursery zone. The lower reaches containing sufficient cover were used by sockeye, coho, and Dolly Varden as a nursery area. Migratory adults of all five salmon species pass through this area.

M Tributary streams of the McArthur River. All five salmon species were found to spawn in these streams. Chinook and coho salmon were more abundant than in the upper McArthur (area L). Pink salmon were more abundant in the streams flowing from the mountains. The streams were also used as nursery areas by juvenile Dolly Varden and chinook salmon.

6.3.4 Summary and Conclusions of 1981 Studies

The 1981 studies, although of limited duration and consiting of only a limited "look" at the Chakachatna and McArthur River systems, collected a substantial amount of data. The data indicated that:

- o Large numbers of sockeye salmon utilize Lake Chakachamna as a nursery area and the Igitna and Chilligan Rivers as spawning sites.
- o Lake Chakachamna may contain sockeye spawning sites.
- o Side channels in the Chakachatna River are used as spawning sites by chum, pink and sockeye salmon.
- o Side channels in the upper McArthur River are used as spawning sites by chinook, chum, coho, pink, and sockeye salmon, and also by anadromous Dolly Varden.
- o Clearwater and other tributary streams are used for spawning by chinook, chum, coho, pink, and sockeye salmon.
- o The intertidal areas of both river systems do not contain suitable substrate for salmonid spawning.
- o Areas with cover and low water velocities are used as nursery areas.
- o Noaukta slough is used extensively as a nursery area, particularly by coho and sockeye salmon.

- o Migratory pathways for spawning adults and outmigrant juveniles include most reaches of both river systems.

6.4 Terrestrial Vegetation and Wildlife

6.4.1 Background

The objective of the terrestrial component for the environmental study of the Chakachamna Hydroelectric Project was to analytically characterize the vegetative and wildlife communities. Because this project could affect the lands and waters of both the Chakachamna and McArthur drainage systems, qualitative data were collected throughout the study area and vegetation and wildlife habitat maps were prepared so that areas of a sensitive or critical nature could be identified.

Previous investigations conducted in the area by the Alaskan Department of Fish and Game (ADF&G) and the U.S. Fish and Wildlife Service (USFWS) have concentrated on documenting waterfowl utilization of the coastal marshes of Cook Inlet. In addition to annual aerial surveys of the Trading Bay State Game Refuge performed by the personnel of ADF&G, personnel of USFWS have conducted aerial swan surveys encompassing the lands in and adjacent to the refuge. Although the main purpose of these surveys has been to census waterfowl, information has also been gathered on bald eagle nest sites, moose calving grounds, and the occurrence of Beluga whales near the McArthur River.

6.4.1.1 Study Area

As previously discussed, the study area encompasses all of the lands and waters from the tributaries of Chakachamna Lake to Trading Bay in Cook Inlet in addition to the lands and waters of the McArthur drainage system. Located approximately 60 miles west of Anchorage on the west side of Cook Inlet, this area supports a wide variety of wildlife and vegetation.

From the tidal flats in Trading Bay the land rises slowly, forming a continuous array of marshes, bogs, and ponds. At the mountains, the land supports a totally different vegetative community. Overall, eight habitat types were identified. These areas which are described in subsequent sections included coastal marshes, the riparian zones around the streams and rivers, bogs, and the rocky slopes around the lake.

6.4.2 Study Objectives and Methodology

The major objectives during the vegetative studies were to describe the vegetative communities within the study area and to provide vegetation maps at a scale appropriate to delineate wildlife habitats. To accomplish this, a combination of aerial surveys, ground surveys, and an analysis of true color aerial photographs were utilized. Throughout the study period (14-25 September), 22 low elevation aerial surveys (50-200 feet AGL) were flown in a random route such that the entire study area was covered. Two observers on opposite sides of the aircraft recorded the location and relative abundance of vegetative stands. In addition, 23 quadrats, each averaging 2 square miles were selected for ground surveys (Figure 6.23). The quadrat sites were not selected in a random fashion, but instead were chosen to be a representative sampling of vegetative types in the area. During these observations, all species of woody vegetation, the major species of herbaceous vegetation, and their relative abundances were noted. Finally, the information gathered on each of the quadrats was used in conjunction with the aerial photographs to interpret the vegetative composition of the remainder of the study area.

The primary objective of the wildlife study was to identify important wildlife resources in the study area, their use of the area, and the importance of identified vegetative and aquatic communities to these resources. To accomplish these objectives, the same 22 low elevation aerial surveys that were used to identify vegetative types were used to classify bird and large mammal distribution and abundance. These observations totaled 12.8 hours and were conducted at various times of the day, ranging from 0730 to 1900 hours. In addition to the aerial surveys, the 23 quadrats used for vegetative analysis were searched for evidence of birds and mammals. Forage areas were studied to determine the species and number of individuals utilizing the area as well as the species that were being consumed. The identification of tracks yielded additional information on both nocturnal and uncommon species and the analysis of scats further defined the species composition, distribution, and food habits.

Due to the difficulty in observing small rodents, a qualitative trapping program was conducted along transects in five representative zones of the study area. These five areas were located at the mouths of the

Chilligan and Nagishlamina Rivers, along the edge of the floodplain on the Chakachatna River near the confluence with Straight Creek, in the heavily wooded area west of the Chakachatna River, and on McArthur Flats near Seal Slough. At each location, 40 snap traps were set for a period of 48 hours.

Vegetation and habitat type maps were prepared based on the classification methodology outlined by Phister et al. (1977). After the field data collections, a subjective grouping of possible types was developed, based on structural differences in the vegetation. Second, a Bray-Curtis ordination was applied which provided a graphical arrangement of the types based on similar species composition. The vegetation type terminology for this classification differs from most type approaches in that the understory species named could either be an understory dominant or simply be an indicator species (important just by its presence or absence). Overall, this classification scheme is more directly related to habitat types than a dominant species approach because it is sensitive to both vegetative structure and relative species composition.

6.4.3 Results and Discussion

6.4.3.1 Vegetation

Within the study area, 40 species of woody vegetation and nine taxa of herbaceous vegetation were identified. Paper birch had the highest frequency among the woody species, having been found in 65 percent of the quadrats. Black cottonwood had the second highest frequency (61 percent) while diamondleaf and feltleaf willow both occurred in 13 of the 23 quadrats (57 percent). Grasses had the highest frequency among all the plants, having been found in all 23 quadrats sampled. Although not all of the grasses present were identified, two of the most common were *Poa* sp. and *Fetuca* sp. The remaining eight taxa of herbaceous plants were fairly site specific with only horsetails being found in more than 50 percent of the quadrats.

Based on the vegetation classification scheme outlined earlier, the terrestrial vegetation within the study area was divided into eight types (Table 6.10 and Figure 6.24):

Upland Alder Thicket (UAT);
High Altitude Riparian (HAR);
Black Cottonwood Riparian (BCR);
Coastal Marsh Riparian (CMR);
Black Spruce Transitional (BST);
Resin Birch Bog (RBB);
Willow Thicket Riparian (WTR);
and Black Spruce Riparian (BSR)

Upland Alder Thicket

This type occurred mainly on the steep slopes above Chakachamna Lake and on the canyon walls above the Neacola, Igitna, Chilligan, Nagishlamina, and McArthur Rivers. It was also interspersed with the other types on Kustatan Ridge near Cook Inlet. These sites were characterized by an abundance of black cottonwood, Sitka alder, and paper birch. Diamondleaf and feltleaf willow were abundant in some locations while herbaceous plants were uncommon, except for grasses.

High Altitude Riparian

This type was more restricted in its distribution, being found only on the floodplains of the rivers flowing into Chakachamna Lake and in the Chakachatna River canyon. This form of riparian habitat was characterized by an abundance of Sitka alder, paper birch, and white spruce. Diamondleaf and feltleaf willow were also widespread. Herbaceous plants included ferns, fireweed, and moderate amounts of grasses.

Black Cottonwood Riparian

At elevations lower than the McArthur and Chakachatna River canyons, this type replaced the high altitude riparian and was found along the shores of most of the streams and rivers. Characterized by an abundance of black cottonwood, thinleaf alder, and paper birch, numerous species of willow were also present, including diamondleaf, feltleaf, Barratt, undergreen, and grayleaf. Herbaceous plants include *Artemesia tilesii*, ferns, sedge, and fireweed.

Coastal Marsh Riparian

This type encompassed most of the area within one mile of Cook Inlet in addition to a few areas along the McArthur River. These sites were characterized by almost a total absence of woody vegetation, and an abundance of grasses, sedge, and horsetails. These sites were better drained than the bogs and were laced with an array of ponds and streams that were often inundated by fluctuating tides.

Table 6.10. The species composition and relative abundance of plants identified within the study area for each of the vegetative types. (1=Dominant 2=Abundant 3=Common 4=Occasional 5=Rare)

Species		Habitat[a]							
		UAT	HAR	BCR	CMR	BST	RBB	WTR	BSR
black cottonwood	*Populus trichocarpa*	1	4	2	5	4		1	
Sitka alder	*Alnus sinuata*	1	1	4				4	3
thinleaf alder	*Alnus tenuifolia*		4	1	3	3		2	3
paper birch	*Betula papyrifera*	2	1	2	5	3	3	4	4
resin birch	*Betula glandulosa*					4	1		
dwarf arctic birch	*Betula nana*					4	3		3
quaking aspen	*Populus tremuloides*	4	5						
black spruce	*Picea mariana*				4	4	1		1
white spruce	*Picea glauca*	4	3	3		5		3	
diamondleaf willow	*Salix planifolia*	2	2	5	5	5	3	1	1
feltleaf willow	*Salix alaxensis*	2	2	2	4			2	2
Barratt willow	*Salix barrattiana*			4					3
undergreen willow	*Salix commutata*			4				4	
grayleaf willow	*Salix glauca*			4				4	3
Alaska bog willow	*Salix fuscescens*					5	3		4
barren-ground willow	*Salix brachcarpa*							5	
Richardson willow	*Salix lanata*			5				5	4
Sitka willow	*Salix sitchensis*							5	4
skunk currant	*Ribes glandulosum*	4							
American red currant	*Ribes triste*	4		3	5	4	4		
trailing black currant	*Ribes laxiflorum*			3		5			
American red respberry	*Rubus idaeus*	4		4	5	5			
Pacific red elder	*Sambucus callicarpa*	4	5	4		5			
high bushcranberry	*Viburnum edule*			4					
mountain-cranberry	*Vaccinium vitis-idaea*					4	4		4
early blueberry	*Vaccinium ovalifolium*					4			
bog blueberry	*Vaccinium uliginosum*					4	2		3
bunchberry	*Cornus canadensis*					5			
crowberry	*Empetrum nigrum*					4	3	4	4

Table 6.10. Concluded

Species		UAT	HAR	BCR	CMR	BST	RBB	WTR	BSR
		Habitat[a]							
saskatoon serviceberry	*Amelanchier alnifolia*					4	4		3
Pacific serviceberry	*Amelanchier florida*							5	
Labrador-tea	*Ledum groenlandicum*					4	3		4
narrow-leaf Labrador-tea	*Ledum decumbens*					5	2		
prickly rose	*Rosa acicularis*			4		4			
sweetgale	*Myrica gale*			5		4	3		3
rusty menziesia	*Menziesia ferruginea*					3	5		
bog rosemary	*Andromeda polifolia*					4	3		
bush cinqfoil	*Potentilla fruticosa*					4	2		
leatherleaf	*Chamaedaphne calyculata*					5	4		
devilsclub	*Oplopanax horridus*	5		5	5				
fireweed	*Epilobium* sp.	3	3	4	5			4	
sedge	*Carex* sp.			5	2	5	3		3
grass	*Gramminaea*	3	3	3	1	3	2	3	2
Fern	*Polystichum* sp.		5	5		4			
-	*Eriophyllum lanatum*					5	4		5
Horsetail	*Equisetum* sp.		4	4	3	5	4	5	4
-	*Angelica genuflexa*				4				
-	*Artemesia tilesii*	5	5	5					
lupine	*Lupinus* sp.							5	

[a]Upland Alder Thicket (UAT);
High Altitude Riparian (HAR);
Black Cottonwood Riparian (BCR);
Coastal Marsh Riparian (CMR);
Black Spruce Transitional (BST);
Resin Birch Bog (RBB);
Willow Thicket Riparian (WTR); and
Black Spruce Riparian (BSR).

Black Spruce Transitional

This type was very limited in its distribution, mainly composing the later successional stages in and around the open bogs. Characteristic of an ecotone, these sites hosted a mixture of riparian species (black cottonwood, thinleaf alder, and paper birch) and bog species (black spruce, bog rosemary, and bog blueberry). Herbaceous taxa were well represented in both number and distribution. Physically, these sites were also intermediate between bog and riparian sites with part of the area dry and well drained while other areas were wet and spongy.

Resin Birch Bog

Although this type was found throughout the lower elevations of the study area, it dominated the area north of Noaukta Slough. Characterized by a predominance of bog shrubs such as resin birch, bog blueberry, and narrow-leaf Labrador-tea, these areas also hosted an abundance of herbaceous plants including sedge and grasses. Physically, these sites were poorly drained and supported large mats of floating vegetation.

Willow Thicket Riparian

The distribution of this type was limited, only being found along the floodplain of the McArthur River canyon. This riparian area was characterized by an abundance of willows (seven species), black cottonwood, and thinleaf alder. Herbaceous plants were sparse but included fireweed, grasses, and lupine.

Black Spruce Riparian

This type was common at intermediate elevations, between the higher elevations of the Resin Birch Bog and the lower elevations of the Coastal Marsh Riparian and was the dominant type found on the Trading Bay Refuge. These areas were characterized by an abundance of diamondleaf willow, black spruce, and an absence of black cottonwood. Both species of alder were present along with an abundance of sedge and grasses. Physically, these sites were poorly drained, but unlike the bog, there was no mat of floating vegetation to cover the large amounts of water.

6.4.3.2 Mammals

Of the 16 species of mammals that were identified, the grizzly bear, black bear, and moose had ranges occurring throughout the study area. Also common were the coyote and gray wolf, both of which were found in more than 50 percent of the quadrats sampled. Less common mammals included the river otter, barren ground caribou, and wolverine.

The same eight habitat types used to classify the terrestrial vegetation were also used to classify the distribution and relative abundance of the mammals that occurred in the study area (Table 6.11). Grizzly bears, black bears, and moose were found to utilize all eight habitat types. During the two weeks in September that this study encompassed, the grizzly bear appeared to be most abundant in the High Altitude Riparian and Black Cottonwood Riparian habitats. The black bear appeared most abundant in the Upland Alder Thicket and High

Table 6.11 The species composition and relative abundance of mammals identified within the study area for each of the habitat types. (1=Abundant 3=Common 5=Occasional)

Species		Habitat[a] UAT	HAR	BCR	CMR	BST	RBB	WTR	BSR
grizzly bear	*Ursus horribilis*	3	1	3	3	5	5	3	3
black bear	*Ursus americanus*	1	1	3	3	5	3	3	3
gray wolf	*Canis lupus*	5	3	5	5	5		5	
coyote	*Canis latrans*	3	3	3	1	3	3	3	3
moose	*Alces alces*	5	1	1	3	3	3	3	3
barren ground caribou	*Rangifer arcticus*		5						
wolverine	*Gulo luscus*	5	5	5				5	5
mink	*Mustela vison*	5	5	3				5	3
river otter	*Lutra canadensis*			5				5	5
beaver	*Castor canadensis*			3				3	3
muskrat	*Ondatra zibethica*		5	3				3	3
red squirrel	*Tamiasciurus hudsonicus*	5	5	5	5	5			5
tundra redback vole	*Clethrionomys rutilus*	1	3	3	3	3	3		
tundra vole	*Microtis oeconomus*			3					
porcupine	*Erethizon dorsatum*		3	3	5				
dusky shrew	*Sorex obscurus*	3	3	3					
harbor seal[b]	*Phoca vitulina*				5				
beluga whale[b]	*Delphinapterus leucas*				5				

[a] Upland Alder Thicket (UAT);
High Altitude Riparian (HAR);
Black Cottonwood Riparian (BCR);
Coastal Marsh Riparian (CMR);
Black Spruce Transitional (BST);
Resin Birch Bog (RBB);
Willow Thicket Riparian (STR); and
Black Spruce Riparian (BSR).

[b] sighted offshore near the mouth of the McArthur River.

Altitude Riparian habitats, while the moose was most abundant in High Altitude Riparian and Black Cottonwood Riparian habitats. Unlike the distribution of most of the other mammals, moose were common in all habitats except in the upland Alder Thickets.

The only other ungulate that occurred in the project area besides moose was the barren ground caribou, and its distribution was restricted to the High Altitude Riparian habitat. Both species of Canids that were present, occurred over a fairly large range. Although not as abundant as the coyote, the gray wolf was found in all habitats except the Resin Birch Bog and the Black Spruce Riparian while the coyote was found in all eight types. The order that was best represented in the study area was Rodintia. The two largest members of the order, beaver and porcupine each occupied three habitats while the muskrat inhabited four types.

The habitat type that had the highest diversity (as measured by the number of species) was the Black Cottonwood Riparian. This habitat contained 15 of the 16 mammals found in the study area. The lowest diversity (five species) was found in the Resin Birch Bog habitat.

The analysis of scats, tracks, and feeding areas supplied additional information on the seasonal distribution and food habits of some species. Both species of bears appeared to be consuming berries, salmon, and grasses. Although the direction of travel for most of the bears was towards the High Altitude Riparian habitat it is not known if this is indicative of the location of winter denning sites. During the two weeks of this study, moose were feeding mostly on willows that were taller than five feet and were seldom seen very far from tall dense vegetation. Calving grounds, as indicated by the skeletal remains of juvenile moose, appeared to be located in and near the Black Cottonwood Riparian habitat around the Middle River, Noaukta Slough, and the McArthur River. Wintering areas, as indicated by shed antlers, were found throughout the High Altitude Riparian habitat above Chakachamna Lake. Beaver, otter, and muskrat had more limited distributions. While beaver and muskrat were found throughout the Black Cottonwood Riparian, Willow Thicket Riparian, and Black Spruce Riparian habitats, porcupine were found in the High Altitude Riparian, Black Cottonwood Riparian and Coastal Marsh Riparian habitats. Areas that are utilized by these mammals were identified by the presence of beaver lodges, woody plants, chewed by beaver, muskrat houses, otter slides and tracks.

In addition to the terrestrial mammals, two species of marine mammals were present. A harbor seal was sighted at the mouth of the McArthur River and although Beluga whales were not observed during this study, personnel of ADF&G have sighted whales in Trading Bay.

6.4.3.3 Birds

Within the study area, 56 species of birds were identified. Of these, the three that occurred in all 23 quadrats sampled, were the bald eagle, common raven, and black-billed magpie. Also common in the area were marsh hawks, black-capped chickadees, and various species of waterfowl. Species that were only sighted occasionally included fox sparrows, Swainson's hawks, brown creepers, and snow buntings.

The same habitat types that were used to describe the distribution of mammals and vegetation were used to describe the distribution and relative abundance of the 56 species of birds (Table 6.12). The habitat that hosted the largest diversity of avifauna was the Coastal Marsh Riparian. Included is the 38 species sighted in that type were trumpeter swans, bald eagles, black bellied plovers, short-billed dowitchers, and lapland longspurs. The Upland Alder Thicket type only hosted 10 species, most of which were common throughout the study area. Nearly as low in species richness were the Resin Birch Bog and Willow Thicket Riparian habitats, containing 11 and 12 species of birds, respectively.

Two of the larger species that nest in the study area are the bald eagle and the trumpeter swan (Figure 6.25). As of May 1980, ADF&G personnel had documented the location of five eagle nests on the Trading Bay Refuge. During this two week study, eagles were observed from the Chilligan River to Cook Inlet, however, they were concentrated near the confluence of Straight Creek and the Chakachatna River. In August, 1980, personnel of USFWS recorded the location of trumpeter swan nests in and near the refuge. At the time of the survey, there were 25 pairs of breeding swans and a total of 143 swans in the project area. Similar to the distribution of eagle nests, swan nests were concentrated near Cook Inlet. The area within seven miles of the tidal mud flats provided habitat to 55 percent of the total population, 48 percent of the nesting pairs, and 63 percent of the fledgling cygnets (Figure 6.26). Although the largest proportion of the population was near Cook Inlet, the area with the highest density was from Noaukta Slough to the Blockade Glacier, along the McArthur River. This area, encompassing 70 square miles, contained 56 trumpeters (0.8 swans/mile2).

A species that is commonly found feeding in the study area, (Timm and Sellers, 1981) yet was not observed during this study, is the tule white-fronted goose (*Anser albitfrons gambelli*). Currently, the only known nesting areas for the tule goose in Cook Inlet are at Redoubt Bay and Susitna Flats. Although personnel of USFWS and ADF&G have searched the study area for nesting pairs, no evidence exists that would support the contention that this species nests on the Trading Bay Refuge. However, since this species often nests in dense vegetation, undetected nesting sites may exist.

Table 6.12. The species composition and relative abundance of birds identified within the study area for each of the habitat types. (1=Abundant 3=Common 5=Occasional)

Species		Habitat[a]							
		UAT	HAR	BCR	CMR	BST	RBB	WTR	BSR
trumpeter swan	*Olor buccinator*		5	3	3				3
Canada goose	*Branta canadensis*			5	3				
white-fronted goose	*Anser albifrons*	5	5						
mallard	*Anas platyrhynchos*				1				
pintail	*Anas acuta*	5	5	5	1				5
American wigeon	*Mareca americana*				1				5
green-winged teal	*Anas carolinensis*				1				
greater scaup	*Aythya marila*								5
common goldeneye	*Bucephala clangula*				5				
oldsquaw	*Clangula hyemalis*				5				
common merganser	*Mergus merganser*			5					3
red-breasted merganser	*Mergus serrator*				5				
sharp-shinned hawk	*Accipiter striatus*				3				
marsh hawk	*Circus cyaneus*	5	3	3	3		3	5	3
red-tailed hawk	*Buteo jamaicensis*			5	5	5	5		
Swainson's hawk	*Buteo swainsoni*				5				
bald eagle	*Haliaeetus leucocephalus*	3	3	3	3	5	5	5	3
spruce grouse	*Canachites canadensis*			3		5	5		
willow ptarmigan	*Lagopus lagopus*				5	5			
sanhill crane	*Grus canadensis*				3		5		
black-bellied plover	*Squatarola squatarola*				5				
spotted sandpiper	*Actitis macularia*			5	5				
greater yellowlegs	*Totanus melanoleucus*				5				
short-billed dowitcher	*Limnodromus griseus*				3				
pectoral sandpiper	*Erolia melanotos*				1				3
least sandpiper	*Erolia minutilla*				5				
northern phalarope	*Lobipes lobatus*				5			5	5
common snipe	*Capella gallinago*				5			5	3
glaucous-winged gull	*Larus glaucescens*	5	3	3	3				
herring gull	*Larus argentatus*			5					
mew gull	*Larus canus*	5	3	3	3	5			

Table 6.12. Concluded.

Species		Habitat[a]							
		UAT	HAR	BCR	CMR	BST	RBB	WTR	BSR
arctic tern	Sterna paradisaea				3				
short-eared owl	Asio flammeus			5	5	5			
hawk owl	Surnia ulula			5					
belted kingfisher	Megaceryle alcyon			5					
hairy woodpecker	Dendrocopos villosus		5						
bank swallow	Riparia riparia			3	3				
gray jay	Perisoreus canadensis			5	5	3	5	5	5
black-billed magpie	Pica pica	3	3	3	3	3	3	3	3
common raven	Corvus corax	3	3	3	3	3	3	3	3
black-capped chickadee	Parus atricapillus	1	1	3	5	5	5	1	5
boreal chickadee	Parus hudsonicus		5						
brown creeper	Certhia familiaris					5			
hermit thrush	Hylocichla guttata		5						
ruby-crowned kinglet	Regulus calendula			5		5	5		
water pipit	Anthus spinoletta			3	3	5			
yellow warbler	Dendroica petechia					5			
common redpoll	Acanthis flammea				3	5		3	
pine siskin	Spinus pinus		3	5		5			
savanah sparrow	Passerculus sandwichensis			5	3				
dark-eyed junco	Junco hyemalis		3	3		3		3	
tree sparrow	Spizella arborea		3	5	3			3	
chipping sparrow	Spizella passerina			3			5		
fox sparrow	Passarella iliaca	5							
lapland longspur	Calcarius lapponicus				3			3	
snow bunting	Plectrophenax nivalis			3					

[a] Upland Alder Thicket (UAT); High Altitude Riparian (HAR); Black Cottonwood Riparian (BCR); Coastal Marsh Riparian (CMR); Black Spruce Transitional (BST); Resin Birch Bog (RBB); Willow Thicket Riparian (WTR); and Black Spruce Riparian (BSR).

Of all of the species of plants, mammals, and birds that were identified in the study area, none of the species that are present are listed as threatened or endangered by the Federal Government. However, as of May 1981, it was proposed that the tule goose be considered for threatened or endangered status (M. Amaral, USFWS, personal communication 2 November 1981).

6.4.4 Conclusions

The relatively high diversity in both flora and fauna found within the study area is the product of climate topography and fluctuations in the stream and river discharge. Due to periodic tidal inundation of the coastal marshes, both salt water and brackish marsh vegetation is found. Surface flows resulting from precipitation are apparently retained for long periods of time in bogs. Combined with these factors are dynamic river channels and varying successional stages. As a result. the study area is composed of a variety of vegetation types that, individually and collectively provide important habitat to species of wildlife throughout the year. Although all species of plants and animals in the area are important, there are several vegetative types that are more critical to the overall stability of the community than others. Two of these are the High Altitude Riparian and the Black Cottonwood Riparian habitats. These areas not only provide food and cover to a wide variety of animal life throughout the year, they also provide wintering and calving grounds for moose, nesting sites for bald eagles and trumpeter swans, and feeding areas for grizzly and black bears. The other two critical areas are the Coastal Marsh Riparian and the

Black Spruce Riparian habitats. Due to the large expanses of standing water and dense vegetation, these areas provide nesting and staging areas for waterfowl and shore birds.

6.5 Human Resources

6.5.1 Background

The Human Resources element of the report was prepared with several objectives in mind:

(1) identification of concerns of government agencies and general public

(2) evaluation of project alternatives,

(3) conformance with FERC guidelines, and

(4) preparation of the 1982 scope of study.

Accordingly six areas of study were selected: archaeological and historical resources, land ownership and use, recreation, socioeconomics, transportation, and visual resources.

The general project area has a long and varied history of human habitation, and therefore has a high potential for archaeological and historical resource sites. However, little field work has been done in the project area and the distributrion of potential resource sites is unknown. Federal and State agencies and Native corporations involved in the proposed project have varying requirements for the protection of archaeological and historic resources.

As elsewhere in the state, land is owned by a mix of federal, state, Native, and private entities. The status of land selections, conveyence and patents is complicated and often involves several parties in the manaqement of one parcel of land. Land use revolves around resource extraction, processing, and transportation.

Recreational use of the project area is currently limited, but increasing in popularity. Recreation activities in neighboring Lake Clark National Park and Trading Bay Game Refuge could have a bearing on the project. In addition, the State Division of Parks will be inventorying recreation resources in western Cook Inlet in the near future and is interested in the Chakachamna River area.

Project construction and operation will both create jobs and impact the socioeconomic characteristics (population, employment, income, infrastructure and subsistence) of the region. Impacts will affect the village of Tyonek, the Kenai Peninsula Borough, and the greater Anchorage area.

The remoteness of the project site emphasizes the importance of existing transportation networks. Project use of roads, docks, and air strips may conflict with existing uses, and new facilities required for the project may provide new public access that is not desired by local residents.

Both the Bureau of Land Management and FERC have specific requirements regarding visual resources. The scenic nature of the project area led to its consideration for inclusion as national interest lands under Section

17(d)-2 of the Alaska Native Claims Settlement Act. Project proximity to Lake Clark National Park and Trading Bay State Game Refuge may place more importance on visual resource impacts.

This Human Resource element was prepared using three methods. Field reconnaissance was employed to evaluate the potential for archaeological resource sites. Several recent reports associated with coal and petroleum resource development proposals were also utilized. Finally, federal, state, and Native entities were contacted to obtain resource data and concerns about the project.

6.5.2 Archaeological and Historic Resources

6.5.2.1 Introduction

This section evaluates the historic and archaeological resources of the area through a literature review, personal contacts, and consultations with the State Historic Preservation Officer and the State Archaeologist. A one day helicopter reconnaissance allowed a field evaluation of the power generation facility sites.

6.5.2.2 Historical Background

The project area lies within the traditional territory of Tanaina Athapaskan Indians. The earliest record of European contact with the Tanaina resulted from Captain James Cook's voyage to the upper inlet in 1778 (Cook 1784). In July of 1786, two English ships captained by Dixon and Portlock made a trading trip to Cook Inlet.

The bay in which they anchored was named Trading Bay by Capt. Portlock. Trading lasted for about a week (Dixon 1789; Portlock 1789). During this same period Russian presence was increasingly more evident in the Cook Inlet region (Bancroft 1886; Townsend 1965).

After the Russians settled in the area there began a period of struggle between the various Russian trading companies. The Tanaina were caught up in this struggle and open hostilities broke out between the Tanaina and the Russians. The Russian American Company was founded in 1799" (Van Stone and Townsend 1970:14). An outpost had been established by the Russians at Tyonek around 1790. In 1797 the Tyonek Outpost was destroyed. "Dissension among the Russians and persecutions of the Natives reached such an extreme that the infuriated Kenais (Tanaina) destroyed the two outposts at Iliamna and Tuiunuk (Tyonek), killed 20 Russians, and almost 100 subject natives" (Tikhmenev 1978:46).

After 1800, hostilities between the Tanaina and the Russians seem to have subsided. This relatively peaceful period saw renewed trade and the introduction of Christianity (Townsend 1965:55). Unfortunately, a smallpox epidemic swept through the region in the late 1830s.

With the sale of Alaska to the united States in 1867 the Russian-American Company assets were purchased and reorganized to form the Alaska Commercial Company. The Alaska Commercial gained a virtual monopoly in 1883 after the Western Fur and Trading Company sold out.

During the late 1890s and early 1900s, Tyonek became a major disembarking point for both goods and people as prospectors and miners moved into the Cook Inlet region.

Aboriginal use of the project area appears to have been extensive and ancient. Extensive use of several mountain passes and trails is well documented for the late prehistoric/early historic period. The Tanaina from the Tyonek area utilized the interior region for hunting and trading purposes as did the inland Tanaina groups from Lake Clark, Mulchatna, Stony River, and the Susitna basin. Key subsistence items for the Tyonek Tanaina, however, centered on marine resources. Procurement of food items such as salmon, eulachon, seal, and beluga made it possible for the Tanaina to maintain semi-permanent villages along the coast. In late April the Tyonek Tanaina would move to traditional fish camps along the inlet. Waterfowl were caught at tidal flats and at the mouths of rivers along Trading Bay. Beluga and Susitna flats were also used. During the spring, fish traps were set for trout at interior lakes. Beaver were also hunted inland at streams and lakes (Chickalusion and Chickalusion 1979). The favored land hunting area for the Tyonek Tanaina was the region around Chakachamna Lake. Inland hunting was concentrated during late August through October. Moose seemed to be scarce throughout the region during early historic times. In addition to hunting in the Chakachamna Lake region the Tyonek people would sometimes cross the Hayes River Pass (Tubughna Kalidiltuni) to Rainey Pass (Htal) to hunt caribou and sheep. Here they would meet and trade with Susitna Tanaina (Fall 1981:193).

The Tyonek people had a tradition of trading with other groups from the interior. They would meet upper Kuskokwim Natives at Merrill Pass in the summer or fall to conduct trading. Apparently the Tanaina enjoyed the role of middleman traders between the Russians at Cook Inlet and the deep interior upper Kuskokwim Indians (Zagoskin 1967:16B-169).

A review of the archaeological literature indicates that the project area and immediate vicinity have not been studied. Most of what is known of the prehistory in the Cook Inlet region pertains to the western side of Knik Arm (de Laguna 1975; Dumond and Mace 1968), the northern shore of Turnagain Arm (Reger 1977b, 1981), Kenai Peninsula (Kent et al. 1964; Borras 1975, 1976; Reger 1977a), Kachemak Bay (de Laguna 1975; K. Workman 1977; W. Workman 1977), and the Matanuska River (West 1975, 1980; Bacon 1978). The only archaeological investigation very close to the project area is that of de Laguna at Kustatan in 1930. She briefly investigated a prehistoric midden on the first bench behind the cannery. On the second bench she observed several house pit depressions and excavated one of them (de Laguna 1975:138). De Laguna commented that although the collection was meager (faunal remains and a few artifacts) it appeared similar to Kachemak Bay collections (de Laguna 1975:148).

The following outline of Cook Inlet prehistoric cultural events is based upon Reger's recent summary (Reger 1981).

A. The earliest cultural remains recognized in the Cook Inlet region are from component I at the Beluga Point-North site on Turnagain Arm. It consists of a core and microblade technology which can be compared to other sites dating between 8000 and 10,000 years ago. These sites fall within the broad American Paleoarctic tradition described by Anderson (1968:29). This tradition includes collections from interior Alaskan locations such as Dry Creek (Nenana Valley), Healy Lake (Tanana Valley), and Onion Portage (Kobuk Valley). These sites have consistently been associated with an environment thought to support herds of bison, horse, mammoth, and caribou. Thus, these early cultures are believed to have been primarily exploiters of large land mammals. Heusser's reconstruction of the early post-glacial vegetation for southcentral Alaska postulates generally treeless tundra and somewhat moister conditions than the deep interior (Heusser 1960). A greater expanse of tundra than at present would have been able to support a large number of caribou.

B. The next occupation in the sequence is found in Beluga Point-North component II and Beluga Point-South component I. Artifact comparisons with surrounding geographic areas, i.e., the Alaska Peninsula, Afognak Island, and Lake Iliamna indicate an age of 3000 to 4000 years old.

C. Norton related culture (cf Dumond 1977:106) is represented by Beluga Point-South component II. "The time period of approximately 1500 to 3000 years ago was a period in which influences (Norton culture) from Bristol Bay diffused into Cook Inlet as indicated by the BPS-II collection" (Reger 1981:202). Although there was a fairly strong Norton influence during early Norton times, the archaeological record indicates that cultural influences between Bristol Bay and Cook Inlet had ceased during late Norton times.

D. Reger suggests that Kachemak culture (de Laguna 1975), which flourished in the Kachemak Bay area, may have provided a mechanism for limiting Norton influences in the Cook Inlet area. He feels that between 1500 to 2000 years ago a separate cultural pattern developed in the upper inlet which was based on seasonal use of riverine and interior resources "Such a pattern appears to be evident at the Moose River site and the Merrill site, and by inter- pretation will probably be found in the Upper Inlet area" (Reger 1981:205).

E. Between 600 and 800 years ago another cultural occupation was present at Beluga Point, Beluga Point-North component III. This component is distinct with only a few traits showing close comparison with nearby collections, i.e., from Prince William Sound, Kodiak Island, and Kachemak Bay. The presence of native copper implements indicates trade contacts with interior Indian groups, possibly Atna Athapaskans of the Copper River country.

F. The late prehistoric period in the upper Cook Inlet region is poorly documented. It is generally believed that interior Athapaskan influences were introduced by the arrival of Tanaina Indians, perhaps during the second half of the 18th century A.D.

6.5.2.3 Methodology and Results

The Alaska Heritage Resource Survey File (AHRS), maintained by the State Historic Preservation Office, was searched for any reference to historic or archaeological sites at or near the Chakachamna Hydroelectric Project. No sites are listed for the project area. A review of the archaeological, ethnological, and historical literature indicates that the project area has not been well studied.

The potential for prehistoric human use and habitation within the project area is moderately high. The literature indicates that prehistoric peoples were ranging throughout the Cook Inlet and Susitna basin region over many thousands of years, perhaps as early as 8000 B.C.. Several diverse cultural traditions have exploited the region. Thus far, nearly all of the archaeological investigations in the Cook Inlet region have been at coastal sites. The interior exploitive pattern has only recently been investigated.

De Laguna made note of four old village sites between Trading Bay and Beluga River, although she did not visit any of them.

> Ladd. The modern village is on an ancient site, Tsluiltna from which the name of the river, Chuit, is probably derived.
>
> Tyonic or Moquawkie. There is an old village site, Qalqesle, near the modern village. In the woods at the top of the hill behind the village are the houses where the natives used to live for fear of raids made by the Kodiak Eskimo.
>
> Old Tyonic. This village is called Tatlnaq, and may be old. This seems to be the "Toyonek" of Petroff's map.
>
> Granite Point. The site of Tsilalxna is at a small stream south of Granite Point (de Laguna 1975:139).

The one-day helicopter reconnaissance provided an overflight of the potential power generation facility sites, on the southeast shore of Chakachamna Lake and near the upper limits of McArthur River. The lake shore in sections 18 and 19 of Township 13N/Range 17W and section 24 of Township 13N/Range 18W, Seward Meridian was examined from the air. There was no landing area for the helicopter because the steep, rocky slope decends abruptly into the lake and the helicopter was not equipped with pontoons. The possibility of any impact to cultural resources resulting from the facility at Chakachamna Lake is so unlikely that an on-the-ground archaeological survey is not considered necessary.

The porbable location of the powerhouse lies somewhere within section 30 of Township 12N/Range 17W, Seward Meridian. This area, a small narrow valley with steep walls, was examined from the air only. Although it appears unlikely that any cultural resources will be impacted by the facility, an on-the-ground archaeological clearance should be done after the exact location is selected and the limits of the construction zone determined, but prior to the actual construction.

Because transmission line corridors and access road alignments have yet to be finalized, only a reconnaissance flight over the broad zone of probable impact was possible. It is here that potential impacts to cultural resources are most likely to occur, especially with the building of roads and development of borrow pits. Therefore, archaeological on-the-ground survey will be necessary prior to any construction activities involving transmission lines and roads.

The likelihood of archaeological site occurrence can be depicted on maps as areas classified high, medium, and low potential. Such areas can be identified using basic criteria of vegetation communities, physiography, slope, aspect, soils, and proximity to resources such as food, fuel, raw materials, and water. Mapping of archaeological potential can be aided by air photo interpretation, but primarily depends on the judgement of the archaeologist. This judgement is based upon experience in site survey, familiarity with specific geographical areas, and the data base of identified archaeological sites found in similar environmental settings throughout Alaska.

Areas of low potential are generally flat wetlands or have high topographic relief. Either condition is restrictive to human habitation. Low potential areas also include active floodplains where periodic flooding and erosion would have destroyed evidence of past human activity. High potential areas are generally those with moderate topographic relief which ordinarily are well-drained. Areas of medium potential might include some portions of high and low potential but are not classified predominately high or low.

6.5.3 Land Ownership and Use

6.5.3.1 Land Ownership

Figure 6-27 shows the existing land ownership in the proposed project area. Historically the federal government owned all the land in the area as "public domain". Large areas of federal land have been transferred to Alaskan Natives and the State of Alaska. A small amount of state land was subsequently transfered to the Kenai Peninsula Borough. Land ownership patterns have not been finalized in the area. The largest unresolved matter involves the settlement of land claims associated with the Alaska Native Claims Settlement Act (ANCSA) of 1971. Extensive federal and state lands have been selected by the Natives but not all the legal transfers have been completed. Native landowners include Cook Inlet Region, Inc., Tyonek Native Corporation and the Native Village of Tyonek.

A number of small parcels have been patented to individuals, primarily along the coast, by both the federal and state governments. Numerous easements and rights-of-way exist in the area, again primarily along the coast.

Rights to various resources, including timber, petroleum and coal, have been sold in the area by both the state and the Natives. Resource development activities will continue to have a major impact on the area.

6.5.3.2 Federal Land

Federal lands in the area have been involved in complicated proceedings due to often times overlapping selections by the state and Alaska Natives and the establishment of the boundaries of Lake Clark National Park. Native selections on federal lands in the area have been unofficially relinquished (CIRI, personal communication, November 10, 1981). State selections are still in force and are being processed. Thus, the state may eventually gain patent to some of these lands. All federal lands outside of the park are administered by the Bureau of Land Management. Federal land in the park is administered by the National Park Service.

Bureau of Land Management

Federal lands administered by BLM include the Lake Chakachamna power site and a number of townships surrounding the power site. In 1947 lands in the immediate vicinity of Lake Chakachamna system were withdrawn as a power site under Power Site Classification 395 (USS 3970). The power site includes all public lands lying within one-quarter mile of Chakachamna Lake, Kenibuna Lake, and the Chakachatna River from the outlet at the lake to the mouth of Straight Creek.

The remaining BLM land, some of which is unsurveyed, is being passively managed. Most of these townships have been selected by the state. Native selections have also been made on some townships but these selections are to be officially relinquished in the near future (personal communication, CIRI, November 10, 1981). Until official relinquishment is made BLM cannot act on the state selections. Townships or portions of townships selected by the state in the area but not selected by the Natives, are on the state's priority list and may be conveyed in the near future.

Lake Clark National Park

The park is administered by the National Park Service. Lake Clark National Park and Preserve were established on December 2, 1980 by the Alaska National Interest Lands Conservation Act. This act provided for a national park of approximately 2,439,000 acres and a national preserve containing approximately 1,214,000 acres. The federally owned or controlled lands of the park and preserve, by virtue of their becoming part of the National Park System, are subject to title 16 of the United States Code and title 36 of the Code of Federal Regulations. Management of all areas of the National Park System follow the administrative policies setting forth broad guidelines for park managers.

The portion of the park bordering the study area including the Chilligan River, Lake Kenibuna and its tributaries is designated as wilderness.

Use of the park is discussed in the recreation section of this report.

6.5.3.3 State Land

Land in the proposed project area has been conveyed to the State of Alaska by the 1953 Submerged Lands Act, the 1956 Mental Health Enabling Act and the 1958 Alaska Statehood Act. State lands have been classified according to the system described below.

The State Land Classification System which is currently being revised is similar to zoning, in that there are different classification categories which reflect the capabilities and different potential uses of the land. Unlike zoning, however, the classification system applies to State-owned land only. Also unlike zoning, the present state classification system contains no provisions to guarantee that once title to State-owned land is passed, it will continue to be used for the classified purpose. The classification system is presently undergoing revision within the Division of Lands. (State Division of Lands, CZM Report, December 31, 1977.

In the proposed project area the following land classifications exist: Resource Management Lands and Industrial Lands.

Resource Management Lands

Resource management lands contain an association of surface and/or subsurface resources which are especially suited to multiple use management.

In the proposed project area, resource management lands are being used in several ways: oil and gas leasing, coal prospecting and leasing, a timber sale and mining permits, with some uses overlapping.

Industrial Lands

Industrial lands are those which, because of location, physical features or adjacent developments, may best be utilized for industrial purposes. According to the State Administrative Code, these lands may be disposed of by lease or sale (11 AAC 52 070).

There are currently several sites of varying sizes which are classified as industrial sites. These include the Kodiak Lumber docking facility at North Forelands and other sites operated by Texaco and Atlantic Richfield. See Table 6.13 for list of industrial sites.

Lands leased from the State for commercial or industrial purposes can only be used for the purposes designated and are subject to local building and zoning codes, which involves the Kenai Peninsula Borough.

6.5.3.4 Native Land

There are four main classes of Native land ownership in the proposed project area as a result of special legislation:

- Cook Inlet Region, Inc. (CIRI)
- Tyonek Native Corporation (TNC)
- Native village of Tyonek
- Native Allotments

Other Native holdings or land ownership in the area include patented parcels and set net sites.

Cook Inlet Region, Inc.

Unlike most areas of the state, selection of land entitlements by CIRI was complicated by prior selection of traditional village lands by the State of Alaska under its Statehood Act entitlement. The lack of appropriate land for Native selection led to litigation and establishment of the Cook Inlet Land Exchange.

Under the land exchange, CIRI is to obtain patent to the surface and subsurface estate of approximately 1.23 million acres of land. In addition, it receives subsurface estate to another 1.15 million acres of land,

Table 6.13. Industrial Sites.

Site Number	Township Location and Size	Description	Date Classified
C 170	T.11N., R.12W., S.M. Sec. 28, 255 B7 ac.	Tidelands	12-13-61
C 1313	T.11N., R.12W., S.M. Sec. 27, 248.64 ac.	O & G Support Facilities	9-30-65
C 1336	T.11N., R.12W., S.M. Sec. 28, 351.45 ac.	O & G Support Facilities	12-27-65
C 1369	T.11N., R.12W., S.M. Sec. 28, 126 ac.	O & G Support Facilities (tidelands)	4-13-66
C 1483	T.11N., R.12W., S.M. Sec. 29. 397 ac., & Sec. 30, 6 ac.	O & G Support Facilities	2-21-68
C 1487	T.11N., R.12W., S.M. Sec. 28 & 33, 36.82 ac	Ship Docking Facility O & G Support Facilities (tidelands)	2-6-68
C 1906	T.11N., R.11W., S.M. ATS 931, 44.86 ac.	Ship Docking Facility Kodiak Lumber Company	5-28-74

Source: State of Alaska, Department of Natural Resources Status Plats. For complete legal descriptions, including aliquot part descriptions, contact Alaska Division of Lands.

the surface of which is either patented to the village corporations or is within the Kenai National Moose Range.

Village Corporations Associated with CIRI

Within the geographic boundaries of the Cook Inlet Region, Inc., which extend from Seldovia in the south, almost to Mt. McKinley in the north, there are six village corporations: Chickaloon, Eklutna, Knik (Called Knikatnu by the villagers), Ninilchik, Seldovia and Tyonek. The acreage received by the Village Corporations is based on the number of stockholders who traced their heritage back to a village and enrolled to a village corporation. Approximately 6,000 Eskimos, Indians, and Aleuts have enrolled to Cook Inlet Region, making it the fifth largest Native regional corporation.

Under the conditions of the land exchange, six land selection pools were established. By far the largest, the Beluga Pool at 311,040 acres was made available to CIRI by the State of Alaska. Cook Inlet Region, Inc. has selected all of the lands in the Beluga Pool and expects convenyance of all except T.14N, R.15W. The northern half of that township covering the central part of Capps Glacier was not state land and should not have been set aside initially in the State's Beluga Pool.

Because the Beluga Gas Field subsurface and the Nikolai Gas Field subsurface were both excluded in the exchange agreement, Cook Inlet Region expects to receive only the surface estate to the affected land located in T.12 and 13N, R.10W. (Beluga Gas Field) and T.11N, R.12W. (Nikolai Gas Field). Land selected by the Kenai Peninsula Borough in T.12N, R.10W are available to CIRI for the subsurface only. The surface estate will go to the borough. Inasmuch as there is more subsurface estate available to CIRI from the Boroughs' lands than there is surface available, due to the gas fields' exclusion, there is an imbalance in CIRI's selections.

In an effort to select their full entitlement of 311,040 acres, CIRI has selected somewhat more surface than subsurface in T.16N, R.14W. The above lands are considered the first priority for selection. These selections exclude Beluga Lake and Lower Beluga Lake, and the section of the Beluga River running between the lakes. They also exclude U.S. Survey 3970, which protects Power Site Classification 395 (April 22, 1948) for potential hydroelectric development at Chakachamna Lake and Chakachatna River.

Conveyance of the Beluga Pool Land to CIRI was subject to any lawful reservations of rights or conditions contained in the State conveyance as provided by the Terms and Conditions document. Within two years after initial conveyance, the Secretary of Interior is authorized to identify and reserve any easement he could have lawfully reserved before conveyance. All valid existing rights to coal prospecting permits, coal leases, oil and gas leases, mineral leases, etc. are protected under terms of the exchange.

The attitude of Cook Inlet Region, Inc. toward rights-of-way across their lands, is quite different than that of Tyonek Native Corporation. While the Tyonek Native Corporation has been opposed to all rights-of-way and easements, CIRI is willing to consider them. They recognize that in order to remove the natural resources, such as coal, easements must be made available.

Tyonek Native Corporation

One of the six CIRI village corporations, the Tyonek Native Corporation was organized as a result of the passage of the Alaska Native Claims Settlement Act by Congress and represents the 303 Native people enrolled to the village of Tyonek. The Tyonek Village entitlement according to Section 14(a) of ANCSA is 115,200 acres - substantially larger than the 69,120 acres most villages receive. The size of Tyonek's entitlement is based on the fairly large Native population which the village had on the 1970 census enumeration date. Villages with a population between 200 and 399 were entitled to 115,200 acres.

The lands patented to Tyonek Native Corporation will be limited to just the surface estate of the lands - in accordance with Section 14(a) and (b) of ANCSA. Patent to the subsurface estate will be made to Cook Inlet Region, Inc. according to Section 14(f) of ANCSA.

A stipulation of the regional corporation patent to the subsurface estate is that the right to explore, develop or remove minerals from the subsurface estate in the lands within the boundary of Tyonek Village, are subject to the consent of the Village. Essentially this provision gives Tyonek a "veto power" over unwanted development by Cook Inlet Region.

Because there are not sufficient lands available for selection to meet the village entitlement from among lands surrounding the village, the Secretary of Interior set aside "deficiency lands" from nearby unreserved, vacant and unappropriated public lands. Thus, much of the

Tyonek Village's land selected under ANCSA is not adjacent to the village site. Adjacent selectable lands consisted of the Moquawkie Indian Reservation (the Tyonek Village Indian Reserve) and State tentatively approved lands. Several miles across Cook Inlet from the village, lands within the Kenai National Moose Range were also selected.

Deficiency selections were made south of the village along the West Coast of Cook Inlet and from lands in the upper Susitna River area, where the Susitna Hydroelectric Project is planned.

Tyonek Native Corporation has leased land to Kodiak Lumber Mills, Inc. for the lumber camp, chip mill, and access roads and to various petroleum companies for access roads.

Native Village of Tyonek, Inc.

Tyonek, which is located on the former Moquawkie Indian Reserve is not incorporated as a city under the laws of the State of Alaska. However, it is a Federally chartered Native village, governed by an IRA (Indian Reorganization Act) Tribal Council. The Tribal Council -- also called the Village Council -- is the political arm of Tyonek and which, prior to December 18, 1971 (the date ANCSA was enacted) controlled the lands within the former Moquawkie Indian Reserve under a trust relationship with the U.S. Department of Interior, Bureau of Indian Affairs. On December 18, 1971, this Reserve was abolished by Section 19 of ANCSA, and the lands came under the jurisdiction of the U.S. Department of

Interior, Bureau of Land Management. The Tyonek Native Corporation succeeded to the rights of the surface estate of the Reserve under terms of ANCSA that had been enjoyed by the Village Council. Because the Village of Tyonek was located on the Moquawkie Indian Reservation, Section 19(b) of ANCSA came into play. This section of the Settlement Act provides for an election of its members to decide whether to retain the Indian Reserve and receive the surface and subsurface estate to the reserve or to opt for benefits of ANCSA. Tyonek Native Corporation voted for the provisions of ANCSA. Had they taken the former reserve, the village would have received fee simple title (both surface and subsurface estates) to 26,918.56 acres of land compared to the 115,200 acres of surface lands they are to receive under their ANCSA entitlement.

The Village Council may own lands under reconveyance provisions of Section 14(c) of ANCSA. The Village Council has been considering incorporation as a city under the laws of the State of Alaska. One reason stems from an interest in retaining control of village lands and lands destined for village expansion. Under ANCSA, it is necessary for the village corporation, the Tyonek Native Corporation, to convey "the remaining improved land on which the Native Village is located and as much additional land as is necessary for community expansion, an appropriate rights-of-way for public use, and land for other foreseeable community needs" to the appropriate municipal corporation where one exists or otherwise to the State in trust for any municipal corporation established in the Native Village in the future. The amount of land to be transferred to the municipal corporation or in trust shall be no less than 1,280 acres, an area equivalent to two (2) square miles. Tyonek Native Corporation will be receiving title to the lands for the future city. If Tyonek were an incorporated city under State law, Tyonek Native Corporation would reconvey title to the City (their own tribal members) rather than to the State to be held in trust for them.

The Tyonek Airfield is one of several private airfields in the area. The field is maintained by the Village Council and has been found to be a costly public improvement. At one time, the Village Council attempted to transfer the airfield to the State in an effort to ease their financial burden. At that time, the offer to give the airfield to the State was not accepted. The Village Council has retained the right to refuse landing privileges to unwelcome aircraft. The village residents prefer to have control over who visits their community and because of their outright ownership of the airfield they have had some control. However, the villagers do not like the costs associated with ownership.

The surface estate of the existing Tyonek airport, airway beacons, and other navigational aids, together with such additional acreage and/or easements as are necessary to provide related services and to insure safe approaches to the airport runways must be reconveyed to the Federal, State or Municipal government according to the requirements in Section 14(c)(4@ of ANCSA.

Native Allotments

The Native Allotment Act of May 17, 1906, as amended August 2. 1956, authorized the Secretary of Interior to allot land to any Indian, Aleut, or Eskimo of full or mixed blood who resides in and is a Native of Alaska and who is the head of a family or is 21 years of age. A land area not to exceed 160 acres of vacant, unappropriated and unreserved non-mineral land in Alaska, or subject to the provisions of the Act of March 8, 1922, certain vacant, unappropriated and unreserved public land in Alaska that may be valuable for coal, oil or gas deposits or under certain conditions of National Forest Lands in Alaska was made available if various conditions were met.

The title to a Native Allotment is under a restricted title; the land cannot be mortgaged, leased, sold, or deeded away without the approval of the Secretary of Interior or someone designated by him. The allotee or his heirs may deed the allotted land to another with the approval of the Secretary of Interior and the purchaser will then receive an unrestricted or fee simple title unless the purchaser is a Native whom the Secretary of Interior determines should continue to have a restricted title.

There are six Native Allotments in the proposed project area. Two have been patented, and four are still in the application stage and have not been fully adjudicated by the Bureau of Land Management; see Table 6.14.

Private Land

Five private patented land holdings (U.S. Surveys) are located in the project area and shown in Figure 6.27. Privately held leases are discussed in the following land use sections. Many of the parcels of lands that have been transferred to the state and Natives in the area have ROW reservations. Approximately 29 ROW permits and applications are on file with Alaska DNR.

Easements Across Native Lands

One of the thorniest issues of land rights in the proposed project area has been that of easements across Native lands. The Tyonek Native Corporation has adamantly refused to accept any easements across their former Moquawkie Indian Reserve and has also taken a very strong position relative to easements across lands they have selected north of the reservation (Division of Energy and Power Development). However the Interim Conveyance, I.C. 087, to their former Moquawkie Indian Reserve, contains several easements, at least temporarily set aside by the federal government.

Easement On and To the Marine Coastline

Interim conveyance documents cite a continuous 25-foot wide linear easement along the coastline for purposes of public access and recreation. The Department of Interior has suggested reducing the continuous easement to site easements along the coast at appropriate points to facilitate travel purposes only, such as beaching of water craft. A limited number of linear access easements perpendicular to the coast would be reserved to allow access to interior public lands.

Easements On and To Waterways (Rivers, Lakes and Streams)

The present federal policy of reserving easements along recreational rivers and streams is restricted to periodic points along "major" waterways. Major waterways are to be defined by the criteria of significant commercial or transportation use, or significant resource value (including recreation). The use of these site easements will be limited to activities related to travel along the waterway (e.g beaching of boats and float planes). Some linear access easements to "major" waterways and to public lands beyond conveyed Native lands may be reserved.

Transportation and Utility Corridors and Statutory Easements

Interim Conveyances retain rights-of-way for ditches, canals, telephone and telegraph lines and railroads constructed by the authority of the federal government. Easement corridors for energy, fuel, and natural resources transportation were also reserved and included the right of eminent domain. These easements must be justifiable, and site specific at the time of conveyance.

Section Line Easements

Section line easements of 33 feet on each side of the section line for a total of 66 feet provide legal access to federal lands. State lands have a 50-foot section line easement, 50 feet on each side of the section line. Although section line easements do not provide access that relates to the topography, they do provide legal access across the land.

An important question regarding the existing right-of-way between section lines is the possible and potential usage of the land for purposes other than highways, or in conjunction with highways. Alaska Statutes 19.25.010

provides the legal authority and required approvals for the use of utilities along the constructed highways rights-of-way. There is presently considerable overlapping of authority of the rights-of-way. The Department of Transportation and Public Facilities and the Division of Lands, are currently establishing regulations which will disentangle the overlapping authority, clarify accepted uses and revise procedural materials.

6.5.3.5 Land Use

The major land uses are shown in Figure 6.28.

Timber Harvesting

On August 22, 1973, the state sold the timber rights on 223,000 acres to Kodiak Lumber Mills, Inc. (KLM). Much of the timber had been damaged by spruce beetle infestation and is only useful for salvage. The quantity of timber involved in the sale is estimated to be 6 million board feet. KLM's 30 million dollar chip mill, camp, and pier are located 5 miles south of Tyonek on land leased from the Tyonek Native Corporation. A network of logging roads has been constructed to gain access to the timber. The majority of workers are transients who are housed in the camp. From time to time, 5-15 villagers work for the company. The current slump in the chip market has led to a reduction in shipping activities during 1981.

Table 6.14. Native allotments in shoreline townships.

Application No.	Location and Size	Certificate No. and Date	Date Occupied
AA 6459	T.12N., R.11W., S.M. M & B, 160 ac.	Apln 8-23-71	1949
AA 7268	T.12N., R.11W., S.M. 160 ac.	Apln 3-20-72	7/1946
AA 7324	T.12N., R.11W., S.M. 160 ac.	Apln 3-23-72	5/1953
AA 7788	T.12N., R.11W., S.M. 160 ac.	Apln 4-20-72	6/1957
A 055082	T.12N., R.11W., S.M. U.S.S. 4547, 119.39 ac.	50-75-0138/3-14-75	11-16-40
A 055680	T.12N , R.11W., S.M. U.S.S. 4546, 160 ac.	50-66-0608/6-20-66	9-15-41

Source: BLM Status Plats, June 1978. For complete descriptions, including aliquot part descriptions, contact Alaska Division of Lands.

The current timber leases expire in 1983. The state is considering leasing more land for additional salvage purposes. If Kodiak Lumber Mills is the successful bidder, another 5-6 years of work could be anticipated.

Petroleum

Interest has been shown in the area's oil and gas resources since the late 1950's. There have been several state, federal, and private lease sales, both on and offshore, since the mid-1960's. Extensive seismic testing and test drilling has been and continues to be conducted on many of the leases. Several gas fields have been discovered onshore and both oil and gas fields have been discovered offshore. Information on each of these fields is presented in Table 6.15.

Other than pipelines there are two petroleum-related facilities on the west side of Cook Inlet in the vicinity of the proposed project. Marathon Oil Company has an oil and gas treatment plant 20 miles southwest of Tyonek on Trading Bay. The other facility is the Drift River Petroleum Terminal, which is described in the transportation section of this report.

The most recent State lease sale in the area, Number 33, held on May 13, 1981, received strong interest (Anchorage Daily News, May 15, 1981 p. A-3). Two State lease sales are now scheduled or proposed that will probably include tracts on or near the proposed project's area. They are listed in Table 6.16.

Table 6.15. Oil and Gas Fields in the Project Area.

Field	Type	Location	Date of Discovery Well
1. West Foreland	Gas	Onshore	April 1962
2. Middle Ground Shoal (MGS)	Oil	Offshore	June 1962
3. North Cook Inlet	Gas	Offshore	September 1962
4. Beluga River	Gas	Onshore	December 1962
5. North MGS	Gas	Offshore	November 1964
6. Trading Bay	Oil	Offshore	June 1965
7. Granite Point	Oil	Offshore	June 1965
8. McArthur River	Oil & Gas	Offshore	October 1965
9. Moquawkie	Gas	Onshore	November 1965
10. Nicolai Creek	Gas	Onshore	May 1966
11. Ivan River	Gas	Onshore	October 1966
12. Albert Kaloa	Gas	Onshore	January 1968
13. Redoubt Shoal	Oil	Offshore	September 1968

Source: Situations and Prospects Kenai Peninsula Borough 1981.

Table 6.16. State Oil and Gas Lease Sales

Number	Sale Area	Proposed Date	Comment
40	Second Upper Cook	9/83	Scheduled
49	Cook Inlet	5/86	Proposed

Source: State of Alaska Current Five-year Oil and Gas Leasing Schedule - DNR revised 8/31/81 and DNR-DMEM Call for Comments 81.

Oil and Gas Leases

The Department of Natural Resources, through the Division of Minerals and Energy Management, is authorized to lease subsurface oil and gas resources on a competitive and noncompetitive basis. All lands in the public domain are open for oil and/or gas exploration and development. The provisions of the Miscellaneous Land Use Permit apply to surface oil and gas related activity on state lands where no lease has been issued. In addition, the state, under provisions of the Alaska Land Act, reserves rights to all subsurface gas and oil resources on lands disposed for any other purpose.

Federal leasing in the area has all taken place on offshore tracts, further south, in lower Cook Inlet.

Coal

Both coal prospecting permits and coal leases are available on State lands.

Table 6-17. Coal Leaseholdings.

Company	Acreage	Employees	Startup Date
Placer Amex Inc. (Beluga Coal Company)	25,926	Construction - ? Operation - 500	1987 (30 years)
Diamond-Chuitna (Diamond Alaska Co)	20,571	Contruction - 2000 Operation - 800	1987
Mobil Oil	23,080	N/A	N/A
AMAX, Inc. (Meadowlark Farms)	3,880	N/A	N/A

Source: Tyonek Community Profile (Draft) Ralph Darbyshire and Associates, September 1981.

Table 6.18. Locations where Subsistence Occurs.

Polly Creek	The beaches in this area are used for clamming in the spring.
Redoubt Bay	The beaches in this area are used heavily and have been relied upon for many years for clams. Use occurs in both spring and fall, but spring use is especially important after winter food supplies have been depleted and before the spring salmon run begins. The beaches south of Drift River Terminal to Harriet Point are used most extensively.
	a. Drift River: Historically, the upper and middle reaches were used most heavily for hunting and trapping. Today, some duck and seal hunting is pursued in the lower reaches.
	b. Kustatan River: The entire vicinity is hunted heavily when the McArthur River area and other areas do not have many moose. Some trapping takes place here.
Trading Bay and	Upper McArthur River areas are used for moose hunting
McArthur River	and furbearer trapping. McArthur Flats is used for waterfowl hunting and furbearer trapping.
	a. Middle River and lower area flats are used for moose hunting, trapping and waterfowl hunting.

Chakachatna River Noaukta Slough	Used for moose hunting, trapping, and waterfowl hunting.
Chuitkilnacha Creek and associated marsh areas	Used for duck hunting.
Granite Point to Chuitna River	The shoreline areas here are relied upon for subsistence and commercial salmon and herring fishing. This is the main fishing area for Tyonek residents.
Chuitna River and Chuit Creek Area	Both are used extensively in winter months for trapping and moose hunting. a. <u>Chuitbuna Lake</u> referred to as Chuit Lake) area is used for trapping and hunting especially in the winter. During the fall the area around this lake is used for berry picking. This area has a particular importance because of its proximity to Tyonek village. b. The areas west and north of Beluga village are used very heavily in fall for hunting moose and in winter for furbearer trapping. This is also an important berry picking area. c. <u>Old Tyonek Creek</u> and the lakes area around Congahbuna Lake are used for moose hunting and trapping.
Beluga Flats and Lower reaches of Beluga River	These locations are very important for hunting whale and waterfowl. Some seals are also taken here.

Susitna River	The mouth and lower reaches are used for beluga whale and seal hunting in the spring and fall.

Source: A Social, Economic and Environmental Analysis of a State Oil and Gas Lease Sale in Upper Cook Inlet; Governor's Agency Advisory Committee on Leasing, 1981.

Coal Prospecting Permits

A coal prospecting permit allows the permittee to determine the existence or workability of coal deposits in an unclaimed and undeveloped area. The permit is valid for two years and each permit may include up to 5,120 acres. If within the period of two years, the permittee shows that the land contains coal in commercial quantities and submits a satisfactory mining plan for coal rerovery, the permittee can obtain a lease. A coal prospecting permit may be extended for a period of two years if the permittee can provide adequate reasons (regulated by the Department of Natural Resources).

Coal Leases

Coal leases run for an undetermined period of time, conditional upon the continued development and/or operation of a mine. Coal lease contracts can be assignable, upon the approval of the Director of the Division of Lands, by the lessee subject to the laws and regulations applicable to the lease.

There are three major coal lease areas in the vicinity of the proposed project: the Capps lease area, the Chuitna Lease area and the Three Mile lease area. Table 6.17 indicates the number of workers expected in each project and an expected start-up date.

A coal-to-methanol plant has been proposed in the area but with recent federal budget cuts the probability of the plant being financed solely by private money at this time is uncertain.

Most of the coal in the area is planned to be open-pit mined but the methods for transporting the coal to tidewater have not yet been determined.

Mining Claims

There has been some interest shown in the mineral resources, other than coal, on state lands in the proposed project area. Many of these claims were filed quite recently. A large block of mining claims is located along the Upper McArthur River.

Subsistence

Subsistence activities of the villagers are described in the Socioeconomics section of this report. The discussion in this section focuses on the location of these activities. Subsistence activities of the villagers occur both on Tyonek Native Corporation land and on adjacent coastal areas. Subsistence use areas are identified in Table 6.18. The general area of greatest use extends from the village south to the Polly Creek area and north along the coast to the mouth of the Susitna River. The use an area receives is dependent both upon access and the availability of resources. For example, coastal areas, river banks, and areas along the road system where boats and vehicles can be used to transport hunters and game are used more extensively than areas only accessible by foot. The use of areas within the general subsistence harvest area may also vary from year to year depending upon the availability of subsistence resources.

Subsistence users of resources, other than Tyonek residents, may also be in the area of interest. Of the 1600 subsistence permits for salmon issued for upper Cook Inlet in 1979, 62 permits were used in the area from the Susitna River to West Forelands (A. p. 67).

Shore Fishery Lease -- Set Net Sites

Possibly as little as ten percent of the fishermen using set nets along the coast have obtained shore fisheries leases. Normally leases are obtained only when encroachment is threatened by other fishermen. Although shore fishery leases protect the fishing site from the encroachment of other fishermen, leases do not protect the shore fishery lease holder from other uses, such as a dock. Although apparently not required by state law, it is suggested that set net fishermen with shore fishery leases and fishermen without leases be reimbursed for the loss of livelihood, once that loss has been established, or another site of equal productivity satisfactory to the fishermen be sought as a replacement. The State of Alaska, Department of Fish and Game can identify any affected set net fishermen in the area, all of whom must also have Limited Entry Permits to fish in the Inlet.

6 5.4 Recreation

While the project area under consideration is remote and sparsely populated, considerable recreational use is made of it. Recreational use is concentrated toward the coast but is increasing on Chakachamna Lake and tributaries feeding into the lake.

Water related recreation occurs most frequently along the coast where the Chakachamna and McArthur Rivers empty into Trading Bay. Recreational use of the Trading Bay State Game Refuge is somewhat quantified and is discussed in the following subsection.

Recreation activities have been increasing in the vicinity of Chakachamna Lake, primarily fly-in hunting, fishing, hiking, and kayaking. Future promotion and use of Lake Clark National Park could increase use of Chakachamna Lake.

6.5.4.1 Trading Bay State Game Refuge

The 168,930 acre Trading Bay State Game Refuge (TBSGR) was created in 1976 for the protection of waterfowl and big game habitat. The refuge includes uplands, tidal and submerged lands. Public access is by small aircraft, both wheel and float equipped, and less commonly by boat.

A series of shallow brackish marshes, encompassing approximately 2500 acres, runs the length of Trading Bay. These marshes support vast numbers of migrating ducks, geese, swans, and shorebirds in both spring and fall, as well as providing nesting for a substantial number of dabbling ducks. Nesting geese are unknown in this area, although nesting occurs to the north at Susitna Flats and to the south at Redoubt Bay.

The Trading Bay Refuge is the ninth most important waterfowl hunting area in the state. In 1978 there were 735 hunting days of effort expended in the refuge, 1.1 percent of the state waterfowl hunting total. (Seller, 1979)

Coastal areas of western Cook Inlet, which includes the Trading Bay Refuge, are considered critical calving and overwintering moose habitat. The latest harvest figures indicate that a number of moose were taken in this area in 1980.

Nikolai Creek receives limited fishing pressure. The creek contains rainbow trout, Dolly Varden, and pink and silver salmon.

A number of cabins (2 on private land, 13 on state land) have been built within the refuge by waterfowl hunters. In June, 1978, ADF&G announced a moratorium on new cabin construction on state game refuges. Although ADNR was given authority to issue permits for cabins on state land within Trading Bay Refuge, no permits have been issued to date. The Shirleyville lodge caters to recreationists in the area and several air charter businesses provide access to the refuge.

6.5.4.2 Chakachatna/McArthur Rivers

Recreational use of the upper stretches of the Chakachatna and McArthur Rivers is less well known. The rapids in the upper reaches of the Chakachatna are quite difficult but they are thought to be navigable (DNR Division of Parks, personal communication). Thus kayak trips from a starting point in Lake Chakachamna are a possibility but this potential use is undetermined.

6.5.4.3 Chakachamna Lake

Lake Clark National Park rangers report the use of the western end of Lake Chakachamna as a staging area for recreational use (personal communication). Gravel bars on the east end of the lake and other gravel bars at the river deltas are used to unload visitors from float and wheeled planes both air taxi and privately owned (personal communication, Hartell). People kayak on the lake and hike by the lake and up the many drainages such as the Chilligan River. One of these routes goes west toward Lake Kenibuna and leads into Lake Clark National Park.

6.5.4.4 Lake Clark National Park

The eastern boundary of Lake Clark National Park crosses Kenibuna Lake. This portion of the park is classified as wilderness, and is considered by the park supervisor to be the heart of the park (personal communication Hartell). No formal recreation facilities have been planned for this area, nor are any use statistics available.

6.5.5 Socioeconomics

The proposed project is located in an isolated and sparsely populated area within the Kenai Peninsula Borough. Tyonek, a Native village, is the only community in the vicinity of the project area. The proposed Chakachamna Hydroelectric project has the potential to create population, employment, income, infrastructure and subsistence impacts in the Tyonek area. Because it has the responsibility for providing government services the Kenai Peninsula Borough (KPB) will be the principal impacted local government entity. Due to the small population of Tyonek, employment impacts will primarily occur on the Kenai Peninsula and in the greater Anchorage area. For each impact area (Tyonek, KPB and Anchorage), baseline socioeconomic information is presented.

6.5.5.1 Tyonek

The Native village, Tyonek, is located on the western shore of Cook Inlet, 42 miles east of Lake Chakachamna and 22 miles northeast of where the Chakachatna River enters Cook Inlet.

Population

The census figures for Tyonek are reported below:

Year	1880	1890	1900	1910	1920	1930	1940	1950	1960	1870	1980
Population	117	115	107	N/A	58	78	136	132	187	232	239

Source: U.S. Census

The recent Tyonek population has seen periods of relative stability broken by significant increases in population. The 1980 census has not been officially completed, but the population appears to have stabilized since 1970.

The 1970 census indicated that 95% of the population was Native with 127 males and 105 females. Median ages were 16.6 and 18.6 years for males and females, respectively. Non-Native residents are, for the most part, teachers who remain in the village for one to several years.

Employment

In many respects Tyonek is a traditional Alaskan Native village. Commercial fishing is the primary source of earned cash income. In addition to the limited number of service jobs available within the village, work is also obtained with the nearby timber operation and occasionally with petroleum exploration activities in the area. Like many Native villages, a heavy reliance is placed on subsistence resources. The following indicates the employment status of a sample of Tyonek's population.

EMPLOYMENT BREAKDOWN BY PERCENT OF HOUSEHOLD RESPONSE

No. of Members in Household	Full time Percent	Part-Time/ Seasonal	Retired	Unemployed
0	55	38	91	-
1	38	54	9	26
2	7	8	-	16
3	-	-	-	26
4	-	-	-	16
5	-	-	-	10
6	-	-	-	3
7	-	-	-	3

Source: Report on the Survey Conducted in Tyonek, 1980 ADF&G, Alice Stickney, Subsistence Section, Anchorage.

Commercial fishing (limited entry) permits are held by 27 residents. A permit holder may employ up to six people as crew. The fishing season is usually open only 2 days a week from July 1 to August 15. Salmon are the target species with most of the permits for set gill nets and a few for drift gill nets. Commercial catches tend to be low and profitability is further hampered by the lack of a processor or cannery in the vicinity. Fish are either flown out, pot scows utilized or a tender cooperatively hired. Most fishermen use little if any of their catch for subsistence needs, opting rather for cash sales to pay expenses.

The majority of workers employed by the Kodiak Lumber Mills'operation near Tyonek are transients who are housed in the camp. Employment of villagers varies from 5-15 workers throughout the year (Kodiak Lumber Mills, Inc. personal communication). Due to a variety of lifestyle/personal conflicts, full advantage of employment opportunities in the timber operation have not been taken by residents of the Tyonek Village (Braund and Behnke 1980).

Occassionally work with petroleum exploration firms is available on a temporary basis.

Permanent employment opportunities in the village are limited to the following positions: teachers and school support staff - 20, village administration - 6, firemen - 3, store retailers - 2, day care center employees - 2, and one each of the following: constable, community health aide, community health representative, post-mistress, air taxi operator, and emergency responder with the fire department. CETA funded 3 full time positions (supervisor of youth employment, laborer and recreation worker) as well as 16 summer positions for youth in 1981. (Darbyshire and Assoc. 1981). With the recent federal budget cuts the future of the CETA positions is uncertain.

Personal Income

The cash flow through the village economy is low. A profile of incomes obtained through a 40 household survey is shown below.

INCOME BREAKDOWN BY PERCENT OF HOUSEHOLD RESPONSE

Total Income Dollars	Percent of Households	Percent of Commercial Fishery Households	Percent of Other Households
0- 3000	13	0	20
3- 6000	30	16	45
6-10,000	30	47	15
10-15,000	12	21	5
15-20,000	5	5	5
20-30,000	10	11	10

Source: Report on the Survey Conducted in Tyonek, 1980, Alice Stickney, Subsistence Section, ADF&G, Anchorage.

Over 70 percent of all the responding households earned less than $10,000 in gross annual income. Thirty percent of these were commercial fishermen who made up 63 percent of the total responding commercial fishermen. The type of aid coming into the village was also limited. Fifty-five percent of the responding households had only Native/Public Health benefits, while the other 45 percent had additional aid in the form of Social Security, disability, unemployment checks, ADFC and food stamps.

Subsistence

Subsistence, the traditional hunting/fishing/gathering of local resources, is important to Tyonek residents for several reasons. The traditional pursuit of subsistence is interwoven into village social structure and sharing among residents. Because of this, and village preference for local food, subsistence resources cannot be equated in terms of market goods. Additionally, the limited job and income opportunities in Tyonek place great importance on subsistence as a means of providing food.

Subsistence patterns vary with the season and abundance of particular species. Although fish and game regulations have modified traditional patterns, local residents continue to follow a cycle resembling that of their ancestors. Residents of Tyonek fish, hunt, trap, dig clams, and pick berries. Four wheel drive vehicles, snow machines and outboard motors are used in subsistence pursuits.

King salmon comprise one of the important subsistence species. During the 1980 season 67 subsistence fishing permit holders harvested 1936 king salmon and 262 incidental red salmon. Each permit had a limit of 50 king salmon and the maximum season harvest for the community was set at 3000 kings. Sixty-five percent of the allowed harvest was reached.

Moose, ducks, geese, and spruce hens are hunted in season while porcupine are hunted year-round. A few village residents set traps for marten, mink, red fox, and beaver. Euchalon, rainbow trout, Dolly Varden and whitefish also provide a source of food for many residents. Residents of the community also hunt beluga whales and seals. Blueberries, raspberries, high and low bush cranberries, and salmonberries ripen in the late summer and early autumn and are primarily gathered by women in the village.

6.5.5.2 Kenai Peninsula Borough

The proposed project is located within the Kenai Peninsula Borough. Most of the population of the Borough is located on the western half of the Kenai Peninsula, across Cook Inlet from the proposed project. The Kenai Peninsula will be a source of labor and materials for the proposed project.

Population

The population of the Borough is 25,072, up 51.2 percent from 1970 (U.S. Census 1980). The Kenai census division which encompasses the western half of the Kenai Peninsula has a population of 22,271.

Employment

The labor force as of August, 1981, contained 12,300 workers, 9.8 of whom were unemployed. (Alaska Department of Labor 1981). Both the labor force and the unemployment rates exhibit marked seasonal variations. The following table (Table 6-19) indicates employment and wages by industry for the Kenai-Cook Inlet Division.

The Kenai Peninsula is likely to be a significant source of labor for the proposed project. Employment impacts are not quantifiable at this point in the feasibility study.

Personal income impacts while not quantifiable at this time are likely to be minimal. The unemployment rate may drop somewhat and thus reduce the amount of unemployment insurance payments.

6.5.5.3 Anchorage

Alaska's largest city, Anchorage is located approximately 60 miles east of the proposed project area. Anchorage is likely to serve as a major supply center for both labor and materials.

The Anchorage area is likely to be the major source of in-state labor for the proposed project but the employment impacts are not quantifiable at this time. Many of the area's construction workers are available for out of town work. The extent of their availability will depend on the status of other construction projects in the state such as the North Slope, Susitna dam, etc.

Population

The Municipality of Anchorage has a population of 173,992 as of 1980, up 37.7 percent from 1970 (U.S. Census 1980).

Employment

As of August, 1981, the Municipality had a labor force of 91,671 persons with 6.9 percent unemployment (Alaska Economic Trends, October 1981, Department of Labor, State of Alaska). Table 6-20 indicates employment and wages by industry.

Table 6.19. Kenai-Cook Inlet Division Area Nonagricultural Employment and Payroll Industry Series - Alaska. 3rd Quarter 1980.

Industry	Average No. of Employees	Average Monthly Wage ($)
Mining	793	3,085
Construction	902	3,531
Manufacturing	2022	1,581
Transportation, Communication and Utilities	671	3,142
Wholesale Trade	272	2,515
Retail Trade	1048	1,021
Finance, Insurance and Real Estate	203	1,259
Services	1023	1,366
Agriculture, Forestry and Fisheries	51	2,387
Government	1169	1,981
Unclassifiable	1131	1,158
Totals	8185	2,055

Source: Statistical Quarterly - 3rd Quarter, 1980. Department of Labor, State of Alaska.

6.5.6 Community Infrastructure

6.5.6.1 Housing

There are 89 homes in Tyonek, almost all of which are owned by the Tyonek Village IRA Council. Approximately 60 prefabricated homes were barged to and erected in Tyonek in the mid-1960's. These homes, as well as 6 trailers, (2 of which are owned by the KPB school district for teacher housing), form the housing stock of the older part of the village. Outbuildings such as smokehouses and steambaths are situated in this portion of town.

An additional 27 wood-frame homes were built in 1978-79 through the joint efforts of the Department of Housing and Urban Development and Cook Inlet Native Association. These homes are located west of the airstrip in Indian Creek subdivision or the "new subdivision" as it is referred to by the townspeople.

All the transient employees of Kodiak Lumber Mills, Inc. are housed in the company camp south of Tyonek. The camp can accommodate up to 200 people. The camp has six 20-person bunkhouses, five 3-bedroom modular homes, about 12 trailers and six duplexes. The Shirleyville Lodge is located adjacent to the Nickolai Creek airstrip. The lodge includes trailers and cabins that can accommodate 24 people. Meals are also available.

6.5.6.2 Education

Bob Bartlett School serves grades K through 12 and is financed and managed by the Kenai Peninsula Borough School District. Located in the Village of Tyonek, it is the only school serving the area. The school has four regular classrooms, a home-economics suite, and a portable classroom, for a total capacity of 240 students.

Enrollment history and school district projections are presented below. The total 1976-1977 enrollment was 108, with 75 in grades K-8, and 33 in grades 9-12. As of May 1978, 98 students were enrolled and 7 teachers (5 regular and 2 cultural resource teachers) were employed. The Borough's 1977 school-construction report indicates that no facilities other than a new home-economics suite need to be provided during the 5-year period ending in 1982.

When the Kodiak Lumber Mills' mill was in full operation, approximately 20 children were bussed from the camp to the village to attend the school.

PUPIL ENROLLMENT AND PROJECTIONS, BOB BARTLETT SCHOOL, TYONEK

School Year	K-8	9-12	Total
1972-73	76	21	97
1873-74	65	22	87
1974-75	73	18	91
1975-76	87	28	115
1976-77	75	33	108
1977-78	82	34	116
1978-79	90	34	124
1979-80	95	37	132
1980-81	103	38	141
1981-82	110	41	151

Source: Kenai Peninsula Borough School District, Enrollment Projections and School Construction Report, April 1977.

Table 6.20. Anchorage Division Area Nonagricultural Employment and Payroll Industry Series - Alaska. 3rd Quarter 1980.

Industry	Average No. of Employees	Average Monthly Wage ($)
Mining	2,915	3,286
Construction	7,190	3,252
Manufacturing	2,532	2,636
Transportation, Communication and Utilities	8,318	2,264
Wholesale Trade	4,230	2,150
Retail Trade	13,324	1,171
Finance, Insurance and Real Estate	4,900	1,649
Services	17,182	1,125
Agriculture, Forestry and Fisheries	197	1,019
Government	20,356	2,061
Unclassifiable	607	1,522
TOTALS	81,751	1,958

Source: Statistical Quarterly - 3rd Quarter, 1980. Department of Labor, State of Alaska.

6.5.6.3 Police Services

Police services in the Tyonek area are provided by the Alaska State Troopers through a resident constable. The constable serves the area from the Beluga power station south to Trading Bay, including the oil and gas facilities at Trading Bay and Granite Point and the lumber mill camp near Tyonek. A four-wheel drive vehicle is used by the constable to patrol the area and an airplane is available to fly the area if the need arises.

The constable at Tyonek has the time and ability to handle an additional number of complaints and other police activity, but the point at which population increases will require the state troopers to add another policemen is difficult to estimate.

In a work-camp situation, the troopers encourage private companies to hire their own staff for internal security. The troopers are then available to provide emergency assistance. The temporary assignment of additional troopers to the area is another option, especially if camp activity is short-term or seasonal. In the proposed project area, this would involve assigning staff from the Soldotna regional office of the state troopers.

6.5.6.4 Fire Protection

Publicly provided fire protection services are currently available in Tyonek through the U S. Department of Interior, Bureau of Land Management.

6.5.6.5 Health Care and Emergency Medical Services

The state troopers are responsible for supervising rescue operations for emergency situations in the proposed project area. Medical evacuations are usually accomplished by private charter plane. The U.S. Air Force also handles some emergency evacuations.

Health care services are available to the residents of Tyonek through a medical center located in the village. The facility handles both medical and dental work and is staffed by a resident, licensed practical nurse. The clinic also has a community health aide (and alternate) provided through the U S Public Health Service. The health aide may provide services to non-Natives on an emergency basis only. Non-Natives are billed for the service. Emergency medical care is received at the ANS hospital in Anchorage.

The Kenai Borough's Central Hospital service area encompasses over 1000 square miles of land on both the east and west side of Cook Inlet. On the west side of Cook Inlet, the service area extends from Beluga River to Drift River, including the study area. A 32-bed hospital is located at Soldotna.

6.5.6.6 Water and Wastewater Systems

The existing water source for the village of Tyonek is a nearby lake. The former ground water supply was abandoned because of its high iron content (with manganese). The water system, which includes an infiltration gallery and pump house, was installed by the Village in 1976. The lake water is chlorinated, stored in a tank, and filtered with activated carbon before being delivered to the underground distribution system, which was completed in 1972 under an EDA contract. A previous groundwater well was developed in 1964 by the U S. Public Health Service, but is used only for public water supply. Each house and the school is served by the distribution system. The 27 new housing units planned for the village by Cook Inlet Housing Authority will be connected to the distribution system.

The primary method of wastewater disposal at the village of Tyonek is by septic tanks with subsurface leach fields; some cesspools are also used. The septic tanks were installed in 1965, have a capacity of 200 to 400 gallons, and are constructed of low-grade steel. Some of the tanks are rusting. The soils have a gravel base, making them good for subsurface disposal. The problems that have developed with the onsite systems are probably a result of the small size of the tanks and inadequate maintenance. An unfenced sanitary landfill is located 4.2 miles from the village. The Kenai Peninsula Borough is in the process of establishing a new landfill for the village, but it may be some time before all approvals are obtained

Water for the Kodiak Lumber Mills Camp is supplied from three wells, which have been adequate to support 200 people to date; no water shortages have occurred. The water contains an excessive amount of iron and barely meets water quality standards. However, no bacteria problems exist. Water is distributed through an underground system that requires standard maintenance. No winter freezing problems have been encountered.

Septic tanks with perforated-pipe drainfields are used for waste disposal. The systems have required normal maintenance; no special problems have developed. The soils (consisting of a gravel base, covered with a few feet of sandy loam and some clay) are good for subsurface disposal.

Water for Trading Bay is supplied from wells at Marathon Oil Company's Trading Bay facility and no shortages have occurred. Septic tanks with drain fields have also been used with very few problems.

6.5.7 Transportation

Transportation facilities on the west side of Cook Inlet are few and small in size. These facilities consist of logging and petroleum exploration roads, several airfields, a wood chip loading pier and a petroleum loading dock. The numerous resource development potentials in the area may eventually lead to an expansion of facilities.

Roads

All roads in the area of the project are shown in Figure 6.29. Most of the road system in the proposed project area has been developed by Kodiak Lumber Mills in the form of logging roads. The road system connects Granite Point, Tyonek, Nicolai Creek, Kaloa, North Foreland, and Beluga. There are about 100 miles of primary and secondary roads. These roads are in good condition, especially the main roads. Some of the bridges on the secondary roads have washed out and have not been replaced. The main logging road extends approximately 16 miles northwest of Congahbuna Lake to within 8 miles of Capps Coal Field. Most roads are sand, overlain with gravel, and require no special maintenance. The roads are resurfaced following breakup.

Road rights-of-way (100 feet wide) are established along the section lines of all state land (or land acquired from the state). All other land has a 66-foot right-of-way along section lines. Some legal questions have been raised about how this right-of-way provision applies to land "reserved for public use." No rights-of-way are associated with the network of logging roads. Access was permitted as part of the state's timber sale contract with Kodiak Lumber Mills.

The Beluga area, north of Tyonek, and Anchorage are not connected by a year-round road; however, a winter road has been used in the past when the Susitna River was frozen. The road was originally constructed to carry large, heavy equipment to the area, but it has not been used since the mid-1970's.

The Alaska Department of Transportation and Public Facilities has studied the Beluga area and developed plans for river crossings and roadways. A proposed highway would run from Tyonek to Goose Bay (about 65 miles), crossing the Susitna and Beluga Rivers. Existing roads already connect Goose Bay to Knik (10 miles), Knik to Wasilla (19 miles), and Wasilla to Anchorage (47 miles).

The proposed highway is not likely to be constructed in the near future, primarily because the economic benefits to be derived from it do not justify the co@struction costs. The proposed highway may become more attractive as additional projects for resource and industrial development in the Beluga area (aluminum smelter, coal generating plants, etc.) are proposed or become feasible.

Two historic trails, identified in Table 6.21, in the area were identified in a 1973 inventory done by the State Department of Highways (now the State Department of Transportation and Public Facilities). The Highway Department claims legal access through prescriptive rights along these traditionally travelled ways.

Table 6.21. Historic Trails.

Trail Name	Quandrangle & Number	Location	Source	Description
Susitna - Tyonek	Q70 - #2	T.11, 12, 13, 14, 15, 16, 17N. R.7, 8, 9, 10, 11W. SM	ARC Annual Report 1930 Part II, Page 61. & Fifty Years of Highways - AK Dept. Public Works, Div. of Highways 1960, pg. 29-30.	Trail begins at town of Susitna T.17N. R.7W. and runs in a SW direction for 46 miles to town of Tyonek T.11N.R11W.
Winter Trail	Q70 - #3	T.11N.R.12, 13W, SM	USGS Tyonek Quad	Trail runs from Trading Bay to cabins on Nikolai Creek.

Source: State of Alaska. Department of Highways. Alaska Existing Trail System. 1973.

Table 6.22. Airport facility characteristics.

Name	Owner	Class	Length	Surface	Comments
Tyonek	Pvt.	Utility	3350' x 100' 1427' x 100'	Gravel	
Beluga	Pvt.	Non CAB Non CAB	3500' x 110' 5000" x 110'	Gravel Gravel	Lighted Lighted
Nikolai Creek	Pvt.	Non CAB	4100' x 75'	Gravel	
Trading Bay	Pvt.	Non CAB	4500' x 100'	Gravel-dirt	Lighted
West Foreland (Unit No. 2)	Pvt.	Utility	1975'	Dirt	
Drift River	Pvt.	Non CAB	4300' x 150' 40'	Gravel Gravel	Lighted

6.5.7.2 Air

The larger air facilities within the vicinity of the project are identified in Table 6-22. The airport in Tyonek is operated by the Native Village of Tyonek. Planes as large as DC-6's and Hercules can be accommodated. Pilots must obtain permission from the Village before landing. The FAA estimates that there are approximately 2000 annual air taxi landings at Tyonek. Air taxi operators serving Tyonek include Trading Bay Air Taxi, Spernak Airways, Wilbur's Flight Operations, Hudson Air Taxi, Gil's Aircraft Service, and Alyeska Air Service, Kenai Air, Kenai Aviation, and Arctic Aviation.

Other airstrips in the area include a poorly maintained 3500-foot City Services Oil Co. field, 8 to 10 miles west of Beluga; a 1700-foot airstrip in good condition at North Foreland that will handle a Sky Van; and several light aircraft strips, including two 900-foot strips at Capps Field.

All airfields in the Tyonek-Beluga area are privately owned and maintained. Use of the airstrips requires permission of the owners.

6.5.7.3 Marine

A private wood chip loading pier owned by Kodiak Lumber Mills is located 3 miles south of Tyonek. The pier is 260 feet long with 685 feet of berthing space and a depth alongside of 35 feet at mean low water. The dock would need to extend about 3700 feet from shore to reach a 60 foot depth. The dock is used from April to November depending on shipping schedules. The largest ship to dock here was 607 feet long and 45,000 metric tons. During 1980 only six freighters were loaded from the pier and with the decline in the chip market even fewer will dock in all of 1981. Recently, a test shipment of coal was loaded from the pier onto a freighter headed for Japan.

A special purpose petroleum dock owned by Cook Inlet Pipeline Co. and operated by Mobil Oil is located at Drift River, 47 miles southwest of Tyonek. The terminal at Drift River was built in 1966 and is used solely to load tankers with crude oil which is transferred to Drift River via pipelines from offshore wells in Cook Inlet. The dock is 100 feet long with a 100 foot face and depth alongside is 70 foot. There is 780 feet of berthing space with breasting and mooring dolphins. The dock can accommodate 150,000 dead weight ton tankers (medium size).

There is also a barge off-loading ramp, owned by Standard Oil, located 4 miles southwest of the Beluga River.

Tyonek and the Tyonek Lumber Mills' camp both receive supplies by barge which are off-loaded on the beach.

6.5.8 Visual Resources

The project area falls into three categories of landform characteristics: steep mountainous terrain, vegetated uplands and coastal wetlands. Chakachamna Lake, Chakachatna River Canyon, and the headwaters of the McArthur River are located in narrow glaciated valleys surrounded by steep, rugged mountains. Scenic quality is high, particularly on Chakachamna Lake and the Chakachatna River. The lake allows a long view where hanging glaciers drop to lake level, and tributaries to the lake form symmetrical deltas. The Chakachatna River exits the lake into a canyon surrounded by steep mountains. At this point the river alternates between single channel and braided systems, and has relatively continuous whitewater. Because of its scenic quality, Chakachamna Lake was originally considered for inclusion as national interest lands under Section 17(d)-2 of the Alaskan Native Claims Settlement Act of 1971. The braided floodplain of the upper McArthur River is 3/4 of a mile wide, and is roughly 50 percent vegetated with contrasting exposed sandbars. Because of the twisting nature of the canyon, the length of viewshed is relatively short. Vegetation on the steep lower slopes of the lake and both drainages consists of a thick mixture of conifers and deciduous birch and alders, above which lies a band of shrub thicket, and alpine vegetation. This vegetation provides a contrast to both the lake and river floodplains.

Upon leaving the mountains both the Chakachatna and McArthur Rivers enter well-vegetated uplands. Here the broader river valleys fluctuate between braided and single channels. The dense vegetation of cottonwood, white spruce and willow limits views from the rivers and screens out the backdrop of mountains. Two relatively unusual visual areas are located within the upland landform. An expanse of dry sand flats is found along the middle reach of the McArthur River. This dune-like area provides visual relief (texture and color) from the dense vegetation, and allows longer vistas of the surrounding mountains. A border of lichencovered flats further contributes to the aesthetics of this area. Similar, but smaller, areas of lichen flats are located along the Chakachatna River at the logging road bridge.

The vegetated uplands gradually give way to open wetlands along both rivers. These coastal wetlands extend inland roughly five miles from the coast. The low vegetation of grasses and sedges and open water allows long vistas of the surrounding mountains, Cook Inlet, and the Kenai Peninsula across the Inlet. The primary river form in these wetlands are meandering single channels with steep mud banks. Tidal influence extends four or more miles upchannel in some instances. These coastal wetlands provide excellent waterfowl habitat, and have relatively high visitor use compared to other portions of the project area.

6.6 REFERENCES

Hydrology

Lamke, R.D. 1979. Flood characteristics of Alaskan streams. U.S. Geological Survey Water Resources Investigations 78-129. 66 pp.

Tennant, D.L. 1975. Instream flow regimes for fish, wildlife, recreation and related environmental resources, U.S. Fish and Wildlife Services, Billings, Montana.

Aquatic Biology

Alaska Dept. of Fish and Game. Undated. Fish Survey Reports of Lower Cook Inlet.

Bailey, J.E. 1964. Intertidal spawning of pink and chum salmon at Olsen Bay, Prince William Sound, Alaska. Manuscript Report MR 64-6. USFWS. Bureau of Commercial Fisheries. Biological Laboratory. Auke Bay, Alaska.

Bailey, J.E. 1969. Alaska's Fishery Resources: The pink salmon. Fishery leaflet 619. USFWS. Bureau of Commercial Fisheries. Washington, D.C.

Balon, E.K. (Ed.) 1980. Charrs, salmonid fishes of the genus salvelinus. Dr. W. Junk by Publishers. The Hague, The Netherlands.

Baxter, R. and S. Baxter. 1961. Stream surveys-west side Cook Inlet-1961, ADF&G. Cook Inlet Data Report. 61-1.

Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries-Engineering Research Program, Corps of Engineers, North Pacific Division. Portland, Oregon.

Blackett, R.F.. 1968. Spawning behavior, fecundity, and early life history of anadromous Dolly Varden, *salvelinus malma* (Walbaum) in Southeastern Alaska. Research Report No. 6. Alaska Dept. Fish and Game, Juneau, Alaska.

Blahm, T.H., R.J. McConnel and G.R. Snyder. 1975. Effect of gas supersaturated Columbia riverwater on the survival of juvenile chinook and coho salmon. NOAA Technical Report SSRF-688. National Marine Fisheries Service, Seattle, WA.

Burns, J.W. 1970. Spawning bed sedimentation studies in northern California streams. California Fish and Game, 56(4): 253-270.

Committee on Environmental Effects of the United States Committee on Large Dams. 1978. Environmental effects of large dams. American Society of Civil Engineers, New York, N.Y.

Fickeisen, D.H. and M.J. Schneider (Ed). 1976. Gas bubble disease. Technical Information Center, Office of Public Affairs Energy Research and Development Administration, Oakridge, TN.

Forester, R.E. The sockeye salmon. *Oncorhyncus nerka*. Bulletin 162. Fisheries Research Board of Canada. Ottawa, Canada.

Garner, J. 1977. How to make and set nets. Fishing News Books LTD. London, VIC.

Hart, J.L. 1973. Pacific fishes of Canada. Bulletin 180. Fisheries Research Board of Canada. Ottawa, Canada.

Hasler, A.D. 1971. Orientation and fish migration in S.W. hoar and D.J. Randall (Editors). Fish Physiology, Volume VI, Environmental Relation and Behaviors, Academic Press, NY.

Krcma, R.F., C.W. Long, C.S. Thompson, W.E. Farr, T.W. Newcomb, and M.H. Gessel. 1979. The development of an improved fingerline protection system for lowhead dams-1978, National Marine Fisheries Service, Seattle, WA.

Kubik, C.W. 1981. Memorandum: king salmon data. ADF&G unpublished.

Leggett, J.W. 1980. Reproductive ecology and behavior of Dolly Varden charr in British Columbia. IN E.K. Balon (Editor) Charrs, Salmonid Fishes of the Genus Salvenlinus.

Martin, N.V. and C.H. Olver. 1980. The lake carr, salvelinus namaycush in E.K. Balon Charrs, Salmonid Fishes of the genus Salvenlinus.

McConnel, R.J. and G.R. Snyder. 1972. Key to field identification of anadromous juvenile salmonids in the Pacific northwest. NOAA Technical Report NMFS CIRC-366. US Dept. of Commerce Seattle, WA.

Merrell, T.R., Jr., M.D. Collins, and J.W. Greenough. 1971. An estimate of mortality of chinook salmon in the Columbia River near Bonneville Dam during the summer run of 1955. Fishery Bulletin 68(3): 461-492.

Merrell, T.R., Jr. 1970. Alaska's fishery resources the chum salmon. Fishery leaflet 632. USFWS. Bureau of Commercial Fisheries. Washington, D.C.

Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company. Anchorage, Alaska.

Nelson, D.C. 1976. Russian river red salmon study. Study AFS-44-2. ADF&G. Sport Fish Division, Anchorage, Alaska.

Nikolski, G.V. 1961. Special ichthyology. 2nd Edition. Isreal Program for Scientific Translations, National Technical Information Service, Springfield, VA.

Oglesby, R.T., Carlson, C.A., McCann, J.A. (ed) 1972. River ecology and man. Academic Press, NY.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. Fourth edition. American Fisheries Society, Special Publication No. 12 American Fisheries Society. Bethesda, MD.

Russell, R. 1978. Lake survey summary, Lake Chakachamna. Alaska Department of Fish and Game. Unpublished.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 84. Fisheries Research Board of Canada. Ottowa, Canada.

Shaw, P.A. and J.A. Maga. 1943. The effect of mining silt on yield of fry from salmon spawning beds. California Fish and Game. 29(1): 29-41.

Smith-Root, Inc. 1978. A brief introduction to electrofishing. Smith-Root, Inc. Vancouver, WA.

Smoker, W.A. (Editor). 1955. Preliminary key for identification of salmon fry, juveniles, and adult. State of Washington, Dept. of Fisheries.

Tennant, D.L. Instream flow regimes for fish, wildlife, recreation and related environmental resources. USFWS. Billings, Montana.

Troutman, M.B. 1972. A guide to the collection and identification of presmolt pacific salmon in Alaska with an illustrated key. NOAA Technical Memorandum NMFS ABFL-2. U.S. Dept. of Commerce. Seattle, WA.

von Brandt, A. 1972. Fish catching methods of the world. Fishing News (Books) Ltd. London, U.W.

Wydoski, R.S. and R.R. Whitney. 1979. Inland fishes of Washington. University of Washington Press. Seattle, WA.

U.S. Bureau of Reclamation. 1960. Chakachatna River and Chakachamna Lake, Alaska. 2 sheets. U.S. Geological Survey, Washington, D.C.

Ward, J.V. and Stanford, J.A. (Ed) 1979. The ecology of regulated streams. Plenum Press, New York.

Wells, R.A., and W.J. McNeil. 1970. Effect of quality of the spawning bed on growth and development of pink salmon embryos and alevins. USFWS Special Scientific Report-Fisheries #616, U.S. Fish and Wildlife Service, Washington, D.C.

<u>Wildlife Biology</u>

Pfister, R.D., B.L. Kovalchik, S.F. Arno, and R.C. Presby. 1977. Forest habitat types of Montana. Intermountain Forest and Range Experiment Station, USDA Forest Service.

Sellers, R. 1979. Waterbird use of and management considerations for Cook Inlet State Game Refuges. Alaska Department of Fish and Game. Unpublished report.

Timm, D. and R. Sellers. 1981. Annual report of survey and inventory activities-waterfowl. Project progress report on federal aid in wildlife restoration, project job number 10.0, volume 12.

<u>Human Resources</u>

Alaska Department of Labor, 1980. Statistical Quarterly, 3rd Quarter.

Alaska Department of Labor, September 1981. Alaska Economic Trends (monthly).

Braund, S.R. and Associates. 1980. Lower Cook Inlet, petroleum development scenerios, Socio Cultural Systems Analysis-Technical Report Number 47, Socioeconomic Studies Program.

Darbyshire, R. and Associates. 1981. Community Profile - Tyonek (draft) Anchorage, Alaska unpublished report.

Division of Energy and Power Development, DC&ED, Alaska Regional Energy Resources Planning Project, Phase 2 - Coal Hydroelectric and Energy Alternatives, Vol. 1 - Beluga Coal District Analysis, for Dept. of Energy.

Governor's Agency Advisory Committee on Leasing. 1981. A social, economic analysis of a State oil and gas lease sale in upper Cook Inlet.

Sellers, R. 1979. Waterbird use of and management considerations for Cook Inlet State Game Refuges. Alaska Department of Fish and Game. Unpublished report.

Stickney, a. 1980. Report on the survey conducted in Tyonek. Subsistence Section, Alaska Department of Fish and Game, Anchorage, Alaska.

EVALUATION OF ALTERNATIVES

7.0 EVALUATION OF ALTERNATIVES

7.1 Engineering Evaluation

7.1.1 General

The figures quoted in this section of the report for the estimated cost of energy are considered to be conservative for two basic reasons as set forth below.

The first reason is the conservative approach taken to calculate the amount of energy that could be generated by each of the four alternatives. In the power studies, the maximum lake level was taken as elevation 1128 which had been reported as the approximate invert elevation of the lake outlet channel. The natural maximum lake water level is reported to have been at about elevation 1151.5 and the records show that the lake rose to that level or within about 5-feet of it each year. No credit has been taken in the calculations for any additional energy that would accrue from the higher heads that would temporarily be available when the lake water level exceeded elevation 1128. There is also the possibility that once diversion of water for power generation begins, the outlet channel may choke and its invert may rise above its present elevation thus creating a higher head for power generation. If the maximum water level is taken, as elevation 1142, the installed capacity for Alternative B would increase from 330 MW to 350 MW and the average annual energy would rise by 6% from 1446 GWh to 1533 GWh.

The second reason is that the approach to estimating the cost of constructing each of the alternatives is considered to have been realistic. Analyses have been made of bids received for projects involving similar types of construction and the unit prices used in the estimates are consistent with those that have been received in recent competitive bidding in cases where the analyses have permitted such comparisons to be drawn. Furthermore, although the estimates make allowances for certain lengths of the tunnels where production may slip and costs may increase due to adverse rock conditions, an overall 20% contingency allowance over and above the estimated cost of construction, engineering and construction management has been included in arriving at the estimated total project costs.

7.1.2 Chakachatna Dam

On the basis of what was seen in surface exposures during reconnaisances of the Chakachatna Valley, little encouragement could be found for pursuing a course based on the concept of siting a dam anywhere in the valley between the lake outlet and the mouth of the canyon. Although the possibility has not been completely ruled out, it is considered most unlikely that justification for siting a dam here could be confirmed.

7.1.3 Alternative A

This alternative, which would take all controlled water from Chakachamna Lake for the generation of electrical power in a powerplant located in the McArthur Valley, is the most advantageous identified by the present studies when regarded strictly from the point of view of power generation. As may be seen by reference to Table 7-1, the powerplant would have the maximum installed capacity (400 MW), and would yield the maximum average annual firm energy (1664 GWh) at the lowest unit cost (37.5 mills per kWh). It is considered that these figures can safely be regarded as conservative for the reasons set forth in Section 7.1.1 above.

Although some modification and refinement of the basic elements of the development, as they are presently shown on the drawings, will probably become desirable during the course of optimization studies to be performed in 1982, it is technically feasible to design and construct all features of a project following the concept of Alternative A.

7.1.4 Alternative B

This alternative follows the same basic layout as that for Alternative A, but approximately 19% of the average annual flow of water into Chakachamna Lake, during the period of outflow gauge records, would be reserved for release into the Chakachamna River near the lake outlet, to satisfy the tentative minimum instream flow requirements discussed in Section 7.3.2 of this report. This would cause the installed capacity to be reduced from 400 MW to 330 MW. The average annual firm energy would reduce 1374 GWh at a unit rate of 43.5 mills/kWh. This is 16% higher in cost than for Alternative A but is still significantly less than the 55.6 mills/kWh which is the estimated cost of energy from the most competitive thermal source, a coal fired plant, as discussed in Section 9.4 of this report. Alternative B has the advantage that instream flows are provided in the Chakachamna River for support of its fishery and based on the tentative amount of water reserved for these instream flow requirements the project would still be an economically viable source of energy.

The same comments set forth above in Section 7.1.3 regarding feasibility of designing and constructing Alternative A apply equally to the structures for Alternative B except that a design concept has not yet been identified for a fish passage facility that would maintain a means of entry into and exit from Chakachamna Lake for migrating fish. This will be included in the 1982 studies.

7.1.5 Alternatives C and D

Both of these alternatives would divert water from Chakachamna Lake to a powerplant located near the downstream end of the Chakachamna Valley. For Alternative C, all controlled water would be used for power generation. For Alternative D, water required to meet the instream flow releases discussed in Section 7.3.3 of the report would not be available for power generation. This water amounts to 30 cubic feet per second average annually, which is less than 1% of the total water supply. Being that small, it can be ignored at the present level of study.

As may be seen from Table 7-1, the installed capacity for both Alternatives C and D would be 300 MW. The average annual firm energy would be 1314 GWh at 52.5 mills/kWh for Alternative C and 54.5 mills/kWh for Alternative D. The installed capacity and energy that would be generated by Alterntatives C and D are significantly less than in the case of both Alternatives A and B, and the cost of energy is significantly higher. Alternatives C and D are inferior in comparison with Alternatives A and B as sources of hydro power. At 55.6 mills/kWh, energy from a coal fired plant would be only marginally more expensive than the energy that could be generated by implementing Alternatives C or D. It would thus appear that these two alternatives could be dropped from further consideration.

TABLE 7-1

COST OF ENERGY

Alternative	A	B	C	D
Installed capacity-MW	400	330	300	300
Annual generation-GWh	1752	1446	1314	1314
Deduct 5% for transmission losses and station service-GWh	88	72	66	66
Firm annual energy-GWh	1664	1374	1248	1248
Capital cost including IDC at 3% - $Billions (1)	1.5	1.45	1.6	1.65
Annual cost 3.99% including interest, amortization and insurance for 50-year project life - $Millions	59.9	57.9	63.8	65.8
Net cost of energy - Mills/kWh	36	42	51	53
O&M - Mills/kWh	1.5	1.5	1.5	1.5
Total cost of energy - Mills/kWh	37.5	43.5	52.5	54.5

(1) Excluding Owner's costs and escalation.

7.2 Geological Evaluation

7.2.1 Chakachatna Dam

Although the canyon like topography along the Chakachatna River about six miles downstream from Chakachamna Lake might appear to be suitable sites for a dam, the geologic characteristics of the canyon suggest that construction of a dam there is unlikely to prove feasible, and if such construction is attempted, it is likely to be very costly and a complex engineering problem for the reasons discussed below.

As discussed in Section 5.2.2, there is a marked difference in the bedrock from one side of the Chakachatna Canyon to the other. The south side of the canyon consists of a steep wall of glaciated granite, which appears to be well suited for a dam abutment. In contrast, the north wall of the canyon exposes a complex of geologic units dominated by lava flows, pyroclastics, and volcaniclastics, but including outwash and fill. If the ideas presented in Section 5.2.2.2 are basically correct, the volcanics may overlie alluvium below the present valley floor; both the volcanics and the alluvium rest on granitic bedrock at an unknown depth below the valley floor. In addition to specific adverse foundation conditions suggested by deposits found on the north valley wall (e.g. high permeabilities, low strength), the chaotic character of those deposits would make the prediction of foundation conditions at a given site very difficult.

Any impoundment in the Chakachatna Canyon will be subject to the volcanic hazards associated with Mt. Spurr (Section 5.2.2.2). The youthfulness of Mt. Spurr, as a whole, and the fact that it has been active in historic time suggest that continued eruptive activity should be factored in as a design consideration for any facilities in the Chakachatna Canyon.

7.2.2 Alternative A

On the basis of the observations made during the 1981 field program, it is possible to comment on several geologic factors that may influence consideration of Design Alternative A (and B); see also Sections 5.2.1.6, 5.2.2.3, 5.2.3.4, and 5.2.3.3.

(1) Although any lake tap site between the lake outlet and First Point Glacier would be subject to impact from a very large eruption of Mt. Spurr, no site in that area is likely to be disturbed by Crater Peak type events (Section 5.2.2.2).

(2) The bedrock characteristics pertinent to tunnelling have not been specifically studied; this will be a subject of study during 1982. General observations in the Chakachatna Canyon, aerial observations of snow-and-ice-free bed- rock exposures between the Chakachatna and McArthur canyons, and general observations in the McArthur Canyon suggest that bedrock conditions are likely to be well suited to tunnel construction, with the exception of the lowermost portion of the canyon, near the Castle Mountain fault. The Castle Mountain fault, which has had Holocene activity along at least part of its

length, is present near the mouth of the canyon and has apparently disrupted the bedrock (shears, intense jointing) in the lower reaches of the canyon. For any project facilities constructed in the fault zone, there would be a risk associated with fault rupture; large ground motions would likely occur during an earthquake on the fault. One of the design alternatives presented in this report include facilities in the fault zone, as it is now know. Additional work is planned for this area in 1982.

(3) Slope conditions above both the proposed lake tap site and outlet portal site are generally similar in that there is no evidence of large-scale slope movements in the recent past and rockfall appears to be the dominant slope process. Talus at the base of the slope at the proposed outlet portal/powerhouse site (Figures 3-1, 3-2) suggests a significant amount of rockfall activity in post-glacial time.

(4) As discussed in Section 5.2.1.4, a significant advance of Blockade Glacier could disrupt drainage in and near the lower reaches of the McArthur Canyon. There was no evidence identified during the 1981 field work to suggest that such an event is likely in the near future.

7.2.3 Alternative B

The comments in Section 7.2.2 apply to this alternative, also.

7.2.4 Alternatives C and D

On the basis of the observations made during the 1981 field program, it is possible to comment on several geologic factors that may influence consideration of Design Alternative C (and D); see also Sections 5.2.1.6, 5.2.2.3, 5.2.3.4, and 5.3.3.3.

(1) In this alternative, both ends of the hydroelectric system would be sugject to the volcanic hazards associated with Mt. Spurr. Comment No. 1 for Alternative A (Section 7.2.2) applies here, also. Volcanically-induced flooding is judged to be the volcanic hazard most likely to affect the outlet portal/powerhouse site (Figure 3-3) in the Chakachatna canyon.

(2) On the basis of general observations (i.e., not observations specifically designed to assess tunnelling conditions), the granitic rock types that predominate in the area of the proposed tunnel alignment (Figure 3-3) are generally well suited for tunnelling. Local zones of intensive weathering, alteration, or extensive jointing and shearing may provide poor tunnelling conditions.

(3) The slopes above both the lake tap and outlet portal sites consist of glaciated granitic bedrock. No evidence of large-scale slope failure was observed during the 1981 reconnaissance field work. Rockfall appears to be the dominant slope process.

7.3 Environmental Evaluation

The preliminary environmental overviews presented in the following sections for each project alternative are based on data obtained from agency personnel, available literature, and the limited information collected during the 1981 fall reconnaissance programs. Although a complete evaluation of all influences of each alternative is not included in this section, anticipated major environmental differences between alternatives are presented. These differences should not be considered definitive, and are only included at this time to facilitate comparisons of the alternatives.

7.3.1 Chakachatna Dam Alternative

If a dam was constructed and operated on the Chakachatna River, impacts would be inflicted on the anadromous fish. Even if Chakachamna Lake and its tributary streams remained accessible by fish ladders for upstream migrants, losses of downstream migrating fingerlings would occur unless an effective method could be developed to allow their safe passage past the dam. Due to the water quality alterations in the river downstream from the dam, the use of important fish migratory and spawning habitat likely would be reduced. This, in turn, could impact Cook Inlet commercial fishery resources.

If a large decline in the lake fishery occurred, wolves, bears, and eagles would probably migrate to lower elevations, thus increasing the density of animals in the remaining forage areas. Other large mammals that ordinarily utilize the Chakachatna River canyon for migration to and from summer and winter range would probably also be impacted. Since the canyon area upstream from the dam would be flooded, a high quality visual resource will be affected by the loss of the white-water reach of the river. In addition, fluctuating Chakachamna Lake water levels associated with all alternatives will impact the scenic quality of the lake shoreline. If the lake levels are raised so that the tributary deltas are inundated, additional juvenile rearing and spawning areas may be created for resident lake fish, (primarily lake trout). However, although fishing and hunting access to the lake by wheeled airplanes would be reduced, access by float plane will be unaffected.

Although the impacts from this alternative may be severe in that a major fishery could be lost, many of the impacts, including the damage to the aquatic resources, potentially could be mitigated, primarily through the installation of appropriate fish passage structures.

7.3.2 McArthur Tunnel Alternatives A and B

Through the implementation of Alternatives A or B, the impacts resulting from construction and logistical support activities would be very similar. Although the major impacts will be inflicted on the fish and wildlife of the area, the human resources will also be affected. With increased access to the McArthur Canyon and Chakachamna Lake, important visual resources as well as fisheries and wildlife habitat may be degraded.

Once in operation, the increased flows in the McArthur River may result in changes in water quality and alternations in the chemical cues that direct anadromous fish to their spawning grounds. Although the possibility also exists that the population of salmon will increase in the McArthur River, predation may also increase. If large mammals begin to concentrate in these high density fish areas, sport and subsistence hunting pressure will probably also increase.

The major difference in these alternatives is that in Alternative A, no water would be provided in the upper reaches of the Chakachatna River, while in Alternative B, some flows would be maintained. Since this distinction means the difference in whether the anadromous fish population survives in the lake and the lake tributaries, the difference in impacts is substantial. Again, impacts on commercial fishing would be tied to direct changes in anadromous fish populations.

In Alternative A, with a reduction in the lake fishery due to the obstruction of migration pathways, and resident fish spawning activities limited by fluctuations in the lake level, the large mammals and eagles that ordinarily make use of that resource as a food source will probably migrate to lower elevations where the density of wildlife will then probably increase. This will have both positive and negative effects on the human resources. If the lake fishery were lost, commercial fisheries in Cook Inlet may be impacted. However, subsistence fishing will most likely not be affected since there is currently very little use of this fishery resource for subsistence. With increased access to the area and perhaps increased numbers of large mammals, sport and subsistence hunting success may improve. In addition, increased access may open new areas to timber harvesting, petroleum development, and mineral exploration.

Alternative B would provide for year round flows in the upper reaches of the Chakachatna canyon (Table 7.2). The amount of instream flows selected are approximately 30 percent of the average annual flow during April through September and between approximately 10 and 20 percent of the average annual flow during the winter months, October through March. These flow quantities are very tentative and the final recommendations regarding flows to be released to mitigate potential adverse impacts will be based on further studies to be performed in 1982, and then may be greater or less than the values presented herein. Through the implementation of Alternative B there should be little long-term impact on the fish and wildlife of the Chakachamna drainage provided that fish passage facilities are provided at the lake outlet to permit upstream and downstream fish migrations. The influence of the human resources will probably also be less severe since the commercial fishery will probably not be as heavily impacted.

While the impacts related to Alternative A affecting local resources would be difficult to mitigate and significant changes in both the distribution and abundance of fish and wildlife populations would almost certainly occur, the impacts resulting from Alternative B would be less severe and relatively more amenable to mitigative measures, again primarily through the installation of fish passage structures.

It should be noted, however, that while not directly stated, the loss of spawning areas, and juvenile habitat due to any of the project alternatives will most likely eventually manifest itself as a decline in the population of adult fish as well. In addition since eggs, fry, and

Table 7.2 Natural and Alternative B regulated mean monthly and mean annual flow at the Chakachamna Lake outlet.

Month	Natural (cfs)	Regulated (cfs)
Jan	613	365
Feb	505	343
Mar	445	345
Apr	441	536
May	1,042	1,094
Jun	5,875	1,094
Jul	11,950	1,094
Aug	12,000	1,094
Sep	6,042	1,094
Oct	2,468	365
Nov	813	365
Dec	1,206	360
Mean Annual Flow	3,645	679

a Regulated flows were estimated using the Montana Method as described in Section 6.2.2.1

juveniles of all species provide food (prey) for other species, losses of spawning and nursery areas will almost certainly result in eventual reductions in the standing crop of their predators. For example, losses of juvenile sockeye salmon in Chakachamna Lake would probably also result in an overall decline in lake trout.

7.3.3 Chakachatna Tunnel Alternatives C and D

Through the implementation of Alternatives C or D, the impacts resulting from logistical support or construction activities would be similar. However, since all activities are restricted to the Chakachatna flood-plain in these alternatives, the resources in the McArthur drainage will not be affected. Although impacts on the wildlife populations may occur, significant impacts will occur to the fisheries. Since access to Chakachamna Lake will be increased, sport and subsistence fishing pressure may increase. However, with the road, campsite and disposal site for rock excavated from the tunnel, all located in the Chakachatna canyon, an important visual resource will be modified. In addition the presence and activity associated with these facilities may impede large mammal movements through the canyon temporarily during construction of the project.

During the pre-operational phases, the fishery in the Chakachamna drainage will probably only be impacted to a small extent over a relatively short term. Above the powerhouse, the impact on the Chakachatna River and Chakachamna Lake fishery will be dependent on whether flows are maintained and fish passage facilities provided. Alternative C does not allow for these mitigative measures. Therefore, the impacts to the

Table 7.3 Natural and Alternative D regulated mean monthly and mean annual flows at the Chakachamna Lake outlet.

Month	Natural (cfs)	Regulated (cfs)
Jan	613	30
Feb	505	30
Mar	445	30
Apr	441	30
May	1,042	30
Jun	5,875	30
Jul	11,950	30
Aug	12,000	30
Sep	6,042	30
Oct	2,468	30
Nov	1,206	30
Dec	1,206	30
Mean Annual Flow	3,645	30

a Regulated flows were assumed to be sufficient minimum flows to maintain migratory passage as described in Section 6.2.2.1.

fishery at or above the lake, and thus the wildlife and commercial fishery in the surrounding area will be similar to that inflicted through Alternative A. Since Alternative D does provide flows (Table 7.3) and migratory passages, the impacts would be similar to those described for Alternative B.

Within the project area, some resources will be affected no matter which alternative is chosen. This is particularly true of scioeconomic, land use, and transportation characteristics. Through the implementation of mitigative measures, it may be possible to offset many of the adverse impacts. However, the mitigation technniques outlined will probably not restore the environment to pre-operational condition.

CONSTRUCTION COSTS
AND SCHEDULES

8.0 CONSTRUCTION COSTS AND SCHEDULES

8.1 Estimates of Cost

Estimates of construction costs have been prepared for the following alternatives for project development:

Alternative A - 400 MW McArthur tunnel development

Alternative B - 330 MW McArthur tunnel development

Alternative C & D - 300 MW Chakachatna tunnel development

The estimates are based on schedules of quantities of materials and equipment needed for the major features of each alternative to the extent permitted by the drawings for Section 3.0 of this report. In some cases, quantities were proportioned from the construction records of other projects bearing significant similarity of structures and conditions expected to be encountered during construction of the Chakachamna Hydroelectric Project. Unit prices developed for this and other projects involving similar types of construction and from analyses of bids received for the construction of similar types of projects in Alaska, adjusted as necessary to reflect January 1982 price levels, were then applied to the schedules of quan- tities to arrive at the estimated costs set forth in the estimate summaries at the end of this section of the report. The summaries show the following estimated project costs excluding owner's costs and escalation:

Alternative A	$1.5 billion
Alternative B	$1.45 billion
Alternative C	$1.6 billion
Alternative D	$1.65 billion

The above costs include a 20% contingency added to the specific construction cost plus engineering and construction management, and interest during construction. The costs for Alternatives B and D additionally include a provisional allowance of $50 million for fish passage facilities at the lake outlet.

For all of the alternatives, the principal structures consist of the following:

- Intake structure at Chakachamna Lake with underwater lake tapping, and control gate shaft.
- Concrete lined power tunnel with construction access adits.
- Surge chamber and emergency closure gates at the downstream end of the power tunnel.
- Underground concrete lined pressure penstock shaft and manifold.
- Concrete and steel lined penstock branches leading to a valve chamber and the turbines.
- Four unit underground powerhouse with exploratory adit (to become the ventilation tunnel) and main access tunnel.

- o Underground transformer vaults and high voltage cable gallery.
- o Tailrace tunnel and surge chamber.
- o Tailrace outlet channel and river protection works.
- o High voltage cable terminals and switchyard.
- o Transmission lines to northerly shore of Knik Arm.
- o High Voltage submarine cable crossing of Knik Arm.

8.1.1 Power Tunnel

The cost of constructing the power tunnel is the dominant feature, representing more than half the estimated cost of constructing each alternative. Detailed evaluations were made of all operations and the direct costs considered necessary to construct the 25-foot diameter concrete lined power tunnel for Alternatives A, C and D, using both rubber tired and rail haulage equipment. The difference in cost between the two was found to be small. Thus, the choice of haulage equipment will probably be determined by other considerations such as for example, whether excavation and concrete placement would be scheduled by a Contractor to take place concurrently in a given tunnel heading. This can be accomplished if necessary in a 25-foot diameter tunnel with either rail haulage or rubber tired equipment.

The estimated cost of constructing the 23-foot diameter tunnel required for Alternative B is proportioned from the estimated unit cost per lineal foot for constructing the 25-foot diameter tunnel for Alternatives A, C, and D.

The estimated tunnel construction costs are based on the following items:

- Excavation would be by conventional drilling and blasting generally with full face excavation, drilling 12-foot depth rounds. Allowance is included for a nominal length of tunnel where the depth of rounds might have to be reduced, or where top heading and bench techniques might have to be used temporarily, if less favorable ground conditions are encountered.

- The assumptions are made that 25% of the tunnel length would require steel rib support, 25% would be supported by patterned rock bolts and 50% would be unsupported.

- Chain link mesh for the protection of workmen from rock falls is provided above the spring line over the full tunnel length.

- Estimated excavation costs include provision for handling and removing 2000 gallons per minute of ground water inflow in each tunnel heading.

- Excavation and concrete lining would proceed on a 3-shift basis, 6-days per week.

- Construction access adits would be located near the upstream and downstream ends of each tunnel alternative. In addition two intermediate adits would be provided for Alternatives C and D.

8.1.2 Underground Powerhouse and Associated Structures

For purposes of the current estimates, the powerhouse has been taken as an underground installation for each alternative, with a high pressure penstock shaft and low pressure tailrace tunnel. The estimates of cost are based on the following conditions:

- All excavation and concrete work would proceed on a 3-shift, 6-days per week basis.
- The powerhouse cavern, valve chamber and tailrace tunnel would be excavated by top heading and bench.
- The penstock and surge shafts would be excavated first by pilot raise, then by downward slashing to full diameter.
- Excavation for the horizontal penstock and manifold, access tunnel, cable gallery and draft tubes would be full face.
- Chain link mesh is provided for protection of workmen over the upper perimeter of all excavations exceeding 12-feet in height.
- All permanent excavations would be supported as determined necessary by patterned rock bolts.
- Allowance is included for lining the upper perimeters of all caverns, chambers and galleries required for permanent access and those housing vulnerable generating or accessory equipment with wire mesh reinforced shotcrete (this may only be needed locally according to rock conditions exposed during construction).

- Excavation of an exploratory adit, and a program of core drilling and rock testing will precede and confirm the suitability of the site for the underground powerhouse complex during the design phase and the costs thereof are included in the estimates.

- The costs included for the major items of mechanical and electrical equipment are based on current data with added allowance for delivery and transportation to the powerhouse site. Installation costs are also included.

- Costs of mechanical and electrical auxiliary equipment and systems, control and protective equipment are included.

8.1.3 Tailrace Channel

The estimates include a monetary allowance for the construction of an outlet channel and river training works to protect it from damage during floods in the river. Details of such requirements are not well defined at the present stage but it is contemplated that extensive use would be made of rock spoil from excavation of the powerhouse complex for these purposes.

River gravels excavated from the tailrace channel would be processed and used to the maximum extent possible for concrete aggregate.

8.1.4 Switchyard

In each alternative, due to space limitations, the switchyard would be located outside the mouth of the canyon on gently sloping land and an appropriate allowance is included in the estimates for their cost.

8.1.5 Transmission Line and Cable Crossing

Field data acquisition is not scheduled until the 1982 exploratory program and information regarding construction conditions is limited to aerial observation of the proposed transmission line alignment and cable crossing. The cost allowed in the estimate for the transmission line is based on experience and includes the estimated cost of the submarine cable crossing to a dead end structure on the Anchorage Shore of Knik Arm.

8.1.6 Site Access and Development

The estimates include costs of constructing access and support facilities needed for construction of the permanent works. These would consist basically of the following installations:

- Unloading facility on tidewater at Trading Bay, complete with receiving and warehousing provisions, bulk cement and petroleum fuels storage plus a small camp for operating staff.

- Gravel surfaced all-weather access roads to construction sites. It has been assumed that where existing roads are suitably located, permission to use them could be negotiated with their owners in exchange for improvements that would include widening them to full two-way traffic roads. Bridges and culverts would be provided at all streams and water courses and where needed for drainage. Year-round maintenance costs are included throughout the construction period.

- An aircraft landing facility with a runway of sufficient length to handle aircraft up to DC-9 and 737 types, and ground support facilities.

- For Alternatives A and B major construction camps would be located outside but close to the mouth of the McArthur Canyon to accommodate workers employed on the downstream heading of the power tunnel, the powerhouse and associated structures. A second camp for workmen employed on the upstream heading of the power tunnel and intake works would be provided just east of the Barrier Glacier on the northerly side of the river.

- For Alternatives C and D the main construction camp would be located outside the mouth of the Chakachatna Canyon for workers employed on the downstream heading of the power tunnel, the powerhouse and associated structures and also for the second intermediate access adit to the power tunnel. A second camp for workers employed on the upstream heading of the power tunnel, intake works and headings driven from the first intermediate access adit to the power tunnel would be located east of the Barrier Glacier.

- The construction camps would be self-contained with all needed support facilities which would include water supply, sewage treatment, solid waste disposal, catering and medical services.

- Electrical power during construction is provided for on the assumption that diesel driven equipment would be used.

- Major compressed air facilities would be required for the excavation work and their cost is provided for in the estimates.

- Camps needed to accommodate transmission line workers would be light weight "fly camps". Much of the line work would be undertaken in winter and would be avoided during waterfowl nesting periods.

As construction work approaches completion, all temporary facilities will be dismantled and removed from the site, which will be restored insofar as is possible to its original condition, and the cost of such demobilization and site restoration is included in the estimates.

8.2 Exclusions from Estimates

The estimates of construction costs do not include provision for the costs of the following items:

- Owner's administrative costs.

- Financing charges.

- Escalation

- Land and Land Rights.

- Water Rights

- Permits, licenses and fees.

- Switchyard at the Anchorage transmission line terminal.

8.3 Construction Schedules

Typical construction schedules are shown on Figure 8-2 for Alternatives A and B and on Figure 8-3 for Alternatives C and D. These schedules have as their beginnings the existing schedule for completion of the project feasibility study and preparation of the application to the Federal Energy Regulatory Commission (FERC) for a license to construct the project.

The assumption has been made that the license application would be submitted to FERC March 1, 1983. Assuming also that the FERC licensing process continues in much the same manner as it does at the present time, an early step will be the preparation of an environmental assessment of the project by FERC staff. This generally takes about 12 months following which is a 60-day period for review and comment by interested agencies. Thus, by the end of April, 1984, it should have become clear whether there are any outstanding unresolved issues. If there are not, then it would be possible to forecast with reasonable certainty that the FERC license would be issued in early 1985, in which event there would not appear to be any reason why the construction of access facilities and camp installations could not commence by June 1, 1984. In order to provide adequate lead time to commence design and prepare plans and specifications for the construction of access facilities, design engineering of the project would need to commence at the beginning of 1984.

Noting that there is a possibility that FERC might also require completion of an exploratory adit and rock testing program at the powerhouse site before issuing the project license, June 1, 1984 would appear to be a logical time to commence that program. Making an early start in the manner described above would permit the plant to commence commercial operation a year earlier than if the design of the project and construction of infrastructure did not commence until after the FERC license had been issued.

Construction of the power tunnel lies on the critical path for completion of development via the McArthur River in Alternatives A and B. The schedule is based on the tunnel excavation advancing at an average rate of approximately 26 feet per day in each heading. At that rate, excavation would be completed in 3-1/2 years. Placement of the concrete lining would proceed concurrently with the excavation in both headings. Total construction time for the tunnel is thus 50 months and the first unit in the powerhouse could be started up by August 1, 1990. As discussed in section 10.2.4 of this report, a significant saving in time might be effected if the rock is suitable for tunnel excavation to be performed by means of a boring machine and also if any lengths of the tunnel can be left unlined.

For development via the Chakachatna River in Alternatives C and D, the ability to provide two intermediate construction access adits enables the tunnel construction to be completed within 32 months, or 18 months less than for the McArthur tunnel. Timely delivery of the turbines and generators, and construction of the powerhouse complex becomes more critical. Asssuming an early start on site access and development as described above for Alternatives A and B, the first unit in Alternatives C and D could be started up by February 1, 1989, or 18 months earlier than would be the case with Alternatives A and B. The implications of this are discussed in Section 7.3.5 of this report.

CHAKACHAMNA HYDROELECTRIC PROJECT
CONCEPTUAL ESTIMATE SUMMARIES – SHEET 1 OF 2

ALTERNATIVES	ESTIMATED COSTS IN THOUSANDS OF DOLLARS							
	A		B		C		D	
LAND AND LAND RIGHTS		0		0		0		0
POWER PLANT STRUCTURE AND IMPROVEMENTS								
Valve Chamber	5,600		5,500		5,600		5,600	
Underground Power House	26,200		25,200		26,200		26,200	
Bus Galleries	200		200		200		200	
Transformer Gallery	4,600		4,300		4,300		4,300	
Valve Chamber and Transformer Gallery – Access Tunnel	400		400		400		400	
P. H. Access Tunnel	13,500		13,500		13,500		13,500	
Cable Way	800		800		800		800	
		51,300		49,900		51,000		51,000
RESERVOIR, DAM AND WATERWAYS								
Reservoir	100		100		100		100	
Intake Structure	10,400		9,300		10,400		10,400	
Intake Gate Shaft	13,200		12,400		13,200		13,200	
Access Tunnel								
– At Intake	21,600		19,100		21,600		21,600	
– At Surge Chamber, No. 3	6,600		5,900		8,900		8,900	
– At Mile 3, 5, No. 1	0		0		20,800		20,800	
– At Mile 7, 5, No. 2	0		0		14,500		14,500	
Power Tunnel	626,800		580,400		712,500		712,500	
Surge Chamber – Upper	12,900		11,000		12,900		12,900	
Penstock – Inclined Section	18,000		16,500		15,400		15,400	
– Horizontal Section and Elbow	6,700		6,000		6,700		6,700	
– Wye Branches to Valve Chamber	13,200		11,900		12,100		12,100	
– Between Valve Chamber & Power House	800		600		800		800	
Draft Tube Tunnels	1,900		1,700		1,900		1,900	
Surge Chamber – Tailrace	2,400		2,400		2,400		2,400	
Tailrace Tunnel and Structure	10,300		9,600		10,300		10,300	
Tailrace Channel	900		700		900		900	
River Training Works	500		500		500		500	
Miscellaneous Mechanical and Electrical	7,100		6,100		5,700		5,700	
		753,400		694,200		871,600		871,600

CHAKACHAMNA HYDROELECTRIC PROJECT
CONCEPTUAL ESTIMATE SUMMARIES – SHEET 2 OF 2

ALTERNATIVES	ESTIMATED COSTS IN THOUSANDS OF DOLLARS							
	A		B		C		D	
TURBINES AND GENERATORS		67,900		57,900		54,500		54,500
ACCESSORY ELECTRICAL EQUIPMENT		11,200		9,500		9,000		9,000
MISCELLANEOUS POWER PLANT EQUIPMENT		8,600		7,300		6,900		6,900
SWITCHYARD STRUCTURES		3,600		3,600		3,600		3,600
SWITCHYARD EQUIPMENT		13,800		12,500		12,100		12,100
COMM. SUPV. CONTROL EQUIPMENT		1,600		1,600		1,600		1,600
TRANSPORTATION FACILITIES								
Port	4,600		4,600		4,600		4,600	
Airport	2,000		2,000		2,000		2,000	
Access and Construction Roads	59,600		59,600		44,100		44,100	
		66,200		66,200		50,700		50,700
TRANSMISSION LINE & CABLE CROSSING		63,200		63,200		56,500		56,500
TOTAL SPECIFIC CONSTRUCTION COST AT JANUARY 1982 PRICE LEVELS		1,040,800		965,900		1,117,500		1,117,500
ENGINEERING & CONSTRUCTION MANAGEMENT		124,900		115,900		134,100		134,100
SUBTOTAL		1,165,700		1,081,800		1,251,600		1,251,600
CONTINGENCY @20%		233,100		216,400		250,300		250,300
ESCALATION		Not Incl.		Not Incl.		Not Incl.		Not Incl.
INTEREST DURING CONST. @3% PER ANNUM		111,900		104,100		101,400		101,400
OWNER'S COSTS		Not Incl.		Not Incl.		Not Incl.		Not Incl.
ALLOWANCE FOR FISH PASSAGE FACILITIES		–		50,000		–		50,000
TOTAL PROJECT COST AT JANUARY, 1982 PRICE LEVELS		1,510,700		1,452,300		1,603,300		1,653,300
USE		1,500,000		1,450,000		1,600,000		1,650,000

ECONOMIC EVALUATION

9.0 ECONOMIC EVALUATION

9.1 General

An evaluation has been made of the economic tunnel diameter as well as the economic tunnel length for the four basic alternatives presented in this report. Determination of the economic tunnel diameter involves comparing the construction costs of tunnels of varying diameters, with the present worth of the difference in power produced over the life of the project as a result of the changes in hydraulic loss in the tunnel as the diameter is varied. The economic tunnel length is determined from an economic balance between the cost of increasing the tunnel length to develop additional head on the powerhouse, and the present worth of the additional power produced by the higher head over the life of the project.

9.2 Parameters for Economic Evaluation

Alaska Power Authority has developed the following parameters for economic analyses of hydroelectric projects.

Inflation Rate	0%
Real Discount Rate	3%
Economic Life of Hydroelectric Projects	50 years
Economic life of thermal plants (conventional coal fired or combined cycle)	30 years

In sizing the various project elements, i.e., tunnel diameter and length, the value of power generated by the hydroelectric project has been considered equal to the cost of the equivalent power generated thermally by coal fired plant or by natural gas fired combined cycle plant.

As agreed with APA, in order to arrive at a project cost which can be readily compared with that for the Susitna Project a 50% plant factor has been used for determining the installed capacity of the power plants discussed in this report. Future studies will concentrate on refining the preferred plant factor for the project.

9.3 Cost of Power from Alternative Sources

9.3.1 General

To ensure uniformity of data between the various feasibility studies of hydroelectric projects which are currently in progress, including the Susitna Hydroelectric Project, APA requested that the following sources be used for the development of cost of power from alternative thermal generation:

(1) Acres American Incorporated report "Susitna Hydroelectric Project" Task 6 Development Selection Report, Appendices A through I, July 1981 for construction cost of coal fired and combined cycle thermal plants.

(2) Battelle Pacific Northwest Laboratories, for the cost of operation and maintenance and fuel for coal fired and combined cycle thermal plants. Data on these items were obtained during a visit to Battelle's office on September 1, 1981.

9.3.2 Construction Cost

(a) Coal fired thermal plant:

The Acres American report referred to above develops the construction cost of a 250-MW coal fired thermal plant at Beluga in 1980 dollars to be $439,200,000 direct construction cost and $627,650,000 total cost including 16% contingency, 10% for construction facilities and utilities and 12% for Engineering and Administration, but not including interest during construction. This total cost corresponds to $2510/kW. Including interest during construction at 3 percent per year for a 6 year construction period, the total cost amounts to $2706/kW. (This differs but little from the $2744/kW value given in Table B.13 of the Acres Report apparently because of some rounding of numbers in the Acres calculation and apparently slight difference in cash flow during the construction period.)

(b) Combined Cycle Plant

The Acres American report also develops the construction cost of a 250-MW combined cycle plant in 1980 dollars to be $121,830,000 direct construction cost and $174,130,000 total cost including 16% contingency 10% for construction facilities and utilities and 12% for Engineering and Administration, but not including interest during construction. This corresponds to $697/kW. When interest during construction is added at 3 percent per year, the total cost is $707.5/kW.

9.3.3 Operation & Maintenance Cost

Data obtained from Battelle is summarized below for 1980 price levels.

(a) Coal-fired Thermal Plant

Fixed Operation and Maintenance $16.71/kW/year
Variable Operation and Maintenance 0.6 mills/kWh.
Escalation above general inflation rate 1.9% until year 2012 with no escalation after 2012.

(b) Combined Cycle Plant

Fixed Operation and Maintenance $35.00/kW/year
Variable Operation and Maintenance 0 mills/kWh.
Escalation above general inflation rate 1.9% until year 2012 with no escalation after 2012.

9.3.4 Fuel Cost

Data obtained from Battelle is summarized below for 1980 price levels

(a) Coal from Beluga

Fuel cost $1.09/mill. BTU
Escalation above general inflation rate 1.5% until year 2012 with no escalation after 2012.
Heat Rate 10,000 BTU/kWh.

(b) Natural Gas - Combined Cycle Plant

The natural gas prices as estimated by Battelle for the future years are given in Table 9-1.

Heat rate 7500 BTU/kWh.

TABLE 9-1

NEW CONTRACT GAS PRICE (AML&P)-ANCHORAGE

Year	Gas Price $/Mill BTU
1980	1.08
1981	1.08
1982	1.09
1983	1.09
1984	1.09
1985	1.09
1986	1.35
1987	1.56
1988	1.65
1989	1.89
1990	2.11
1991	3.62
1992	3.74
1993	3.86
1994	3.98
1995	4.11

Forecast escalation after 1995 = 3% per year until the year 2012, and no escalation thereafter.

9.4 Value of Hydro Generation

The value of the hydro generation is established by determining the cost of generating power from alternative sources. For the purpose of this study an analysis has been made of the cost of alternative coal-fired and combined cycle generation, using the basic cost data presented previously in Section 9.3.

The annual cost of interest, depreciation and insurance for the alternative thermal plants were calculated on the following basis:

Interest	3.0%
Depreciation (30 year life)	2.1%
Insurance	0.25%
Annual Charge on Capital Cost	5.35%

Based on an arbitrary selection of 1990 as the in-service date for the Chakachamna Project and examining a fifty year period, equal to the economic life of the hydro plant, and using the unit costs for thermal generation discussed above, comparative costs were prepared for each year of the 50 year period of the cost of generating power at 50% load factor by each of the two alternatives, conventional thermal using Beluga coal and combined cycle using gas. These annual costs over the 50 year period were then used to determine their present worths at the first year of generation taken as 1990. The calculations were performed on a cost per kWh basis and are presented in Tables 9-2 & 9-3 for the conventional coal fired and combined cycle cases respectively.

TABLE 9-2 (Sheet 1 of 2)

COAL FIRED PLANT

Year	Amortization & Insurance	O&M	Fuel	Total	Present Worth
1	33.02	5.32	12.65	50.99	49.50
2	33.02	5.42	12.84	51.28	48.34
3	33.02	5.52	13.03	51.57	47.19
4	33.02	5.63	13.23	51.88	46.09
5	33.02	5.74	13.43	52.19	45.02
6	33.02	5.84	13.63	52.49	43.96
7	33.02	5.96	13.83	52.81	42.94
8	33.02	6.07	14.04	53.13	41.94
9	33.02	6.18	14.25	53.45	40.96
10	33.02	6.30	14.46	53.78	40.02
11	33.02	6.42	14.68	54.12	39.10
12	33.02	6.54	14.90	54.46	38.20
13	33.02	6.67	15.12	54.81	37.32
14	33.02	6.79	15.35	55.16	36.47
15	33.02	6.92	15.58	55.52	35.64
16	33.02	7.06	15.82	55.90	34.84
17	33.02	7.19	16.05	56.26	34.04
18	33.02	7.33	16.29	56.64	33.27
19	33.02	7.47	16.54	57.03	32.52
20	33.02	7.61	16.79	57.42	31.79
21	33.02	7.75	17.04	57.81	31.08
22	33.02	7.90	17.29	58.21	30.38
23	33.02	7.90	17.29	58.21	29.49
24	33.02	7.90	17.29	58.21	28.64
25	33.02	7.90	17.29	58.21	27.80
					946.54

NOTE: Escalation rates above the general escalation rate are as follows.

Amortization & Insurance - Nil.

Operation & maintenance - 1.9% for first 22 years only

Fuel - 1.5% for first 22 years only.

TABLE 9-2 (Sheet 2 of 2)

COAL FIRED PLANT

Year	Amortization & Insurance	O&M	Fuel	Total	Present Worth
					Fwd. 946.54
26	33.02	7.90	17.29	58.21	26.99
27	33.02	7.90	17.29	58.21	26.21
28	33.02	7.90	17.29	58.21	25.44
29	33.02	7.90	17.29	58.21	24.70
30	33.02	7.90	17.29	58.21	23.98
31	33.02	7.90	17.29	58.21	23.28
32	33.02	7.90	17.29	58.21	22.61
33	33.02	7.90	17.29	58.21	21.95
34	33.02	7.90	17.29	58.21	21.31
35	33.02	7.90	17.29	58.21	20.69
36	33.02	7.90	17.29	58.21	20.08
37	33.02	7.90	17.29	58.21	19.50
38	33.02	7.90	17.29	58.21	18.93
39	33.02	7.90	17.29	58.21	18.38
40	33.02	7.90	17.29	58.21	17.84
41	33.02	7.90	17.29	58.21	17.32
42	33.02	7.90	17.29	58.21	16.82
43	33.02	7.90	17.29	58.21	16.33
44	33.02	7.90	17.29	58.21	15.85
45	33.02	7.90	17.29	58.21	15.39
46	33.02	7.90	17.29	58.21	14.94
47	33.02	7.90	17.29	58.21	14.51
48	33.02	7.90	17.29	58.21	14.09
49	33.02	7.90	17.29	58.21	13.68
50	33.02	7.90	17.29	58.21	13.28
					1430.64

Equivalent Levelized Annual Cost = 55.60 mills/kWh.

TABLE 9-3 (Sheet 1 of 2)

COMBINED CYCLE PLANT

Year	Amortization & Insurance	O&M	Fuel	Total	Present Worth
1	8.64	9.64	21.1	39.38	38.23
2	8.64	9.82	36.2	54.66	51.52
3	8.64	10.01	37.4	56.05	51.29
4	8.64	10.20	38.6	57.44	51.03
5	8.64	10.39	39.8	58.83	50.75
6	8.64	10.59	41.1	60.33	50.53
7	8.64	10.79	42.33	61.76	50.22
8	8.64	11.00	43.60	63.24	49.92
9	8.64	11.21	44.91	64.76	49.63
10	8.64	11.42	46.26	66.32	49.35
11	8.64	11.64	47.65	67.93	49.07
12	8.64	11.86	49.08	69.58	48.80
13	8.64	12.08	50.55	71.27	48.53
14	8.64	12.31	52.06	73.01	48.27
15	8.64	12.55	53.63	74.82	48.02
16	8.64	12.78	55.23	76.65	47.77
17	8.64	13.03	56.89	78.56	47.53
18	8.64	13.28	58.60	80.52	47.30
19	8.64	13.53	60.36	82.53	47.07
20	8.64	13.78	62.17	84.59	46.84
21	8.64	14.05	64.03	86.72	46.62
22	8.64	14.31	65.95	88.90	46.40
23	8.64	14.31	65.95	88.90	45.04
24	8.64	14.31	65.95	88.90	43.73
25	8.64	14.31	65.95	88.90	42.46
					1195.92

NOTE: Escalation rates above the general escalation rate are as follows.

Amortization & Insurance - Nil.

Operation & maintenance - 1.9% for first 22 years only

Fuel - 1.5% for first 22 years only.

TABLE 9-3 (Sheet 2 of 2)

COMBINED CYCLE PLANT

Year	Amortization & Insurance	O&M	Fuel	Total	Present Worth
				Fwd.	1195.92
26	8.64	14.31	65.95	88.90	41.22
27	8.64	14.31	65.95	88.90	40.02
28	8.64	14.31	65.95	88.90	38.86
29	8.64	14.31	65.95	88.90	37.72
30	8.64	14.31	65.95	88.90	36.63
31	8.64	14.31	65.95	88.90	35.56
32	8.64	14.31	65.95	88.90	34.52
33	8.64	14.31	65.95	88.90	33.52
34	8.64	14.31	65.95	88.90	32.54
35	8.64	14.31	65.95	88.90	31.59
36	8.64	14.31	65.95	88.90	30.67
37	8.64	14.31	65.95	88.90	29.78
38	8.64	14.31	65.95	88.90	28.91
39	8.64	14.31	65.95	88.90	28.07
40	8.64	14.31	65.95	88.90	27.25
41	8.64	14.31	65.95	88.90	26.46
42	8.64	14.31	65.95	88.90	25.69
43	8.64	14.31	65.95	88.90	24.94
44	8.64	14.31	65.95	88.90	24.21
45	8.64	14.31	65.95	88.90	23.51
46	8.64	14.31	65.95	88.90	22.82
47	8.64	14.31	65.95	88.90	22.16
48	8.64	14.31	65.95	88.90	21.51
49	8.64	14.31	65.95	88.90	20.89
50	8.64	14.31	65.95	88.90	20.28
					1935.25

Equivalent Levelized Annual Cost = 75.21 mills/kWh.

The levelized annual cost of generation by a coal fired plant using Beluga coal is calculated to be 55.60 mills per kWh compared with 75.21 mills per kWh for the combined cycle plant, based on 50% load factor generation. The higher cost for the combined cycle plant is due primarily to a higher initial fuel cost, a much higher escalation on the cost of fuel, and somewhat higher operation and maintenance cost. Taken collectively these more than offset the much lower annual charge on the capital cost of constructing the combined cycle plant. The cost of power produced by the coal fired plant was therefore adopted as the alternative for establishing the value of hydro generation.

The capital cost of a hydro plant which gives a levelized annual cost over the 50 year life equal to the levelized annual cost of the coal fired thermal plant of 55.60 mills per kWh, based on 50% plant factor, and including a credit of 5% less installed capacity required in a hydro plant because of the reduced system reserve requirements with hydro generation, is calculated to be $6,117 per kW. This total cost includes contingency, construction camp facilities, engineering, and construction management and interest during construction.

9.5 Economic Tunnel Sizing

The economic diameter of the main power tunnel has been investigated by comparing the incremental cost of varying the tunnel diameter with the incremental value of the difference in power produced as a result of such variation in tunnel diameter. For the same powerhouse flow, increasing the tunnel diameter reduces the head losses in the tunnel thereby increasing the total head on the powerhouse with a consequent increase in power production.

In establishing the variation in estimated tunnel construction cost it has been assumed that the tunnel will be fully concrete lined with the typical horseshoe section shown in Figure 3-2. Future studies are planned to evaluate the merits of a nominally unlined tunnel.

For the case of Alternatives A & C with no water release to meet instream flow requirements in the Chakachatna River (i.e., all controlled water being diverted for power production purposes), Figure 9-1 shows the plot of estimated tunnel construction cost and value of power production with variation in tunnel diameter. This curve shows that the economic diameter of a concrete lined tunnel is 25 feet. In Alternative B, with the flow diverted to a powerhouse sited on the McArthur River, but with water reserved for instream flow requirements in the Chakachatna River as discussed in Section 7.3.3, a separate study to establish the economic diameter was not made. Instead, as an approximation, the tunnel diameter was selected such that the velocity of flow through the tunnel with the generating units operating at full output and at full level at Lake Chakachamna would be the same as that obtained under these same operating conditions in Alternative A for which the economic diameter had been calculated. This approximation gives a 23-foot tunnel diameter which is believed reasonable at this stage, but future studies will review its acceptability.

In the case of Alternative D where only an average release of 30 cfs flow is maintained below Chakachamna, Lake, the 25 foot diameter tunnel was retained, since the powerhouse flow differs by less than 1%.

9.6 Economic Tunnel Length

For both basic alternative developments by diversion to the McArthur River or downstream along the Chakachatna River, an examination has been made of the economic tunnel length. As the powerhouse is moved downstream to develop additional head, the power tunnel becomes longer and hence more costly. The economic tunnel length is therefore determined from an economic balance of estimated tunnel construction cost and value of power produced. Based on the value of the hydro generation as discussed in Section 9.4, the present worth of the power produced by 1 foot of head when all controlled water is used for power generation is equal to approximately $3,500,000 which corresponds to $139,000 annually over the 50 year life of the plant at 3% rate of interest.

The economic balance includes consideration of the additional estimated tunnel construction cost by increasing the tunnel length, additional powerhouse cost to develop the power produced from the additional head and the value of the additional power generated by the additional head developed. The additional head is based on the increased gross head due to the lower tailwater obtained by extending the tunnel less the increased friction head loss in the longer tunnel.

Figure 9-2 and 9-3 show respectively the plots of the economic tunnel length for the development via the McArthur River and down the Chakachatna River. The final selected tunnel lengths and corresponding powerhouse locations are shown in Figures 3-2 and 3-3.

1982 STUDY PROGRAM

10.0 1982 STUDY PROGRAM

10.1 Engineering Studies

Since development of the project by means of a tunnel to a powerhouse located in the McArthur Valley will yield the maximum electrical power benefits at lowest unit cost, the 1982 engineering studies are planned to concentrate on optimizing the structures and layout for that form of development. Due to the limitation on availability of funds until after June 30, 1982, the main thrust will be delayed until such time as the allocation of funds will permit.

10.1.1 Hydrological Studies

Extension of the Chakachamna Lake outflow records by correlations with other stations will be completed and power studies will be made using lake inflows derived from the extended outflows. It appears that satisfactory correlations can be established to derive discharge records that will extend the date base from 12 years to 31 years. Studies will also be made to examine the effects on power generation of limiting the allowable range of lake water surface elevation.

It is planned to purchase meteorological instruments necessary to record field date needed for studies that will evaluate the effects of operation of the project on the water temperature structure of Chakachamna Lake.

10.1.2 Chakachatna Dam

As was discussed earlier in Section 3.2 of this report consideration of dam sites on the Chakachatna River was placed in obeyance in the initial studies because of problems that were immediately evident. These comprised foundation problems in the left abutment and in the river channel, siting difficulties for a spillway capable of handling flood flows in the order of half a million cubic feet per second, hazards posed by future eruptions of Mount Spurr, and possibility of problems that may develop at the lake outlet. It is planned to re-examine the situation to verify that nothing has been overlooked before completely dismissing the possibility of a dam as a viable alternative.

10.1.3 Reservoir and Fish Passage Facilities

Studies will be conducted to examine how an outlet could be provided that would permit fish passage into and out of the reservoir.

10.1.4 Power Intake and Tunnel

Mr. Christian Groner, a consulting engineer of international repute with extensive experience in lake tapping projects has been contacted and indicated his willingness to make his expertise available in developing plans for the tapping of Chakachamna Lake.

The optimum tunnel length and diameter will be reviewed and recalculated, if necessary, according to revisions in the data base. When data become available from the tunnel line geological exploration, as assessment will be made of the feasibility and savings in cost and schedule that may be attainable if a nominally unlined tunnel instead of a concrete lined one were to be constructed in those locations where rock quality would permit.

After some indication has been obtained regarding the physical properties and composition of the rock, it is also planned to evaluate the feasibility of excavating the power tunnel by tunnel boring machine. A tunnel of comparable size was recently bored on the Kerckhoff II project in California Sierra granite. A bored tunnel would have a potential for significant savings in cost by virtue of possible reductions in time and labor needed for excavation, rock support and in volume of concrete needed for lining the tunnel.

10.1.5 Underground Powerhouse Complex

Studies are planned to optimize the penstock configuration and layouts for the manifold, value chamber, powerhouse cavern, draft tubes, access and tailrace tunnels, and the transformer and high voltage cable galleries. General arrangements and equipment layouts will be prepared for the major components. Performance data for the major mechanical and electrical equipment will be defined.

10.1.6 Transmission Line and Submarine Cable Crossing

The planned alignments for the transmission line and cable crossing will be determined. Requirements for tower foundations, tower types and conductors will be evaluated and identified. It is planned to engage the services of Mr. H.B. White, a transmission line consultant of international repute to advise in all aspects of the transmission line route location and design.

10.1.7 Access Roads and Construction Facilities

Alignments for the access road system required for the project construction and operation will be selected. These will include access to the permanent facilities in both the Chakachatna and McArthur valleys. The location and size of construction camps, airstrip and unloading facilities at Trading Bay and other temporary construction facilities will also be defined.

10.1.8 Cost Estimate and Construction Schedule

Based on the layouts developed for the various project structures, quantities will be prepared. From these, the project cost estimate and construction schedule will be developed.

10.1.9 Feasibility Report and FERC License Application

The proposed 1982 studies are planned to culminate in the preparation of a formal project feasibility report that will identify the recommended form of development with firm estimates of the power benefits and updated estimates of the cost of construction comparison with other power sources will also be made. The preparation of the exhibits for the FERC license application will be based on the form of development identified in the feasibility report.

10.2 Geologic Studies

Elements planned for inclusion in the 1982 program of geologic studies include:

(1) A two week program of detailed field investigations of faults and lineaments that may be faults, which have been identified in the project area on the basis of the literature review, air photo analysis, field reconnais- sance, and analysis of low-sun-angle aerial photography.

(2) A field investigation of the geology along the proposed tunnel alignment and at the proposed powerhouse site. The investigation will include mapping of pertinent geologic features, a limited geophysical investigation of sub- surface conditions at the proposed powerhouse site and of lake bottom characteristics at the proposed lake tap site, and a drilling program at the proposed powerhouse site.

(3) A brief geologic and geophysical study of aggregate sources in and around the site proposed for project facilities.

(4) A reconnaissance of the geologic conditions along the proposed road and transmission line alignment.

(5) Preparation of those components of the feasi- bility study report that address geologic factors.

10.3 Environmental Studies

During the two reconnaissance level efforts conducted in 1981, areas and species that may be impacted by the proposed alternatives were identified. While hydrologic efforts were concentrated on assessing the effects of the alternatives on the characteristics of the major rivers, fisheries investigations were conducted to evaluate the species and age class distributions. Together, these disciplines derived a preliminary assessment of the minimum amount of water that would need to be released from the lake into the Chakachatna River so that fish migrations would not be obstructed. Terrestrial investigations concentrated on the species distribution and relative abundance of both vegetation and wildlife. The socioeconomic investigations centered on identifying the major concerns of the government agencies and the general public.

Although significant data were collected in all disciplines, more information will need to be gathered during 1982 so that site specific impacts can be identified. The 1982 environmental studies are designed to provide data sufficient to prepare:

- a final Chakachamna Hydroelectric Project feasibility report; and

- environmental exhibits to accompany the Alaska Power Authority's License Application to the Federal Energy Regulatory Commission.

A preliminary design of the 1982 study program is presented below for the disciplines of environmental hydrology, aquatic biology, wildlife biology, and human resources. A more detailed work program is being prepared for presentation at program scoping meetings with State and Federal Agencies in December 1981.

10.3.1 Environmental Hydrology

The objectives of the 1982 environmental hydrology study program are to collect data and conduct analyses sufficient to:

- o assess the impacts of project flow regulation of the physical process of the Chakachatna and McArthur River systems; and

- o allow the aquatic bilogy, wildlife biology, and human resources disciplines to meet their study objectives.

The studies are designed to provide more detailed information of the type presented in Sections 6 and 7 so that a more detailed impact assessment can be conducted.

Hydrologic data collection will include a network of stream gages to establish the seasonal and areal distribution of flow in the Chakachatna and McArthur River systems. Discharge measurements will be taken periodically to establish rating curves. Water quality data will be collected as necessary for the FERC license application and to support the aquatic biology studies. Selected wetlands will be investigated to identify their water sources and the potential impacts of regulating flow.

Hydraulic studies will include the evaluation of a number of stream and floodplain transects encompassing sites with gages as well as other areas selected from fishery habitat information. More specific information on the number and locations of transects will be included in the detailed study plan. Hydraulic parameters will be collected where discharge measurements are taken and also in other site specific locations as needed to support the fisheries investigations. Water surface profiles will also be surveyed.

Channel configuration and other regime characteristics will be investigated. Channel configuration will be identified in sufficient detail to assess the impacts on the configuration caused by the change in flow. Other observations of river regime will be made that include:

- flow obstructions,
- characteristics of side channels and high water channels,
- tributary characteristics,
- lateral migration evidence,
- bed scour, degradation, or aggradation,
- flood debris and high water marks, and
- stream geomorphology.

Substrate observations and samples will be collected in representative study areas for sediment transport and fisheries habitat investigations. The shoreline bottom material in the lake will also be evaluated for erosion studies related to lake drawdown.

The collected data will be used to evaluate the physical changes that are expected to occur in the affected river systems resulting from the construction and operation of the project. In addition, the collected data will be used in conjunction with the fisheries habitat data to obtain an assessment of the instream flow requirements for the maintenance of the fisheries resource.

10.3.2 Aquatic Biology

Aquatic biological studies needed for 1982 will be designed to fill the following data needs:

- documentation of the aquatic ecosystem sufficient for preparation of FERC applications exhibits and other environmental documents;

- the type and extent of impacts expected from proposed project alternatives will be delineated and quantified to the extent possible; and

- the type and extent of measures needed to mitigate environmental impacts will be defined.

The studies are designed to provide more detailed information concerning the aquatic communities by characterizing community distribution and relative abundance of important species.

Specifically, important support organisms will be investigated. Major taxonomic groups of macroinvertebrate drift and benthic macroinvertebrates will be characterized for the various habitat types. Particular attention will be given to areas subject to change due to project operation. The macrozooplankton, which are extensively used by sockeye salmon juveniles will be characterized in major sockeye salmon nursery areas.

Fish populations will be studied in detail. Both resident and anadromous fishes will be studied to characterize populations and habitat use. As discussed above for support organisms, habitats and populations subject to the greatest chage will be emphasized. Efforts will be made to estimate the size and extent of the fisheries and the timing of their migration. Particular emphasis will be placed on identifying the location of spawning areas and the size of the escapement. Spawning and upstream migrants will be monitored during the spawning season.

Migratory pathways used by both in-migrants and out-migrants will be investigated. This will be particularly important in assessing the potential for project related impacts to block migratory routes and for determining mitigating measures. A program of regular monitoring for out-migrants will be established to aid in assessing seasonal flow requirements and evaluate the potential for migratory pathway obstructions.

Seasonal distributions of fishes will be identified. This is also important in evaluating seasonal instream flow requirements and habitat use. The location of fish overwintering sites are of particular importance to establish flow required to maintain this habitat. In addition, winter water depth and water temperatures will be measured in selected locations to evaluate whether flow reduction could potentially cause freezing of spawning redds or overwintering habitats. Such freezing could have substantial adverse impacts on fish population using these areas.

Since most project alternatives involve changes in water level in Chakachamna Lake, the use of near shore and mid-lake habitats will be studied. Potential impacts on near shore lake trout spawning areas will be examined as well as shoreline spawning and sockeye salmon nursery habitat. Potential impacts to both the fish and macroinvertebrate communities will be evaluated.

Detailed site-specific habitat use will be investigated. The physical components of the environment will be measured in the various life stage habitats for each of the important fish species. Evaluations of specific habitat characteristics that are likely to be affected by project operation will be made. Collection of these data will allow quantification of expected habitat loss or gain, an assessment of the impact of project operation, and an evaluation of flow releases and other similar mitigative measures.

An evaluation will be made of the practicality of various mitigative methods based upon the data collected.

10.3.3 Wildlife Biology

The terrestrial components of the Chakachamna Lake project area will be evaluated using a technique similar to the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures (HEP).

During the reconnaissance level investigations of 1981, the project boundaries were established and a preliminary determination of vegetation types was made. In the spring of 1982, the project boundaries will be re-evaluated based on the criteria that the study area should include the total land and water areas where either direct or indirect changes, due to the implementation of the proposed project, could occur. Based on the area encompassed by the potential impacts of the project, a set of study quadrats will be established. Within each quadrat, the frequency, density, and dominance will be evaluated for each species of vegetation. A Bray-Curtis community ordination will be conducted to separate the various habitat types. These types will then be delineated on maps and the area occupied by each type will be calculated.

The selection of evaluation species will be based on three criteria;

- those species that are known to be sensitive to the types of changes that may occur through the implementation of the project;
- those species that are important to the overall community due to their role in nutrient cycling or energy flows; and

- those species that have habitat requirements that are indicative of the requirements of a group of species found in the area.

During the 1981 reconnaissance, six species where chosen that fulfilled these criteria. However, for the 1982 investigations, the species componsition of the area will be reevaluated and, if necessary, different species chosen.

The next procedure that is advised under the HEP is the development of the Habitat Suitability Indices (HSI). Since the HSI is derived from a general model of the habitat requirements of the species, the prediction capabilities ofthe model when applied to specific sites may not be totally accurate. For this reason, the models will be modified as needed to more accurately represent the habitat requirements of the evaluation species.

As more detailed information becomes available concerning the chronology and design of the project alternatives, the change in the habitat suitability for the evaluation species will be noted. Ordinarily, the procedure is to project these changes over a future span of time and to compare these forecasts with the predicted future habitat suitability without the influences of the project. However, since it is not possible to accurately predict the effect of other programs (development of the Beluga coal field, additional timber harvesting, offshore oil development, etc.) on either the habitat or the wildlife, there is no way to accurately assess the suitability of the habitat without the influence of this project. Therefore, subjective predictions will be based on the assumption that this hydroelectric facility will be the only manmade influence on the habitat.

In addition to evaluating the potential impacts of the project through the Habitat Evaluation Procedures, the relative abundance of selected species of wildlife will be expressed for each habitat type and a subjective evaluation of the influence of the project on the evaluation species and habitats will be made.

10.3.4 Human Resources

The 1982 Human Resources work program has four general objectives:

- o address agency and public concerns
- o identify specific project characteristics that will impact human resources and quantify those impacts
- o recommend measures to mitigate impacts
- o discuss the projects contribution to the cumulative impacts of regional development

Archaeological and Historical Resource investigations will consist of a general reconnaissance level survey that will provide the basis for subsequent intensive investigations of small portions of the project. The survey will concentrate on three general areas:

(1) The transmission line corridor-representing the preferred route between the power house facility and the Beluga Station;

(2) access roads, material borrow/disposal sites and work camps; and

(3) powerhouse facility.

Field work will include foot traverse over areas to be surveyed and limited subsurface testing (small test pits) in areas considered to have high potential. If identified prior to the field survey, it is possible that some construction sites can receive archaeological clearance during the 1982 season.

The Land Ownership and Land Use program will concentrate on several tasks. Land owners of specific transmission line, access road, and facility sites will be identified and contacted. Land management and use conflicts will be quantified with mitigation measures recommended. Finally, permit requirements for site use will be addressed.

The Recreation program will attempt to gather information on recreation use levels in areas affected by the project. This will be done through limited field surveys and contacts with agencies, guides and air taxi operators. Once this data is available, impacts will be quantified. A second area of emphasis will be to recommend mitigation measures, particularly with regard to Chakachamna Lake.

The Socioeconomic program will contain several elements. Employment opportunities, potential population and income, and infrastructure impacts will be identified. Contacts with Cook Inlet Region Inc. (CIRI), The Tyonek Native Corporation, Village of Tyonek, and Kenai Peninsula Borough will request information on preferences for local hire, workforce housing, and infrastructure support. As data on impacts to the anadromous fish populations are developed, the potential impact to the Cook Inlet commerical fishery will be assessed.

The Transportation program will attempt to gether more data on existing transportation systems, such as traffic levels, facility capacities, and maintenance schedules. The managers of the various transpot facilities will be contacted to determine use preferences. Project transportation needs and impacts will be quantified, and mitigation measures recommended.

The Visual Resource program will classify the project area using a Bureau of Land Management classification system. As specific project facilities are located, impacts will be described. Specific mitigation measures, such as facility placement and screening, will be recommended.

Because of the number of resource development activities proposed for the Tyonek area, the Chakachamna Hydro project's contribution to regional cumulative impacts will be discussed. Impacts on socioeconomic, transportation, and land use characteristics will be emphasized.

FIGURES

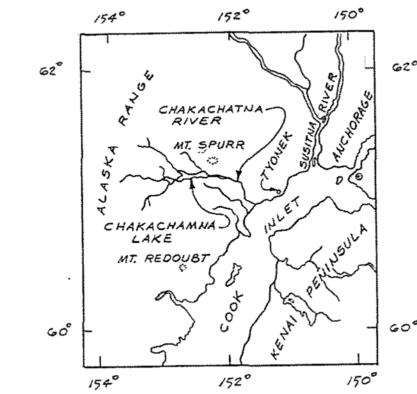
LIST OF FIGURES

Figure No.	Title
1-1	Location Map
3-1	McArthur Tunnel, Alternative A-1
3-2	McArthur Tunnel, Alternative A-2
3-3	Chakachatna Tunnel, Alternatives C and D
3-4	Power Intake, Elevation
3-5	Power Intake, Sections
3-6	McArthur Power Development, General Arrangement
3-7	Chakachatna Power Development, General Arrangement
3-8	Transmission Line, Route Location
4-1	Hydrometeorological Station Locations
4-2	Hydrometeorological Stations, Periods of Record
4-3	Chakachamna Lake, Stage - Area and Storage
4-4	Alternatives A and B - Lake Level Variations
4-5	Alternatives C and D - Lake Level Variations
5-1	Quaternary Geology Site Locations
5-2a	Glacial and Volcanic Features in the Chakachamna-Chakachatna Valley
5-2b	Glacial and Volcanic Features in the Chakachamna-Chakachatna Valley
5-3	Plate Tectonic Map
5-4	Major Earthquakes and Seismic Gaps in Southern Alaska
5-5	Historic Earthquakes of all Focal Depths in the Site Region from 1929 through 1980
5-6	Historic Earthquakes of Focal Depth Greater than 20 Miles in the Site Region from 1929 through 1980

Figure No.	Title
5-7	Historic Earthquakes of Focal Depth Less than 20 Miles in the Site Region from 1929 through 1980
5-8	Seismic Geology Investigation Sequence
5-9	Map Showing Locations of Candidate Significant Features in the Project Study Area
6-1	Approximate Boundary of Chakachamna Lake Study Area
6-2	Locations of Hydrologic Study Areas, Representative Locations and Channel Configuration Reach Boundaries
6-3	Stream and Floodplain Transect on Chakachatna River Showing Approximate Range of Natural Stages
6-4	Stream and Floodplain Transect on Upper McArthur River Showing Approximate Range of Natural Stages
6-5	Stream and Floodplain Transect on McArthur River Showing Approximate Range of Natural Stages
6-6	Hydraulic Geometry of Chakachatna River Showing Approximate Range of Natural Flow
6-7	Hydraulic Geometry of Upper McArthur River Showing Approximate Range of Natural Flow
6-8	Hydraulic Geometry of McArthur River Showing Approximate Range of Natural Flow
6-9	Chakachamna Lake Bottom Profile Offshore from Shamrock Glacier Rapids
6-10	Chilligan River and Chakachamna Lake Bottom Profiles
6-11	Electroshocking and Seine Sampling Locations
6-12	Location of Fixed Net Sets
6-13	Habitat Utilization of Chakachatna River
6-14	Sockeye Salmon Spawning Area - Chilligan River and Kenibuna Outflow
6-15	Potential Sockeye Spawning Areas - Chakachamna Lake
6-16	Chum and Sockeye Spawning Areas - Chakachatna River Canyon and Straight Creek

Figure No.	Title
6-17	Chakachatna River Mainstem Sockeye, Chum and Pink Salmon Spawning Areas
6-18	Lower Reaches of Chakachatna, Middle and McArthur Rivers Showing Sand, Silt and Mud Substrates
6-19	Habitat Utilization of McArthur River
6-20	Upper McArthur River Identified Spawning Areas
6-21	McArthur River Sampling Sites
6-22	Designated Habitat Areas
6-23	Location of Sampling Quadrats in Chakachamna Study Area
6-24	The Location of Habitat and Vegetative Types Within the Study Area - Sheet 1 of 6
6-24	The Location of Habitat and Vegetative Types Within the Study Area - Sheet 2 of 6
6-24	The Location of Habitat and Vegetative Types Within the Study Area - Sheet 3 of 6
6-24	The Location of Habitat and Vegetative Types Within the Study Area - Sheet 4 of 6
6-24	The Location of Habitat and Vegetative Types Within the Study Area - Sheet 5 of 6
6-24	The Location of Habitat and Vegetative Types Within the Study Area - Sheet 6 of 6
6-25	The Cumulative Number of Breeding Pairs Within the Study Area
6-26	Nesting Locations: Bald Eagle Nests as of May 1980. Trumpeter Swan Nests as of August 1980
6-27	Current Land Ownership
6-28	Existing and Potential Land Use
6-29	Existing and Proposed Transportation Facilities
8-1	Access Roads
8-2	McArthur Development, Construction Schedule
8-3	Chakachatna Development. Construction Schedule

Figure No.	Title
9-1	Economic Tunnel Diameter
9-2	McArthur Tunnel Economic Length
9-3	Chakachatna Tunnel Economic Length



VICINITY MAP

4 0 4 8

SCALE : 1" = 4 MILES

NOTES:

1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS

2.) VERTICAL DATUM IS MEAN LOWER LOW WATER

3.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM

No.	DATE	REVISION	BY	CHK'D	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

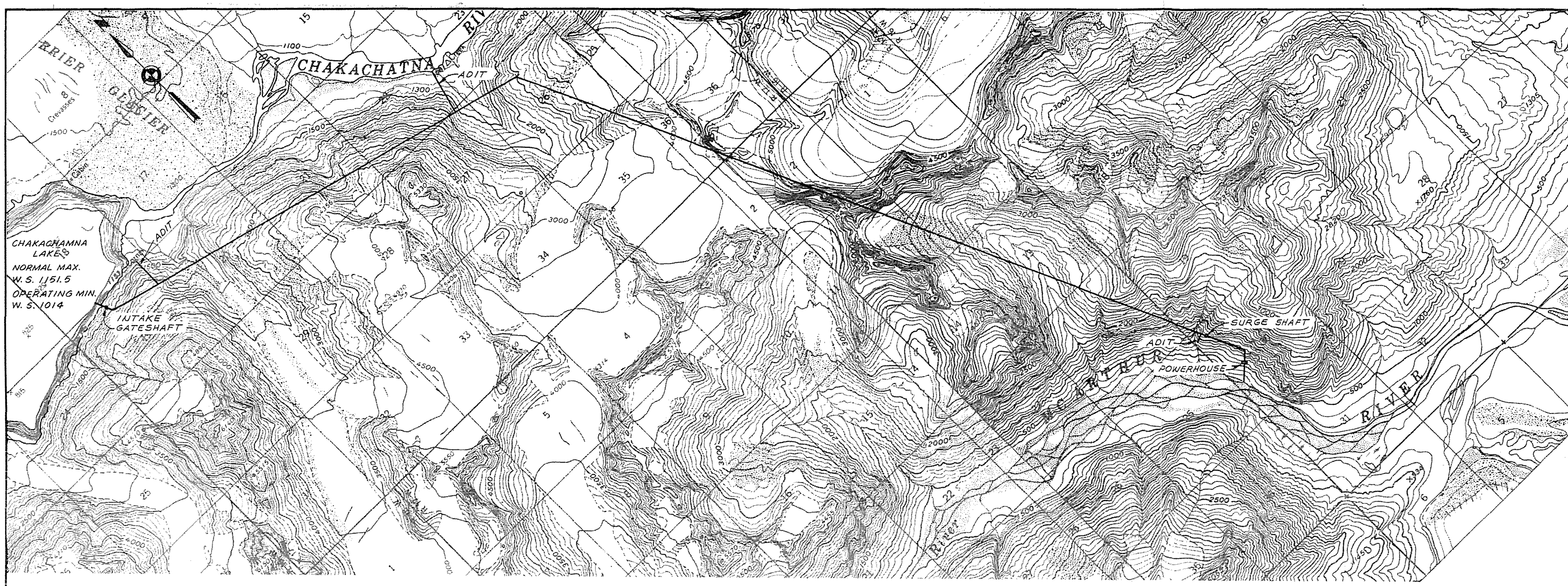
CHAKACHAMNA HYDROELECTRIC PROJECT

LOCATION PLAN

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

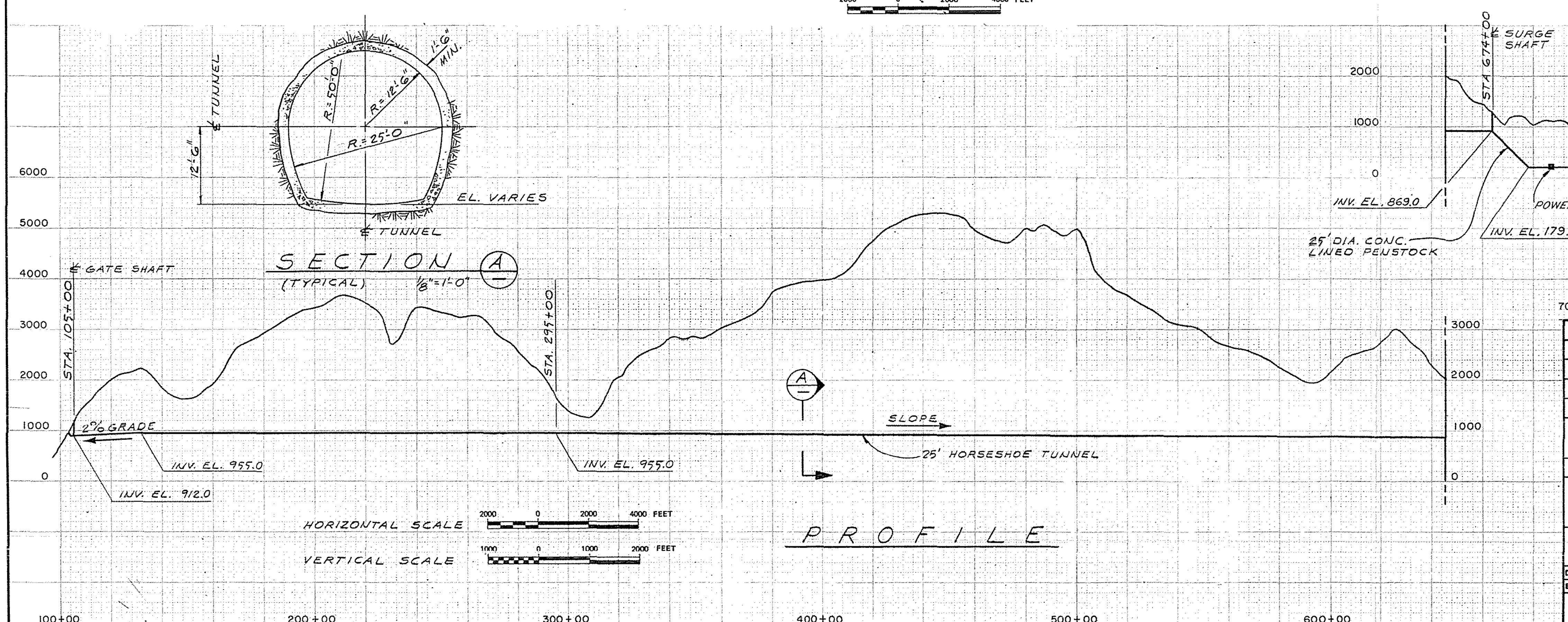
DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 1-1	B



PLAN

2000 0 2000 4000 FEET



NOTES:

1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS.

2.) CONTOUR INTERVAL IS 100 FEET.

3.) VERTICAL DATUM IS MEAN SEA LEVEL.

4.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.

5.) SEE FIGURES 3-4 AND 3-5 FOR GATE SHAFT DETAILS AND FIGURE 3-6 FOR SURGE TANK, PENSTOCK AND POWERHOUSE GENERAL ARRANGEMENT.

No.	DATE	REVISION	BY	CHK'D	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

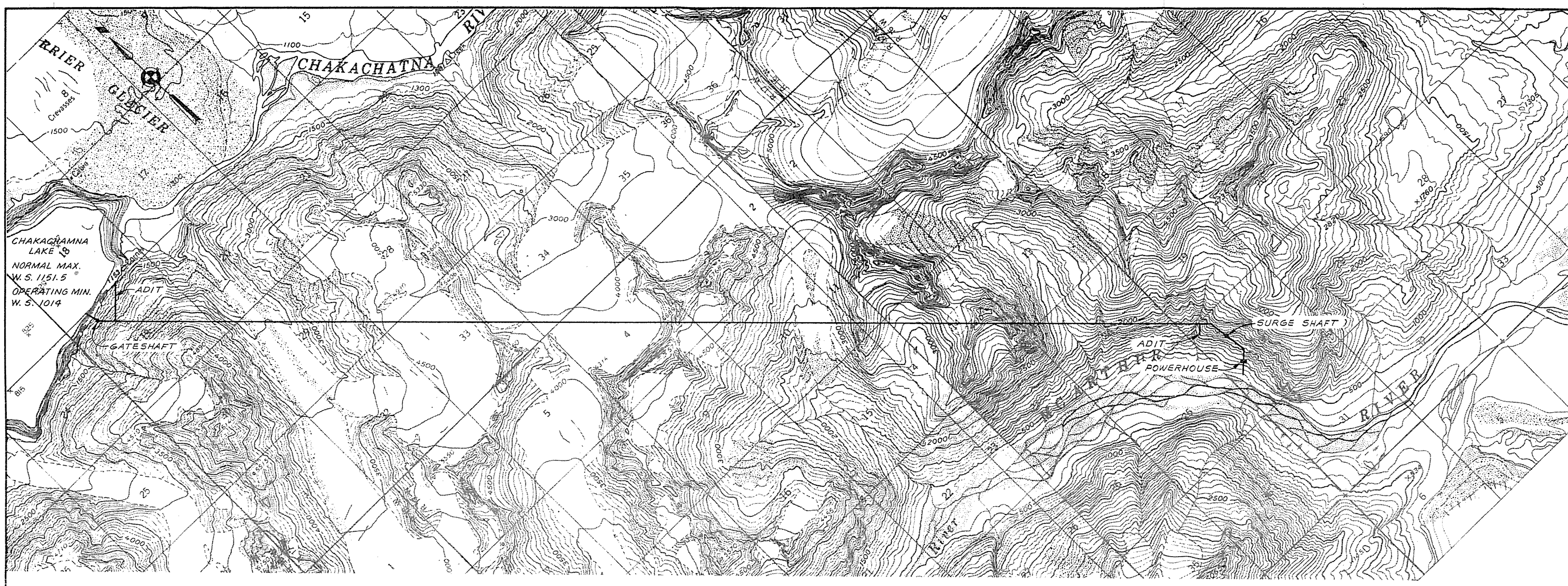
CHAKACHAMNA HYDROELECTRIC PROJECT

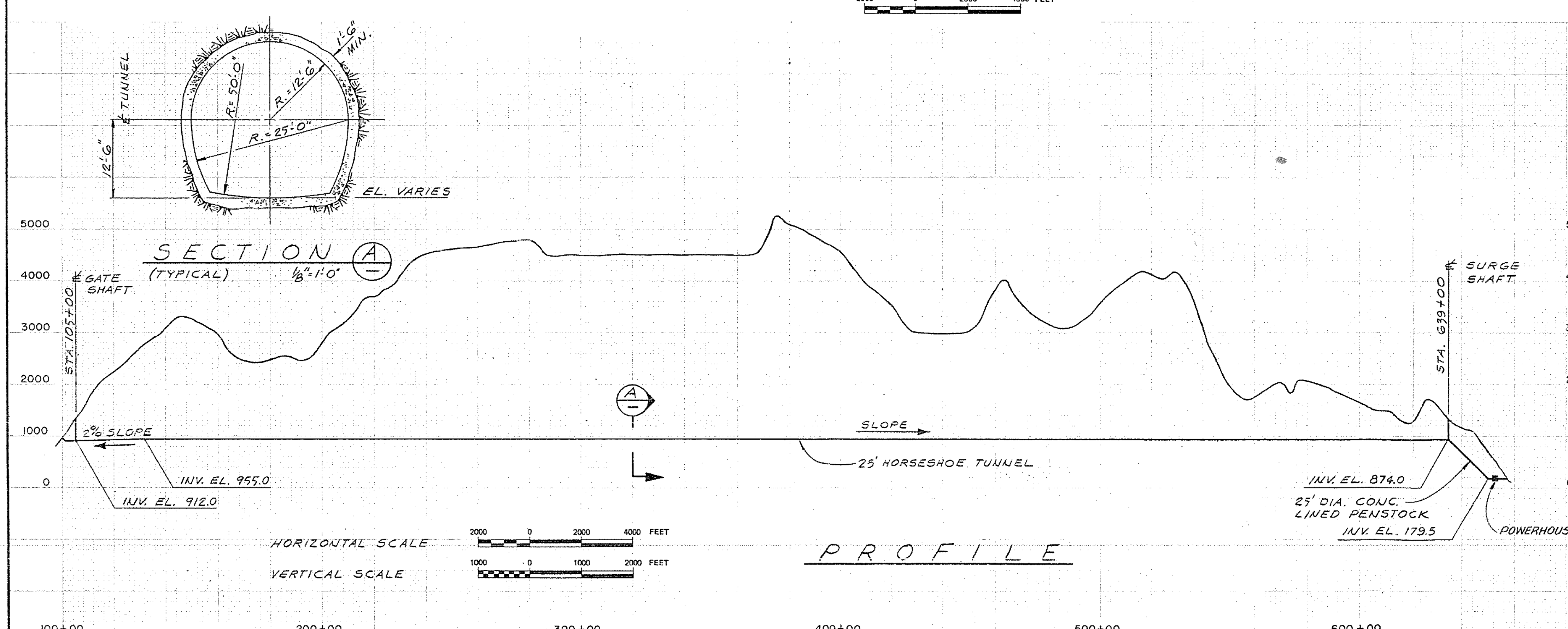
McARTHUR TUNNEL
ALTERNATIVE A-1

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-1	B





NOTES:

1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS
2.) CONTOUR INTERVAL IS 100 FEET
3.) VERTICAL DATUM IS MEAN SEA LEVEL.
4.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.
5.) SEE FIGURES 3-4 AND 3-5 FOR GATE SHAFT DETAILS AND FIGURE 3-6 FOR SURGE TANK, PENSTOCK AND POWERHOUSE GENERAL ARRANGEMENT.

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

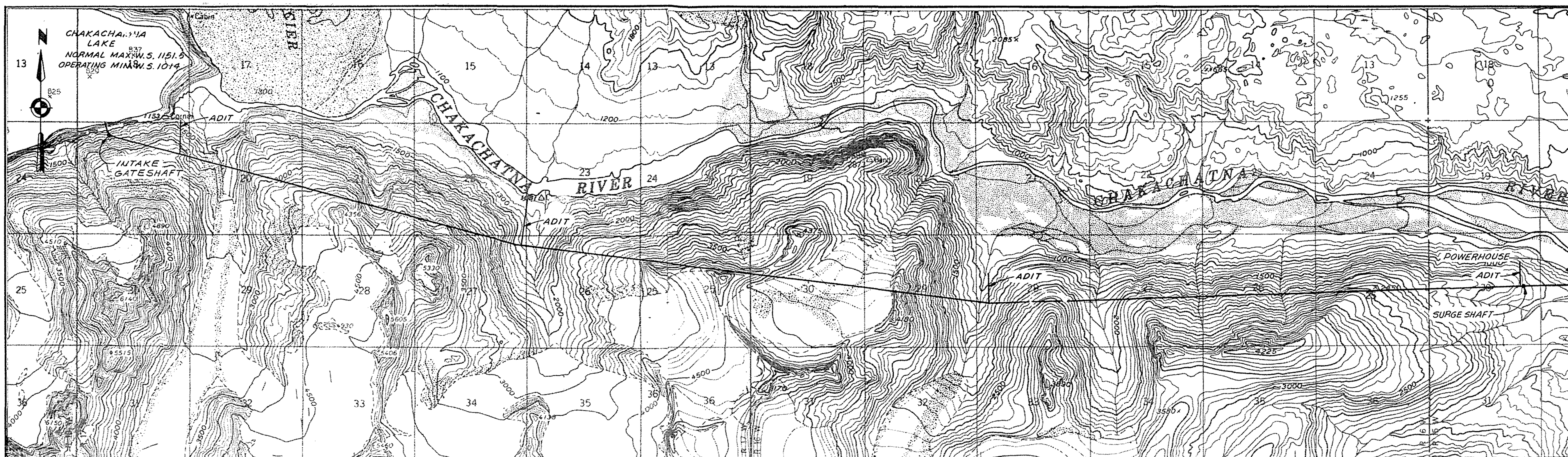
CHAKACHAMNA HYDROELECTRIC PROJECT

McARTHUR TUNNEL
ALTERNATIVE A-2

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-2	B

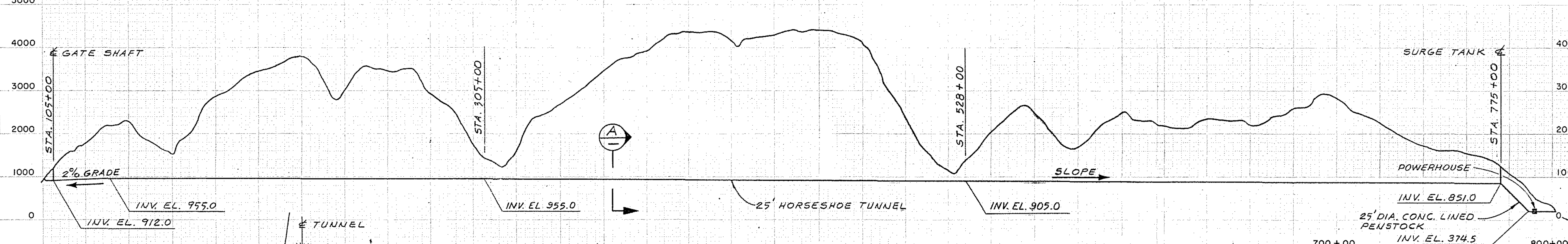


PLAN

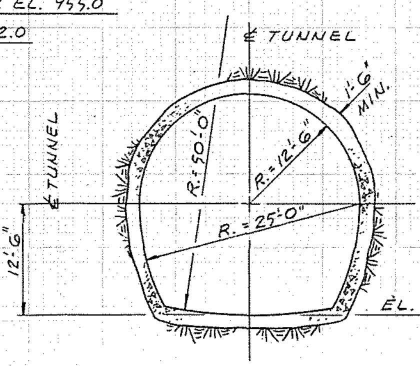
2000 0 2000 4000 FEET

NOTES:

1. TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS.
2. CONTOUR INTERVAL IS 100 FEET
3. VERTICAL DATUM IS MEAN SEA LEVEL
4. HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.
5. SEE FIGURES 3-4 AND 3-5 FOR GATE SHAFT DETAILS AND FIGURE 3-6 FOR SURGE TANK, PENSTOCK AND POWERHOUSE GENERAL ARRANGEMENT.



PROFILE



SECTION A
(TYPICAL) 1/8" = 1'-0"

HORIZONTAL SCALE 2000 0 2000 4000 FEET

VERTICAL SCALE 1000 0 1000 2000 FEET

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

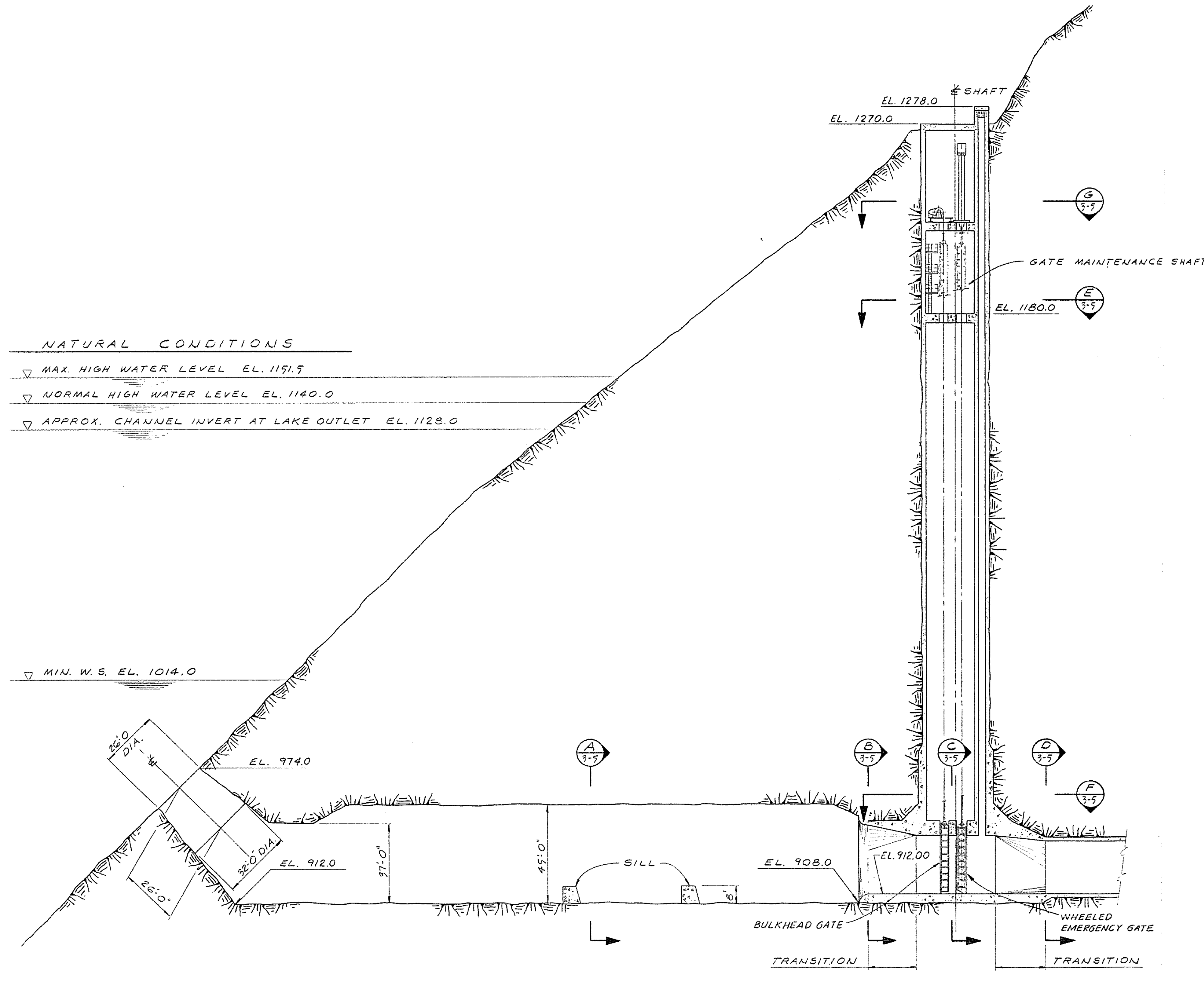
CHAKACHAMNA HYDROELECTRIC PROJECT

CHAKACHATNA TUNNEL
ALTERNATIVES C AND D

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-3	B



SECTIONAL ELEVATION

1" = 20'-0"

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

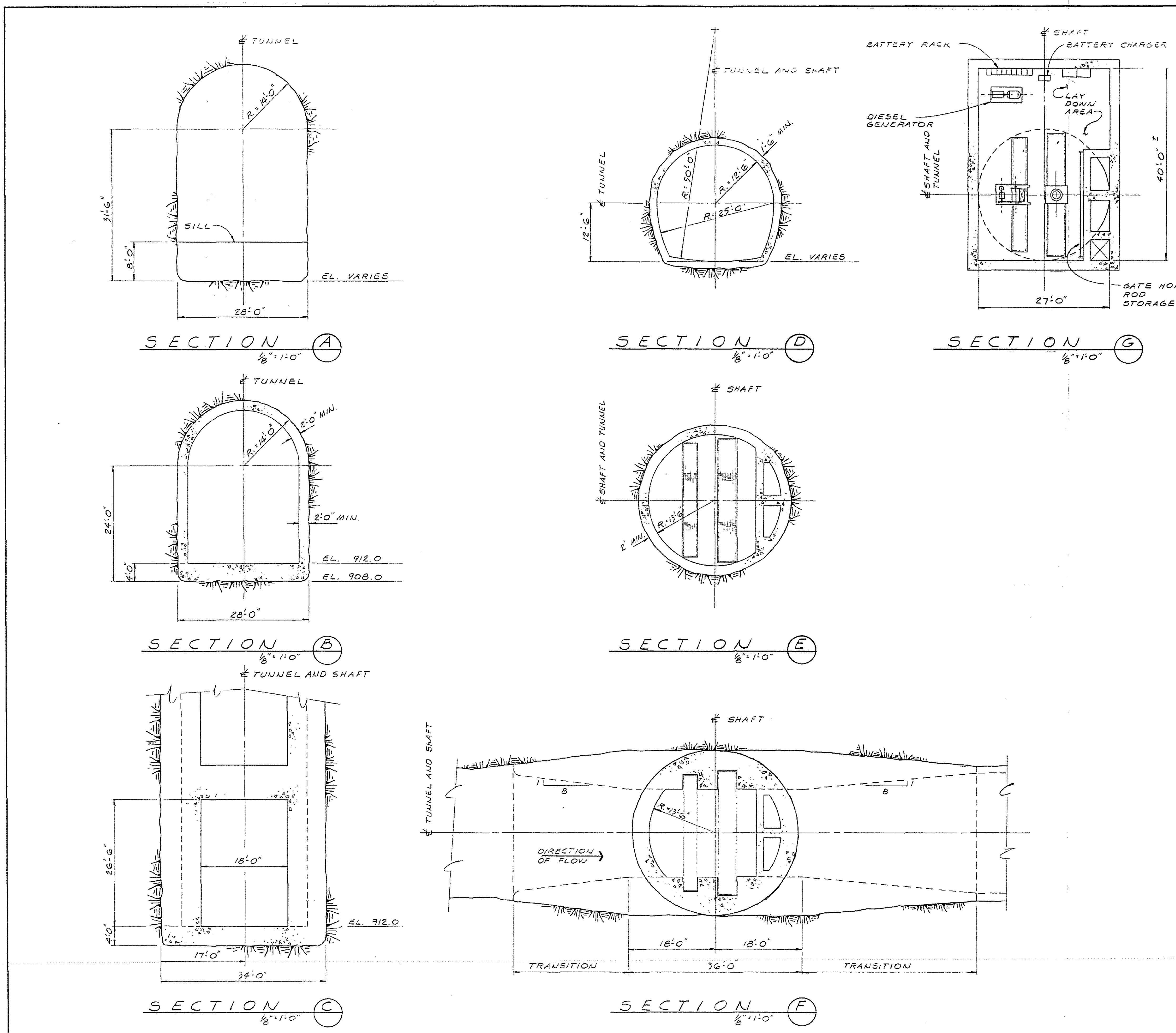
CHAKACHAMNA HYDROELECTRIC PROJECT

GATE SHAFT SECTION
SHT-1

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-4	B



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

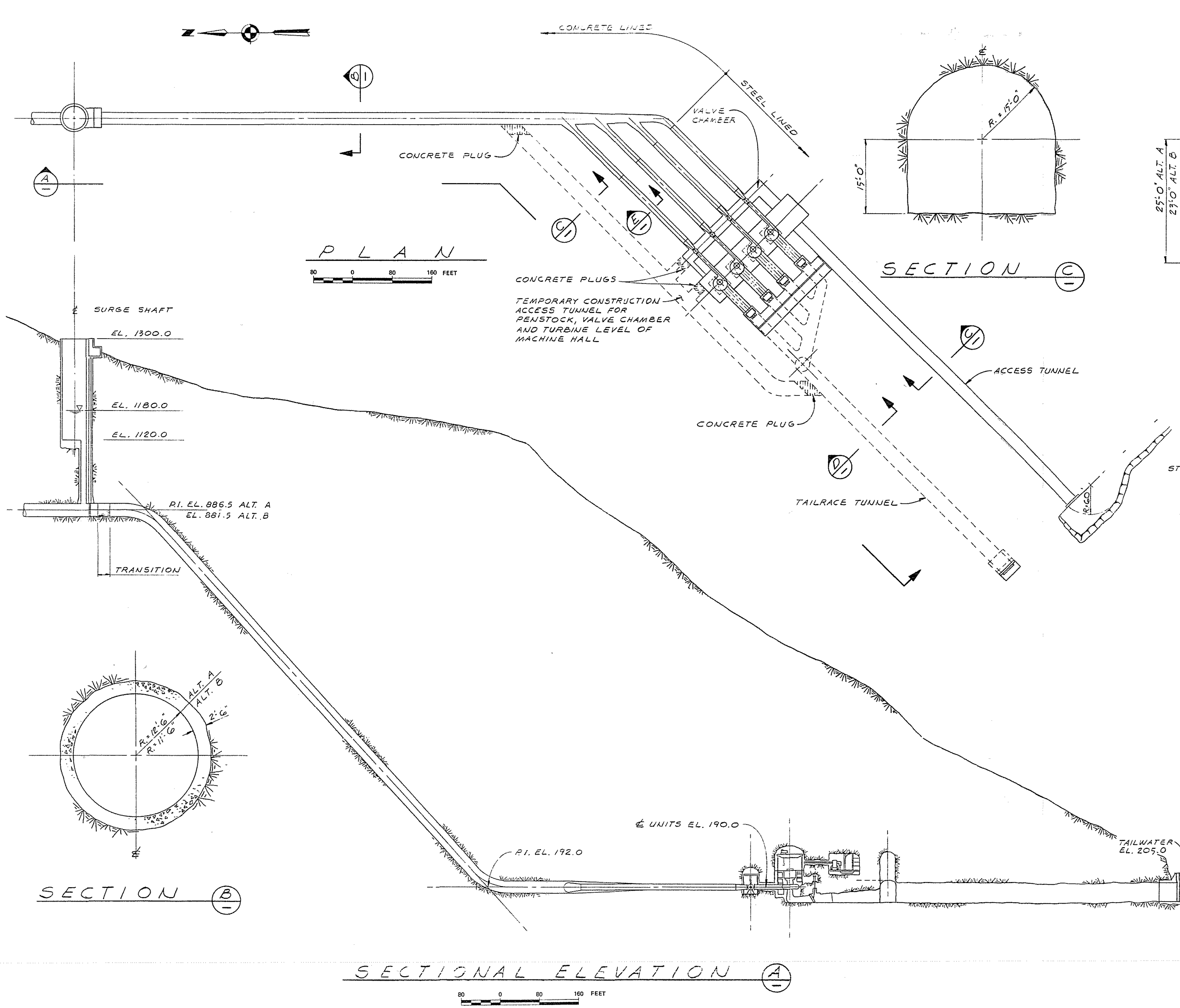
ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

GATE SHAFT SECTIONS
SHT-2

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D
JOB No. 14879	DRAWING No. FIGURE 3-5	REV. B



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

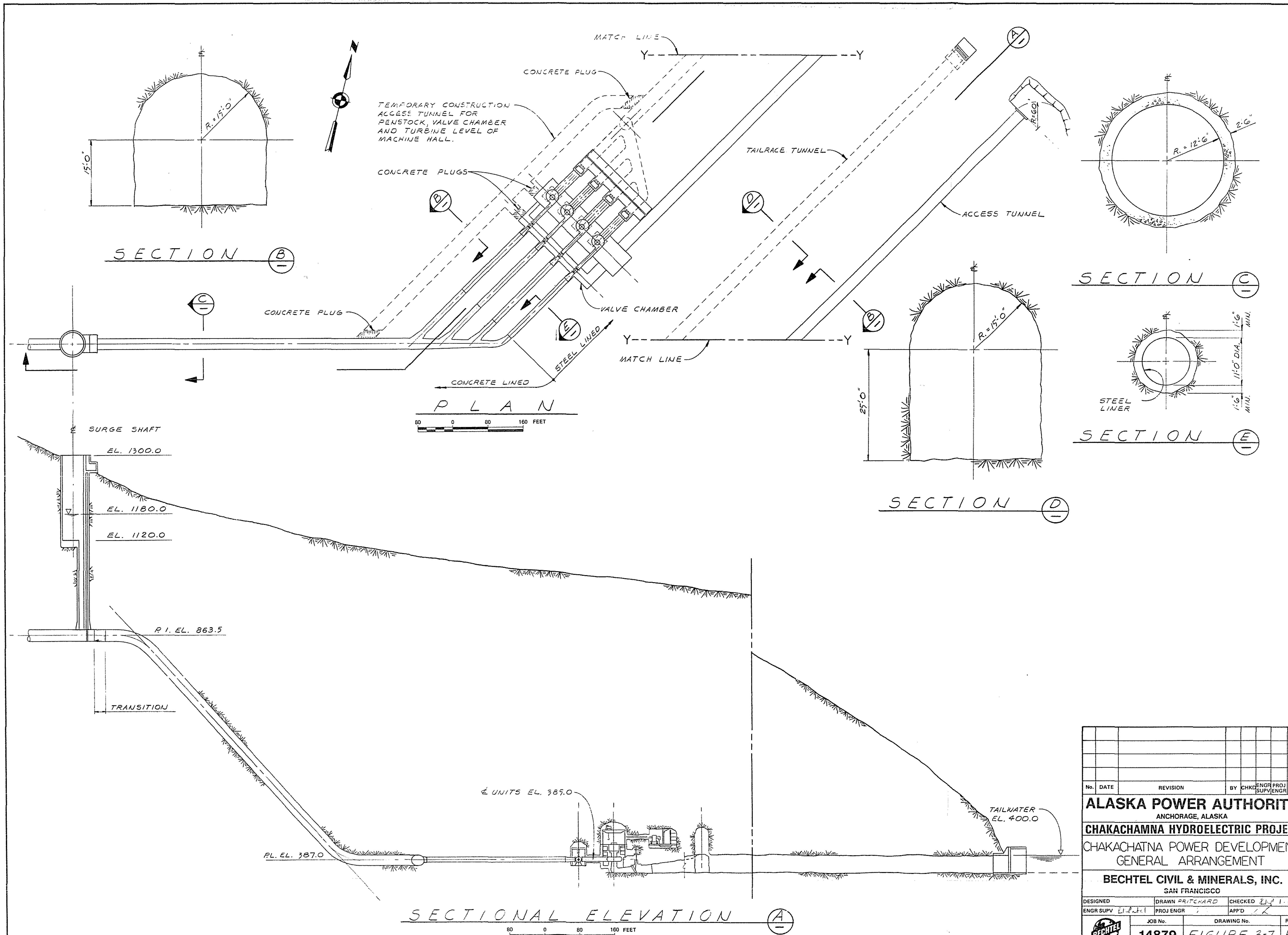
CHAKACHAMNA HYDROELECTRIC PROJECT

McARTHUR POWER DEVELOPMENT
GENERAL ARRANGEMENT

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED RWJd
ENGR SUPV RWJd	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-6	B



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

CHAKACHATNA POWER DEVELOPMENT
GENERAL ARRANGEMENT

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-7	B

NOTES:

1) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS
2) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.
3) VERTICAL DATUM IS MEAN LOWER LOW WATER.

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA
CHAKACHAMNA HYDROELECTRIC PROJECT

TRANSMISSION LINE

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 3-8	B

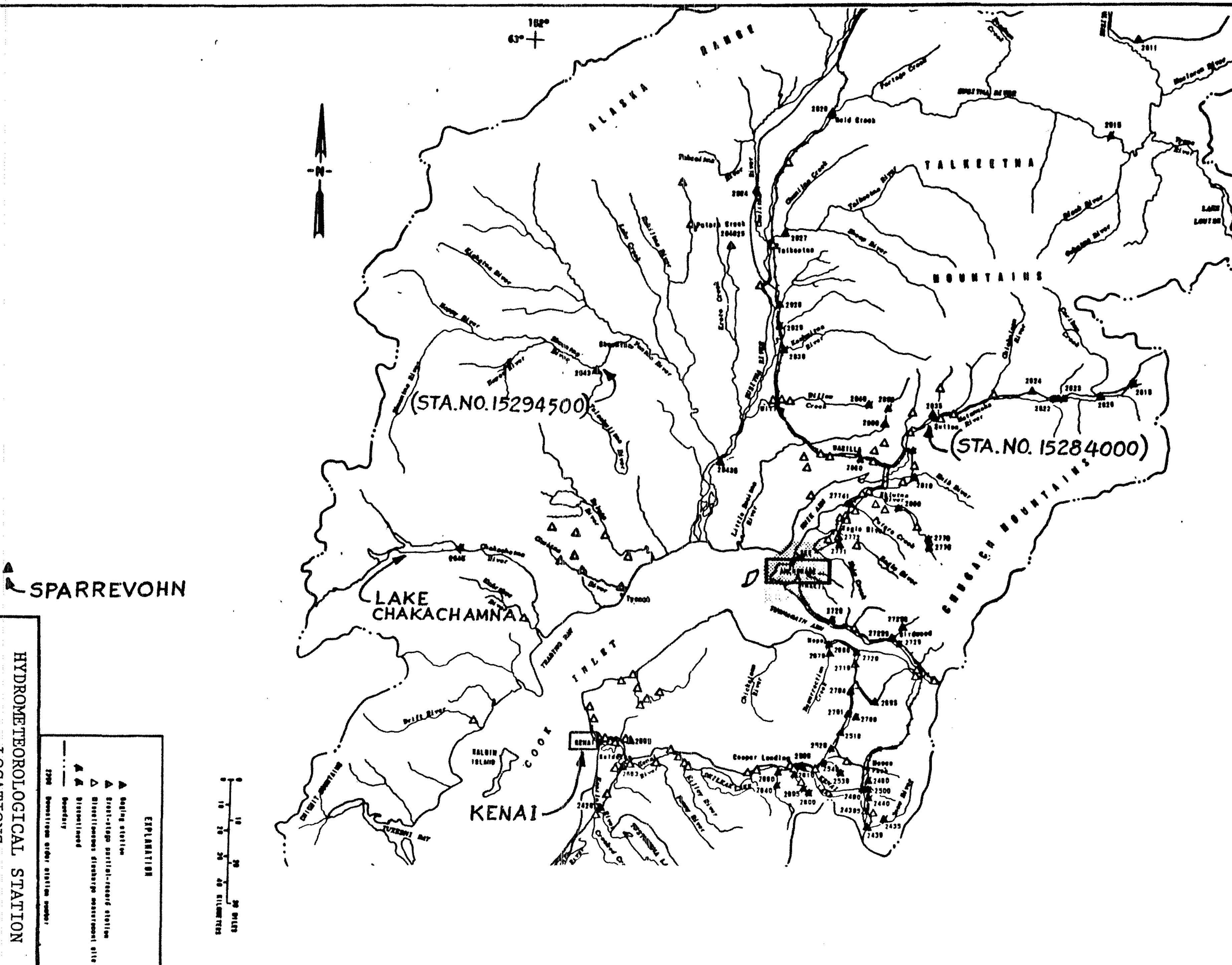


FIGURE 4-1

HYDROMETEOROLOGICAL STATION LOCATIONS

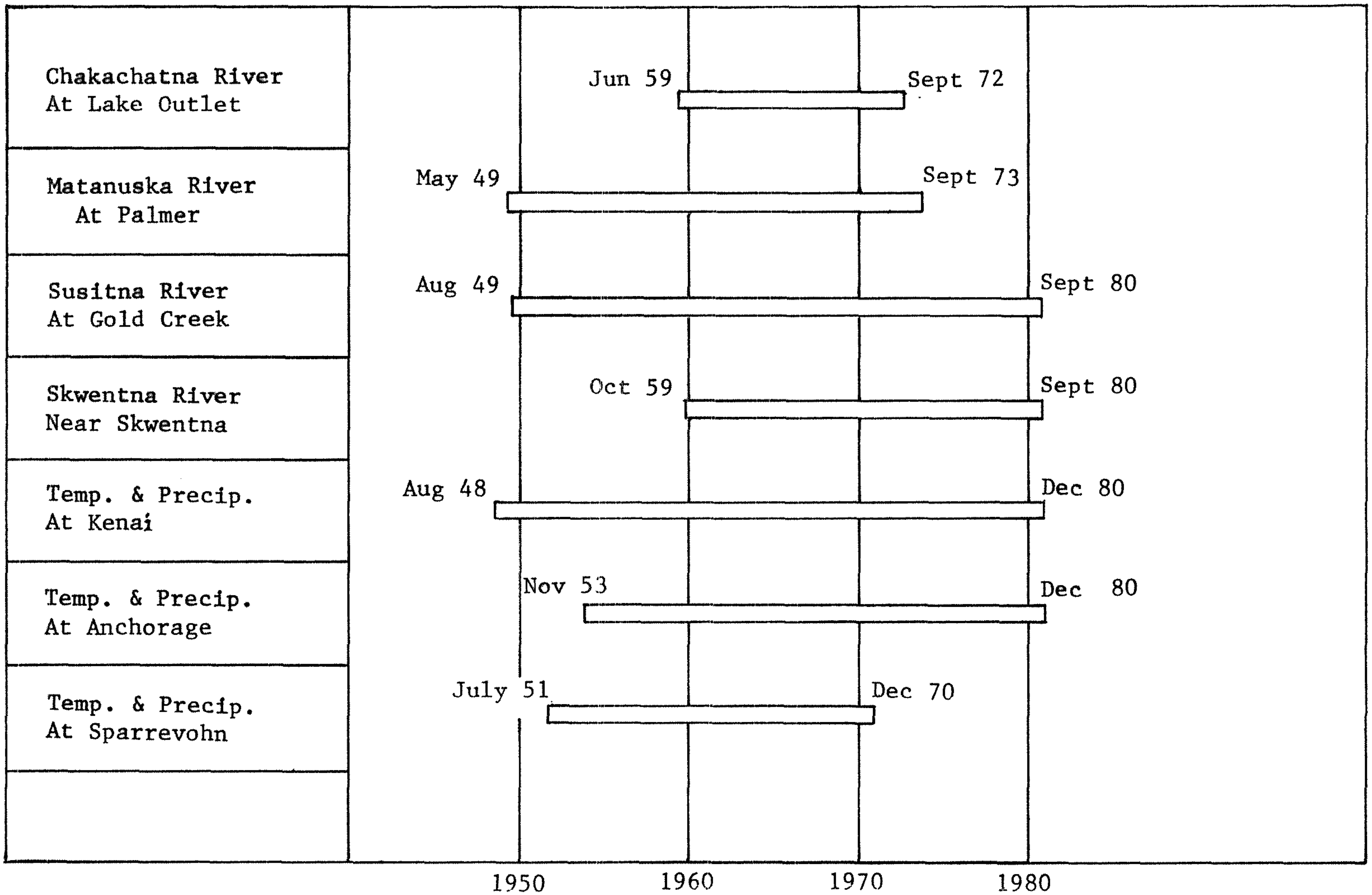
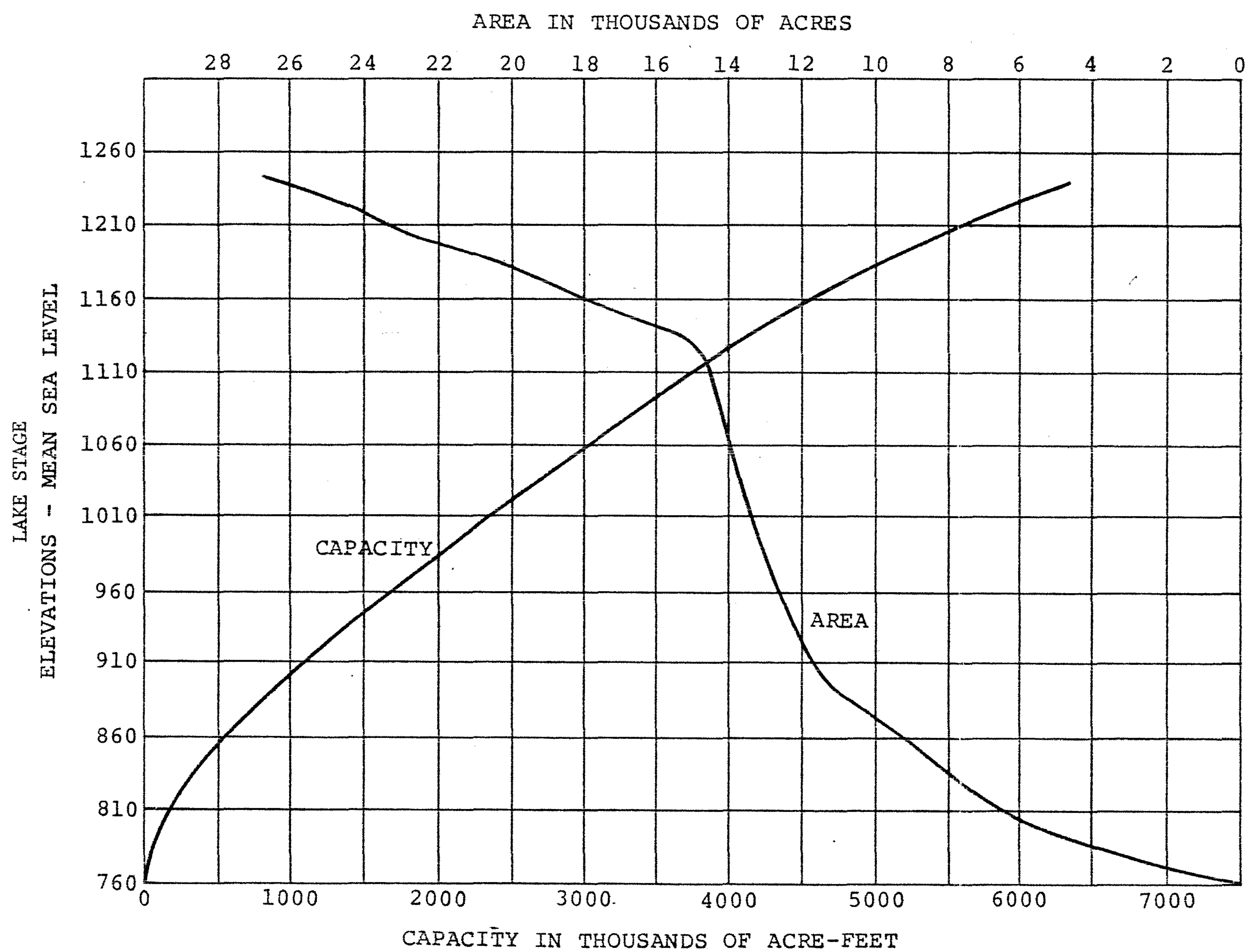


FIGURE 4-2

HYDROMETEOROLOGICAL STATIONS
PERIODS OF RECORD

CHAKACHAMNA
LAKE
AREA & CAPACITY DATA

ELEV. M.S.L.	AREA IN ACRES	CAPACITY ACRE FEET
760	0	0
765	810	2,025
770	1,300	7,300
780	2,690	27,200
800	5,670	111,000
20	7,320	241,000
40	8,270	397,000
60	9,280	572,000
80	10,400	769,000
900	11,590	988,000
20	11,960	1,224,000
40	12,320	1,467,000
60	12,650	1,717,000
80	12,980	1,973,000
1000	13,280	2,236,000
20	13,520	2,504,000
40	13,740	2,776,000
60	13,960	3,053,000
80	14,170	3,335,000
1100	14,390	3,620,000
20	14,620	3,910,000
40	16,100	4,218,000
42	16,780	4,250,000
60	18,250	4,572,000
80	19,900	4,953,000
1200	22,956	5,382,000
20	24,104	5,852,000
40	26,038	6,354,000



CHAKACHAMNA LAKE
LAKE STAGE-AREA AND CAPACITY

FIGURE 4-3

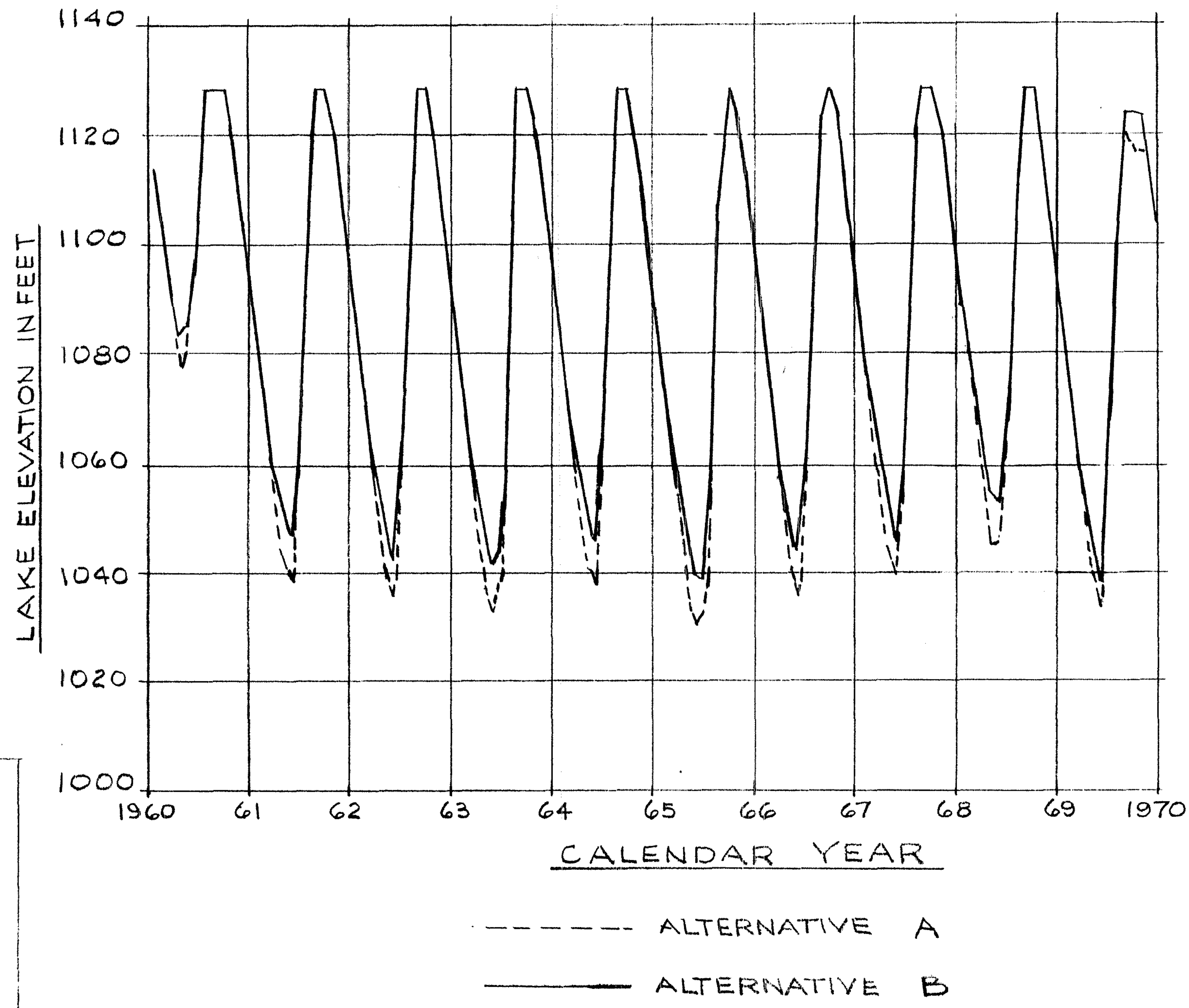
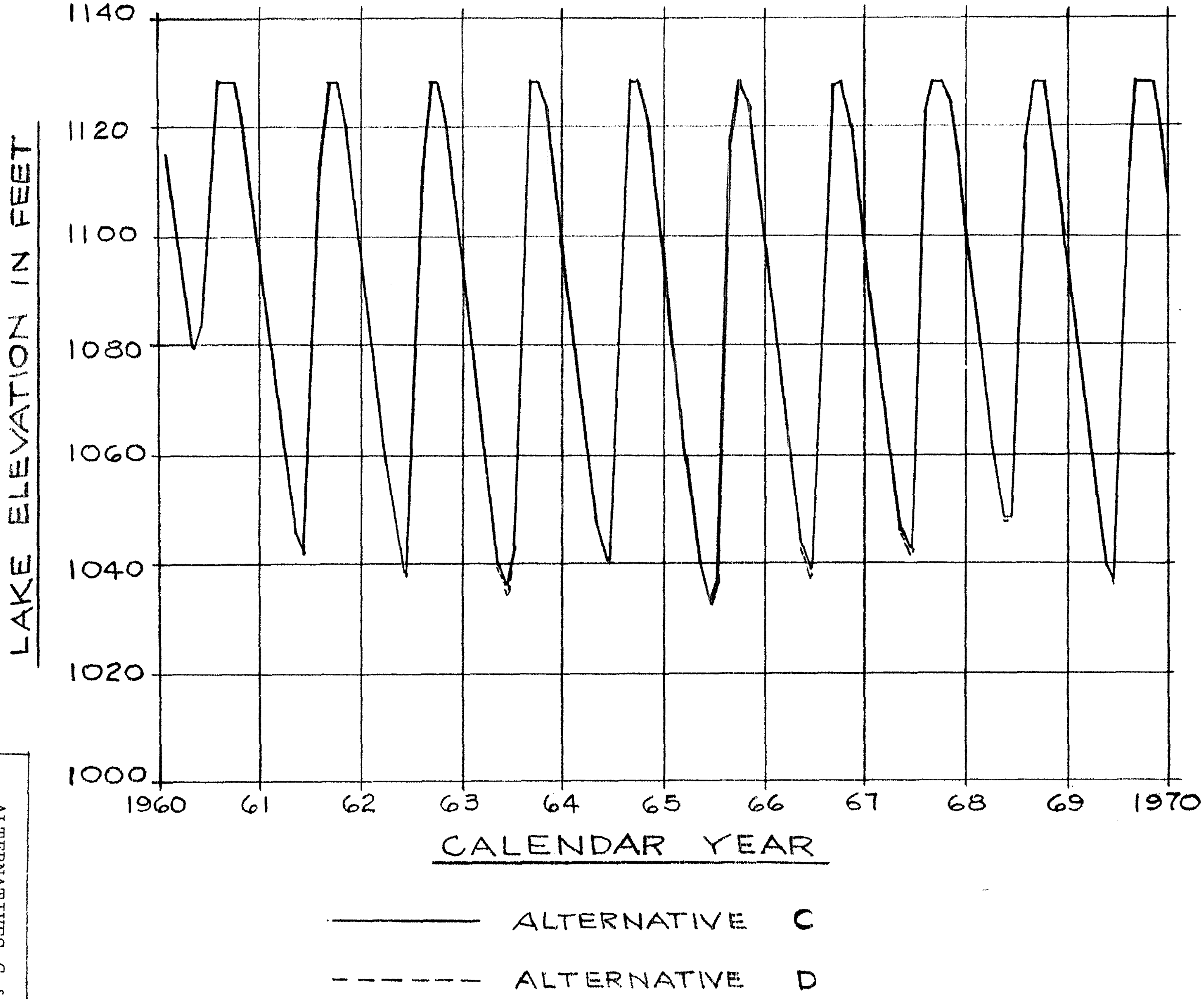


FIGURE 4-4

ALTERNATIVES A & B
LAKE LEVEL VARIATIONS



ALTERNATIVES C & D
LAKE LEVEL VARIATIONS

FIGURE 4-5

EXPLANATION

PLACE NAMES AND LOCATIONS WITHIN THE QUATERNARY GEOLOGY RECONNAISSANCE AREA INVESTIGATED BY WOODWARD-CLYDE CONSULTANTS DURING THE 1981 FIELD SEASON.

0 5 10 15

SCALE IN MILES

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

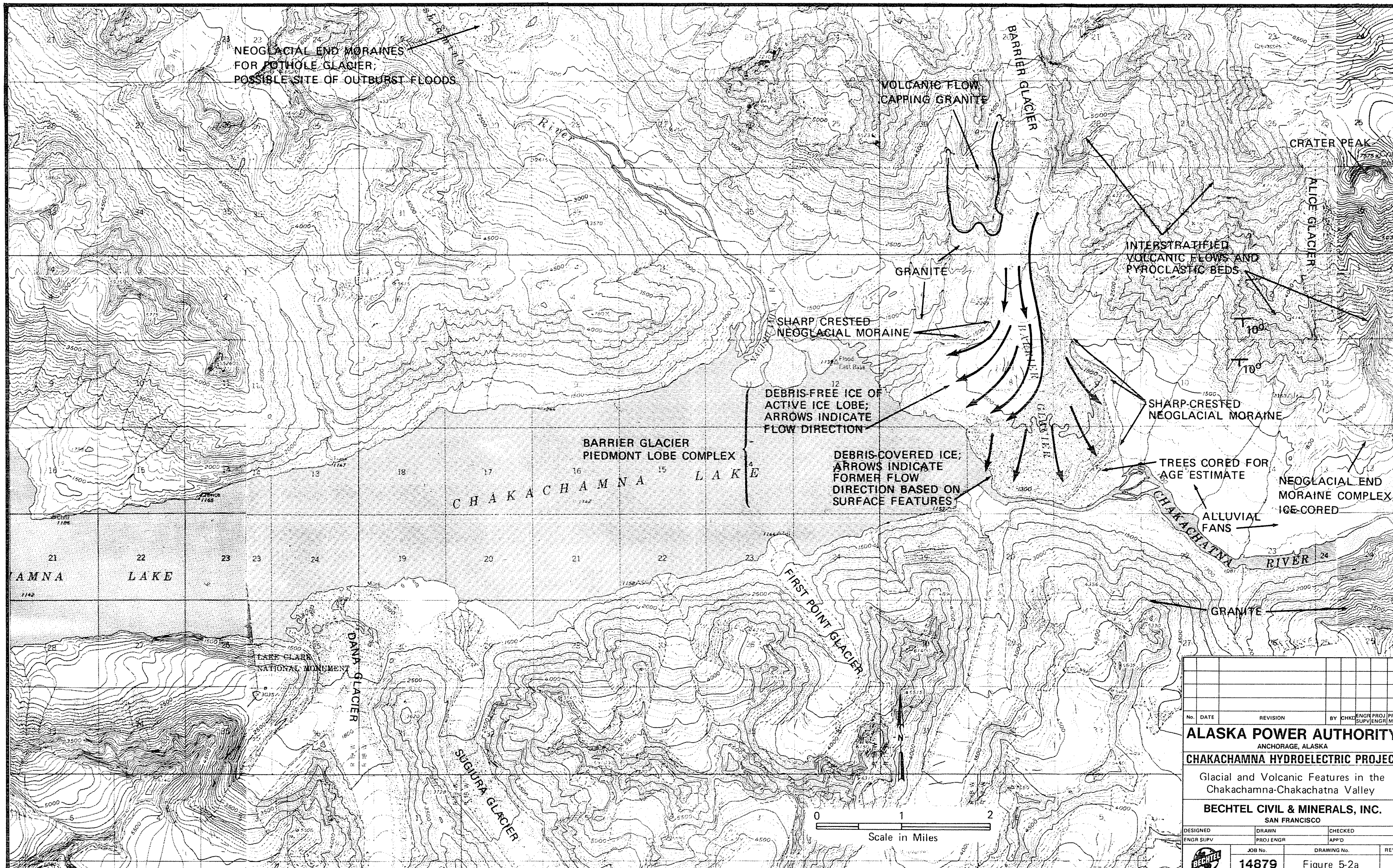
CHAKACHAMNA HYDROELECTRIC PROJECT

QUATERNARY GEOLOGY
SITE LOCATIONS

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-1	



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

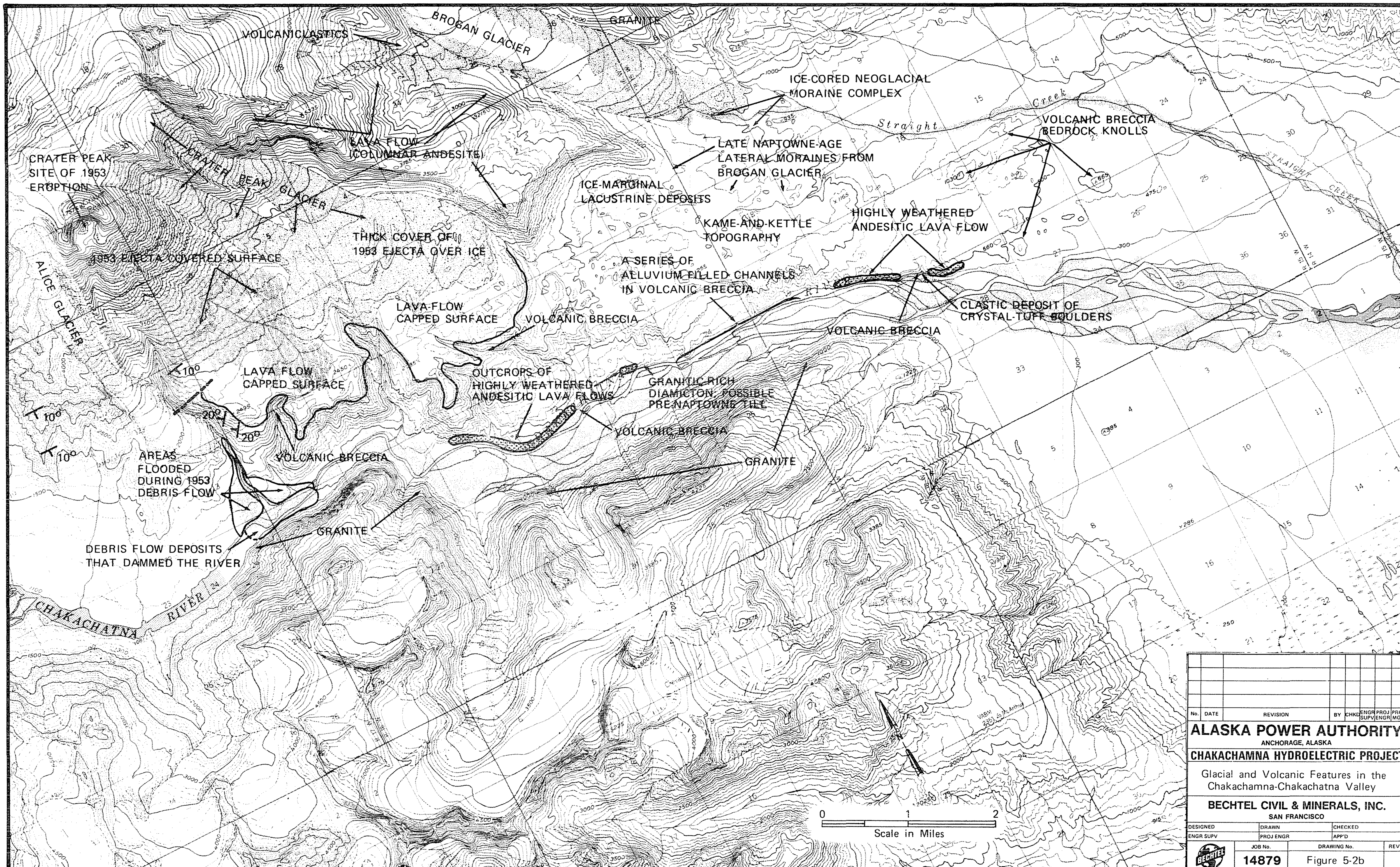
CHAKACHAMNA HYDROELECTRIC PROJECT

Glacial and Volcanic Features in the Chakachamna-Chakachatna Valley

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

	JOB No.	DRAWING No.	REV.
BECHTEL	14879	Figure 5-2a	



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

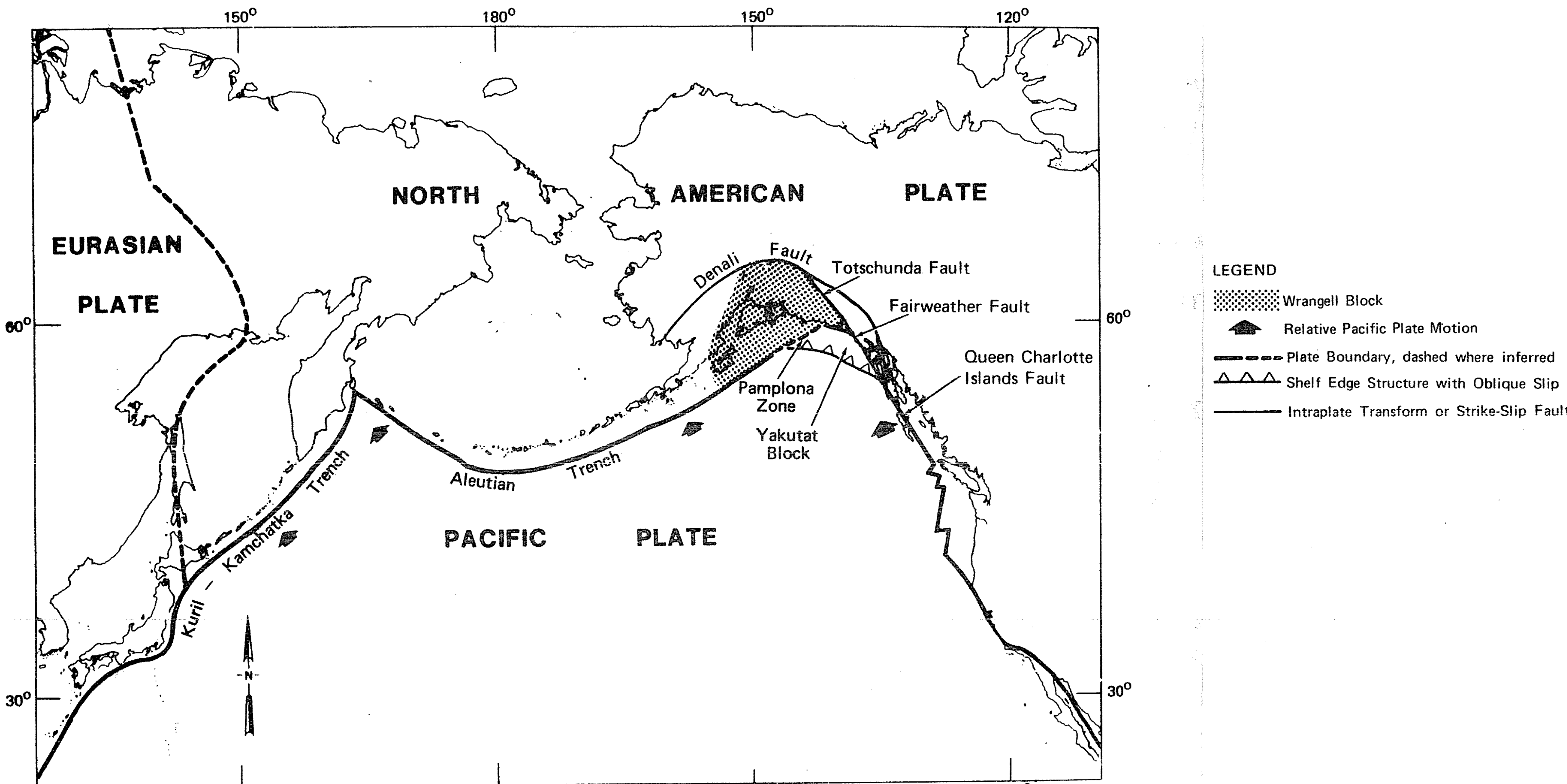
CHAKACHAMNA HYDROELECTRIC PROJECT

Glacial and Volcanic Features in the Chakachamna-Chakachatna Valley

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV
14879	Figure 5-2b	



WOODWARD-CLYDE CONSULTANTS

NOTES

1. Base map from Tarr (1974).
2. After Packer and others (1975), Beikman (1978), Cormier (1975), Reed and Lamphere (1974), Plafker, and others (1978).

No.	DATE	REVISION	BY	CHK'D	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

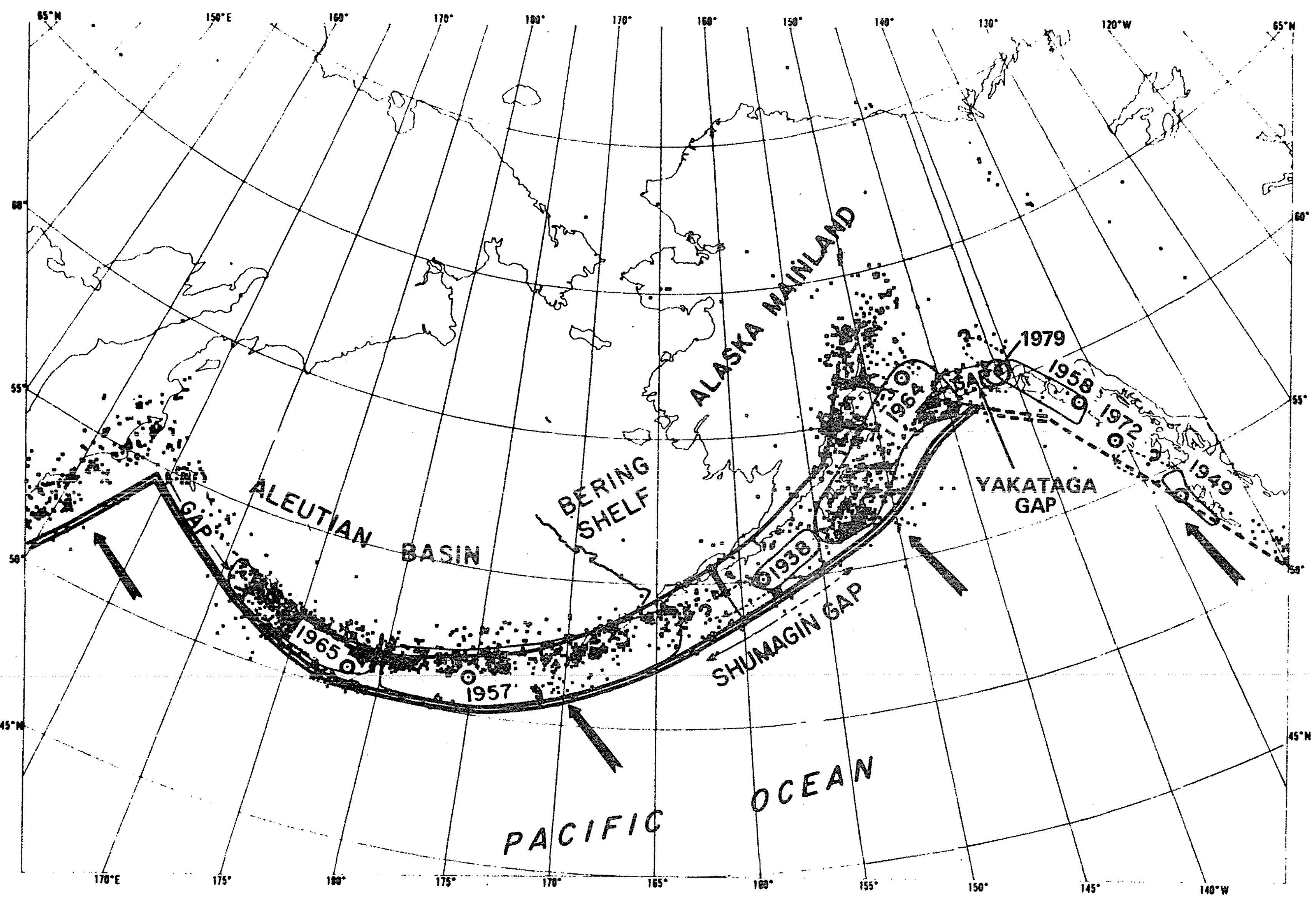
CHAKACHAMNA HYDROELECTRIC PROJECT

Plate Tectonic Map

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-3	



LEGEND

- ⊙ 1964 Location and year of major earthquake; rupture zones including aftershock areas are outlined
- Inferred direction of motion of Pacific plate
- Trench axis
- Approximate transform plate margin

NOTE

1. Modified after Davies and House (1979)

WOODWARD-CLYDE CONSULTANTS

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

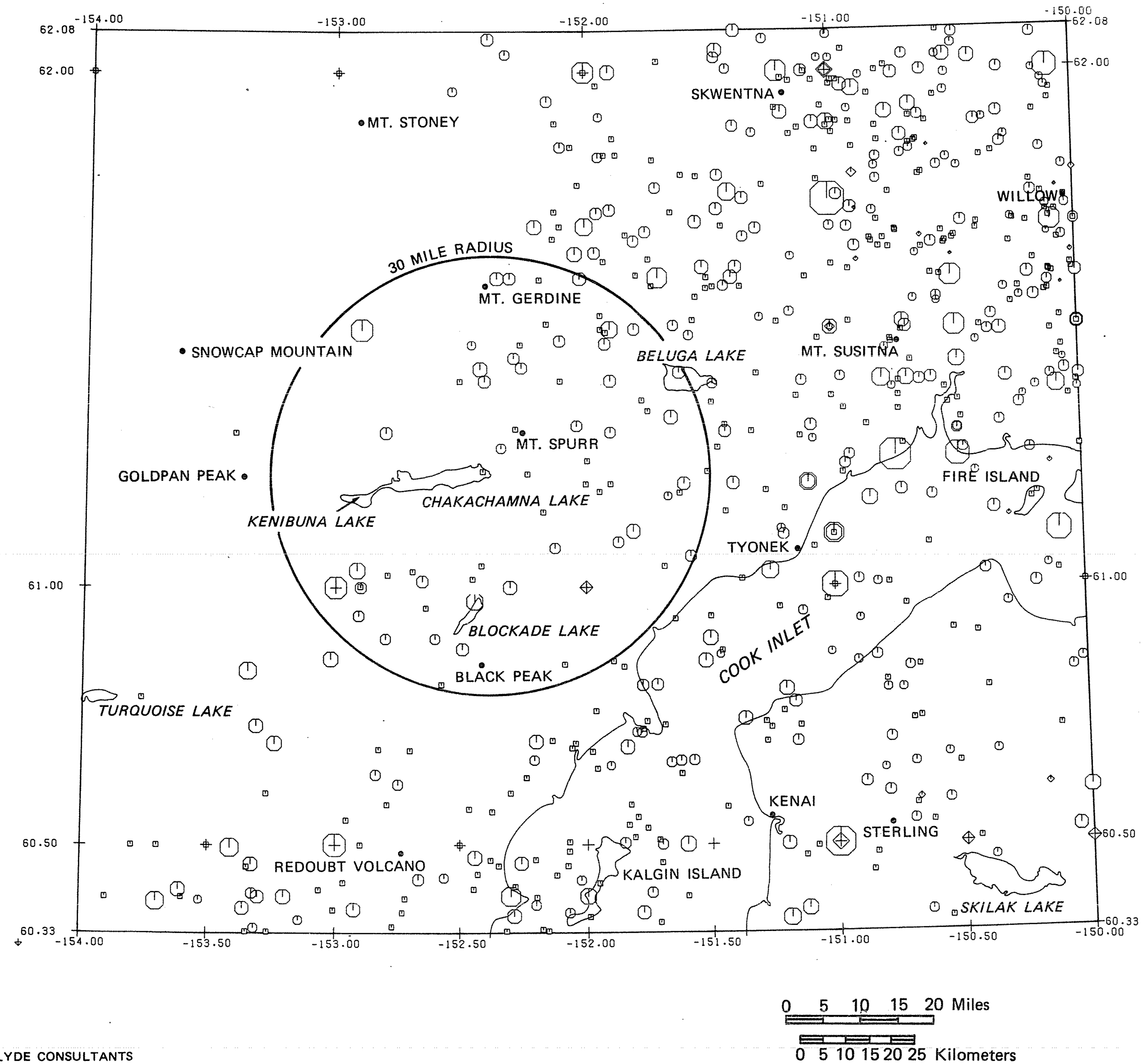
ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

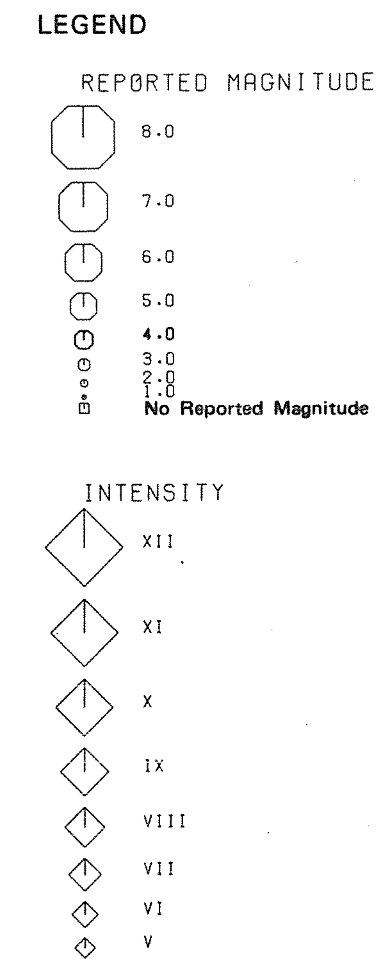
CHAKACHAMNA HYDROELECTRIC PROJECT

Major Earthquakes and Seismic Gaps in Southern Alaska

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED	
ENGR SUPV	PROJ ENGR	APP'D	
JOB No. 14879	DRAWING No. Figure 5-4	REV.	





NOTE

1. Magnitude symbol sizes are shown on a continuous nonlinear scale

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

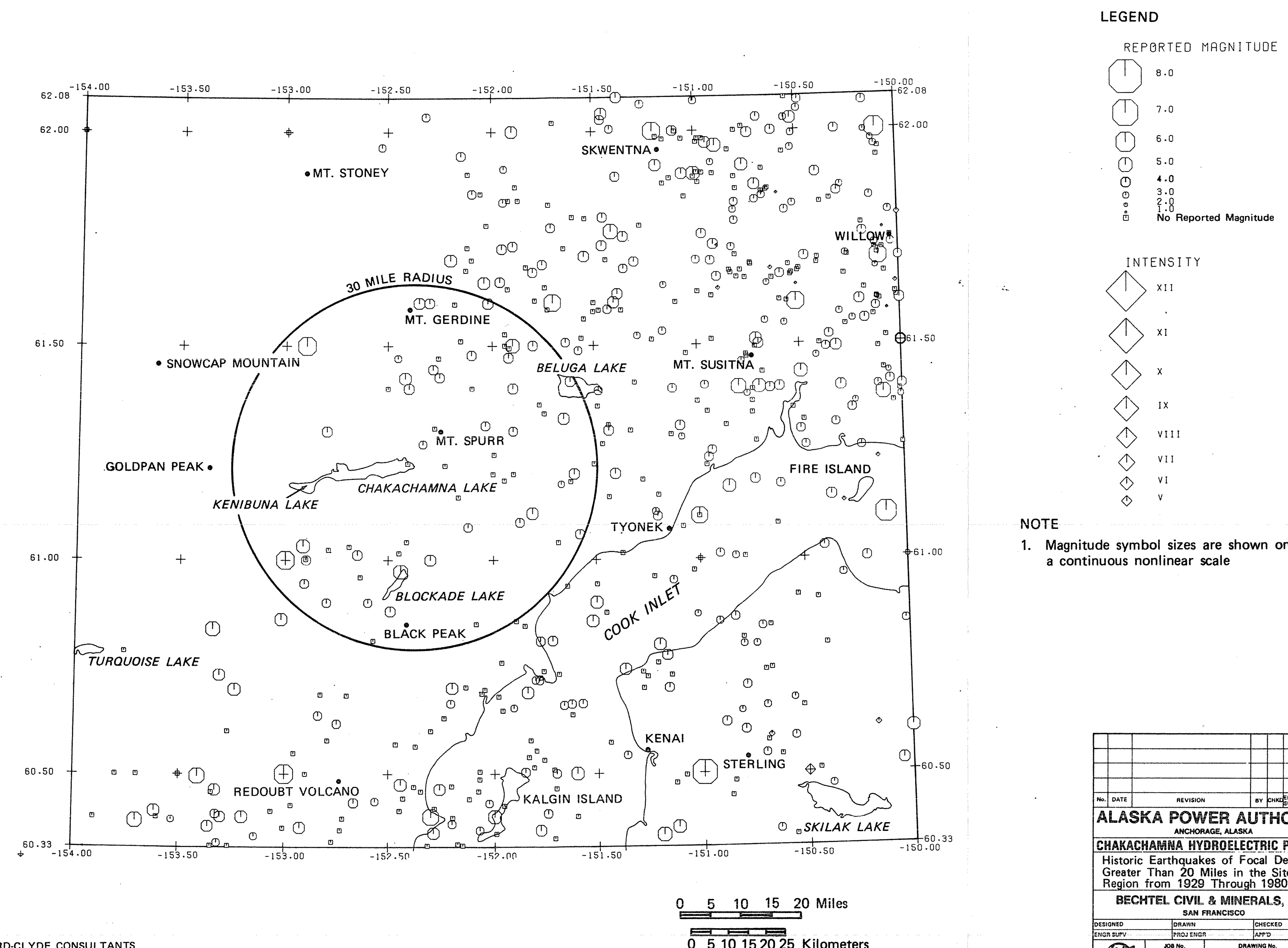
Historic Earthquakes of All Focal Depths in the Site Region from 1929 Through 1980

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-5	

WOODWARD-CLYDE CONSULTANTS



NOTE

1. Magnitude symbol sizes are shown on a continuous nonlinear scale

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

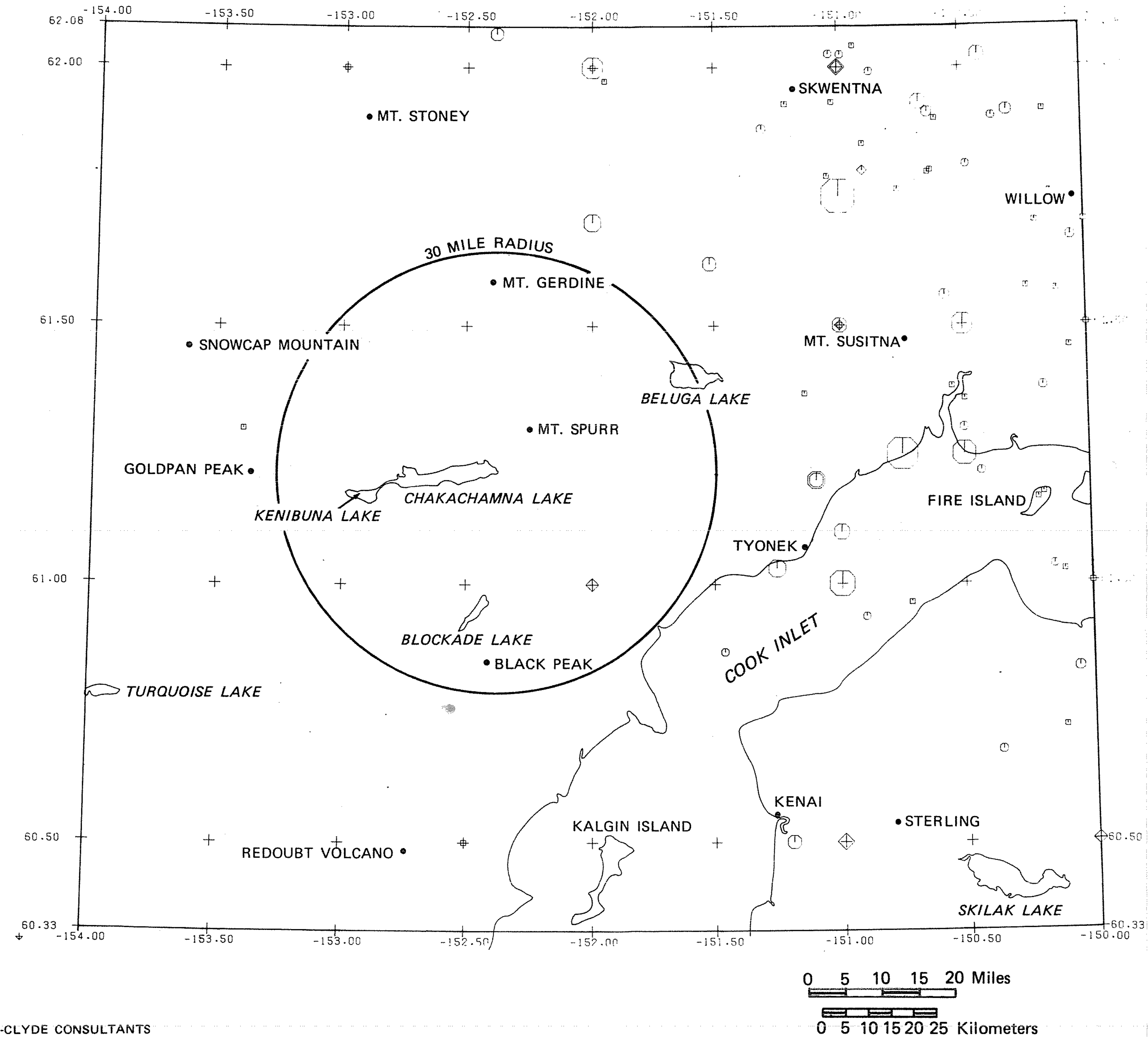
CHAKACHAMNA HYDROELECTRIC PROJECT

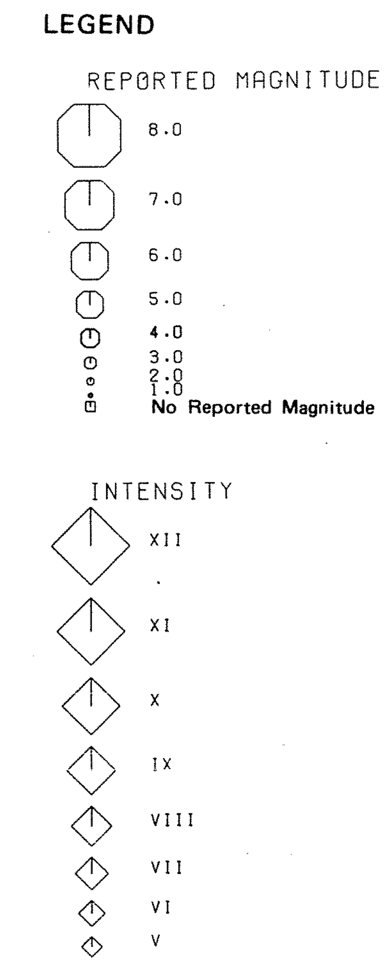
Historic Earthquakes of Focal Depth Greater Than 20 Miles in the Site Region from 1929 Through 1980

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-6	





NOTE

1. Magnitude symbol sizes are shown on a continuous nonlinear scale

WOODWARD-CLYDE CONSULTANTS

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

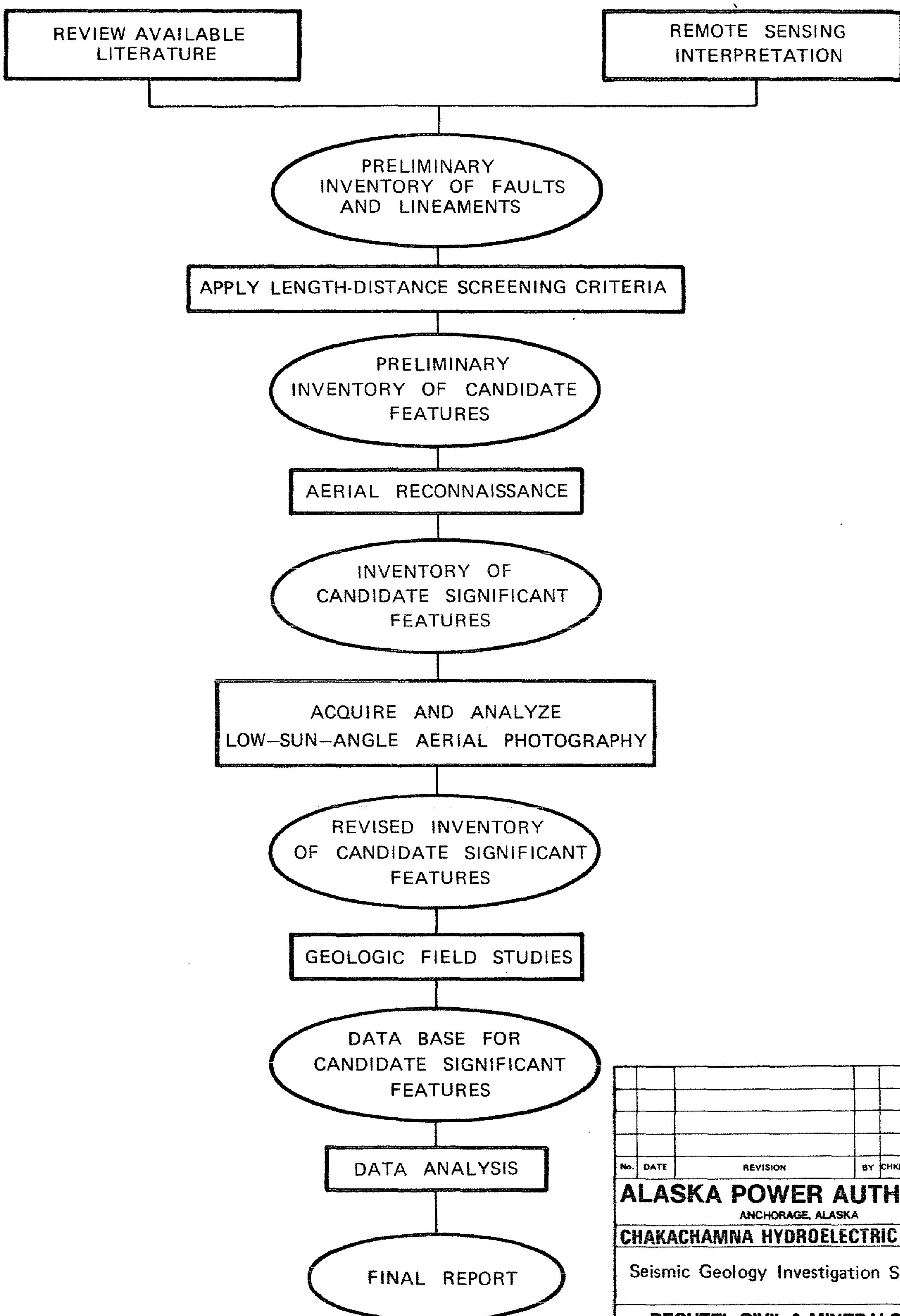
CHAKACHAMNA HYDROELECTRIC PROJECT

Historic Earthquakes of Focal Depth Less Than 20 Miles in the Site Region from 1929 Through 1980

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-7	



No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

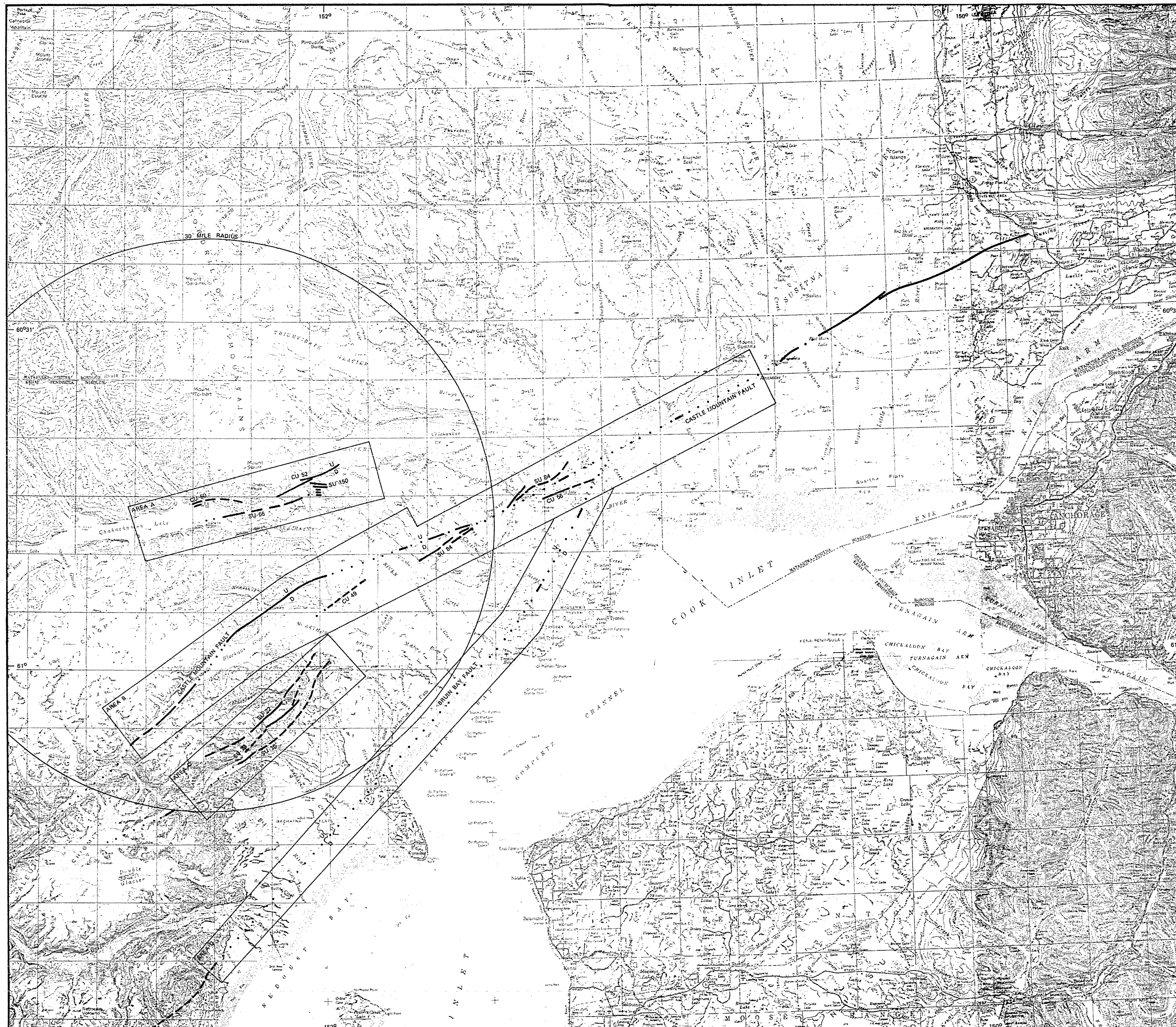
Seismic Geology Investigation Sequence

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-8	

WOODWARD-CLYDE CONSULTANTS



EXPLANATION

Candidate significant fault or lineament, dashed where approximately located, dotted where concealed, queried where location uncertain or inferred

Project Study Area. Reconnaissance assessment of surface fault rupture by Woodward-Clyde Consultants during 1981 field season

AREA A — Areas discussed in Section 5.3.3.3

0 5 10 15
SCALE IN MILES

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

MAP SHOWING LOCATIONS OF CANDIDATE SIGNIFICANT FEATURES IN THE PROJECT STUDY AREA

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	Figure 5-9	

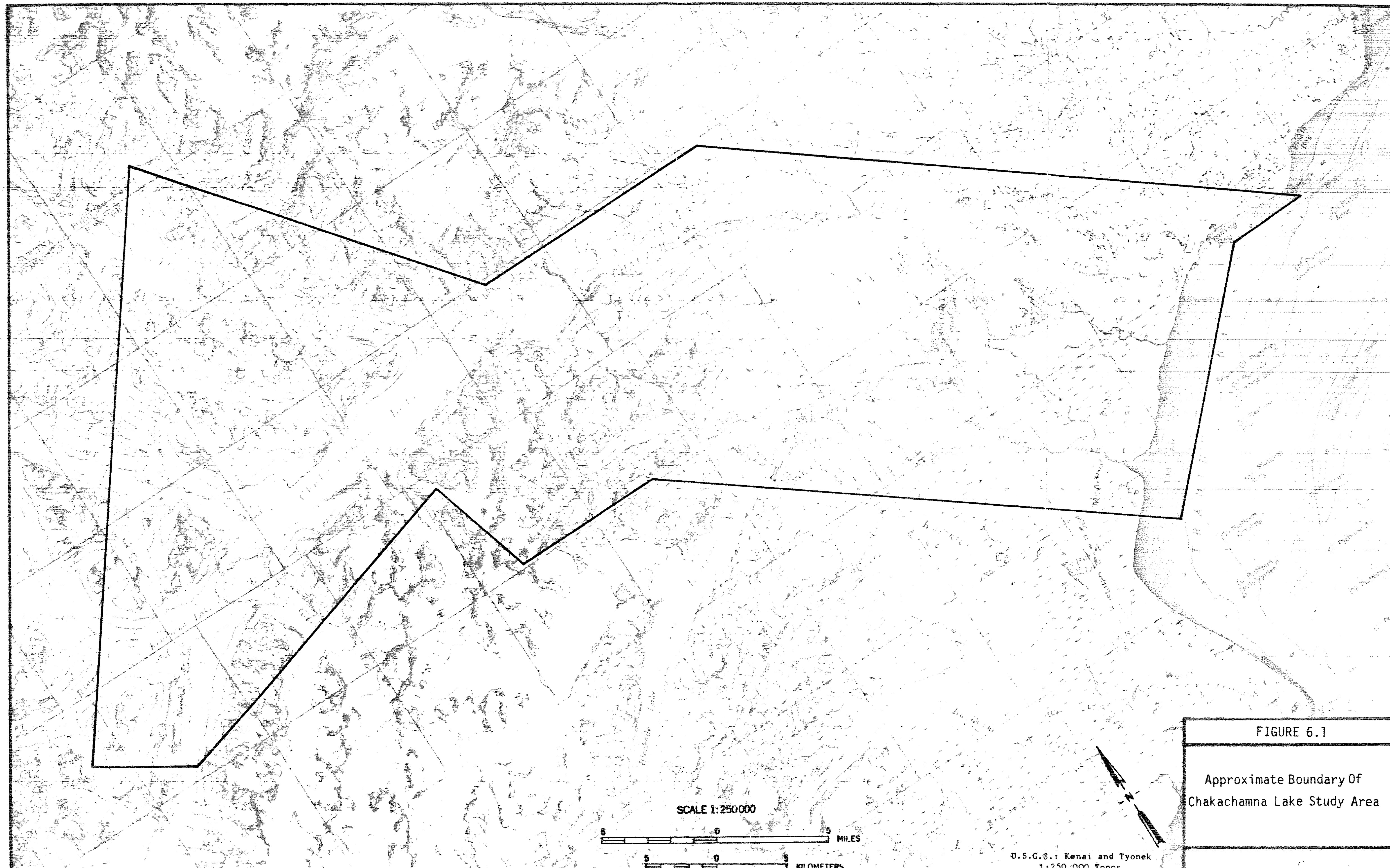


FIGURE 6.1

Approximate Boundary Of Chakachamna Lake Study Area

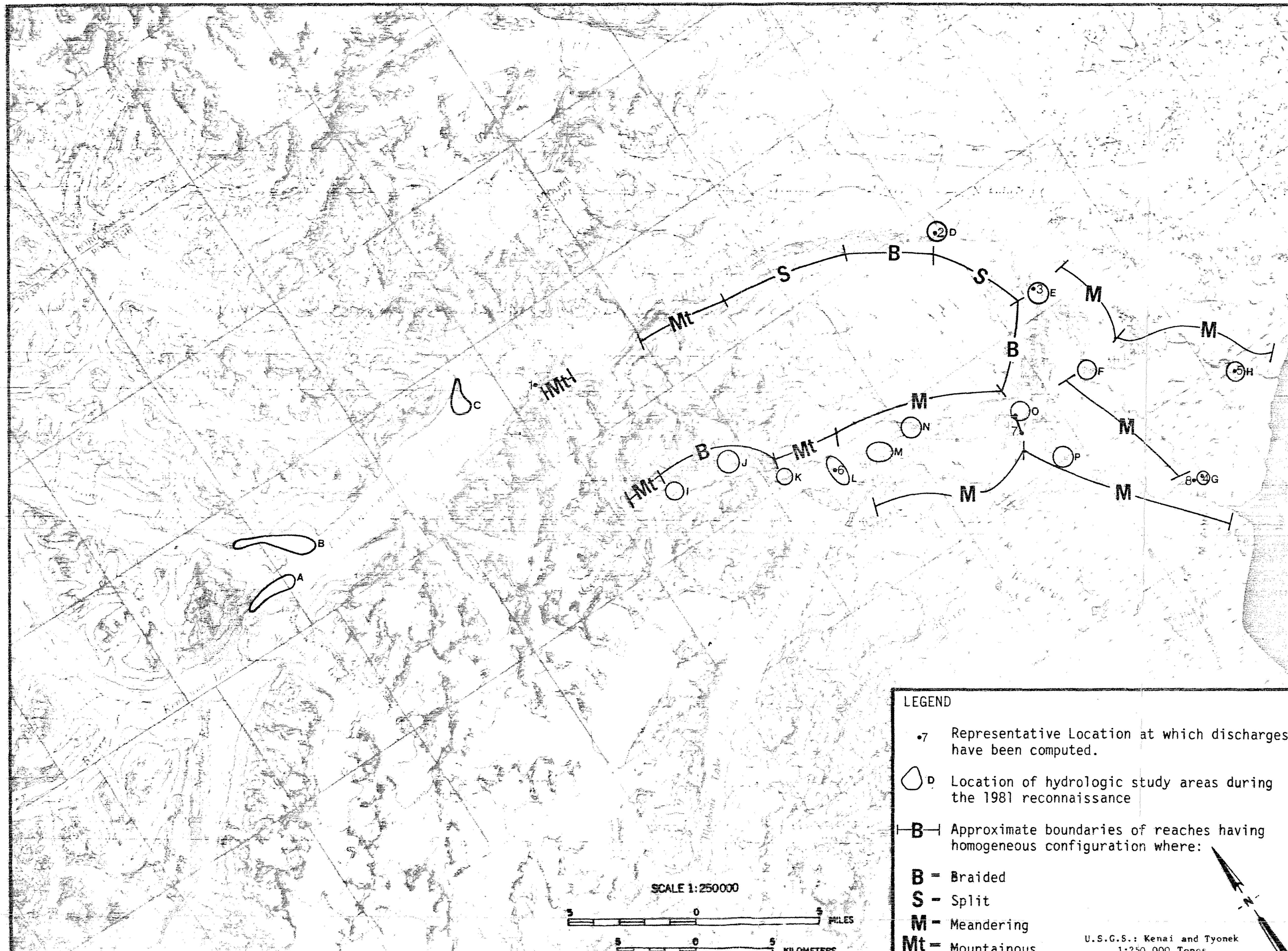
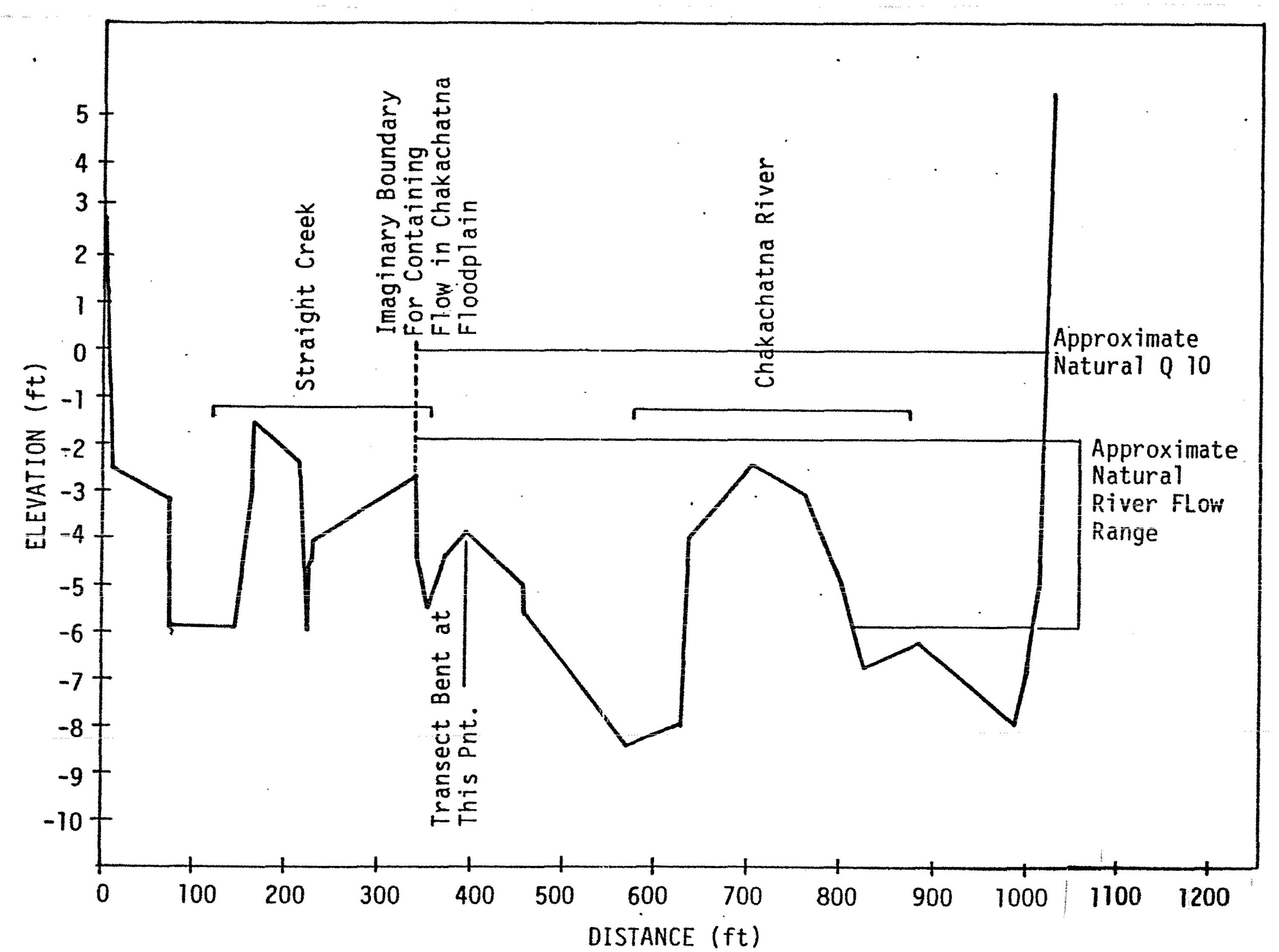


FIGURE 6.2

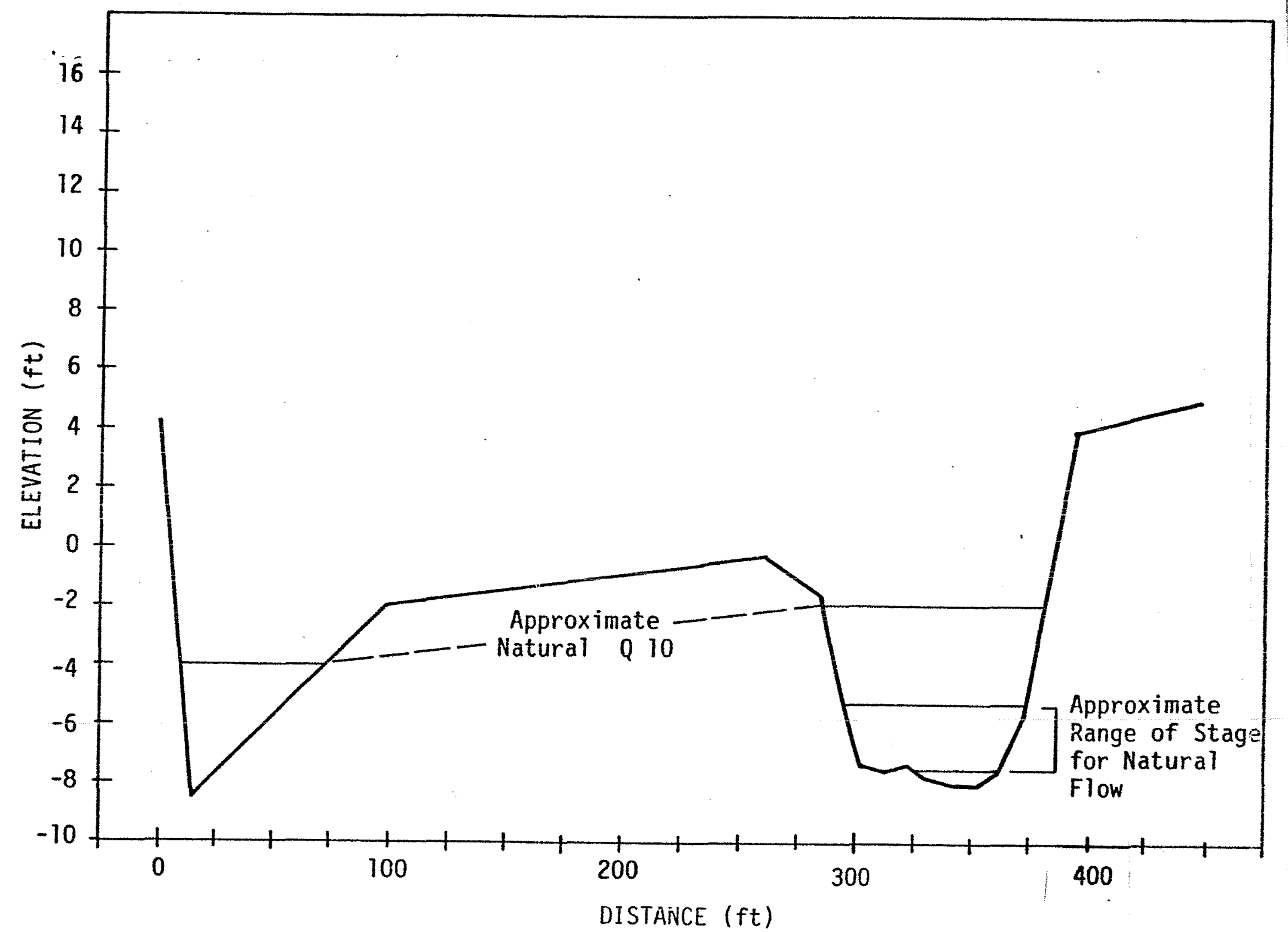
Locations Of Hydrologic Study Areas, Representative Locations, And Channel Configuration Reach Boundaries



Note: Site is located upstream of confluence with Straight Creek in Study Area D. Transect as shown is looking in downstream direction.

Figure 6.3

Stream And Floodplain Transect on Chakachatna River Showing Approximate Range of Natural Stages



Note: Site is located upstream of confluence with Upper Blockade Glacier Channel in Study Area L. Transect as shown is looking in downstream direction.

Figure 6.4

Stream and Floodplain Transect on Upper McArthur River Showing Approximate Range of Natural Stages

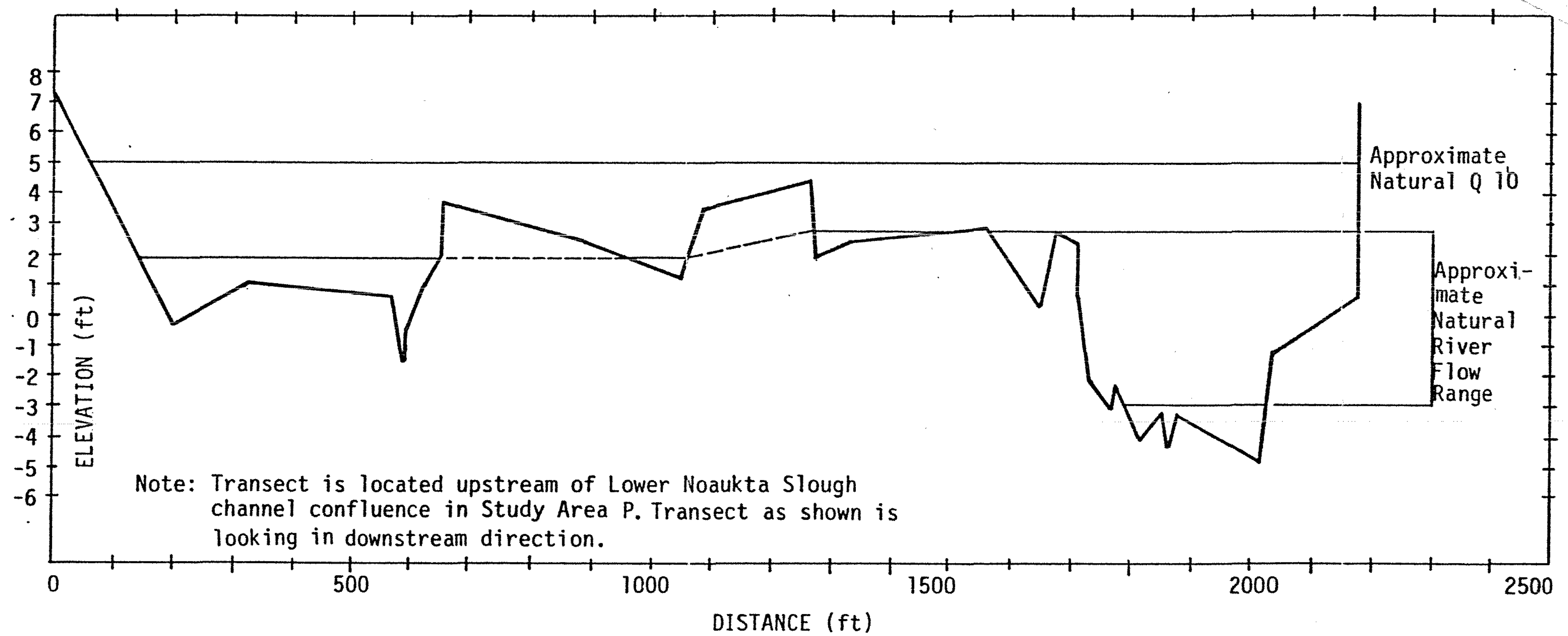
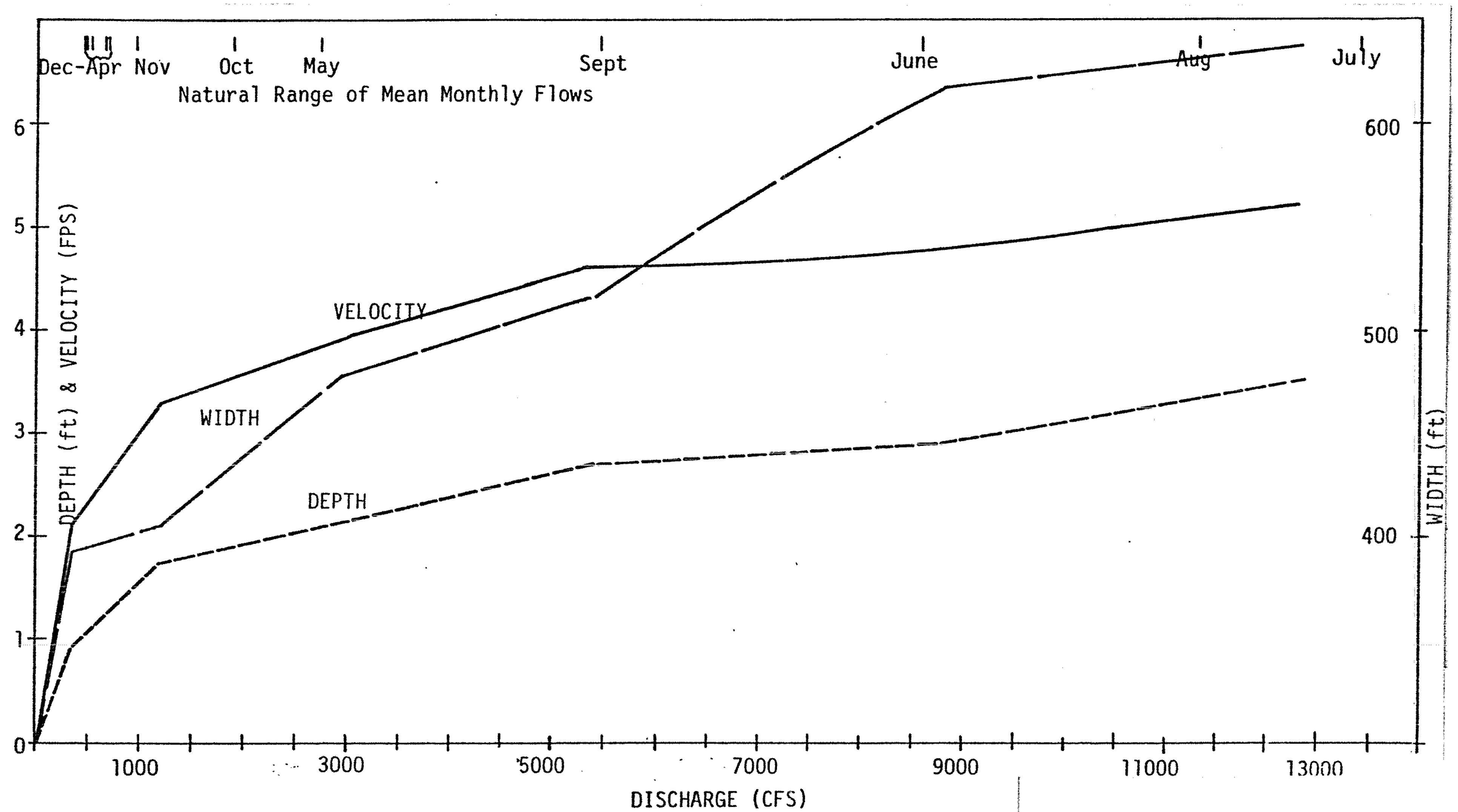


Figure 6.5

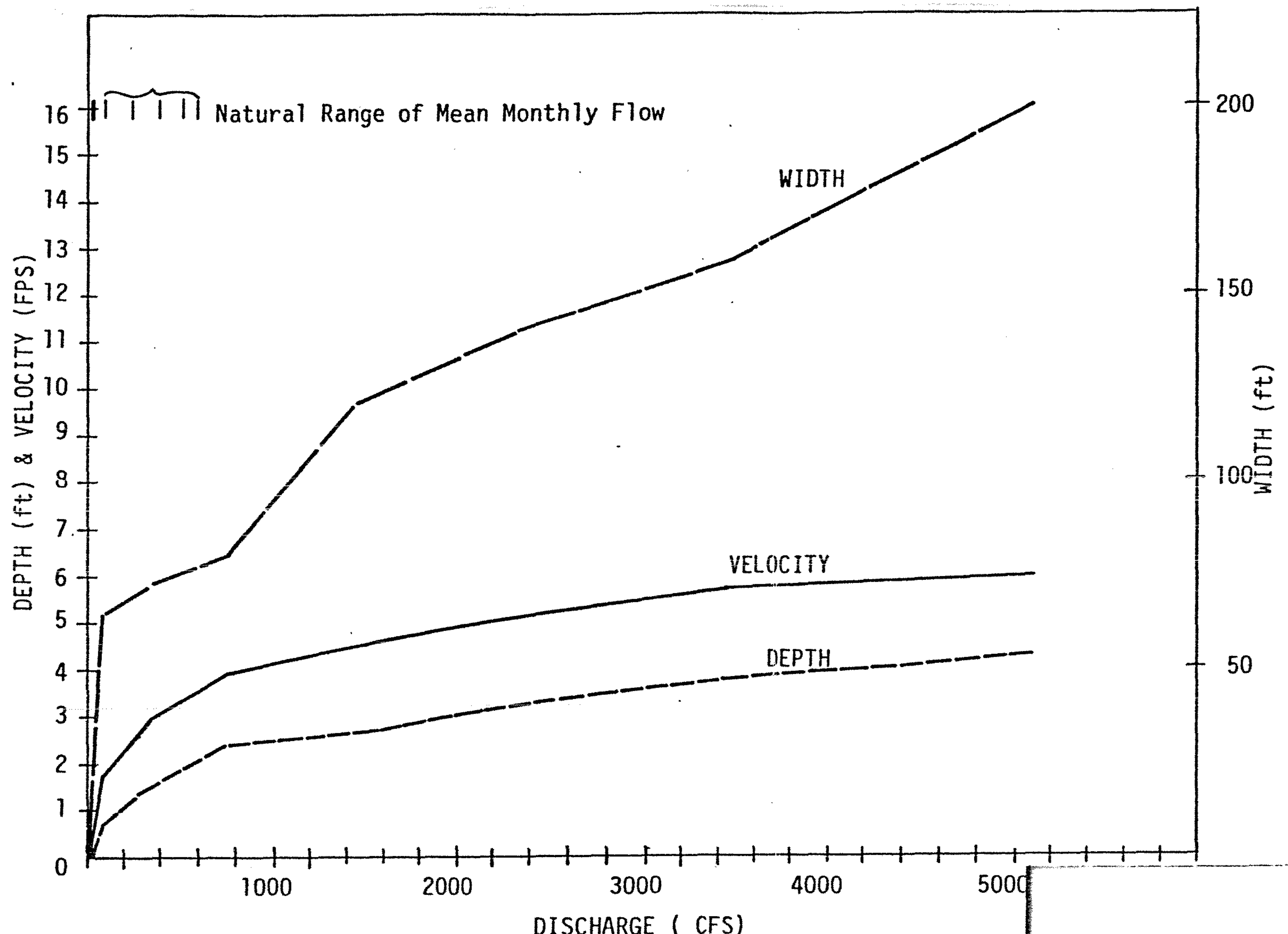
Stream and Floodplain Transect on McArthur River Showing Approximate Range of Natural Stages



Note: Site is located upstream of confluence with Straight Creek in Study Area D. For transect, refer to Figure 6.3.

Figure 6.6

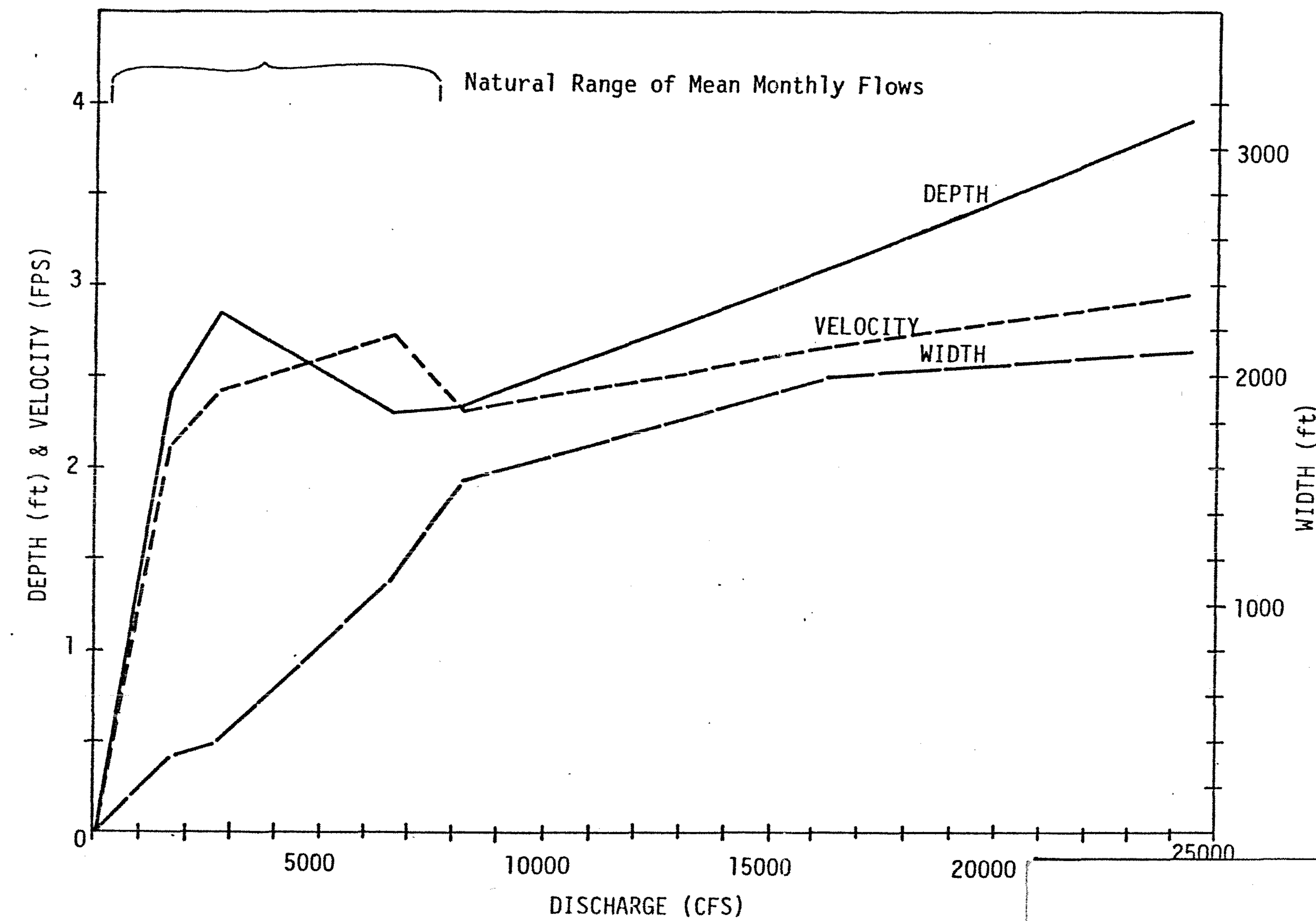
Hydraulic Geometry of Chakachatna River Showing Approximate Range of Natural Flow



Note: Site is located upstream of confluence with Upper Blockade Glacier Channel in Study Area L. For transect, refer to Figure 6.4.

Figure 6.7

Hydraulic Geometry of Upper McArthur River Showing Approximate Range of Natural Flow



Note: Site is located upstream of confluence with Lower Noaukta Slough Channel in Study Area P. For transect, refer to Figure 6.5.

Figure 6.8

Hydraulic Geometry of McArthur River Showing Approximate Range of Natural Flow

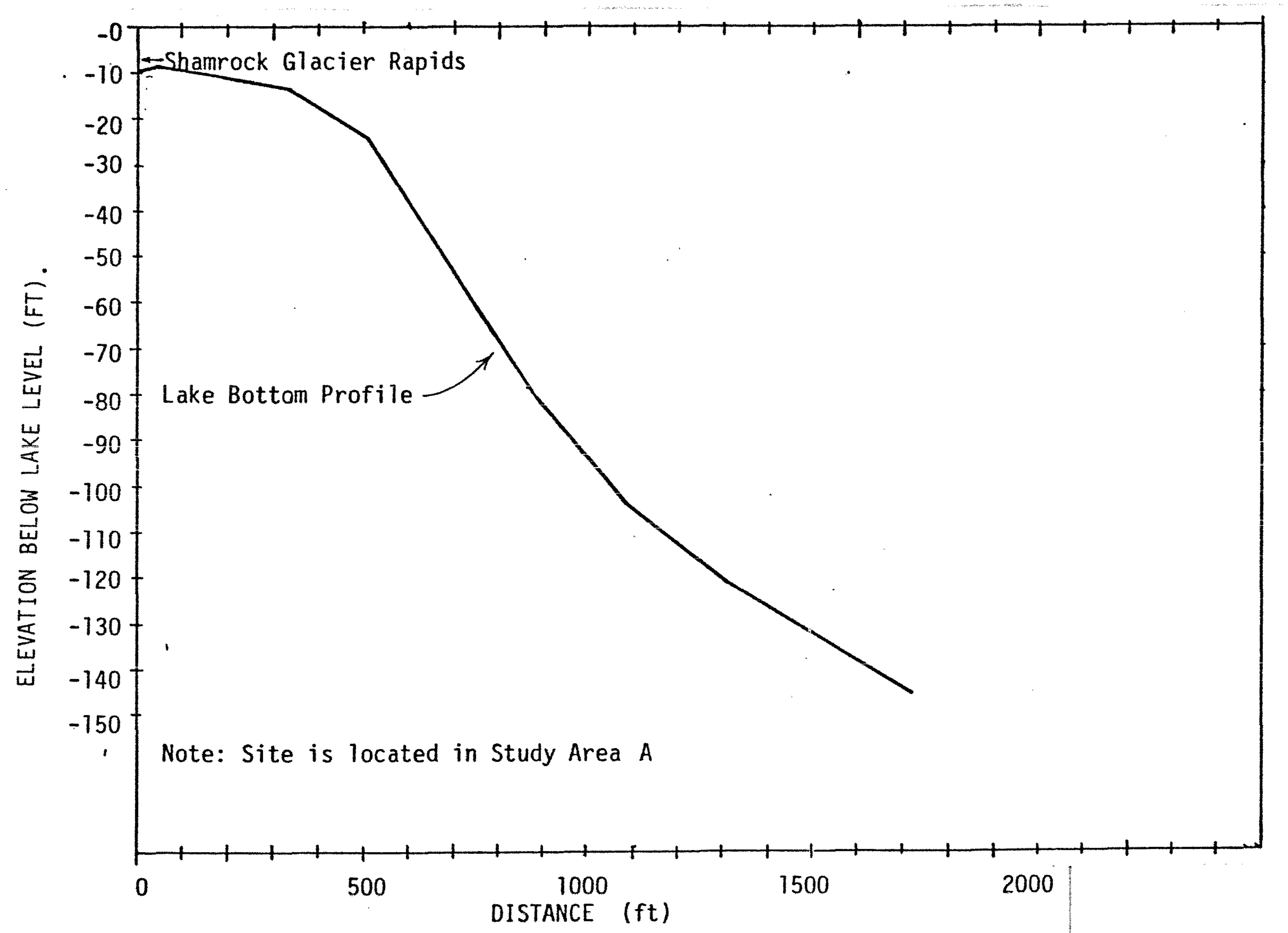
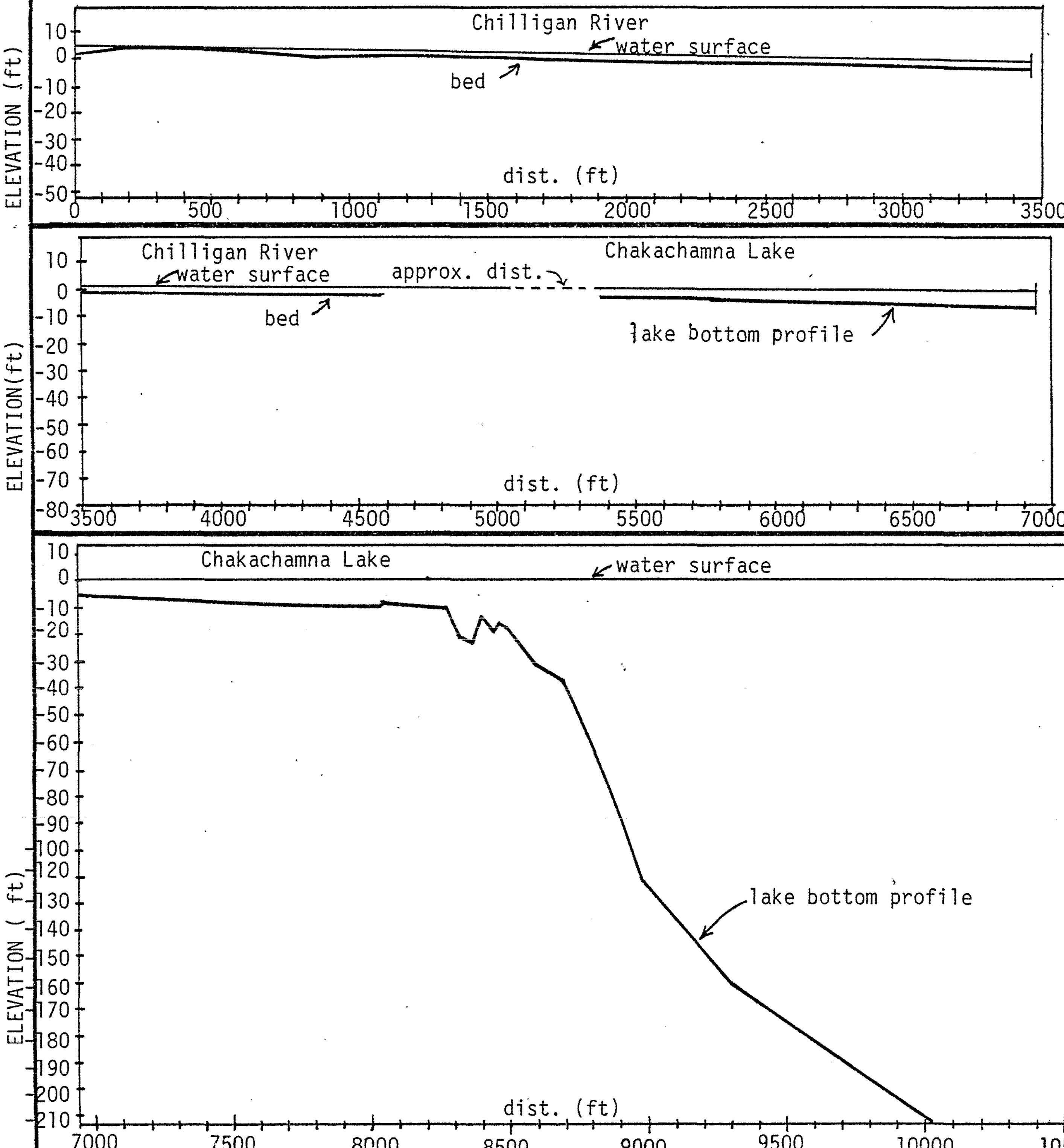


Figure 6.9

Chakachamna Lake Bottom Profile Offshore From Shamrock Glacier Rapids



Note: Site is located in Study Area B.

Figure 6.10

Chilligan River and Chakachamna Lake Bottom Profiles

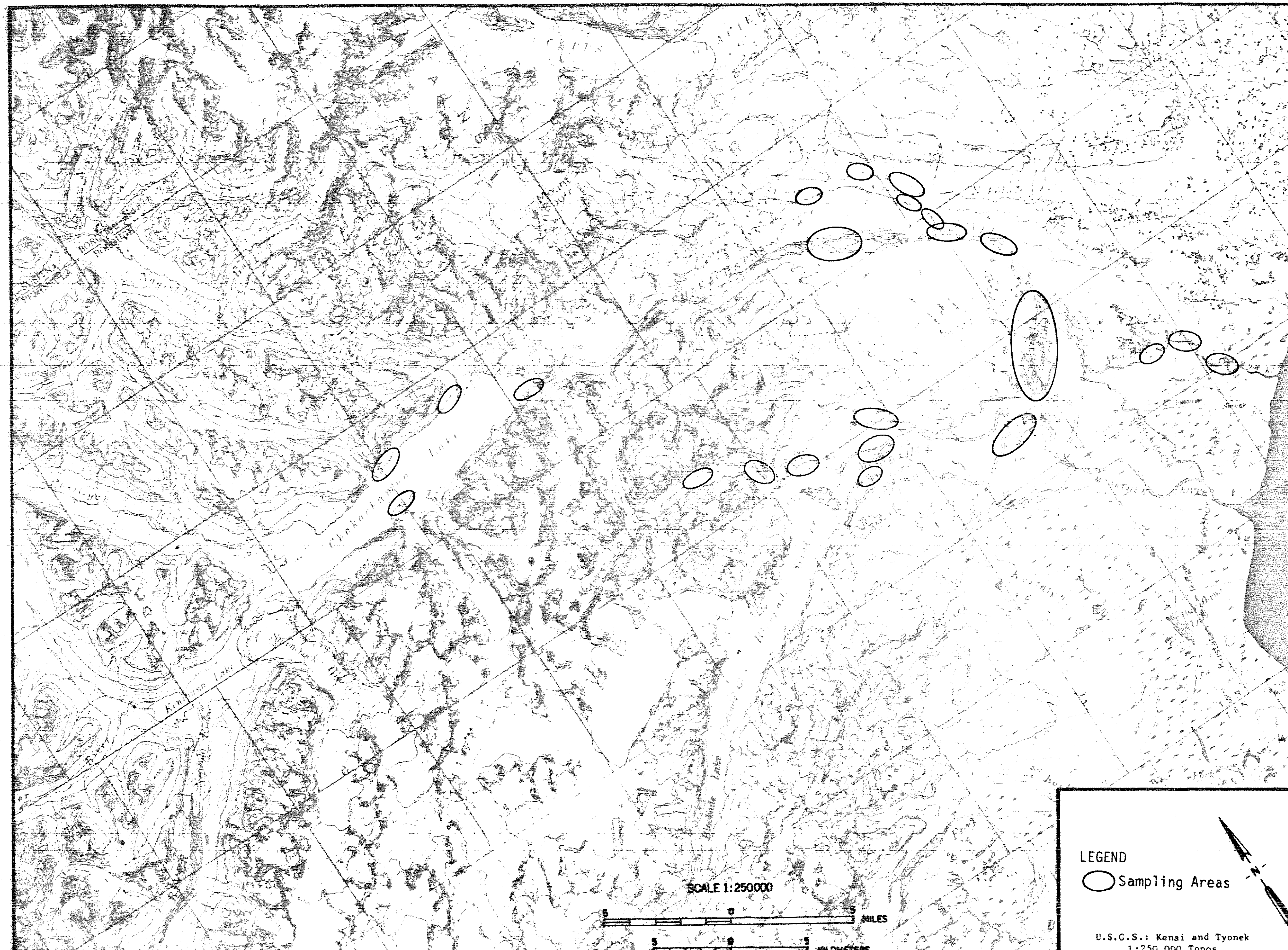


FIGURE 6.11

Electroshocking And Seine Sampling Locations

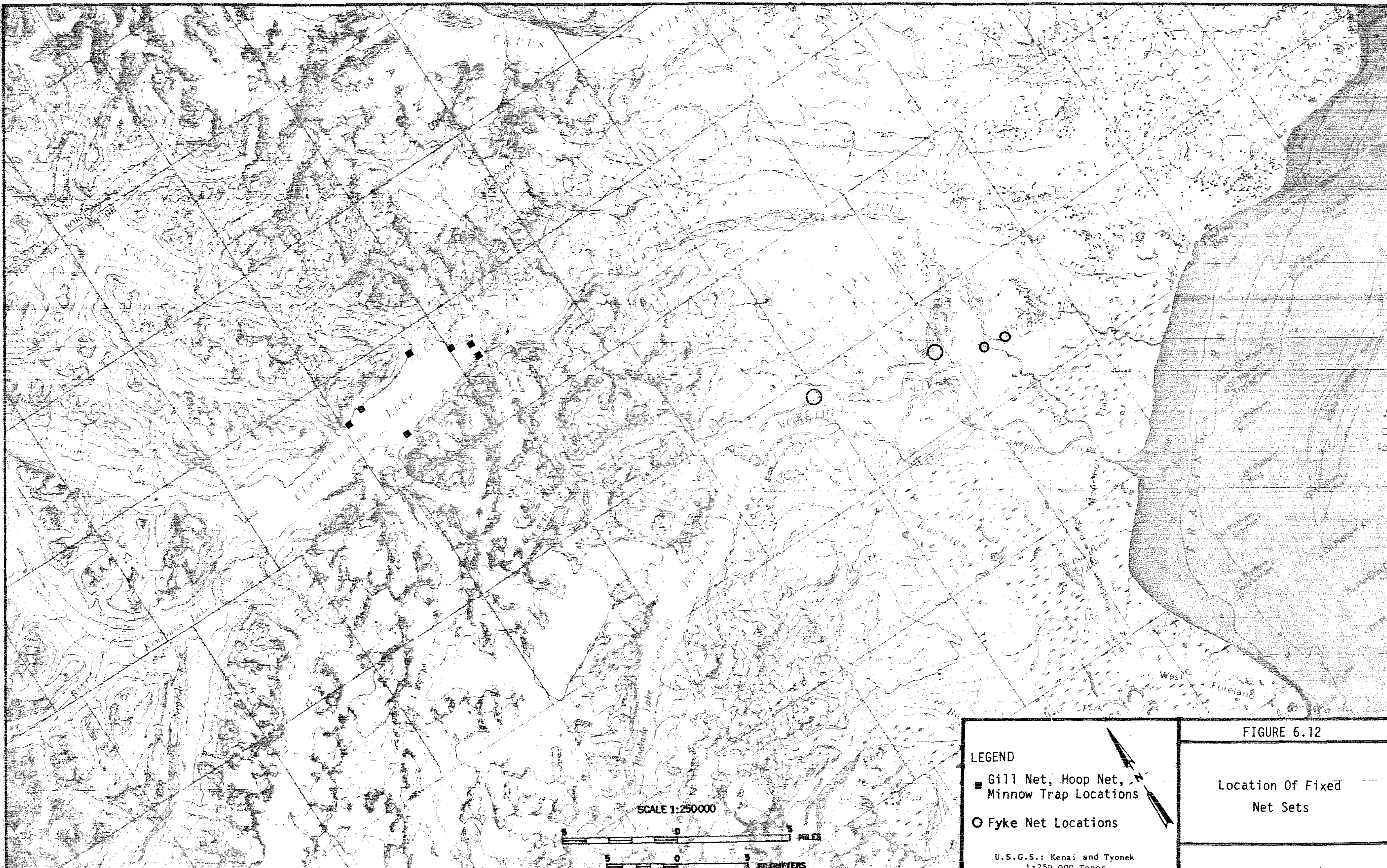
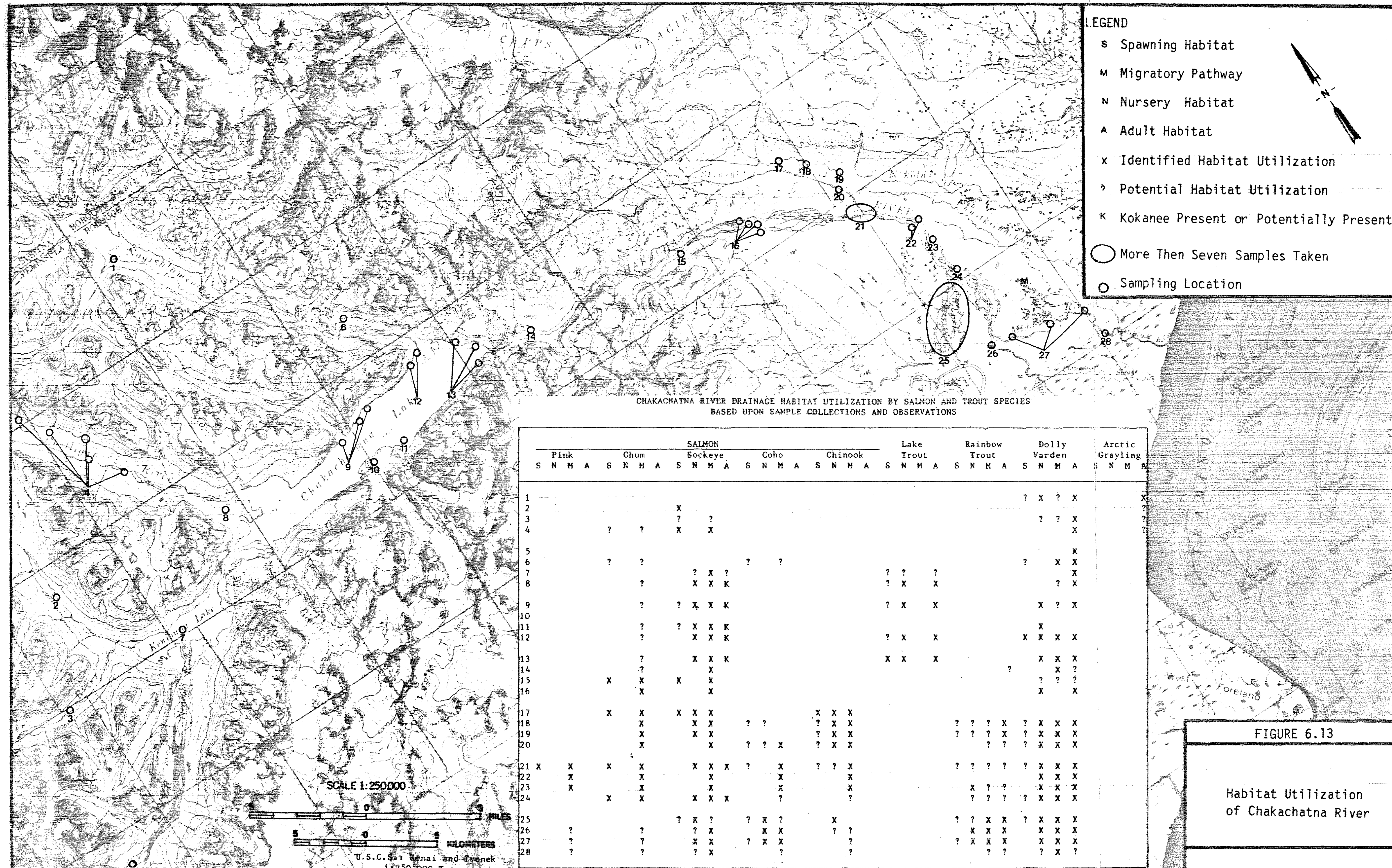


FIGURE 6.12

Location Of Fixed Net Sets



CHAKACHATNA RIVER DRAINAGE HABITAT UTILIZATION BY SALMON AND TROUT SPECIES
BASED UPON SAMPLE COLLECTIONS AND OBSERVATIONS

	SALMON																															
	Pink				Chum				Sockeye				Coho				Chinook				Lake Trout				Rainbow Trout				Dolly Varden				Arctic Grayling			
	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A
1																													?	X	?	X				X
2									X																											?
3									?		?																			?	?	X				?
4					?		?		X		X																					X				?
5																																X				
6					?		?						?		?														?		X	X				
7										?	X	?									?	?		?								X				
8							?			X	X	K									?	X		X							?	X				
9							?		?	X	X	K									?	X		X						X	?	X				
10																																				
11							?		?	X	X	K																		X						
12							?			X	X	K									?	X		X					X	X	X	X				
13							?			X	X	K									X	X		X						X	X	X				
14							?				X																	?			X	?				
15					X		X		X		X																			?	?	?				
16							X				X																			X		X				
17					X		X		X	X	X						X	X	X																	
18							X			X	X		?	?			?	X	X						?	?	?	X	?	X	X	X				
19							X			X	X						?	X	X						?	?	?	X	?	X	X	X				
20							X				X		?	?	X		?	X	X								?	?	?	X	X	X				
21	X		X		X		X			X	X	X	?		X		?	?	X						?	?	?	?	?	X	X	X				
22			X				X				X				X				X											X	X	X				
23			X				X				X				X				X							X	?	?		X	X	X				
24					X		X			X	X	X			?				?							?	?	?	?	X	X	X				
25									?	X	?		?	X	?			X							?	?	X	X	?	X	X	X				
26			?				?			?	X			X	X			?	?							X	X	X		X	X	X				
27			?				?			X	X		?	X	X				?						?	X	X	X		X	X	X				
28			?				?			?	X				?				?								?	?		?	X	?				

FIGURE 6.13

Habitat Utilization of Chakachatna River

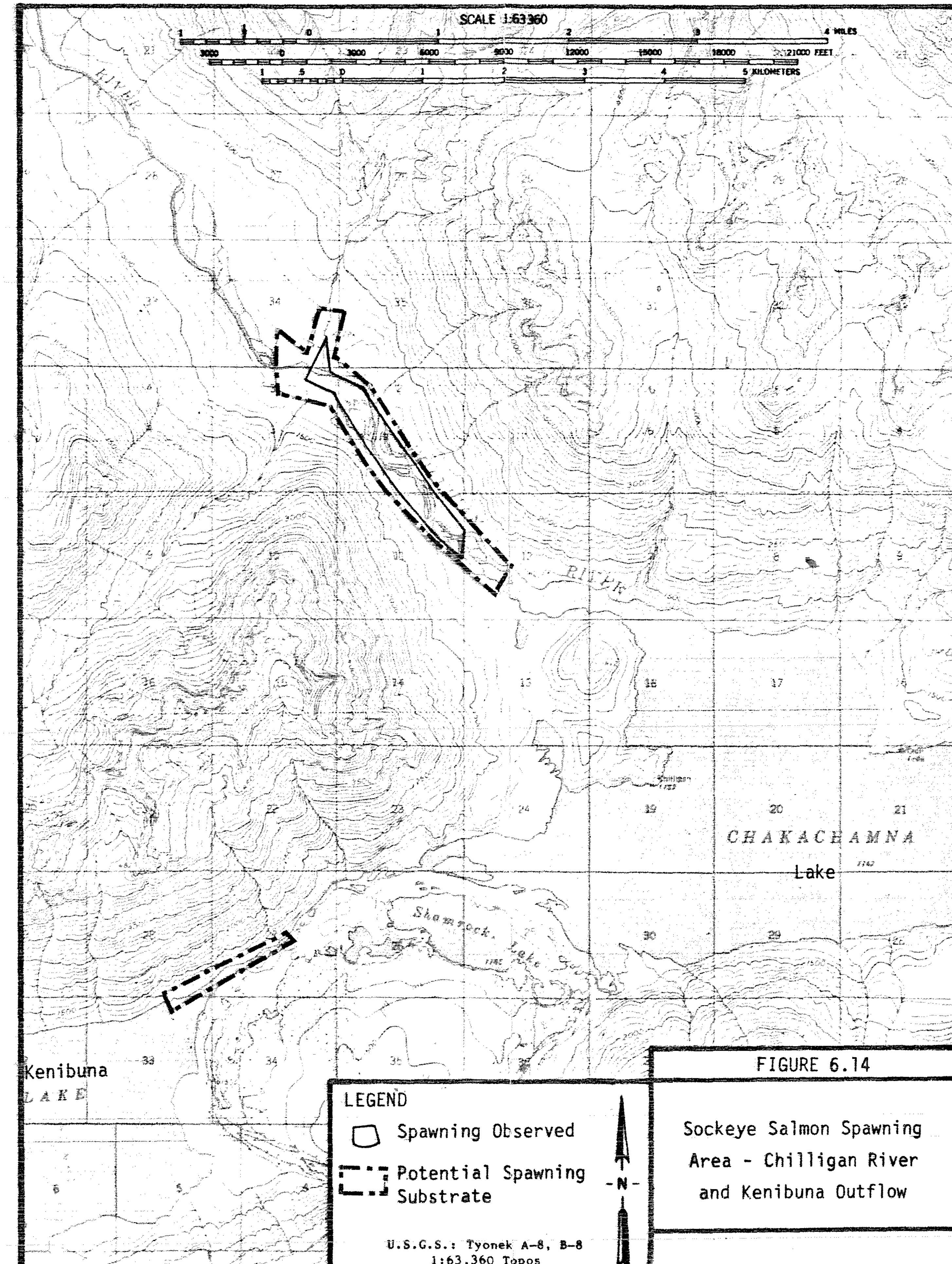


FIGURE 6.14

Sockeye Salmon Spawning Area - Chilligan River and Kenibuna Outflow

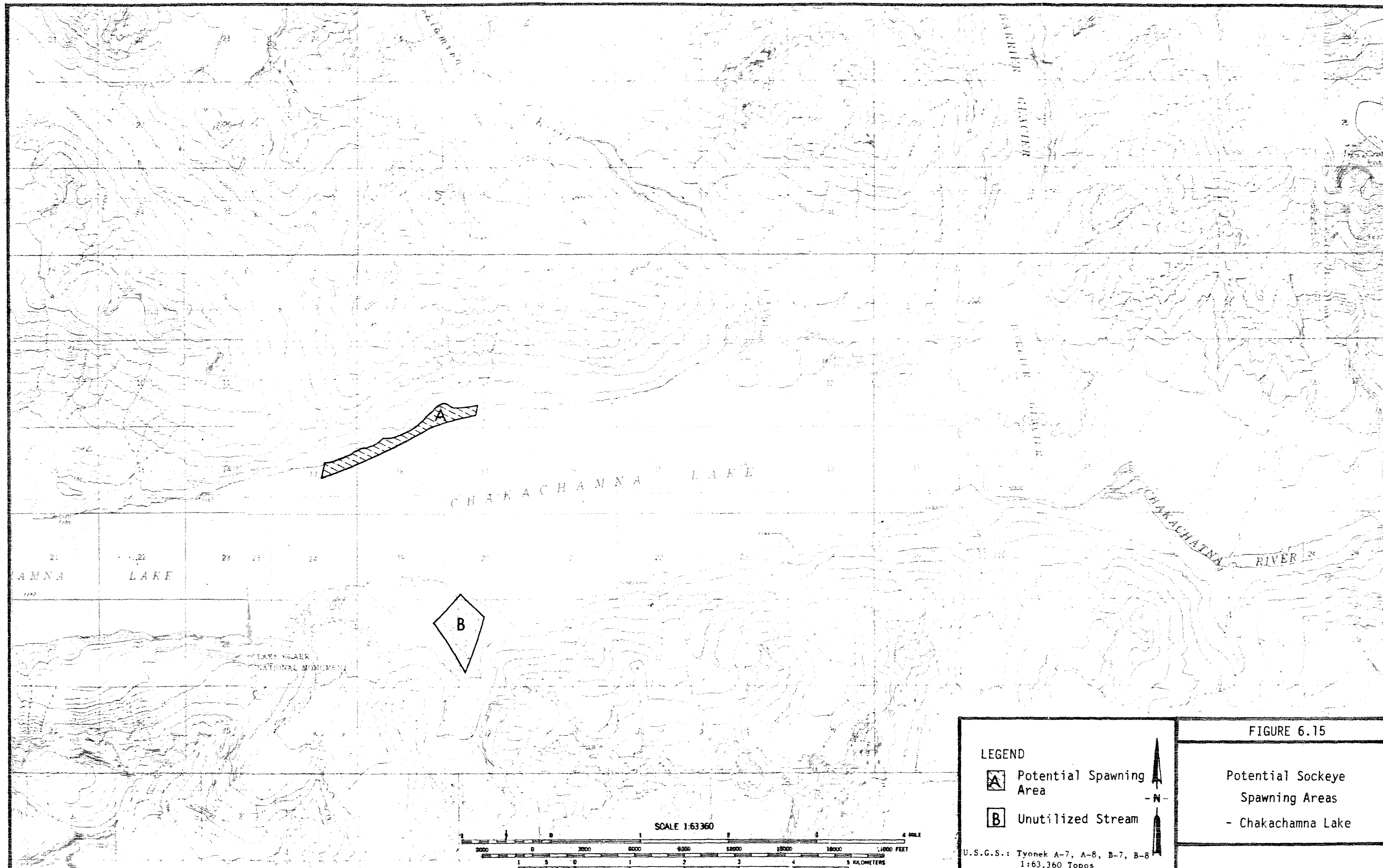


FIGURE 6.15

Potential Sockeye Spawning Areas - Chakachamna Lake

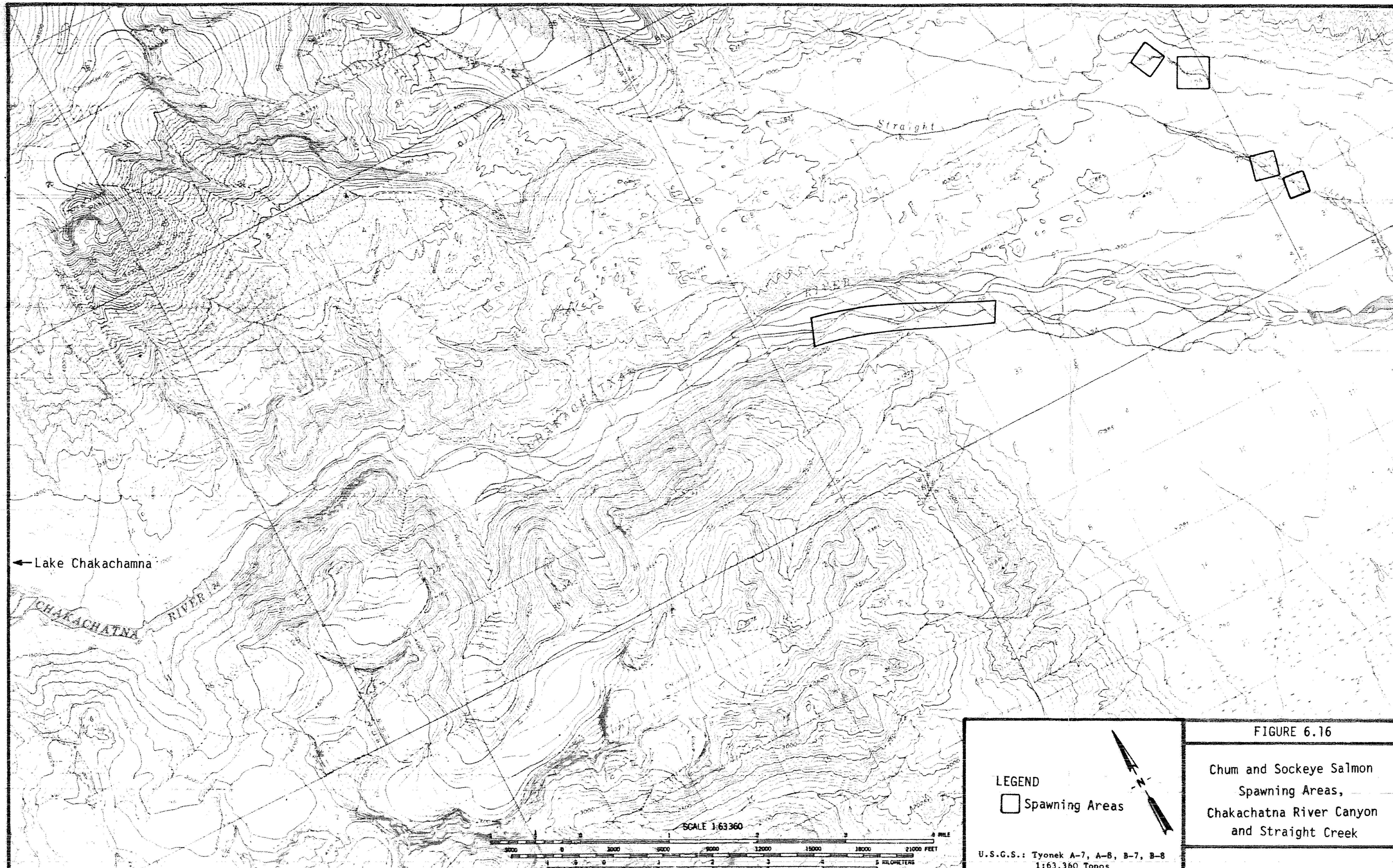


FIGURE 6.16

Chum and Sockeye Salmon Spawning Areas, Chakachatna River Canyon and Straight Creek

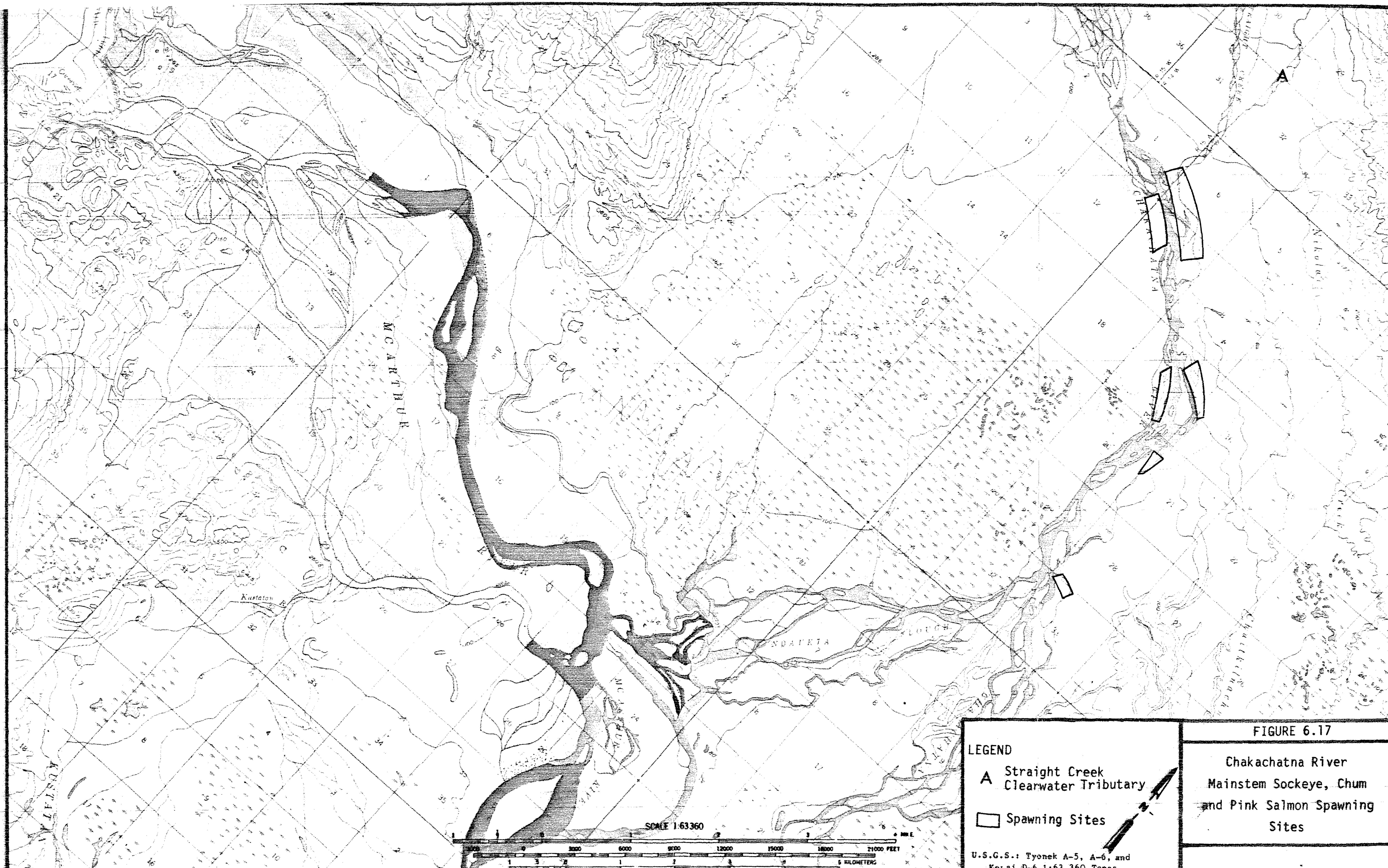


FIGURE 6.17

Chakachatna River Mainstem Sockeye, Chum and Pink Salmon Spawning Sites

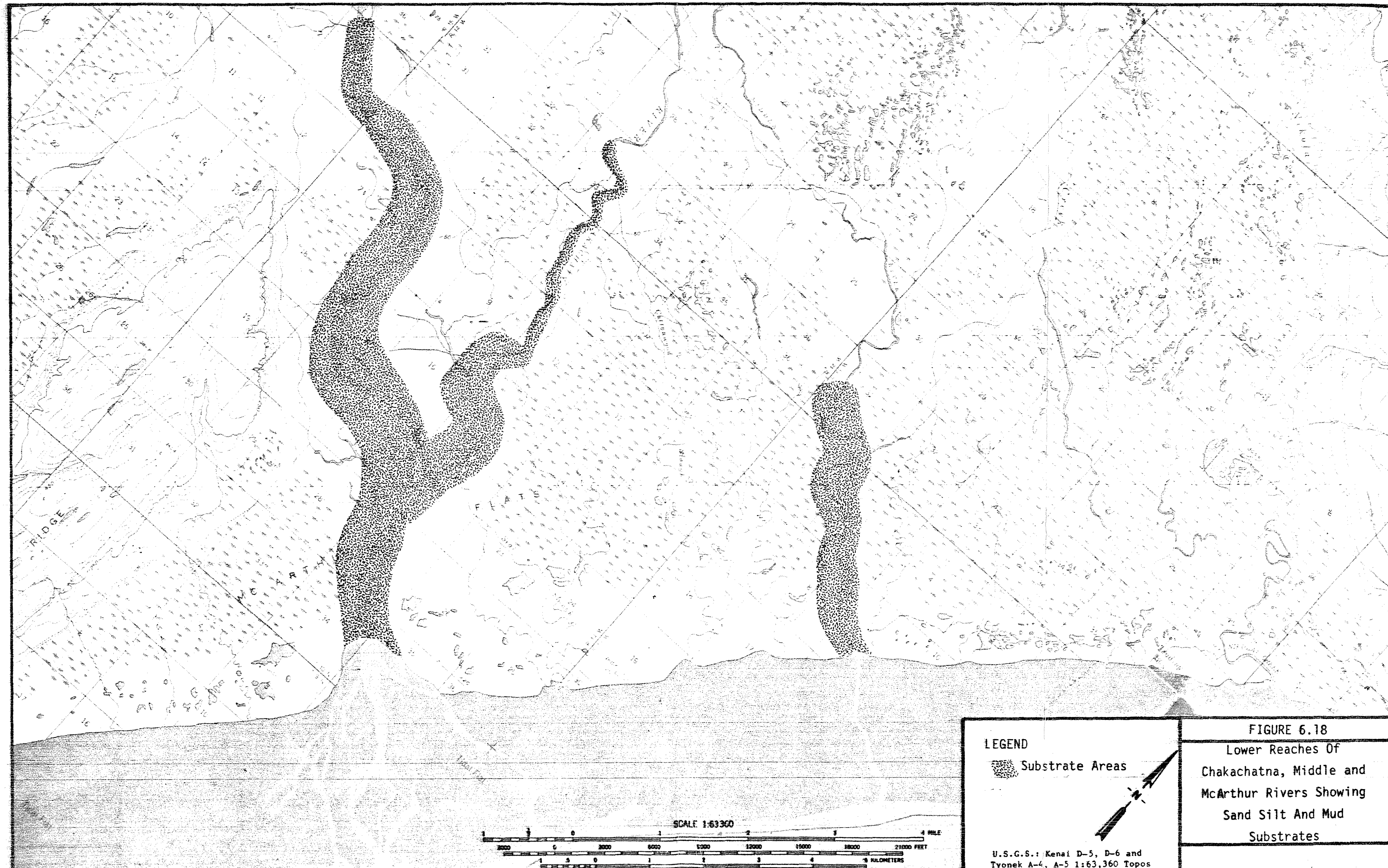
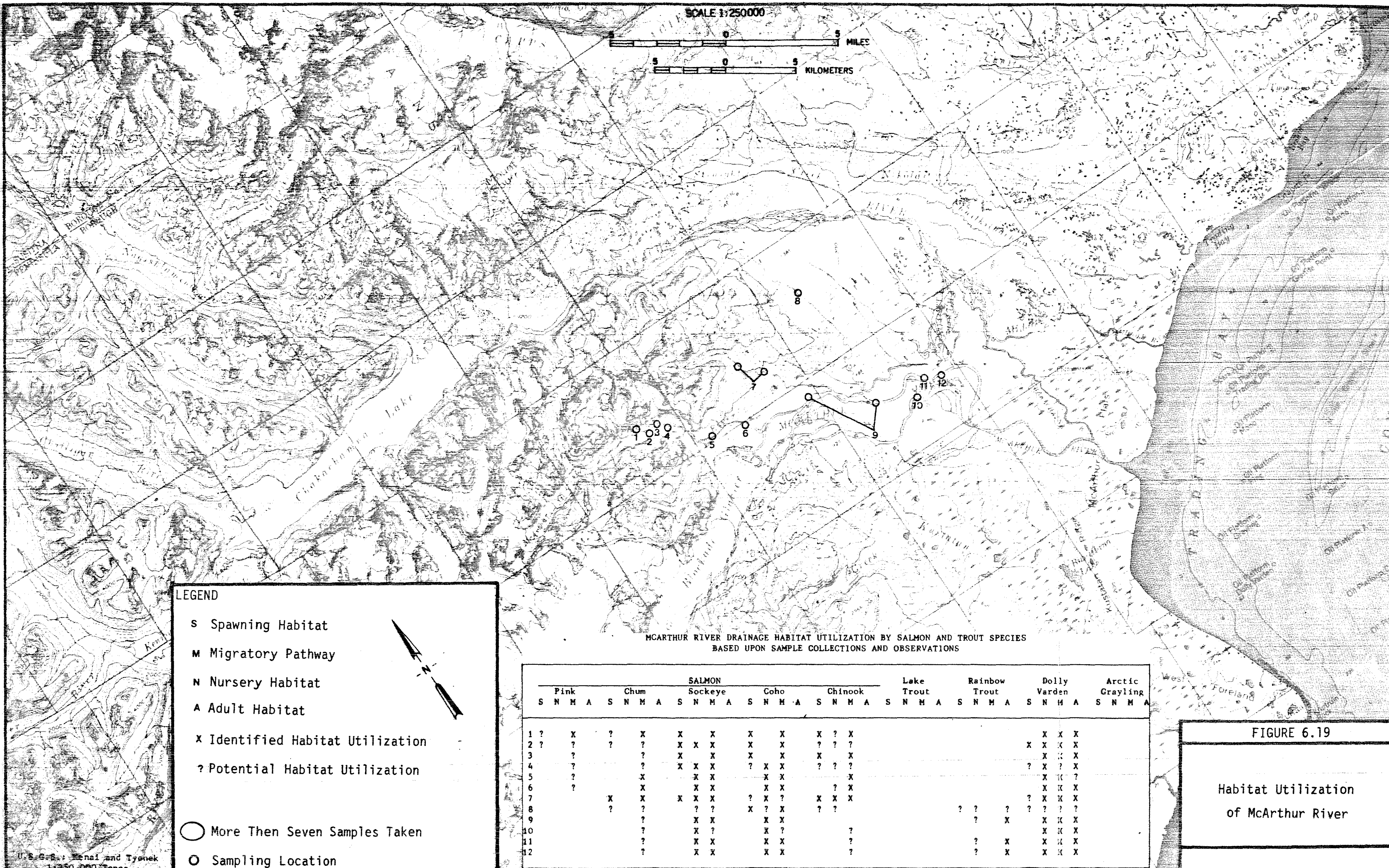


FIGURE 6.18

Lower Reaches Of Chakachatna, Middle and McArthur Rivers Showing Sand Silt And Mud Substrates

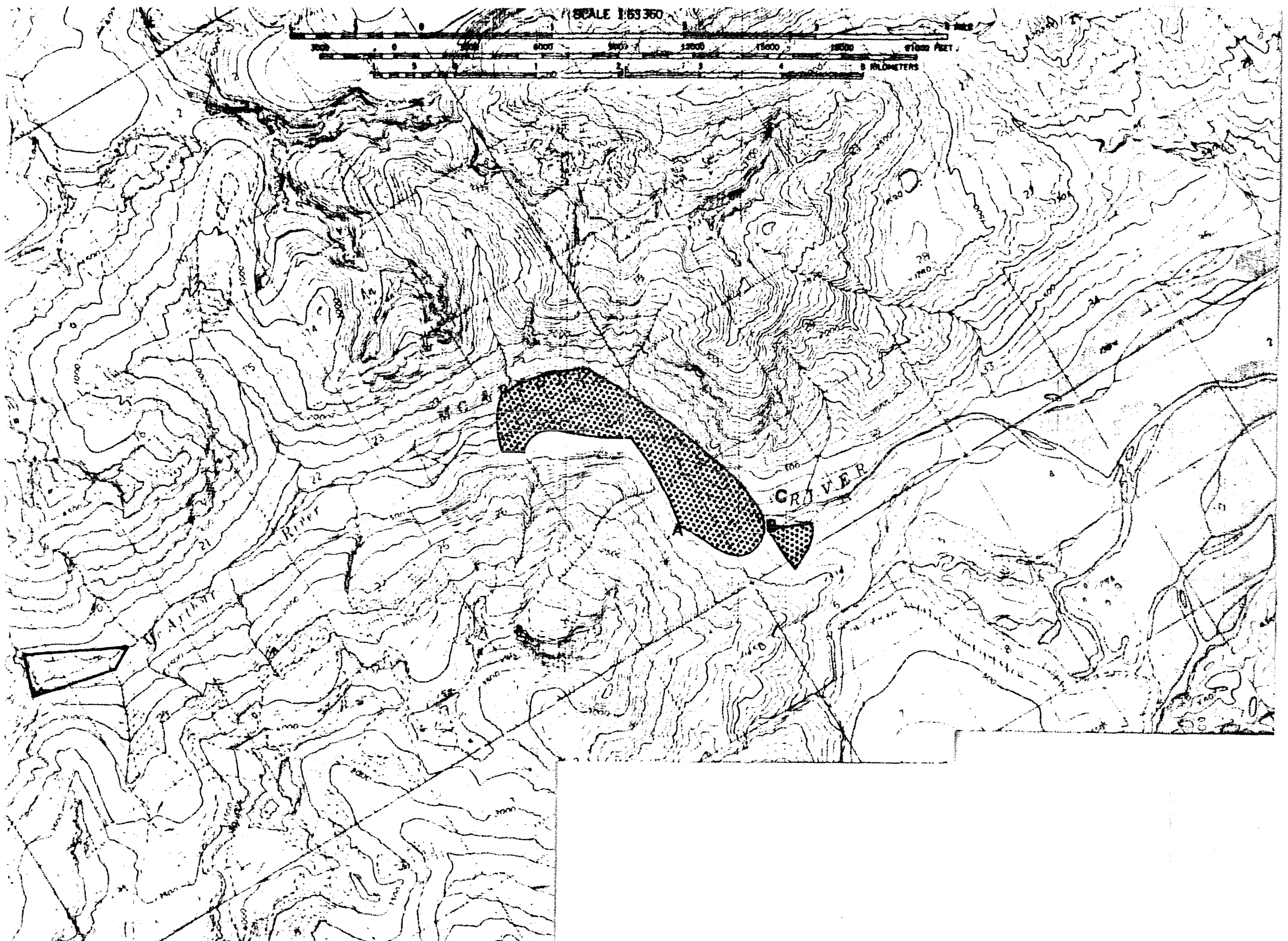


MCARTHUR RIVER DRAINAGE HABITAT UTILIZATION BY SALMON AND TROUT SPECIES
BASED UPON SAMPLE COLLECTIONS AND OBSERVATIONS

	SALMON																				Lake				Rainbow				Dolly				Arctic			
	Pink				Chum				Sockeye				Coho				Chinook				Trout				Trout				Varden				Grayling			
	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A	S	N	M	A
1	?		X		?		X		X		X		X		X		X	?	X											X	X	X				
2	?		?		?		?		X	X	X		X		X		?	?	?										X	X	X	X				
3			?				?		X		X		X		X		X		X											X	X	X				
4			?				?		X	X	X		?	X	X		?	?	?										?	X	?	X				
5			?				X			X	X			X	X				X											X	X	?				
6			?				X			X	X			X	X			?	X											X	X	X				
7					X		X		X	X	X		?	X	?		X	X	X										?	X	X	X				
8					?		?			?	?		X	?	X		?	?							?	?		?	?	?	?	?				
9							?			X	X			X	X											?		X		X	X	X				
10							?			X	?			X	?				?											X	X	X				
11							?			X	X			X	X				?							?		X		X	X	X				
12							?			X	X			X	X				?							?		X		X	X	X				

FIGURE 6.19

Habitat Utilization of McArthur River



LEGEND

Area Uninhabited by Fish

Spawning Areas

A Apparent Beaver Pond Areas

U.S.G.S.: Tyonek A-6, A-7
1:63,360 Topos

FIGURE 6.20

Upper Mcarthur River
Identified Spawning Areas

LEGEND

Ⓓ Sampling Sites

U.S.G.S.: Tyonek A-5, A-6 and Kenai D-6 1:63,360 Topos

FIGURE 6.21

McArthur River Sampling Sites

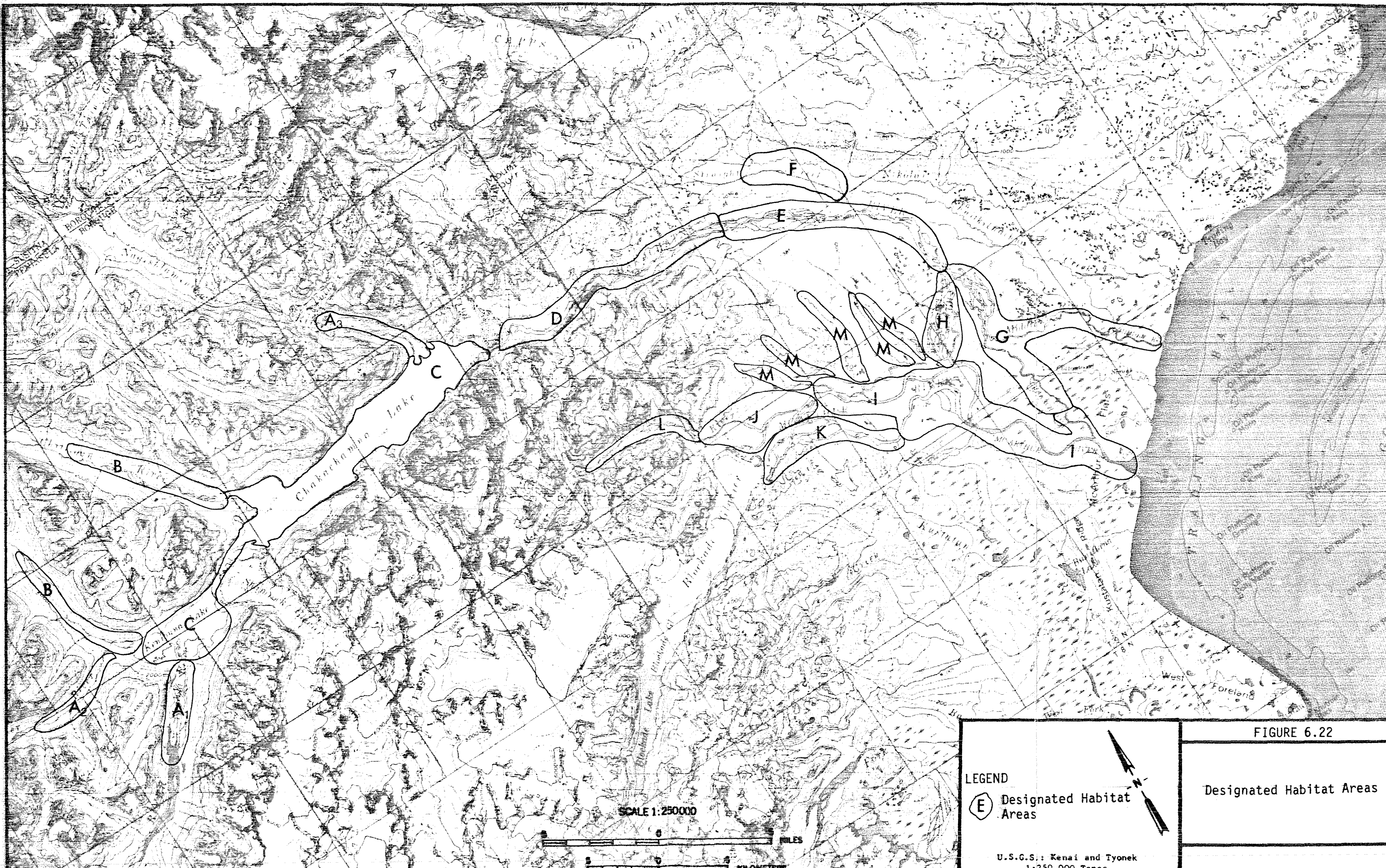


FIGURE 6.22

Designated Habitat Areas

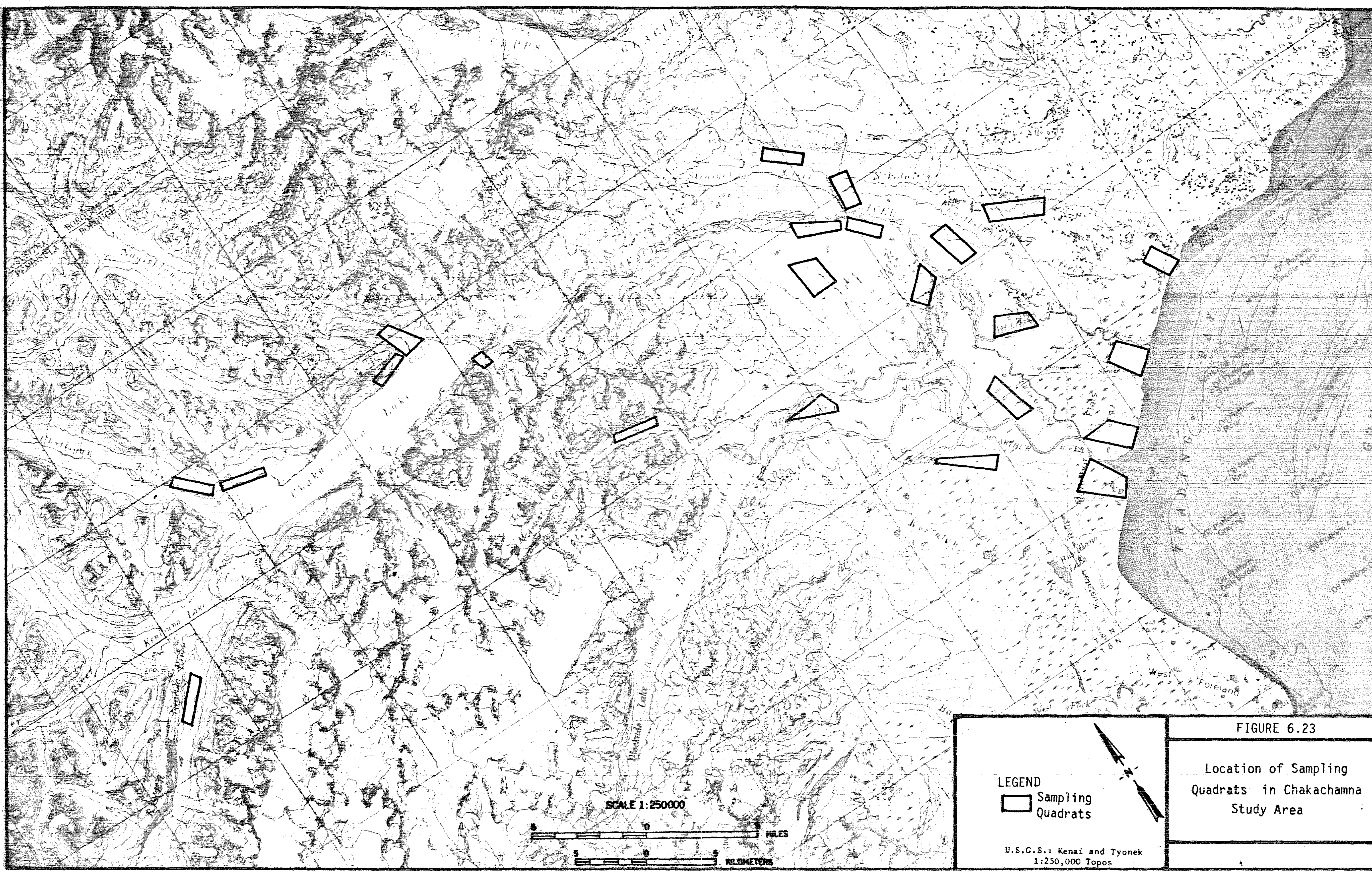


FIGURE 6.23

Location of Sampling Quadrats in Chakachamna Study Area

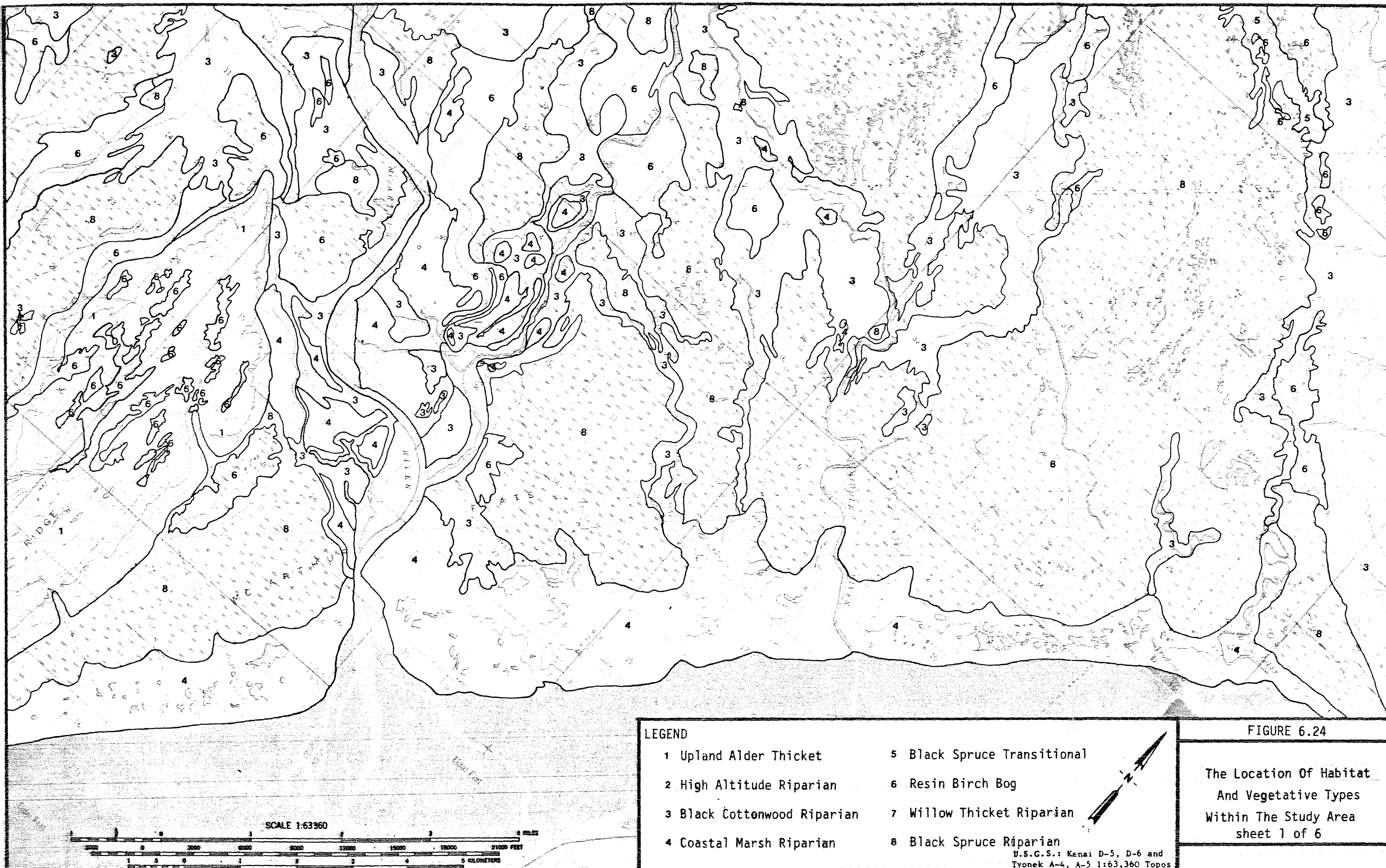
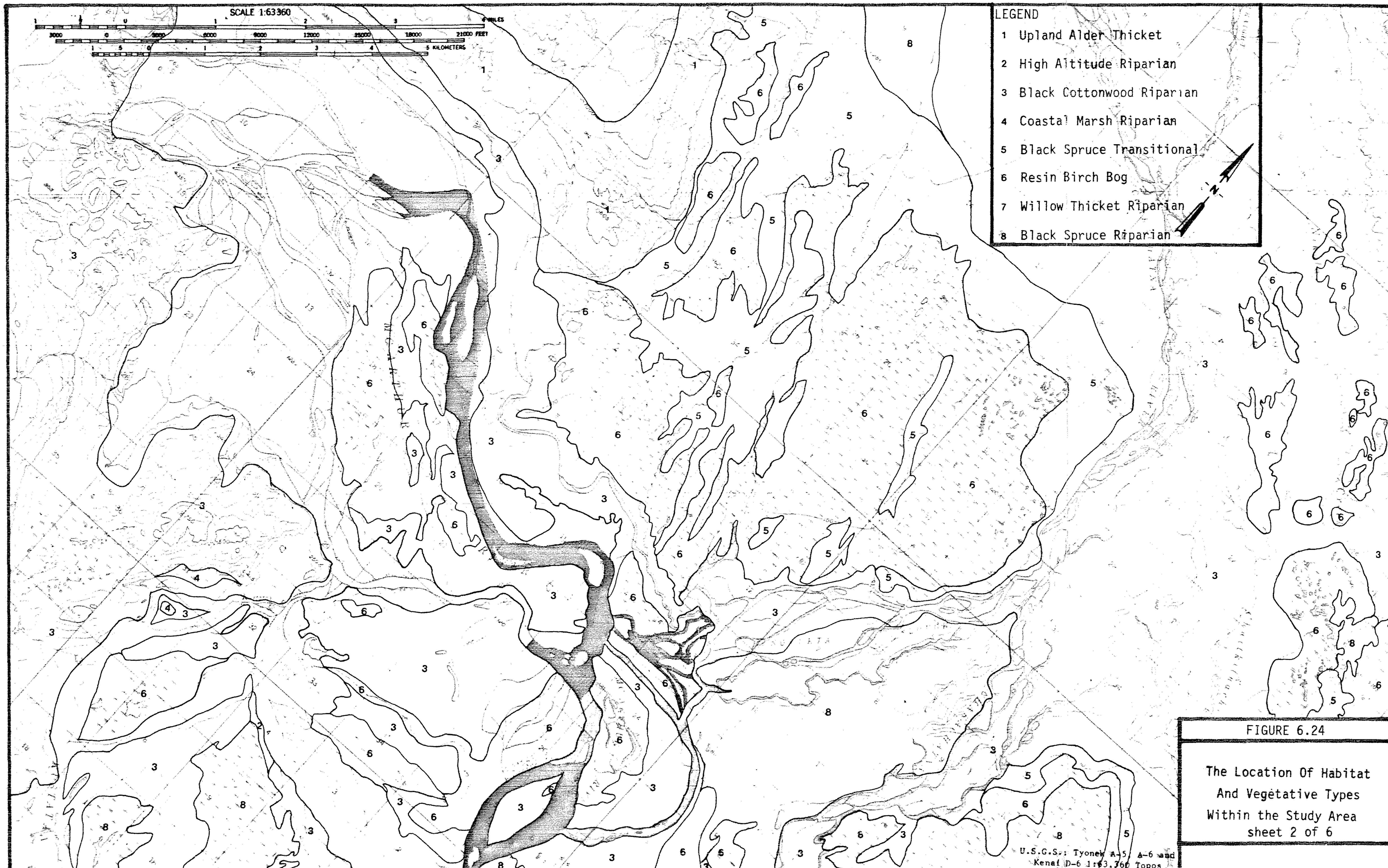


FIGURE 6.24

The Location Of Habitat And Vegetative Types Within The Study Area sheet 1 of 6



SCALE 1:63360
LEGEND
1 Upland Alder Thicket
2 High Altitude Riparian
3 Black Cottonwood Riparian
4 Coastal Marsh Riparian
5 Black Spruce Transitional
6 Resin Birch Bog
7 Willow Thicket Riparian
8 Black Spruce Riparian
N
FIGURE 6.24
The Location Of Habitat And Vegetative Types Within the Study Area sheet 2 of 6
U.S.G.S.: Tyonek A-5, A-6 and Kenai D-6 1:63,360 Topos

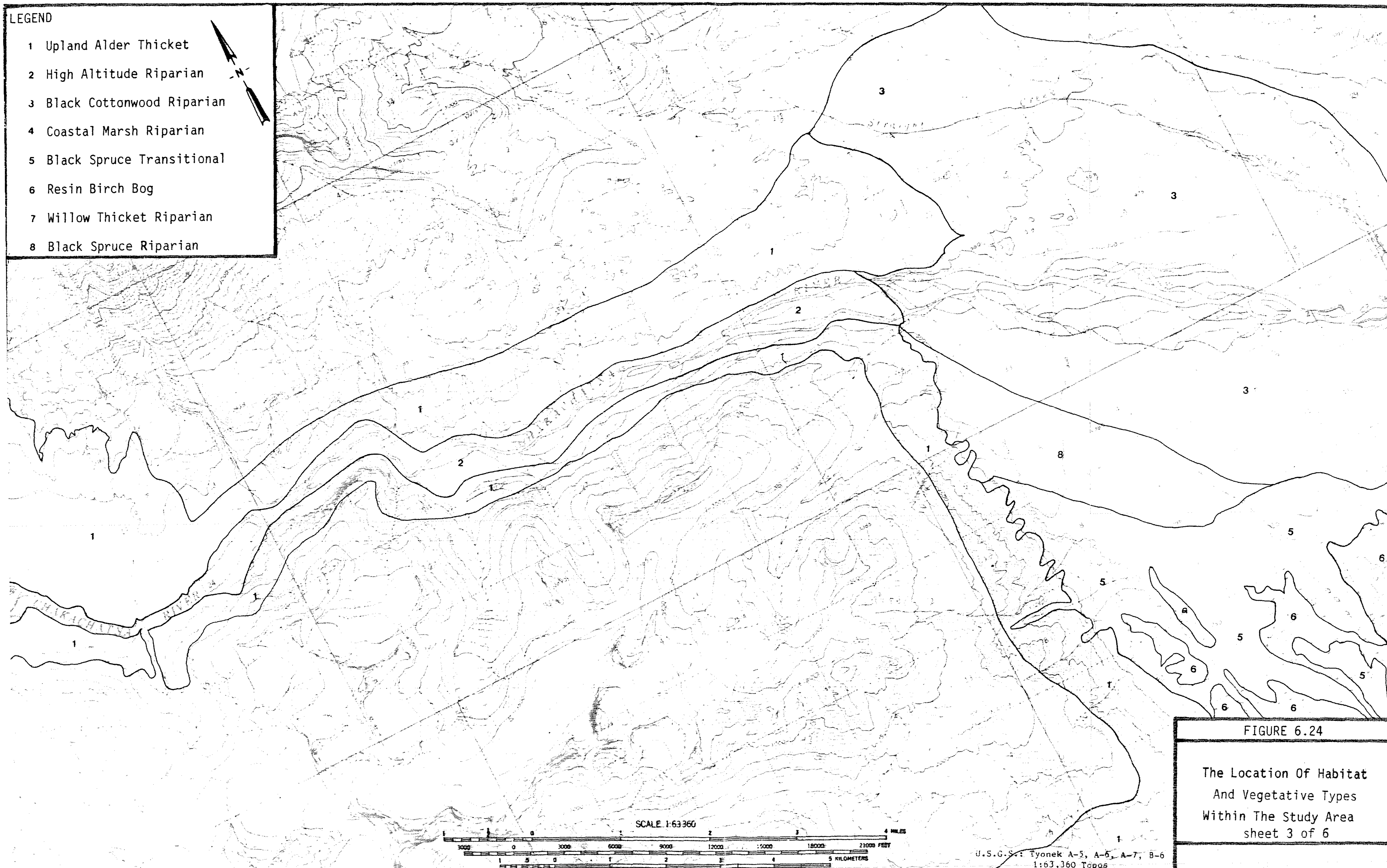


FIGURE 6.24

The Location Of Habitat
And Vegetative Types
Within The Study Area
sheet 3 of 6

FIGURE 6.24

The Location Of Habitat And Vegetative Types Within The Study Area
sheet 4 of 6

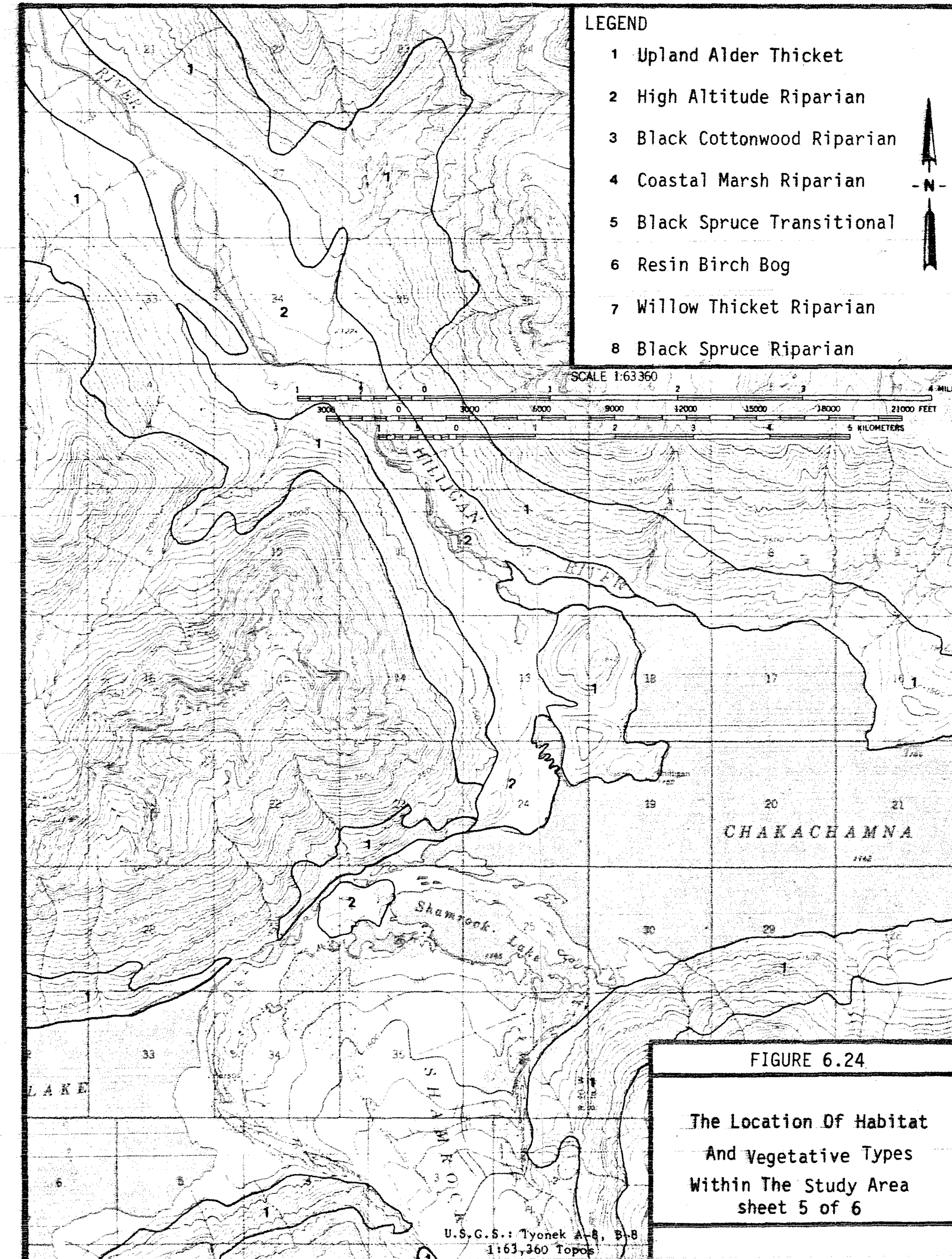


FIGURE 6.24

The Location Of Habitat And Vegetative Types Within The Study Area sheet 5 of 6

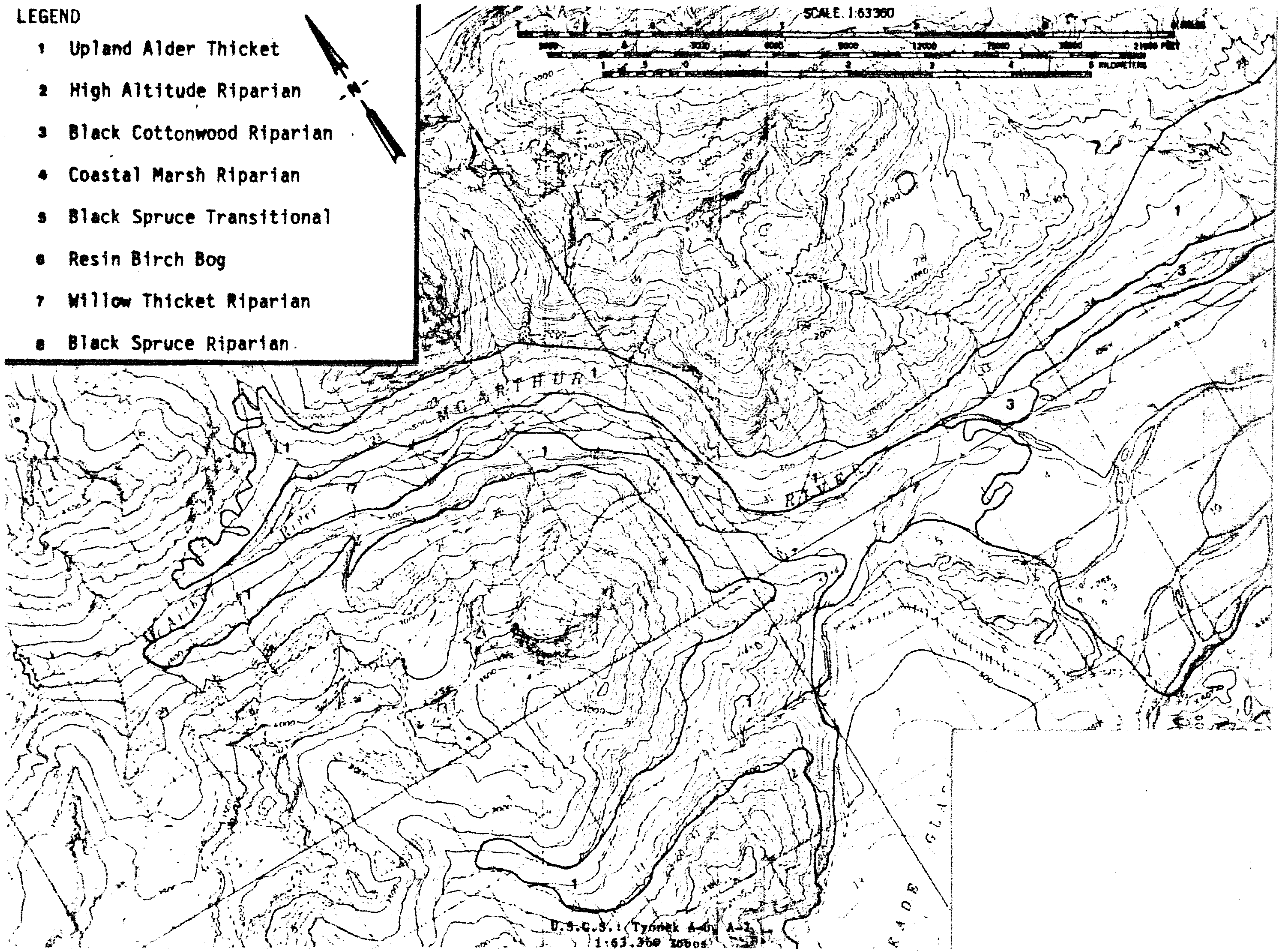


FIGURE 6.24

The Location Of Habitat And Vegetative Types Within The Study Area
sheet 6 of 6

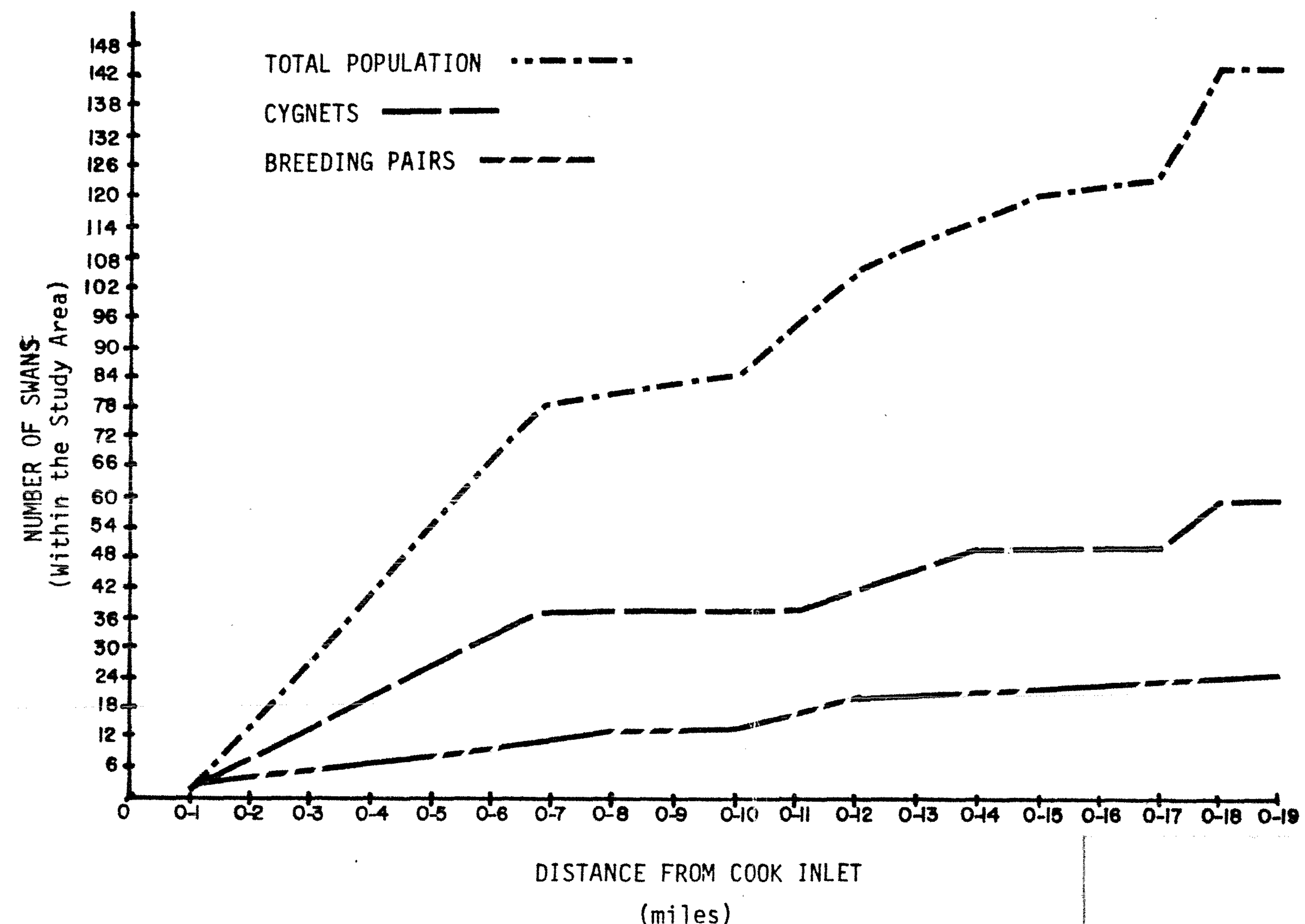


Figure is based on data obtained in a 1980
USFWS survey of the Cook Inlet waterfowl refuges.

FIGURE 6.25

The Cumulative Number of Breeding Pairs Within the Study Area

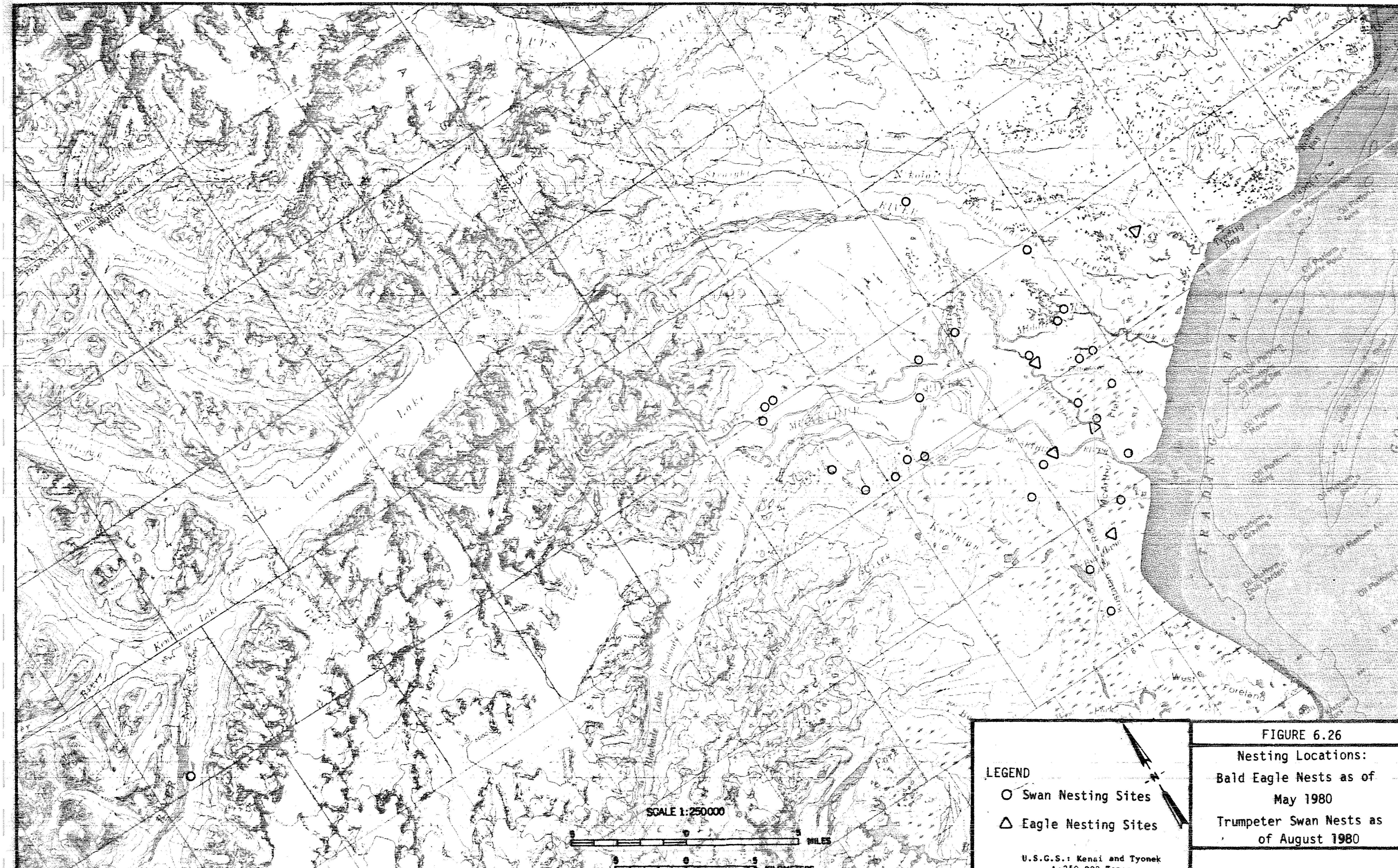


FIGURE 6.26
Nesting Locations:
Bald Eagle Nests as of May 1980
Trumpeter Swan Nests as of August 1980

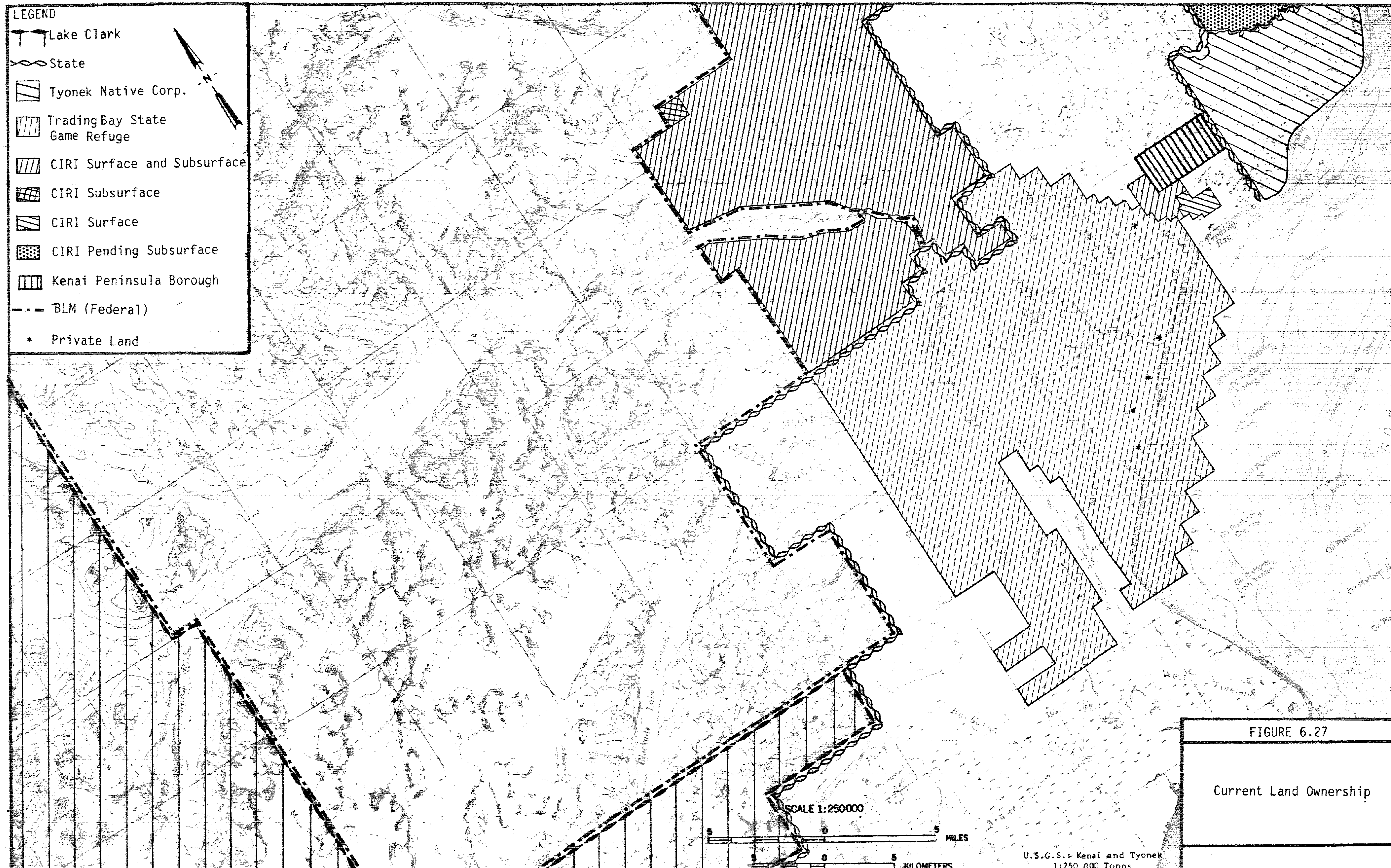


FIGURE 6.27

Current Land Ownership

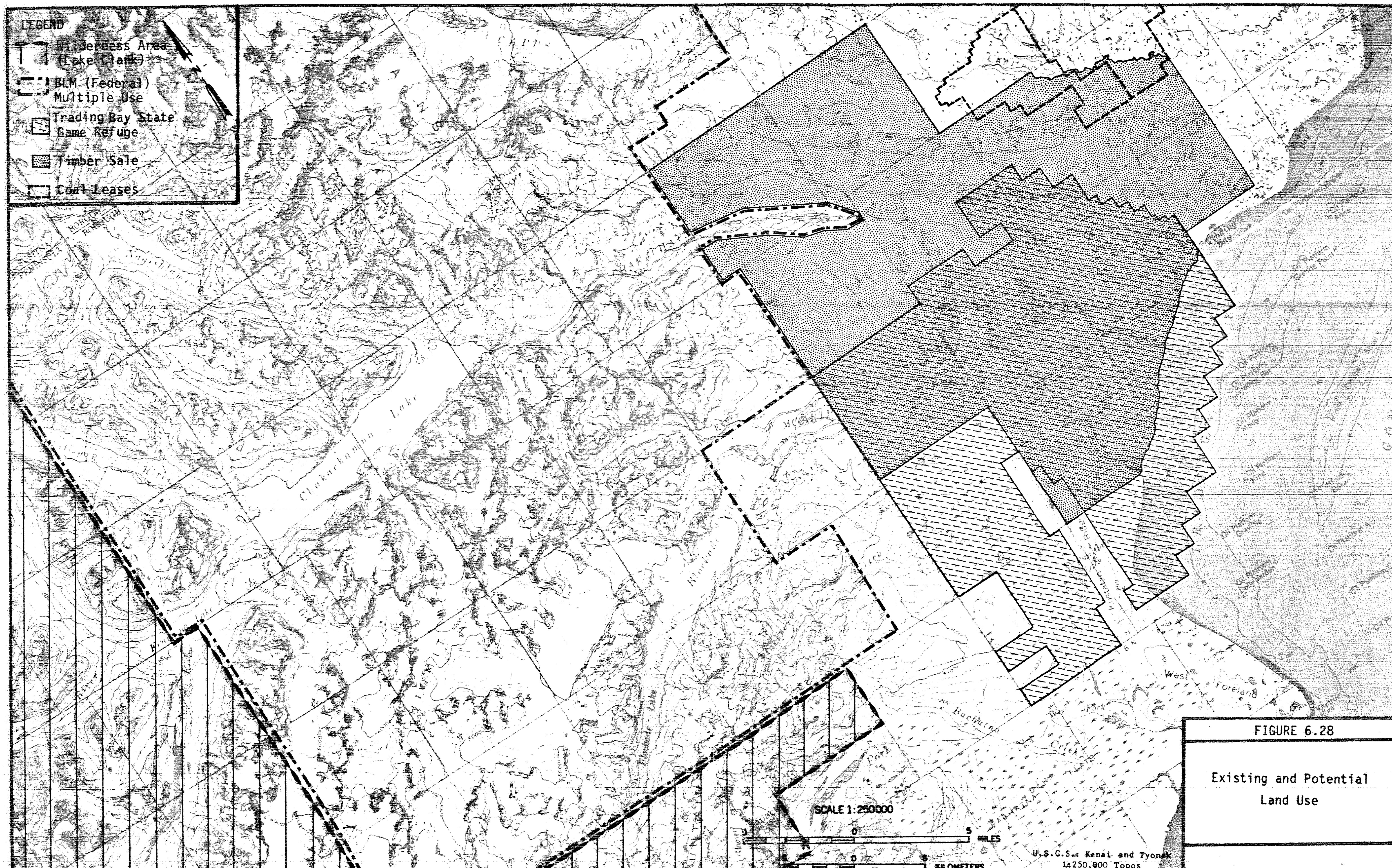


FIGURE 6.28

Existing and Potential Land Use

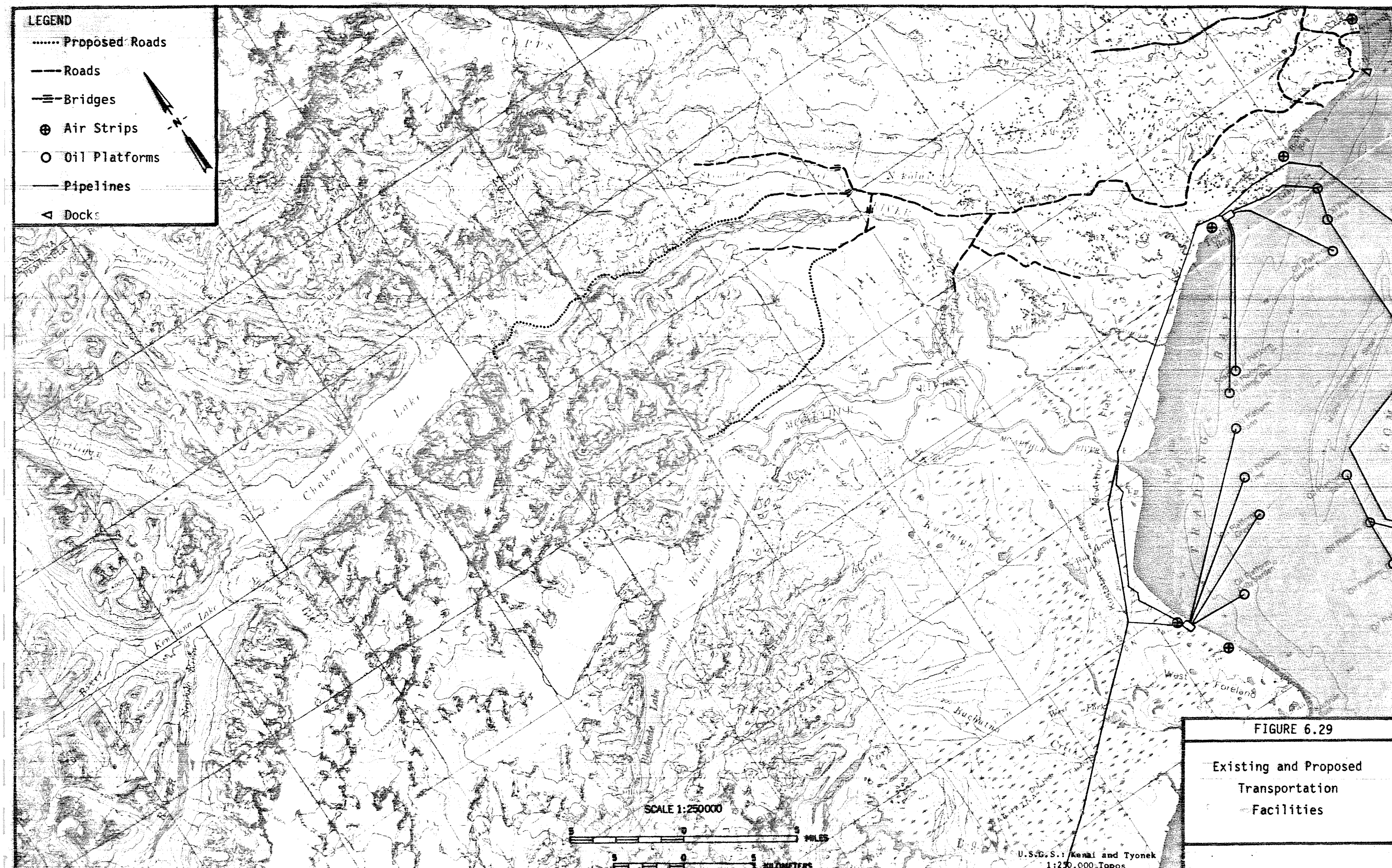


FIGURE 6.29

Existing and Proposed Transportation Facilities

NOTES:

1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS

2.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MECATOR PROJECTION, 1927 NORTH AMERICAN DATUM.

3.) VERTICAL DATUM IS MEAN LOWER LOW WATER.

LEGEND:

—•—•— EXISTING ROAD TO BE IMPROVED

——— EXISTING ROAD

- - - - NEW ACCESS ROAD

2 0 2 4 MILES

SCALE : 1" = 2 MILES

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

ACCESS ROAD

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

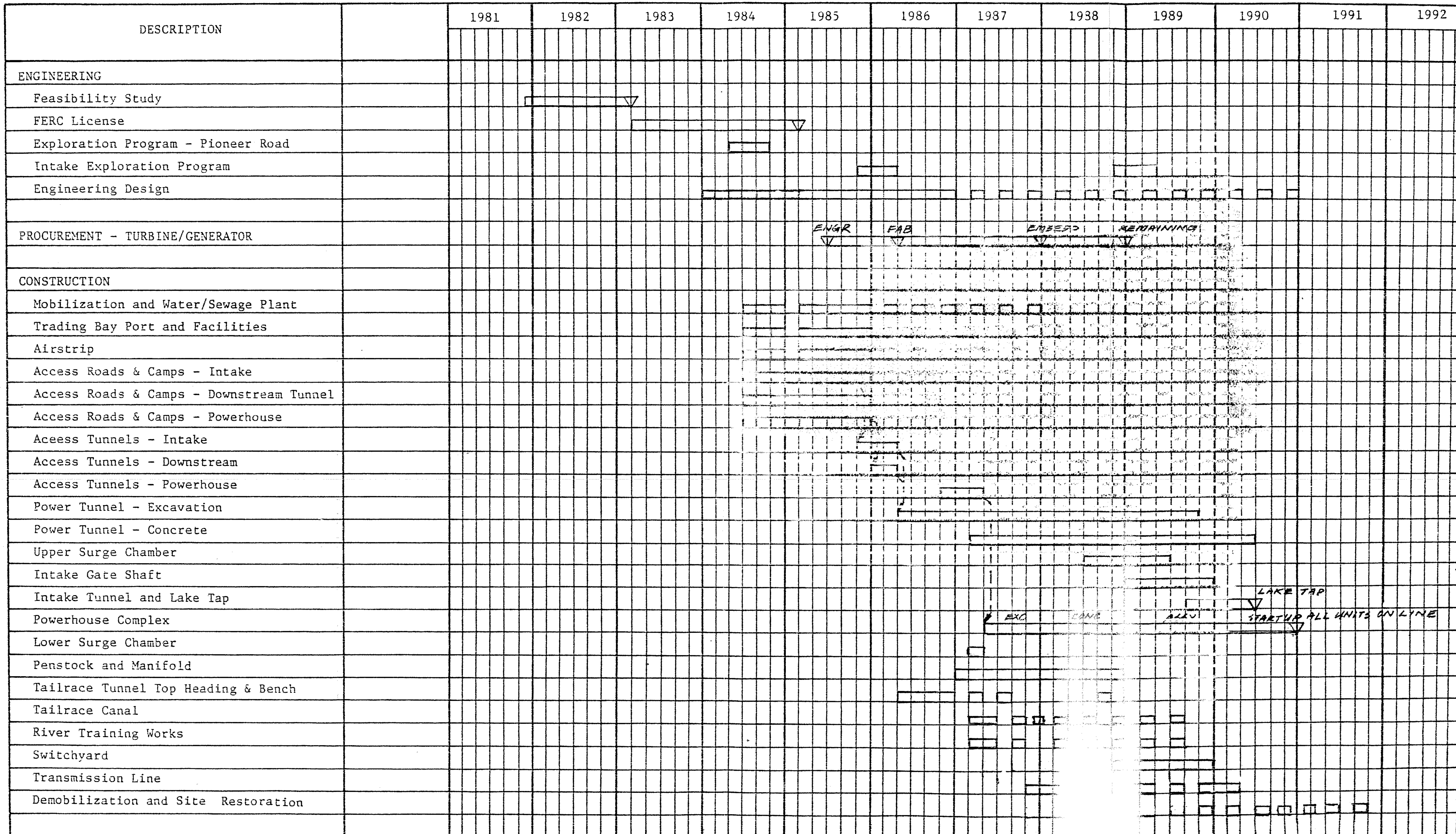
DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D
JOB No. 14879	DRAWING No. FIGURE 8-1	REV. B

CHAKACHAMNA HYDROELECTRIC PROJECT

PROJECT SCHEDULE Alternatives A and B

JOB 14879-001

November 20, 1981



H&CF CE-70 (3-75)

PROJECT SCHEDULE
ALTERNATIVES A AND B
FIGURES 8-2

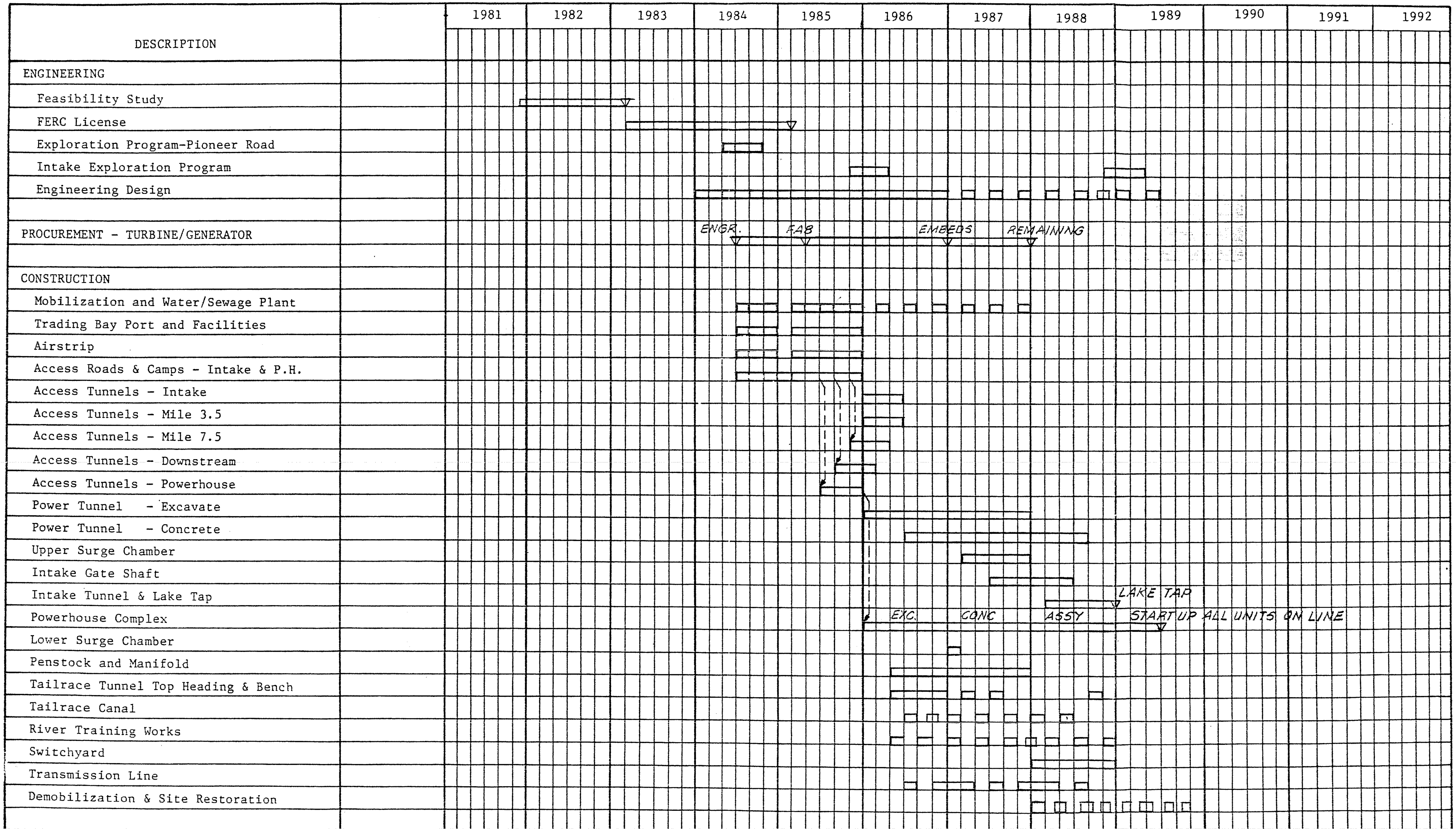
CHAKACHAMNA HYDROELECTRIC PROJECT

PROJECT SCHEDULE

JOB 14879-001

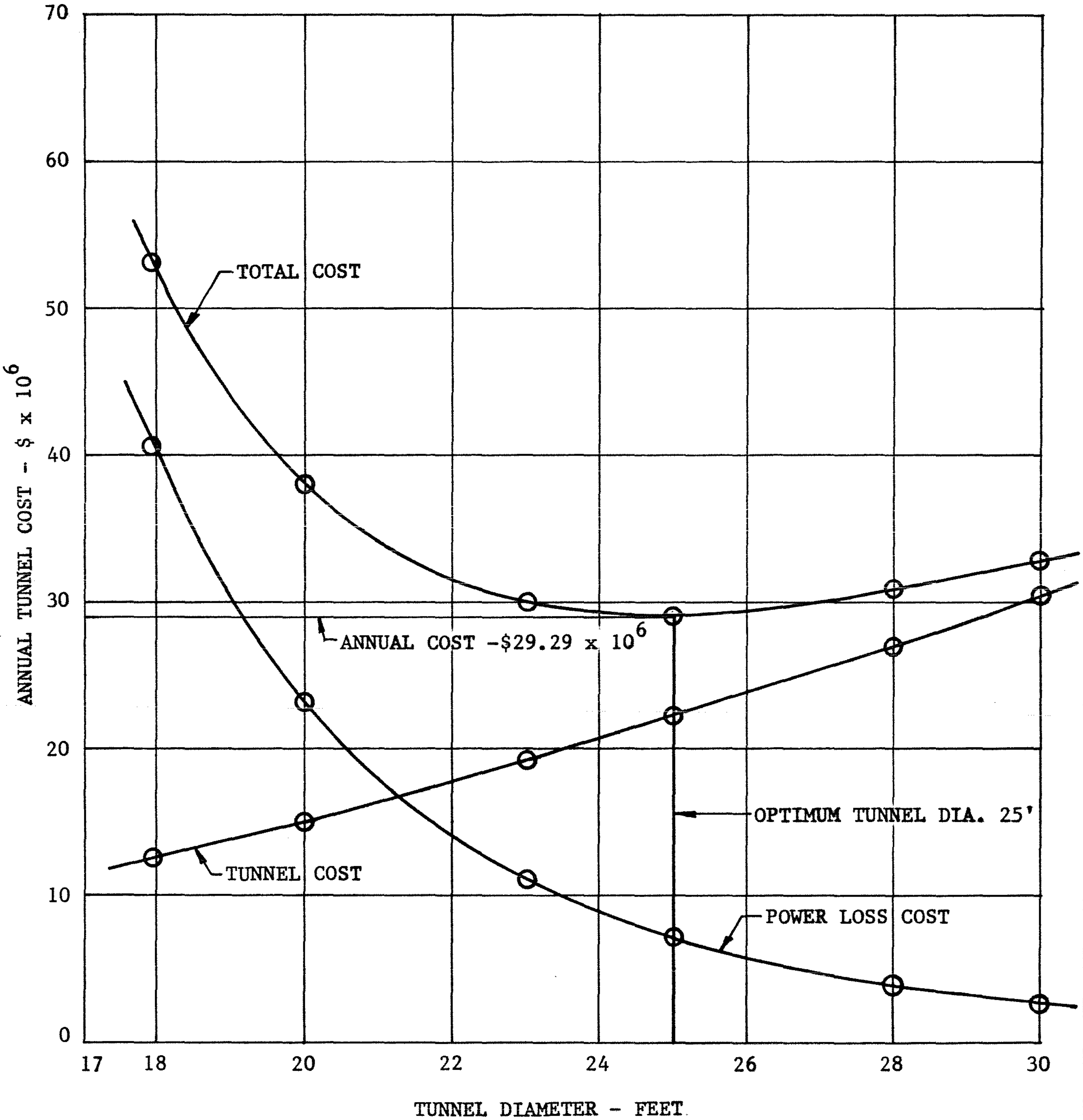
ALTERNATIVES C and D

November 20, 1981



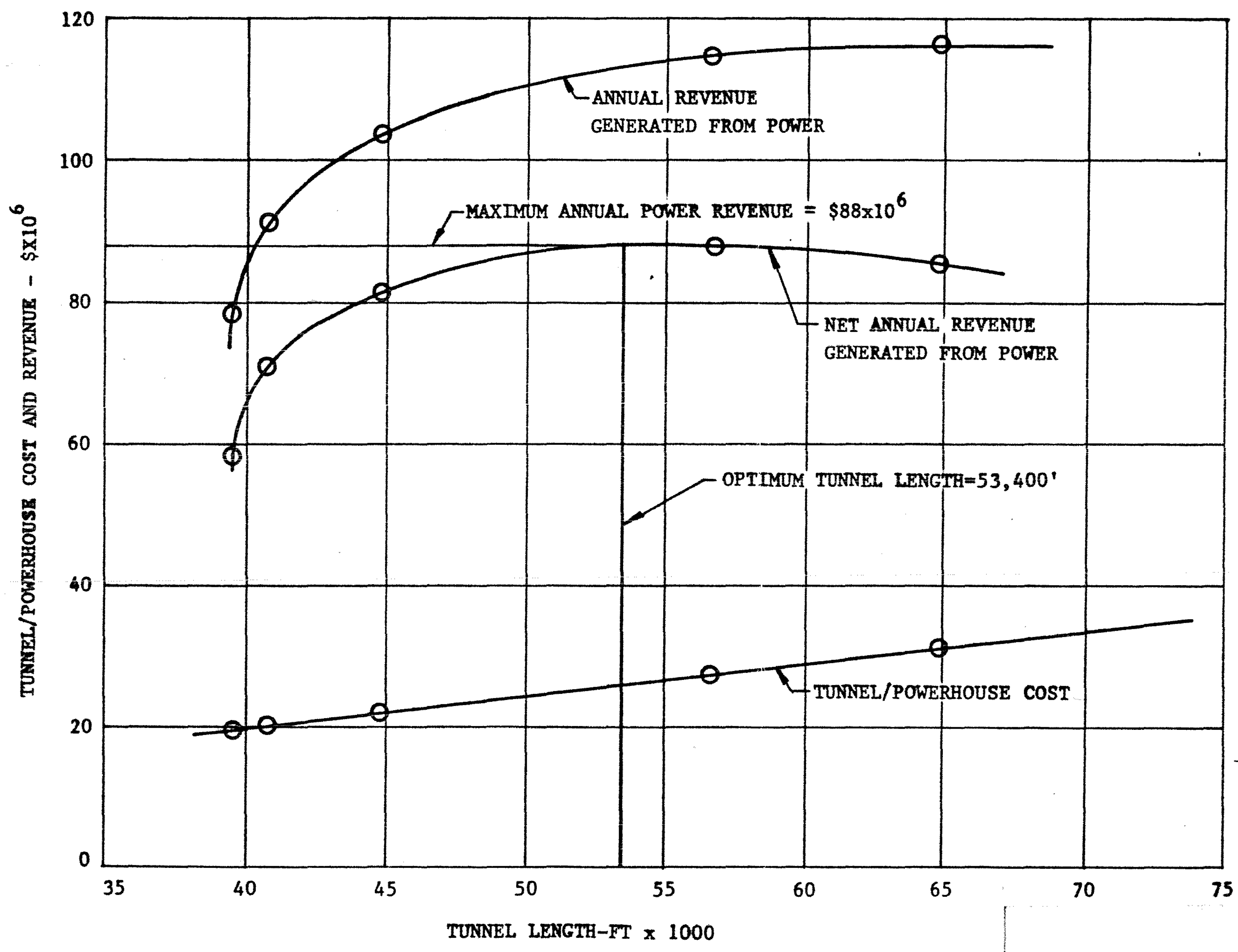
H&CF CE-70 (3-75)

PROJECT SCHEDULE
ALTERNATIVES C AND D



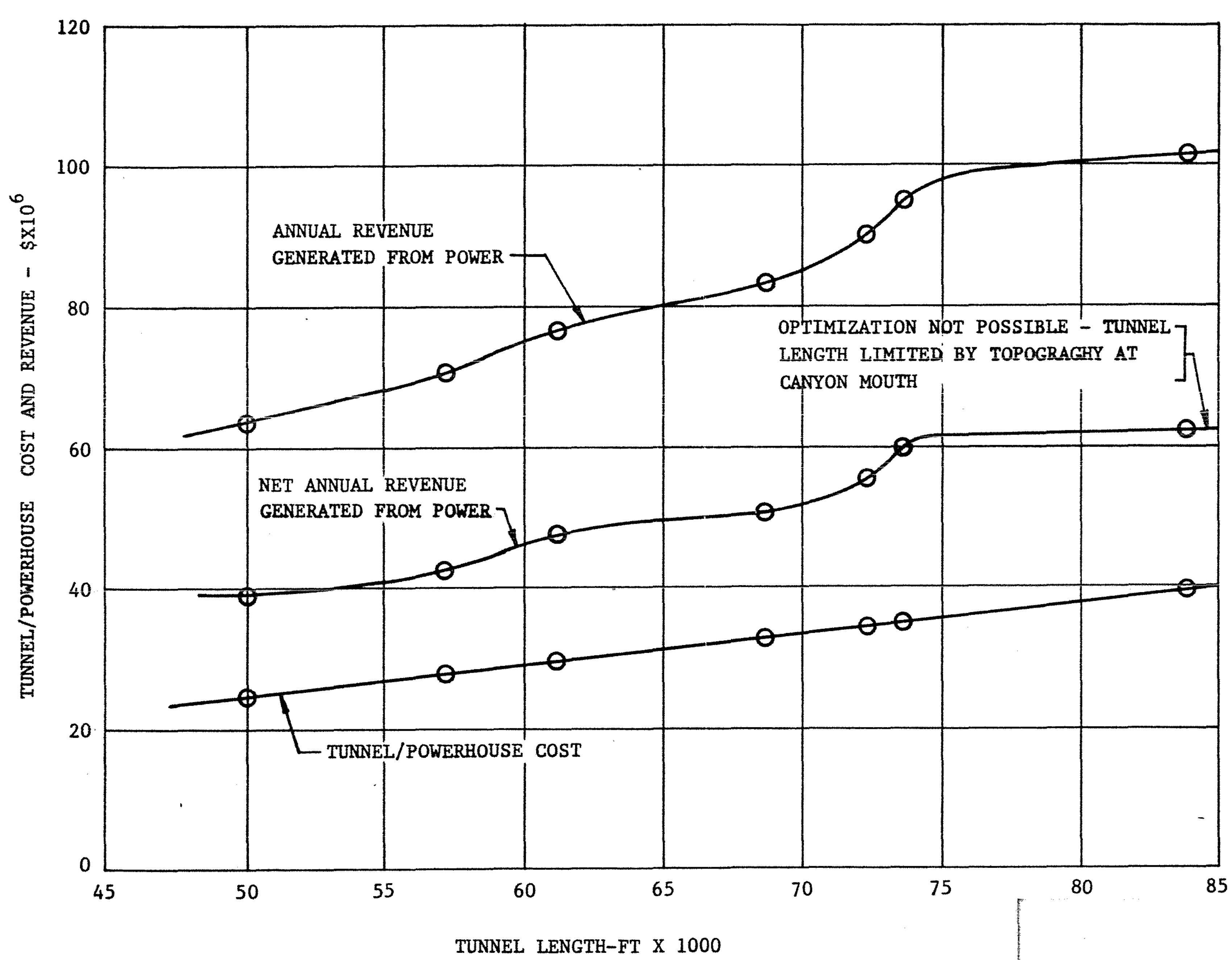
ECONOMIC TUNNEL DIAMETER

FIGURE 9-1



McARTHUR TUNNEL
ECONOMIC LENGTH

FIGURE 9-2



CHAKACHATNA TUNNEL
ECONOMIC LENGTH

FIGURE 9-3