

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, 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 without consideration of raising the lake level above the present outlet channel invert, taken as El. 1128, and a minimum drawdown of the water level to El. 1014.

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 1752 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 GWh.

If a small rock dike were to be constructed at the outlet of the lake and the maximum lake level is raised to the natural maximum, El. 1155, this would allow 72 feet lake drawdown to accommodate fish passage facilities. If the tunnel diameter remained 23 feet to avoid excessive losses, then the installed capacity in the powerhouse would be 330 MW and the average annual firm energy 1301 GWh. The reduction in firm energy is due to the lesser volume of regulatory storage contained within the narrower range of lake level needed for gravity operation of the fish passage facilities.

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 2.5.3.

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 doubts as to the feasibility of damming Chakachatna River by a dam located downstream of the glacier.

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 McArthur Rivers. Records of mean daily flows were initiated in mid-August 1982 at the site of the previously operated U.S. Geological Survey gage site and in the Upper McArthur River downstream from the powerhouse location. 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 in 1981 was elevation 1142 and is typical of the September Lake stage records in the 12 years preceding the major flood of August 1971. Lake bottom profiles were surveyed at the deltas of the Nagishlamina and Chilligan Rivers, and the Shamrock Glacier Rapids.

Reaches of the McArthur and Chakachatna Rivers vary in configuration from mountainous through meandering and braided. All except the most infrequent large floods are mostly contained within the unvegetated flood plan. 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:

<u>Resident:</u>	Rainbow trout	Arctic grayling
	Lake trout	Slimy sculpin
	Dolly Varden	Ninespine stickleback
	Round Whitefish	Threespine stickleback
	Pygmy Whitefish	
<u>Anadromous:</u>	Chinook salmon	Pink salmon
	Chum salmon	Sockeye salmon
	Coho salmon	Dolly Varden
	Eulachon	Rainbow smelt
	Longfin smelt	Bering cisco

Salmon spawning in the Chakachatna River drainage and its tributaries occurs primarily in tributaries and sloughs. A relatively small percentage of the 1982 estimated escapement was observed to occur in mainstem or side-channel habitats of the Chakachatna River.

The largest salmon escapement in the Chakachatna drainage was estimated to occur in the Chilligan and Igitna Rivers upstream of Chakachamna Lake. The escapement of those sockeye in 1982 was estimated to be approximately 41,000 fish, or about 70 percent of the escapement within the Chakachatna drainage. Chakachamna Lake is the major rearing habitat for these sockeye. It also provides habitat for lake trout, Dolly Varden, round whitefish, and sculpins.

In the McArthur River over 96 percent of the estimated salmon escapement occurred in tributaries during 1982. The estimated escapement of salmon of all species was slightly greater in the McArthur than the Chakachatna drainage. Other anadromous fish including eulachon, Bering cisco, longfin smelt and rainbow smelt have been found in the McArthur River.

The contribution of salmon stocks originating in these systems to the Cook Inlet commercial catch is presently unknown. Although some commercial and subsistence fishing occurs, the extent to which the stock is exploited is also not known.

Rearing habitat for juvenile anadromous and resident fish is found throughout both rivers, although the waters within the Chakachatna River canyon below Chakachamna Lake and the headwaters of the McArthur River do not appear to be important rearing habitat. There appears to be extensive movement of fish within and between the two drainages, and seasonal changes in distribution have also been noted.

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 whitefronted goose, which feeds and may nest 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 (lumber, oil and gas), subsistence and the rural residential village of Tyonek.

Recreational activity takes place in the project area, 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 are airstrips at Tyonek and on the shoreline at Trading Bay. A woodchip loading pier is located near Tyonek. Several miles of logging roads exist between Tyonek and the mouth of the Chakachatna Valley; many of these roads and bridges are being removed as timber activities are completed in specific areas. The Chakachatna River was bridged near its confluence with Straight Creek until 1982. There is no permanent road linking the project area with 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 at 50% load factor (1446 GWh) at 43.5 mills/KWh, which is still significantly more economical than the coal fired alternative. Assuming that the power tunnel were to be machine bored, if the maximum pool level of the lake is raised to El. 1155 and can be drawn down to El. 1083, the powerplant will produce 330 MW (1301 GWh) at 44.5 mills/KWh with 45% load factor. In all the 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

Several alternative methods of developing the project were identified and reviewed in 1981. Based on the analyses performed in 1982, the most viable alternative has been identified for further study. That is Alternative E in which water would be diverted from Chakachamna Lake to a powerhouse located near the McArthur River.

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. The cost estimate included an allowance for facilities for downstream flow release and for passage of fish at the lake outlet. Layouts of these facilities were not prepared. Obviously, the long term environmental impacts of the project in this Alternative B are significantly reduced in comparison to Alternative A.

2.5.3 Chakachatna Tunnel Alternatives C and D

An alternative to the development of this hydro-electric 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 flow 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 E and is close to the cost of alternative coal-fired resources. Therefore, it was decided to concentrate further studies on the McArthur River alternatives.

2.5.4 Alternative E

In the development of Alternative B, no specific method was developed for release of instream flows into the Chakachatna River immediately downstream from the lake outlet, and no specific facilities were developed for the passage of upstream and downstream migrant fish at the lake outlet. Instead a lump sum cost allowance was provided to cover these items for Alternative B.

However, in Alternative E which is a refinement of Alternative B, development by tunnel to the McArthur River, specific facilities for providing instream flow releases and fish passage facilities were developed and incorporated into the proposed project structures. To facilitate the arrangement of these facilities, it became evident that a more limited reservoir drawdown was essential. The range of

reservoir level adopted was maximum level El. 1155 near the historical maximum level, and minimum level El. 1083 to permit gravity discharge of water through the facilities at the lowest operating water level.

With this operating range in the reservoir and with an installed capacity of 330 MW, the project can produce 1301 GWh per annum at a 45% load factor. If a 50% load factor were to be retained, the installed capacity of the powerhouse would reduce to approximately 300 MW, which would reduce the overall project cost by about 5-10%. However, at this stage of the project development, such a refinement was not considered warranted, and the same installed capacity as developed for Alternative B was retained for Alternative E, i.e. 330 MW. Significant project data for Alternative E are set forth in Table 2-1.

Alternative E is also based on the power tunnel being driven by a tunnel boring machine which resulted in a significant reduction in cost compared with conventional "drill and shoot" methods previously adopted for Alternatives A through D. In addition, the power tunnel profile in Alternative E was modified to a uniform grade from the intake at Lake Chakachamna to the powerhouse in the McArthur valley. The estimated cost of energy is 44.5 mills per kWh.

It should be noted that the significant saving in tunnel cost for Alternative E, as compared with Alternative B, is offset by the increased cost of the fish passage facilities and slightly lower energy production, thereby yielding a firm energy cost slightly higher for Alternative E than for Alternative B.

TABLE 2-1
 RECOMMENDED ALTERNATIVE E
 PROJECT DATA

Chakachamna Lake

Maximum water level, natural conditions, (ft.)	1,155
Minimum water level, natural conditions, approx. (ft.)	1,128
Surface area at elevation 1155 (sq. mi.)	27
Total volume at elevation 1155 (Ac. ft.)	4,483,000
Drainage area (sq. mi.)	1,120
Average annual inflow, 12 years (cfs)	3,606
Correlated average annual inflow, 31 years (cfs)	3,781

Reservoir Operation

Normal maximum operating water surface elevation (ft.)	1,155
Normal minimum water surface elevation (ft.)	1,083
Active storage (Ac. ft.)	1,105,000

Dike

Type	Overflow rockfill
Length, (ft.)	600
Crest elevation (ft.)	1,177
Maximum height (ft.)	49
Volume (Cu. yd.)	250,000

Spillway

Type	Free overflow
Crest elevation (ft.)	1,155
Discharge capacity (cfs)	55,000

Power Tunnel

Type	Circular, concrete lined
Diameter, internal (ft.)	24
Hydraulic capacity (cfs)	7,200
Surge chamber (Dia. x Ht. Ft.)	48 x 450

TABLE 2-1 (cont'd)

Penstock

Number/Type	1-Circular, concrete lined 4-Circular, steel lined
Diameter, internal (ft.)	
Concrete lined	24
Steel lined	10

Powerhouse

Type	Underground
Cavern size (L x W x H Ft.)	250 x 65 x 130
Turbines	4 Vertical Francis
Generators	Synchronous
Unit output (MW)	82.5
Maximum net head (ft.)	938
Minimum net head (ft.)	866
Maximum discharge (cfs)	7,200
Distributor centerline elevation (ft.)	190
Installed capacity (MW)	330
Average annual firm energy (GWh)	1,301
Average annual secondary energy (GWh)	290
Load factor	.45

Fish Passage Facilities

Maximum release (cfs)	1,094
Minimum release (cfs)	343
Fish passage tunnel (L x W x H Ft.)	7800 x 18 x 20

Economic Parameters

Estimated total cost \$ billion	1.31
Cost of energy (mills per kWh)	44.5
Cost per installed kW (\$)	3,985
Construction period (Mos.)	76