STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

Steve Cowper, *Governor*

Judith M. Brady, *Commissioner*

Robert B. Forbes, *Director and State Geologist*

December 1986

Report of Investigations 86-13

PRELIMINARY FEASIBILITY STUDY OF A COAL MINE AT CHICAGO CREEK, ALASKA SUMMARY REPORT

By
R.M. Retherford, T.K. Hinderman,
and C.C. Hawley

STATE OF ALASKA
Department of Natural Resources
DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

According to Alaska Statute 41, the Alaska Division of Geological and Geophysical Surveys is charged with conducting 'geological and geophysical surveys to determine the potential of Alaskan land for production of metals, minerals, fuels, and geothermal resources; the locations and supplies of ground water and construction materials; the potential geologic hazards to buildings, roads, bridges, and other installations and structures; and shall conduct such other surveys and investigations as will advance knowledge of the geology of Alaska.'

In addition, the Division of Geological and Geophysical Surveys shall collect, record, evaluate, and distribute data on the quantity, quality, and location of underground, surface, and coastal water of the state; publish or have published data on the water of the state and require that the results and findings of surveys of water quality, quantity, and location be filed; require that water-well contractors file basic water and aquifer data, including but not limited to well location, estimated elevation, well-driller's logs, pumping tests, flow measurements, and water-quality determinations; accept and spend funds for the purposes of this section, AS 41.08.017 and 41.08.035, and enter into agreements with individuals, public or private agencies, communities, private industry, and state and federal agencies; collect, record, evaluate, archive, and distribute data on seismic events and engineering geology of the state; and identify and inform public officials and industry about potential seismic hazards that might affect development in the state.

Administrative functions are performed under the direction of the Director, who maintains his office in Fairbanks. The locations of DGGS offices are listed below:

.794 University Ave.
(Basement)
Fairbanks, 99709
(907)474-7147

.3601 C St. (8th fl.)
P.O. Box 7028
Anchorage, 99510
(907)561-2020

.400 Willoughby Center
(3rd fl.)
Juneau, 99801
(907)465-2533

.Fish Hatchery Road
P.O. Box 772116
Eagle River, 99577
(907)696-0070

This report is for sale by DGGS for $4. DGGS publications may be inspected at the following locations. Mail orders should be addressed to the Fairbanks office.

.794 University Ave.
(Basement)
Fairbanks, 99709

.3601 C St. (8th fl.)
P.O. Box 7028
Anchorage, 99510

.400 Willoughby Center
(3rd fl.)
Juneau, 99801

CONTENTS

FIGURES

TABLES

PRELIMINARY FEASIBILITY STUDY OF A COAL MINE AT CHICAGO CREEK, ALASKA
SUMMARY REPORT

by
R.M. Retherford,[1] T.K. Hinderman,[1] and C.C. Hawley[1]

SIGNIFICANT FINDINGS

On the basis of results of the 1985 and previous drilling programs, the potentially mineable identified coal resource at Chicago Creek is about 4.7 million short tons, of which 1.5 million can be mined at a stripping ratio of 1.7:1. The remaining 3.2 million short tons have a stripping ratio of 4:1 to 5:1. The heating value of Chicago Creek coal averages 6,800 Btu/lb on an as-received basis, but the samples contained excess surface moisture; therefore, the actual heat content of the mined coal will probably be closer to 7,500 Btu/lb. Other coal parameters are compatible with the proposed thermal use: about 8 percent ash, about 0.8 percent sulfur, and fusibility temperatures that exceed 2,200°F.

A review of current and future growth trends and energy requirements for the city of Kotzebue suggests moderate, continued growth. By 1990, assuming a 30-yr mine life, the electrical needs of Kotzebue (not including heating) can be satisfied by 23,000 short tons of Chicago Creek coal per year (assuming 6,500 Btu/lb and 25-percent plant efficiency). By 2020, Kotzebue's energy needs may exceed 150,000 short tons/yr. To simplify mining, transportation, and electrical-power-generation feasibility studies, this report assumes a fixed production rate that is an average of the total forecast requirement over 30 yr, rather than a production rate based on a steady increase. We assumed two basic scenarios: 1) supplying the requirements of Kotzebue with an average of 50,000 short tons of coal per year; and 2) supplying the electrical-energy requirements of Kotzebue and the proposed Red Dog Mine with an average of 150,000 short tons of coal per year. A simplified financial analysis was made of the coal-mining, coal-burning, and electrical-generation systems at the two production rates. The analysis assumed 10.5-percent interest, full capitalization within 2 yr, amortization over 30 yr, 15-percent return on investment, and no inflation or royalties.

Mining-cost estimates assume modern open-pit mining methods, purchase of new equipment, and maximum use of local labor. Estimated mining costs, including delivery of coal to a stockpile located 10 mi north on tidewater at Willow Bay, will range from $28/short ton at the higher production rate to $74/short ton at the lower production rate. The estimated cost of transporting the coal by barge from Willow Bay to Kotzebue and delivering it to a covered stockpile ranges from $14 to $22/short ton at the higher and lower production rates, respectively.

The choice of a power-plant location near Kotzebue was based on three arguments: 1) barging the coal will be cheaper than transmitting the energy; 2) construction and operation costs for a plant at Chicago Creek will be higher than at Kotzebue; and 3) integration with the existing power system

[1]Hawley Resource Group, Inc., 7011 Old Seward Highway, Anchorage, Alaska 99518.

will be simpler. Appraisal of alternative plant configurations suggests that currently available, rebuilt electrical-power-generation facilities can be installed much less expensively than new equipment. In addition, because older rebuilt systems tend to be smaller multiboiler units, they will be more adaptable to the needs of an expanding Kotzebue. Therefore, we examined two alternative electrical-generation systems for each of our basic-demand scenarios. One alternative assumes the power is generated by newly manufactured boilers of 10 MW capacity; the other alternative assumes that smaller rebuilt 7.5 kW boilers are used.

The cost per kilowatt hour for energy at the busbar (generating plant) was calculated for four cases. Costs ranged from $0.18 to $0.07/kWh, decreasing substantially for the higher demand scenario. Diesel-powered electrical-power-generation cost was $0.155/kWh in 1984. With a production rate of 50,000 short tons/yr, a coal-fired facility will be marginally competitive. However, providing power to the Red Dog Mine and using a rebuilt plant facility will cost half that of the present system. Power can be transmitted to the Red Dog Mine for about $0.03/kWh with the total delivered cost about $0.11/kWh.

This preliminary feasibility study demonstrates that coal-fired electrical-power generation is an attractive alternative for Kotzebue and that a mine at Chicago Creek can provide the coal. Coal can also be supplied from more distant sources; for energy requirements of 50,000 short tons or less, the delivered cost per short ton of coal will probably be cheaper from other sources. Coal from more distant sources can make coal-fired electrical-power generation attractive for Kotzebue without the added load of the Red Dog Mine. However, at the higher production rate for the combined energy requirements of Kotzebue and the Red Dog Mine, the Chicago Creek coals will become very competitive at an estimated $42/short ton delivered, or an equivalent $3.20/million Btu.

This study is preliminary, and changes in the assumptions will affect the results. Three factors can increase the cost: 1) the increasing cost of meeting environmental regulations (for example, the Surface Mining Act and Environmental Protection Agency Air Quality Regulations); 2) lower future energy requirements of Kotzebue; and 3) lower than predicted as-mined coal quality. On the other hand, other potential differences or alternatives can enhance the economics of the Chicago Creek coal: 1) a possible higher average heat content of the coal suggested by differences between as-received and equilibrium-bed moisture analyses; 2) the effect of barge ownership by the mining company or utility as opposed to the contractural arrangement considered here; 3) additional demand for coal for direct heating; and 4) the option of increasing mine production slowly (for example, beginning with a smaller operation and an accompanying smaller capital outlay). If energy requirements continue to grow as predicted, finance costs will decrease.

The confidence level of the estimates contained in this report is about ±15 percent. Assuming that the true cost of coal-fired electrical-power generation is as much as 20-percent higher than we have calculated, it still remains very competitive with today's cost of diesel power and is worthy of further consideration.

ACKNOWLEDGMENTS

We acknowledge the help and cooperation of the people of Deering, especially the Karmen and Moto families, and those in Kotzebue, particularly John Schaeffer and the people at NANA Regional Native Corporation (NANA). Without their support, the field portion of this project could not have been done. We also owe particular thanks to Virgil and Mike Vial, Ken Upchurch, and Rhinehart Berg for their help with logistics. G.R. Eakins and the staff at the Alaska Division of Geological and Geophysical Surveys were very supportive, and we owe them special thanks for their trust and patience. In addition, Eakins' careful edit substantially improved the text.

We also acknowledge a special debt to a member of our study team, Ralph R. Stefano, who passed away in August 1985. This study incorporates some of his last professional efforts. Despite the daily discomfort he faced during his illness, he was extremely generous in sharing his wealth of experience and knowledge. Ralph's courage and indomitable spirit stand as an inspiration to us all.

INTRODUCTION

This report summarizes the technical considerations and conclusions of a study that addresses the feasibility of providing electrical power to Kotzebue and nearby villages using coal mined at Chicago Creek, about 8 mi south of Kotzebue Sound. It draws on the results of two seasons of field work by Hawley Resource Group, including drilling, geologic mapping, and downhole and surface geophysical surveys. Data from previous studies are also used. A more comprehensive discussion with technical details, calculations, and appended field data can be found in Retherford and others (1986).

In early 1985, Hawley Resource Group personnel convened a group of consultants with specific engineering experience to conduct a preliminary analysis of the feasibility of using coal from the Chicago Creek area for electric power for Kotzebue and northwestern Alaska. The study group addressed all aspects of production and use of Chicago Creek coal, including market demand, mining, transportation, power generation, and electrical transmission. They also touched on other pertinent factors, such as geotechnical considerations, financial analysis, and the permitting process. In June and July 1985, a field-exploration program at Chicago Creek included 7,709 ft of rotary drillings; 224 ft of core were recovered in the core-drilling phase of the program. This program supplemented information from field programs in 1982 and 1983 and increased resource estimates substantially.

Location

The Chicago Creek coal deposit is located on the northeastern part of the Seward Peninsula, about 70 mi south of Kotzebue (fig. 1). The proposed mine site is on Chicago Creek, about 1¼ mi east of its confluence with the Kugruk River, and about 8 mi south of the coast of Kotzebue Sound.

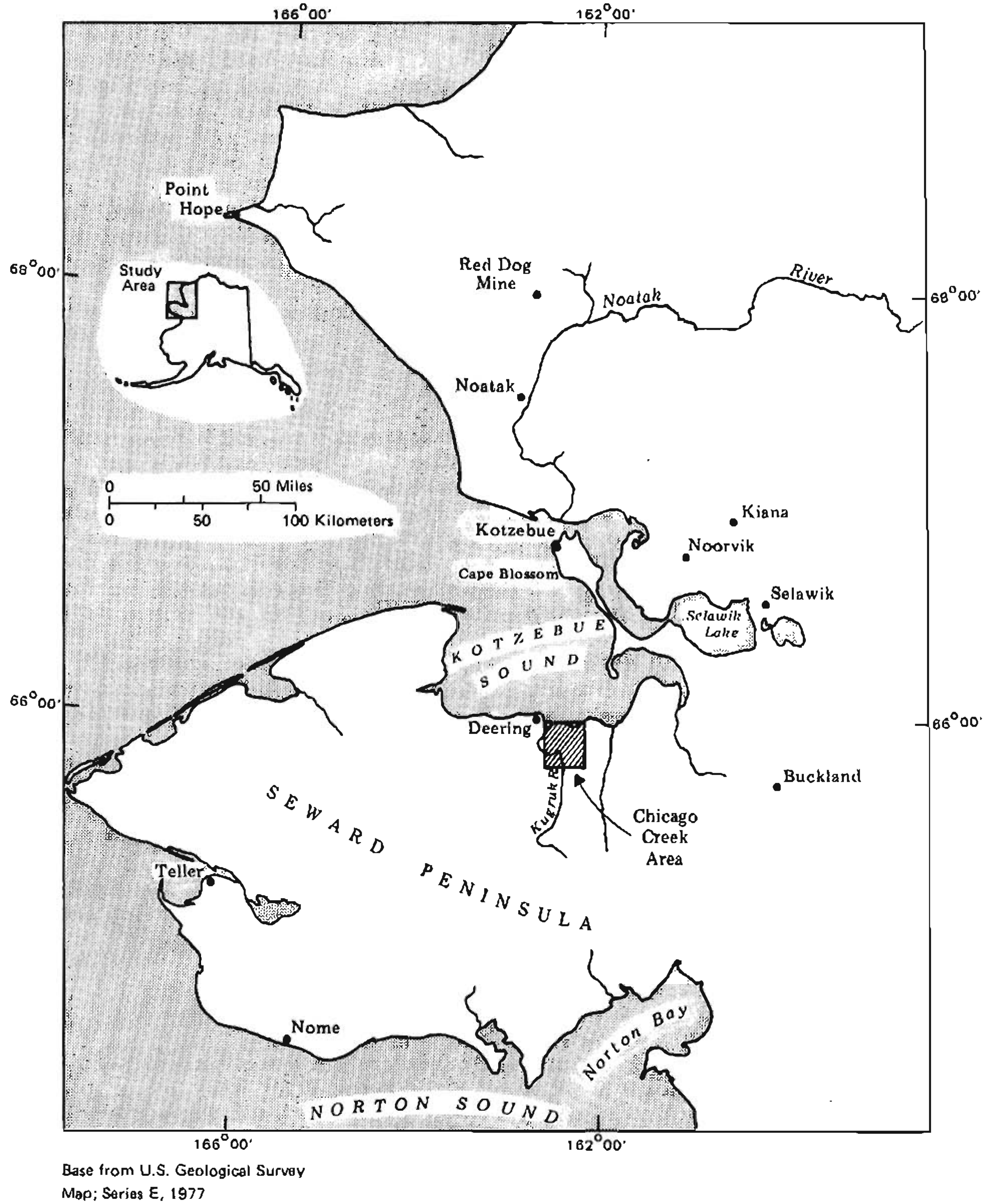


Figure 1. Regional map showing the location of the Chicago Creek study area, northwest Alaska.

Land Status

The lands of the Chicago Creek coal field (fig. 2) were selected by NANA and the village corporation of Deering under the terms of the Alaskan Native Claims Settlement Act. The lands were conveyed to the corporations on an interim basis by the U.S. Bureau of Land Management. Although the subsurface resources technically belong to NANA and the surface resources to Deering village, NANA and its villages have a cooperative agreement on the authorized uses of the surface and subsurface of Native-conveyed land. NANA, Kotzebue, and other nearby villages are strongly interested in the development of local coal resources and have designated an access route through their property from Chicago Creek to the coast in anticipation of future coal development.

Active federal placer-mining claims pending patent and native-allotment applications have been filed on land near the coal field. The claims and allotments may become fee-simple land. These transfers will not affect the site of the Chicago Creek coal mine, but may influence the location of construction-material sites or transportation routes.

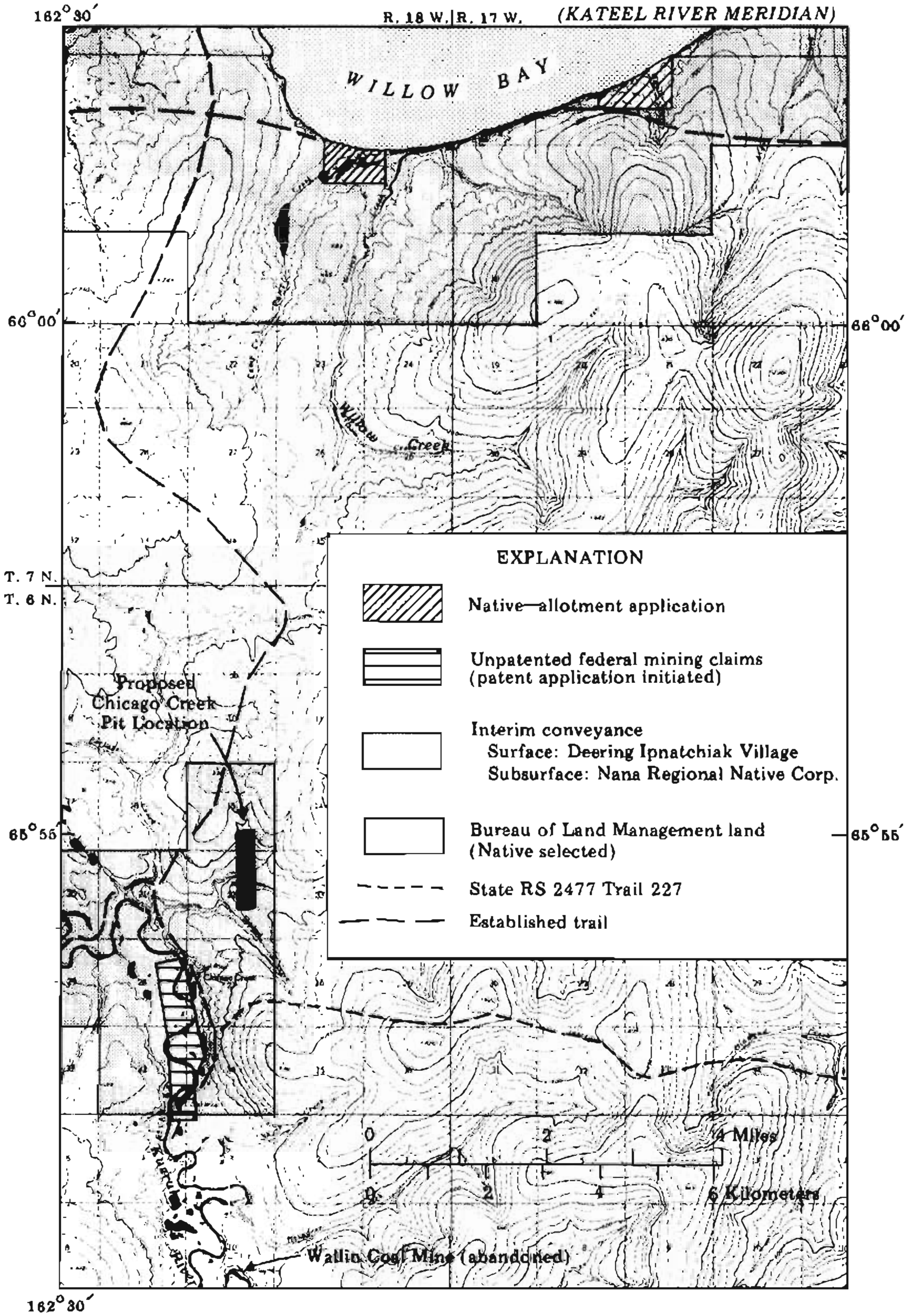
History of the Chicago Creek Coal Mine

Coal was first discovered on Chicago Creek by gold prospectors in 1902 (Moffit, 1906). Some development work was conducted that year, but coal was in little demand until the winter of 1904-05 when gold was discovered on the terraces above Candle Creek. A need arose for a fuel source to steam-thaw placer ground. The coal deposit was staked in 1905, and production began in 1908. The mine was operated during the winter months only and was sealed during the summer to prevent thawing and subsequent ground instability. The mine had an estimated total production of up to 100,000 short tons through 1911 when it was abandoned (Toenges and Jolley, 1947).

Previous Investigations

During the late 1970s and early 1980s, the State of Alaska funded several programs to investigate new energy sources and innovative ways to use traditional fuels in remote regions. One study (R.W. Retherford and Associates, 1980) suggests that coal could be a cost-effective energy alternative for the Kotzebue Sound area.

The Retherford study sparked interest in the coal reserves of the Kotzebue area. In 1982, a state-funded exploration program that included 1,637 ft of drilling was conducted at Chicago Creek by Denali Drilling, Inc., and Stevens Exploration Management Corporation (Manning and Stevens, 1982). Drilling included 520 ft of core and 1,117 ft of rotary drilling in 14 separate holes. Forty samples were collected, and proximate analyses were performed. In 1983, a continuation of the program by C.C. Hawley and Associates, Inc., included 2,800 ft of rotary drilling (Ramsey and others, 1983). No coring was done in 1983, but 68 samples were collected from 14 holes; 35 of the samples were within the coal beds. These samples were submitted to DGGS, but no analyses were performed. All holes were geophysically logged.



Base from U.S. Geological Survey
Bendeleben D—1 and Kotzebue A—1
Quadrangles, Alaska.

Figure 2. Land status of the Chicago Creek area.

Present Study

The study described in this report began in December 1984. Personnel involved were C.C. Hawley, R.M. Retherford, T.K. Hinderman, J.P. Hawley, and W.E. Shoemaker (Hawley Resource Group, Inc.). Several consultants were also involved: R.R. Stefano, a power-plant engineer; R.W. Retherford and Tom Humphrey, electrical engineers with backgrounds in electrical transmission; R.W. Christensen, a civil engineer; and John Wood, a mining engineer experienced in operating coal mines in Alaska. Henry Springer (Alaska Department of Transportation and Public Facilities) commented on aspects of the transportation system, and John Rense and Burton Greist (NANA) provided information on Kotzebue and the NANA region. In addition, study sessions were initially attended by Dave Denig-Chakroff and Brent Petrie (Alaska Power Authority). Because of the contract deadline, it was necessary to obtain most of the consultants' input before the field phase of the program.

Field studies were conducted in June and July of 1985 to refine information on the reserves and geology of the coal deposit. A track-mounted air-rotary drill contracted from Thrasher and Associates of Nome was transported to Candle in a Hercules aircraft; from there it was driven overland to Chicago Creek. In all, 50 rotary holes were drilled for a total of 7,709 ft. A total of 224 ft was cored in 9 holes, and 152 ft were recovered. A total of 5,353 ft of the rotary holes was geophysically logged using downhole-probe equipment operated by Nancy Hanneman of Fairbanks. Thirty-seven samples from the coring program and another eight from cuttings were submitted for proximate analysis.

The engineering consultants drafted reports in their areas of expertise; these were edited for inclusion in a comprehensive report (Hawley Resource Group, 1985). Hawley Resource Group condensed pertinent sections of the comprehensive report for this summary report and updated it to reflect the results of the 1985 field work.

MARKET DEMAND

Recent reports by Dames and Moore Consulting Engineers (1981, 1983), Arctic Slope Technical Services and others (1982), Arctic Slope Consulting Engineers (1984), and International Engineering Company (1985) contain estimates of electrical-load growth for Kotzebue. Some studies also contain direct-heat energy demands for Kotzebue and electrical and heating demands for nearby villages. In this study, the power demand of the Red Dog Mine project is also considered. The mining company currently plans to generate its own power, but will consider buying power from a reliable commercial source if the price is competitive. In addition to use in electrical-power generation, coal can also be burned for direct heat. The potential demand for such heating coal is addressed in the report by Arctic Slope Technical Services (1982), wherein a significant additional demand for such coal is forecast. For simplicity and because of the uncertainty involved in conversion of home heating systems, this study ignores coal for heating.

Table 1 summarizes what we consider to be reasonable electrical-need projections for Kotzebue, the Red Dog Mine, and nearby villages. The demands for various years are expressed in megawatt hours (MWh), and the energy equivalent is in short tons of Chicago Creek coal.

GEOLOGY

Much of the northeastern Seward Peninsula is underlain by marine metasedimentary rocks of probable Paleozoic age. These rocks have been deformed and subjected to greenschist-facies metamorphism through a series of tectonic events that are not well understood. Complex folding within the Paleozoic sequence is evidence of at least one major compressional event. It is also clear that broad structural warping began to occur by mid-Cretaceous time as there are several examples of gentle basins filled with continental sediments that range in age from recent Quaternary through Cretaceous. Major zones of weakness such as the Kugruk fault, which bisects and deforms the relatively young Chicago Creek coals, document a still later episode of tectonism.

East of the Chicago Creek area, the crystalline metamorphic rock units are juxtaposed against and locally overlain by Cretaceous sediments of the Yukon-Koyukuk province. According to Patton (1973), these sediments are locally coal-bearing; in the past, the Chicago Creek coals were correlated with them. On the basis of palynology (Hideyo Haga, Micropaleo Consultants, written commun., 1984) and geologic similarity to other coal deposits of known age, it seems more likely that the coal-bearing sediments of the Chicago Creek area are Tertiary in age (Ramsey and others, 1983).

Bedrock in the Chicago Creek area is mantled by 5 to 35 ft of loess that is covered by tundra. Consequently, geology and reserve estimates discussed in this section are based almost entirely on information from the drilling programs. Figure 3a is an interpretive geologic map of the bedrock units as they occur beneath the overburden; representative cross sections are shown in figure 3b.

Lithologic Units

In the Chicago Creek area, five bedrock units were distinguished on the basis of scattered outcrops along Chicago Creek, cored sections of the coal unit and overlying shale, and examination of rotary cuttings.

Gravel, sandstone, and siltstone

The stratigraphically youngest unit in the Chicago Creek area consists primarily of interbedded, poorly consolidated gravel, sandstone, and siltstone of fluvial origin. The unit appears to truncate the coal bed in some cases and is probably of Pleistocene age.

Gray and brown siltstone, mudstone, and sandstone

The coal beds of the Chicago Creek area occur in a sequence of poorly consolidated, gray and brown siltstone and mudstone with local sandy beds and rare layers of fluvial gravel. The unit contains medium- to dark-brown carbonaceous layers, many of which grade into coal beds. Toward the bottom, the unit grades into weathered schist and then into fresh schist.

Table 1. Electrical needs for Kotzebue, the Red Dog Mine, and nearby villages.

Location	1985	1990	2000	2010	2020
Kotzebue[a]					
MWh	15,000	23,000	44,000	72,000	150,000
short tons[b]	15,690	24,060	46,030	75,330	156,930
Red Dog Mine[c]					
MWh	110,000	110,000	110,000	110,000	110,000
short tons	115,080	115,080	115,080	115,080	115,080
Noatak[d]					
MWh	660	790	---	---	---
short tons	690	830	---	---	---
Kiana[d]					
MWh	860	1,025	---	---	---
short tons	900	1,080	---	---	---
Selawik[d]					
MWh	961	1,145	---	---	---
short tons	1,005	1,205	---	---	---
Noorvik[d]					
MWh	1,065	1,270	---	---	---
short tons	1,114	1,340	---	---	---
Buckland[e]					
MWh	374	455	---	---	---
short tons	391	470	---	---	---
Deering[f]					
MWh	374	445	---	---	---
short tons	391	470	---	---	---
Teller[c]					
MWh	640	765	---	---	---
short tons	670	800	---	---	---
Nome[c]					
MWh	20,300	28,650	---	---	---
short tons	21,315	30,080	---	---	---

[a] Developed from International Engineering Company, 1985.
[b] All short tons assume 6,500 Btu/lb and 25-percent plant efficiency.
[c] Data from Cominco (J. Booth, oral commun., February 1986).
[d] Developed from Alaska Power Administration data, 1984.
[e] Developed from International Engineering Company, 1981.
[f] Estimate based on unpublished data collected by R.M. Retherford in 1985.

Lignitic coal

Coal beds in the Chicago Creek area range from a few inches to several tens of feet thick. Most mineable reserves occur in a single bed that reaches up to 100 ft in apparent true thickness; however, some of this thickness may be due to structural repetition. On the basis of Btu/lb and carbon content, the coal is a high-grade lignite.

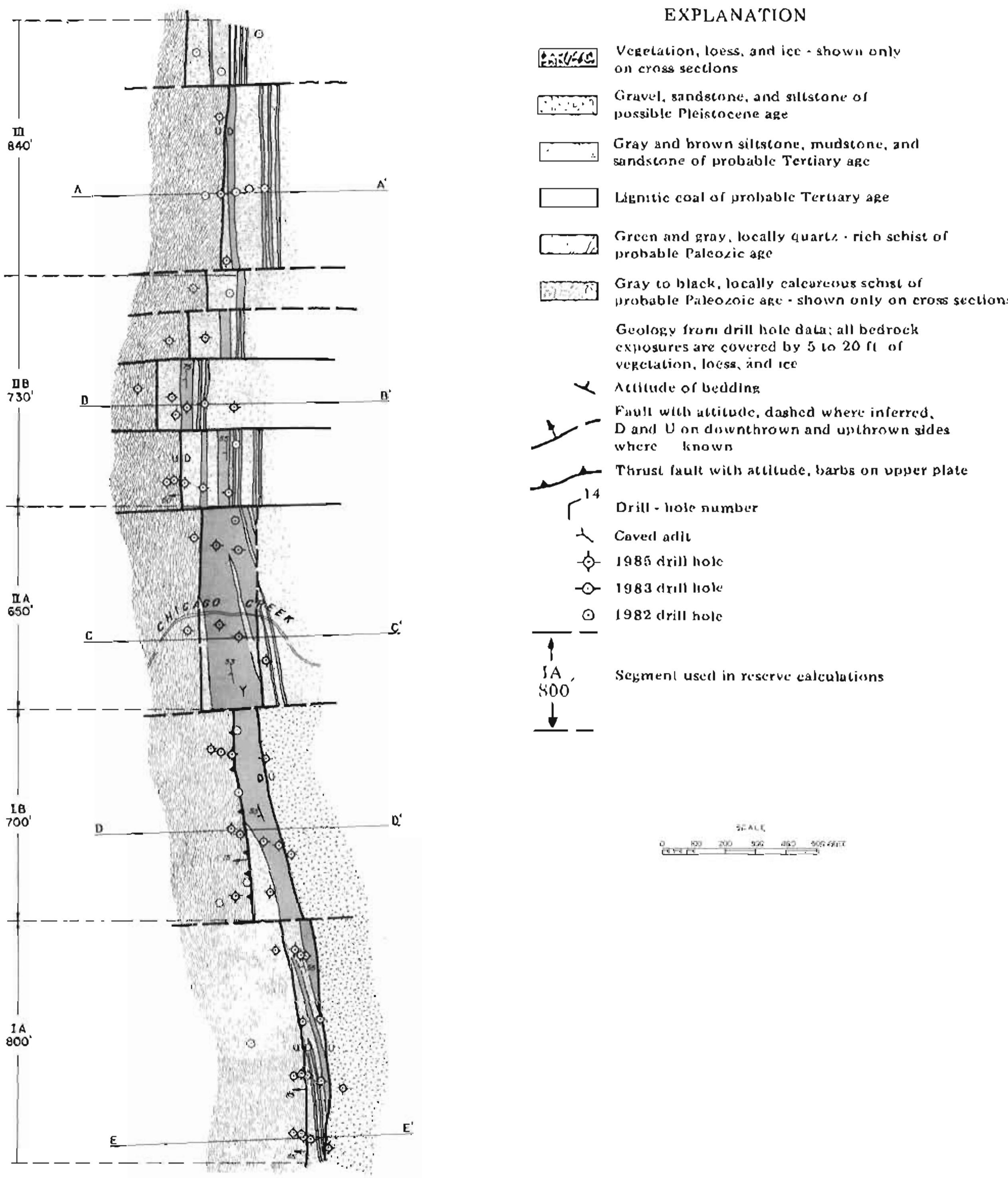
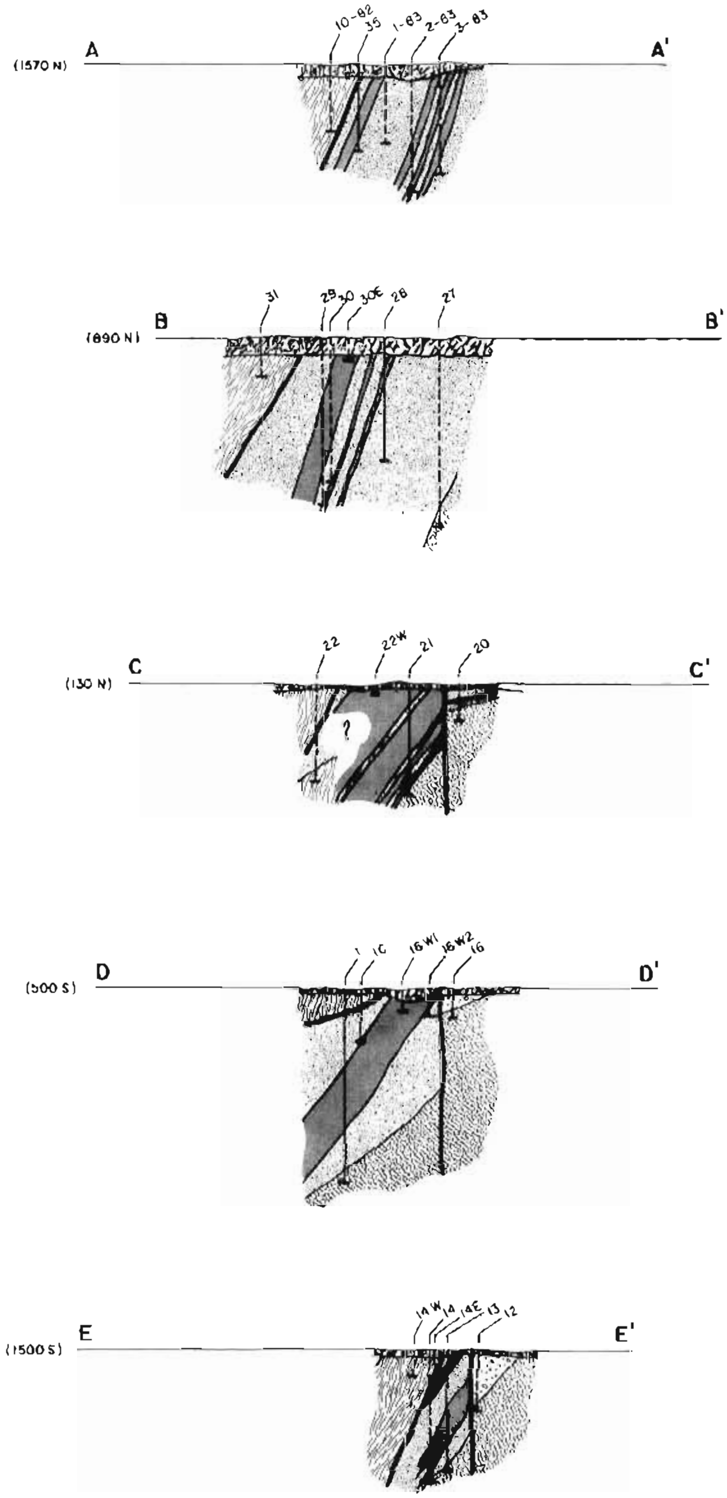


Figure 3a. Interpretive geologic map of the bedrock units beneath overburden in the Chicago Creek study area.



(Vertical scale no exaggeration;
horizontal scale 1.4 x exaggeration)

Figure 3b. Cross sections of bedrock units in the Chicago Creek study area. From Retherford and others (1986).

The largest coal bed has a distinctive parting that averages 3 ft thick and is located about two-thirds below the top of the bed. Small partings and bony lenses are more common below this main parting.

Green and gray schist

The coal-bearing section is bounded on the west by a heterogeneous quartz-mica schist unit. Where fresh, the schist is predominately green and contains up to 1 percent disseminated sulfide minerals.

Gray to black schist

A relatively homogeneous, gray to black quartz-mica schist unit with local calcareous phases forms the basement of the coal-bearing unit and underlies the gravel unit east of the main coal-bearing section.

Structure

The coal-bearing sediments occur in a narrow, north-trending structural basin with little topographic expression. As shown on cross-section E-E' of the geologic map (figs. 3a,b), the basin narrows to less than 100 ft wide at the southern end. Despite this constriction, it has been traced along strike by drilling for about 8,000 ft. On the basis of geophysics, the basin probably continues to the north for at least another mile. Although the basin appears to pinch out to the south, coal occurs at the Wallin Coal Mine, which is roughly on strike 4 mi south of the last known occurrence at Chicago Creek (fig. 2).

The 1985 drilling was concentrated on the southern end of the known trend, along approximately 3,600 ft of strike length as shown in figure 3a. This part of the basin is bounded on the west by a thrust fault that juxtaposes the Tertiary sediments with the green and gray schist unit. The fault dips west at angles that range from 15° to 85°. Because of this thrusting, part of the coal deposit is actually capped with crystalline basement rocks (section D-D', fig. 3b).

The narrow elongate coal deposits of the Chicago Creek Coal Field suggest they probably formed or at least were preserved in a topographic low controlled by activity along a linear zone of weakness. This zone is parallel to, if not coincident with, the mapped location of the Kugruk fault. From evidence of thrusting and normal faulting found within the coal deposit, it is also evident that structural activity persisted well into Tertiary time.

Coal Quality

From the 1985 program, 37 samples of drill core and an additional eight samples from cuttings were submitted for proximate analysis to the University of Alaska Mineral Industry Research Laboratory (MIRL) in Fairbanks. The samples were tested for heating value (Btu/lb) and moisture, volatile-matter, fixed-carbon, ash, and sulfur content. Because the samples contained a significant amount of surface water, equilibrium moisture was determined on five samples to give a better approximation of expected true bed moisture. The averages of the test results and values for other Alaska coals are shown in table 2.

Table 2. Averages of proximate analyses of Chicago Creek and other Alaska coals.

Source	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	Total sulfur (%)
Chicago Creek, as received	38.64	29.27	27.54	8.55	6,400	0.82
Chicago Creek, equilibrium bed moisture	28.83	30.95	32.43	7.78	7,708	0.83
Cape Beaufort (Arctic Slope Consulting Engineers, 1984)	4.2-6.0	- -	- -	8.0-26.6	9,117-12,287	0.1-0.3
Chuitna River, Beluga Field (Ramsey, 1980)	- -	- -	- -	7.3-18.2	6,782-8,216	0.2-0.3
Usibelli Mine, Healy Field (Denton, 1980)	27	- -	- -	6	8,000	0.2
Bering River Field (Barnes, 1967)	1.0-8.6	13.1-17.4	65.0-91.1	2.1-18.0	11,000-15,000	0.6-3.4

Compared to most Alaska coals, Chicago Creek lignite is low in heating value. The analytical results for moisture content were high probably partly due to melting of contained ice in fractures and lenses after the samples were bagged. Such ice would tend to melt and drain off in a stockpile. This process also occurs at the Usibelli coal operation. The ash content for the Chicago Creek coal is about average for Alaska coals. The sulfur content is somewhat high for Alaska coal, but low to average for coals worldwide.

MIRL also performed ash-fusibility and washability tests on core from the 1982 Denali drilling program. The fusibility tests indicate that the coal can be used without significant problems in any type of firing system; the washability tests indicate that washing will not significantly reduce the ash content of the coal.

Resource Estimation

According to currently used definitions, the Chicago Creek coal is properly classed as a demonstrated resource, which implies a reasonable level of geologic confidence in the quantity present. Demonstrated resources are divided into measured (high-assurance level) and indicated (moderate-assurance level) classes. The relative density of drill holes and sample analyses from the southern part of the Chicago Creek deposit justify the classification of the coal in segments I, II, and III (fig. 3a) as measured demonstrated resources. Additional coal resources to the north that were intercepted by widely spaced drill holes in earlier programs (Ramsey and others, 1983) should probably only be considered as indicated.

On the basis of drill data gathered during and previous to the 1985 field season, the Chicago Creek area contains a total demonstrated resource of at least 4.7 million short tons of coal within 300 ft of the surface (table 3). This figure is a little over 1 million short tons larger than the previous estimate of Chicago Creek coal resources (Ramsey and others, 1983), a reflection of the 1985 discovery of thicker and more continuous coal beds in segments I and II (fig. 3a). The measured demonstrated coal resource within segments I, II, and III is about 2.5 million short tons and will probably be the initial target of any future mining plan.

A magnetometer survey conducted north of the drilled area in the fall of 1984 suggests that the coal basin extends for at least an additional mile past the last drill holes. If an average bed thickness of 20 ft is assumed, the additional mile of strike may contain 1.7 million short tons of coal. The district probably contains still more coal along strike to the north and south. Additional, undiscovered, parallel coal basins may also exist to the east and west.

MINING PLAN

Although other mining methods were considered, environmentally acceptable, modern open-pit mining is probably by far the most economical. This is especially true within the thicker sections of the seam where stripping ratios are less than 2:1. The following discussion is based on an open-pit

Table 3. Estimates of coal resources[a], Chicago Creek, Alaska (see fig. 3a for location of segments).

Segment	Cross-section station or hole used	Mineable strike length (ft)	Average bed thickness (ft)	Density factor	Previously mined (short tons)	Mining depth (ft)	Dip depth (ft)	Demonstrated coal resource (short tons)
IA	1500S	800	37.5	80 lb/ft³	None	100	65	78,000
	1300S			2,000 lb/ton		200	196	235,000
	1100S					300	360	459,000
	880S							
IB	700S	700	85.0	80 lb/ft³	100,000	100	92	218,960
	500S			2,000 lb/ton		200	229	545,020
	250S					300	360	910,000
	130N							
Subtotal of IA and IB						100		196,960
(Less 100,000 short						200		780,020
tons previously mined)						300		1,369,000
IIA	130N	650	83.0	80 lb/ft³	None	100	103	222,274
	420N			2,000 lb/ton		200	240	517,920
	510N					300	392	845,936
IIB	620N	730	34.0	80 lb/ft³	None	100	83	82,400
	890N			2,000 lb/ton		200	195	193,600
	1100N					300	310	307,770
Subtotal of IIA and IIB						100		304,674
						200		711,520
						300		1,153,706
III	1240N	840	18.0	80 lb/ft³	None	100	83	50,200
	1350N			2,000 lb/ton		200	195	117,900
	1570N					300	298	180,230
	1820N							
IV[b]	7-82	1,200	28.0	80 lb/ft³	None	100	141	189,500
	8-82			2,000 lb/ton		200	283	380,350
						300	424	569,850
VA[b]	7-83	1,000	39.0	80 lb/ft³	None	100	141	219,960
	8-83			2,000 lb/ton		200	283	441,480
						300	424	661,440
VB[b]	9-83	2,300	20.0	80 lb/ft³	None	100	141	259,440
	thru			2,000 lb/ton		200	283	520,720
	14-83					300	424	780,160
						100	141	1,220,734
						200	283	2,951,990
	Total (all segments)	8,220	N/A		N/A	300	424	4,714,386

[a]Wood (1981); includes measured and indicated resources.
[b]Segment shown only on plate 1 of Ramsey and others (1983).

design where waste from one section of the pit is backhauled to a previously mined section and used to reclaim the pit to near-original topography. Costs are expressed in 1985 dollars. Although amortization of equipment is included, the cost of financing is not.

Initial Mine Development

Initial mine development will require construction of a haulroad, coal-stockpile pad, airstrip, camp facility, and diversion ditch (fig. 4). Haulroad and camp construction will occur over a 2-yr period. Heavy equipment, fuel, and temporary camp facilities will be delivered to Willow Bay in the fall. Before breakup, the equipment and camp will be moved cross-country to the campsite. Airstrip and haulroad construction will occur the first summer; gravel from the bars and flood plains of the nearby Kugruk River or suitable material from within the pit area will be used. The same equipment used for this initial development will later be used to strip and mine the coal.

Earthfill structures

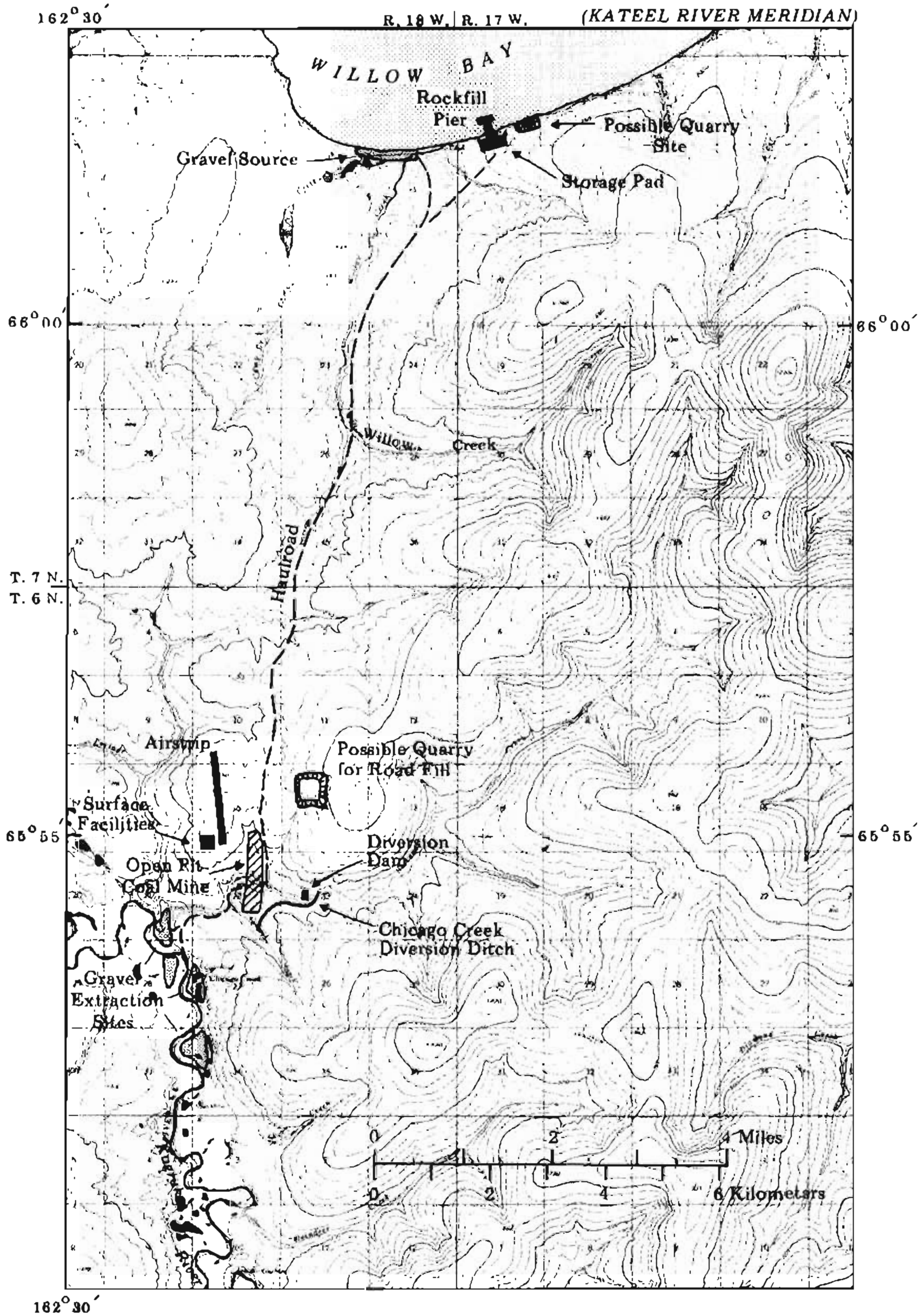
The largest and earliest earthmoving effort will be construction of the road. The road, which will require 5 mo to build, will be a gravel overlay that averages 35 ft wide, 5 ft thick, and about 10 mi long. About 350,000 yd^3 of gravel will be required. A straight section wider than the rest will be built near the camp to serve as an airstrip. Gravel pads will also be constructed for shop, generator, fuel-storage, and bunkhouse areas. A pad suitable for a coal stockpile will be laid at the terminus of the road at Willow Bay. A 5,000-ft-long ditch and a small diversion dam will be constructed on Chicago Creek upstream from the pit area. About 115,000 additional cubic yards of gravel will be needed for that construction. A total gravel-resource base of 500,000 yd^3 is assumed for construction. Because most heavy hauling will occur in April while the roadbed is still frozen, road-design requirements can be minimized. The cost of this construction (including limited funds for a temporary camp, and planning, engineering, and environmental baseline studies over a 2-yr period) will be about $4.6 million.

Permanent camp facility

The permanent camp will have complete facilities for 20 people and will include a 60- by 140-ft shop-warehouse complex. Construction materials and permanent fuel-storage tanks will be delivered to Willow Bay during the fall of 1990. The initial camp will have diesel generators that use waste heat. In future years, a small coal-fired system will eventually provide prime power. Most of the permanent camp will be constructed during the spring and summer of 1991, concurrent with the onset of coal-stripping activities. Full occupancy is planned for the early part of 1992 when the first coal mining will actually begin. The permanent camp will cost about $1.8 million.

Design of the Open Pit

The latest reserve estimates indicate that initial development of the pit will logically commence in segments IB and IIA (figs. 5a,b and table 4), where stripping ratios are 1.7 and 1.6:1, respectively. Taking advantage of the low topography of the Chicago Creek valley, pit development can commence in IIA and move south into IB. Maximum pit depths of 300 ft below the surface are planned for segments IA and IB. The depth will decrease to 250 ft below



Base from U.S. Geological Survey
Bendeleben D—1 and Kotzebue A—1
Quadrangles, Alaska.

Figure 4. Proposed facilities for the Chicago Creek Coal Mine.

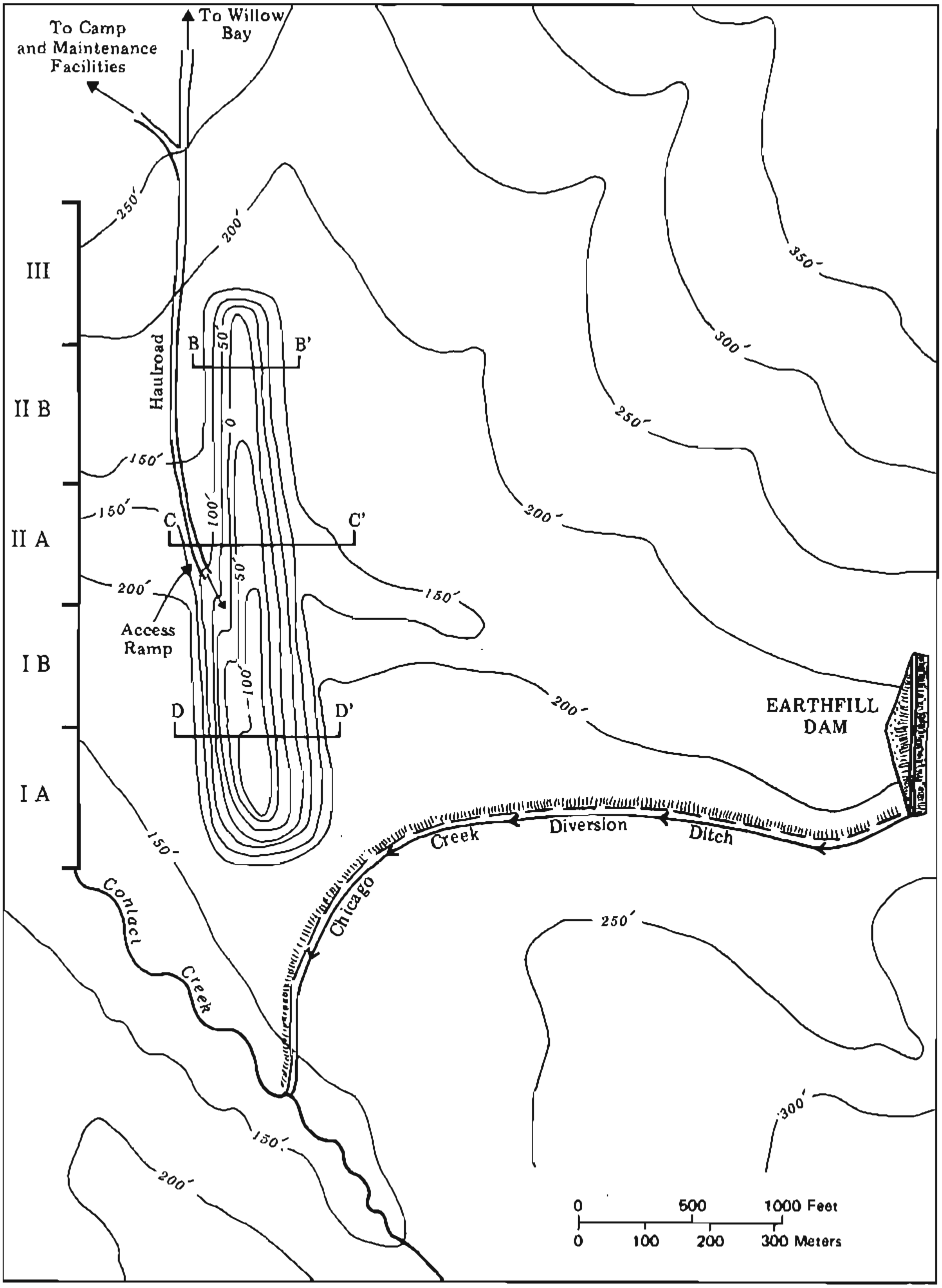


Figure 5a. Map of the proposed 30-yr open-pit mine and associated structures at Chicago Creek.

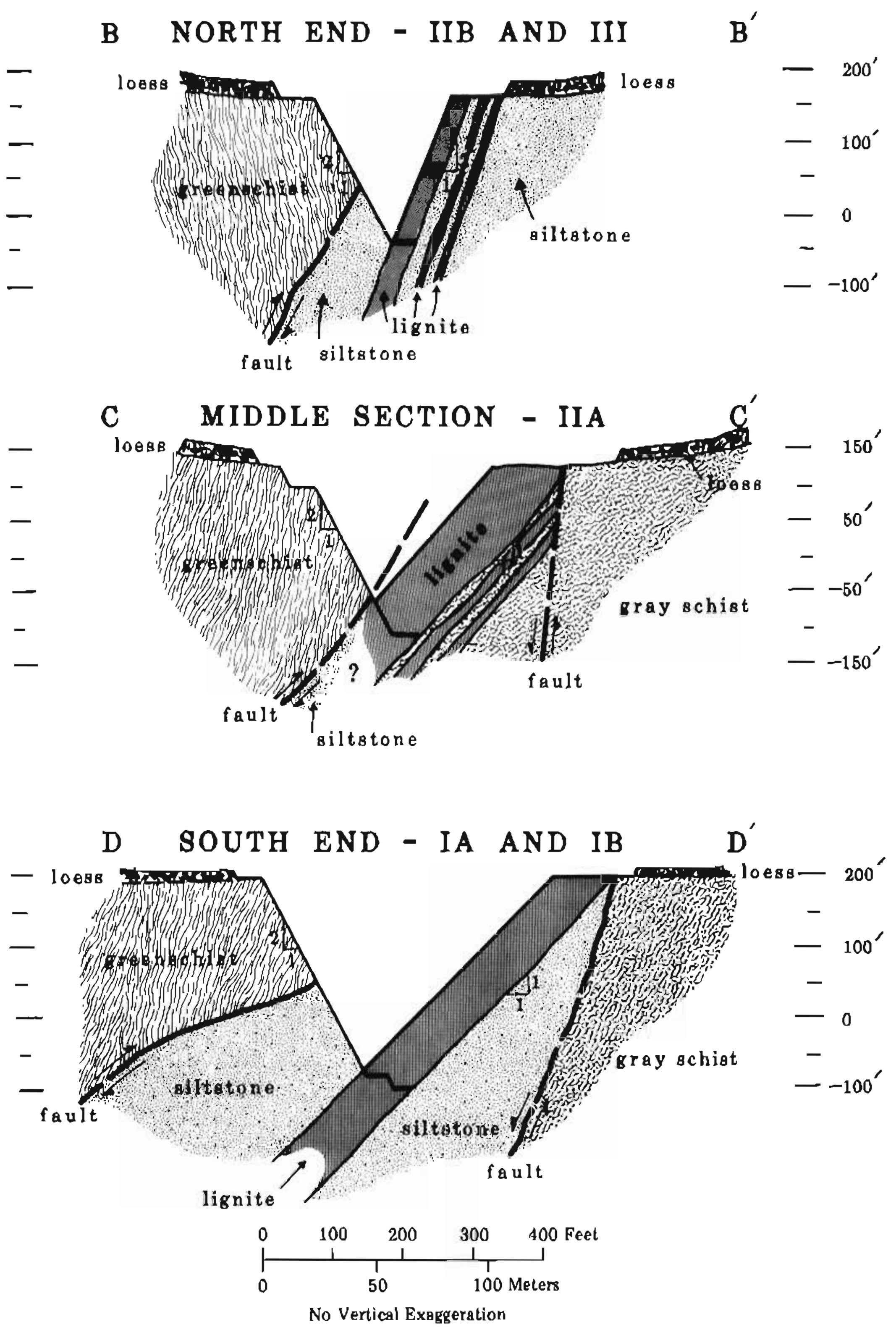


Figure 5b. Representative cross sections of the proposed 30-yr open-pit mine at Chicago Creek.

Stripping and mining activities will be restricted to the spring and summer months to take advantage of the long daylight hours and warm weather and to minimize equipment maintenance. In a typical year, operations will begin in early April when the exposed coal will be mined, hauled to Willow Bay, and stockpiled. This mining and hauling will take 1 mo. All heavy haulage over the road to Willow Bay will be completed by early May before the ground thaws. The crews will then begin to strip the overburden for the next season's mining, which will continue for 2 to 3 mo depending on the depth of the pit. Stripping and reclamation operations will be completed by September 1.

The average annual mining-development and production costs developed in this study are summarized in table 5. The table shows that the average annual cost to strip and haul 50,000 tons of coal to stockpile at Willow Bay with no provision for royalties or taxes is $1.5 million.

Equipment selection

Several characteristics of the project suggest that new, proven construction equipment should be selected. Equipment usage averages 1,000 hr/yr. The volume of material to be moved is also small---2.5 million yd^3 of overburden and 1.5 million short tons of coal over 30 yr, or 85,000 yd^3 and 50,000 short tons annually. Although annual use is low, any equipment downtime in this remote location will significantly impact production and expenses. Therefore, new rather than used or rebuilt equipment should be specified for the project. The selected equipment suite has been time-proven in Alaska conditions at Healy and on the North Slope. The suite includes equipment for drilling and blasting; ripping, loading and hauling the waste; and hauling the coal to Willow Bay. The total capital cost of equipment is about $3.5 million.

Labor

A crew of 12 is planned for the mining operation during the 3-month field season with an additional year-round office staff of three stationed in Kotzebue. A fully burdened wage rate of $35/hr, which includes all overtime and employer's contributions, is used in the analyses. The superintendent/engineer, foreman, and shop foreman are key people to the field operation and should be paid year-round to insure their availability; possibly, they could also help operate Kotzebue facilities in the winter. Besides a year-round home-office staff of three, a winter caretaker should be retained at the mine to prevent vandalism. Although all hourly employees will probably be hired from Kotzebue or the vicinity, several of the initial salaried and year-round crew will probably need to be brought in from outside the immediate area until local people can be trained for the jobs. Their salaries should be sufficient to insure that they remain long enough to successfully train a resident staff.

COAL HANDLING AND TRANSPORT

Assuming that the power plant is built south of Kotzebue, it will be necessary to transport the coal out of the mine area. Some possible

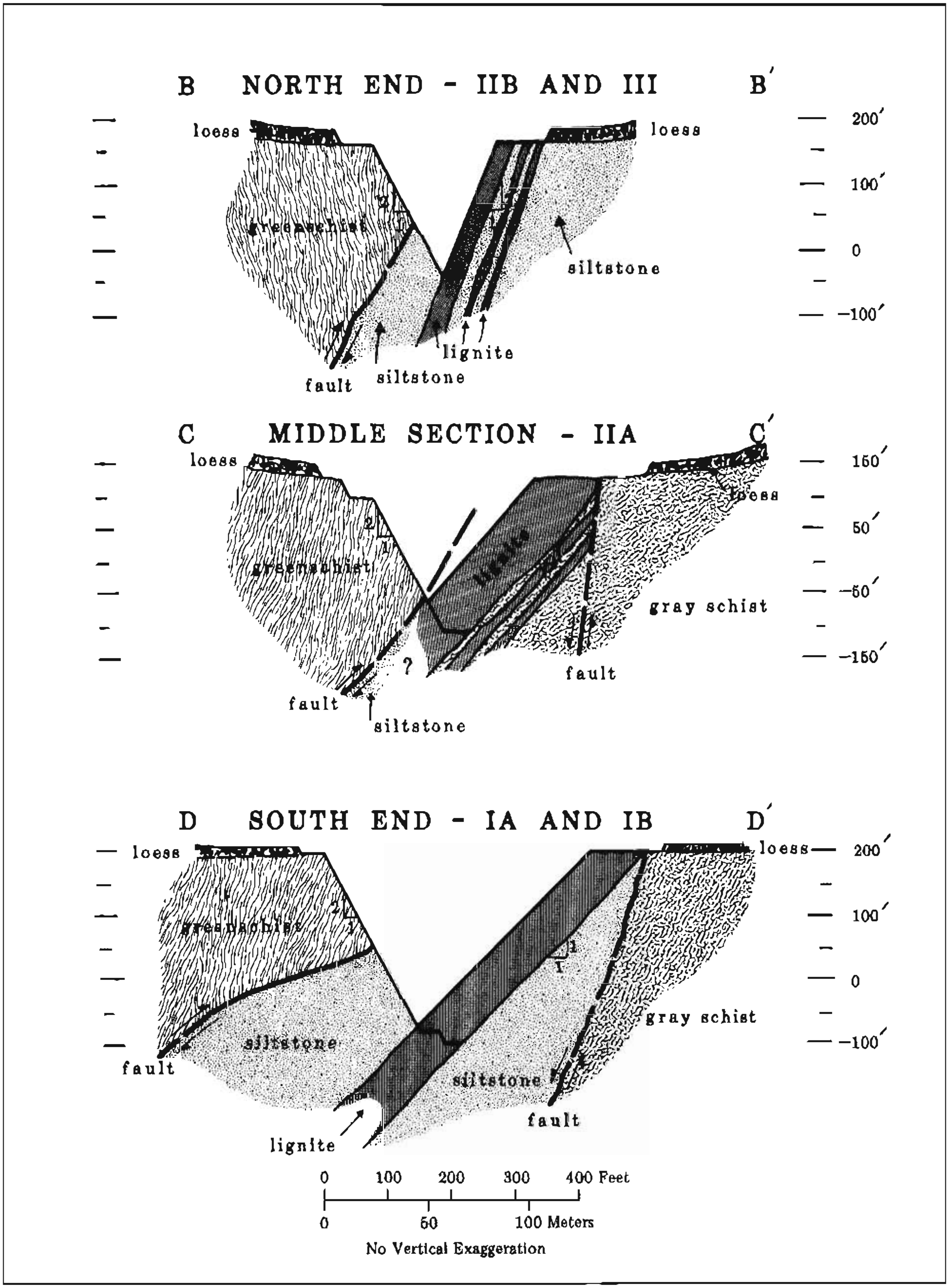


Figure 5b. Representative cross sections of the proposed 30-yr open-pit mine at Chicago Creek.

Table 4. Summary of data for open-pit mine.

	Segments IA	IB	IIA	IIB	III	Average	Total
Average coal thickness (ft)	37.5	85.0	83.0	34.0	18.0	51.5	- -
Average dip (°)	45	51	47	69	70	56	- -
Depth of overburden (ft)	15.0	15.0	25.0	25.0	25.0	21.0	- -
Total vertical depth (ft)	300.0	300.0	250.0	200.0	200.0	- -	- -
Dip depth (ft)	360.0	360.0	250.0	195.0	195.0	- -	- -
Length (ft)	800.0	700.0	650.0	730.0	840.0	744.0	3,720
Stripping volume (1,000 yd^3)	1,832	1,566	993	679	781	- -	5,851
Mineable coal volume (1,000 short ton)	459	910	610	194	118	- -	2,291
Years to be mined (@ 50,000 short ton/yr)	9.1	18.2	12.2	3.9	2.4	- -	45.8
Stripping ratio	4.0:1	1.7:1	1.6:1	3.5:1	6.6:1	2.55:1[a]	- -

[a]Average stripping ratio is weighted according to volume within each segment.

surface in IIA, partly because of topography, and to 200 ft in segments IIB and III. Initially, excavated waste rock will be used as road-base material, but excess or unsuitable material can be stockpiled downstream from the operation next to the access ramp.

The coal and wall rock are permanently frozen; thus, slopes should remain reasonably stable and little, if any, ground water should be encountered. Therefore, the pit highwall is designed with a slope of 0.5:1. Similar slopes in comparable material were used successfully at the Healy and Matanuska coal operations.

If slope failure occurs, it will probably be along or behind the footwall of the seam. Stripping no more than 2 yr in advance will allow the toe of the seam to be buttressed. Also, if massive slope failure suddenly occurs, it will destroy only a 2-yr supply of stripped coal at most. In a typical year, ample time will remain in August and September for remedial slope repairs if they become necessary.

Segment I/pit I can be accessed by cutting a shallow slot along strike to the south and building a haulroad at a maximum 15-percent grade into the pit highwall (fig. 5a). The pit will have a strike length sufficient to allow haulroads along the highwall without having to cut additional access slots. Representative cross-sections of the pit are shown in figure 5b.

Operations

The problems with a short mining season, relatively small demand for coal, remote location, short ice-free barging season, and shallow water of Kotzebue Sound will require creative solutions if the delivered price of coal is to be kept to a minimum. One of the best solutions will be to sequence mining and transportation of coal according to climate and ground conditions.

Table 5. Summary of mining-development and production costs.

Rate of coal production	50,000 short tons/yr	100,000 short tons/yr	150,000 short tons/yr
Development costs			
Year 1			
Exploration	$ 1,400,000	$ 1,400,000	$ 1,400,000
Site improvement	2,820,000	2,820,000	2,938,000
Equipment	3,521,000	3,960,000	4,547,000
Subtotals	$ 7,741,000	$ 8,180,000	$ 8,885,000
Year 2			
Site improvement	$ 1,786,000	$ 1,786,000	$ 1,862,000
Permanent camp	1,800,000	2,000,000	2,200,000
Subtotals	$ 3,586,000	$ 3,786,000	$ 4,062,000
Totals	$11,327,000	$11,966,000	$12,947,000
Annual production costs	$ 1,553,000	$ 2,356,000	$ 3,188,000
Nominal cost/ton[a]	31.06	23.56	21.25

[a]Excluding financing costs.

transportation options, such as construction of a road or railroad, are impractical because of the small scale of the operation and the low unit value of the commodity. A winter ice road is not feasible across Kotzebue Sound because of pressure ridges and annual construction and maintenance expenses.

The transportation system considered in this report was selected because it uses proven, existing technology. The coal will be transported by truck to Willow Bay and then by tug and barge to Kotzebue. As stated earlier, annual production rates of 50,000 and 150,000 short tons of coal are considered.

Transportation of 50,000 Short Tons of Coal Annually

At the Willow Bay site, coal will be held in a stockpile located on a level gravel pad. The pad must be designed for adequate drainage and treatment of runoff water. Coal trucks will haul the coal from the mine site, and D-9 bulldozers will stockpile the coal. In this study, the costs of construction of the stockpile pad and of transporting the coal to the pad are included in the mining costs.

Coal will be loaded at the Willow Bay site using a conveyor system fed by a Cat-988 loader, assuming that one of the mine's loaders is available at the time of the loading operation. Therefore, only operating costs are included in loading expenses.

Preliminary costs and design factors for the conveyor system were obtained with the help of Van Ooteghem Equipment Company of Anchorage. The conveyor will be a 250-ft-long, 30-in.-wide, wire-rope system with a hopper feeder and a telescoping barge loader. A preliminary cost estimate for equipment adequate to move 50,000 short tons of coal is about $1,000,000.

Barges will be moored at a dock facility to allow loading regardless of the tides. The dock facility will be kept as simple as possible to minimize costs. On-site engineering, oceanographic, and ice studies will be required before design specifications for a dock can be finalized. Mike Swalling of Swalling Construction Company---an Anchorage-based firm with experience in marine construction---suggested several possible alternative designs that range from $750,000 (or possibly less) to more than $2,000,000 (oral commun., 1985). For this study, we chose a conservative design that includes a short pier with dolphins; this dock facility will cost about $1,000,000 (oral commun., 1985) .

All barging will occur during the ice-free season, which typically extends from mid-July to mid-October. We assumed that a commercial marine-transportation company will be used. Arctic Slope Consulting Engineers (1984) concluded that purchase of a tug and barge might save some money, particularly if used equipment is available. The uncertainties in that approach, however, make the costs difficult to identify. For this study, a conservative approach using available equipment was chosen.

With the equipment described above, barges can be loaded at a rate of about 300 short tons/hr; a similar rate should be attainable in unloading. Using this rate and assuming the use of a tug and two tandem 2,000-ton barges traveling 100 mi/day, 50,000 short tons of coal can be moved in about 22 days of continuous operation. We obtained a tentative telephone quote of $400,000 from Crowley Maritime Corporation (Portland) to move the coal using equipment such as this. This figure is based on a rate of $8,000/day and includes travel time to and from Portland. The use of an additional set of barges would allow the tug to be underway more or less continually and would also allow a significant contingency for weather and other delays at the same or reduced cost.

Shallow-draft barges can be unloaded at existing facilities in Kotzebue. A proposed port facility at Cape Blossom (about 10 mi south of Kotzebue) could also possibly be used, allowing for the use of large-tonnage, deep-draft barges. However, because of the costs of truck transportation, there would be an appreciable cost savings if the unloading facility were close to the stockpile site. It is therefore assumed that construction costs of a separate barge-docking facility would be offset by savings in transportation and other costs and that the unloading would be done at a new facility just south of Kotzebue and immediately adjacent to a stockpile site. Because of environmental factors and the necessity of keeping the coal from freezing in the winter, it is assumed that the storage facility would be enclosed by a simple, uninsulated structure.

The unloading is assumed to be done by a wheeled loader similar to that used in the loading operation. In practice, some sort of specialized barge-unloading equipment may prove to be cost effective. Two trucks will transport the coal to the stockpile site, where it will be stacked by a D-7 Cat. If barge transportation can be used after mid-August, the D-7 Cat and some trucks from the mine will be available. We have, however, assumed purchase of a loader, because one will be needed on a year-round basis to feed the plant.

Transportation of 150,000 Short Tons of Coal Annually

Assuming an annual production of 150,000 short tons of coal, more stockpile space will be needed at both ends. The loading and unloading facilities described above will probably not be adequate to load the barges at an efficient rate, especially because two sets of tugs and barges might be necessary to move the tonnage during the short shipping season. Therefore, the capital cost of transportation facilities would significantly increase. The operational cost of loading and unloading would increase in a linear manner, and an extra Portland-Kotzebue-Portland run would be required if a second tug were used. Capital and operating costs of the necessary transportation facilities are shown in table 6.

Table 6. Summary of transportation cost.

	50,000 short tons/yr	150,000 short tons/yr
Capital cost		
Willow Bay facilities	$2,000,000	$3,500,000
Kotzebue facilities	2,000,000	3,500,000
Total	$4,000,000	$7,000,000
Annual operating cost		
Willow Bay facilities	$ 22,560	$ 67,680
Kotzebue facilities	44,640	133,920
Tug and barge costs	400,000	800,000
Annual total	$ 467,200	$1,001,600

Financial Analysis of Delivered-coal Costs

Although there are not enough hard data available to determine a final selling price for Chicago Creek coal delivered to the power-plant stockpile south of Kotzebue, a reasonably accurate range of selling prices (in 1985 dollars) can be projected using several assumptions:

1. Inflation is not considered.

2. Eighty percent of the hard capital and development costs are borrowed at an average interest rate of 10½ percent.

3. Development costs and interest are amortized evenly over the estimated 30-yr life of the mine.

4. Current tax rates and laws remain the same.

5. Chicago Creek coal is not subject to a royalty claim, because it is mined by the resource owners.

A range of costs for mining the coal and delivering it to Kotzebue can be determined at different annual production rates (table 7). The financial calculations were deleted for this summary report.

Table 7. Total cost of Chicago Creek coal delivered to Kotzebue.

Cost category	50,000 short tons/yr	100,000 short tons/yr	150,000 short tons/yr
Mining	$74	$47	$28
Transportation	22	16	14
Total cost (per short ton)	$96	$63	$42

POWER PLANT

Many factors enter into planning a power plant, some of which cannot be determined without extensive further study. By considering the various alternatives, however, and drawing on the consultants' experience, a reasonable choice of facilities and locations can be identified for a base-case cost study.

Site Selection

Three power-plant locations were considered in developing this study: 1) the mine mouth, 2) the Red Dog Mine, and 3) Kotzebue. Although a mine-mouth plant would be at the resource site, a transmission line would have to be built from the mine to Kotzebue, and the power plant would have to be constructed and operated at a remote site. This option would definitely increase construction and operating costs and add to the problems of operating an integrated power system. Personnel problems associated with hiring and keeping qualified people in isolated locations would also be added.

A location at the Red Dog Mine would have numerous advantages, and currently the mine's power needs far outweigh those of Kotzebue. The remote location, however, would have many of the same problems that a mine-mouth plant would face. It is also unlikely that coal from Chicago Creek would be used for this option. The somewhat higher quality coal from the Cape Beaufort area would be considerably closer, yet even the Beaufort coal may not be competitive with coal from Canada or other foreign sources that is brought in on the backhaul from the mine's concentrate shipments.

A power plant in Kotzebue will have the advantages of being constructed and operated near a developed community with an already operating, successful electric utility. Plant construction and operation and the use of the coal as a local energy resource would financially benefit the region. For this study, therefore, only a Kotzebue plant location is considered.

Choice of a specific site in the Kotzebue area requires a detailed study---with community involvement---to consider the potential impacts that relate to coal use, possible waste-heat uses, employment opportunities and other monetary impacts, and many other environmental and socio-economic factors. Our preliminary choice is a location about 1 mi south of the airport near the current waste-disposal area.

Plant Requirements

The power plant must be sized to meet the peak loads of its service area. Today's peak requirement in Kotzebue is 4,000 kW (International Engineering Company, 1985). Generating unit sizes now used in the Kotzebue diesel-electric plant vary from 500 kW to about 2,000 kW. This allows an efficient operation of units to match the varying electrical loads of the community. Addition of coal-fired facilities to the system will require unit sizes that can handle peak loads of 20,000 kW, which could be expected in Kotzebue within the 30-yr study period.

Although most of this discussion is based on a newly manufactured boiler and plant, rebuilt plants appear to be a viable alternative. Remanufacturing enterprises can provide a wider range of unit sizes at prices substantially less than those for new equipment. Numerous factors are involved with remanufactured units that affect capital and operating costs and the local economy:

1. Remanufactured units can reduce initial plant cost by 50 percent.

2. Careful analysis must be made to compare relative efficiencies of new vs. remanufactured units. A 20-percent loss in efficiency can absorb all the gain of a lesser investment.

3. Because of their slightly lower efficiency, remanufactured plants will require somewhat greater amounts of fuel. This in turn will require more production at the mine and, therefore, more labor and will effectively reduce the cost on a per-ton basis.

Another power-plant option that should be considered is the use of fluidized-bed combustion. Small fluidized-bed plants are currently being used in industrial applications in many parts of the world, and the technology is rapidly developing. Additional information on fluidized-bed combustion is available in Retherford and others (1986).

Equipment Requirements

The following discussion is based on the construction of a newly manufactured plant. The plant will be sized to output 10,000 kW of electric capacity from a condensing unit with provision for extracting steam at 10 psig for heating feed water. Total throttle flow to the turbine will be from 140,000 to 160,000 lb/hr of 650-psig/750°F steam. To handle soot blowing, blow down, and miscellaneous radiation and leakage losses, the boiler selected will have a steam capacity of about 180,000 lb/hr with a standby capacity of 180,000 lb/hr.

The type of firing best suited to the characteristics of Chicago Creek coal will probably be one with a chain-grate stoker, provided it can be uniformly loaded with fuel across its entire width. By varying the speed and height of the bed and the flow of combustion air, the heat release from the grate could follow load requirements. A major advantage of this type of firing is its automatic and continuous discharge of ash off the end of the chain and its ability to handle clinker formation.

Another possible form of firing would be pile burning in four fuel cells arranged two by two. The cells could closely control the flow of undergrate and overfire combustion air. Although ash removal would be manual, the ability to shut down one cell at a time for cleaning without disturbing the other cells would permit ash removal with little or no change in steam pressure or release of pollutants to the atmosphere. This combustion method would be limited to fuels with less than 50 percent moisture and an ash and dirt content of less than 3 percent.

Environmental Considerations

Environmental standards that must be met by this power plant should be established by appropriate regulatory authority and the local community. Such standards have not been set for this potential development. The following comments are based on what are believed to be reasonable assumptions:

> For this study, an air quality standard of 0.10 grains per standard dry cubic foot of gas (corrected to 12-percent carbon dioxide) for particulates and 30-percent opacity is used. This standard can be met by the requirements listed in preceding paragraphs if the coal-moisture content does not exceed 30 percent. For higher moisture contents, options would include the installation of coal-drying equipment, a dry charged-bed scrubber, or a bag house. Wet scrubbers are not considered feasible because of waste-discharge problems.

Preliminary Construction-cost Estimate

The construction-cost estimates listed in table 8 are approximate and must be revised to suit design criteria as they become better identified. The final estimated construction cost includes the power plant, its stepup substation, and covered storage for the coal stockpile. To compare the cost of energy at an increased-use rate, estimated costs for addition of a second unit to the plant are also included in the table.

ELECTRICAL TRANSMISSION

Electrical-transmission lines are used to transmit electrical energy from one point to another by means of wires. These wires are supported above the ground at safe heights. Experience with construction and operation of such lines in Alaska provides the background for the estimates and comments that follow.

The following section begins with a discussion of the basic information, assumptions, and costs involved in the economic analysis of transmitting power in northwest Alaska. Using this information, a comparison can be made between barging coal to Kotzebue from Chicago Creek vs. the transmission of energy to Kotzebue from a mine-mouth power plant. On the basis of this comparison and other reasoning, we select Kotzebue as the most probable power-plant location. However, we included a series of examples of transmitting energy from a plant based at Chicago Creek to various combinations of towns and villages to show how the cost of delivering energy is affected by a central power facility that feeds an expanding net of users.

Economic Factors

The annual cost of operating and paying for a transmission line is expected to be added to the price of the electricity that it transfers from one point to another. For a preliminary estimate, the following cost estimates and assumptions are stated here and used in later calculations:

Transmission-line investment costs:

Gravity-stabilized 3-phase, 138 kV (per mi)...	$ 100,000
Submarine-cable 3-phase, 138 kV (per mi)......	1,500,000
Gravity-stabilized 1-phase, 80 kV (per mi)....	67,000
Substations, 3-phase, 138 kV (per kVA)........	100
Substations, 1-phase, 80 kV (per kVA)........	200

Assumptions of annualized operation costs as a percentage of investment are itemized below:

Nonprofit cooperative operating utility (1985 dollars with electrical needs estimated for 1990 amortization of investment; 30 yr @ 9-percent interest)...........................	9.65%
Insurance and interim replacements.........................	0.40%
Reserve for contingencies (20 percent of amortization)......	1.95%
Operation and maintenance................................	2.00%
	14.00%

An additional important factor that enters into the following calculations is the coal to electricity ratio (6,500 Btu/lb: 13,652 Btu/kWh), which yields 2.1 lbs of Chicago Creek coal/kWh.

Figure 6 shows the location of many northwest Alaska villages and towns and possible electrical-transmission routes and interties. Table 1 shows the current and future energy needs of specific villages.

Table 8. Construction-cost estimates (1985 basis) of a 10-MW power plant located in Kotzebue.

Description	Cost: First unit	Cost: Second unit
Land and land rights	$ 75,000	$ 0
Roads	85,000	0
Site and yard improvements	95,000	0
Intake and structures		
Piling and concrete structures	100,000	50,000
Traveling screen, pumps, and piping	85,000	85,000
Structural		
Foundation and substructure	400,000	400,000
Building and structural steel	500,000	500,000
Concrete and miscellaneous metal	400,000	400,000
Covered coal storage	500,000	1,000,000
Mechanical		
Turbine-generator	2,000,000	2,000,000
Steam generator (boiler) and auxiliaries	7,200,000	7,200,000
Machinery, pumps, and equipment	1,200,000	1,200,000
Instruments and controls	780,000	780,000
Mechanical work and piping	1,700,000	1,700,000
Coal and ash handling	1,200,000	1,000,000
Circulating-water and plumbing systems	500,000	300,000
Water treatment	420,000	300,000
Precipitator	2,500,000	2,500,000
Electrical		
Switchgear and control	400,000	400,000
Wire, cable, conduit, and motor control center	300,000	300,000
Lighting and distribution	300,000	200,000
Substation (step up)	800,000	700,000
Subtotal direct cost	$21,540,000	$21,015,000
Engineering	4,000,000	3,000,000
Contingencies	500,000	500,000
Interest during construction	781,000	750,000
Construction management	480,000	300,000
Freight and miscellaneous	1,000,000	1,000,000
	$28,301,000	$26,565,000
Total construction cost/kW	$ 2,830	$ 2,657

Coal Transport vs. Transmission Lines for Kotzebue's Needs

If construction and operation costs of a coal-fired power plant are assumed to be the same whether located in Kotzebue or Chicago Creek, the remaining consideration is whether electricity for Kotzebue could be delivered at less cost by transmission line or by barging an amount of coal necessary to produce an equivalent amount of electricity.

Using the economic factors of the preceding section, electrical-transmission costs can be compared with the cost of barging coal. Table 7 shows that coal may be barged to Kotzebue for $22/short ton for a 50,000-short-ton mining-production rate; cost decreases to $14/short ton for a 150,000-short-ton production rate.

For comparison, these estimates are extended to include a 24,000-short ton/yr case that approximates Kotzebue's near-term energy needs for 1990, the beginning of our study period. At 24,000 short tons, $36/short ton is estimated for the transportation cost. The following calculations use these barging costs in comparison to the cost of constructing a transmission line and annualizing the investment of such a project. (Refer to the cost estimates for a transmission line in the preceeding section on economic factors.)

Cost of coal delivered by barge and electricity generated in Kotzebue.

Coal transport cost: ($36/ton)(24,000 short tons) = $864,000
Energy delivered annually:
24,000 short tons coal or equivalent of 23,000,000 kWh

$$\text{Unit cost: } \frac{\$864{,}000}{23{,}000{,}000\ \text{kWh}} = \underline{\underline{\$0.038/\text{kWh}}}$$

Cost of electricity delivered by wire.

Investments:

122 mi transmission line @ $100,000/mi	= $12,200,000
(2 substations @ 10,000 kVA each) ($100/kVA)	= $ 2,000,000
Total investment..........................	$14,200,000

Annualized cost: ($14,200,000)(14%) = $ 1,988,000
Energy delivered annually:
24,000 short tons coal or equivalent of 23,000,000 kWh

$$\text{Unit cost: } \frac{\$\ 1{,}988{,}000}{23{,}000{,}000\ \text{kWh}} = \underline{\underline{\$0.086/\text{kWh}}}$$

Using 48,000,000 kWh or 50,000 short tons of coal equivalent, unit costs would be as follows:

$$\text{Unit cost by wire} = \frac{\$1{,}988{,}000}{48{,}000{,}000\ \text{kWh}} \approx \underline{\underline{\$0.041/\text{kWh}}}$$

$$\text{Unit cost by barge} = \frac{(50{,}000\ \text{short tons})(\$22/\text{short ton})}{48{,}000{,}000\ \text{kWh}} = \underline{\underline{\$0.023/\text{kWh}}}$$

Table 2. Averages of proximate analyses of Chicago Creek and other Alaska coals.

Source	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Heating value (Btu/lb)	Total sulfur (%)
Chicago Creek, as received	38.64	29.27	27.54	8.55	6,400	0.82
Chicago Creek, equilibrium bed moisture	28.83	30.95	32.43	7.78	7,708	0.83
Cape Beaufort (Arctic Slope Consulting Engineers, 1984)	4.2-6.0	- -	- -	8.0-26.6	9,117-12,287	0.1-0.3
Chuitna River, Beluga Field (Ramsey, 1980)	- -	- -	- -	7.3-18.2	6,782-8,216	0.2-0.3
Usibelli Mine, Healy Field (Denton, 1980)	27	- -	- -	6	8,000	0.2
Bering River Field (Barnes, 1967)	1.0-8.6	13.1-17.4	65.0-91.1	2.1-18.0	11,000-15,000	0.6-3.4

Compared to most Alaska coals, Chicago Creek lignite is low in heating value. The analytical results for moisture content were high probably partly due to melting of contained ice in fractures and lenses after the samples were bagged. Such ice would tend to melt and drain off in a stockpile. This process also occurs at the Usibelli coal operation. The ash content for the Chicago Creek coal is about average for Alaska coals. The sulfur content is somewhat high for Alaska coal, but low to average for coals worldwide.

MIRL also performed ash-fusibility and washability tests on core from the 1982 Denali drilling program. The fusibility tests indicate that the coal can be used without significant problems in any type of firing system; the washability tests indicate that washing will not significantly reduce the ash content of the coal.

Resource Estimation

According to currently used definitions, the Chicago Creek coal is properly classed as a demonstrated resource, which implies a reasonable level of geologic confidence in the quantity present. Demonstrated resources are divided into measured (high-assurance level) and indicated (moderate-assurance level) classes. The relative density of drill holes and sample analyses from the southern part of the Chicago Creek deposit justify the classification of the coal in segments I, II, and III (fig. 3a) as measured demonstrated resources. Additional coal resources to the north that were intercepted by widely spaced drill holes in earlier programs (Ramsey and others, 1983) should probably only be considered as indicated.

On the basis of drill data gathered during and previous to the 1985 field season, the Chicago Creek area contains a total demonstrated resource of at least 4.7 million short tons of coal within 300 ft of the surface (table 3). This figure is a little over 1 million short tons larger than the previous estimate of Chicago Creek coal resources (Ramsey and others, 1983), a reflection of the 1985 discovery of thicker and more continuous coal beds in segments I and II (fig. 3a). The measured demonstrated coal resource within segments I, II, and III is about 2.5 million short tons and will probably be the initial target of any future mining plan.

A magnetometer survey conducted north of the drilled area in the fall of 1984 suggests that the coal basin extends for at least an additional mile past the last drill holes. If an average bed thickness of 20 ft is assumed, the additional mile of strike may contain 1.7 million short tons of coal. The district probably contains still more coal along strike to the north and south. Additional, undiscovered, parallel coal basins may also exist to the east and west.

MINING PLAN

Although other mining methods were considered, environmentally acceptable, modern open-pit mining is probably by far the most economical. This is especially true within the thicker sections of the seam where stripping ratios are less than 2:1. The following discussion is based on an open-pit

Compare this cost with a coal-fired power plant located in Kotzebue and energy transmitted to the Red Dog Mine by wire. Assuming barge transportation of coal to Kotzebue, the following unit costs develop:

Unit cost: 139,000 short tons @ \$14/short ton (see table 7) =
\$1,946,000 freight

$$\frac{(\$1,946,000 + \$2,128,000)}{133,000,000 \text{ kWh}} = \underline{\$0.031/\text{kWh}}$$

In this case, the cost of delivering energy by wire is very close to the cost of delivering energy by wire and barge transport. The comparison demonstrates that as the load increases, transmission costs per kilowatt-hour decrease. The primary reason that transmission costs approach the costs of coal barging is that, although a relatively larger quantity of energy is involved, the cost of transmitting the energy does not increase appreciably, whereas shipping costs do increase as a larger tonnage of coal is moved. These simple calculations disregard a few minor factors, such as energy losses in the transmission system.

<u>Additional effects of added loads through various transmission nets</u>

Using the preceding methods for estimating costs and again assuming a mine-mouth plant located near Chicago Creek, additional simple approximations for average transmission costs and coal requirements to include other interties can be made:

Chicago Creek - Kotzebue - Red Dog Mine (CC-K-RD) intertied with Nome and the villages of Teller, Deering, Buckland, Noorvik, Selawik, Kiana, and Noatak:

Averaged unit cost = \$0.043/kWh

Coal requirement = 192,000 short tons

CC-K-RD intertied with the villages of Deering, Buckland, Noorvik, Selawik, Kiana, and Noatak only:

Averaged unit cost = \$0.035/kWh

Coal requirement = 152,000 short tons

Chicago Creek - Kotzebue (CC-K) intertied with the villages of Deering, Buckland, Noorvik, Selawik, and Kiana only:

Averaged unit cost = \$0.081/kWh

Coal requirement = 36,000 short tons

The last example uses the same villages as in the immediately preceeding example except that transmission costs and coal requirements are calculated assuming that Kotzebue pays all charges related to the transmission line between Chicago Creek and Kotzebue. The villages, then, share only the costs related to the lines connecting the villages to the main Chicago Creek-Kotzebue intertie:

Kotzebue unit costs = $0.064/kWh

Coal requirement = 30,000 short tons

Village unit costs = $0.179/kWh

Coal requirement = 6,000 short tons

Conclusions on Electrical Transmission

1. Clearly, transmitting electricity for Kotzebue by wire from Chicago Creek is much more expensive than transporting the coal necessary to generate the same amount of electricity in Kotzebue.

2. The costs of transmitting energy by wire approach an economically favorable level when increased loads, such as the Red Dog Mine, are considered.

3. A transmission line from Chicago Creek to Kotzebue would allow the villages along the way to be intertied at an overall cost that, although relatively high, would probably still be less than the power-cost-equalization subsidy now provided by the State of Alaska.

ESTIMATED COST OF ELECTRICITY

The coal-fired power plant discussed earlier is a single unit, 10,000 kW, modern steam-turbine generating station designed to operate in conditions of the Alaska arctic at Kotzebue.

A plant location near the Kotzebue load center and electrical-power generation plant provide the best opportunity to coordinate with existing facilities and reduce risks from any catastrophic event. The proposed power system is assumed to be operated by the existing utility organization. Table 9 provides a preliminary estimate of costs that would accrue to the coal-fired power plant under the alternatives summarized above. Table 10 provides current costs for a diesel plant at Kotzebue.

RECOMMENDATIONS

The projected delivered cost of power to Kotzebue and the surrounding area using coal is sufficiently attractive that a more definitive feasibility study is justified. Three studies that may expose a fatal flaw in the concept of the proposed project could be done without additional field work:

1. Comparative economic studies with other coals from Alaska and other areas.

2. A review of leveraged, tax-driven private financing, and low-interest financing options available to government entities.

Table 9. Projected energy costs for coal-fired power plants (1990-95).

Plant data (alternative)	Kotzebue only A	Kotzebue only B	Kotzebue and Red Dog C	Kotzebue and Red Dog D
Unit no./size kW[a]	1/10,000	1/7,500	2/10,000	3/7,500
New (N) or rebuilt (R)[b]	N	R	N	R
Cost est.[c] ($ x 10³)	28,301	9,750	54,866	28,275
Net MWh delivered[d]	48,000	48,000	139,000	139,000
Heat rate (Btu/kWh)[e]	13,652	15,000	13,652	15,000
Heat value (lb/kWh)[f]	2.1	2.3	2.1	2.3
Coal consumed (short ton)[g]	50,400	55,200	145,950	159,850
Annual costs ($ x 10³)				
Amortization[h]	2,731x	941x	5,295x	2,729
	1,823y	628y	3,533y	1,821
Production expense[i]				
Payroll[j]	990	900	1,500	1,575
Fixed expense[k]	40	40	80	120
Variable expense[l]	20	20	58	58
Fuel cost ($/short ton)[m]	96	96	42	42
Fuel cost (total)[n]	4,838	5,299	6,130	6,714
Total annual cost[o]	8,619x	7,200x	13,063x	11,196
	7,711y	6,887y	11,301y	10,288
Net electricity cost				
Net MWh delivered[d]	48,000	48,000	139,000	139,000
Cost per kWh ($)[p]	0.179x	0.150x	0.094x	0.080
	0.161y	0.143y	0.081y	0.074

[a] Number of units in plant; unit size in kW.

[b] New (N) or remanufactured (R) units.

[c] Estimated costs: New unit costs from table 8 of this report. Remanufactured unit costs based on $1,300/kW estimate supplied by Eric Haemer in letter dated December 1, 1985 (Retherford and others, 1986, app. E). For alternative D, price for second and third units taken as 95 percent of $1,300/kW for single unit.

[d] For alternatives A and C, projected demand at average historic growth rate for year 1995 was used. This energy requirement will require about 50,000 tons of coal annually.

[e] Heat rates for alternatives A and B are developed from assumption that a 25-percent-efficient coal-fired power plant is reasonable for modern machinery in Kotzebue. Heat rates for remanufactured units are increased by 10 percent to account for older equipment characteristics.

[f] Heat values of the coal may be calculated using the conservative heat content value of 6,500 Btu/lb and the respective heat rates for alternative plant designs. Example: In alternatives A and C, heat rates require that 13,652 Btu's are required for each kWh of energy generated. Heat value is calculated by dividing the heat rate by the heat content or 13,652/6,500 = 2.1 lb/kWh.

[g] Method of computation: $\frac{\text{(net MWh delivered)(1,000 units?)(2.1 units)}}{\text{2,000 units}}$

[h] Based on 9-percent interest for 30-yr period, paid back in monthly installments for option x. Option y assumes that 5-percent interest for similar period is available. Respective annual factors are 9.65 percent and 6.44 percent.

[i] Operating and maintenance costs estimated for coal-fired power plants in arctic.

[j] Value of man-hr required for plant operation and maintenance.

[k] Miscellaneous fixed annual expenses.

[l] Miscellaneous variable annual expenses, such as supplies.

[m] Taken from table 7 of this report.

[n] Method of computation: (fuel cost)(coal consumed).

[o] Sum of amortization + payroll + fixed expenses + total fuel cost.

[p] Method of computation: $\frac{\text{total annual cost}}{\text{net MWh delivered}}$

Table 10. Current costs for a diesel plant at Kotzebue.

Plant data	
Unit no./average size (kW)[a]	7/950
Net MWh delivered[b]	14,247
Average net heat rate (Btu/kWh)[c]	10,600
Diesel fuel (1,000 gal)[d]	1,118
Annual costs ($ x 10^3)	
Depreciation and interest[e]	159
Operator cost (not including fuel)[f]	668
Maintenance cost[g]	131
Fuel cost[h]	1,261
Total annual cost[i]	2,219
Net electricity cost	
Net MWh delivered[b]	14,247
Average cost per kWh[j]	0.156

[a]In 1984, Kotzebue Electric Association (KEA) diesel plant included two 500-kW, one 1025-kW, one 1000-kW, and one 1800-kW diesel-electric units, plus two 900-kW diesel-fired gas-turbine-electric units.

[b]Actual energy delivered to KEA electric-distribution system in 1984.

[c]Calculated from average Btu content of gallon of diesel fuel (135,295. Btu), number of gallons consumed (1,118,000 gal), and net kWh delivered (14,246,800): $\frac{(135,295\ \text{Btu})\ (1,118,000\ \text{gal})}{(14,246,800\ \text{kWh})}$

[d]From KEA records; fuel consumed during 1984.

[e]From KEA records for 1984; can be compared with amortization costs of table 22, option b, in Retherford and others, 1986.

[f]From KEA records; includes operating labor, insurance, taxes, and miscellaneous costs.

[g]From KEA records; includes all maintenance costs.

[h]From KEA records; shows average cost of about $1.13/gal.

[i]Sum of depreciation and interest, and operator, maintenance, and fuel costs.

[j]$\frac{\text{Total annual cost}}{\text{Net MWh delivered}}$

3. Once the above studies are completed, a regional-power study of northwest Alaska to weigh the benefits of siting a generation facility in Kotzebue as opposed to other areas and to consider various transmission-intertie options and their benefits in more detail should be conducted.

When these studies have progressed far enough to justify additional work, a thorough on-site geotechnical study, mining of a bulk sample to help resolve equilibrium-moisture questions and allow a better determination of coal-burning characteristics, and an air-quality survey in Kotzebue should be conducted.

Early in this investigation, we opted for conventional steam-boiler construction using new equipment. However, fluid-bed-reactor technology is developing rapidly, and improvements are being made in design, operation, and maintenance of units. These technological advances, coupled with substantial savings if remanufactured equipment is used, indicate that a definitive feasibility study should consider fluid-bed technology and remanufactured boilers. The choice of conventional vs. fluid-bed boiler units should be made in conjunction with on-site air-quality information.

REFERENCES CITED

Alaska Power Administration, 1984, Alaska electric power statistics (9th ed.), September 1984: U.S. Department of Energy, 57 p.

Arctic Slope Consulting Engineers, 1984, Western Arctic coal development project: Anchorage, report prepared for the State of Alaska Department of Community and Regional Affairs and Alaska Native Foundation, contract no. 85-108, 2 v., 190 p., various scales, 11 sheets.

Arctic Slope Technical Services, Ralph Stefano Associates, and Veco, Inc., 1982, Coal-fired cogeneration, district heating and other energy alternatives feasibility assessment: Anchorage, report prepared for the State of Alaska Power Authority, v. 1 and 2, 240 p.

Barnes, F.F., 1967, Coal resources of Alaska: U.S. Geological Survey Bulletin 1242-B, 36 p., scale 1:2,500,000, 1 sheet.

Dames and Moore Consulting Engineers, 1981, Assessment of the feasibility of utilization of coal resources of northwestern Alaska for space heating and electricity - phase II: Anchorage, report prepared for the State of Alaska Power Authority, 110 p.

__________ 1983, An economic and technical assessment of the marketability of western Arctic Slope coals: Anchorage, report prepared for the State of Alaska Division of Legislative Finance, 98 p.

Denton, S.W., 1980, Geology and coal resources of the lower Lignite Creek area, in Rao, P.D., and Wolff, E.N., eds., Focus on Alaska's coal '80: Alaska Coal Conference, 2nd, Fairbanks, 1980, Proceedings: University of Alaska Mineral Industries Research Laboratory Report 50, p. 138-143.

Hawley Resource Group, 1985, Preliminary feasibility study of a coal mine at Chicago Creek: Fairbanks, Alaska Division of Geological and Geophysical Surveys Public-data File Report 86-57, 67 p.

International Engineering Company, 1981, Reconnaissance study of energy requirements and alternatives for Buckland, Chuathbaluk, Crooked Creek, Hughes, Koyukuk, Nikolai, Red Devil, Russian Mission, Sheldon Point, Sleetmute, Stony River, Takotna, and Telida: Anchorage, report prepared for the State of Alaska Power Authority, 75 p.

__________ 1985, Construction work plan - 1985-86: Anchorage, report prepared for the Kotzebue Electric Association, 16 p.

Manning, K.H., and Stevens, D.L., 1982, The Chicago Creek and Norton Sound area coal exploration programs: Fairbanks, Alaska Division of Geological and Geophysical Surveys Public-data File Report 86-58, 103 p., scale 1:500, 9 sheets.

Moffit, F.H., 1906, Gold mining on the Seward Peninsula, in Mineral resources of Alaska, report on progress of investigations in 1905: U.S. Geological Survey Bulletin 284, p. 132-144.

Patton, W.W., Jr., 1973, Reconnaissance geology of the northern Yukon-Koyukuk province, Alaska: U.S. Geological Survey Professional Paper 774-A, p. A1-A17.

Ramsey, J.P., 1980, Geology, coal resources, and mining plan for the Chuitna River Field, Alaska, in Rao, P.D., and Wolff, E.N., eds., Focus on Alaska's Coal '80: Alaska Coal Conference, 2nd, Fairbanks, 1980, Proceedings: University of Alaska Mineral Industries Research Laboratory Report 50, p. 111-121.

Ramsey, J.R., Retherford, R.M., Hickok, B.H., and Williams, J., 1983, Northwest Alaska coal investigation: Fairbanks, Alaska Division of Geological and Geophysical Surveys Public-data File Report 86-55, 81 p.

Retherford, R.M., Hinderman, T.K., and Hawley, C.C., 1986, Preliminary feasibility study of a coal mine at Chicago Creek, Alaska: Fairbanks, Alaska Division of Geological and Geophysical Surveys Public-data File Report 86-25, 172 p., scale 1:200.

R.W. Retherford and Associates, 1980, Assessment of power generation alternatives for Kotzebue: Anchorage, report prepared for the State of Alaska Power Authority, 75 p.

Toenges, A.L., and Jolley, T.R., 1947, Investigations of coal deposits for local use in the arctic regions of Alaska and proposed mine development: U.S. Bureau of Mines Report of Investigations 4150, 19 p.

Wood, G.H., Jr., 1981, Historical review of and current progress in coal resource estimation in the United States: Geological Society of America Bulletin, v. 92, no. 8, pt. 1, p. 520-528.