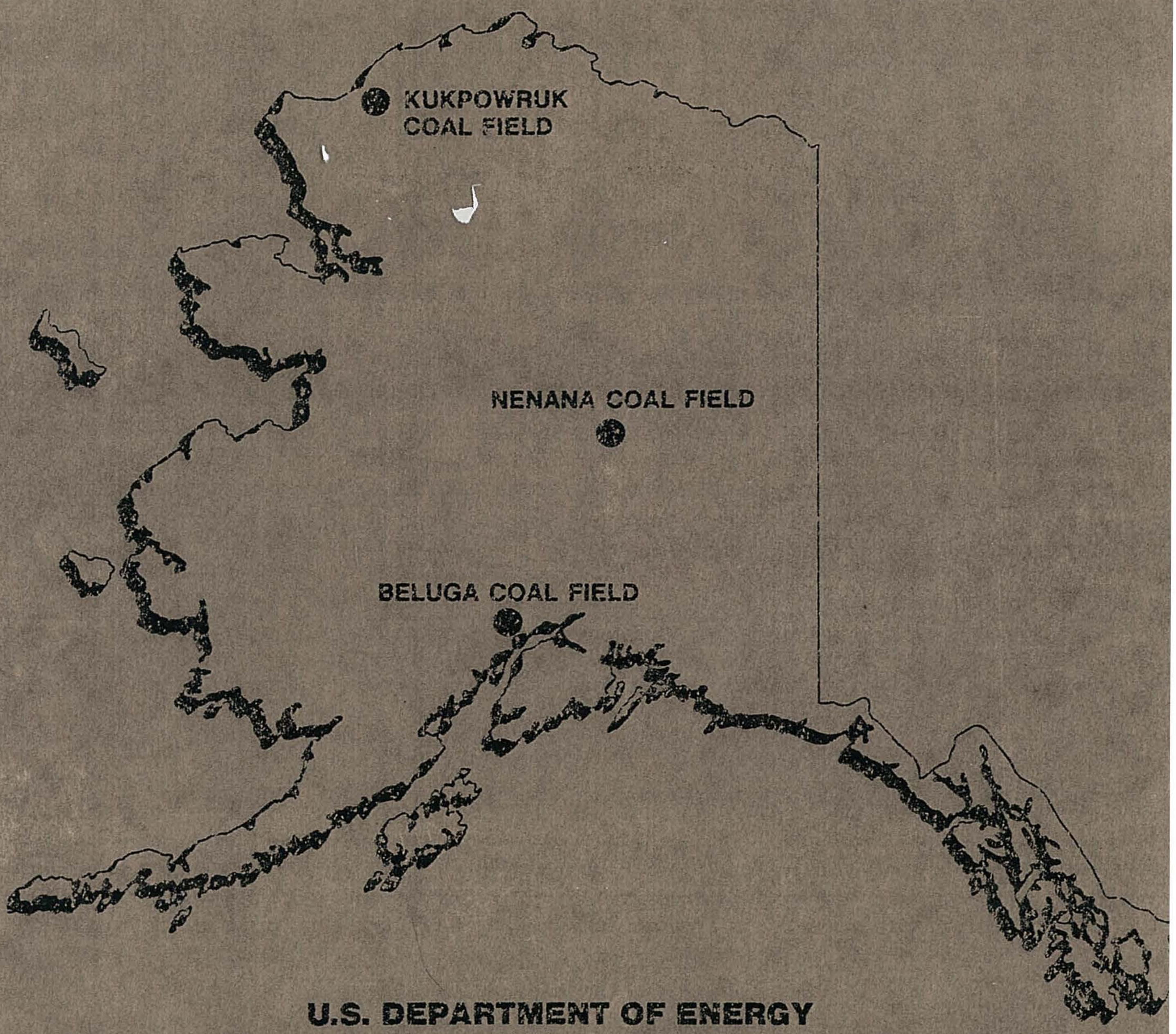
TRANSPORTATION AND MARKET ANALYSIS OF ALASKA COAL



U.S. DEPARTMENT OF ENERGY

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The study team appreciates the comments received from those who reviewed the various drafts of the report.

The following identifies those who brought their technical, administrative and clerical skills into play in developing and writing this report. They are as follows:

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The Alaska Environmental Information and Data Center of the University of Alaska, Anchorage is recognized for its contribution to the environmental sections of the report.

TRANSPORTATION AND MARKET ANALYSIS OF ALASKA COAL

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EXECUTIVE SUMMARY

Background

With the world price of oil increasing rapidly, coal is again becoming more viable as an energy source. Coal reserves that, at one time, were considered too costly to mine and transport to potential markets are now being given closer scrutiny. Energy experts throughout the world agree that coal will be playing an increasing role in the world's energy picture in the years to come. The world steam coal trade will have to increase many fold to meet the projected demands for coal in the next 20 years and thereafter. Because of its large share of the world's coal reserves, the United States is expected to be a leader in the coal export market. The President has established an Interagency Coal Export Task Force, headed by DOE, to determine means to substantially increase U.S. coal exports, identify impediments to such increases and recommend appropriate government and private sector actions to achieve them.

The United States is expected to export between 157 to 252 million short tons of coal annually by the year 2000.[44] The development and export of Alaska coal could contribute materially to the production increases required to meet the export market. Alaska coal has several advantages over conterminous U.S. coal reserves with respect to export trade: (1) its proximity to potential Far East markets offers transportation cost advantages; (2) large quantities of Alaska coal are located near tidewater, a unique occurrence with United States coal fields; and (3) Alaska coal entry into the export market would displace the need for expensive and environmentally sensitive overland transportation routes that would otherwise be required to move coal from conterminous United States' fields to marine ports.

Scope of Analysis

This report examines the development and marketability of coal from three areas in Alaska. The three areas are the Beluga Coal Field in south central Alaska near the Cook Inlet, the Kukpowruk Coal Field in northwest Alaska, and the Nenana Coal Field in central Alaska. At each of these sites, an assessment was made of the economics of mine development, inland transportation requirements, loading facilities and overseas transportation costs. Selling prices were developed for coal at both the Alaska port and the port of entry for the potential markets. In addition, competitive coal sources (Australia, South Africa, Canada and the contiguous U.S.) were assessed for export projections and selling price. Legal, institutional and environmental considerations of coal development in Alaska were also addressed.

There are five appendices to the report. Appendix A contains detailed information on Alaska coal resources. Appendix B, which was prepared for DOE by the University of Alaska, Arctic Environmental Information and Data Center in Anchorage, Alaska, is an assessment of potential environmental impacts associated with coal development in Alaska. Appendix C provides a look at competitive coal sources that is more extensive than that provided in the text of the report. Appendix D, which was developed by the Region X's Office of Regional Counsel, examines the Legal and Institutional Considerations that will affect coal development in Alaska. Appendix E reports new developments in coal utilization technology.

Findings:

The study found that Alaska coal could be delivered to primary market areas (Puget Sound, Northern California, Japan, Taiwan, and Korea) for a cost of between $1.87 to $3.31 per million BTU ($28 to $53 per ton) depending on the coal source and the destination (all monetary values in this report are given in 1980$). Coal from competing countries (Canada, Australia, South Africa) can be delivered to the same markets for $33 to $45 per ton. The figures are further explained in Chapters I and II and can be found in TABLE II-3. A representative example from TABLE II-3 shows that coal from the Beluga Coal Field could be delivered to Japan for a cost of $1.87 to $2.40 per million BTU. It was found that the Far East will probably be the principal market when Alaska coal is developed.

In general it was determined that coal from the Beluga field offered a cost advantage to both foreign and Western U.S. Markets. However, the cost advantage is not so great as to clearly eliminate the other two as viable economic choices. Due to severe arctic conditions, environmental impacts associated with mine development in the Kukpowruk area are significant and may severely reduce its viability as a potential coal development site.

The demand for Alaska steam coal in California is expected to be rather small due, in part, to the development of captive coal mines in Utah by California electric utilities. A total demand of only 5 million tons per year is expected in California in the 1990's compared with 30 to 80 million tons in the Far East by 1990. However, it was determined that Alaska coal utilization on the U.S. West Coast (that displaces imported crude oil) would have twice the favorable impact on the balance of payments than coal exported to the Far East. Due to existing coal-fired power plant construction plans, which rely on coal from Wyoming, Utah or Montana, utilities in Oregon and Washington will not be in the market for Alaska steam coal until about 1995.

However, by converting Alaska coal into a synthetic fuel (e.g. methanol) with clean-burning characteristics, it could provide a valuable energy source to serve the U.S. West Coast markets. This potential use of Alaska coal may become a viable alternative. The DOE recently (July 1980) selected for award a $3.9 million dollar contract to Placer Amex Inc. and Cook Inlet Native Corporation, Inc. to perform a feasibility study of converting Alaska Beluga coal to methanol.

Alaska coal will have to compete with coal from other sources for a share of the foreign demand. Coal from Australia, Canada and South Africa will probably be the main competitors. It does not appear likely that bulk coal from the Western conterminous United States will capture a significant share of the Far East market in the near term. This is primarily due to the lack of bulk coal shipment ports on the West Coast of the U.S. as well as the lack of adequate transportation linkages from the Western coal fields (Montana, Wyoming, Utah) to the West Coast.

Although Alaska's coal would be competitive with Canadian coal it is about \$.40 to \$1.00 per million BTU more expensive than Australia and South Africa coal for delivery to Japan. It is not clear, however, if Australia and South Africa have the ability and desire to expand their production to meet the projected Far East demand of the 1990's.

The legal and institutional analysis (Chapter VIII and and Appendix D) of developing coal in Alaska found that no single regulatory requirement would preclude development. However, as is the case with all major energy projects, cumulative Federal and State requirements would be substantial and could pose serious delays in the development process.

CONCLUSIONS

- The Foreign export market (Japan, Korea, Taiwan) comprise the primary markets and will likely be the greatest determining factor in the development of Alaska coal.
- Conversion of Alaska coal into synthetic fuels would expand the viable market area and enhance the marketability of the coal.
- Although exports of Alaska coal to the Far East would reduce the U.S. Balance of Payments' deficit, utilization of an equivalent amount of coal on the U.S. West Coast (that backs out imported crude oil) would have twice the favorable impact on the balance of payments as coal exports to the Far East.
- The technological knowledge for the control of adverse environmental effects associated with surface coal mining in the three study areas does, for the most part, exist and could be applied to the Nenana and Beluga fields. A coal mining operation in the Kukpowruk field, however, would pose significant obstacles which may preclude the field from being a viable development site.
- Alaska bulk coal cannot favorably compete with western conterminous coal for the U. S. West Coast steam coal market unless perhaps coal-fired power plants are sited on the coast.
- The cumulative impacts associated with Federal and State regulatory requirements may be a significant procedural barrier to Alaska coal development.
- Given the enormous coal requirement in the Far East, 90-150 million tons/yr by 2000, the U.S. is the only country capable of supplying the Far East's coal demand in the 1990's.

- Specific coal quality requirements of the consuming market(s) will strongly influence the specific Alaska coal source(s) that will be developed.

- Additional geologic investigations are needed to better assess the quantity and quality of Alaska coal resource.

RECOMMENDATIONS

1. A comprehensive economic and engineering feasibility study is needed to assess the potential of converting Alaska coal into synthetic fuels for consumption in the United States.

2. The potential export market, particularly the Far East, needs to be more thoroughly investigated. This knowledge would be necessary to obtain the long-term commitments required to develop new coal mines and terminal facilities.

3. Alaska coal potential should be given equal status with other U.S. coal sources in forums concerned with U.S. coal exports (e.g. the President's Interagency Coal Export Task Force).

4. The Department should conduct a joint study with the State of Alaska and affected parties to determine permit requirements and scenarios and to identify site specific institutional barriers.

5. The Department should take the required steps to ensure that local district CZM programs in Alaska adequately consider and do not arbitrarily exclude coal development sites.

6. As authorized in the Surface Mining Control and Reclamation Act of 1977 (PL. 95-87), we recommend that consideration be given to the establishment and funding of a University of Alaska Coal Research Laboratory. The Laboratory could provide much of the information required to better assess Alaska coal as a potential export commodity.

FOREWORD

This report was prepared by the Office of Assessment and Integration staff within the Region X (Seattle) Office of the Regional Representative of the Secretary of Energy. The work was done under the auspices of the Office of Energy Supply Transportation, U.S. Department of Energy, Washington, D.C.

The major sections of this report were written during April and May 1980 using the latest information available at that time. The report is intended to be an assessment of the potential of developing Alaska coal in the near term (1990 or before) using existing technology. Major technological breakthroughs were not considered to be a prerequisite for Alaska coal development.

INTRODUCTION

Background

Coal currently supplies 25 percent of the world's energy and according to the recent world coal study will supply between 50 and 66 percent of the world's energy by 2000.[44] Thus, the world coal trade will have to expand many fold during the next 20 years to keep pace with the projected demand.

There are abundant coal reserves throughout the world; on a BTU basis, they are many times greater than oil reserves. The United States, in particular, is well endowed with coal resources, with approximately 28 percent of the world's technically and economically recoverable reserves.

Coal can be mined, transported and burned in an environmentally acceptable manner with existing technology.[44] Research continues, however, in many countries, on methods to improve upon the current state-of-the-art, particularly in conversion technology (gasification, liquefaction, etc.).

Because of its large coal reserve base and its proclaimed goal of increasing exports the United States will contribute substantially to the world coal trade. Within the U.S., the State of Alaska has extensive coal deposits that are situated close to potential markets in the Pacific Rim. Although Alaska coal has been studied for many years it has not been subjected to a rigorous analysis of its potential in the national or world energy picture. In the past, the remoteness of Alaska coal from major consumers and the price of oil and gas has hampered its serious consideration in the market place. Only in recent years, particularly since the OPEC oil embargo of 1973-74, have the coal reserves in Alaska begun to be given serious consideration as a viable energy source for domestic and foreign markets.

In addition to the OPEC oil embargo, several other factors have caused researchers and policy makers to reassess the potential role of Alaska coal. These include:

- The President's Energy Plan emphasizes utilization of the United States vast coal reserves.
- The Powerplant and Industrial Fuel Use Act of 1978 mandates that utilities and industries consider utilizing coal rather than oil and gas.
- The reluctance of the public to accept increased use of nuclear power has directed more attention to consideration of coal-fired powerplant.
- Potential major consumers of Alaska coal are proximate to navigable waterways.
- Significant quantities of Alaska coal are located close to navigable waterways.

- Export of Alaska coal to foreign markets would favorably affect the U.S. balance of payments.

These factors, and others, have been the driving forces that prompted the initiation of this report. We feel that now is the time to examine the options and costs of producing and transporting Alaska coal. Information is needed to supply accurate and up-to-date information to the market place so that major utility and industrial fuel decisions can be made with a certain amount of confidence.

ABOUT THIS REPORT

This study focuses on the development potential and market economics of three coal-bearing areas of Alaska. These areas were selected because they represent a range of environmental issues, climatic differences, transportation issues, demonstrated interest in development, coal quality and others. Although these areas are considered likely candiates for near-term development, the study recognizes that other areas of Alaska offer similar development opportunities. The three areas studied in this report are:

a) Beluga Coal Field - located on the north side of Cook Inlet, low-medium BTU coal (avg. 7,500 BTU/lb), relatively moderate climate, near tidewater, total reserves of approximately 2.2 billion tons, and high level of interest in development.

b) Nenana Coal Field - located in Central Alaska, medium BTU coal (avg. 8,000 BTU lb), discontinuous permafrost area, existing railroad and roads to Fairbanks and Anchorage area, total reserves of approximately 7 billion tons, existing mine with annual production of 750,000 tons per year.

c) Kukpowruk Coal Field - located in northern Alaska, high BTU coal (avg. 12,000 BTU/lb.), Arctic environment, seasonal barge access, no existing overland transportation systems, total reserves of approximately 1.7 billion short tons.

By focusing on these diverse areas we were able to address many of the issues that may typically concern readers that have an interest in Alaska coal.

All monetary figures used in this report are in 1980 dollars which were, in most cases, obtained by escalating original source data by appropriate price indices.

Chapter I

Economics of Mine Development and Alaska Transportation

A. Introduction

The exact amount of Alaska coal is currently unknown and a subject of much debate. Undiscovered Alaska coal resources are currently estimated at 1.85 to 5 trillion short tons[2], while identified Alaska coal resources are only estimated at 130,126 million short tons.[5] The wide range of estimates for Alaska coal resources is primarily due to the lack of geological data as almost all Alaska coal fields have not been investigated or developed. Estimated identified coal resources of Alaska are shown by coal field and coal type in Table I-1 and Table I-2 respectively. A more extensive description of Alaska's coal resources is provided in Appendix A, "Coal Resources of Alaska."

Although coal exists throughout the entire State of Alaska, this study only investigates the development of coal resources from the three specific coal-bearing areas mentioned in the introduction; (1) the Beluga Coal Field, (2) the Nenana Coal Field and (3) the Kukpowruk Coal Field. Figure I-1 illustrates the locations of these coal fields and Figure I-2 shows the five major coal regions in Alaska. The three coal fields were selected for investigation to represent the wide range of environmental, transportation, mining and socioeconomic issues that would be encountered in developing any of Alaska's coal resources. The intent of the study is to estimate prices of three specific Alaska coals and determine if these specific Alaska coals are or may become competitive in Pacific Rim steam coal markets.

In this chapter, Alaska coal selling price estimates free-on-board (FOB) at Alaskan ports, which are navigable year-round, are determined for coal from the Kukpowruk Coal Field, the Usibelli Mine in the Nenana Coal Field and the Beluga Coal Field. The selling price estimates are based on (1) projected mining costs, (2) mine-support infrastructure costs, (3) inland transportation costs and (4) port costs. The selling price estimates in this chapter combined with marine transportation costs estimated in Chapter II will serve as the basis for comparing Alaska coal prices with other coal supply prices in the specific market areas identified in Chapter III.

Figure I-1

Three Representative Alaska Coal Fields

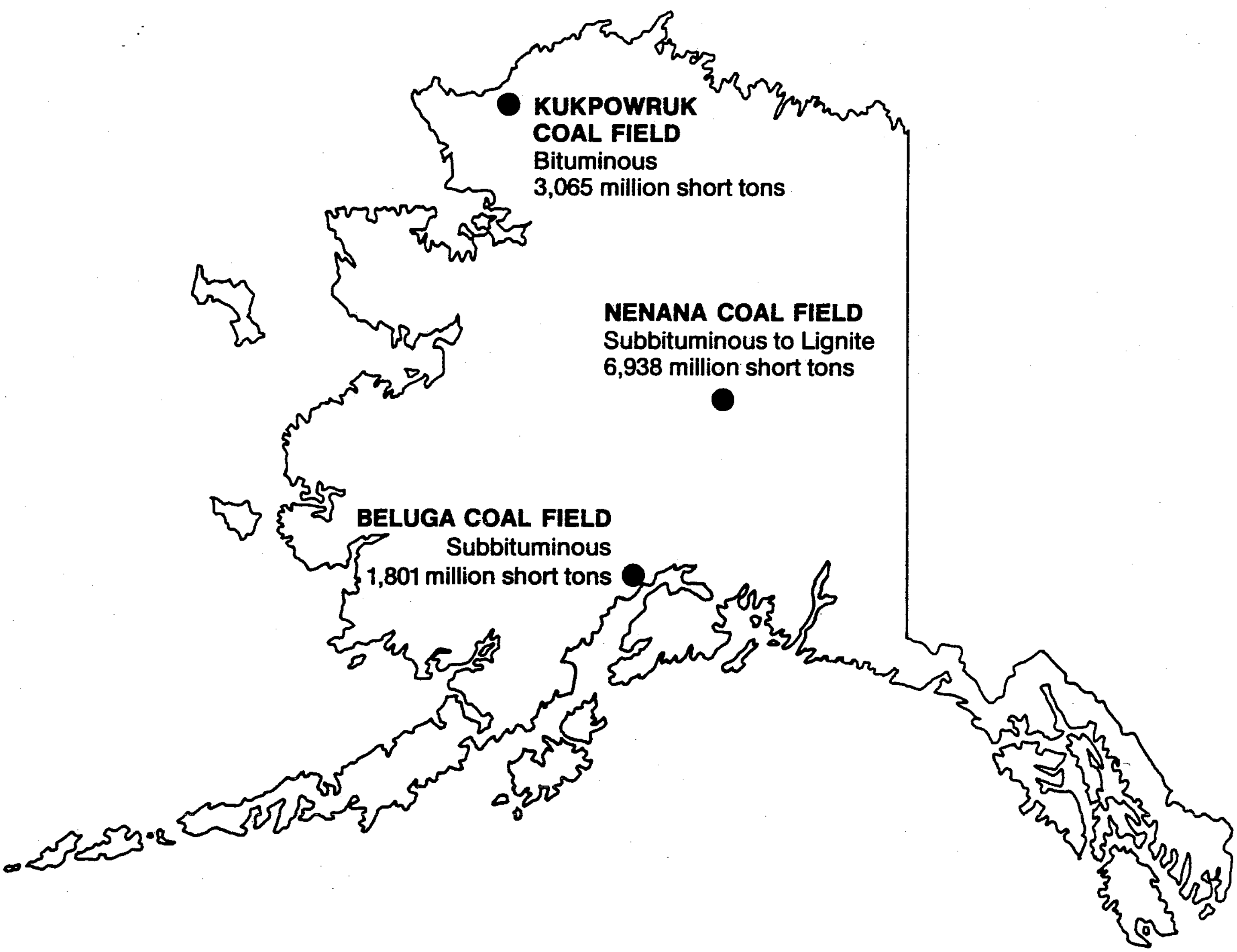


Figure I-2

The Five Major Regions of Alaska Coal

Table I-1
Estimated Identified Coal Resources of Alaska
By Coal Field
(Million Short Tons)

Coal Field	Bituminous	Subbituminous and Lignite	Total
Northern Alaska	19,292	100,905	120,197
Nenana	-	6,938	6,938
Jarvis Creek	-	77	77
Broad Pass	-	64	64
Matanuska	137	-	137
Susitna (Beluga)	-	2,395	2,395
Kenai (Homer Dist.)	-	318	318
Total Identified Coal Resources	19,429	110,697	130,126

Source: Reference #5 Bibliography

Table I-2
Estimated Identified Coal Resources of Alaska
By Coal Type
(Million Short Tons)

	Measured	Indicated	Inferred	Total
Anthracite	Trace	-	-	Trace
Bituminous	6.6	890.4	18,532.2	19,429.2
Subbituminous & Lignite	861.6	7,028.8	102,806.4	110,696.8
Total Identified Coal Resources	868.2	7,919.2	121,338.6	130,126.0

Source: Reference #5 Bibliography

B. Mine Development

1. Beluga Coal Field

The Beluga Coal Field is located in south central Alaska approximately 60 miles west of Anchorage in the Kenai Peninsula Borough. Although the Beluga Coal Field is relatively close to Anchorage, Alaska's largest population center, the field is totally undeveloped and lacks the necessary transportation and support facilities required by a major coal mine's labor force. However, due to the field's close proximity to tidewater and existing utility generation and transmission facilities, it is generally considered a most likely candidate for near-term development. The characteristics of Beluga coal are:

Rank of Coal: Subbitiminous
Total Identified Resources (million short tons): 1,801
Thickness of Beds: Ranges widely from a few inches to 50 feet
Moisture: 11% - 30%
Volatile Matter: 27.8% - 30.1%
Fixed Carbon: 25.8% - 34.6%
Ash: 8% - 30.5%
Sulfur: .2%
Heating Value (BTU/lb): 6,290 - 8,890

Placer Amex Inc., a Beluga leaseholder and experienced mining company, has performed extensive geological exploration in this field and has formulated a realistic development plan. This report bases its estimated selling prices on the Placer Amex development proposal.

The Placer Amex mine development proposal would produce coal averaging 7,500 BTU/lb at an estimated selling price at the mine of $15.00 to $22.50 per ton or $1.00 to 1.50 per million BTU. (1980 $'s)[6] The proposed mining operation would require an annual production level of at least 5 million tons to provide sufficient revenues to support the necessary auxiliary facilities for mine employees working in an undeveloped area. Run-of-mine coal would be crushed, screened and stockpiled for delivery. The stockpiled coal could be hauled to tidewater by tractor trailers until market demands increased to 2-3 million tons/year and therefore justified the construction of a railroad. The mining and inland transportation systems would utilize conventional technologies.

2. Nenana Coal Field

The Nenana Coal Field is the only major producing coal field in Alaska and extends for about 80 miles along the north flank of the Alaska Range. The Usibelli mine, located in the Nenana field near Healy, is the only mine currently producing coal in the Nenana field. The Nenana field's coal characteristics are:

Rank of Coal: Subbituminous to Lignite
Total Identified Resources (million short tons): 6,938
Thickness of Beds: Ranges widely from a few inches to 60 feet
Moisture: 11.7% - 32.7%
Volatile Matter: 31.2% - 42.9%
Fixed Carbon: 22.7% - 36.6%
Ash: 3.3% - 15.9%
Sulfur: 0.1% - .4%
Heating Value (BTU/lb): 6,320-10,385

The selling price estimates for Nenana coal are based on data provided by Joeseph Usibelli, President, Usibelli Mines, Inc.[42] These estimated selling prices represent a minimum price for Nenana coal at the Usibelli mine at indicated production levels. The extrapolation of Usibelli coal selling prices to other Nenana coals is certainly not a totally precise estimating method. However, Usibelli prices at the 4.1 million tons/yr production level, which would require the expansion of the mine and the establishment of new draglines and support facilities similiar to new mines in other areas of the Nenana coal field, provide a good price estimate for coal from other promising minesites in the Nenana Coal Field.

The Usibelli mine currently sells coal at an approximate FOB mine price of $18.00 per ton or $1.12 per million BTU. The coal, which has an average heating value of 8,000 BTU/lb., is distributed and consumed entirely within the State of Alaska. At the current production rate of 750,000 tons/yr the mine is currently operating below capacity and could increase production to 2.1 million tons per year with existing capital equipment. The average selling price FOB mine at a 2.1 million ton per year production rate is estimated by Usibelli Mines, Inc. at $16.00 to $18.00 per ton or $1.00 to $1.12 per million BTU. (1980$'s) However, Usibelli Mine, Inc. also estimates that any production above the 2.1 million ton per year rate, which would require additional mining equipment and new coal leases, will increase average FOB mine selling prices to $26.00 to $28.00 per ton or $1.62 to $1.75 per million BTU. (1980 $'s) Table I-3 summarizes Nenana FOB mine coal prices based on Usibelli FOB mine estimates at increased production levels which would produce coal in excess of current demand.

TABLE I-3
Nenana Coal Prices
FOB Mine

Production Level	$/Ton	$/Million BTU
2.1 million tons/yr*	16.00 - 18.00	1.00 - 1.12
4.1 million tons/yr	26.00 - 28.00	1.62 - 1.75

Source: Reference 42 Bibliography

*maximum production level with existing equipment

3. Kukpowruk Coal Field

The Kukpowruk Coal Field is located in a wilderness area at the northern edge of the Arctic foothills, 14 miles east of the Chukchi Sea coast. This part of Alaska, due to its harsh climate, delicate environment and remoteness, creates a number of environmental, social, economic, legal and technical constraints to development. This chapter attempts to incorporate all the reasonable costs associated with these constraints. However, in considering the development plan proposed for the Kukpowruk Coal Field, it must be remembered that the costs of solutions to technological, environmental, or legal problems may prevent all mining in northern Alaska. A recent example of the possible increased costs, which may be incurred on projects in northern Alaska, is the Trans-Alaska Pipeline System (TAPS), built by the Alyeska Pipeline Service Company. The TAPS cost increases of over 100 percent during its three years of construction serve as a warning to any development project in northern Alaska to expect unbudgeted costs and large cost increases in almost all budgeted expenses.

The Kukpowruk Coal Field represents the northwest area of the North Slope of Alaska. Its coals are of high quality and coal-bearing rocks are exposed along the lower 25 miles of the Kukpowruk River and also underlie a small area 70 miles above the mouth of the river. The field's coal characteristics are:

Rank of Coal: Bituminous
Total Estimated Resources (million short tons): 3,065
Thickeness of Beds: 1-1/2 - 13 feet
Moisture: 0.8% - 9.9%
Volatile Matter: 31.4% - 35.6%
Fixed Carbon: 52.6% - 56.1%
Ash: 2.5% - 15.0%
Sulfur: 0.2% - .3%
Heating Value (BTU/lb): 11,910 - 12,880

An August, 1977, Bureau of Mines study performed by Kaiser Engineers, Inc.[30] provides the basis for Kukpowruk coal selling price estimates projected in this report. The Kaiser Engineers designed a hypothetical mine using three different mining methods; (1) draglines, (2) shovels and trucks, and (3) combinations of draglines and shovels and trucks. The dragline mining method was the most economical, so only those costs are used here. The equipment requirements and mining costs were estimated for a mine producing 5 million tons of coal per year over a period of 20 years. Since measured and indicated resources of only 20 million tons of bituminous coal have been identified, it is assumed that the mine's 20 year life will be supported by future coal discoveries. The coal's heating value is estimated to average 12,000 BTU/lb.

The estimated selling price, FOB mine, for Kukpowruk coal was determined by escalating Kaiser's 1976 data. Table I-4 summarizes the basic index data, the price indices used and the cost category updated by the specific index.

TABLE I-4

Percentage Change in Price Indices

Price Indices	Cost Category
Producer Price Index-Machinery and Equipment	
December, 1976.......175.4	Mining Equipment,
April, 1980..........235.8	Coal Storage and
Percentage Change....+34.4	Transfer Equipment
Producer Price Index-All Commodities	Exploration,
December, 1976.......187.1	Operating Supplies,
April, 1980..........262.3	Power Supply,
Percentage Change....+40.2	Townsite and Utility Facilities
Engineering News Record, Building Index	
December, 1976.......142.2	Buildings
April, 1980..........179.2	
Percentage Change....+26.0	
Federal Highway Administration Composite Index	
Fourth Quarter, 1976......145.0	Road Construction
Fourth Quarter, 1979......254.8	
Percentage Change.........+75.7	
EPA-Sewers Index	
November, 1976.......152.5	Water and Sewer System
November, 1979.......200.8	
Percentage Change....+31.7	

Source: Bureau of Labor Statistics
Engineering News Record
Federal Highway Administration
Environmental Protection Agency

Table I-5 presents the quarterly percentage change in the Employer Cost Index (ECI), White-Collar Workers and Blue-Collar Workers from fourth quarter, 1976 to third quarter, 1979. The ECI, white collar workers index was used to escalate Kaiser's 1976 salary cost estimate and the ECI, blue-collar workers index was the basis for escalating Kaiser's 1976 wage cost estimate.

Table I-6 summarizes total estimated capital requirements and Table I-7 summarizes estimated annual production costs in 1976 and 1980 dollars. For example, mining equipment costs of $56,858,000 in 1976, were increased 34.4 percent to $76,417,000 in 1980 to reflect the percentage increase in the Producer Price Index - Machinery and Equipment shown in Table I-4. The 1980 interest charges during construction are based on a 12 percent interest rate with a total construction time of three years. Total 1980 capital requirements are estimated at $179,433,000 and 1980 annual production costs are approximately $68,499,107.

The estimated coal selling price based on 1980 capital requirements and 1980 annual production costs is calculated in Table I-8. The estimated coal price is $18.52 per ton or $.77 per million BTU. However, this price does not include costs for employee auxiliary facilities, such as employee housing, community buildings and a power plant, which the Kukpowruk mine site would have to support due to its remoteness.

TABLE I-5
Quarterly Percentage Change in Wage Indices

Quarter and Year	Employer Cost Index White-Collar Workers	Employer Cost Index Blue-Collar Workers
4th, 1976	+1.9	+1.9
1st, 1977	+1.3	+1.7
2nd, 1977	+1.6	+2.2
3rd, 1977	+1.7	+1.8
4th, 1977	+1.8	+1.8
1st, 1978	+1.8	+1.8
2nd, 1978	+2.1	+2.2
3nd, 1978	+1.9	+2.0
4th, 1978	+1.2	+1.9
1st, 1979	+1.9	+1.9
2nd, 1979	+1.7	+2.3
3rd, 1979	+2.3	+2.0

Source: Bureau of Labor Statistics

TABLE I-6
TOTAL ESTIMATED CAPITAL REQUIREMENTS
KUKPOWRUK COAL FIELD
5 MILLION TONS PER YEAR
(thousand of dollars)

	KAISER 1976	DOE 1980
Exploration, Roads, and Buildings	$ 11,287	$ 15,284
Mining Equipment	56,858	76,417
Coal Storage and Transfer Equipment	4,500	6,048
Total Direct	72,645	97,749.
Field Indirect (7-1/2%)	5,448	7,331
Total Construction	78,093	105,080
Engineering (3%)	2,343	3,152
Substotal	80,436	108,232
Overhead & Administration (7-1/2%)	6,033	8,117
Subtotal	86,469	116,349
Contingency (15%)	12,970	17,452
Subtotal	99,439	133,801
Fee (3%)	2,983	4,014
Total Plant Cost (Insurance-Tax Base)	$102,422	$137,815
Interest During Construction	18,436	33,074
Subtotal	120,858	170,889
Working Capital	6,000	8,544
Total Capital Requirements	$126,858	$179,433

Source: Reference 30 Bibliography

TABLE I-7
ESTIMATED ANNUAL PRODUCTION COST
KUKPOWRUK COAL FIELD
5 MILLION TONS PER YEAR

Cost Item	KAISER 1976	DOE 1980
Direct Cost		
Wages		
Operating Labor	$ 3,343,156	$ 4,235,461
Maintenance labor	2,267,189	2,844,882
Subtotal	$ 5,610,345	$ 7,080,343
Salaries		
Production	397,500	490,520
Maintenance	488,750	603,067
Administrative	1,071,250	1,321,577
Subtotal	$ 1,957,500	$ 2,415,164
Payroll Overhead	3,027,138	3,798,203
Total Wage & Salary Cost	$10,594,983	$13,293,710
Operating Supplies		
Spare Parts	3,884,370	5,446,299
Explosives	3,665,316	5,139,165
Fuel & Lubricants	1,543,510	2,164,723
Tires	784,575	1,098,787
Miscellaneous	1,837,140	2,575,331
Total, Operating Supplies	$11,714,911	$16,424,305
Power	1,897,140	2,652,790
Union Welfare	4,800,000	4,800,000
TOTAL DIRECT COST	$28,989,034	$37,177,805
Indirect Cost - (15% of Labor & Material)	3,346,484	4,457,702
Taxes & Insurance - (2% of Plant Cost)	2,048,440	2,756,300
Depreciation	7,234,000	10,574,294
Deferred Expense	1,518,625	1,955,000
Total Annual Production Cost	$43,136,583	$56,921,010
Royalty (12 1/2 % of Selling Price)	8,645,054	11,578,006
TOTAL ANNUAL COST	$51,781,637	$68,499,107

Source: Reference 30 Bibliography

TABLE I-8
CALCULATION OF COAL SELLING PRICE
KUKPOWRUK COAL FIELD
5 MILLION TONS PER YEAR

20 YEAR PROJECT LIFE - 15% RETURN ON INVESTMENT

	KAISER 1976	DOE 1980
Annual Gross Profit		
After-Tax Cash Flow (Initial Investment/6.259)	$20,268,094	$28,667,998
Less Depreciation	7,234,000	10,574,294
Depletion & After-Tax Profit (=3/4 Gross Profit)	13,034,094	18,093,704
GROSS PROFIT	$17,378,792	$24,124,939
Annual Sale		
(Sales= Production Cost + Royalty + Gross Profit)		
Production Cost	$43,136,583	$56,921,101
Gross Profit	17,378,792	24,124,939
Subtotal	60,515,375	81,046,040
Royalty (12 1/2% of Sales)	8,645,054	11,578,006
Annual Sales	69,160,429	92,624,046
Selling Price Per Ton	$ 13.83	$ 18.52
Cash Flow		
Gross Profit	$17,378,792	$24,124,939
Depletion (50% of Gross Profit)	8,689,396	12,062,470
Taxable Income	8,689,396	12,062,469
Federal Income Tax	4,344,698	6,031,235
After Tax Income	4,344,698	6,031,234
Plus Depreciation	7,234,000	10,574,294
Plus Depletion	8,689,396	12,062,470
Cash Flow	$20,268,094	$28,667,998

Source: Reference 30 Bibliography

Kaiser Engineers estimated capital and operating costs for a townsite, employee housing and power plant at $4.15 per ton for a 5 million ton-per-year operation in 1976. The 1980 cost of the same facilities is estimated at $5.82 per ton based on the 40.2 percent increase in the Producer Price Index-All Commodities from December, 1976 to April, 1980. Therefore, the estimated FOB mine selling price of Kukpowruk coal is $23.20 to 25.60 per ton or $.97 to 1.07 per million BTU.

C. Alaska Coal Transportation

This section focuses on the role of transportation from the mine to an Alaska port, which is navigable year-round, in the development of Alaska coal resources. The cost of Alaska coal ocean transport from Alaska to potential markets is discussed in the next chapter. Transportation is a fundamental requirement for the development and marketing of Alaska coal and its costs must be included in selling prices. Beluga, Nenana and Kukpowruk require different transportation systems and each is considered separately.

1. Beluga Coal Field

The proximity of Beluga coal to port simplifies the logistics of its transportation. A number of transportation systems have been proposed. The Alaska Railroad has investigated a 70 mile spur which would connect the Beluga field with the existing mainline of the Alaska Railroad for movement to Anchorage, Seward or Whittier. Placer Amex, in their Beluga Status Report, September, 1979, proposed moving Beluga coal by truck initially and then later as production increases to 2-3 million tons/year, the coal would be transported by rail to a port facility to be constructed on Cook Inlet at Trading Bay.[6] Both the Alaska Railroad and Placer Amex systems are feasible, but the extremely high cost of railroad construction and the time delay associated with Congressional approval of any extension of the Alaska Railroad leads this report to conclude that the Placer Amex plan is the more viable as it offers both a much shorter lead-time and greater liklihood of success.

The Placer Amex transportation system would initially use 120 to 150 ton tractor-trailer units to haul the coal to tidewater. If volume increased to 2 million tons/yr or more, the transportation system would be converted to rail and a larger stockpile would be constructed, incorporating a tunnel-conveyor reclaim system to deliver crushed coal to a high capacity railway storage facility. The ground transportation system would feed a loading facility consisting of a pier equipped with a 72 inch wide conveyor belt. Several possible Cook Inlet port sites have been considered and appear suitable to handle ships as large as 100,000 DWT. The total estimated cost of the ground transportation system and port facilities is $5.50 to $6.00 per ton or $.37 to $0.40 per million BTU.[(6)]

2. Nenana Coal Field

For out of state sale, the only viable method of transportation for Nenana coal is predicted to be rail to a year-round port where it will be loaded onto ships or barges. The Alaska Railroad currently transports approximately 600,000 tons of coal per year from the Usibelli mine to the Fairbanks, Alaska area. The Alaska Railroad also connects the Nenana Coal Field with three Alaska year round ports - Anchorage, Seward and Whittier. According to the Alaska Railroad, a totally owned Federal government system, the total increased production forecasted for the Usibelli mine could be hauled from Healy to Anchorage on existing railroad trackage without upgrading the system.[27] The Alaska Railroad would use 100 car unit trains with a maximum load of 8,000 tons per train to haul the coal to Anchorage. The estimated price for hauling the coal is $6.50 to $7.00 per ton if the Railroad owns rather than leases the rail cars.

The next step in exporting Nenana coal would be to build an Anchorage facility large enough to receive, store, and load the coal on ships or barges. Anchorage Sand and Gravel Inc., which currently performs all of these functions with sand and gravel, recently explored the possibility of creating a coal facility in the Anchorage area. The firm estimates Anchorage port and loading fees would be approximately $4.75 to $5.25 per ton if a suitable site in the Anchorage Port can be obtained. The combined cost of inland transportation and port costs for Nenana coal is estimated at $11.25 to 12.25 per ton or $.70 to $.77 per million BTU.

3. Kukpowruk Coal Field

The transportation of Kukpowruk coal to a year-round port could be accomplished by at least two different transportation systems. One system would involve the construction of a railroad from the field to Nenana, a distance of approximately 720 miles, and would connect the field with the existing Alaska Railroad. A second system would transport the coal by barge on a seasonal basis to the year-round port of Dutch Harbor, Alaska for storage and future shipment to markets. Dutch Harbor, which is located in the Aleutian Islands, was selected as a transhipment point for Kukpowruk coal since it is navigable throughout the whole year and is centrally located between potential markets in the Far East and on the West Coast of the United States. Direct shipment of coal from the Kukpowruk coal field to markets was not thoroughly investigated due to the limited shipping season (3-5 months) and the adverse weather conditions usually encountered during the winter months in northwestern Alaska.

The Kaiser study investigated both transportation systems.[30] It determined that the railroad system was too costly to be viable so this report does not consider it. The seasonal barge system, however, was deemed to provide a reliable transportation system at a reasonable price and this study will once again update the Kaiser figures to determine 1980 costs.

The barge system would consist of; (1) a roadway for trucks, belt conveyor or slurry pipeline from the field to the Chukchi Sea coast, (2) a barge-loading facility at the Chukchi Sea coast, and (3) a transhipment and storage facility at the year-round port of Dutch Harbor. The Kaiser Engineers concluded that the combination slurry pipeline and barge system was the most economical at $11.60 (1976 Dollars) per ton. This report assumes that relative costs of the systems have remained constant since 1976 and therefore only escalates the costs of Kaiser's slurry pipeline and barge transportation systems. The slurry pipeline and seasonal barge system is estimated to cost $15.50 to $17.00 per ton based on increases in the Producer Price Index - All Commodities between December, 1976 and April, 1980.

The transhipment of Kukpowruk coal at Dutch Harbor is estimated at $4.75 to $5.25 (1980 $) per ton based on Anchorage Sand and Gravel's port loading costs in the Anchorage, Alaska area. The total transportation costs from mine to Dutch Harbor for Kukpowruk coal are estimated at $20.25 to $22.25 per ton or $.84 to $.93 per million BTU (1980 $).

D. Summary of Selling Price Estimates

Tables I-9 and I-10 summarize the FOB year-round port selling prices of Beluga, Nenana and Kukpowruk coal given the assumptions outlined in this chapter. Obviously, Beluga coal and Nenana coal at a 2.1 million ton per year production rate are the most economical at the mine on a $1980 per million BTU basis. However, the limited production in the Nenana field available at the lower price and the greater transportation costs required for Nenana coal would probably make the development of the Beluga field a more favorable project. Kukpowruk coal is slightly more expensive than Beluga coal or Nenana coal (2.1 million tons/yr) on a $1980 per million BTU basis. However, the price differences between the three coals are so small, it is doubtful that price alone would be the determining factor in selecting an Alaska coal field for development.

The causal factors in addition to price for selecting one of the Alaska coal fields for development may be the location and coal specifications of the market for Alaska coal. For example, if the market specified a high ranking coal then Kukpowruk coal would be a possible choice, if environmental concerns can be relieved. However, if quantity is the most desirable characteristic, Beluga Coal may be the first site developed. And finally, if the market is relatively small and located in the Alaska interior, Nenana coal production may be increased first. Also, development at one site does not necessarily preclude development at other sites. Several of the factors and various market demands could come into play simultaneously, and coal would flow from two or more areas.

TABLE I-9
Selling Price Estimates
($1980/Ton)

	Mine Price	Transportation	FOB Year-Round Port
Beluga Coal Field 5,000,000 tons/yr	$15.00 - 22.50	$ 5.50 - 6.00	$20.50 - 28.50
Nenana Coal Field (Usibelli Mine)			
2,100,000 tons/yr	$16.00 - 18.00	$11.25 - 12.25	$27.25 - 30.25
4,100,000 tons/yr	26.00 - 28.00	11.25 - 12.25	37.25 - 40.25
Kukpowruk Coal Field 5,000,000 tons/yr	$23.20 - 25.20	$20.25 - 22.25	$43.45 - 47-85

TABLE I-10
Selling Price Estimates
($1980/Million BTU)

	Mine Price	Transportation	FOB Year-Round Port
Beluga Coal Field 5,000,000 tons/yr	$1.00 - 1.50	$.37 - .40	$1.37 - 1.90
Nenana Coal Field (Usibelli Mine)			
2,100,000 tons/yr	$1.00 - 1.13	$.70 - .77	$1.70 - 1.89
4,100,000 tons/yr	1.63 - 1.75	.70 - .77	2.33 - 2.52
Kukpowruk Coal Field 5,000,000 tons/yr	$ .97 - 1.05	$.84 - .93	$1.81 - 1.99

Chapter II

Transportation Costs from Alaska to Individual Markets/Users.

A. Economic analysis of transporting coal or coal derived fuels from sources to primary market areas.

In order to determine marketability of Alaska coal in various markets, it is first necessary to specify the costs of delivering coal to the receiving port. It is clear that, in terms of the universe of possibilities, certain market areas are more likely to be interested in purchasing Alaska coal resources than others. For the purpose of this study, as detailed in Chapter III, the prime market areas are those which either have manifested interest in utilizing Alaska coal or are relatively close to Alaska.

Both the Puget Sound and Oregon (Seattle, Portland) areas and the northern California area (San Francisco and Sacramento) have been mentioned as U.S. West Coast markets for increased use of coal for electric power generation. Puget Sound Power and Light Company, a utility in the Puget Sound area, is investigating the feasibility of low-medium BTU gas (derived from coal) as a fuel for the generation of electricity. In California, siting discussions are being held concerning construction of coal-fired generation facilities in the Sacramento Delta area. Therefore, these two areas are appropriate for analysis as leading U.S. West Coast market destinations.

In terms of foreign markets on the Pacific Rim, Chapter III identified Japan, Taiwan and Korea as countries actively pursuing the possibilities of using coal from both Canadian and Alaska sources. They currently import Australian coal. Thus, if Alaska coal could be shipped competitively (i.e., to permit a delivered price in the same range as Australian and other coals), coal trade with Alaska could be established.

As discussed in Chapter I, the transportation modes that may be considered to move the mined coal to tidewater transhipment points include barges, slurry pipelines, trains and trucks. Because of the unique challenges of transporting resources over Alaska's terrain, the link between mine source and tidewater is crucial in the transportation chain between resource site and use.

Once the coal has arrived at tidewater, the question of marine transhipment facilities arises. In this study, we assume that the three coal sources (Kukpowruk, Nenana and Beluga) have corresponding tidewater transhipment points (Dutch Harbor, Anchorage and Trading Bay (Cook Inlet), respectively). Each of these transhipment locations have technical and environmental questions to be answered before construction and transhipment could commence. The specific environmental questions on each mine site are addressed in Appendix B. In developing the estimates for the selling price at tidewater (FOB), detailed in Chapter I, the costs used are those which individual companies have presented in technical analyses of construction and operation of their projects. Since the methods of deriving the estimated selling price of coal thus incorporates each firm's cost estimates, the selling price itself implicitly reflects the technical aspects of constructing the facilities.

Once the bulk coal departs the transhipment point, it would move via conventional marine transport. This report bases its analysis on the use of 25,000 dead weight ton (DWT) vessels, a common size for such transport. However, it is recognized that larger vessels could be used that would provide a corresponding reduction in unit transportation costs. Since Alaska's distance from major market areas has proved in the past to be the prime deterrent to efforts to develop Alaska coal for out-of-State markets, marine shipping, the lowest cost alternative over long distances, is the appropriate method to be considered in a lower bound (best case) transportation scenario.

As with transhipment ports, there are technical and environmental issues associated with siting receiving ports. These issues need to be addressed in some detail in order to determine the feasibility of receiving coal in each considered location. If port siting at a particular location encounters significant delays in the permitting process, costs would increase. In this chapter, we address the cost to purchaser at the port of entry (i.e., the FOB price at Alaska point of departure plus shipping cost to destination). These cost estimates can then be used to make comparisons with other coals and fuels.

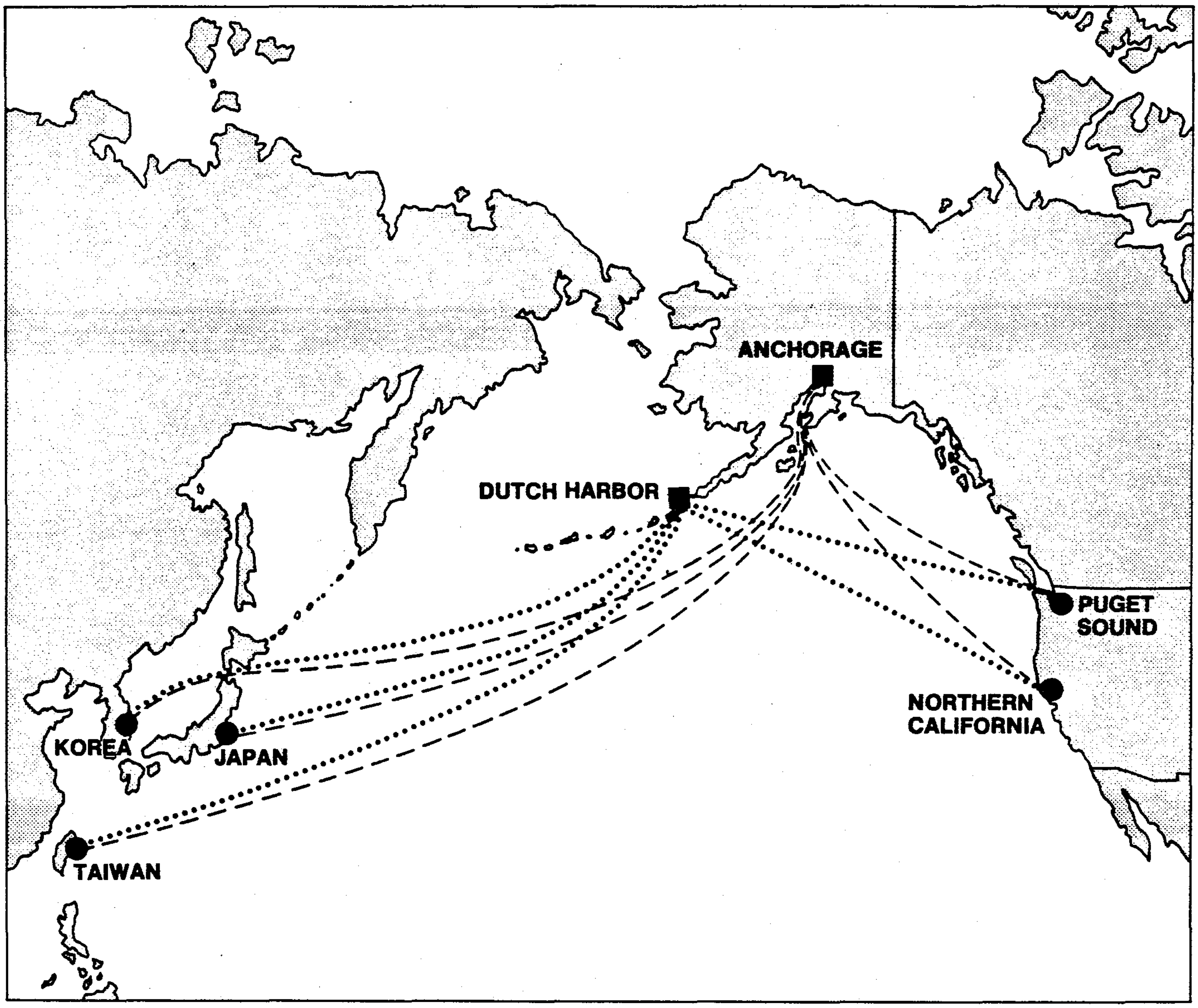
This report considers only currently available transportation methods to maintain the focus on near-term potential for marketing Alaska coal. Discussions of the possibilities of Arctic marine transport systems and high technology versions of slurry pipelines show that more time will be needed to plan, approve and construct a system than the limits assigned to this report permit. These systems also would be capital and/or new-technology intensive. The possibilities that open up when synthetic fuels (derived from coal) including methanol are considered are distinct from those for bulk coal.

Although these alternatives may offer real and viable options for the future, their contribution before 1986 is constrained because of questions of timing, capital requirements and technology considerations in addition to the basic criterion of economic profitability. The potential for synfuels in the latter half of the 1980's is, however, more promising. (See discussion in Chapter VII.)

Figure II-1 serves as a visual guide to the trade flows that are discussed here as potential routes for Alaska coal trade. In the following section, the transportation costs associated with these transportation links are developed for the routes shown in this map.

Figure II -1

Possible Trade Routes Between Alaska and Primary Pacific Rim Market Areas for Alaskan Coal.



·················· Routes Originating in Dutch Harbor

– – – – – – – – Routes Originating in Anchorage/Cook Inlet

■ Transshipment Points

● Destination Points

B. Investigation of Possible Transportation Modes

For moving bulk coal to Japan, Korea and Taiwan, the only near term transportation mode currently available from Alaska is marine transport. For U.S. West Coast markets, however, alternatives to marine transport (railroad and coal slurry pipelines) are technically possible but economically questionable. With regard to those alternatives, however, the capital costs of construction of such an extensive system of fixed facilities make it prohibitively expensive.

Assumptions pertinent to transportation cost estimates in this chapter are:

1. Ships used are 25,000 DWT, and are dedicated and fully used on a specific route - vessels do not haul anything of value on the return trip. (If they could, costs would be reduced.)

2. Cost estimates are based on a quote of $10.00 per ton for the Vancouver-Japan route. (F-1)

3. Shipping costs are proportional to distances.

4. Due to the requirement imposed by the Jones Act to use U.S. ships between American ports, costs were increased 2.5 fold over international rates.

Discussions held with shippers and a recent report (45) indicate that shipping in American registered vessels as required by the Jones Act costs from two to three times as much as shipping in foregin registered vessels. With these assumptions, the following table of transportation costs per short ton of coal was developed.

TABLE II-1
Transportation Costs Between Alaska Port and Destination Market
(Dollars Per Short Ton of Coal)

Destination	Puget Sound	Northern California	Japan (Tokyo)	Taiwan	Korea
Origin					
Kukpowruk (Dutch Harbor)	$9.75	$12.00	$6.10	$8.60	$7.20
Nenana (Anchorage)	7.00	10.00	7.70	10.20	8.80
Beluga (Cook Inlet)	7.00	10.00	7.70	10.20	8.80

This table shows the relative costs of transporting coal to the five market areas. Due to requirements imposed by the Jones Act, costs to U.S. West Coast ports are, in some cases, higher than costs to Far East Markets. Considering the Far East Market, the Table shows the relative marine transportation cost advantage that coal shipped from Dutch Harbor has over Cook inlet and Anchorage shipped coal. However, for shipments to U.S. West Coast markets, th Nenana and Beluga coals have a marine considerable transportation cost advantage over Kukpowruk coal.

C. Total Delivered Cost of Coal From Alaska Sources to Primary Markets

Estimates for total delivered cost of coal per ton can be calculated by combining the selling price estimates from Table I-9 with the transportation cost estimates shown in Table II-1. These estimates are presented in terms of dollars per short ton, according to shipment origin and market destination in Table II-2.

TABLE II-2
Total Delivered Cost of Alaska Coal
From Sources to Primary Market Areas
(Dollars Per Short Ton)

Destination	Puget Sound (Seattle)	Northern California (San Francisco)	Japan (Tokyo)	Taiwan	Korea
Origin					
Kukpowruk (Dutch Harbor)	$53-58	$55-60	$50-55	$52-57	51-56
Nenana* (Anchorage)	$34-37	$37-40	$35-37	$37-40	$36-38
	$44-47	$47-50	$46-50	$49-53	$47-51
Beluga (Cook Inlet)	$28-36	$31-39	$28-36	$31-39	$29-37

*The two-tier costs for Nenana coal refer to the different scales of operation as discussed in Chapter I.

Table II-3 presents these same estimates on a dollars/million BTU basis.

TABLE II-3
Total Delivered Cost of Alaska Coal
From Sources to Primary Market Areas
(Dollars Per Short Ton)

Destination	Puget Sound (Seattle)	Northern California (San Francisco)	Japan (Tokyo)	Taiwan	Korea
Origin					
Kukpowruk (Dutch Harbor)	$2.21 - 2.42	$2.29 - 2.50	$2.08 2.29	$2.17 - 2.37	$2.12 - 2.33
Nenana* (Anchorage)	$2.12 - 2.31	$2.31 - 2.50	$2.19 - 2.31	$2.31 - 2.50	$2.25 - 2.37
	$2.75 - 2.93	$2.93 - 3.12	$2.87 - 3.12	$3.05 - 3.31	$2.94 - 3.19
Beluga (Cook Inlet)	$1.87 - 2.40	$2.07 - 2.60	$1.87 - 2.40	$2.06 - 2.60	$1.93 - 2.47

*The two tier costs for Nenana coal refer to the different scales of operation as discussed Chapter I.

Table II-3 shows that for all market areas Beluga coal has a BTU cost advantage. In the Northern California market areas, for example, Beluga coal can be delivered for $2.07 to $2.60 per million BTUs compared to about $2.30 - 2.50 for the other two coal supply areas. Similar relationships hold for the other market areas, i.e. Puget Sound and the Far East markets.

Although the lower bound of the cost range is lowest in all cases for Beluga Coal, it should be noticed that the upper bound is consistently higher than those for the other areas. In other words, if the upper range of costs prove to be more accurate, the cost advantage of Beluga coal would diminish.

Due to the environmental concerns of the Kukpowruk area, however, the possibilities of development in the Kukpowruk region may be significantly constrained. Such potential restrictions on developing the resources in the Kukpowruk area should be kept firmly in mind when considering the options for Alaska coal.

Chapter III

Market Areas for Alaska Coal

A. Introduction

Future prospects for Alaska coal can be properly assessed only against the background of overall world energy demands and supplies. Due to the large dependence on oil the world energy demands and supplies will be primarily determined by world economic growth and OPEC pricing and production levels. The International Energy Agency (IEA) estimates a 3.4 percent average annual rate of economic growth and a 2.7 percent per year increase in energy demand for the Organization for Economic Co-operation and Development's (OECD) twenty-four member countries.[21] The quantity of oil that oil-exporting countries may make available to meet world energy demand is concluded to be insufficient and extremely expensive to energy importing countries. Therefore, the IEA and World Coal Study (WOCOL) foresee an expansion of international coal trade to satisfy future world energy demands.[44]

This chapter examines future market demand for steam coal in which Alaska coal can be expected to become economically competitive with other coal supplies. Synthetic fuel markets are discussed in Chapter VIII. Coking coal markets have been eliminated from consideration since no Alaska coal in mineable beds has been found and tested which possesses the necessary combination of qualities (i.e., greater than 13,000 BTU/lb. and less than 8.0 percent ash and 1.0 percent sulphur) to be considered as coking coal.

The area of concern is the Pacific Rim market area; Alaska markets, U.S. West Coast markets, and Far East markets. The analysis is limited to these Pacific Rim markets due to; (1) their proximity to Alaska resources, (2) associated advantages of water transportation and (3) demonstrated interest by utilities in increasing coal consumption. Also, other market areas could be analyzed by extending transportation routes and increasing associated transportation costs.

The predicted range of steam coal consumption for each of the three main market areas was determined by reviewing private and government energy demand forecasts. The data contained in these forecasts were then summarized to produce a range of steam coal consumption for each market area. The availability and reliability of data sources for each of these potential steam coal markets varies greatly, the results, therefore, are presented as a general guideline to the future size of the Pacific Rim steam coal market. Nevertheless, it is obvious that steam coal demand in these markets will be large enough to require coal from several sources.

B. Alaska Markets

The potential major market areas in Alaska for indigenous coal are the Anchorage - Cook Inlet and the Fairbanks - Nenana Valley areas, which comprise the Railbelt area. The Railbelt area possesses Alaska's largest concentrations of population, economic activity, energy demand and industry. The Railbelt area also has an existing transportation system that currently hauls approximately 600,000 tons of coal per year.

The Alaska Power Administration (APA) recently analyzed current and future power and energy requirements for Alaska's Railbelt area.[3] APA determined future power requirements based on forescasted energy use per capita, projected population and an assumed utility load factor of 50 percent. Table III-1 summarizes APA's forecasted power and energy requirements for the Railbelt area. The installed 1979 nameplate capacity for the Railbelt area was approximately 795 MW. The need for new generation capacity between 1980 and 2000 is well documented. The question is, "Will any new generation be coal-fired and if so, how much?"

The probability that all future electric power generation in the Railbelt area will be coal-fired is not great, as Alaska possesses a number of large potential hydroelectric power sites. However, an integrated power supply system based on a combination of hydroelectric and coal-fired power plants has support of some interested parties in Alaska. Therefore, due to favorable economics for hydroelectricity, this report assumes that coal-fired generation will not supply more than 25 percent of future Railbelt power demands and that 500,000 tons per year of Alaska coal will be required to fuel a 100 MW plant. Table III-2 provides a summary of Alaska Railbelt area increased coal demand for power generation based on these assumptions.

TABLE III-1
Power and Energy Requirements
Railbelt Area

	1973	1977	1980	1985	1990	1995	2000
Peak Power	MW	MW	MW	MW	MW	MW	MW
Total							
High			890	1,671	2,360	3,278	4,645
Mid	389	650	829	1,162	1,592	2,134	2,852
Low			729	961	1,177	1,449	1,783
Annual Energy	GWH*	GWH	GWH	GWH	GWH	GWH	GWH
Total							
High			3,928	7,636	10,684	14,844	20,935
Mid	1,838	2,681	3,663	5,133	7,078	9,528	12,738
Low			3,391	4,256	5,219	6,430	7,890

*GWH = 1,000 MWH.
Source: Reference 3 Bibliography

TABLE III-2
Increased Power Generation Coal Demand
for Railbelt Area

Year	Tons/Year
1985	207,500 - 1,095,000
1990	477,500 - 1,956,250
1995	817,500 - 3,103,750
2000	1,235,000 - 4,812,500

C. U.S. West Coast Market

The U.S. West Coast energy market consists of Washington, Oregon and California. Washington is currently the only State of the three which produces electricity by burning coal. The 1330 MW mine-mouth power plant at Centralia, Washington consumes approximately 5 million tons of coal per year. The next coal-fired power plant to come on stream in this market area will be Portland General Electric Company's 530 MW power plant at Boardman, Oregon which will consume 2 million tons of Wyoming coal per year.

Washington, Oregon and California utilities have usually been able to rely on hydro, oil, gas and nuclear to meet growing electricity demands. However, each of these traditional energy resources has either become fully developed or new capacity has become economically, socially or environmentally unacceptable. Therefore, public and private utilities have started to seriously consider coal-fired electrical generation as an alternative to more traditional sources.

The California steam coal market is projected to be limited to 20 million tons per year since the California Energy Commission has placed an upper limit of 5,000 MW of coal-fired generation within the State by the year 2000.[7] However, it is unlikely that much Alaska coal will be able to penetrate the California market as the Pacific Gas and Electric Co. and the Southern California Edison have already applied for permits to build more than 3,000 MW of coal-fired generation to be supplied Utah coal. If one assumes that a 1,000 MW coal-fired plant will be built on California's coast in the 1990's, a maximum annual California market for Alaska steam coal would be 5 million tons annually.

Forecasts of future steam coal markets in Oregon and Washington have been developed by a number of organizations over the last few years. The most comprehensive analysis of the Oregon and Washington energy situation is the Northwest Energy Policy Project (NEPP) sponsored by the Pacific Northwest Regional Commission and carried out in 1976-78.[25] This project included three forecasts of consumption and supply mixes. However, this DOE report will base its steam coal consumption estimates on the NEPP projected mid- and high-levels of energy demand, since the projected low-level of energy demand has already been surpassed.

The NEPP forecasts use a methodology that relates State energy consumption to State demographic and economic variables, such as the number of people and households in the State, per capita personal income, and the prices of energy products. The NEPP forecasts for coal consumption were divided into direct uses and electrical generation uses. Table III-3 summarizes the annual tons of Alaska coal that would be required to satisfy increased forecasted steam coal demand in Oregon and Washington.

Table III-3 assumes that the proposed Washington Water Power Company's Creston Plant, the expected Puget Sound Power and Light Company's Hanford Plant and the probable Portland General Electric Company's Boardman II Plant will be the only coal-fired power plants built in Oregon and Washington before 1990 and that these power plants will probably consume Montana, Wyoming or Utah coal. Therefore, Alaska coal is not expected to penetrate the Oregon and Washington steam coal market before 1990.

TABLE III-3
Estimated Alaska Steam
Coal Consumption in
Oregon and Washington

Year	Tons/Year
1985	-
1990	-
1995	2,250,000 - 6,000,000
2000	4,300,000 - 15,000,000

Source: Reference 25 Bibliography

D. Far East Markets

The Far East energy market consists primarily of Japan, Korea and Taiwan. These three countries are extremely deficient in fuels and sources of energy required for heavy manufacturing. Japan is the most energy dependent industrialized country in the world. According to United Nations 1976 data, Japan imported 99% of its oil supply, 73% of the natural gas consumed, 77% of its coal supply and 100% of the uranium used to fuel Japan's nuclear power plants.[31] Japan is therefore dependent on foreign energy supplies for over 90% of its energy requirements. This large energy market, which is over 4,100 statute miles from Alaska's Cook Inlet, may prove to be the major market for Alaska coal. Korea and Taiwan are similarly dependent on foreign energy supplies, although exact figures are not available.

The Japanese, Korean and Taiwanese government's realization that the instability of oil supplies and higher oil prices are potentially the greatest bottlenecks to their economic development have forced each government to enact a national energy policy.

The Japanese national energy policy, which was a model for Korea and Taiwan, recommends; (1) the promotion of nuclear power, (2) the utilization of indigenous energy resources, (3) the diversification of overseas energy supplies by expanding coal and LNG imports, and (4) the establishment of a stable petroleum supply.

Forecasts of future steam coal markets in the Far East have been developed by a number of organizations over the last few years. The predicted range of steam coal demand for the Far East market in this report is a summary of the various government and private estimates encountered while investigating future steam coal markets for this report. The data from these studies are summarized in Table III-4.

TABLE III-4
Total Steam Coal Demand
for Japan, Taiwan and Korea

Year	Million Tons/Year
1985	20 - 40
1990	30 - 80
1995	45 - 100
2000	90 - 150

Sources: Reference 42, 17 and 32 Bibliography

Chapter IV

Competitive Coal Sources

This chapter is a summary of information and data on sources of coal that are anticipated to be competitive with Alaska coal. Information is presented for the following countries: Australia, Canada, South Africa and the conterminous United States. Detailed information on coal characteristics, producing regions, institutional barriers, etc. for each of these countries can be found in Appendix C.

A. Australia

Australia has over 350 billion tons of coal resources and is expected to become a major coal producer and exporter in the future. In 1978, Australia produced 124 million short tons and exported 39 million tons of coal (steam and metallurgical).

Table IV-1 shows the production increases anticipated in Australia under current (1978) plans. Data are summarized from information contained in Appendix C.

Table IV-I
Increases in Australia Coal Production
(million of short tons)

	1980	1985	1990
Steam	8.2	25.5	33.7
Coking	29.2	50.6	56.2
Lignite	14.0	20.0	25.0

Source: "Coal Development Potential and Prospects in the Developing Countries," World Bank, Washington, D.C., 1979.

Table IV-2 summarizes the projected steam coal exports from Australia. As can be seen Australia is expecting to increase its coal exports dramatically, from a little over 3 million tons in 1977 to 50 million tons per year by 2000.

TABLE IV-2
Projected Steam Coal Exports from Australia
(million of short tons)

1977 (actual)	1980	1985	1990	2000
3.3	7.0	18.5	30	50

Source: "Coal Development Potential and Prospects in the Developing Countries," World Bank, Washington, D.C., 1979.

It has been projected that Australia surface-mined coal can be landed in Japan for $35 Per ton or $1.44 per million BTU (1980 dollars)[35].

B. Canada

Canada is rapidly becoming one of the largest coal producing and exporting countries. In 1978, Canada produced 34 million tons while exporting 14 million tons (mostly metallurgical).

As illustrated in Table IV-3, Canada expects to increase its steam coal production from 15.2 million tons in 1976 to 83 million tons in 1990.

TABLE IV-3
Estimated Canadian Steam Coal Production

	1976 (actual)	1980	1985	1990
Steam Coal	15.2	30	57	83

Source: "Coal Development Potential and Prospects in the Developing Countries," World Bank, Washington, D.C., 1979.

Table IV-4 summarizes potential steam coal exports from Canada. Although Canada will increase its steam coal exports, most of the expected new production is destined for internal consumption in new coal-fired electrical plants.

TABLE IV-4
Potential Steam Coal Exports From Canada
(millions of short tons)

	1976	1980	1985	1990
Steam Coal	0.7	2.0	5.0	10.0

Source: "Coal Development Potential and Prospects in the Developing Countries," World Bank, Washington, D.C., 1979.

According to a DOE study, Canadian coal can be delivered to Japan for an average price of $45 per ton or $2.35 per million BTU's (1980 dollars).[35]

C. South Africa

Since 1970, coal production in South Africa has been increasing at an annual rate of over 6.0 percent, from 58 million tons in 1970 to 96 million tons in 1978. South Africa has the world's only commercial coal liquefication plant, SASOL I, which consumes 4 million tons per year.

Table IV-5 illustrates the projected steam coal production for South Africa through 1990.

TABLE IV-5
Steam Coal Production for South Africa
(millions of short tons)

	1980	1985	1990
Steam Coal	90	127	144

Source: "Coal Development Potential and Prospects in the Developing Countries," World Bank, Washington, D.C., 1979.

Also, shown in Table IV-6 is South Africa's projected steam coal exports. Exports are expected to increase from 6.6 million tons in 1976 to 23 million tons by 1990.

TABLE IV-6
Steam Coal Export Projections from South Africa
(millions of tons)

1976 (actual)	1980	1985	1990
6.6	11	20	23

Source: "Coal Development Potential and Prospects in the Developing Countries," World Bank, Washington, D.C., 1979.

Steam coal from South Africa can be delivered to Japan for an average price of $33 per ton or $1.51 per million BTU.

D. Conterminous United States

The United States has tremendous quantities of technically and economically recoverable coal reserves, estimated to be approximately 28 percent of the world's total.[11] The U.S. is also the world's largest coal producer, 647 million tons in 1978.

The U.S. is expected to increase its total coal production to over 1 billion tons per year by 1985.[21] The recent emphasis in the U.S. with respect to steam coal development has been on western surface mines. A recent DOE report indicates that in the Western U.S. the productive capacity in 1980, 1985 and 1990 will be 286, 547 and 710 million tons/year respectively.[41] These represent potential steam coal production increases of 49.5, 311 and 474 million tons per year over the 1979 level of 236 million tons. It should be noted that this expansion will not be without associated transportation, port development, water boom town, etc. type of obstacles.

The U.S. is projecting significant increases in steam coal exports as detailed in Table IV-7.

TABLE IV-7
Projected Steam Coal Exports From the United States
(millions of tons)

	1985	1990	2000
Steam Coal	15.8	23.4	73.8

Source: International Energy Agency, "Steam Coal, Prospects to 2000," Organization for Economic Co-Operation and Development, Paris, 1978.

It has been estimated that U.S. Western surface-mined coal can be delivered to Japan for an average price of $45 per ton or about $2.25 per million BTU.

E. Summary

All of the countries discussed in this chapter, and perhaps other countries have the potential and the inclination to expand their exports of coal, particularly to the Far East. Since Japan and perhaps other countries intend to diversify their coal supply sources for security reasons, all of these countries will probably capture a share of the Far East demand. It can be seen by comparing the delivered price with those for Alaska coal (see Chapter I) that Alaska can indeed compete on the world coal market.

Table IV-8 summarizes steam coal export projections for each of the competing countries. It is important to remember that the export tonnages given are for total exports and not exclusively those destined for the Far East Market.

TABLE IV-8

Summary of Steam Coal Production and Exports
Projections from Competing Countries

Coal Production Increases
(million short tons per year over current levels)

	1980	1985	1990
Australia	8.2	25.5	33 7
Canada	14.8	41.8	67.8
South Africa	17.7	54.7	71.3
Lower U.S.	49.5	311	474

Projected Coal Exports

	1980	1985	1990
Australia	7.0	18.5	30.0
Canada	2.0	5.0	10.0
South Africa	11.0	20.0	33.0
Lower U.S.	15.8	23.4	73.8

Source: "Coal Development Potential and Prospects in the Developing Countries," World Bank, Washington, D.C., 1979.

International Energy Agency, "Steam Coal, Prospects to 2000," Organization for Economic Co-Operation and Development, Paris, 1978.

Chapter V

Competitiveness of Alaska Coal

This chapter compares Alaska coal price estimates developed in Chapters I and II, with competing coal prices from other coal sources estimated in Chapter IV. The comparison is on a U.S. dollar (1980) per million BTU (heating value) basis and does not consider other coal characteristics which the specific market might desire. The analysis assumes total steam coal market demand identified in Chapter III, and summarized in Table V-1 is larger than the steam coal supply which could be produced by employing excess coal mine capacity in the world today. This assumption means that future steam coal prices should increase in real terms, but probably not until after 1990 when steam coal demand is expected to rise dramatically in Pacific Rim markets. This assumption also suggests that the question of when Alaska coal may be developed can be answered simply by comparing Alaska coal prices with the price of competing coals in specific markets.

TABLE V-1
Potential Estimated Pacific Rim
Steam Coal Market
(million tons)

Year	Alaska	U.S. West Coast	Far East	Total
1985	0.2-1	-	20 - 40	20.2 - 41
1990	0.4-2	4.0 - 5.0	30 - 80	34.4 - 87
1995	0.8-3	7.2 - 11	45 - 100	53 - 114
2000	1.2-8	9.3 - 20	90 - 150	100.5- 178

The first market which was examined in Chapter I - Section B was the Alaska Railbelt Area. If coal-fired power plants are built to supply electricity to the Alaska Railbelt Area, then it is obvious that increased production in the Nenana Coal Field would be able to supply all the necessary steam coal at the best price until at least 1995. Nenana coal's price advantage is due primarily to location. The Nenana field is located in the Railbelt Area and therefore transportation charges would be minimal since mine-mouth power plants could be utilized. The Nenana Coal would be delivered to the Alaska Railbelt market at a price of $1.00 - $1.75 per million BTU compared to Beluga Coal and Kukpowruk Coal at $1.37 - $1.99 per million BTU.

The second market which was investigated was the U.S. West Coast steam coal market. This market is similar to the Alaska market in that it is also forecasted as being insignificant until the late 1990's. The main difference between the U.S. West Coast market and the Alaska Railbelt market is that Alaska coals should be in direct competition with western U.S. coals for all future coal purchase agreements. According to DOE, western U.S. surface mines can produce and deliver coal to Washington, Oregon and California steam coal markets for $1.00 to $1.75 per million BTU.[37] The total delivered cost of

Alaska coal to U.S. West Coast ports calculated in this report and summarized in Table II-3 range from $1.87 to $3.12 per million BTU. Therefore, unless future coal-fired power plants are built on the Oregon, Washington or California coast, bulk Alaska coal is not competitive in U.S. West Coast steam coal markets at this time.

Primarily due to its vast size the Far East market may offer the best opportunity for Alaska coal. Alaska coals are currently competitive with Canadian and other U.S. coals in the Far East market, but are $.40 to $1.00 per million BTU more expensive than Australia or South Africa coal in Far East steam coal markets. However, it is not clear that Australia and South Africa can expand their coal production to meet their internal demands and at the same time supply Far East steam coal markets. Most coal experts predict that Australia and South Africa will be able to meet Far East steam coal requirements until the late 1980's or early 1990's. However, in the 1990's as Far East steam coal demands rise, the United States appears to be the only coal supplier with the reserves capable of meeting the Far East's steam coal demands.

In summary, the key to Alaska coal development should be the future growth of steam coal markets in the Far East. As these coal markets increase to the 80 million ton per year range in the 1990's, the United States could be the only country capable of meeting the demand. Since Alaska coal is currently price competitive in Far East markets with other U.S. coal supplies, Alaska coal should be in a position to compete for a share of the Far East steam coal market within the next fifteen years.

Chapter VI

Potential Balance of Payments Effect of Alaska Coal Export and Use

The development of the Alaska coal resources can have a two-fold impact on the U.S. Balance of Payments. First, if exports of Alaska coal to Pacific Rim countries grow, the U.S. balance of payments situation would be improved, both in general and vis-a-vis the customer nations (Japan, Taiwan and Hong Kong). Because of Alaska's proximity to Pacific Rim markets, and because of Alaska coal's ability to compete on a cost basis, the logical coal for potential export from the United States to the Far East is Alaska coal. Second, if increased coal utilization within the United States contributes to backing out imports of crude oil and petroleum products from foreign sources, the balance of payments would be affected favorably. It should be noted that this same effect could be gained from increased U.S. coal utilization from any U.S. coal source be it Alaska, Western United States or others.

The facts that (1) the U.S., in 1973, had a trade surplus of $911 million but, in 1978, had a trade deficit of $30 billion, and (2) the bill for the volume of U.S. crude oil imports totalled approximately $26 billion in 1976, but approximately $50 billion in 1979, in combination, indicate the importance to the U.S. of increasing its exports and decreasing crude oil imports in order to reduce the growing deficit in the U.S. balance of payments accounts.

In terms of market development potential in the Far East, the most likely scenario for initial trade would be the export of five million short tons of coal per year to those market from the Beluga fields. The export of this volume to Japan would mean that, if the coal is transported in U.S. vessels, the U.S. balance of payments would benefit by a total of $160 million per year (5 million tons X $33 per ton). To the extent that the Far East market for Alaska coal would expand beyond the volume of five million tons per year, the positive balance of payments effect would be correspondingly greater.

The second most likely market is California. If Alaska coal were shipped to California at the rate of five million tons per year, and if this coal backed out imported oil that is used for electricity generation approximately 12 million barrels of oil (on a BTU for BTU basis, a short ton of Beluga coal is equivalent to 2.4 barrels of crude oil) could be saved. Using the February 1980 price of $32.40 per barrel of imported crude oil (source: Monthly Energy Review, July 1980), a displacement of this quantity of imported crude oil would translate into a balance of payments saving of almost $400 million per year. Thus, the displacement of the crude oil equivalent in terms of energy to five million tons per year has more than twice the impact on the balance of payments that direct export of this amount of coal has, at February 1980 prices. Since the price of imported crude oil continues to rise (The April 1980 price level was $33.54. Source: Monthly Energy Review, July, 1980), the balance of payments effect of backing out imported crude oil would increase accordingly. In addition, if even larger quantities of coal were utilized, and that led to backing out imported crude oil as well, the effect on the balance of payments would be even more favorable.

The Puget Sound and Oregon market is the least likely of the market areas discussed in this report to purchase Alaska coal for electricity generation. If it is assumed, however, that 2.5 million tons per year were used for electricity generation that is in turn used for home heating that displaces fuel oil, then additional balance of payments benefits of approximately $180 million could be realized.

It should be noted that, for the equivalent tonnage of coal, shipment to and utilization on the U.S. West Coast (if the coal backs out imported crude oil) from only U.S. coal source would have twice the favorable impact on the U.S. balance of payments. In terms of the balance of payments, utilization of coal within the U.S. (assuming the backing out of imported crude oil) would have significantly greater impact than direct export. In addition, to this important impact, utilization of Alaska coal on the West Coast would have the related impacts of (1) reduction of U.S. dependence on foreign sources of supply of crude oil, (2) added motivation for the coal conversion program, (3) impetus to expand Alaska coal exploration and development, (4) increased employment, and (5) promotes American shipping activity North-South from Alaska.

Thus, export of 5 million short tons of Alaska coal to the Far East could lead to expanding exports by almost $160 million per year. In fact, even larger benefits to the balance of payments situation could be gained if increased coal utilization on the West Coast backed out imported coal. For the case in which California and the Puget Sound areas purchase a total 7.5 million short tons of Alaska coal per year, the balance of payments impact would be a saving of almost $600 million with the back-out of imported crude oil.

Thus, even the limited scale that these examples discuss, the impact on the balance of payments is sizeable. If exports are larger and coal conversion and utilization occurred on a larger scale, the impact on the balance of payments would be correspondingly greater.

Chapter VII

Potential For Synfuels From Alaska Coals

A. Introduction

One of the conclusions from the preceeding chapters is that Alaska coal will probably not supply future U.S. West Coast steam coal markets due to a price disadvantage when compared to western conterminous U.S. coal. However, the inability of Alaska coal to penetrate West Coast steam coal markets does not preclude its use as an energy resource for other West Coast energy markets. The West Coast steam coal market is a small segment of a large energy market that consumes oil, natural gas, hydroelectricity and nuclear power. Steam coal prices, on a BTU basis, are relatively low compared to oil and natural gas prices. With oil and natural gas prices increasing, in the late 1970's and 1980's, at rapid rates the potential for coal-derived synthetic fuels is being assessed in a new light. Technologies for converting coal into gaseous or liquid products, that were, until recently, considered too costly are undergoing close scrutiny.

The purpose of this chapter is to provide a cursory look at the possibility of using Alaska coal as a feedstock for a synthetic fuel facility that would supply U.S. West Coast needs. This is not intended to be a technical chapter which details economic and engineering parameters relative to synthetic fuels development.

Due to the more advanced state-of-the-art on coal to methanol technology, this chapter will focus only on methanol. Methanol has been produced from coal for years and the technology is well known and understood, although research is being conducted to assess more efficient production methods.

Since methanol is a liquid fuel with clean burning characteristics it is ideally suited for use in combustion turbine generating stations. Due to delays being experienced by Northwest utilities in siting and building conventional generating facilities, they are investigating the possibility of using combustion turbines fueled with coal-derived methanol. In addition, California's utilities have long expressed their interest in using methanol to produce electrical power. Particularly for peaking use, combustion turbines using methanol derived from Alaska coal would be a logical and environmentally sound end-use of the synthetic fuel.

B. Economics and Time Scale

One company (Placer Amex Inc.) has studied the cost of methanol production from Alaska coal and estimates that methanol produced in Alaska from the Beluga coal field could be delivered to Puget Sound for about $7/million BTU (± 20%) by 1986. Other estimates (see Appendix E) have ranged from approximately $5.00 to over $11.00 per million BTUs to produce methanol from coal. Current costs for imported crude oil is over $5.00 per million

BTU. The proposed plant would be designed to produce 54,000 barrels per day of methanol to be transported through an existing pipeline system to tanker loading facilities across Cook Inlet. A plant of this size could produce methanol sufficient to supply 800 MWe of combined cycle generation.

A methanol facility, utilizing currently available technology, could be completed by the mid-1980. This time-frame would be particularly beneficial to the electrical utilities in the northwest which need additional generation to meet projected deficits in electrical power. A thorough review of Federal and State environmental requirements associated with the point of production should be completed as early as possible. Existing air quality, availability of water, waste disposal, surface reclamation and other environmental aspects appear initially to permit siting of a synthetic fuel plant at or near the Beluga coal field.

Although there have been estimates that the cost of building a methanol facility in Alaska would be 30% more than in the contiguous United States, this cost differential could be partially alleviated by innovative construction methods. For example, a methanol plant could be built in modules and towed by barge to Alaska where it would be assembled on the northerly shore of Cook Inlet near the Beluga coal field. This technique was used for some of the Prudhoe Bay facilities, and was recently (1978) used by a Japanese manufacturer who built an entire pulp mill/electrical power plant that was towed from Japan to Brazil.

Since Alaska coals typically have high ash and high moisture the economic seem to favor conversion of coal in Alaska to a high quality, clean burning fuel rather than shipping bulk coal to U.S. markets. In contrast, coal or methanol produced from Western U.S. coal (Wyoming or Montana) would require a new pipeline or would be subject to high cost of overland transportation systems. These costs have not been estimated and warrant further study.

C. Role of Industry

Industrial interest in coal-derived electric utility fuel is demonstrated by the large number of proposals that were submitted to DOE for feasibility study funding. These include proposals by Placer Amex/Cook Inlet Region, Inc., (officially selected for funding) Puget Sound Power and Light Company and a consortium of Western natural gas companies. This expressed and implied interest combined with utility interest in combustion turbines will assist with perceived near term shortages of electricity, particularly in the Northwest. Seattle City Light and other regional utilities have ongoing feasibility studies on the use of gas turbine installations that will have the capability of using coal-derived methanol as a fuel.

It appears that industrial producers and industrial customers are interested in Alaska coal-derived methanol as a utility fuel, and they may be willing to invest in a coal-to-methanol system if the economics can be determined to be favorable, and if the regulatory climate is also favorable. The results of the recently awarded contract to Placer Amex to study the feasibility of such a system will be a valuable input in the decision to construct an Alaska coal-to-methanol project.

D. Legal Considerations

State government would have primary permitting and siting responsibility. The State of Alaska looks favorably to projects which would develop Alaska coal, and has offered State financial participation in the Placer Amex proposal. The State and Federal permit requirements are explained in Chapter VIII and in Appendix D.

It has been contrued that the Power Plant and Industrial Fuel Use Act (FUA) permits exemptions for coal-derived methanol-fueled combustion turbines. Section 211(b) of the Act provides for a temporary exemption from the prohibition of using natural gas or petroleum products in certain power plants based upon the future use of synthetic fuels, such as coal-derived distillate.

Chapter IX, Legal and Institutional Considerations, provides additional information relative to synfuel production from Alaska coal. Basically, synfuel facilities are subject to the same regulatory constraints as other energy facilities. In addition, some of the real-world issues surrounding synfuel facilities are not yet known and could contribute to delays.

E. Recommendations

Serious consideration should be given to Alaska coal derived fuel projects which could produce fuels to displace imported oil, since there seems to be no significant technological or regulatory barriers, and there appears to be a receptive political climate in Alaska for such an effort.

Early consideration should be given to preparing a short-term, conceptual engineering and system design study of Alaska coal-derived synthetic fuel in order to better determine costs and time schedules. While different industries have done such studies on pieces of the option described herein, we believe that DOE should have its own, independent figures upon which to base Departmental policy decisions.

CHAPTER VIII

Legal and Institutional Considerations

Study Limitations

Legal and institutional considerations will play a central role in the development of Alaska coal resources. Unresolved issues surrounding the strip mining and coal conversion methods, transportation and utility corridor systems, ports facilities and marine delivery systems, and the use of coal or coal-derived synthetic fuels pose significant obstacles to Alaska coal development. Topical areas include: (1) existing and evolving land tenure and management regimes of Alaska coal fields; (2) environmental degradation; (3) socio-economic impacts on existing communities and the creation of new communities; (4) developing policies and actions toward coal development by affected units of State, local and Native government; (5) existing and merging Federal, State and local regulatory requirements necessary for development; and (6) Federal policies and laws concerning coal conversion and use requirements.

This chapter will address Federal, State and local regulatory requirements and selected institutional considerations that will influence Alaska coal development. Except for a brief status review of the Alaska Lands Bill, it will not include a detailed discussion of existing and changing land tenure regimes or acquisition, or issues concerning land transportation and utility corridors, associated powerplants, port facilities and marine transportation consideration. This chapter assumes that Federal, State, local and Native lands in selected study areas can be acquired for surface coal mining, synfuels facility development, transportation and utility cooridors and ports and associated facilities. The scope of materials presented in following sections will generally not include a discussion of State environmental or regulatory requirements that will influence Alaska coal development. A tentative list of likely Federal and State permits, licenses and approvals necessary for land acquisiton, land transportaion and utility corridors, port facilities and marine transportation and safety is included in Appendix D. The assumption is also made that pending Alaska Naitive Claims Settlement Act Selections, Exchanges, Federal Alaska lands legislation and Federal coal leasing requirements will allow development of such lands. On August 19, 1980, HR-39 passed the Senate and would place 104.3 million acres of Federal lands into conservation areas. HR-39 would finalize the State of Alaska's selection of 98 million acres of the 105 million acres the State was entitled to under its Statehood Act. HR-39 also guarantees the conveyance of 44 million acres to Alaska natives. Information contained in this chapter should not be considered an exhaustive checklist for determining compliance with Federal, State or local regulatory requirements.

A. Environmental Requirements for Mining Operations and Synfuel Facility Development

1. All phases of proposed strip mining in Alaska are currently regulated by the U.S. Department of Interior (DOI), Office of Surface Mining (OSM) under the Surface Mining Control and Reclamation Act. (P.L.

95-87) Alaska is currently developing a State reclamation program to control environmental impacts of surface coal mining for submission to OSM. Until OSM approval and State legislative authorization, all surface mining activities in Alaska will continue to be regulated by OSM.

The Act requires: restoration of land to its prior condition after mining; restoration of land to its appropriate original contour; segregation and preservation of top soil; minimization of hydrologic disturbance; construction of coal mine waste piles used as dams or embankments; and revegetation of mined areas. If the proposed program is approved by the Secretary of DOI, the State will assume the responsibility for issuing mining permits and for enforcing the provisions of its regulatory program. However, if the State fails to resubmit an acceptable program or at any time fails to resubmit an acceptable program or at any time fails to implement, enforce, or maintain an approved program in accordance with the Act, OSM is required to prepare and implement a "Federal Program" of regulation within that State.

2. In addition to mining reclamation considerations, surface mining and the construction and operation of synthetic fuels projects must comply with an ever-growing list of Federal, State and local regulatory requirements. A recent DOE study of permits and approvals necessary for oil shale development in selected western States discovered that more than 400 permits may be required for any given project.[34] Major Federal laws regulating surface coal mining and the development of synthetic fuels facilities include the National Environmental Policy Act, Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act and Toxic Substances Control Act. Other likely Federal laws affecting Alaska coal development include the Safe Drinking Water Act, Endangered Species Act, Rivers and Harbors Act, Fish and Wildlife Coordination Act, National Historic Preservation Act, Coastal Zone Management Act, and Occupational Health Safety Act.

The National Environmental Policy Act (NEPA) sets forth the basic policy for all Federal agencies: that environmental protection is to receive consideration in Federal decision-making. In connection with Federal decision-making which may have significant impact on man's environment, NEPA establishes three principal procedural requirements. The Act calls for "systematic, interdisciplinary approach which will insure the integrated use of the national and social sciences and the environmental design arts." Alternatives to the recommended course of action must be considered. Lastly and most importantly, a detailed environmental impact statement is required for all "major Federal actions significantly affecting the quality of the human environment." NEPA's procedural duties are judicially enforceable. A decision made in violation of NEPA's requirements is subject to judicial invalidation.

The Clean Air Act (CAA) establishes national ambient air quality standards designed to prevent adverse effects of certain pollutant involving particulates, sulfur dioxide, petrochemical oxidents, hydrocarbons, carbon monoxide, nitrogen xide and lead. The CAA directs participating States to develop State Implementation Plans (SIPs) which set forth control efforts designed to achieve compliance with the national standards. State standards can be more stringent than those imposed under the CAA. The CAA also authorizes the promulgation of new source performance standards for individual industrial categories, requiring new plants to utilize the best demonstrated system of emission reduction. In addition to these basic requirements, the CAA has created two complex regulatory requirements, one of which must be considered in reference to Alaska strip mining and synfuels plant operation, viz., the Act's nonattainment requirements which apply in areas continuing to violate air quality standards and requirements to prevent significant deterioration (PSD) of air quality in areas of the country, such as Alaska, which are currently cleaner than air quality standards.

The Clean Water Act (CWA) prohibits any discharge of pollutants into public waters without a permit and imposes stringent pollution control requirements on all discharges, whether existing or new. Although the CWA does not present the same degree of potential barriers to new coal development in Alaska as the CAA, it does represent one of the major components of environmental law which must be satisfied in connection with construction and operation of a synfuels facility. Under the National Pollutant Discharge Elimination System (NPDES), a discharge must comply with applicable Federal or delegated State water quality standards. State water quality standards may also exceed minimum Federal standards. In addition to requirements to prevent spillage of oil and hazardous wastes, the Act's new source performance standards (NSPS) specifying the greatest degree of effluent reduction through the best available demonstrated control technology also impose stringent operational standards on new plant construction.

The Resource Conservation and Recovery Act places "cradle to grave" controls over the generation, transportation and disposal of hazardous and other solid wastes. The Act establishes a permit system and authorizes criteria for identifying hazardous wastes based on ignitability, corrosiveness, reactivity and toxicity. In addition to establishing a system for classifying industrial wastes presumed to be hazardous, recently proposed toxicity criteria would classify as a hazardous waste any substance for which a primary drinking water standard has been established if its concentration is ten times greater than the drinking water standard. Like the CAA and CWA, RCRA contemplates that States will assume permit and program enforcement responsibilities.

The Toxic Substances Control Act (TSCA) directs EPA to identify and regulate the manufacture, processing, distribution, use and disposal of hazardous chemical substances and mixtures. Synthetic liquids are generally considered to have a high potential for containing toxic or carcinogenic constituents. TSCA requires a developer to nofify EPA or participating State 90 days prior to production of a new chemical or product and submit environmental and health data. If EPA determines that introduction of the product would pose an unreasonable risk, it could restrict or prohibit production, require further testing or regulate the handling, transportation and end-use of the product.

B. Application of Environmental Requirements

1. Despite the very bst mining technology and pollution control efforts, strip mining and synthetic fuel plant operation of any significant size will have some adverse health and environmental effects. Degradation of the air and water supplies, disposal of huge amounts of wastes that contain traces of toxic metals represent well recognized environmental impacts. Development of the Beluga and Kukpowruk River District fields may also cause more extensive socio-economic impacts on nearby residents and communities than expansion of the Usibelli Mines in the Nenana field. Housing, schools, police and fire protection, water and sewer systems, roads, utility services and other community-related service needs can be expected to result from any moderately sized development activity.

   Several issues involving compliance with NEPA would be presented by development of Alaskan coal fields. Since Federal permits, licenses and approvals discussed in greater detail below will likely be required, a determintion of whether an EIS will be required must be made at the outset. Assuming an EIS is to be produced, its scope and range of alternatives to be considered must be defined. This chapter does not attempt to address all NEPA-related questions, rather, it is intended to identify general problem areas that can be expected to arise under NEPA. The Usibelli mine in the Nenana field near Healy, Alaska is the only producer of coal in Alaska. The Usibelli mine has the potential for expanding production. Expansion of a previously approved existing use may not constitute a major Federal action significantly affecting the quality of the human environment. Requirement of an EIS is likely to rest on the magnitude and nature of expanded mining activity at the existing Usibelli Mine site and whether mining methods go beyond existing activities or technology. The use of new synthetic fuels technologies, such as solvent refined coal (SRC) processes and coal gasification, would likely cause new environmental impacts not currently associated with th existing Usibelli Mine operation and therefore require preparation of an EIS. For example, in-situ conversion processes could adversely impact ground water and drinking water supplies (salinity, organics, trace metals) and large volumes of toxic or hazardous wastes could require costly disposal techniques.

A decision to proceed with development of the Beluga, Nenana and Kukpowruk area fields and need to prepare a NEPA EIS will require a fundamental decision regarding the scope of the EIS. A "site specific" EIS would address only the environmental impact resulting from individual Federal actions. A "comprehensive" EIS would examine a proposal's entire system impact. Because of the absence of exisiting facilities and the scale of development at the Beluga and Kukpowruk area sites, a "comprehensive" and perhaps a "Regional" EIS examining mining operation, synthetic fuels technology, overland and marine transportation routes, port development community-related impacts, and associated facilities and powerplant development may be necessary.

Recently approved and mandatory Council on Environmental Quality (CEQ) regulations implementing NEPA set forth regulations designed to streamline the EIS process. The CEQ regulations provide for the preparation of a single, lead agency EIS and utilization of a draft EIS as an initial project planning document. To avoid delays and insure that planning and decision reflect environmental values, the regulations require integrating and requirements of NEPA with other planning, environmental review and consultation procedures required by law so that all such procedures run concurrently rather than consecutively.

2. Any plan to develop or convert Alaska coal resource must not only comply with existing regulatory requirements but accept certain risks associated with the impact of future promulgated environmental requirements. Since regulation requirements of synfuel technologies are difficult to predict, a situation could occur where facilities would be required to alter their design and plant operation to comply with new regulations. A recent DOE analysis has concluded that despite reclamation, hazardous waste and solid waste management impacts, there appear to be no absolute environmental prohibitions for indirect liquefaction of coal utilizing surface conversion technologies at low (500,000 BPD) and medium (1,000,000 BPD) levels. However, higher levels of production (2,000,000 BPD) rapidly increase the chances of siting and operation difficulties.[35] Direct coal liquefaction, although expected to contribute commercially to synthetic fuels production by 1990, runs a greater potential for worker and public exposure to toxic substances. Indirect coal liquefaction (e.g., coal gasification, coal to methanol, coal to gasoline and Fischer-Tropsch methodology) appear to generate far fewer toxic wastes and potential for harm to the environment and danger to man.

The DOE analysis summarizes general impacts of the applicable environmental laws as well as existing institutional processes that influence synfuels development. The most important Federal environmental requirement affecting synfuels develoment in Alaska is the Clean Air Act. No new source performance standards (NSPS) or air shed models currently exist for single or cumulative impacts of synfuels facilities. Because of the likelihood that candidate development areas may be immediately near or within designated as Class I PSD areas, major synfuels and related facility development could be substantially limited or precluded. Synfuel facilities located near Class I PSD areas (e.g., National Parks) could be required to install pollutant control devices beyond BACT. Although it does not appear that proposed National Emission Standards for Hazardous Pollutants will unduly restrict or preclude synfuels development, DOE's analysis indicates that compliance with any such requirements could require costly plant modification.

DOE's environmental analysis further indicates that existing Clean Water Act requirements should not preclude or severely restrain coal development at candidate sites. States, however, are not required to adopt Environmental Protection Agency water quality criteria for toxic substances and accidental pollution of State waters. Alaska could impose more strict water quality standards than required under the CWA which could restrain larger scale surface mining and conversion activities.

EPA has recently promulgated RCRA regulations covering the identification, generation, transportation and disposal of hazardous wastes. Although portions of certain wastes from direct and indirect coal liquefaction technologies may be identified as hazardous, compliance with RCRA permit and control requirements should increase costs of wasts disposal but generally should not prohibit or unduly restrict synfuels facility development. Application of such regulations to Alaska coal development is highly site and technology specific.

The impact of TSCA on Alaska coal development is uncertain. DOE's environmental analysis of TSCA's impact on synthetic liquid fuels indicates that the most likely impact would occur in the storage and transportation of synthetic crude oil.[40]

The impact of Federal and State regulatory requirements on Alaska coal development are uniquely site-specific. No single requirements standing along appears initially to preclude or severely restrict development of candidate sites. However, the cumulative impact of all such requirements could protract development of acceptable sites. Recent changes in Federal and State requirements appear to provide an opportunity for reducing time, manpower and informational requirements. For example, in addition to recently finalized Council on Environmental Quality environmental review integration requirements mentioned earlier, EPA regulations now consolidate RCRA hazardous waste, Safe Drinking Water Act underground injection control, CWA NPDES, 404 dredge or fill and CAA PSD requirements. Department of Commerce and Interior regulations establish uniform procedures for compliance with the Fish and Wildlife Coordination Act at the same time that action agencies are complying with NEPA regulations prior to and during preparation of a Draft EIS. Alaska's Department of Environmental Conservation administers a "one-stop" master application for development subject to separate water rights acquisition and local approvals.

As the size of strip mining and synfuels development grows, the likelihood of regulatory conflict at the Federal, State and local level increases. Although State, local and Native entities may initially support new and increased coal development, opposition may occur at later development stages. The following material examines additional issues which are likely to influence initial Alaska coal development.

3. Obtaining necessary Federal and State regulatory approvals to undertake development of Alaska coal resources will be significantly influenced by Alaska's evolving State and district coastal zone management (CZM) programs and the extent to which local government can control Federal and State lessees engaged in the development of hydrocarbons and minerals. In 1972, Congress enacted the Coastal Zone Management Act (CZMA) to provide States with a lead role in coastal planning and management through the design and implementation of coastal management programs. The CZMA provides for reciprocal Federal and State responsibilities in the development and administration of State management programs. Before approving a State's management program, the Secretary of Commerce must find, among other things, that the views of affected Federal agencies and the National interest in the siting of facilities (including energy facilities) which are other than local in nature have been adquately considered, and that local land- and water-use regulations do not unreasonably restrict or exclude uses of regional benefit.

Following approval of Alaska's coastal management program by the U.S. Department of Commerce, Federal actions (regulatory activities, development projects, permits and outer continental shelf approvals) affecting the coastal zone are required to be consistent with the State's CZM program and approved District CZM programs. The importance of approved local District CZM programs should not be underestimated. In addition to Federal actions which affect the coastal zone (including spill-over effects from excluded Federal lands) State agencies and municipalities ae also required to administer land and water use regulations and controls in conformity with approved District

CZM programs. District program authorities are required to conduct a resource inventory and analyze and describe land and water uses subject to the program, including:

1) coastal development,
2) development in geophysical hazard areas,
3) recreation,
4) energy facilities,
5) transportation and utilities,
6) fish and seafood processing,
7) timber harvest and processing,
8) mining and mineral processing, and
9) subsistence.

District coastal programs must address all above uses that may affect habitats, air, land and water quality and historic, prehistoric and archaeological resources. In addition, coastal resource districts are also responsible for designating and developing special management policies for coastal areas meriting special attention (AMSA's). An AMSA is an area which is " sensitive to change or alteration and which because of plans or committments or because a claim on the resources within the area would preclude subsequent use of the resources to conflicting or incompatible use warrants special management attention...

The Kenai Peninsula Borough and Matinuska-Susitua Borough, which are likely to be substantially affected by development of the Beluga field, are in a unique position to influence development activities. In addition to exercising limited jurisidictional authority over land-use planning, education, tax assessment, recreation and solid waste disposal, both Boroughs are beginning efforts to develop District CZM plans. The Kenai Borough has proposed that the Beluga/Tyonek area be designated an AMSA in anticipation of coal-related development and the need to protect area heritage and fragile, highly productive natural resource value of the area. In related developments, the Kenai Borough is also attempting secure legislature authority from the State which is necessary for port development. The City of Anchorage, a likely market for Beluga coal, has recently received concept approval of its local CZM program.

District coastal programs for the Kenai Peninsula and Matinuska-Susitna Boroughs are in a paramount position to permit or restrain the siting of coal mining and synthetic fuels facilities, transportation systems, ports and associated facility development. In a recent legal opinion issued on May 12, 1980, to the Alaska Coastal Policy Council, the Alaska Law Department has indicated that, under certain circumstances, District CZM programs can restrict, control or exclude "uses of

State concern", such as the exploration, development and production of hydrocarbons and minerals, on offshore Federal lands and coastal lands subject to State or local jurisdiction. A local district CZM program reasonably restricting oil and gas development through a permit system would apparently be upheld as long as the plan is not unconstitutionally vague.

The development of district CZM programs offers another procedural advantage which could expedite Federal, State and local regulatory requirements. The CZMA and implementing regulations provide an important opportunity for public and private input in shaping District CZM program standards, objectives and policies which are binding on Federal, State and local government. The CEQ's mandatory procedures implementing NEPA could be incorporated into the development of District CZM programs in coal development areas. Environmental and socio-economic impacts associated with land acquisition, mining operations, synfuels facility siting, transportation and utility corridor siting, port development and associated facilities and community development could be proposed and considered together in the creation of District CZM programs and consolidated in a required NEPA EIS for the District CZM program. Integration of CZMA and Alaska State program development requirements with CEQ requirements should facilitate later site-specific industry planning and public participation, and ensure that all major Fedeal and State environmental and regulatory requirements are fully and simultaneously considered early in State and local land-use decision-making. Initiation of early NEPA planning with District CZM program development could result in an intergovernmental programmatic or comprehensive EIS that could avoid replaying major Federal regulatory review and serve as the principal environmental planning and decision-making record for later Federal and State decision-making.

Another important issue likely to influence Alaska coal development is the creation of "boom towns", the need for new and permanent communities and socio-economic impacts on existing communities. Mitigating the impacts of coastal and upland coal development in Alaska could be funded through a variety of mechanisms. Coastal Energy Impact Program (CEIP) assistance is available under CZMA Section 308 for coastal communities affected by energy development. Proposed legislation extending CZMA program authorization for CEIP assistance would provide up to $25,000,000 a year to States adversely affected by coal transportation. Additional Federal assistance for socio-economic impacts to local communities may be available from the Economic Development Administration of the Department of Commerce and the Department of Agriculture under Title VI of the Industrial and Powerplant Fuel Use Act. In the absence of Federal efforts, assistance for mitigating local community-related and environmental impacts may be secured through imposition of State or local severance or conversion taxes.

C. Other Factors Affecting Alaska Coal Development

A variety of regulatory and non-regulatory factors could influence Alaska coal development. Enactment of the Industrial and Powerplant Fuel Use Act (FUA) would appear to provide an incentive to Alaska coal development by prohibiting the use of oil or natural gas in new utility generation facilities and certain new industrial boilers. Existing facilities capable of using coal may also be required to use coal under the FUA. Coal is only one of many fuels which can be used to comply with the Act. In addition to encouraging coal gas use by classifying coal as an alternate fuel the FUA provides temporary exemptions from FUA prohibitions for facilities which plan to use coal-derived alternate fuel (e.g., coal derived methanol). FUA prohibitions and exemptions apply to both new and existing major fuel burning installations. FUA prohibitions and exemptions, however, apply only to new powerplants in Alaska.

Despite enactment of FUA prohibitions, the current availability of natural gas and ability of firms to obtain exemptions from the Act have not prompted contiguous U.S. or Alaskan utilities to convert to coal. To encourage utility conversion, the Administration has recently proposed a grant program authorizing $3.6 billion for utilities without sufficient financial ability to convert to coal. Such utilities would be eligible for grants to construct coal handling facilities, pollution control equipment and other changes to permit burning of coal. Additional incentives to greater coal use may be generated by Executive Order 12217 which mandates Federal facilities compliance with FUA construction and conversion requirements.

Title I of the recently enacted Energy Security Act provides incentives that may contribute to Alaska coal development. The Act establishes a goal of producing an equivalent of at least 500,000 barrels of crude oil per day (BPD) of synthetic fuel by 1987 and 2,000,000 BPD of synthetic fuel by 1982. Under Phase I of the program the Board is authorized to award $20 billion to private firms to construct synthetic fuels facilities. To encourage private capitol investment in the domestic production of synthetic fuels, Title I authorizes creation of an Energy Security Corporation (ESC) to provide price guarantees, direct loans, loan guarantees up to 75 percent of project costs, purchase agreements and joint ventures with the ESC. Financial assistance would be available for: production facilities; land and mineral rights required for use in connection with a plant; equipment used to extract minerals for conversion to synthetic fuels from either a mine located next to a plant or located elsewhere if no other source of the mineral for the plant were available; and transportation facilities, electric powerplants, transmission lines or other equipment necessary for the project.

CONCLUSIONS

1. Assuming that lands can be acquired, no single Federal or State regulatory requirement standing alone appears to preclude development of selected study sites.

2. Together, cumulative Federal and State regulatory requirements can pose substantial procedural barriers to development of study sites and development activities involving surface mining, the siting of synthetic fuels facilities, powerplants, transportation and utility corridors and port facilities and marine transportation systems.

3. Proper utilization of integration provisions contained in Council on Envionmental Quality environmental review, planning and decision-making regulations implementing the National Environmental Policy Act (NEPA) provide significant opportunity to expedite Federal and State regulatory requirements for complete coal mining, synfuels facility and transportation systems.

4. Active participation by affected Federal, State, local, Native and private entities in the development of District Coastal Zone Management Programs in concert with NEPA EIS requirements to ensure adequate consideration in the siting of "use of State concern" and "national interest" is needed to preserve acceptable sites in study areas for future development and expedite Federal and State regulatory requirements.

RECOMMENDATION

1. The Department should conduct a joint study with the State of Alaska and affected units of local, Native and Federal government to (1) determine likely permit, license and approval scenarios (2) identify institutional barriers to coal development at specific sites and (3) prepare draft intergovernmental agreements or Memorandum of Understanding for expediting regulatory requirements.

2. The Department, through its participation in the Federal Critical Energy Facility Program (Executive Order 12129) and Energy Coordinating Committee (Executive Order 12083) should begin consultation with affected Federal agencies to determine permit, licensing and and approval scenarios for development of the candidate study areas and means to expedite Federal regulatory requirements, including utilization of CEQ integration requirements for implementing NEPA.

3. The Department of industry should take immediate steps to ensure that developing local District Coastal Zone Management Programs adquately consider and do not arbitrarily exclude or unreasonably burden acceptable sites for coal systems development (surface mining, synthetic fuels facilities, powerplants, transportation and utility corridors, ports and marine transportation systems) in coastal areas.

4. The Department and affected Federal, State, local and tribal agencies, together with industry, should jointly examine how the Council on Environmental Quality's environmental review, planning and decision-making regulations can expedite development of acceptable sites.

Chapter IX

Environmental Impacts Associated with Coal Development

A. Introduction

This chapter provides a brief overview of part of the information contained in Appendix B. Information provided herein will focus on environmental effects of surface mining. For detailed information on this and to obtain information on the natural environment of the three sites the reader is referred to Appendix B.

This chapter and Appendix B examine only those impacts associated with mine development in the three areas previously discussed. It does not examine potential issues associated with transportating coal or converting coal into synthetic fuels. Although these are important areas of concern which need to be addressed, they are beyond both the scope and resources allotted for this study.

B. Environmental Effects of Surface Mining

The following is a review of expected major effects that would be associated with surface mining Alaska. Discussed are direct effects on water quality, water quantity, surface topography, and air quality and the secondary effects pertinent to fish, wildlife, and other living organisms.

1. Water Quality

Water quality can be expected to be affected in any of the three fields--Beluga, Nenana, or Kukpowruk--as the natural terrain is disturbed, drainage patterns are altered, and excavation activities produce silt and sediment, leachates, and dust. Expected quality changes include turbidity, dissolved solids levels, pH, dissolved oxygen, and temperature.

The main differences for surface mine development in the fields of concern here, in comparison with operating mines elsewhere in the United States, are the presence of frozen ground/permafrost, the extremely contrasting summer and winter hydrologic cycles, and presence and duration of ice and aufeis*. In addition, there are very little hydrologic data available and theoretical approaches to runoff prediction are unreliable. Thus, the engineering considerations required for the removal and stockpiling of overburden, the maintenance of slope stability, and the construction of impoundment areas, etc., are difficult. Materials, particularly those of fine grain, will flow, slump, and slide. Impoundments in permafrost areas will thaw, and summer-excavated pits in the Kukpowruk will fill with water. This latter situation could also occur at Beluga or Nenana, depending upon the presence of absence of permafrost.

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*augeis - sheet of ice formed on a river flood plain in winter when shoals in the river freeze solid so that water spreads over the flood plain and freezes.

In the Kukpowruk area, gravel is scarce making construction of good road beds difficult. All of these natural situations and engineering considerations increase the possibility that water quality will be affected by terrain disturbance.

Water Quality effects are regulated by a number of State and Federal statutes and regulations falling within the purview of a number of agencies. Obviously, one of the major hindrances to Alaska coal development will be to convince such authorities of the efficacy of a number of engineering practices required to prevent the reduction of water quality in situations of natural extremity and limited knowledge.

2. Water Availability

Water availability as well as water quality will be impacted by any coal mining program. In Alaska, water quantity and availability are affected by a number of natural factors, including seasonal temperature, permafrost, ice, and high runoff in spring "breakup" and often again during August storms. Furthermore, groundwater resources are often unavailable or, if available, frequently highly mineralized, adding to the discharge quality problem when used in washing or other processing activities. In effect, then, surface waters are the main usable sources and these can be highly variable in availability throughout the year.

Not only is the availability of water for coal operations a potential problem, but also the effect on downstream availability is also of concern. In addition to the quality of waters discharged after use, there is the question of adequacy of volume available for downstream users (real or potential), including fish and wildlife and on a seasonal basis consonant with natural factors. Large volumes of water would be required in all of the regions for mining and reclamation activities, coal conversion and use plants, conjunctive developments, and population increases. Water withdrawals could affect aquatic systems by reducing habitats and by changing physical regimes such as the temperature and dissolved oxygen levels of the remaining water. In areas such as the Kukpowruk, where seasonal flows are either very high or very low, the maintenance of minimum stream flow for aquatic life could be an important consideration to the permitting of water appropriation.

3. Land Surface

The physical effects of surface mining are most obvious on land. A few of the more evident examples are barren areas caused by road construction, claim location and development, active mining, overburden removal and stockpiling, tailing ponds, waste disposal areas, open pits and slides, etc.

Natural terrain is altered during exploration, survey and mine location, mine operation, and processing. Access roads would be required in the development of deposits associated with the Beluga, Nenana and Kukpowruk fields. Ports and terminal facilities would be required at Kukpowruk and Beluga. As discussed in Chapter III, railroad spurs would be utilized at Nenana. In transportation construction, gravel would be required, necessitating additional landform change at gravel borrow areas.

Less obvious impacts than those given above, are a number of landform changes which would occur secondarily as a result of the alteration of permafrost terrains if it exists in the mine area. Several examples are: stockpiled, fine-grained, ice-rich overburden materials are liable to thaw into muddy flows with often disastrous and uncontrollable results; thaw ponds and watered ditches would also appear when tundra over ice-rich permafrost is disturbed; and slopes would fail, slide, fall, and be altered.

Finally, any restoration of land following the removal of the coal and associated waste materials would depend on the character of materials originally removed as overburden or interburden. If materials are ice rich, as discussed in the previous paragraph, they are liable to be unstable even on fairly gentle slops. Over time, permafrost will develop some natural stability, but real stability of landform will only come after vegetation is restored as an insulator for the active (area that freezes in winter and thaws in summer) upper few feet of material.

4. <u>Air Quality</u>

Another major environmental impact which can be expected to be associated with surface coal mining is air quality degradation from dust. In many ways, the dust problem is no different in Alaska than in other coal-producing areas of the United States.

All three coal field situations of concern here lie in areas of low-level air inversion. The effect of this generally winter-month phenomenon, which exhibits temperature differences in the Interior up to 20°C in the lowest 600 feet (200 m) and is one of the strongest found anywhere, is to trap dust as well as hydrocarbon engine emissions at extremely cold temperatures below a "roof" of warmer air. The dust and hydrocarbons serve as nucleids to form "ice fog." In its more serious forms, ice fog is deleterious to human health and offers hazards to industrial operations due to reduced visibility and worker discomfort.

During the winter months, dust from coal operations and from routine travel on gravel roads will settle on the snow, often over many miles, in accordance with prevailing winds. As spring approaches, with greater solar radiation and warmer temperatures, dust-covered snow will melt more rapidly then uncovered snow. The effect of this is to speed up insect and other invertebrate life development. In some areas this occurrence would have a disruptive chain reaction effect on the food webs of many higher forms of life.

5. Summary

Environmental effects of coal operations in Alaska are, in the main, similar to those elsewhere in the United States and are generally well known. The main set of differences in Alaska stems from differences in physical conditions (i.e., permafrost, hydrologic cycles which exhibit seasonal and volume extremes and which are imperfectly known, and coal air temperature phenomena), all of which require special engineering and operational techniques during mining and which can cause conditions making reclamation activities virtually impossible on some sites.

C. Engineering and Reclamation Considerations

For purpose of discussion here, engineering and reclamation considerations pertinent to both prevailing natural conditions and the induced effects of coal operations associated with the Beluga, Nenana and Kukpowruk fields are divided into three parts; (1) Terrestrial situation, (2) Hydrologic situation and (3) Atmospheric situations.

1. Terrestrial Situations

Discontinuous permafrost affects the mining at the Usibelli Mine near Healy (Nenana coal field), however, to date, has not been encountered in the Beluga field. At the Kukpowruk field, operations would take place in an environment of continuous permafrost. In whatever permafrost conditions encountered, the essence of the degree of both engineering and reclamation problems would be directly attributable to the volume and form of ice within the permafrost materials and the type of material with which the ice is associated (i.e., grain size, particularly).

The removal of overburden would disturb the permafrost regime when ambient temperature reach high enough levels to induce melting. Removal of frozen ground is technologically difficult. Special equipment is often required for breaking up materials, and blasting requires specific expertise to be effective. If thawing is used, special problems are encountered, often making mud conditions worse when materials are fine gravel and rich in ice content.

The methods used in excavation of overburden and interburden materials have a direct bearing on the success or failure, even the possibility, of postdevelopment reclamation when fine-grained materials are encountered. Excavation and future reclamation in coarse materials are easier, but major reclamation problems are the presence of water-filled pits (whether excavated in summer or winter, if open during the summer months permitting permafrost thaw), the storage of muddy materials under site conditions which often do not allow the percolation of water and compaction of materials into stable forms, and the acceptability of materials for revegetation.

As discussed earlier, the slopes of permafrost materials forming the banks of walls around excavations offer their own special problems of stability from thawing and pore water pressures making revegetation impossible. This problem of slope stability, together with the lack of sufficient and suitable materials for stable backfilling would, in areas of ice-rich, small-grained permafrost, make it difficult to restore original land surface. Again, in order to give emphasis, the handling of coarser-grained materials is quite possible, and the Usibelli Mine experience gives examples of success on some sites.

In summary, the operational conduct of terrain excavation and reclamation appear with some certainty to be manageable in the Nenana field (although some sites are at variance with present experience) and also in the Beluga field, based primarily on a comparative geologic analysis with other regions of coal production. However, it should be pointed out that specific sites can offer problems. In the case of the Kukpowruk, terrain and reclamation control will be very difficult.

2. Hydrologic Situations

Engineering and reclamation practices in the Beluga, Nenana and Kukpowruk fields will encounter an extreme variation in existing hydrologic data interpretation and overall knowledge. As a result, the site-specific design of diversions, ditches, and settling ponds is often fraught with uncertainty. The best hydrologic data probably exist for the Nenana area, the worst for the Kukpowruk. The Beluga area, on the other hand, has some gauged streams, and nearby southcenter Alaska community data may be extrapolated. Difficulties arise, however, with geologic hazard-induced flooding from volcanic activity and the occurrence of unpredictable storm situations arising from North Pacific August storm tracks.

In the Kukpowruk area, precipitation data are very scant, with only some relevant data at Point Lay and Point Hope. In addition, much of this area is devoid of vegetation or sparsely covered with tundra. In any event, runoff is scarcely retained, and velocities and volumes can be quite high during storm occurrences.

The point of the foregoing is that design criteria for hydrologic waste and sediment control facilities are minimal at best, and in order to have safest and adequate settling ponds, etc., overdesign may have to be the rule rather than the exception.

3. Atmospheric Situations

Coal mining constraints associated with low external ambient air temperatures for surface works are essentially the same as those for any other arctic operation. Previously, some ice fog factors have been discussed. In addition, some other considerations pertinent to low ambient air temperature follow. Vehicles utilized for hauling wet coal require some means of preventing the coal from freezing to the truck bed. Covering the bed with antifreeze has worked as has heating the bed of the truck with vehicle exhaust.

Appropriate measures for preventing permafrost degradation under surface structures need to be taken, as well as measures for insuring vehicles operation. The latter may include providing heated warm-up sheds as well as low temperature lubrication. Practices in the Soviet Union include the utilization of thermopane windows, insulation, and double heaters in the vehicle cabs.

Due to the high moisture content of the coal, it tends to slack and produce excessive dust upon drying. During summer, water is used to suppress dust, but so far it appears that no effective solution has been found to suppress dust in winter. The combination of high moisture content in the coal and extremely low humidity in winter produces a dust and fire situation that ranks among the most serious of the cold weather problems.

Conceptually, a water washing plant for winter operation in the Arctic is possible. The plant would need to be heated and the coal dried after washing to prevent freezing in the coal storage piles. The tradeoff between the cost of winter coal washing and transportation without washing appears to favor the latter.

D. Revegetation

Prerequisites of revegetation in Alaska as elsewhere are first, the stabilization of land form and second, the ability of instituting and maintaining a self-regenerative vegetative cover type. In the Nenana field effective revegetation practices have been demonstrated. Stability appears to be practical at Beluga, also, and plant species are available which are suited to site and climatic conditions.

The Arctic has special revegetation problems. Domesticated plant species are not well adapted to rigorous arctic conditions, and their success is generally marginal at best. Native plants are slow growing and slow to become established. Many of the revegetation tests in the Arctic have utilized seed from subarctic plants. Seed from plants of arctic origin would likely be required for the arctic plantings of perennials. In developing a program to employ native plants for revegetation, the seed producing and harvesting characteristics of the plants also must be considered. Some that are aggressive colonizers are not good seed producers or are difficult to manage for the obtaining of seed.

The selection of grasses with revegetation potential is much narrower than it is in the boreal region. Furthermore, the significance of varietal differences within a species is more acute. Early germination is particularly advantageous. However, a problem inherent in the precipitation and temperature patterns of the Arctic involves obtaining suitable moisture conditions along with favorable temperatures. The characteristic low rainfall pattern in the Arctic may lead to dryness, thus delaying germination when temperatures are favorable. This is particularly true where a site is inherently dry or where a disturbance has resulted in a deep thaw and enhanced drainage. Further, a cooler than normal season may inhibit germination.

Despite what appear to be severe limitations and difficult conditions, growth of certain species placed in trial at Prudhoe Bay has occurred, and, so far, some have survived one or two winters. Undoubtedly, 24 hours of daylight during the heart of the growing season helps to compensate for the short growing period. First-year growth in the Arctic may be severely restricted, with two years required to develop a stand.

E. Summary

The control of adverse environmental effects due to surface coal mining operation in the Beluga, Nenana and Kukpowruk, fields will not be easy and may adversely affect cost/benefit ratios. The technological and environmental knowledge for such control, however, does for the most part exist and could be applied to the Nenana and Beluga fields. The operation of coal mining in the Kukpowruk field under existing knowledge and legal restraints, however, is much more difficult and may well be impossible. An alternative is to encourage active development research directly applicable to coal mining under arctic conditions.

CHAPTER X
SUMMARY

The purpose of this chapter is to discuss, in some detail, the rationale that the authors used in reaching the conclusions listed in the Executive Summary, Conclusion and Recommendations section of this study. The study is intended to be an assessment of the potential for developing Alaska coal in the near term, 1990 or before, using existing technology.

It was determined early in the study process that the major market areas that should be addressed are the Alaska, U.S. West Coast and the Far East markets. European markets were not assessed primarily because of their distance from Alaska coal resources. However, it should be recognized this once the FOB cost of Alaska coal at an Alaskan port is determined the cost of shipping the coal to any other port in the world can be calculated by knowing the distances involved.

It was found that the demand for bulk steam coal in Alaska and the U.S. West Coast, particularly for electrical generation, is somewhat limited. Alaska's hydroelectric potential may preclude accelerated coal use in the State and result in a projection of only about 0.5 to 2.0 million tons per year by 1990. In California, the total demand for steam coal could reach 20 million tons per year; however, California utilities are already applying for permits to develop their coal interests in Utah. Also, since Alaska coal use would probably be limited to plants built on the coast it was assumed that only one coastal 1,000 MW plant requiring 5 million tons/yr, would be capable of using Alaska coal, and this would not be operable until sometime in the 1990's. Thus, there would basically be no demand for Alaska coal in California by 1990. In Oregon and Washington there are existing plans to build additional coal-fired generation; however, the plants will be located inland where Alaska coal could not be easily transported. Also, the utilities involved have indicated that the coal source will be from Western Contiguous U.S. mines. Therefore, it appears at this time that Alaska coal cannot favorably compete against the Western U.S. coal sources (i.e., Montana, Wyoming, Utah) for a share of the California, Oregon and Washington steam coal market.

By far the largest demand sector will be the Far East where 1990 demand is expected to be from 30 to 80 million tons per year. This study concludes that the Far East demand will be the predominant force behind Alaska coal development. This conclusion was not based solely on the tremendous coal demand projection from Japan, Taiwan, Korea and the Phillipines. These countries, particularly Japan, have demonstrated interest specifically in Alaska coal both by sending delegations to Alaska to discuss coal development with industry and State government officials and by having large samples of Alaska coal shipped to their country for burning tests. Korean officials have also recently visited Alaska and have made arrangements for trail shipments of coal to be their country. In addition these countries have made national committments to increase their coal-fired electrical generting capacity and have announced plans to construct both coal receiving ports and coal-fired power plants.

Although there will be competition from other countries to supply steam coal to the Far East it appears that the United States may be the only country capable of meeting the large supply requirement. Canada, South Africa and Australia are all coal exporting countries and have individually announced plans to expand coal production and increase coal exports. These countries will undoubtedly supply a share of the demand, particularly since some of the Far East countries insist on diversifying their coal supply sources for security reasons. However, since the U.S. coal reserve base is so vast and there has been a favorable and consistent U.S. policy promoting coal exports, the Far East countries probably feel that the U.S. is the only country capable of supplying their coal demands in the long term.

The recent passage of the Energy Security Act has provided a new impetus to synthetic fuel production. The production of synthetic fuels from Alaska coal is considered to be a viable and important alternative. A large portion of the coal in Alaska is of a low quality (high ash, high moisture) making it relatively unattractive for use as a fuel source for power plants in the United States. An alternative that is discussed in this report is the conversion to a clean burning fuel that can be burned in combustion turbines to produce electricity. This is particularly relevant in the Pacific Northwest where there are projections for an electricial energy shortage commencing in early-mid-1980's. A methanol from coal plant could be built using existing technology and be on-line in time to assist in alleviating the electrical shortage issue. In essence, converting Alaska coal to methanol would expand the viable market area and enhance the marketability of the coal.

Another aspect of developing Alaska coal that this study addresses is the balance of payment effect. Using a selling price of $33.50 per ton and a production level of 5 million tons/year the balance of payments would benefit by over $175 million per year. However, if the same amount of Alaska coal were used on the U.S. West Coast and backed-out imported crude oil, the balance of payment saving would be almost $400 million. If exports from Alaska are larger than this example, the impact on the balance of payments would be correspondingly greater.

A detailed analysis was made of the various laws that could effect coal development in Alaska. The National Environmental Policy Act, Clean Water Act, Clean Air Act and others were evaluated for their potential impact on coal development in the three areas selected for study in this report. It was found that no single regulatory requirement would preclude development; however, the cumulative impacts associated with Federal and State regulations requirements may present a significant procedural barrier to Alaska coal development.

The Arctic Environmental Information and Data Center of the University of Alaska provided an assessment of the potential environmental impacts associated with coal development at the three locations. Their basic conclusion is that although there will be environmental impacts associated with coal development at all locations, they can probably be controlled with existing environmental knowledge at the Nenana and Beluga Coal Fields. However, due primarly to severe arctic climatic conditions, environmental impacts associated with coal development in the Kukpowruk Coal Field will pose significant obstacles to development and perhaps preclude development altogether.

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Appendix A

Coal Resources of Alaska

1. Estimates of Total Alaska Coal Resources

The Federal government has classified approximately 33 million acres of Alaska as prospectively valuable for coal. The exact amount of Alaska coal is currently unknown and estimates range from 1.85 to 5 trillion short tons.(2) The wide range of estimates for Alaska coal is primarily due to the lack of geological data as most Alaska coal fields are not well known or developed. For example, an entire possible coal province along the Yukon and Kuskokwin Rivers is so poorly known that it must be ignored altogether in resource estimates. In this study, the 1967 Barnes Report, Coal Resources of Alaska,(5) is used as the basis for resource estimates. The Barnes Report is the most current comprehensive study on Alaska coal resources.

Alaska coal resources can be categorized from three different points of view. This depends on whether the appraiser is concerned with; (1) the amount of coal originally in the ground, (2) the amount of coal remaining in the ground as of the date of appraisal, or (3) the amount of coal that is expected to be recovered by future mining.

In addition to Alaska's original, remaining, and recoverable coal resources, are the undiscovered resources. They are divided into hypothetical and speculative coal resources. Hypothetical resources are accumulations expected to be found in known geologic settings. Speculative resources are accumulations expected to be found in unknown of or new typessettings.

a. Original Resources

Original resources are those in the ground prior to mining. From data available for coal fields presented in table IA-1, estimated original resources total 130,126 million short tons.(5)

Many parts of Alaska that are known to contain significant amounts of coal are not included in this estimate because of insufficient data. These include areas such as; (1) the Yukon River which contains beds of mineable thickness exposed at several points, (2) the Alaska Peninsula which has three little-known coal fields of considerable extent, (3) the Bering River field containing many high-rank coal beds, but which may be impossible to mine economically due to its structure complexity, and (4) numerous smaller coal areas.

Of the measured 130,126 million short tons estimated, 19,429 million short tons are bituminous and 110,697 million short tons are subbituminous and lignite.(5)

Table A-1
Estimated Original Coal Resource of Alaska
By Coal Field
(Million Short Tons)

Coal Field	Bituminous	Subbituminous and Lignite	Total
Northern Alaska	19,292	100,905	120,197
Nenana	-	6,938	6,938
Jarvis Creek	-	77	77
Broad Pass	-	64	64
Matanuska	137	-	137
Susitna (Beluga)	-	2,395	2,395
Kenai (Homer Dist.)	-	318	318
Total Original Coal Resources	19,429	110,697	130,126

Source: Reference #5 Bibliography

Original coal resource estimates are further divided into two subcategories according to the relative abundance and reliability of data used in preparing the estimates. These categories are classified as; (1) demonstrated resources, which is the total measured and indicated resources and (2) inferred resources. The combined tonnage of these two categories are also known as the identified resources. All coal in the identified category is further classified according to rank of coal, thickness of bed and thickness of overburden.

i. Demonstrated Resources

These reources are the combined tonnage in the measured and indicated resource categories. The total demonstrated coal resources are estimated to be 8,787.4 million short tons.(5)

aa) Measured Resources

The tonnage of measured resources is computed from diversions revealed in outcrops, trenches, mine workings, and drill holes. Computed tonnage is judged to be accurate within 20 percent of the true tonnage. The spacing points of observation necessary to demonstrate continuity of coal are generally 1/2 mile apart, although these points may vary from region to region according to the character of the coal beds. Measured coal resources are estimated to be 868.2 million short tons.(5)

bb) Indicated Resources

The tonnage of indicated resources is computed in much the same way as measured resources. However, the spacing points of observation used to compute indicated resources are more widely spaced, about 1 to 1-1/2 miles apart depending on known continuty of coal beds. The thickness of coal beds are also projected overlonger distances on the basis of geological evidence. Indicated coal resources are estimated to be 7,919.2 million short tons.(5)

ii). Inferred Resources

The tonnage estimates of inferred resources are computed on knowledge of the geologic character of the bed or region and for which few measurements of bed thickness are available. The estimates are based on assumed continuty for which there is geologic evidence. Generally, inferred coal resources lie more than two miles from outcrops, from points of mining, or from drill-hole information. Inferred coal resources are estimated to be 121,338.6 million short tons.(5)

Table A-2
Estimated Original Coal Resources of Alaska
By Category
(Million Short Tons)

	Demonstrated			
	Measured	Indicated	Inferred	Total
Bituminous Coal	6.6	890.4	18,532.2	19,429.2
Subbituminous & Lignite Coal	861.6	7,028.8	102,806.4	110,696.8
Total Original Coal Resources	868.2	7,919.2	121,338.6	130,126.0

Source: Reference #5 Bibliography

b. Remaining Resources

Remaining resources are in the ground on the data of appraisal. They may be determined by subtracting past production and mining loses from the original resources. There is little or no coal that has been produced in many of the Alaska coal fields, therefore, the original and remaining resources are virtually the same. Data on mining loses are available for only one small area, the Wishbone Hill district of the Matanuska coal field. Total coal production (through 1964) was estimated at 16.4 million short tons. This was mainly made up of 9.9 million tons of subbituminous coal from the Nenana coal field and 6.5 million tons of bituminous coal from the Matanuska coal field. The amount of coal represented by mined-out areas was approximately twice the reported production (for 1964) which indicates a mining loss of 50 percent. On that basis, the amount of coal mined and the amount lost in mining totals twice the reported production, or about 33 million short tons. Therefore, the remaining resources are the original resources, 130,126 million short tons, minus the mining losses and past production (33 million short tons) or 130,093 million short tons (as of 1/1/65).[4]

c. Recoverable Resources

Recoverable resources are resources in the ground on the date of appraisal that are considered to be recoverable by mining. It is difficult to assign an average figure, because recoverability can vary greatly due to the character of the beds being mined, or the methods used in mining. If we use the 50 percent mining loss as indicated for the remaining resources of the Wishbone Hill district, the recoverable resources would be equal to half the remaining resources of 130,093 million short tons or 65,047 million short tons.[5] This 50 percent recoverability factor is considered justified because in some places strip mining efficiency can run as high as 90 percent, but in the long view strip mining may be applicable to a relatively small percentage of the total estimated resources.

d. Undiscovered Resources

Alaska's undiscovered resources are the hypothetical and speculative resources. These reosources are not included in the total resource estimate, but they are estimated to be two to five trillion tons.[2]

i. Hypothetical Resources

Hypothetical resources are estimated tonnages of coal in the ground in the unmapped and unexplored areas of known coal basins expected to exist in an area under known geologic conditions. These resources are subject to a high degree of error since they are confined to depositional areas where coal occurs in

Table A-3
Estimated Undiscovered Resources of Alaska
(Million Short Tons)

Hypothetical	1,900
Speculative	1,000
Total Undiscovered Resources	2,900

Source: Reference #5 Bibliography

outcrops. However, they will be helpful when the coal gasification and liquefaction technologies develop where extraction of coal or coal products become commercially feasible. Hypothetical coal resources are estimated to be 1.9 trillion tons.[5]

ii. Speculative Resources

Speculative resources are categorized as areas with coal occurrences outside Alaska's known coal fields, such as coal on the continental shelves. The offshore areas's coal resource has been estimated to be one trillion tons.[5]

2. Glossary of Terms

a. Rank of Coal

The American Society for Testing and Materials has established a standard classification for coals in the United States by rank of coal. This classification is used uniformly to estimate coal resources. Table I-A4 shows the classification of coal by rank.

b. Thickness of Beds

The U.S. Geological Survey uses a standard procedure to calculate and report resources according to the thickness categories of coal beds described in Table I-A5. These categories were used to classify the coal resources for this report.

The thickness of beds is evaluated whenever possible by the use of isopachs, such as in the Nenana Coal Field. Where data are insufficient for construction of isopachs, average figures, weighted according to the approximate area of bed represented by each observation, are used. When points of observation are not evenly spaced, weighting is done by assigning intermediate values for the thickness at places where data was needed to fill out a system of evenly spaced points. Tables I-A6 and I-A7 show detailed estimates of original resources according to the thickness of beds' categories.

c. Thickness of Overburden

It is a standard procedure to report resource data in the following three categories according to thickness of overburden in feet: (1) 0-1,000; (2) 1,000-2,000; and (3) 2,000-3,000. In most Alaska coal fields, the estimated resources lie within 1,000 feet of the surface. North Alaska and the Nenana field are the only fields where the resources were calculated in all three categories. Coal more than 3,000 feet below the surface were not included in any of the estimates. Tables I-A6 and I-A7 also show the thickness of overburden used to report the estimated resources according to each coal field.

Table A-4
Classification of Coals by Rank

Class	Group	Fixed carbon limits, dry, mineral-matter-free basis (percent)		Volatile matter limits, dry, mineral-matter-free basis (percent)		Calorific value limits, moist,[2] mineral-matter-free basis (Btu per lb)		Agglomerating character
		Equal or greater than	Less than	Greater than	Equal or less than	Equal or greater than	Less than	
I. Anthracite	1. Meta-anthracite	98			2			Nonagglomerating.[3]
	2. Anthracite	92	98	2	8			
	3. Semianthracite	86	92	8	14			
II. Bituminous coal	1. Low volatile	78	86	14	22			Commonly agglomerating.[5]
	2. Medium volatile	69	78	22	31			
	3. High volatile *A*		69	31		[4] 14,000		
	4. *B*					[4] 13,000	14,000	
	5. *C*					11,500	13,000	
						10,500	11,500	Agglomerating.
III. Subbituminous coal	1. *A*					10,500	11,500	Nonagglomerating.
	2. *B*					9,500	10,500	
	3. *C*					8,300	9,500	
IV. Lignite	1. *A*					6,300	8,300	
	2. *B*						6,300	

[1] This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 Btu per lb (moist, mineral-matter-free basis).
[2] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.
[3] If agglomerating, classify in low-volatile group of the bituminous class.
[4] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.
[5] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile *C* bituminous group.

Table A-5
Thickness Categories of Coal Beds

Rank		*Thickness categories*
Anthracite, semianthracite, and bituminous coal	**inches**	**>42**
		28–42
		14–28
Subbituminous coal and lignite	**feet**	**>10**
		5–10
		2½–5

Table A-6

Estimated Original Resources of Bituminous Coal

(Million Short Tons)

Coal field and district	Overburden (feet)	Measured resources: Bed thickness (inches) 14-28	28-42	>42	Measured Total	Indicated resources: Bed thickness (inches) 14-28	28-42	>42	Indicated Total	Inferred resources: Bed thickness (inches) 14-28	28-42	>42	Inferred Total	Total resources: Bed thickness (inches) 14-28	28-42	>42	Total
Northern Alaska:																	
Corwin Bluff-Cape Beaufort district	0-1,000					25.1	9.0	21.9	56.0	119.6	38.9	78.8	237.3	144.7	47.9	100.7	293.3
	1,000-2,000									158.4	52.5	106.9	317.8	158.4	52.5	106.9	317.8
	2,000-3,000									183.0	61.9	126.3	371.2	183.0	61.9	126.3	371.2
Kukpowruk River	0-1,000					31.2	75.7	140.6	247.5	351.6	276.4	820.6	1,445.5	382.8	352.1	961.1	1,693.0
	1,000-2,000									100.9	118.2	435.8	654.9	100.9	118.2	435.8	654.9
	2,000-3,000									120.1	139.6	445.7	714.4	120.1	139.6	445.7	714.4
Kokolik River	0-1,000					10.4	10.8	77.7	98.9	71.9	184.2	663.3	919.4	82.3	195.0	741.0	1,018.3
	1,000-2,000									90.5		513.6	604.1	90.5		513.6	604.1
	2,000-3,000									106.9		606.8	713.7	106.9		606.8	713.7
Utukok River	0-1,000					12.8	8.5	69.5	90.8	409.9	54.9	1,055.0	1,519.8	422.7	63.4	1,124.5	1,610.6
	1,000-2,000									34.8	69.7	409.3	513.8	34.8	69.7	409.3	513.8
	2,000-3,000									41.2	82.3	490.0	613.5	41.2	82.3	490.0	613.5
Meade River	0-1,000					6.1	12.1	84.4	102.6	62.7		1,128.0	1,190.7	68.8	12.1	1,212.4	1,293.3
	1,000-2,000									75.7		682.6	758.3	75.7		682.6	758.3
	2,000-3,000									89.5		807.2	895.7	89.5		807.2	895.7
Colville River	0-1,000					71.2	121.6	49.4	242.2	1,561.8	1,829.5	427.1	3,818.4	1,633.0	1,951.1	476.5	4,060.6
	1,000-2,000									327.6	783.2	503.3	1,614.1	327.6	783.2	503.3	1,614.1
	2,000-3,000									361.7	711.5	474.4	1,547.6	361.7	711.5	474.4	1,547.6
Total	0-1,000					156.8	237.7	443.5	838.0	2,577.5	2,383.9	4,172.7	9,134.1	2,734.3	2,621.6	4,616.2	9,972.1
	1,000-2,000									787.9	1,023.6	2,651.5	4,463.0	787.9	1,023.6	2,651.5	4,463.0
	2,000-3,000									908.4	995.3	2,953.4	4,857.1	908.4	995.3	2,953.4	4,857.1
Total northern Alaska						156.8	237.7	443.5	838.0	4,273.8	4,402.8	9,777.6	18,454.2	4,430.6	4,640.5	10,221.1	19,292.2
Matanuska coal field:																	
Wishbone Hill	0-2,000	0.1	0.7	5.8	6.6	1.2	9.5	41.0	51.7		10.0	43.7	53.7	1.3	20.2	90.5	112.0
Chickaloon	0-2,000							.7	.7			24.3	24.3			25.0	25.0
Total Matanuska	**0-2,000**	0.1	0.7	5.8	6.6	1.2	9.5	41.7	52.4		10.0	68.0	78.0	1.3	20.2	115.5	137.0
Total Alaska	0-1,000					156.8	237.7	443.5	838.0	2,577.5	2,383.9	4,172.7	9,134.1	2,734.3	2,621.6	4,616.2	9,972.1
	1,000-2,000									787.9	1,023.6	2,651.5	4,463.0	787.9	1,023.6	2,651.5	4,463.0
	2,000-3,000									908.4	995.3	2,953.4	4,857.1	908.4	995.3	2,953.4	4,857.1
	0-2,000	0.1	0.7	5.8	6.6	1.2	9.5	41.7	52.4		10.0	68.0	78.0	1.3	20.2	115.5	137.0
Grand total		0.1	0.7	5.8	6.6	158.0	247.2	485.2	890.4	4,273.8	4,412.8	9,845.6	18,532.2	4,431.9	4,660.7	10,336.6	19,420.2

Table A-7

Estimated Original Resources of Subbituminous Coal and Lignite

(Million Short Tons)

Coal field and district	Overburden (feet)	Measured resources				Indicated resources				Inferred resources				Total resources			
		Bed thickness (feet)			Total	Bed thickness (feet)			Total	Bed thickness (feet)			Total	Bed thickness (feet)			Total
		2½–5	5–10	>10		2½–5	5–10	>10		2½–5	5–10	>10		2½–5	5–10	>10	
Northern Alaska:																	
Utukok River	0–1,000	—	—	—	—	8.2	40.6	21.2	70.0	41.2	223.7	725.8	990.7	49.4	264.3	747.0	1,060.7
	1,000–2,000	—	—	—	—	—	—	—	—	54.3	81.7	—	136.0	54.3	81.7	—	136.0
	2,000–3,000	—	—	—	—	—	—	—	—	64.1	96.5	—	160.6	64.1	96.5	—	160.6
Kaolak Test Well 1	0–3,000	—	—	—	—	29.8	—	71.0	100.8	2,400.0	14,980.0	25,900.0	43,280.0	2,429.8	14,980.0	25,971.0	43,380.8
Kuk River (Wainwright)	0–1,000	—	—	—	—	15.6	20.8	26.2	62.6	496.1	—	899.0	1,395.1	511.7	20.8	925.2	1,457.7
Kugrua River (Peard Bay)	0–1,000	—	—	—	—	—	44.2	—	44.2	—	796.0	—	796.0	—	840.2	—	840.2
Meade River	0–1,000	—	—	—	—	160.0	34.5	—	194.5	5,063.8	1,098.0	—	6,161.8	5,223.8	1,132.5	—	6,356.3
Meade Test Well 1	0–3,000	—	—	—	—	14.2	120.8	462.0	597.0	1,010.0	8,319.0	23,474.0	32,803.0	1,024.2	8,439.8	23,936.0	33,400.0
Ikpikpuk River	0–1,000	—	—	—	—	28.9	14.7	36.8	80.4	751.0	138.0	—	889.0	779.9	152.7	36.8	969.4
	1,000–2,000	—	—	—	—	—	—	—	—	361.0	153.0	—	514.0	361.0	153.0	—	514.0
	2,000–3,000	—	—	—	—	—	—	—	—	59.5	117.0	—	176.5	59.5	117.0	—	176.5
Titaluk Test Well 1	0–3,000	—	—	—	—	17.0	—	—	17.0	947.0	—	—	947.0	964.0	—	—	964.0
Colville River	0–1,000	—	—	—	—	166.2	265.3	—	431.5	2,724.5	4,285.2	—	7,009.7	2,890.7	4,550.5	—	7,441.2
	1,000–2,000	—	—	—	—	—	—	—	—	794.5	1,024.0	1,920.0	3,738.5	794.5	1,024.0	1,920.0	3,738.5
	2,000–3,000	—	—	—	—	—	—	—	—	106.9	—	—	106.9	106.9	—	—	106.9
Umiat Test Well 11	0–3,000	—	—	—	—	11.4	—	—	11.4	191.1	—	—	191.1	202.5	—	—	202.5
Total	0–1,000	—	—	—	—	378.9	420.1	84.2	883.2	9,076.6	6,540.9	1,624.8	17,242.3	9,455.5	6,961.0	1,709.0	18,125.5
	1,000–2,000	—	—	—	—	—	—	—	—	1,209.8	1,258.7	1,920.0	4,388.5	1,209.8	1,258.7	1,920.0	4,388.5
	2,000–3,000	—	—	—	—	—	—	—	—	230.5	213.5	—	444.0	230.5	213.5	—	444.0
	0–3,000	—	—	—	—	72.4	120.8	533.0	726.2	4,548.1	23,299.0	49,374.0	77,221.1	4,620.5	23,419.8	49,907.0	77,947.3
Total northern Alaska	—	—	—	—	—	451.3	540.9	617.2	1,609.4	15,065.0	31,312.1	52,918.8	99,295.9	15,516.3	31,853.0	53,536.0	100,905.3
Nenana coal field:																	
Rex Creek	0–1,000	—	—	—	—	—	9.5	—	9.5	23.0	79.8	10.7	113.5	23.0	89.3	10.7	123.0
Tatlanika Creek	0–1,000	—	—	—	—	—	4.0	113.4	117.4	31.2	8.9	37.0	77.1	31.2	12.9	150.4	194.5
	1,000–2,000	—	—	—	—	—	—	—	—	—	2.4	74.0	76.4	—	2.4	74.0	76.4
Wood River	0–1,000	—	15.0	—	15.0	—	12.0	—	12.0	—	201.0	40.0	241.0	—	228.0	40.0	268.0
	1,000–2,000	—	—	—	—	—	15.0	—	15.0	—	—	—	—	—	15.0	—	15.0
	2,000–3,000	—	—	—	—	—	18.0	—	18.0	—	—	—	—	—	18.0	—	18.0
California Creek	0–1,000	—	4.0	2.0	6.0	—	27.0	206.6	233.6	12.3	50.6	317.0	379.9	12.3	81.6	525.6	619.5
	1,000–2,000	—	—	—	—	—	1.0	6.0	7.0	—	11.0	121.0	132.0	—	12.0	127.0	139.0
Lignite Creek	0–1,000	—	16.0	250.6	266.6	—	93.0	1,326.0	1,419.0	29.0	279.3	1,043.0	1,351.3	29.0	388.3	2,619.6	3,036.9
	1,000–2,000	—	—	—	—	—	7.0	458.0	465.0	3.0	52.0	226.0	281.0	3.0	59.0	684.0	746.0
	2,000–3,000	—	—	—	—	—	—	—	—	—	—	327.0	327.0	—	—	327.0	327.0
Healy Creek	0–1,000	—	—	300.0	300.0	—	1.0	93.5	94.5	—	27.0	114.2	141.2	—	28.0	507.7	535.7
	1,000–2,000	—	—	274.0	274.0	—	1.0	63.0	64.0	—	21.0	112.4	133.4	—	22.0	449.4	471.4
	2,000–3,000	—	—	—	—	—	—	245.0	245.0	—	23.0	87.8	110.8	—	23.0	332.8	355.8
Savage River	0–1,000	—	—	—	—	—	—	—	—	—	12.0	—	12.0	—	12.0	—	12.0
Total	0–1,000	—	35.0	552.6	587.6	—	146.5	1,739.5	1,886.0	95.5	658.6	1,561.9	2,316.0	95.5	840.1	3,854.0	4,789.6
	1,000–2,000	—	—	274.0	274.0	—	24.0	527.0	551.0	3.0	86.4	533.4	622.8	3.0	110.4	1,334.4	1,447.8
	2,000–3,000	—	—	—	—	—	18.0	245.0	263.0	—	23.0	414.8	437.8	—	41.0	659.8	700.8
Total Nenana field	—	—	35.0	826.6	861.6	—	188.5	2,511.5	2,700.0	98.5	768.0	2,510.1	3,376.6	98.5	991.5	5,848.2	6,938.2
Jarvis Creek coal field	0–1,000	—	—	—	—	0.8	5.1	—	5.9	45.0	—	—	45.0	45.8	5.1	—	50.9
	1,000–2,000	—	—	—	—	—	—	—	—	25.6	—	—	25.6	25.6	—	—	25.6
Total Jarvis Creek field	—	—	—	—	—	0.8	5.1	—	5.9	70.6	—	—	70.6	71.4	5.1	—	76.5
Broad Pass coal field:																	
Broad Pass	0–1,000	—	—	—	—	—	0.3	—	0.3	—	63.3	—	63.3	—	63.6	—	63.6
Costello Creek	0–1,000	—	—	—	—	0.3	—	—	.3	—	—	—	—	0.3	—	—	.3
Total Broad Pass field	—	—	—	—	—	0.3	0.3	—	0.6	—	63.3	—	63.3	0.3	63.6	—	63.9
Susitna coal field:																	
Yentna River	0–1,000	—	—	—	—	19.4	8.6	27.9	55.9	—	—	—	—	19.4	8.6	27.9	55.9
Skwentna River	0–1,000	—	—	—	—	6.6	2.5	113.9	123.0	—	—	—	—	6.6	2.5	113.9	123.0
Beluga River	0–1,000	—	—	—	—	17.4	44.6	198.1	260.1	—	—	—	—	17.4	44.6	198.1	260.1
Capps Glacier district	0–1,000	—	—	—	—	—	8.9	396.9	405.8	—	—	—	—	—	8.9	396.9	405.8
Chuitna River	0–1,000	—	—	—	—	16.3	25.5	1,498.7	1,540.5	—	—	—	—	16.3	25.5	1,498.7	1,540.5
Beach southwest of Tyonek	0–1,000	—	—	—	—	3.1	6.3	—	9.4	—	—	—	—	3.1	6.3	—	9.4
Total Susitna field	—	—	—	—	—	62.8	96.4	2,235.5	2,394.7	—	—	—	—	62.8	96.4	2,235.5	2,394.7
Kenai coal field (Homer district)	0–1,000	—	—	—	—	264.2	54.0	—	318.2	—	—	—	—	264.2	54.0	—	318.2
Total Alaska	0–1,000	—	35.0	552.6	587.6	707.0	722.4	4,059.2	5,488.6	9,217.1	7,262.8	3,186.7	19,666.6	9,924.1	8,020.2	7,798.5	25,742.8
	1,000–2,000	—	—	274.0	274.0	—	24.0	527.0	551.0	1,238.4	1,345.1	2,453.4	5,036.9	1,238.4	1,369.1	3,254.4	5,861.9
	2,000–3,000	—	—	—	—	—	18.0	245.0	263.0	230.5	236.5	414.8	881.8	230.5	254.5	659.8	1,144.8
	0–3,000	—	—	—	—	72.4	120.8	533.0	726.2	4,548.1	23,299.0	49,374.0	77,221.1	4,620.5	23,419.8	49,907.0	77,947.3
Grand total	—	—	35.0	826.6	861.6	779.4	885.2	5,364.2	7,028.8	15,234.1	32,143.4	55,428.9	102,806.4	16,013.5	33,063.6	61,619.7	110,696.8

d. Specific Gravity of Coal

Weight of coal in the ground varies according to the rank and ash content. Insufficient data on specific gravity is unavailable for Alaska coals, therefore, the values for weight of coal presented in Table I-A8 were used in this report. These values conform closely to the average of the recorded specific gravities of coal in each of the four major categories.

e. Composition and Heating Value of Coal

Overall, Alaska coals are low in sulfur. Table I-A9 shows the range in composition and the heating value (BTU/lb) of representative Alaska coals.

3. Location and Characteristics of Coal Fields

a. Central Alaska Region

i. Nenana Field

The Nenana coal field is one of the major coal fields in Alaska and extends for about 80 miles along the north flank of the Alaska Range. The Usibelli mine, located in the Nenana field near Healy, is the only area currently producing coal and has proven potential of expanding its production.

Rank of Coal: Subbituminous to lignite
Total Resources: 6,938 million short tons
Thickness of Beds: Ranges from a few inches to 60 feet
Moisture: 11.77% - 32.7%
Volatile Matter: 31.2% - 36.6%
Fixed Carbon: 22.7% - 36.6%
Ash: 3.3% - 15.9%
Sulfur: 0.1% - .4%
BTU/lb: 6,320 - 10,385

ii. Jarvis Creek Field

The Jarvis Creek field is located at the foot of the north flank of the Alaska Range. Its coal-bearing rocks are of tertiary age.

Rank of Coal: Subbituminous
Total Resources: 77 million short tons
Thickness of Beds: Ranges from 1 foot to 7 feet
Moisture: 20.0% - 23.0%
Volatile Matter: 35.1% - 43.4%
Fixed Carbon: 24.1% - 35.3%
Ash: 5.2% - 13.1%
Sulfur: .3% - 1.4%
BTU/lb: 7,815 - 9,415

Table A-8

Weight of Coal

Rank	Specific gravity	Tons per acre-foot	Tons per square mile-foot
Anthracite and semianthracite	1.47	2,000	1,280,000
Bituminous coal	1.32	1,800	1,152,000
Subbituminous coal	1.30	1,770	1,132,800
Lignite	1.29	1,750	1,120,000

Table A-9

Range in Composition and Heating Value of Representative Alaska Coals

(On "as received" Basis)

Location	Source of samples	Rank of coal	Moisture (Percent)	Volatile matter (Percent)	Fixed carbon (Percent)	Ash (Percent)	Sulfur (Percent)	Heating value (Btu)
Northern Alaska Region:								
Corwin Bluff-Cape Beaufort district	Outcrop	Bituminous	3.0- 5.9	28.8-40.1	47.8-58.0	4.1-11.6	----	----
Kukpowruk River	do	do	0.8- 9.9	31.4-35.6	52.6-56.1	2.5-15.0	0.2- .3	11,910-12,8[illegible]
Kokolik and Utukok Rivers	do	do	1.7- 6.2	33.1-37.4	46.8-57.9	2.3-17.4	.2- .6	11,630-13,640
Kuk and Kugrua Rivers	do	Subbituminous	17.8-26.7	29.1-31.9	40.5-42.5	2.3- 9.8	.2- .3	8,760- 9,510
Meade and Ikpikpuk Rivers	Mine	do	14.4	33.5	47.3	4.8	.6	10,330
	Outcrop	do	8.3- 9.9	32.4-35.5	37.7-49.9	6.4-20.0	.2- .8	7,700-10,720
	do	Bituminous	3.4	36.5	46.8	13.3	.7	11,060
Colville River	do	do	2.5- 6.6	30.1-43.7	39.3-62.8	2.6-24.3	.3- .7	10,430-13,450
	do	Subbituminous	5.2-16.4	26.3-31.6	41.9-49.2	11.5-23.4	.3- .7	8,450- 9,300
Central Alaska Region:								
Kobuk River	do	Bituminous	10.5	29.0	52.9	7.6	.4	10,534
Koyukuk River (Tramway Bar)	do	do	4.5	34.2	45.3	12.9	----	----
Chicago Creek (Seward Peninsula)	Mine dump	Lignite	33.8	39.9	19.2	7.1	----	6,525
Ruby-Anvik district (Yukon River)	Mine	Bituminous	1.0-11.2	24.8-40.5	49.9-65.0	3.5-22.6	.2- .6	----
Rampart district (Drew mine)	do	do	9.5	40.1	37.4	13.0	----	----
Eagle-Circle district:								
Washington Creek	Outcrop	Subbituminous(?)	11.1-13.5	42.6-43.7	39.7-44.2	2.1- 3.1	.2- .3	----
Nation River	Mine dump	Bituminous	1.4	40.0	55.6	3.0	3.0	----
Nenana coal field	Mine	Subbituminous	17.8-27.1	33.2-42.0	27.1-35.3	3.5-13.2	.1- .3	7,570- 9,430
	Outcrop	do	11.7-32.7	31.2-42.9	22.7-36.6	3.3-15.9	.1- .4	6,320-10,350
Jarvis Creek coal field	do	do	20.0-23.0	35.1-43.4	24.1-35.3	5.2-13.1	.3-1.4	7,[illegible]- 9,415
Cook Inlet-Susitna Region:								
Broad Pass coal field:								
Costello Creek district	Mine	do	8.7-18.8	32.0-43.4	23.2-42.2	6.0-21.2	.3- .6	7,9[illegible]-10,600
Broad Pass district	Tunnel and trench	Lignite	21.8-35.8	27.8-34.5	20.7-29.3	10.6-21.0	.2- .3	5,4[illegible]- 7,040
Susitna coal field	Outcrop	Subbituminous	19.7-28.2	30.1-39.9	28.7-40.6	2.0-14.2	.1- .4	8,0[illegible]- 9,520
	do	Lignite	31.6-33.1	32.9-37.6	26.4-29.1	2.1- 7.6	.1- .3	7,030- 8,020
Beluga Lake district	Drill hole	Subbituminous	11.3-19.3	27.8-37.9	25.8-34.6	13.3-30.5	----	6,290- 8,990
	Trench	do	24.4	30.1	28.7	16.8	.2	7,160
Matanuska coal field:								
Little Susitna district	Mine	do	17.4-20.3	31.6-32.5	30.6-38.9	9.2-13.5	.4	9,160- 9,210
	Outcrop	do	14.1	31.3	34.1	20.5	.4	8,400
Wishbone Hill district	Mine	Bituminous	2.7- 8.6	31.6-44.0	35.4-51.0	4.4-21.7	.2-1.0	10,390-13,190
Chickaloon district	do	do	1.1- 4.1	13.8-22.9	59.1-72.2	5.5-19.5	.4- .7	11,950-14,350
Anthracite Ridge district	Outcrop	do	1.9- 6.8	14.3-31.5	47.4-78.4	2.4-17.2	.5- .7	11,3[illegible]-14,210
	do	Semianthracite	3.1- 8.7	6.6-10.5	64.3-80.6	7.0-21.0	.2- .7	13,720-13,425
Kenai coal field (Homer district)	do	Subbituminous	21.2-27.7	31.2-35.1	24.1-33.7	3.2-22.0	.2- .4	6,550- 8,0[illegible]
	do	Lignite	27.1-30.4	31.8-41.3	24.5-30.3	3.8-15.7	.1- .2	6,640- 7,640
	Mine	Subbituminous	16.5-21.6	30.3-35.1	31.2-41.1	9.1-12.1	.3- .4	8,350- 9,020
Alaska Peninsula Region:								
Herendeen Bay coal field	**Tunnel**	**Bituminous**	**7.5- 8.0**	**32.1-33.5**	**48.8-51.4**	7.1-11.6	.3- .4	11,260-11,790
	Outcrop	do	4.2- 6.7	35.2-38.6	47.2-53.0	5.0-12.0	.4- .6	11,150-12,420
Unga Island coal field	do	Lignite	23.3	25.4	25.1	26.2	.5	5,810
Chignik coal field	Mine or prospect	Bituminous	5.0-10.8	27.2-34.3	39.6-45.4	14.9-25.3	.7-2.3	9,640-11,240
Southeastern Alaska Region:								
Bering River coal field	Mine	do	1.0- 8.6	13.1-17.4	65.0-91.1	2.1-18.0	.6-3.4	11,000-15,000
	do	Semianthracite	2.9- 6.0	10.8-13.0	60.3-76.1	4.9-22.2	.6-4.9	12,350
	Outcrop	Bituminous	1.5- 7.7	10.9-15.4	55.1-81.7	1.2-25.4	.7-1.4	10,440-14,5[illegible]
	do	Semianthracite	1.6- 9.4	8.7-13.6	60.9-84.7	1.7-24.8	.5-4.1	9,880-15,020
	do	Anthracite	3.0- 8.3	5.0-13.3	66.0-82.5	2.1-20.5	.6-2.9	11,890-12,790
Kootznahoo Inlet (Admiralty Island)	Mine	Bituminous	3.8- 6.4	34.3-35.2	36.3-39.6	21.4-23.0	.9-1.3	9,930-10,030

iii. Eagle-Creek District - Nation River

The Nation River connects with the Yukon. Coal from this area are from the Nation River Formation of Paleozoic age.

Rank of Coal: Bituminous
Total Resources: Unknown
Thickness of Beds: Not defined
Moisture: 1.4%
Volatile Matter: 40.0%
Fixed Carbon: 55.6%
Ash: 3.0%
Sulfur: 3.0%
BTU/lb: Unknown

b. Southcentral Alaska Region

i. Susitna Field - Beluga Area

The Susitna coal field is the major coal bearing area of the extensive lowland that is located north of Cook Inlet. The coal is in the Kenai Formation and is of Tertiary age. Coal-bearing rocks are exposed in scattered areas, mainly around larger steams.

The Beluga and Chuitna Rivers, located in the Susitna field, contain most of the potentially reliable coal deposits. Although the field is presently undeveloped and virtually without roads, it has large proven reserves as some of the best depostis are close to tidewater and therefore has been ranked number one in development potential by most Alaska coal experts.

Susitna Field:

Rank of Coal: Subbituminous to lignite
Total Resources: 2,395 million short tons
Thickness of Beds: Relatively flat
Moisture: 19.7% - 33.1%
Volatile Matter: 30.1% - 39.9%
Fixed Carbon: 26.4% - 40.6%
Ash: 2.0% - 14.2%
Sulfur: .1% - .4%
BTU/lb: 7,030 - 9,520

Beluga Area:

Rank of Coal: Subbituminous
Total Resources: 1,801 million short tons
Thickness of Beds: Ranges from a few inches to 50 feet
Moisture: 11.3% - 30%
Volatile Matter: 27.8% - 30.1%
Fixed Carbon: 25.8% - 34.6%
Ash: 8% - 30%
Sulfur: .2%
BTU/lb: 6,290 - 8,890

ii. Matanuska Field

The Matanuska field occupies much of the Matanuska Valley. There are several coal-bearing areas extending from the head of the Susitna River Valley to the west. The coal is of the Teritary age.

Rank of Coal: Bituminous
Total Resources: 137 million short tons
Thickness of Beds: Ranges from a few inches to 23 feet
Moisture: 1.1% - 8.6%
Volatile Matter: 13.8% - 44.6%
Fixed Carbon: 38.4% - 72.2%
Ash: 4.4% - 21.7%
Sulfur: 0.2% - 1.0%
BTU/lb: 10,390 - 14,380

iii. Kenai Field

The Kenai coal field is located on the west side of the Kenai Peninsula in the lowland between the Kenai Mountains and Cook Inlet. Estimated total resources are stated below, however, larger resources are present farther inland. Inland resource estimates were not computed because of the scarcity of outcrops.

Rank of Coal: Subbituminous to lignite
Total Resources: 318 million to short tons
Thickness of Beds: Ranges from a few inches to 80 feet
Moisture: 16.5% - 30.4%
Volatile Matter: 30.3% - 41.3%
Fixed Carbon: 24.5% - 411.1%
Ash: 3.8% - 15.7%
Sulfur: 0.1% - .4%
BTU/lb: 6,640 - 9,020

iv. Broad Pass Field

The Broad Pass coal field is located south of the Divide of the Alaska Range, on the headwaters of the Chuitna River.

Rank of Coal: Lignite
Total Resources: 67 million short tons
Thickness of Beds: Unknown
Moisture: 21.8% - 35.8%
Volatile Matter: 27.8% - 34.5%
Fixed Carbon: 20.7% - 28.3%
Ash: 10.6% - 21.0%
Sulfur: .2% - .3%
BTU/lb: 5,410 - 7,040

c. Northern Alaska Region

i. Kukpowruk River District

The Kukpowruk River District is located in the northwestern corner of the Northern Slope of Alaska. Its coal is of high quality and coal-bearing rocks are exposed along the lower 25 miles of the Kukpowruk River and a small area 70 miles above the mouth of the river.

Rank of Coal: Bitiminous
Total Resources: 3,065 million short tons
Thickness of Beds: 1 and 1/2 to 13 feet
Moisture: 0.8% - 9.9%
Volatile Matter: 31.4% - 35.6%
Fixed Carbon: 52.6% - 56.1%
Ash: 2.5% - 15.0%
Sulfur: 0.2% - .3%
BTU/lb: 11,910 - 12,880

ii. Utukok River District

The Utukok River has coal-bearing areas between 25 and 80 miles above the mouth of the river.

Rank of Coal: Bituminous
Total Resources: 2,738 million short tons
Thickness of Beds: Ranges from a few inches to 12 feet
Moisture: 1.7% - 6.2%
Volatile Matter: 33.1% - 37.4%
Fixed Carbon: 46.8% - 57.9%
Ash: 2.3% - 17.4%
Sulfur: .2% - .6%
BTU/lb: 11,630 - 13,640

iii. Kuk River District

The Kuk River is located near the Arctic coast, south and east of Wainwright. These beds are nearly horizontal, some of them which have been reported to extend several miles along the east shore.

Rank of Coal: Subbituminous
Total Resources: 1,458 million short tons
Thickness of Beds: 3 to 14-1/2 feet
Moisture: 17.8% - 26.7%
Volatile Matter: 29.1% - 31.9%
Ash: 2.3% - 9.8%
Sulfur: .2% - .3%
BTU/lb: 8,780 - 9,510

d. Southwestern Alaska Region

i. Chignik Field

The Chignik coal field is located on the west shore of Chignik Bay, which indents the southeast shore of the Alaska Peninsula, about 250 miles southwest of Kodiak. Coal bearing rocks are of the Chiqnik formation and are of late Cretaceous age. Data available is insufficient for reliable resource estimates.

Rank of Coal: Bituminous
Total Resources: Unknown
Thickness of Beds: 1 to 5 feet
Moisture: 5.0% to 10.8%
Volatile Matter: 27.2% - 34.3%
Fixed Carbon: 39.6% - 45.4%
Ash: 14.9% - 25.3%
Sulfur: .7% - 2.3%
BTU/lb: 9,640 - 11,240

ii. Unga Island Field

The Unga Island is located off the south coast of the Alaska Peninsula opposite Herendeen Bay. Coal bearing rocks are of the Tertiary age and underlies a 40 mile area in the northwestern part of Unga Island.

Rank of Coal: Lignite
Total Resources: Unknown
Thickness of Beds: Ranges from a few inches to 4 feet
Moisture: 23.3%
Volatile Matter: 25.4%
Fixed Carbon: 25.1%
Ash: 26.2%
Sulfur: .5%
BTU/lb: 5,810

iii. Herendeen Bay Field

Herendeen Bay is located off the north shore of the Alaska Peninsula, abut 350 miles southwest of Kokiak. Coal-bearing rocks are of the Chiqnik Formation and the late Cretaceous age. They underlie 40 square miles on the peninsula between Herendeen Bay and Port Moller.

Rank of Coal: Bituminous
Total Resources: Unknown
Thickness of Beds: Ranges from a few inches to 7 feet
Moisture: 4.2% - 8.0%
Volatile Matter: 32.1% - 38.6%
Fixed Carbon: 47.2% - 53.0%
Ash: 5.0% - 12.0%
Sulfur: .3% - .6%
BTU/lb: 11,150 - 12,420

e. Southeastern Alaska Region

i. Bering River Field

Coal-bearing rocks lie in a continuous belt about 50 square miles northeastward from the east shore of the Bering Lake. The coal is in the Kushtaka Formation.

Rank of Coal: Bituminous & Anthracite
Total Resources: 3,200 million short tons
Thickness of Beds: Ranges from a few inches to 60 feet
Moisture: 1.0% - 9.4%
Volatile Matter: 5.0% - 17.4%
Fixed Carbon: 58.1% - 91.1%
Ash: 1.2% - 25.4%
Sulfur: .5% - .4%
BTU/lb: 9,880 - 15,020

ii. Kootznahoo Inlet

The Kootznahoo Inlet is located 60 miles south Juneau. The coal-bearing rocks are of Tertiary age and underlie about 20 miles on the north and south sides of the Kootznahoo Inlet and the west side of Admiralty Island.

Rank of Coal: Bituminous
Total Resources: Unknown
Thickness of Beds: 2 to 3 feet
Moisture: 3.8% - 6.4%
Volatile Matter: 34.3% - 35.2%
Fixed Carbon: 36.3% - 39.6%
Ash: 21.4% - 23.0%
Sulfur: .9% - 1.3%
BTU/lb: 9,930 - 10,630

APPENDIX B

ENVIRONMENTAL IMPACTS ASSOCIATED WITH COAL DEVELOPMENT IN THE KUKPOWRUK, NENANA, AND BELUGA FIELDS, ALASKA

Prepared for U.S. Department of Energy
by
University of Alaska
Arctic Environmental Information
and Data Center

Anchorage, Alaska

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INTRODUCTION

The United States must find new domestic supplies of energy-producing fuels to lower dependence on foreign supplies of oil and natural gas. The President's National Energy Plan emphasizes the development and use of alternative fuels, such as coal, to reduce petroleum consumption. In addition, the Powerplant and Industrial Fuel Use Act encourages industries to consider the economics of using coal over the oil and gas currently being consumed. New technologies for making coal burn more cleanly promise to make coal more environmentally acceptable. Also, the reluctance of some members of the public to accept the increased use of nuclear power results in serious consideration by utilities of increasing the use of coal in electric generation.

Consequently, Alaska's huge coal reserves, estimated to be as large as two trillion tons, comprise an important national resource. Coal has been mined in Alaska for many years, but most mining efforts have been unorganized and the coal used for local consumption. For example, early immigrants to Cook Inlet utilized coal from the exposed beds in the area to heat their homes. and steam vessels pulled in to shore near exposed seams and refilled their bunkers. (In this manner, the U.S. Revenue Cutter Corwin lent its name to the deposit which includes the Kukpowruk Field.)

The advent of the Alaska Railroad, linking Seward, Anchorage, and Fairbanks, changed this scenario dramatically. Large amounts of high-quality coal were required to fuel steam locomotives and to operate related shop equipment. Relatively modern mines were established near the present-day towns of Palmer and Healy. Opening of these mines stimulated use of coal as a heating fuel, and many households took advantage of the resource. The future of coal mining in Alaska appeared good. In the late 1950s, however, demand began to drop substantially. The railroad began replacing its steam locomotives with diesel-powered engines at about the same time that U.S. military posts in the Anchorage area switched from coal to oil as heating fuel. This double blow seemingly spelled the beginning of the end for coal in Alaska, but markets in Fairbanks have remained stable. At present, the mine at Healy delivers about 700,000 tons of coal per year to Fairbanks consumers.

The Department of Energy and others must examine the environmental, social, and economic costs of mining and marketing Alaskan coal to determine if it can play an important role in meeting America's energy needs in the coming decades. This report represents the beginning of this process for three areas of major interest in Alaska--Kukpowruk, Nenana, and Beluga.

SUMMARY AND CONCLUSION

Historically, the process of finding and extracting near-surface coal resources in the United States has adversely affected both fish and wildlife populations and millions of acres of their habitats. Effects are both direct and indirect and involve physical, chemical, and biological changes. Some of the changes are confined to immediate mine sites, while others affect larger geographic areas through both on-site and downstream erosion and atmospheric and hydrologic processes. These influences and results are also often of long duration. Expected major effects that would be associated with surface mining in Alaska that are discussed in this report are direct effects on water quality, water quantity, surface topography, and air quality and the secondary effects pertinent to fish, wildlife, and other living organisms.

Water quality can be expected to be affected in any of the three fields--Kukpowruk, Nenana, or Beluga--as the natural terrain is disturbed, drainage patterns are altered, and excavation activities produce silt and sediment, leachates, and dust. Expected quality changes include turbidity, dissolved solvent levels, pH, dissolved oxygen, and temperature.

The presence of frozen ground/permafrost, the extremely contrasting summer and winter hydrologic cycles, and presence and duration of ice and aufeis can induce changes to the environment from coal development. These relate to such factors as flow, slump, and slide of fine grained materials; water impoundments in permafrost terrains; changes in runoff patterns; and sedimentation. These changes in turn affect plant and animal communities and population of the aquatic system.

Water quality effects are regulated by a number of state and federal statutes and regulations falling within the purview of a number of agencies. Obviously, one of the major hindrances to Alaskan coal development would be convincing such authorities of the efficacy of a number of engineering practices required to prevent the reduction of water quality in situations of natural extremity and limited knowledge.

Water availability as well as water quality would be impacted by any coal mining program. In Alaska, water quantity and availability are affected by a number of natural factors, including seasonal temperature, permafrost, ice, and high runoff in spring "breakup" and often again during August storms. Furthermore, groundwater resources are often unavailable or, if available, frequently highly mineralized, adding to the discharge quality problem when used in washing or other processing activities. In effect, then, surface waters are the main usable sources and these can be highly variable in availability throughout the year.

Besides availability of water for coal operations being a problem, the subsequent effect on water availability for downstream use is also of concern. An adequate volume availability for both real and potential users, including fish and wildlife; the quality of discharged water; and on a seasonal basis consonance with natural factors are also major concerns. Large volumes of water would be required in all of the regions for mining and reclamation activities, coal conversion and use plants, conjunctive developments, and population increases. Water withdrawals could affect aquatic systems by reducing habitats and by changing physical regimes such as the temperature and dissolved oxygen levels of the remaining water. In areas such as the Kukpowruk, where seasonal flows are either very high or very low, the maintenance of minimum stream flow for aquatic life could be an important consideration to the permitting of water appropriation.

The physical effects of surface mining are most obvious on land. A few of the more evident examples are barren areas caused by road construction, claim location and development, active mining, overburden removal and stockpiling, tailing ponds, waste disposal areas, open pits and slides, etc.

A number of landform changes would occur secondarily as a result of the alteration of permafrost terrains. Stockpiled, fine-grained, ice-rich overburden materials are liable to thaw into muddy flows with often disastrous and uncontrollable results; thaw ponds and watered ditches would also appear when tundra over ice-rich permafrost is disturbed; and slopes would fail, slide, fall, and be altered.

A last major environmental impact which can be expected to be associated with surface coal mining is air quality degradation from dust. In all three coal field situations of concern lie in areas of low-level air inversion. The effect of this generally winter-month phenomenon, which exhibits temperature differences in the Interior up to 20°C in the lowest 600 feet (200 m) and is one of the strongest found anywhere, is to trap dust as well as hydrocarbon engine emissions at extremely cold temperatures below a "roof" of warmer air. The dust and hydrocarbons serve as nucleids to form "ice fog." In its more serious forms, ice fog is deleterious to human health and offers hazards to industrial operations due to reduced visibility and worker discomfort.

During the winter months dust from coal operations and from routine travel on gravel roads would settle on the snow, often over many miles, in accordance with prevailing winds. As spring approaches, with greater solar radiation and warmer temperatures, dust-covered snow would melt more rapidly than uncovered snow. The effect of this is to speed up insect and other invertebrate life development. In some areas this occurrence has a disruptive chain reaction effect on the food webs of many higher forms of life.

Environmental effects of coal operations in Alaska are, in the main, similar to those elsewhere in the United States and are generally well known. The main set of differences in Alaska stems from differences in physical conditions (i.e., permafrost, hydrologic cycles which exhibit seasonal and volume extremes and which are imperfectly known, and cold air temperature phenomena), all of which require special engineering and operational techniques during mining and which can cause conditions making reclamation activities virtually impossible on some sites.

The control of adverse environmental effects due to surface coal mining operations in the Kukpowruk, Beluga, and Nenana fields would not be easy and may adversely affect cost/benefit ratios. The technological and environmental knowledge for such control, however, does for the most part exist and could be applied to the Nenana and Beluga fields. The operation of coal mining in the Kukpowruk field under existing knowledge and legal restraints, however, is much more difficult and may well be impossible unless mining objectives are made paramount to current environmental goals formed under existing law. The only other alternative is to encourage active development research directly applicable to coal mining under arctic conditions.

DESCRIPTION OF THE NATURAL ENVIRONMENT OF THE THREE REGIONS

The three coal fields this report (Kukpowruk, Nenana, Beluga) considers are separated spatially by many hundreds of miles and about 10 degrees of latitude. Local climate and physiography vary markedly between fields, as do the respective biotic communities. Species lists and more detailed information on the physical and biological environments of these three areas can be found in the Alaska Regional Profiles, published by the University of Alaska's Arctic Environmental Information and Data Center, 1975-77. Abbreviated accounts of the salient features of the environments of each region follow:

Permafrost

Permafrost is any earth material (bedrock or unconsolidated materials) that has remained frozen for at least two seasons. Some permafrost has been in existence for tens of thousands of years. The depth of permafrost may range from a few feet along the southern boundary of a permafrost region, to as much as 2,000 feet (610 m) at Prudhoe Bay in northern Alaska.

Continuous permafrost covers the northern part of the state of Alaska and underlies all of the region. South of that, permafrost is discontinuous, or interrupted, and in the southern part of the state permafrost is sparse, or absent altogether (Figure 1). The Kukpowruk coal fields lie within the continuous permafrost zone; the Healy coal fields are within the discontinuous zone; and the Beluga coal fields lie in the sparse permafrost zone, near the southern permafrost limit.

The top of the permanently frozen layer is known as the permafrost table. The zone above that is called the suprapermafrost zone. The part of the suprapermafrost zone that freezes in winter and thaws in summer is the active layer. In some years not all of the suprapermafrost zone would freeze; that part above the permafrost layer that remains unfrozen in known as talik and may contain unfrozen water under high pressure (Figure 2).

The depth to the permafrost table, and the thickness of the permafrost layer, are influenced by the surface topography and soil conditions of the land (Figure 3). The permafrost table rises into hill slopes; it is depressed beneath water bodies such as lakes and rivers, often leaving an unfrozen "thaw bulb" beneath the water bodies that do not freeze to the bottom in winter. The thickness of the suprapermafrost

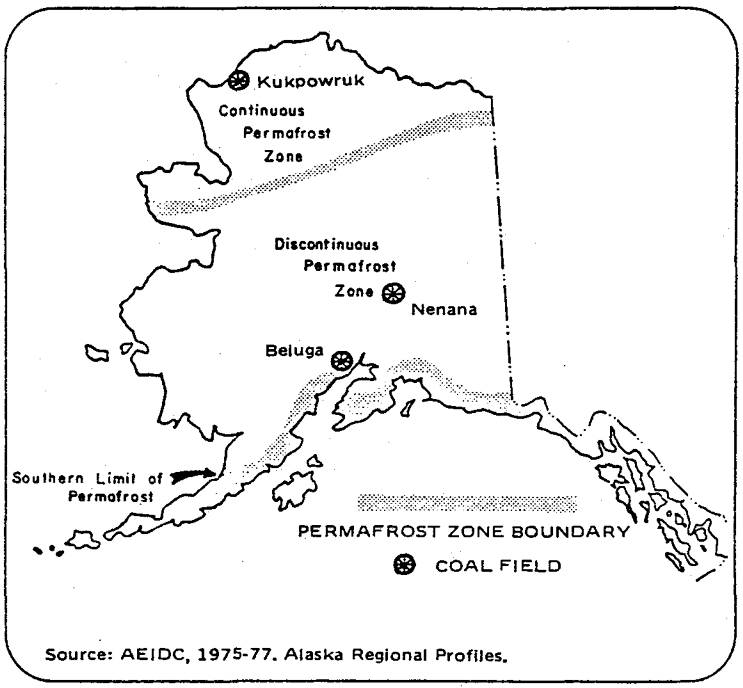
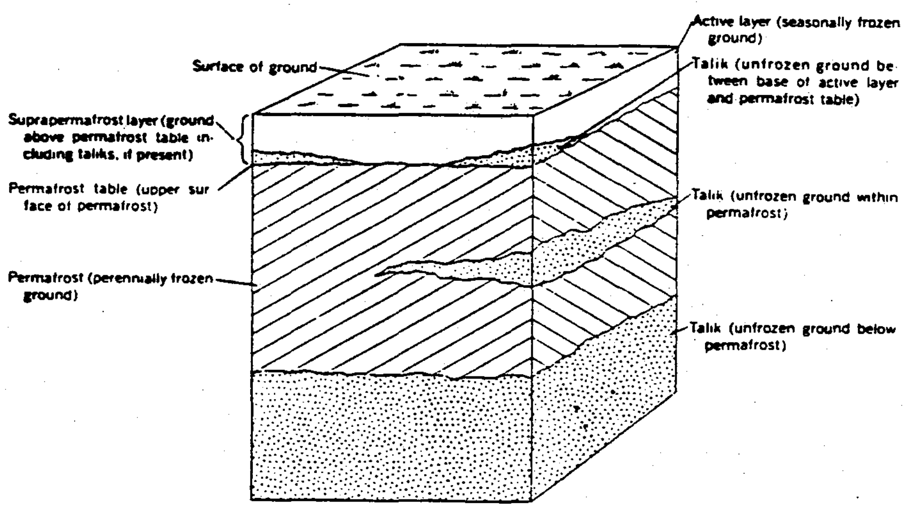
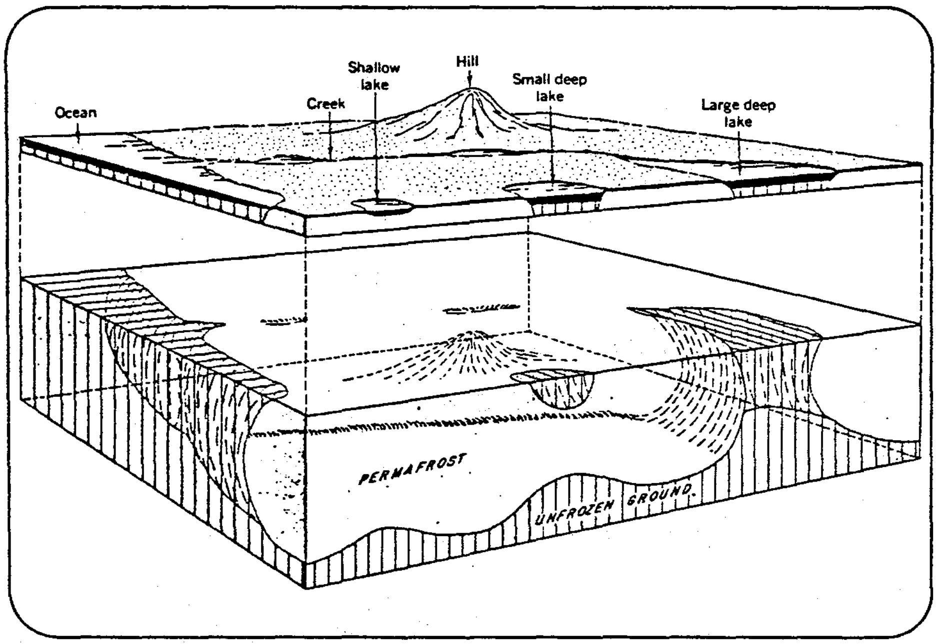


Figure 1 Location of the Three Coal Fields and Permafrost Zones of Alaska



Source: O. J. Ferrians, Jr., R. Kachadoorian and G. W. Greene, 1969. Permafrost and Related Engineering Problems in Alaska. U. S. Geological Survey Professional Paper 678.

Figure 2 Occurrence of Taliks in Relation to the Active Layer, Suprapermafrost Zone, Permafrost Table, and Permafrost



Source: O. J. Ferrians, Jr., R. Kachadoorian and G.W. Greene, 1969. Permafrost and Related Engineering Problems in Alaska. U. S. Geological Survey Professional Paper 678.

Figure 3 The Effect of Surface Features on the Distribution of Permafrost in the Continuous Permafrost Zone

frost layer and active layer are influenced by the type of soils on the surface. Coarse-grained, well-drained soils thaw much deeper in summer than do fine-grained, silty or clayey soils that retain a large amount of interstitial water.

The presence of permafrost affects the physical characteristics of the ground surface, especially in areas overlain by fine-grained, poorly-drained soils. "Patterned ground," a condition of the surface in which a random distribtuion of polygonal crack systems occur, characterizes areas underlain by permafrost. These crack systems occur when winter freezing of the ground surface causes contraction of the soil surface, similar in pattern to mud cracks in dried mud. Polygons are typically 30 to 60 feet (9 to 10 m) across. The cracks freeze and contract in winter followed by summer filling with meltwater, then the following winter they refreeze and contract further, until after a number of years large ice wedges are formed along the boundaries of the polygons, extending downward as much as 30 feet (9 m).

In well-drained areas of topography, high-centered polygons occur in which the polygon centers are higher than the bounding crack systems. Runoff water follows the polygon crack systems and beaded streams often form as drainage waters thaw small meltwater pools at the crack intersections. In poorly drained, marshy areas, low-centered polygons occur in which small soil ridges parallel the crack systems and stand higher than the polygons themselves. In this circumstance, waters tend to collect in the low polygon centers, eventually thawing the permafrost beneath them and creating small pools and ponds. Often, these flooded polygons thaw together and merge, creating thaw lakes that may reach several miles in length.

When permafrost soils thaw they often become unstable, especially if dominated by ice-rich fine-grained sediments. If these soils lie on a slope, even a gentle one, they may begin to flow downhill. Some natural soil flow occurs on slopes due to permafrost thaw. Anything that disturbs the vegetation cover over permafrost soils may induce thaw. The vegetation cover provides an insulative layer over frozen soils that normally prevents melt, but removal or destruction of the vegetation exposes the frozen ground to warm, summer temperatures. Many of the activities of man, including surface mining, may contribute to vegetation damage or destruction, followed by permafrost thaw and ensuing soil instability. This often results in soil flow, ground settling, surface slumping, and initiation of ever-enlarging areas of thaw caused by released meltwaters. The final result often is severely altered drainage patterns and topography which is difficult or impossible to rejuvenate.

The thickness of a permafrost layer is generally controlled by the average annual temperature of a region, though changes in mean temperatures are usually lagged by changes in permafrost configuration. In most of Alaska, the average annual temperature has warmed over the last century or so. Permafrost is slowly warming, and permafrost thickness, especially in discontinuous permafrost, is generally relict from an earlier, cooler time. Because of this, permafrost in most areas, once disturbed, would not reform in its original condition.

Hydrology

Kukpowruk Region

Streamflow in the Kukpowruk region is principally limited to the short summer season. Highest flows occur in most streams during spring breakup (normally in early June) due to the rapid influx in snowmelt waters. Flow then rapidly decreases in most streams to a lower, relatively stable summer level, showing marked increases only during summer storm periods accompanied by high precipitation, especially in the mountains.

Freezeup of the arctic rivers usually commences in mid-September, and most streamflow essentially ceases in most streams by December. During the rest of the winter, flow is very low or nonexistent; some small amount of flow may occur in some rivers beneath the alluvial riverbed.

Lakes in the region usually freeze to the bottom in winter unless they are deeper than about 10 feet (3 m). Lakes begin to freeze in mid-September and usually break out by July.

Groundwater in the region is essentially nonexistent, due to the continuous permafrost cover, which either keeps all subsurface waters frozen or inhibits the flow of any unfrozen water. The one exception to this is occasional small amounts of unfrozen water in thaw bulbs beneath deep rivers and lakes and within alluvial or lake-bottom sediments. The quality of this water is usually low due to the concentration of dissolved solids in the unfrozen water beneath the frozen water bodies.

Nenana Region

Streams traversing the Nenana coal fields are principally draining northward from the Alaska Range. Most of the larger streams have their headwaters at glaciers high in the mountains and exhibit flow characteristics dominated by ice melt there. They have higher average flow rates than streams that do not originate in glaciers and a summer diurnal flow pattern that is usually highest in the evening when ice melt is at its greatest, followed by lowest flow in the morning after a cool night. Highest flow rates occur in July and August because of high glacier melt rates.

Most of the streamflow in streams without glacial runoff occurs during the spring snowmelt period, usually during May and June. Highest flows in these streams generally occurs in June. However, high flow rates can occur in July and August due to high precipitation during storms, especially is associated with high snowmelt rates.

Low flows occur in all streams during the late winter months of March and April, just before spring breakup commences.

Groundwater in the region occurs in sedimentary rock formations and in alluvial gravels in the principal stream valleys. Yields of less than 1,000 gallons per minute have come from the sedimentary rock formations near the present coal mining area near Healy, but few data are available due to the small number of wells. Groundwater flow apparently occurs in alluvial gravels in major streams even during winter low-flow periods.

Beluga Region

Streams in this region have their headwaters either in Alpine glaciers at high elevations or, in the case of many smaller streams, originate at lower elevations within the foothills. In both, about 90 percent of yearly flow occurs during the summer period from mid-April to November. For nonglacial streams, highest flows occur during May, June, and July; peak flows occur somewhat later in glacial streams. August is usually a period of low flow in nonglacial streams and moderate flow in glacial rivers.

In most streams within the region, streamflow increases again during September and October due to increased precipitation. Lowest flows occur during February and March, just prior to spring breakup.

Groundwater resources are mostly unknown in the Beluga region, though there is apparently a large contribution of alluvial groundwater to the area's streamflow. Since permafrost is quite limited, groundwater resources may be more widespread.

Geologic Hazards

Earthquakes

Earth slippage along bedrock fault planes, with its accompanying ground shaking, can have severe effects on the natural environment and man's activities in it. Ground shaking can cause stable soils to become unstable and slump, slide, or avalanche; uplift of portions of the land in relation to others can cause changes in local topography and drainage conditions and affect groundwater flow and water quality. Man-made structures can be destroyed or badly damaged. Earthquake-generated seismic sea waves, or tsunamis, can wreak havoc on coastal structures.

Alaska varies in siesmic risk, with the greatest risk occurring in the southern part of the state. Risk decreases to relatively minor proportions in the northern part of the state. The Kukpowruk coal fields lie within a region considered to have minor to moderate seismic risk; the Nenana fields lie within a zone of major risk; and the Beluga fields lie within the southern zone of severe seismic risk (Figure 4). The most severe earthquake to hit the state was the 1964 earthquake that occurred in upper Prince William Sound, and destroyed much of Anchorage, Seward, and Valdez. It had a magnitude of 8.4 on the Richter scale. An earthquake of this magnitude is quite rare, but earthquakes large enough to cause damage are not infrequent in the southern part of the state.

Flooding

In the arctic region, river flooding occurs annually during spring breakup. During this time, flows commonly overflow riverbanks and inundate river floodplains that do not see flows for the rest of the year. River ice breaks up in a rapid, spectacular manner, with ice blocks being carried well beyond the normal stream bed and isolated

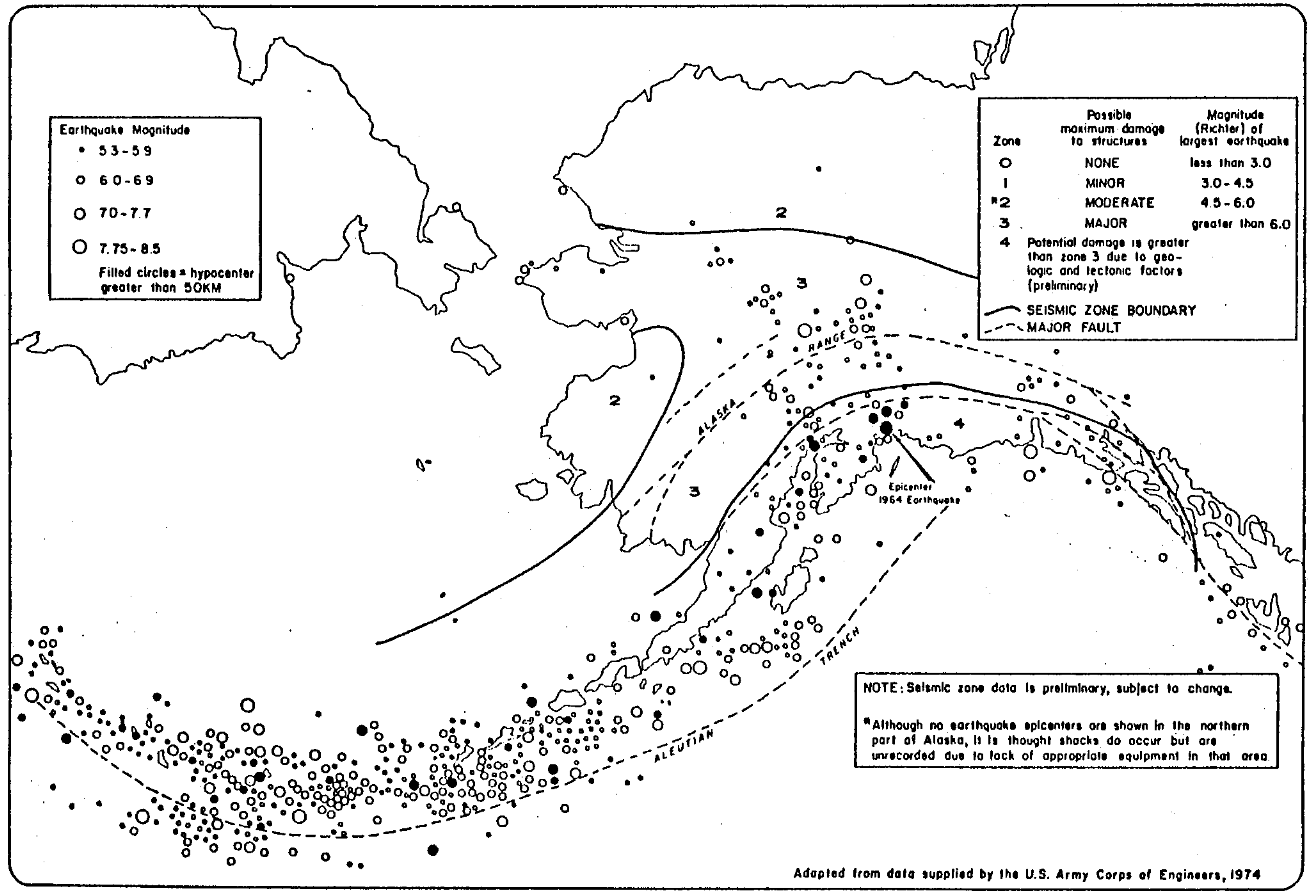


Figure 4 **Seismic Zone Map of Alaska**

there to slowly melt away. River floodwaters with their load of ice blocks and heavy sediment flood nearshore reaches of sea ice, covering it with dark-colored sediments that then accelerate ice melt.

Throughout the rest of the year flooding is rare, but may occur during periods of especially high precipitation, especially in the mountainous headwater region. During this time, flooding is aggrevated by the fact that precipitation must run off over the land surface, rather than being absorbed by it, due to the occurrence of continuous permafrost.

In the central and southern part of the state, especially near the mountain ranges, river flooding occasionally occurs when a period of high precipitation follows a warm period of rapid glacier melt. Then, the combined input of water from precipitation and ice melt can cause rivers to overflow their normal banks and inundate their floodplains.

Some regions are occasionally affected by flooding from glacier-dammed lakes. This occurs when winter flow of a glacier blocks drainage from a side valley. During the warm summer months, glacier melt-back can occur to a sufficient degree that the side valley is suddenly freed of its ice dam, and disastrous flash flooding can occur. In some areas these floods occur annually, usually during July or August, but in other areas they are less predictable.

Volcanoes

Volcanic activity is a potential threat only to activities in the Beluga coal field. Several volcanoes lie nearby, including Mts. Spurr, Redoubt, Iliamna, and St. Augustine. These volcanoes have all been active at some time in the recent century. The greatest threat from eruptions of these volcanoes is from large ashfalls. However, mud flows from actively erupting volcanoes can cause temporary damming of nearby rivers, which usually is followed by severe flash flooding.

Climate of the Three Regions

The statewide, regional, and local climate descriptions and figures in this section are from the Alaska Regional Profiles, AEIDC, 1975-1977.

The land mass of Alaska generally lies between 60 and 70 degrees north latitude and is characterized by arctic to subarctic climatic conditions. Winter temperatures are very low (Figures 5 and 6) and are often accompanied by seasonally high winds that cause severe chill factors (Figure 7). Summer temperatures are generally cool (Figures 8 and 9). Another seasonal feature is the great fluctuations in the amount of daylight. In the Far North there are many days in winter with no daylight and many days in summer with no darkness (Figure 10). Precipitation is low throughout much of the state, particularly in northern and interior regions, but is quite high in others, for instance in southeastern Alaska (Figure 11). Contrary to what might be expected in this latitude, most precipitation falls as rain (Figure 12).

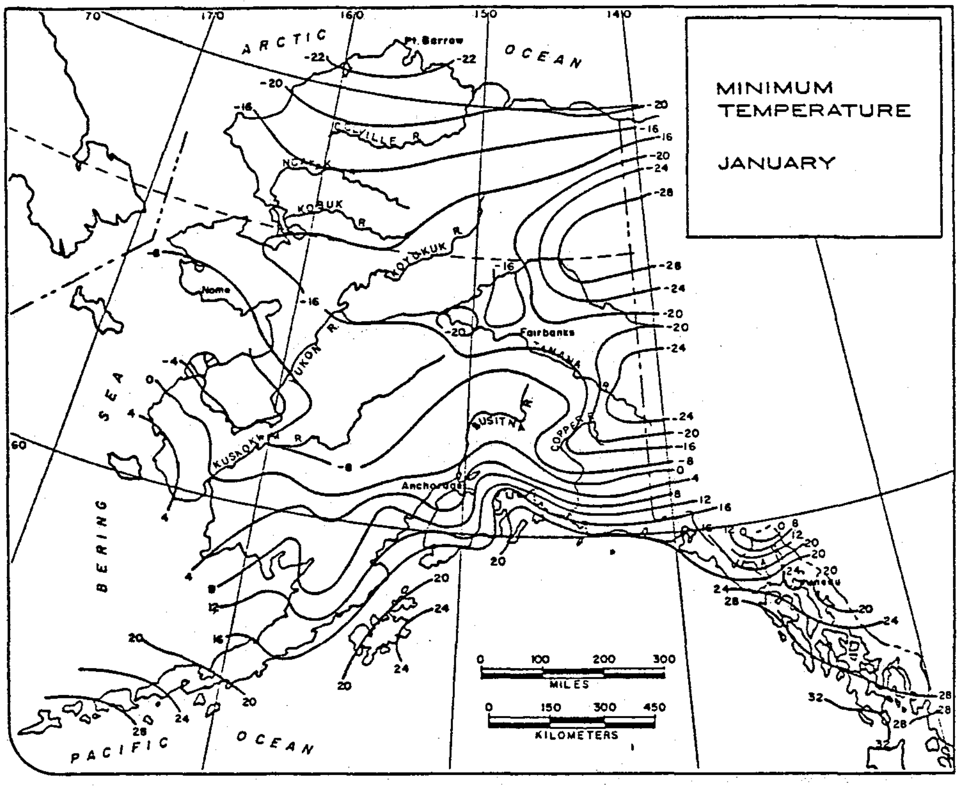


Figure 5 Mean Minimum Temperature Distribution, January

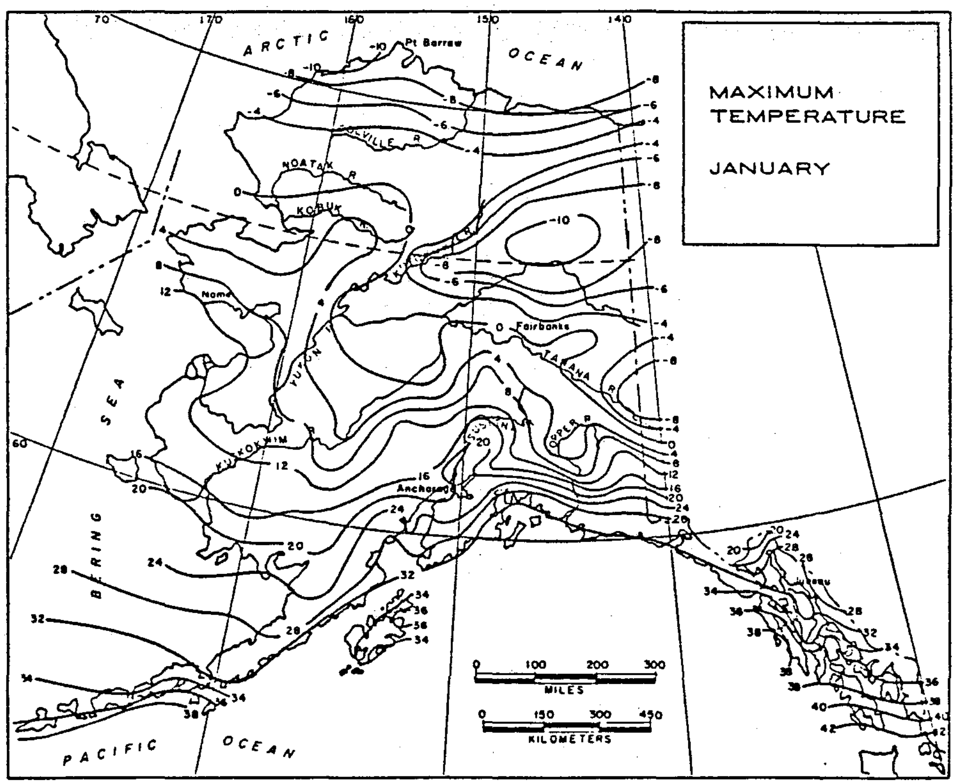


Figure 6 Mean Maximum Temperature Distribution, January

WIND SPEED	COOLING POWER OF WIND EXPRESSED AS "EQUIVALENT CHILL TEMPERATURE"																				
MILES PER HOUR	TEMPERATURE (°F)																				
CALM	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
	EQUIVALENT CHILL TEMPERATURE																				
5	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-65	-70
10	30	20	15	10	5	0	-10	-15	-20	-25	-35	-40	-45	-50	-60	-65	-70	-75	-80	-90	-95
15	25	15	10	0	-5	-10	-20	-25	-30	-40	-45	-50	-60	-65	-70	-80	-85	-90	-100	-105	-110
20	20	10	5	0	-10	-15	-25	-30	-35	-45	-50	-60	-65	-75	-80	-85	-95	-100	-110	-115	-120
25	15	10	0	-5	-15	-20	-30	-35	-45	-50	-60	-65	-75	-80	-90	-95	-105	-110	-120	-125	-135
30	10	5	0	-10	-20	-25	-30	-40	-50	-55	-65	-70	-80	-85	-95	-100	-110	-115	-125	-130	-140
35	10	5	-5	-10	-20	-30	-35	-40	-50	-60	-65	-75	-80	-90	-100	-105	-115	-120	-130	-135	-145
40	10	0	-5	-15	-20	-30	-35	-45	-55	-60	-70	-75	-85	-95	-100	-110	-115	-125	-130	-140	-150
WINDS ABOVE 40 HAVE LITTLE ADDITIONAL EFFECT.	LITTLE DANGER					INCREASING DANGER (Flesh may freeze within 1 min.)						GREAT DANGER (Flesh may freeze within 30 seconds)									
	DANGER OF FREEZING EXPOSED FLESH FOR PROPERLY CLOTHED PERSONS																				

Figure 7 Equivalent Wind Chill Temperatures

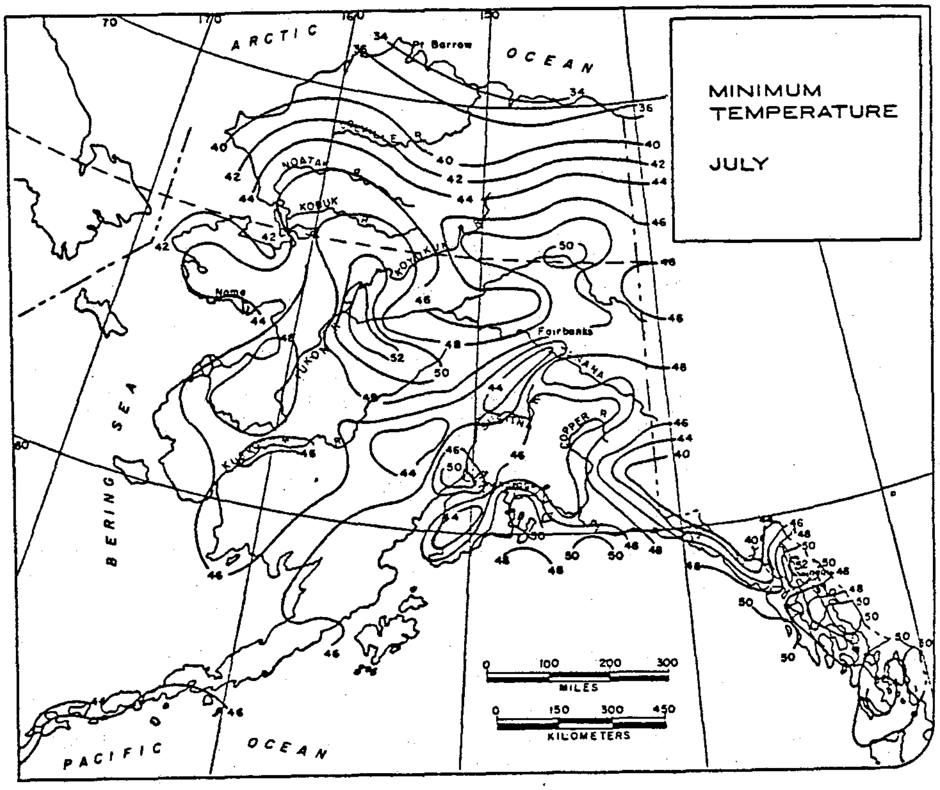


Figure 8 Mean Maximum Temperature Distribution, July

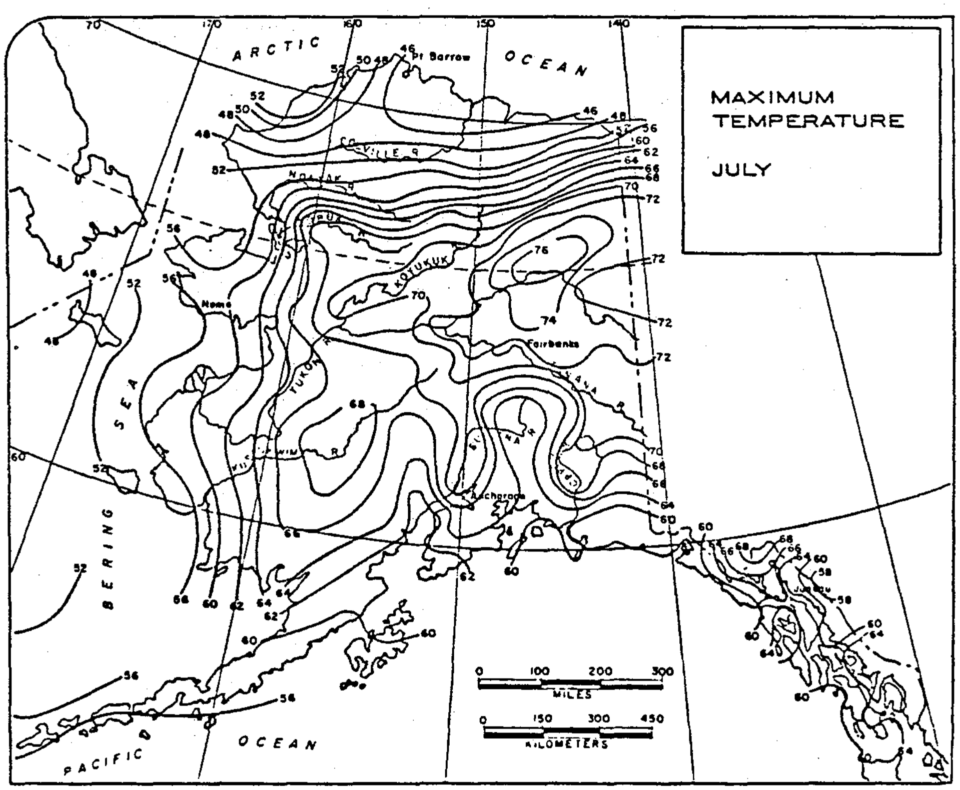
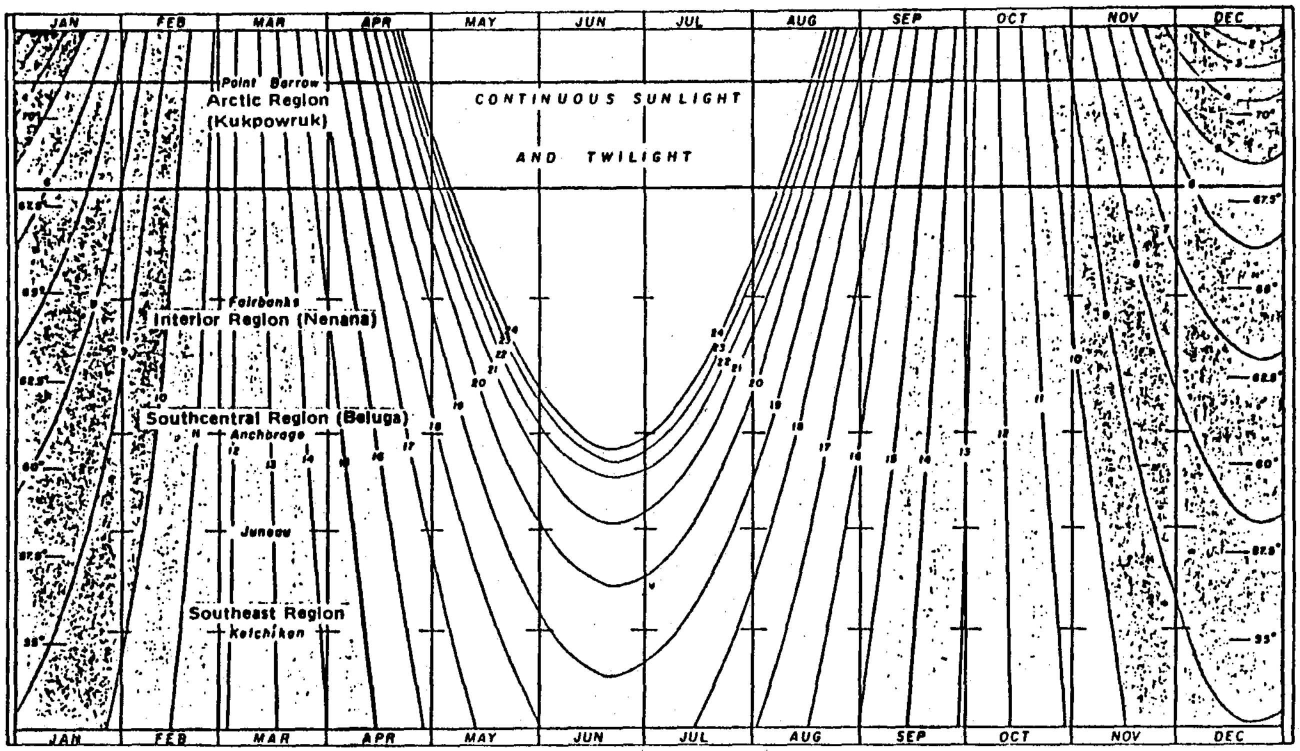


Figure 9 Mean Minimum Temperature Distribution, July



The curved lines are labeled in hours and represent the combined hours of sunlight and civil twilight for different latitudes and months of the year. Hours of darkness can be estimated by computing the difference between the value of the line and the total of 24 hours. The latitude locations of the villages in the Arctic are indicated by a solid horizontal line.

Source: Environmental Atlas of the Greater Anchorage Area Borough, Alaska. L. Selkregg et al. 1972.

Figure 10 Sunlight and Darkness

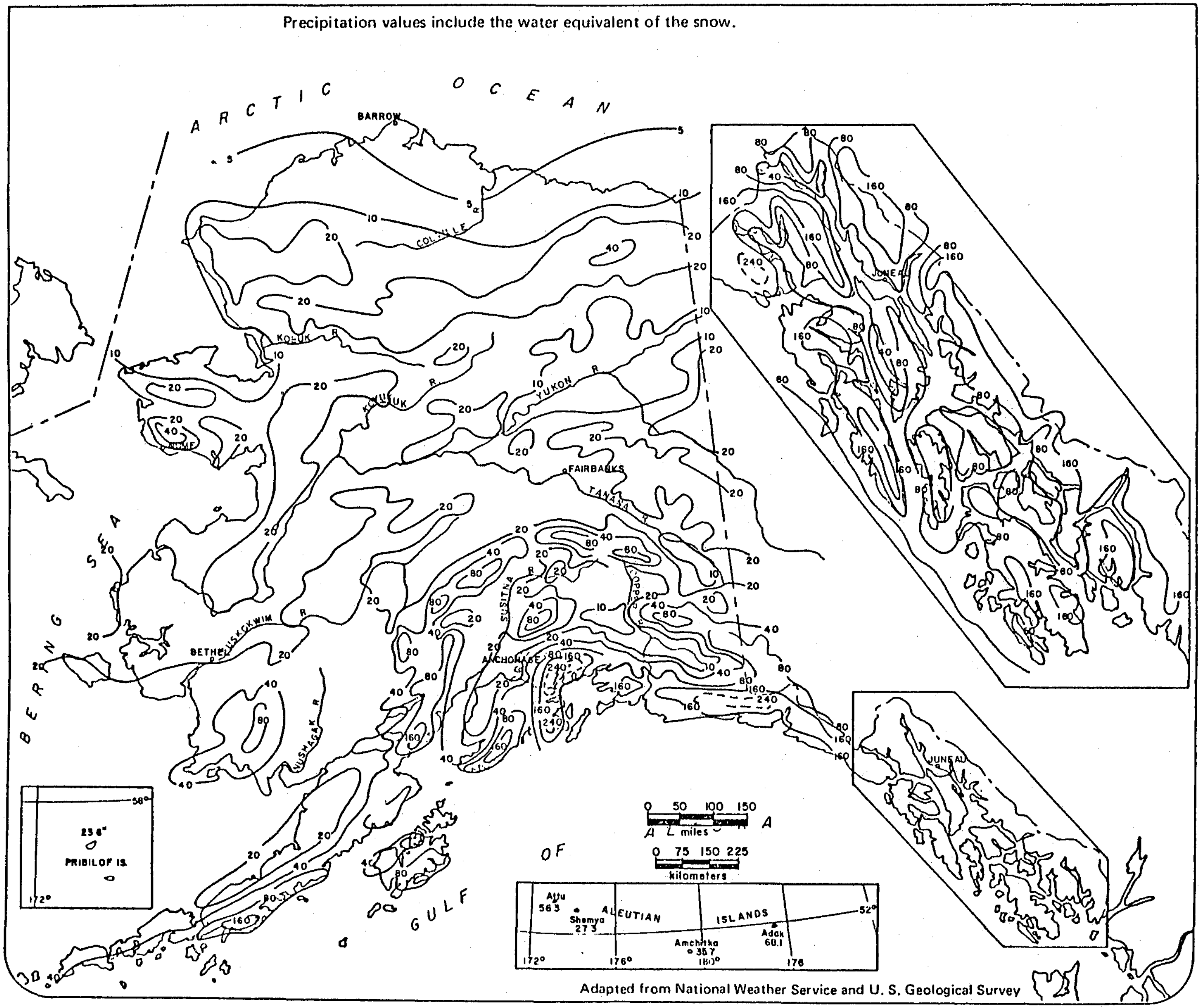


Figure 11 Mean Annual Precipitation Distribution in Inches

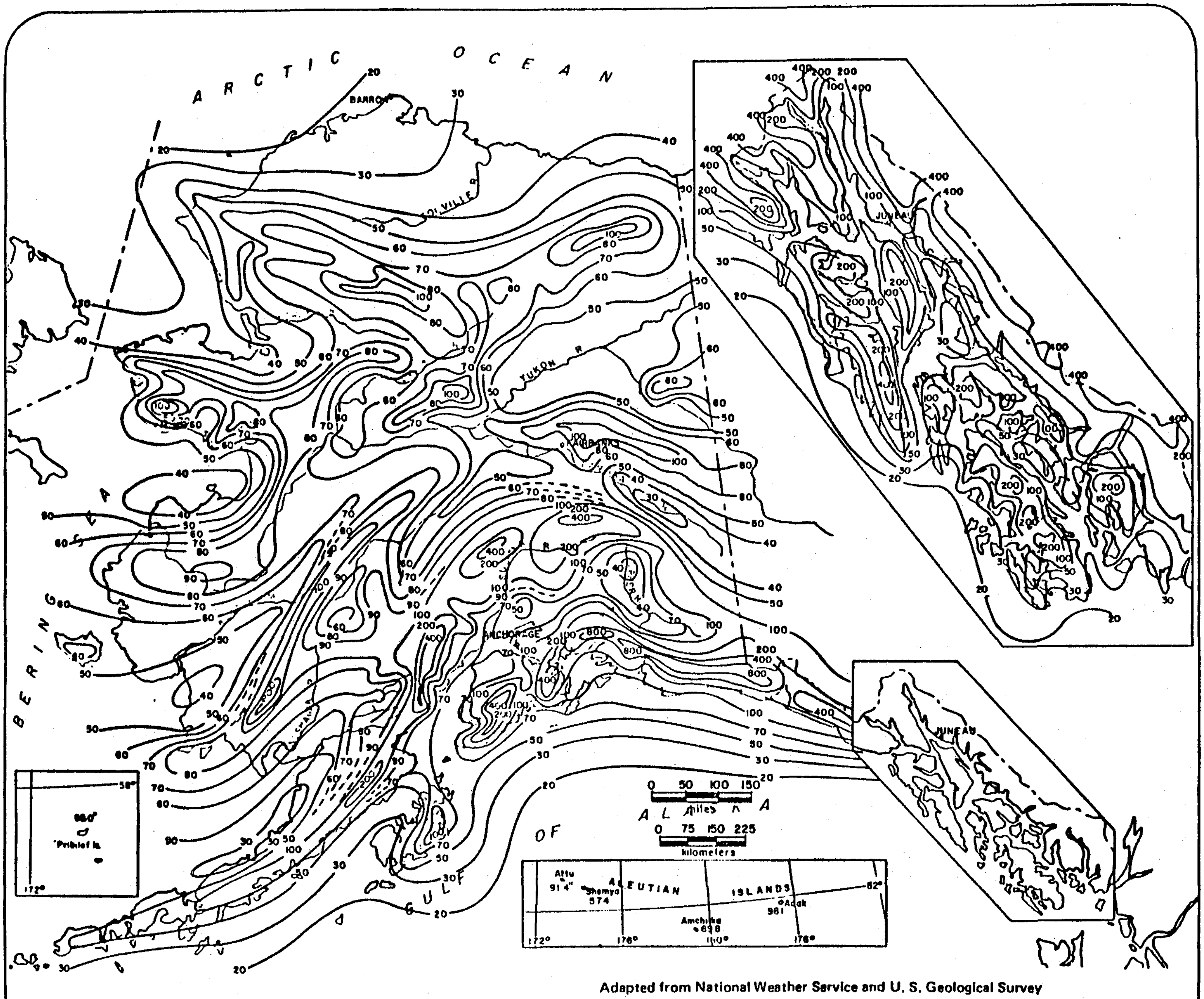


Figure 12 Snowfall Distribution in Inches

In spite of the generalities that can be made about Alaska's climate, the three coal regions under discussion in this report have markedly different climates. Microclimates are the result of many factors, including latitude, altitude, presence or absence of mountains, speed and direction of prevailing winds, and insolation. In turn, these conditions have a bearing on coal extraction and land reclamation. The Kukpowruk field, at 70 degrees north latitude, experiences vastly different conditions than the Nenana field at 64 degrees north latitude and the Beluga at 61 degrees north latitude. When all factors affecting climate are considered, it is easy to see why the climates of the three areas differ so greatly.

Arctic Region (Kukpowruk)

The Arctic is a region of prolonged periods of light and dark, low temperatures and high winds, and low precipitation. Monthly temperatures average below freezing about eight months of the year. Although snowfall in the Arctic is comparatively slight--only about 30 inches (76 cm)--once snow is on the ground it persists until spring. Although the terrain is continuously wet in summer and dotted with lakes, total annual precipitation is very low, generally averaging about 5 inches (13 cm).

Summer temperatures in the Arctic range between 30° and 50°F (-1° and 10°C), though temperatures as high as 80°F (27°C) sometimes occur. From May to July the daily periods of light average 20 hours. The growing season, however, spans a period of only about 10 weeks.

In the Arctic weather is critically important to man's activities. Wind and temperature often make outdoor activities difficult or impossible. The primary mode of transportation, flying, depends heavily on weather conditions. Surface transportation is restricted during warm months but increases when the tundra is frozen and snow-covered.

Despite the proximity of the offshore icepack to land for at least 10 months of the year, the Arctic Ocean and Chukchi Sea have a moderating effect on coastal temperatures. To the south and east of the Kukpowruk fields, the foothills of the Brooks Range affect both temperature and precipitation. Surface winds are relatively strong along the coast but weaken and become more variable further inland. In the mountains, wind speeds accelerate as they are channeled through north-south oriented passes.

Site-specific weather data for the Kukpowruk area are remarkably sparse; however, some data exist from nearby Point Lay. The lowest recorded temperature to date at Point Lay was -55°F (-48.3°C); the record high was 78°F (25.5°C). Precipitation is predictably low. Greatest monthly precipitation was 6.24 inches in August 1948, but most monthly records show less than one inch (2.5 cm).

The Interior Region (Nenana)

In contrast, the Nenana fields are exposed to greater climatic extremes. Climate can be generally classified as continental, but local variables and conditions can produce very different microclimates within short distances. The Interior has recorded both the all-time state high temperature of 100°F (38°C) at Fort Yukon and the lowest temperature of minus 80°F (-63°C) at Prospect Creek. Summer Fahrenheit temperatures generally range from the upper 30s to the upper 60s (about 5 to 20°C) with extreme temperatures over 90°F (32.2°C) not uncommon. Winter temperatures range from the minus 20s to plus 20s (about -29 to -7°C) with extreme low temperatures in the minus 60s not uncommon.

Despite these extremes, the general climate of interior Alaska is less rigorous than that of the Arctic. Summer temperatures are warm, and the extended light, averaging about 18 hours per day during May, June, and July, balances the extreme cold and dark of winter. Precipitation averages 10 to 15 inches (25 to 38 cm) annually, and most of that occurs in late summer and early fall as rain and rainshowers. Storms occur year-round but are most frequent in late summer and early fall when the primary storm track penetrates the interior of the state. The growing season spans about 10 to 15 weeks. Average annual snowfall is about 50 inches (127 cm). For about seven months of the year the average monthly temperature is below freezing, so snow cover persists for much of winter. As in the Arctic, there are significant periods of diminished light.

High winds, common in the Nenana area in winter make the equivalent wind chill temperatures so low that outside activity becomes almost impossible. The long summer days, on the other hand, allow outside activity 24 hours a day for several months of the year. Shipping on the navigable rivers and streams is only possible about five months of the year when the streams are free of ice.

The Southcentral Region (Beluga)

Although far removed from the open coast, the climate of the Beluga coal fields is notably milder than that of the other two areas because of a marked maritime influence. Highest recorded temperature is 83°F (28.3°C), and the all time recorded low is -50°F (-45°C). Normally, summer temperatures range between 45° to 65°F (7° to 18°C) and winter temperatures between 0° and 40°F (-17° to 5°C). Average annual temperature is 37.4°F (3°C). Precipitation is low to moderate, with an average annual total of 31 inches (78.7 cm). Winter snow accumulation ranges from 70 to 100 inches (178 to 254 cm). Long periods of daylight, which average about 16 hours a day between May and July, are typical of the region. The growing season extends over a 10- to 16-week period.

Characteristic Plants and Animals

Arctic Region (Kukpowruk)

Terrestrial vegetation in the Arctic Region is principally represented by tundra. Tundra is a word of Russo-Lapp origin that refers to the rolling, treeless plain of arctic regions throughout the world. The term now commonly includes all biotic communities above timberline in both arctic and alpine regions.

Superficially, much of the tundra of the Alaskan Arctic resembles grassland. Species composition of the vegetation varies with the site according to moisture, slope, and other factors.

Three broad types of tundra are recognized in the region: Alpine, moist, and wet.

Alpine Tundra

Alpine tundra communities occur in mountainous areas and along well-drained, rocky ridges. The coarse soil is rocky and dry. A fellfield community of low, mat-forming heather vegetation is characteristic of much of the area. Exposed outcrops and talus slopes sustain sparse islands of cushion plants and lichens among the rocks. The low growth form protects the vegetation from abrasion by blowing snow and sand in the exposed, windswept habitat. Important plants of this fellfield community include mountain avens, willows, and heather. Lichens, especially reindeer moss and other true mosses, are common. Grasses, sedges, and a few herbs are also evident. Cushion plants, such as moss campion and saxifrages, as well as many lichens are characteristic of the drier talus communities.

Mammals

Many mammals, including wolves, grizzly bears, red foxes, ground squirrels, and hoary marmots, den in the dry soils of the Alpine tundra. Dall sheep also occur in Alpine tundra near steep terrain where their climbing ability gives them an advantage over potential predators. Like the musk-oxen, Dall sheep are intolerant of deep snow, and in winter they often head for the higher ridges that are blown clear.

Birds

The alpine tundra and dry areas are used extensively by a wide variety of birds for nesting and foraging. Typical shorebirds are the whimbrel, bar-tailed godwit, golden plover, black-bellied plover, ruddy turnstone, and the semipalmated and Baird's sandpiper. Some, such as the golden plover, nest nowhere else in the Arctic.

Predatory birds include snowy owls, ravens, golden eagles, rough-legged hawks, gyrfalcons, and an endangered subspecies of peregrine falcon, the Arctic peregrine. This peregrine was once relatively common in the Arctic, but is now scarce. All species of raptors native to the region habitually nest on rocky outcrops or high bluffs. The short-eared owl also occurs in Alpine areas where lemmings are abundant. Passerines, especially snow buntings, yellow wagtails, redpolls, and savannah sparrows, are common.

Invertebrates

There are many kinds of invertebrates, some of which are never free living but instead use other animals for their habitat. Dall sheep of the Alpine community, for instance, are commonly infested with roundworms. Carnivores inturn are similarly infected. The rate of roundworm infestation in wolves may run as high as 84 percent.

Moist Tundra

Moist tundra is the dominant plant community of the foothills region. It is dissected locally by river drainages. Cottongrass tussocks 6 to 10 inches (15 to 25 cm) high, separated by narrow channels, cover large areas of rolling terrain. A tussock forms as a cottongrass clump grows and dies back each year, accumulating dead leaves which decompose slowly in the cold temperatures. Tussock meadows form on moderately drained, residual silt or peat accumulations modified by frost action. Mosses and lichens grow in the moist channels between the tussocks. Frost action creates small frost boils where small grasses and herbs occur. Other plants growing with the cottongrass include small shrubs such as dwarf birch, willows, Labrador tea, and a few herbs like bistort and cloudberry.

Mammals

The most obvious mammal of the moist tundra is the caribou. One large herd, the Arctic, travels over this community and feeds on lichens and sedges. In March the Arctic Herd leaves its wintering grounds in the Kobuk and Koyukuk drainages and begins its northward movement through the passes of the Brooks Range. If the migration is not impeded, the animals calve from late May into late June in the moist tundra of the upper Utokok and Ketik River drainages. After calving, the animals wander widely throughout the western Arctic until fall, when they begin migrating southward.

The abundance of caribou draws wolves to the moist tundra in search of food. Although they also prey on other available animals ranging from moose to voles, caribou are their principal quarry.

In moist tundra the ranges of the Arctic fox and the red fox overlap. Although both occur in the region the former species is most numerous, especially during periods of high microtine populations. Lemmings and voles, both cyclical in abundance, feed on the grasses of the moist tundra and use them for insulating material in their nests.

Musk-oxen also occur in low numbers on moist tundra near the coast. After the native animals were extirpated from the Arctic, musk-oxen from Greenland were reintroduced on Nunivak Island in 1935 and 1936. The first reintroduction to the Arctic took place in 1969 when some were released on Barter Island. Since then, several other transplants were made from Nunivak Island to the eastern Arctic and near Cape Thompson in the western Arctic where appropriate habitat occurs. Musk-oxen cannot feed in deep snow, so they require areas which are swept free of snow by the wind.

Birds

Shorebirds are common throughout the Arctic. Typical breeding species include dunlins and pectoral and semipalmated sanpipers. Arctic terns and Sabine's and glaucous gulls nest on grassy islands in this community. The species composition of jaegers throughout the Arctic depends largely on the lemming cycle. Where lemmings are abundant, pomarine jaegers dominate, where they are not abundant long-tailed and parasitic jaegers dominate.

Many waterbirds nest in the moist tundra, especially white-fronted geese, pintails, oldsquaws, and Steller's, king, and spectacled eiders. Nearly all waterfowl migrate out of the Arctic in winter, some travelling as far as the eastern coast of the United States. Passerines are most commonly represented by the Lapland longspur and snow buntings. Snow buntings further south are found at high elevations, but on the arctic coastal plain they commonly nest in and around human habitation, garbage dumps, and under discarded barrels, lumberpiles, and driftwood.

Marsh hawks are often seen in the moist tundra, but they are conspicuous and may appear more abundant than they really are. Snowy owls are the most common predatory bird.

Invertebrates

The family Diptera is especially well represented in moist and wet tundra environments. The hordes of mosquitoes and flies are essential for the support of the seasonally abundant birdlife. Peak mosquito populations occur in mid-June.

Wet Tundra

A mosaic of small lakes and wet tundra covers the arctic coastal plain. The peaty soil has a shallow, active layer and is saturated throughout the summer. The pattern of high and low center polygons occurs even under the lakes. Several species of sedges (especially *Carex aquatilis*) make up the majority of the vegetation of the community. Differences in the vegetative composition are related to the microrelief of the polygons. Many species of moss grow in the understory, but few lichens occur in the wet habitat. Secondary species include cottongrass, lousewort, and buttercup in the wetter sites and heather and purple mountain saxifrage in the raised drier habitats such as the ridges between the polygons.

Mammals

Wet tundra is inhospitable to burrowing mammals, which are restricted to well-drained sites such as pingos and stream banks. A few shrews feed on the prolific insects. The most common mammals are the Greenland collared and brown lemmings. These are the staple food for Arctic foxes and avian predators. Predatory birds can move from an area during periods of low lemming population, but the less mobile Arctic foxes may be forced to feed on bird eggs from the numerous shorebird and waterfowl nests during such periods. Caribou feed on grasses, sedges, and lichens where they occur. Cottongrass buds, which usually appear during caribou calving season are apparently favored.

Birds

Wet tundra is a foraging area for many birds, particularly shorebirds, which are numerous in summer and migrate south in winter. The red phalarope is especially abundant. Some observers believe that as a vertebrate it outweighs any other species of animal in the Arctic. Other shorebirds found in wet tundra include the long-billed dowitcher, dunlin, common snipe, and pectoral, Baird's, and semipalmated sandpiper. The semipalmated sandpiper is exclusively restricted to feeding on the muddy edges of ponds and lakes. Glaucous gulls, and all species of jaeger prey on small birds and mammals of the wet tundra. Waterbirds that nest and feed in wet tundra include yellow-billed, Arctic, and red-throated loons; whistling swans; pintails; oldsquaws; and Steller's, king, and spectacled eiders. Canada geese commonly nest on dry sites, such as well-drained streambank bluffs and pingos.

Invertebrates

Wet tundra is especially noted for its production of flies and mosquitoes, although other invertebrates and larval forms are equally important. The abundance of invertebrates in the mud along the edges of tundra ponds accounts for the tremendous numbers of shorebirds that nest in this habitat and characterize the arctic coastal plain in spring.

High Brush

The high brush plant community occurs along the floodplains of many large rivers of the Arctic Region, particularly in the mountains and foothills. Soils are usually well-drained gravel, sand, or silt, and the active layer is deeper than in the remainder of the Arctic. Spring floodwaters and floating ice may destroy some vegetation, so the community is constantly changing. Newly exposed gravel bars are invaded by a pioneer flora with such species as horsetail, alpine bluegrass, and dwarf fireweed. The high brush community, found in areas that have not been disturbed for several decades, includes willows, a few herbs, many mosses and lichens, and possibly alder and a few well-developed stands of cottonwood near springs in the eastern foothills of the Brooks Range.

Mammals

For most of the year, moose in the Arctic depend on woody vegetation. They are mostly confined to high brush areas, principally along the Colville and Canning River drainages. A few may be found at times along the Kukpowruk but it appears unlikely. Grizzly bears also concentrate in the watersheds, scavenging along the rivers for food ranging from grasses to fish. Wolves range throughout the Arctic. They often make their dens along the dry riverbanks close to the high brush. Lynx are not common in the Arctic but prey on the hares at times when they become abundant along stream valleys. Wolverines also hunt these hares and other rodents. The red fox usually preys on smaller rodents such as voles and ground squirrels. River or land otters are rare in the Arctic but do occur along some of the more permanent streams associated with high brush.

Birds

A number of birds are closely associated with the high brush community. Many are small and inhabit thick vegetation which provides cover and nesting sites. These include the fox, white-crowned, savannah, and tree sparrows; gray-cheeked thrushes and robins; red polls; yellow wagtails; and Arctic warblers. Several predatory species are found in the high brush, especially the northern shrike and the short-eared owl. The willow ptarmigan is also found here.

Invertebrates

Except for the numerous members of the order Diptera, these invertebrates are seldom noticed, but they are crucial to the continuation of the more visible forms of life. Much of the diversity of birdlife in the brief, arctic summers depends on the abundance of insects, spiders, and mites for food. Saw flies are one of the most numerous insects and feed on willows. Other invertebrates, such as nematodes, are vital to the aeration and fertilization of soil.

Tundra Lakes, Ponds, and Marshes

Tundra lakes, ponds, and marshes, common on the arctic coastal plain, comprise shallow bodies of water less than 20 feet (6 m) deep with mud and organic sediment bottoms. Ponds less than 6 feet (1.8 m) deep may freeze completely to the bottom during most winters.

The zooplankton in these waters are mostly copepods, rotifers, and cladocera. Productivity is low. Arctic ponds without fish may contain fairy and tadpole shrimp. Midge larvae dominate the benthic fauna in this habitat. Aquatic earthworms, stonefly larvae, aquatic beetles, and snails are also present.

Most of the lakes in this permafrost zone are considered unproductive for fish, although fish are present in most waters deeper than 10 or 15 feet (3 to 4.5 m). Whitefish and stickleback are most common and abundant.

These ponds are, however, important waterfowl habitat. As mentioned earlier, ducks and geese are common nesters on the tundra. Typically in late August waterfowl begin their autumn migration, moving with easterly, favorable winds.

Rivers, Streams, and Springs

All but the largest rivers and spring-fed pools of smaller streams may completely freeze to the bottom during winter. Breakup severely erodes streambeds and further heightens the stress on organisms inhabiting this environment.

Zooplankton in flowing waters of the Arctic have not been extensively studied. Apparently caddisfly, mayfly, stonefly, and midge larvae are the most common large invertebrates. Bottom fauna is particularly abundant in spring-fed streams.

Most fish must migrate seasonally to find suitable spawning sites and locations to support them over the winter. Whitefish, grayling, and char use freshwater streams as important summer rearing areas. These species migrate between the ocean and fresh water and between different areas within a freshwater drainage throughout the summer months.

Interior Region (Nenana)

Terrestrial vegetation of the Nenana region is preponderantly tundra in character. Trees are generally restricted to river valleys. Well-expressed brush associations are found throughout the region. Brief descriptions of major communities follow.

Alpine Tundra and Barren Ground

This type occurs on ridges and rubble slopes, usually where bedrock is close to the surface, on such porous soils as alluvial fans and on the driest parts of the river terraces. The soil is usually coarse, shallow, and contains little humus. Alpine tundra is most common in mountains at elevations between 2,000 and 4,000 feet (610 to 1,220 m).

Vegetation is usually sparse and seldom more than a few inches high. Plant associations differ from one place to another, but mountain avens and lichens usually dominate along with low-growing herbs, grasses, and sedges. Associated species are resin birch, dwarf Arctic birch, cassiope, crowberry, Alpine azalea, Labrador tea, mountain heath, moss campion, black oxytrope, and Arctic sandwort.

Lowest production from these plant communities occurs on outcrops and talus mainly in the higher parts of the foothills and in the mountains at elevations from about 2,000 to 4,500 feet (610 to 1,370 m). Above 4,500 feet (1,370 m) most of the mountains are bare except for rock lichens, but a few flowering plants grow at elevations approaching 6,000 feet (1,830 m). The vegetation at high altitudes consists of scattered plants similar to those found at low elevations but not usually combined into any particular plant association.

Mammals

Caribou and brown bear are the most conspicuous residents of this community. Relict populations of Dall sheep also occur in the region. Arctic ground squirrels, marmots, and pikas inhabit elevated, well-drained substrates. Snowshoe hares and voles are distributed throughout the association in typical habitat.

Birds

Numerous species of birds inhabit this community type. Perhaps the most conspicuous member of this fauna is the gyrfalcon. Rock ptarmigan are found on the steeper, more exposed slopes, and water birds such as plovers, turnstones, and tattlers inhabit lower-lying areas. Numerous passerines, ranging from the raven to the Lapland longspur, occur in suitable habitats throughout the association.

Moist Tundra

Moist tundra may vary from stands of nearly continuous and uniformly developed cotton grass tussocks, sometimes interspersed with sparse growth of other sedges and dwarf shrubs, to stands where tussocks are scarce or absent and dwarf shrubs dominate. Associated species are polar grass, bluejoint, tufted hairgrass, sedges, mosses, Alpine azelea, wood rush, mountain avens, bistort, horsetail, low-growing willows, dwarf birch, Labrador tea, American green alder, Lapland rosebay, blueberry, and lingonberry. This type is usually highly productive and forms a complete ground cover. It occurs mainly in the foothills of the Alaska and Brooks Ranges and along portions of the lower Yukon River.

Mammals

Fairly extensive tracts of this community type near Nenana support a fairly diverse fauna. Typical resident mammals include caribou, brown bear, lemmings, shrews, and weasels.

Birds

Birds are farily numerous in this association. Most common are the passerines, such as sparrows and buntings. Some water birds are locally numerous. Ptarmigan are also distributed throughout. Abundance of any single species may be locally high in response to pockets of "better" habitat.

Wet Tundra

As the name implies, wet tundra occurs wherever soils are supersaturated. The type occurs near Nenana but not extensively. Sedges and cotton grass dominate the vegetation, usually forming a mat rather than tussocks. A few woody and herbaceous plants occur on drier sites above the water table. Associated plants are lichens, mosses, low-growing willows, dwarf birch, Labrador tea, cinquefoil, lingonberry, and occasionally bog cranberry.

Mammals

The vertebrate fauna of this community is fairly diverse despite the limited distribution of the type, but overall numbers are low. Typical mammals include shrews, lemmings, voles, caribou, and foxes.

Birds

Passerines, such as buntings and sparrows, predominate in this type. Ptarmigan and water birds are discontinuously distributed in variable abundance throughout the type.

Low Brush, Muskeg Bog

Interior bogs occur where conditions are too wet for tree growth. Bog vegetation consists of varying amounts of sedges, sphagnum and other mosses, bog rosemary, rose, resin birch, dwarf Arctic birch, Labrador tea, willow, bog cranberry, soapberry, and blueberry. Some low-lying saturated soils support cotton grass tussocks surrounded by zones of tall willow and alder brush. Bog surfaces in the region often have uneven, stringlike ridges called string bogs, which are usually too wet to support shrubs. Shrubs dominate on exposed and drier areas, and mosses and herbaceous species dominate on waterlogged areas. Widely spaced dwarf spruce and tamarack may occur on higher ground.

In the Interior, muskegs and bogs occur extensively where conditions are too wet for tree growth, primarily in unglaciated areas, old river terraces, outwash plains, filling ponds, sloughs, and occasionally on gentle north-facing slopes.

Mammals

Moose, caribou, and brown bear are the most conspicuous large mammals of this community in interior Alaska. The varied nature of the vegetation provides numerous habitat types and, consequently, smaller mammals abound. Typical small mammals include shrews, snowshoe hares, voles, lynx, coyote, and weasels.

Birds

Numerous passerines, e. g., rusty blackbirds and sparrows, abound in this association. Occasional observations are also made of northern shrikes and various raptorial species.

High Brush

High brush occurs as two distinct subtypes in the region--floodplain thickets and birch-alder-willow thickets. Floodplain thickets develop rapidly on alluvial deposits in floodplains that are newly exposed after flooding. The dominant shrubs are willows and alders. Associated shrubs are dogwood, prickly rose, raspberry, soapberry, and high bush cranberry. This subtype is found along all meandering streams. Islands and bars of the major rivers are usually bordered by pure willow stands, often in zones according to age. Birch-alder-willow thickets are found near timberline in interior Alaska and are the transition between upland spruce-hardwood and alpine tundra. They consist of resin birch, American green alder, thinleaf alder, and several willow species. Thickets may be extremely dense or open and interspersed with reindeer lichens, low heath-type shrubs, or patches of alpine tundra. Other associated species are alder, bearberry, crowberry, Labrador tea, spirea, blueberry, and lingonberry.

Mammals

High brush communities of interior Alaska provide important winter habitat for moose and brown bear. Small mammals include shrews, red fox, voles, hare, lynx, and weasels.

Birds

Numerous avian species inhabit high brush communities. Natural edges between adjoining brush stands provide numerous habitat types that combine to support this diverse assemblage. Typical inhabitants include willow ptarmigan, thrushes, redpolls, and sparrows. Conspicuous residents include several hawks, which hunt in the area, and the northern shrike.

Upland Spruce-Hardwood Forest

In the Nenena region this type consists of white spruce, birch, aspen, balsam poplar and some tamarack. Black spruce usually replaces white spruce on north-facing slopes and poorly drained flat areas. Trees in this type have shallow roots and are commonly fire scarred. It is a comparatively open forest.

White spruce 40 to 80 feet (12 to 24 m) high and up to 15 inches (38 cm) in diameter occur in mixed stands on south-facing slopes and well-drained soils and may form pure stands near streams.

White birch and aspen stands, usually an early stage of succession following fire, tend to be even-aged and more uniform in size than spruce stands. The largest birches are about 8 inches (20 cm) in diameter and 50 feet (15 m) tall, and aspen trees are found up to 10 inches (25 cm) in diameter and 50 feet (15 m) tall. Average diameters are four inches (10 cm) or less. Aspen and birch predominate on well- to excessively drained southern slopes.

Undergrowth in this type normally consists of mosses and grasses on drier sites and brush on moist slopes. Typical undergrowth species are willow, alder, ferns, rose high bush cranberry, lingonberry, raspberry, currant, Labrador tea, and horsetail.

Tree line decreases in elevation from east to west and varies from 2,000 to 3,500 feet (610 to 1,070 m) along the Alaska-Yukon border, dropping to 2,000 feet (610 m) on southern slopes of the central Brooks

Range and northern slopes of the Alaska Range and to 1,000 feet (305 m) or less along the lower Yukon. Close to treeline, White spruce become scattered among high brush, including dwarf and resin birch and willows.

Mammals

The relatively open nature of this forest acts to maximize the edge, or ecotone, effect, producing the most diverse array of habitat types of any vegetative community in the region. Overall numbers of any single species are low but diversity of forms is high. Typical mammalian residents of this forest include shrews, little brown bats, red and flying squirrels, voles, porcupines, black and brown bears, and moose.

Birds

Avian forms attain their richest diversity in this region in this forest type. Cavity-nesting ducks frequent stream courses, and passerines, such as gray jays, thrushes, and juncos, are distributed throughout suitable habitats. The most common raptor of the association is the goshawk, which is a year-round resident of the community.

Southcentral Region (Beluga)

The Cook Inlet estuarine embayment complex encompasses all the waters north of the Barren Islands. The distribution of plants and animals in the area reflects the complex interactions of tidal mixing of fresh and salt waters, large tidal amplitudes that result in extensive tidal flats, large loads of suspended glacial sediments, the scouring actions of strong tidal currents, and ice during the winter months.

The waters of Cook Inlet can be subdivided into two major regions. Each lies roughly along either side of a line drawn between Cape Douglas and the city of Kenai. The eastern side includes Kachemak Bay and is under the influence of saltier, relatively clear, inflowing coastal waters. The Beluga field lies on the western side which is dominated by the sediment-laden, brackish outflow.

Baseline information on intertidal organisms of Cook Inlet is scant. Perhaps the most reliable indicator of the extent of intertidal biota is the abundance of razor clams collected from the lower inlet for food by the local people.

While little information is available on benthic communities, the presence and abundance of king, tanner, and Dungeness crabs in the Kachemak Bay-southern Cook Inlet area, suggests a diverse and healthy environment. Food for these crabs includes marine worms, molluscs, brittle stars, small crustaceans, some fish, and other assorted invertebrates.

Pandalid shrimp also abundant feed at the bottom on marine worms, small crustaceans, and fresh organic detritus, all abundant in lower Cook Inlet. Herring spawn in abundance along the shores of Kamishak and Kachemak Bays, and eulachon smelts run in upper inlet streams.

All five species of Pacific salmon inhabit and migrate into streams and lakes surrounding the inlet. Additionally, deep water exploratory trawls reveal the presence of 25 species of fin fishes. Butter sole, yellowfin sole, turbot, and Pacific pollock are the most abundant.

The lower segments of streams and their assocaated pond complexes are prime habitat for the spawning and rearing of coho, pink, and chum salmon. During spawning migrations substantial populations of black and brown bears prey heavily on these fish, as do mink, otter, and eagles. Foxes, coyotes, ravens, and a host of other scavengers profit from the leavings. After spawning, the salmon die, their carcasses adding nutrients to the water and soil of adjacent areas. Partly because of this enrichment, ponds, sloughs, and marshes are lush and provide important wildlife habitat. Moose, bear, beaver, and waterfowl (including trumpeter swans) are common.

Low Brush Bog and Muskeg

Dwarf shrubs usually dominate over a mat of sedges, mosses, and lichens. Ponds or standing water are often present in the peaty substrate. This type is found in wet, flat basins where conditions are frequently too moist for tree growth. Two different forms of this system, coastal muskegs and interior bogs, exist in southcentral Alaska. In Cook Inlet coastal muskegs, mountain hemlock is scattered over the drier portions of muskeg, with shrubs dominant on exposed and dry sites. Such associations are poorly represented in the drainages bordering upper Cook Inlet, however. In the interior bogs of the boreal forest, trees are usually not found because conditions are too wet. Some black spruce does occur, however. Large localized patches of cotton grass tussocks may exist in such places within the region. These bogs occur primarily in the Susitna River valley.

Most of the larger mammals use this type only intermittently, but it is an important type for waterfowl.

High Brush

The dominant plant species in this community vary with locale. Willows predominate along streams giving way to alder above timberline. Stands are usually homogenous and dense, some integradation occurs, however. The type occurs between beach and forest, between treeline and Alpine tundra, in avalanche paths through forests, on floodplains, and in old forest burn areas. Trees, such as quaking aspen, Alaska paper birch, and white spruce, may be present but are widely scattered. This plant community occupies a great variety of soils--from poorly drained with permafrost in low river valleys to well-drained shallow upland soils on moraines. It is also found on outwash and mountain slope soils with intermittent permafrost. A coastal alder thicket subsystem extends along the southern portion of the Alaska Peninsula and eastern Cook Inlet. Species composition varies considerably with location. Floodplain thickets comprise another subsystem that develops quickly on periodically flooded river and stream alluvium. Such stands may reach 20 feet (6 m) in height. In interior portions of the region, particularly along parts of the Susitna River vally, a birch-alder-willow thicket type is found near timberline. Areas where fires are common frequently support this type. Thickets may be as high as 5 feet (1.5 m) to 15 feet (5 m).

Many animals in varying abundance use this type for at least part of the year. No one species is typical, or characteristic of the community, however. Resident mammals include brown bears, moose, voles, hares, lynx, weasels, and shrews.

Bottomland Spruce-Poplar Forest

This tall, relatively dense forest system primarily contains white spruce, locally mixed with large cottonwood and balsam poplar, found on level to nearly level floodplains, low river terraces, and more deeply thawed south-facing slopes. This forest type is generally not found at elevations higher than 1,000 ft (305 m). Both black cottonwood and balsam poplar quickly invade floodplains and grow rapidly. Alaska paper birch and quaking aspen are often conspicuous. These species are in turn replaced by white spruce in the successional process. Where this type occurs, a deep thawed layer overlies the permafrost which controls the depth of roots. Extensive stands of this timber type are found in the region. This relatively open forest type provides favored habitat for black bears. Seasonal occupancy by moose may be locally high.

Coastal Western Hemlock-Sitka Spruce Forest

This coastal forest system, primarily Sitka spruce and western hemlock, is an extension of the rainbelt forests so important along the Pacific coast.

In western Cook Inlet, Sitka spruce uncharacteristically dominates within this forest. Mountain hemlock begins to replace western hemlock. The deciduous hardwoods present are found primarily on stream floodplains.

This forest requires cool temperatures, high humidity, and abundant rainfall. Soil types and conditions vary greatly throughout the forest. This vegetation type generally occurs in areas where permafrost is absent. This forest type is located in narrow belts or broad discontinuous expanses, bounded by the Aleutian Range on the west, Cook Inlet on the east, Iniskin Bay on the south, and the Drift River on the north. Some small stands of Sitka spruce have been reported adjacent to the coal fields near Tyonek. The most northerly identification of the species has been made on the southern slopes of Mt. Susitna. Many spruce throughout the area are not identifiable as either white or Sitka, probably due to hybridization.

Timber productivity on the west shore of Cook Inlet is high. A U.S. Forest Service inventory of the area in 1971 indicated almost as much volume produced by the relatively small area (45,000 acres, or 18,200 hectares) as in Alaska's entire Kuskokwim River floodplain. Most of the commercial forest land produces more than 30 cubic feet per acre per year of new growth. Total net volumes per acre range from a low of approximately 600 BF to 30.2 MBF. The overall average is 10.6 MBF, or 1,140 cubic feet (31.9 cubic meters).

No data are available on the timber quality in the area.

Mammals

Brown bears and moose are the most abundant large mammals of this association in Cook Inlet. Both brown and black bears congregate on salmon streams during spawning runs. Typical small mammals include red fox, hares, lynx, weasels, voles, and both red and flying squirrels. Mink, fox, and weasesls join bears in scavenging the remains of salmon.

Birds

Numerous types of birds are found in this association. Several owls and raptors, particularly bald eagles are conspicuous by their presence. Ravens, magpies, gulls, terns, and mallard ducks frequehtly join bald eagles scavenging spawned out salmon. Passerines are numerous and diverse. The dense overstory procludes ease of observation but subjectively sparrows and thrushes dominate.

Endangered Species

Animals

The federal list of endangered species includes two races of peregrine falcon and a curlew from Alaska. *Falco peregrinus tundrius*, the arctic peregrine, breeds exclusively north of the Brooks Range in Alaska. Known nest sites within proximity of the Kukpowruk River occur to the east, near the headwaters of the Utukok River. To the west, identified potential sites occur along the Cape Lisburne sea cliffs. No sites, potential or actual, have yet been described from within the Kukpowruk River valley. Subjectively, there appears to be some potential for doing so.

One other endangered bird, the Eskimo curlew (*Numenius borealis*) have reportedly been sited in northwestern Alaska. Recent sightings are so rare, however, that some consider the form extinct. Actual breeding records are not available from Alaska, but past distribution during the breeding season apparently extended from Norton Sound in the west and generally eastward along the coast to the Mackenzie River delta in Canada. It appears unlikely that the form would be encountered in the Kukpowruk field; however, some potential, although small, exists for doing so.

A second endangered race of falcon, *F. p. anatum*, commonly referred to as the peregrine, at one time bred throughout the major river drainages of interior Alaska. Remnants of the race still return annually to breeding sites along the Tanana River well to the north of the Healy formation near Nenana. Continued human activity in the area, as a subjective judgment, would seem to pose no threat to this race through either habitat modification or usurpation.

Peregrine falcons of an unknown race or races, are reported seasonal migrants in the Cook Inlet area. Subjectively, habitat usurpation poses little direct threat to a life form which simply "passes through" an area. There are no reports of the occurrence of the Eskimo curlew in Cook Inlet.

Plants

At this time there is no official list of federally re~~or~~coganized threatened or endangered plants in Alaska although the Fish and Wildlife Service is developing such a list. The U.S. Forest Service and the Bureau of Land Management hired Dr. David Murray, a University of Alaska botanist, to identify and gather information, make up a list of proposed threatened and endangered plants. So far, Murray lists eight endangered, 13 threatened, and 15 rare taxa with undetermined status (Murray 1980).

One threatened species, the pale poppy (Papaver alboroseum), has been identified in the Alaska Range (headwaters of the Kuskokwim?) and the Cook Inlet lowlands. Although these plants have not been identified from the specific locations of the coal deposits, rigorous searching may turn up several species.

ENVIRONMENTAL EFFECTS OF SURFACE MINING

Introduction

Historically, the process of finding and extracting near-surface coal resources in the United States has adversely affected both fish and wildlife populations and millions of acres of their habitats. Effects are both direct and indirect and involve physical, chemical, and biological changes. Some of the changes are confined to immediate mine sites, while others affect larger geographic areas through both on-site and downstream erosion and atmospheric and hydrologic processes. These influences and results are also often of long duration.

Raw land remaining after surface mining is not capable of supporting most forms of life. It must go through a weathering period, which may take a few years or decades before it again becomes suitable vegetative or other habitat for fish and wildlife. In order to compensate for these effects, man, in recent times, has utilized many mitigation and reclamation techniques to make the land once again naturally productive.

Changes in the ecological succession of plant and animal populations routinely occur with surface mining. These need to be restored, and in many places in the country this can and is being done today. Whether or not Alaska's environment is adaptable to productive mitigation and reclamation approaches in a manner which would permit sustained economic production of coal resources through surface mining is the theme of the remainder of this paper.

Experience with modern, highly mechanized, high-volume surface coal production is nonexistent in Alaska. The most relevant history is that of the Usibelli Mine near Healy, Alaska, and here operations must be viewed as being on a very modest scale. Moreover, the Usibelli pit production does not have to contend with several environmental factors common to the Beluga and Kukpowruk fields. Thus, any analysis of surface mining effects on the environment must rely on other experience.

The following is a review of expected major effects that would be associated with surface mining in Alaska. Discussed are direct effects on water quality, water quantity, surface topography, and air quality and the secondary effects pertinent to fish, wildlife, and other living organisms.

Water Quality

Water quality can be expected to be affected in any of the three fields--Kukpowruk, Nenana, or Beluga--as the natural terrain is disturbed, drainage patterns are altered, and excavation activities produce silt and sediment, leachates, and dust. Expected quality changes include turbidity, dissolved solvent levels, pH, dissolved oxygen, and temperature.

As is obvious from earlier environmental descriptions, the main differences for surface mine development in the fields of concern here, in comparison with operating mines elsewhere in the United States, are the presence of frozen ground/permafrost, the extremely contrasting summer and winter hydrologic cycles, and presence and duration of ice and aufeis. In addition, there are very little hydrologic data available and theoretical approaches to runoff prediction are unreliable. Thus, the engineering considerations required for the removal and stockpiling of overburden, the maintenance of slope stability, and the construction of impoundment areas, etc., are difficult. Materials, particularly those of fine grain, would flow, slump, and slide. Impoundments in permafrost areas would thaw, and summer-excavated pits in the Kukpowruk would fill with water. This latter situation could also occur at Beluga or Nenana, depending upon the presence or absence of permafrost.

In the Kukpowruk area, also, gravel is extremely scarce. Thus, the construction of good road beds would be difficult. All of these natural situations and engineering considerations make it highly probable that water quality cannot help but be affected by terrain disturbance.

The effect on water quality due to sedimentation, pH, and oxygen level change, etc. in turn affects aquatic system plant and animal communities and populations. Fish spawning areas can become unusable due to substrate change, invertebrate life cycles can be affected, and overwintering pools for adult fish can disappear. In effect, entire aquatic life systems are subject to detrimental change.

Sediment, particularly when introduced into surface waters by runoff, can affect aquatic organisms in several ways: it can clog fish gills, cover eggs of fish and insects, eliminate food sources, smother aquatic vegetation, and alter existing habitat. Turbidity resulting from sedimentation decreases light penetration, thereby decreasing photosynthetic activity of aquatic plants and phytoplankton. This effect then often results in a reduction of dissolved oxygen concentration and temperature change.

In other regions of the country, coal seams and overburden often contain pyrites, compounds of iron and sulphur. Pyrite in the presence of air and water reacts to produce sulphuric acid and iron sulfate. The iron sulfate, when dissolved in water, hydrolizes to form more sulphuric acid. In addition, acid water can dissolve and hold more minerals in solution than can neutral water. Aluminum, calcium, and arsenic are often found in high concentrations in acid mine water. During hydrolysis an additional contaminator can be formed--iron hydroxide, or "yellow boy," which coats stream bottoms. This situation is not expected to be severe in Alaska. Most Alaska coal is remarkably low in sulphur-containing compounds. In addition, available sulphur is usually bonded to organic matter, further minimizing pollution effects.

Water quality effects are regulated by a number of state and federal statutes and regulations falling within the purview of a number of agencies. Obviously, one of the major hindrances to Alaskan coal development would be to convince such authorities of the efficacy of a number of engineering practices required to prevent the reduction of water quality in situations of natural extremity and limited knowledge.

Water Availability

Water availability as well as water quality would be impacted by any coal mining program. In Alaska, water quantity and availability are affected by a number of natural factors, including seasonal temperature, permafrost, ice, and high runoff in spring "breakup" and often again during August storms. Furthermore, groundwater resources are often unavailable or, if available, frequently highly mineralized, adding to the discharge quality problem when used in washing or other processing activities. In effect, then, surface waters are the main usable sources and these can be highly variable in availability throughout the year.

Besides availability of water for coal operations being a problem, the subsequent effect on water availability for downstream use is also of concern. An adequate volume availability for both real and potential users, including fish and wildlife; the quality of discharged water; and on a seasonal basis consonance with natural factors are also major concerns. Large volumes of water would be required in all of the regions for mining and reclamation activities, coal conversion and use plants, conjunctive developments, and population increases. Water withdrawals could affect aquatic systems by reducing habitats and by changing physical regimes such as the temperature and dissolved oxygen levels of the remaining water. In areas such as the Kukpowruk, where seasonal flows are either very high or very low, the maintenance of minimum stream flow for aquatic life could be an important consideration to the permitting of water appropriation.

In Alaska the legal doctrine for water use has particular application to coal mining operations, and a word here on how water law affects coal development is in order. Briefly, the doctrine of prior appropriation was in effect at the time of Alaska's admission to the Union. This meant that mines along streams held a limited riparian right and "absolute ownership" of ground water. When the Alaska Constitution was adopted, riparian and "absolute ownership" rules were eliminated and a permit system was added to the doctrine of prior appropriation used in many other states. In addition, reservations for common use by the people and for fish and wildlife were included.

Two salient parts of the Alaska Constitution contained the following sections in Article VII:

> Section 3. Common Use. Wherever occurring in their natural state, fish, wildlife, and waters are reserved to the people for common use.
>
> Section 13. Water Rights. All surface and subsurface waters reserved to the people for common use, except mineral and medicinal waters, are subject to appropriation. Priority of appropriation shall give prior right. Except for public water supply, an appropriation of water shall be limited to stated purposes and subject to preferences among beneficial uses, concurrent or otherwise, as prescribed by law, and to the general reservation of fish and wildlife.

The net effects of these constitutional provisions, along with the Alaska Water Use Act of 1966 and regulations adopted pursuant thereto as regards coal mining operations are as follows:

1. A permit must have been or be secured for water appropriation (i.e., diversion, impounding, or withdrawal of a quantity of water from a water source for a beneficial use).

2. Only after a permit is issued may a party begin whatever construction is needed to appropriate water.

3. Before any permit is granted a determination is made as to the effect of the requested appropriation on fish, wildlife, recreation, water quality, and navigation. A permit may be denied if effects are detrimental to these values.

4. In the case of fish and wildlife values the maintenance of minimum stream flows is an important consideration in permit granting, and the science/technology for making this judgment is a subject of great current interest and concern in Alaska.

Land Surface

The physical effects of surface mining are most obvious on land. A few of the more evident examples are barren areas caused by road construction, claim location and development, active mining, overburden removal and stockpiling, tailing ponds, waste disposal areas, open pits and slides, etc.

Natural terrain is altered during exploration, survey and mine location, mine operation, and processing. Access roads would be required in the development of deposits associated with the Kukpowruk, Beluga, and Nenana fields. Ports and terminal facilities would be required at Kukpowruk and Beluga. Railroad spurs would probably be utilized at Nenana. In transportation construction gravel would be required, necessitating additional landform change at gravel borrow areas.

These are obvious statements. Less obvious are a number of landform changes which would occur secondarily as a result of the alteration of permafrost terrains. Several examples come to mind: stockpiled, fine-grained, ice-rich overburden materials are liable to thaw into muddy flows with often disastrous and uncontrollable results; thaw ponds and watered ditches would also appear when tundra over ice-rich permafrost is disturbed; and slopes would fail, slide, fall, and be altered.

Finally, any restoration of land following the removal of the coal and associated waste materials would depend on the character of materials originally removed as overburden or interburden. If materials are ice rich, as discussed in the previous paragraph, they are liable to be unstable even on fairly gentle slopes. Over time, permafrost would develop some natural stability (we've witnessed this on several arctic sites), but real stability of landform would only come after vegetation is restored as an insulator for the active (area that freezes in winter and thaws in summer) upper few feet of material.

Air Quality

A last major environmental impact which can be expected to be associated with surface coal mining is air quality degradation from dust. In many ways, the dust problem is no different in Alaska than in other coal-producing areas of the United States. There are two consideration, however, which warrant special comment.

The first of these is that in all three coal field situations of concern here lie in areas of low-level air inversion. The effect of this generally winter-month phenomenon, which exhibits temperature differences in the Interior up to 20°C in the lowest 600 feet (200 m) and is one of the strongest found anywhere, is to trap dust as well as hydrocarbon engine emissions at extremely cold temperatures below a "roof" of warmer air. The dust and hydrocarbons serve as nucleids to form "ice fog." In its more serious forms, ice fog is deleterious to human health and offers hazards to industrial operations due to reduced visibility and worker discomfort.

During the winter months dust from coal operations and from routine travel on gravel roads would settle on the snow, often over many miles, in accordance with prevailing winds. As spring approaches, with greater solar radiation and warmer temperatures, dust-covered snow would melt more rapidly than uncovered snow. The effect of this is to speed up insect and other invertebrate life development. In some areas this occurrence has a disruptive chain reaction effect on the food webs of many higher forms of life.

Summary

Environmental effects of coal operations in Alaska are, in the main, similar to those elsewhere in the United States and are generally well known. The main set of differences in Alaska stems from differences in physical conditions (i.e., permafrost, hydrologic cycles which exhibit seasonal and volume extremes and which are imperfectly known, and cold air temperature phenomena), all of which require special engineering and operational techniques during mining and which can cause conditions making reclamation activities virtually impossible on some sites.

Engineering and Reclamation Considerations

For purposes of discussion here, engineering and reclamation considerations pertinent to both prevailing natural conditions and the induced effects of coal operations associated with the Kukpowruk, Nenana, and Beluga fields are divided into four parts--terrestrial, hydrologic and atmospheric situations, and habitat restoration.

Terrestrial Situations

Discontinuous permafrost affects the mining at the Usibelli Mine near Healy and could be expected in the Beluga field. At the Kukpowruk field, operations would take place in an environment of continuous permafrost. In whatever permafrost conditions encountered, the essence of the degree of both engineering and reclamation problems would be directly attributable to the volume and form of ice within the permafrost materials and the type of material with which the ice is associated (i.e., grain size, particularly).

The removal of overburden would disturb the permafrost regime when ambient temperatures reach high enough levels to induce melting. Where the overburden is composed of fine-grained materials (e.g. silts and clays) flowing muds would result. Handling such material is technologically possible, but it is difficult and expensive, possibly requiring dragline or dredge type equipment. Moreover, storage of such material requires diking. Conversely, the larger the particle size and the poorer the ice content, the easier material is to handle and make stable.

Removal of for frozen ground is technologically difficult. Special equipment is often required for breaking up materials, and blasting requires specific expertise to be effective. If thawing is used, special problems are encountered, often making mud conditions worse when materials are fine gravel and rich in ice content.

The methods used in excavation of overburden and interburden materials have a direct bearing on the success or failure, even the possibility, of postdevelopment reclamation when fine-grained materials are encountered. Excavation and future reclamation in coarse materials are easier, but major reclamation problems are the presence of water-filled pits (whether excavated in summer or winter, if open during the summer months permitting permafrost thaw), the storage of muddy materials under site conditions which often don't allow the percolation of water and compaction of materials into stable forms, and the acceptability of materials for revegetation.

As discussed earlier, the slopes of permafrost materials forming the banks of walls around excavations offer their own special problems of stability from thawing and pore water pressures making revegetation impossible. This problem of slope stability, together with the lack of sufficient and suitable materials for stable backfilling would, in areas of ice-rich, small-grained permafrost, make it virtually impossible to restore original land surface. Again, in order to give emphasis, the handling of coarser-grained materials is quite possible, and the Usibelli Mine experience gives examples of success on some sites. Beyond this, it should be noted that in areas devoid of permafrost overburden, backfill would, in most Alaska coal mine situations, (due to removed material expansion), approximate the fill needed to restore natural terrain contours. This latter situation should be the rule in the Beluga field, although some areas of discontinuous and fine-grained permafrost are to be expected.

In summary, the operational conduct of terrain excavation and reclamation appear with some certainty to be manageable in the Nenana field (although some sites are at variance with present experience) and also in the Beluga field, based primarily on a comparative geologic analysis with other regions of coal production. However, it should be pointed out that specific sites can offer problems. In the case of the Kukpowruk, terrain and reclamation control would be very difficult, if not impossible.

Hydrologic Situations

Engineering and reclamation practices in the Kukpowruk, Beluga, and Nenana fields would encounter an extreme variation in existing hydrologic data interpretation and overall knowledge. As a result, the site-specific design of diversions, ditches, and settling ponds is often fraught with uncertainty. The best hydrologic data probably exist for the Nenana area, the worst for the Kukpowruk. The Beluga area, on the other hand, has some guaged streams, and nearby southcentral Alaska community data may be extrapolated for some useful, but perhaps questionable conclusions. Difficulties arise, however, with geologic hazard-induced flooding from volcanic activity and the occurrence of unpredictable storm situations arising from North Pacific August storm tracks.

In the Kukpowruk area, precipitation data are very scant, with only some relevant data at Point Lay and Point Hope. In addition, much of this area is devoid of vegetation or sparsely covered with tundra. In any event, runoff is scarcely retained, and velocities and volumes can be quite high during storm occurrences.

The point of the foregoing is that design criteria for hydrologic waste and sediment control facilities are minimal at best, and in order to have safe and adequate settling ponds, etc., overdesign may have to be the rule rather than the exception.

Atmospheric Situations

Coal mining constraints associated with low external ambient air temperatures for surface works are essentially the same as those for any other arctic operation. Previously, some ice fog factors have been discussed. In addition, some other considerations pertinent to low ambient air temperature follow. Vehicles utilized for hauling wet coal require some means of preventing the coal from freezing to the truck bed. Covering the bed with antifreeze has worked as has heating the bed of the truck with vehicle exhaust.

In the Arctic, even in areas with low snowfall, coal storage areas are bound to have snow. When the snow melts, the water collects at the bottom of the pile and may refreeze. The upper portion of the pile should be removed and the lower allowed to thaw in the summer, be reclassified, and then shipped.

Appropriate measures for preventing permafrost degradation under surface structures need to be taken, as well as measures for insuring vehicle operation. The latter may include providing heated warm-up sheds as well as low temperature lubrication. Soviet practice appears to include the utilization of thermopane windows, insulation, and double heaters in the vehicle cabs. Low winter temperatures increase the failure rate of rippers manyfold in surface mines.

Due to the high moisture content of the coal, it tends to slack and produce excessive dust upon drying. This dust generation occurs at transfer points, especially in the tipple. During summer, water is used to suppress dust, but so far it appears that no effective solution has been found to suppress dust in winter. Rock dust is employed if welding must be performed at the tipple in winter. No welding is performed in the tipple unless absolutely necessary, and a 24-hour fire watch is maintained after any welding. The combination of high moisture content in the coal and extremely low humidity in winter produces a dust and fire situation that ranks among the most serious of the cold weather problems.

Frozen water and low air temperatures make wet coal washing impossible. The Norwegian Store Norske Spitsbergen Kulkompani A/S utilizes an air washing plant at its mines in Longyearbyen, Svalbard. This plant separates coal from rock with a rising air current; poorly sorted coal is recycled. In addition, limited hand picking is utilized at the mine opening and special magnetic devices are used to remove metal objects from the coal entering the washing plant. A limited amount of coal is washed by water during the summer months at the Usibelli Mine, at Healy, Alaska. The Norwegian Kings Bay Kulkompani A/S built a water washing plant for summer operation at their mine in Ny Aalesund, Svalbard. However, the plant did not operate for long before a catastrophe closed the mine. The literature on the Soviet Arctic does not indicate that coal washing is practiced. There are references to coal benefication installations in Vorkuta, but the sources provide few details.

Conceptually, a water washing plant for winter operation in the Arctic is possible. The plant would need to be heated and the coal dried after washing to prevent freezing in the coal storage piles. The Norwegian Store Norske Spitsbergen Kulkompani A/S may be planning such an installation at its proposed coal mine in Svea, Svalbard. However, no detailed studies of either a technical or economic nature appear available. The tradeoff between the cost of winter coal washing and transportation without washing appears to favor the latter as far as the Soviets are concerned and the former as far as the Norwegians are concerned.

<u>Constraints Related to Remoteness</u>

Small-scale Local Mining

Low temperatures and remoteness are often cited as the major constraints on any type of operation in the North. While low temperatures can be measured, remoteness exists basically in terms of transportation costs and locally available resources and labor. These in turn are in large part a reflection of the objectives of the enterprise and the technology employed. A coal mine in the Arctic employing solely locally available resources including labor, and supplying a local market is not, therefore, remote. A mine which relies on external resources and ships to a distant market is, on the other hand, remote.

Revegetation

Prerequisites of revegetation in Alaska as elsewhere are first the stabilization of land form and second the ability of instituting and maintaining a self-regenerative vegetative cover type. In the Nenana field Usibelli practices have demonstrated feasibility on site conditions find at Healy. Stability appears generally practical at Beluga, also, and the plant species required are also generally available and suited to site and climatic conditions.

With proper reclamation after surface mining, fish and wildlife habitats can be enhanced. Pure vegetation stands are broken during the mining of coal, lignite, and other commodities. Edges and voids are created where monotypes previously existed. With aggressive reclamation, preferred food and cover plants can become established in these openings to benefit a wide variety of wildlife. A mixed grass and shrub cover type can support many more species of animals and larger populations than a dense forest. Many factors would affect the degree of revegetation success achieved. Recovery would ultimately depend on whether enough arable soils remain.

The Arctic has special revegetation problems. Domesticated species are not well adapted to rigorous arctic conditions, and their success is generally marginal at best. Native plants are slow growing and slow to become established. Many of the revegetation tests in the Arctic have utilized seed from subarctic plants. Seed from plants of arctic origin likely would be required for the arctic plantings of perennials. In developing a program to employ native plants for revegetation, the seed producing and harvesting characteristics of the plants also must be considered. Some that are aggressive colonizers are not good seed producers or are difficult to manage for the obtaining of seed. It requires a number of years to develop a supply of seed from the original collections (Mitchell 1969).

The selection of grasses with revegetation potential is much narrower than it is in the boreal region. Furthermore, the significance of varietal differences within a species is more acute. Early germination is particularly advantageous. However, a problem inherent in the precipitation and temperature patterns of the Arctic involves obtaining suitable moisture conditions along with favorable temperatures. The characteristic low rainfall pattern in the Arctic may lead to dryness, thus delaying germination when temperatures are favorable. This is particularly true where a site is inherently dry or where a disturbance has resulted in a deep thaw and enhanced drainage. Further, a cooler than normal season may inhibit germination.

Despite what appear to be severe limitations and difficult conditions, growth of certain species placed in trial at Prudhoe Bay has occurred, and, so far, some have survived one or two winters. Undoubtedly, 24 hours of daylight during the heart of the growing season helps to compensate for the short growing period. First-year growth in the Arctic may be severely restricted, with two years required to develop a stand (Cooperative Extension Service 1973).

Relief and microclimate have a significant effect on vegetation in the Arctic. Lower areas provide shelter from desiccating winds, but poor drainage can make them too wet. High spots are very dry. To revegetate disturbed sites spread or place freshly cut native cotton grass, sedges, or other native tundra sod vegetation on disturbed soil. Pack well and fertilize as indicated by soil tests.

Native grasses can be used in the Arctic; however, only limited quantities of seed for a few species are available. *Arctogrostis* and *Calamagrostis* species, Nugget, Kentucky bluegrass, and Arctared fescue are grasses most likely to provide initial ground cover. Fertilizer rates should be determined for individual sites by soil tests (Cooperative Extension Service 1979).

Revegetation in interior and southcentral Alaska is similar.

Preliminary Results and Deductions

Wild and Naturalized Species

Among the most ubiquitous and successful invaders are species associated with nitrogen fixation. Goodman and Bray (1) note similar findings for derelict sites throughout the world.

The main woody plants to invade disturbed sites are black spruce, white spruce, paper birch, balsam cottonwood, quaking aspen, green alder, and several willows. These species invade rapidly and grow vigorously in many sites with much fine materials in the substrate; however, they grow slowly in the most droughty sites or those with little topsoil. Alder, which nodulates well even in extreme sites, is the most rapid and vigorous invader, but it seems limited in that it needs a good seed source near, preferably uphill from a particular bare site. Birch establishes in some extreme sites and can persist as a very small plant for a long time, conferring the advantage of rapid growth under ameliorated conditions but contributing little to revegetation during the stunted phase. Black spruce seeded successfully into all site types on all firelines except those which were extremely wet or dry.

Among herbaceous plants, particularly able invaders are members of the legume family, including the naturalized species noted earlier. On river floodplains, the "peavine" (*Hedysarum* alpinum, *H.* hedysaroides, and hybrids) and the milkvetches (*Astragalus* spp. and *Oxytropis* spp.) are common, and several species of these form dense stands along older highway edges in interior Alaska. Presence of these species along a given road section may be related to nearness of river plains and/or a source of road surface gravels.

Tall and dwarf fireweed (*Epilobium* angustifolium and *E.* glandulosum) have some means for enhancing nitrogen supplies and excellent seed dispersal mechanisms and might be expected to be highly successful invaders of bare sites. Dwarf fireweed, vigorous on river floodplains, was found only rarely in upland denuded sites. Tall fireweed forms dense stands in old fields and similar sites but is slow to establish from seed and grow in the extreme sites. Fireline individuals spread from the line sides by rhizomes were vigorous and flowering five years after a fire, while seedling-derived plants were small and vegetative. Horsetail (*Equisetum* spp.) and bluejoint grass *Calamagrostis* canadensis) show similar behavior. The small redtop (*Agrostis* scabra) rapidly becomes very dense in some sites but maintains itself only if competition from other species is low.

Alsike (white dutch clover), red fescue, hard fescue, and annual ryegrass are preferred domestic grass species in southcentral Alaska. In interior Alaska, red fescue, Alsike or white Dutch clover, hard fescue, and smooth brome are preferred. Creeping foxtail is preferred in both areas for soils with moderate limitations due to excess moisture. Wet, peaty areas should be revegetated with seed cutting of sedges or other native peat-tundra vegetation (Cooperative Extension Service 1977).

A number of practices are known for the culture and management of vegetation. Comments on this subject follow.

Soil

The upper 12 inches (30 cm) of the soil should consist of loamy material that is able to hold at least 1 inch (2.5 cm) of water. The soil must be porous enough to allow root penetration and friable enough to be tillable for good seedbed preparation.

On construction sites such as highways, airports, and subdivisions the topsoil has often been removed. If a good turf is desired, it may be necessary to replace the soil material. Where soil has been entirely removed, at least 4 inches (10 cm) of loamy material should be added before seeding (Cooperative Extension Service 1979).

Woody Plants

The upper 8 inches (20 cm) of the soil should consist of a loamy material and be able to hold at least 1 inch (2.5 cm) of water to permit the establishment of a woody plant. With large shrubs and trees it is necessary to have a minimum of 12 inches (30 cm) of soil or to provide planting pockets for the plants. These pockets should generally be 3 to 4 feet (about 1 m) in diameter and contain 18 to 24 inches (45 to 60 cm) of soil. The soil must be porous enough to allow root penetration, and in most instances fine, smooth-grading hinders plant establishment, particularly when planting by the seeding methods. Soil pH is an important factor to many woody plants, especially for some of our native species. Plants which are well adapted to acid soil conditions normally fall in calcareous soils.

Fertilization and Liming

Fertilization is important to assure good growth of grasses and herbaceous plants in Alaska. On some construction sites it is imperative for establishment and survival of a planting. In revegetation situations where exotic grasses are used for temporary cover until native plants are able to reestablish, the use of fertilizers should be reduced over the second and third years until none is used the fourth year and beyond. This would allow the native species to gradually take over from the exotics since the exotics require artifically high fertility to compete, whereas the native species are adapted to Alaska soil fertility levels (Cooperative Extension Service 1979).

Revegetation would be facilitated if, when working the soil, the top foot or two of material is guarded and replaced at the surface. Providing a mixture of organic and mineral matter for a seedbed would improve the prospects for successful reseeding. Furthermore, any propagates of native materials present in this layer could establish and further the process of revegetation (Mitchell 1969).

Natural reclamation of large excavations, such as gravel pits, is a very long-term process. The site is infertile and superficially dry. The process could be hastened by plugging in young plants of green alder. Alder is an important nitrogen fixer and often is the most abundant plant on relatively sterile, gravelly sites (Mitchell 1969).

Habitat reclamation for fish would be primarily concerned with improving water quality and spawning areas. The improvement of water quality would in most cases involve impoundment of water to permit pooling and settling of pollutants. The importance of pooling pollutants such as acid, silt, and sediment is obvious.

In the case of acid mine drainage, reclamation should be directed at preventing the formation of acid. This could be achieved through burial of toxic materials, improved drainage, impounding water, and inundating acidic materials and neutralization in certain areas. Methods would vary with terrain, toxicity, and volume of water.

The prevention of additional silt and sediment damage to streams from mines would require watershed stabilization programs. Some grading and improved drainage would be needed along with establishment of permanent plant cover. Mixed grasses and shrubs that would provide quick dense cover would be best. Presently, suitable plant species are available in Alaska, although native species are generally not available in quantity. Where practical, plants that would enhance food and cover for wildlife should be considered first.

Improving stream channels already choked with silt and sediment would prove costly and impractical in remote areas of Alaska. In high-gradient streams the pollutants would move downstream through normal processes. The movement of silt and sediment from slower reaches of streams could be accelerated and directed through the use of instream devices, sediment-collecting basins, and dredging. Shifting streambed loads can be stabilized and further downstream damage alleviated in this fashion. Intentional modification of streambeds to accomplish this would require careful coordination between fisheries biologists, hydrologists, and engineers.

Faunal Recolonization of Reclaimed Levels

Faunal recolonization of strip-mined areas would occur following rehabilitation and stabilization of the area. Colonization rates would ultimately depend on the species involved and their respective population levels adjacent to the area. Since the reclaimed substrates would differ somewhat in composition from the original, these substrates should act as new islands to be colonized. Predictably, patterns of recolonization would parallel equilibrium postulates first proposed by MacArthur and Wilson (1967).

Patterns of recolonization by herbivores are more complex than those of carnivorous species. Profound species-specific differences in mobility and range utilization exist among herbivores. This specialization within and between types has lead in part to their preponderance in numbers and kinds. The following discussion illustrates some of the divergent patterns of recolonization anticipated in reclaimed areas.

Gore (1979) examined the patterns of recolonization of benthic macroinvertebrates in a reclaimed coal strip-mined river channel. Colonization occurred primarily through downstream drift of aquatic insects and algal mats. The author concluded that the agents responsible for observed patterns of recolonization were differential drift rates and distances travelled for both aquatic invertebrates and detrital material. Attainment of maximum diversity lagged behind density by about one month. Gore (1979) notes, "This period represented a time of dynamic adjustment within the community to match the undisturbed source area communities."

Terrestrial herbivores are generally more mobile and occupy a more heterogeneous environment than aquatic organisms. Patterns of colonization are also more complex and reflect each species' life-style. Some species would exploit new habitats faster than others.

North American mountain sheep (Ovis spp.) are at the extreme end of the spectrum. These animals are slow to colonize unoccupied habitats. Colonization of new range occurs in the following manner (vide Geist 1970). Prior to lambing, sheep segregate by sex and age into like bands. Males two years old and older form one type of aggregation and females and young the second type. Sheep ranges are typically composed of isolated, discontinuous pockets of seasonal habitat scattered throughout the mountains. Interaction between bands commonly occurs as sheep from one band travel through pockets of habitat occupied by others in transit to their own preferred grazing areas.

The precocious young frequently follow strange individuals from trespassing bands to their destination. Once there, the young "imprint" on the area and it, like their birth areas, becomes part of their seasonal home range when adults. In the process of travelling to this "new" habitat, the band may have travelled through one or more prime sections of habitat.

If these pockets of habitat were unoccupied at the time, however, they would not be recognized. An essential component of sheep range is the presence of other sheep. Adjacent prime, but unoccupied range is unrecognizable to sheep as habitat. Recolonization by sheep has to await the chance utilization of the reclaimed area by a band with attendant young.

Fortunately, most terrestrial herbivores are not so rigidly attuned to their environment. For example, caribou typically exploit new range opportunistically. Caribou herds are in dynamic flux with their environment. Spontaneous fragmentation and dispersion of large herds into new habitats apparently is the rule. Patterns of dispersion among other terrestrial herbivores vary between the two extremes discussed.

Generally, however, recolonization by terrestrial herbivores would progress as soon as an adequate food supply is established.

Recolonization by carnivorous fauna is easier to describe. Carnivorous organisms have evolved in close association with their respective prey animals. Changes in prey distribution and abundance are quickly mirrored by their predators. For example, Gore (1979) described limited upstream colonization of new habitat by predaceous dragonflies. Similarly, Allen (1979) reviewed the history of natural reintroduction of wolves onto Isle Royale, Michigan following an absence of many years.

Summary

The control of adverse environmental effects due to surface coal mining operations in the Kukpowruk, Beluga, and Nenana fields would not be easy and may adversely affect cost/benefit ratios. The technological and environmental knowledge for such control, however, does for the most part exist and could be applied to the Nenana and Beluga fields. The operation of coal mining in the Kukpowruk field under existing knowledge and legal restraints, however, is much more difficult and may well be impossible unless mining objectives are made paramount to current environmental goals formed under existing law. The only other alternative is to encourage active development research directly applicable to coal mining under arctic conditions.

plus title page

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APPENDIX C

Competitive Coal Sources

Although there will be a substantial demand for coal in the market areas described in Part A, Alaska coal will have to compete with coal from other nations as well as from other areas of the U.S. for a share of those markets. The purpose of this section, therefore, is to examine the resources and development potential in those areas considered to be competitive with Alaska coal for this market. This section, then, will focus only on the following areas: Australia; South Africa; Canada; China and the Conterminous U.S. Much of the information presented here was found in a report prepared for DOE by ICF Incorporated.[12] For additional details, the reader is referred to the ICF Report.

World prospects for coal production have improved considerably in the last few years. In the 25-year period prior to the 1973/74 OPEC oil price increase, there was a world-wide trend of oil replacing coal in many uses, i.e. rail transport, power generation, process steam production, residential heating, etc. Coal's contribution to meeting the world's primary energy requirements fell from 49% in 1960 to 29% in 1973. Increases in the price of primary energy since 1973/74 have stimulated serious consideration of methods to increase the use of coal.

The information to provide an overall view of world coal trade is presented in Table C-1. It should be noted that this table includes both metallurgical and steam coal trade.

AUSTRALIA

Since 1966, Australia's bituminous coal production has more than doubled. The amount of coal exported increased six-fold from 1966 to 1976. Large increases in both production and exports are expected through 1990 and beyond.[12] Australia appears to have the reserve base necessary to support these expansionary projections.

a. Reserves

As demonstrated in Table C-2, total Australian resources are estimated at 353.6 billion short tons. Out of that total over 26% are first category (measured/indicated) and over 73% are second category (inferred). Table C-2 also shows that approximately 73% of all Australian coal resources are bituminous or subbituminous and about 27% are lignite.

b. Mining Methods

Both surface and underground mining methods are used in Australia. As shown in Table C-3, in 1976, approximately 65% of

TABLE C-1

COAL SUPPLY, DEMAND, TRADE
1978
(Millions of short tons)

Country/ Region	Production	Consumption	Imports	Exports
Canada	34	35	15	14
U.S.	654	618	3	40
Australia	124	86		39
Japan	21	78	57	
* OECD-Europe	453	526	74	
OECD-Total	1286	1343	149	93
Poland (E)	257	212		42
USSR (E)	800	775	15	29
South Africa	96	80 (E)		16 (E)

E = Estimate

SOURCE: Reference 35 Bibliography

*OECD: Organization for Economic Co-operation and Development

TABLE C-2

AUSTRALIAN COAL RESOURCES
(millions of short tons)

	First Category (measured/indicated)			Second Category (Inferred)	
	Resources	Recoverable Reserves	Saleable	Resources	Total
New South Wales					
Bituminous	17,471	9,714	8,086	93,939	111,410
Subbituminous	336	243	243	11,458	11,794
Total	17,807	9,957	8,329	105,397	123,204
Queensland					
Bituminous	18,588	10,841	8,738	110,230+	129,162+
Subbituminous	344	204	204		
Total	18,932	11,045	8,942	110,230+	129,162+
Tasmania					
Bituminous	132	66	55	NA	132+
Western Australia					
Subbituminous	2,149	430	430	0	2,149
South Australia					
Subbituminous	794	716	716	2,535	3,329
Victoria					
Bituminous	0	0	0	10	10
Lignite	53,793	11,199	NA	41,778	95,570
Australia					
Bituminous	36,191	20,621	16,878	218,172+	257,986+
Subbituminous	3,623	1,593	1,593		
Lignite	53,793	11,199	NA	41,778	95,570
Total	93,607	33,413	NA	259,950+	353,556+

Source: Reference 12 Bibliography

Australia's total production was extracted from surface mines. The majority of non-lignite surface production is located in Queensland.

c. Distribution and Coal Quality

Australia is divided into six States (Queensland, New South Wales, Victoria, Tasmania, South Australia and Western Australia) and one territory (Northern Territory). All six States have coal reserves; however, the reserves in Queensland, New South Wales and Victoria account for over 98% of the total resources.

The following information on coal quality is provided solelyy to give the reader a general idea on the quality of coal in the two major coal bearing States. These analyses represent only a limited number of samples, and results should not be interpreted as definitive for all coal in the particular State. Data are presented only for the two States where development looks promising, i.e. New South Wales and Queensland.

New South Wales

The most important New South Wales coal deposit is in the Sydney Basin. The first coal mining developments occured in this region. Coal from this basin typically has the following characteristics:[12]

	Sydney Basin
Heat Content	10,500 - 12,000 BTU/LB
Ash Content	12-20%
Volatile Matter	25-28%
Sulfur	0.4-0.7%

Queensland

Most of the coal-bearing areas in Queensland lie in the eastern and particularly in the southeastern part of the State. Resources are mainly located within three Basins: Bowen Basin, Clarence-Moreton Basin, and the Galilee Basin. Typical analyses of steam coals from each of these basins are shown below.

	Bowen Basin
Heat Content	12,000-13,000 BTU/lb.
Ash Content	10-20%
Volatile Matter	26-29%
Sulfur Content	0.3-0.8%

TABLE C-3

CURRENT AUSTRALIAN COAL PRODUCTION BY MINING METHOD 1975-1976 FOR SALEABLE COAL

	Production (000 short tons)		Percent of Total Production		
	Underground	Surface	Underground	Surface	Both
New South Wales	34,474.4	9,088.5	31.1%	8.2%	39.3%
Queensland	3,660.7	24,636.4	3.3	22.2	25.5
Western Australia	594.1	2,024.9	0.5	1.8	2.3
South Australia	-	2,144.0	-	1.9	1.9
Victoria	-	34,164.7	-	30.8	30.8
Tasmania	178.6	-	0.2	-	0.2
Total	38,907.8	72,058.5	35.1%	64.9%	100.0%

Source: Reference 12 Bibliography

Clarence-Moreton Basin

Heat Content	10,000-11,500 BTU/lb.
Ash Content	17-28%
Volatile Matter	28-38%
Sulfur Content	0.4-0.7%

Galilee Basin

Heat Content	7,500 BTU/lb.
Ash Content	19-20%
Volatile Matter	37-38%
Sulfur Content	0.6%

d. Production Costs

Actual production cost data are difficult to obtain from coal mining operation in Australia. Information available for New South Wales indicates that total operating costs for the years 1972-73, 1973-74, and 1974-75 were $248 million, $281 million and $389 million respectively.[12] Production for these years was 42.0, 40.4 and 46.6 million short tons. Average production costs for these years, in current U.S. dollars per short ton, are $5.91, $6.96 and $8.39 respectively.

Total cost of production (capital costs and operating costs) for New South Wales was calculated at $8.52 (1972-73); $10.04 (1973-74) and $12.03 (1974-75) per ton. Average nine mouth prices in New South Wales were recorded as $12.41 in 1974; $18.33 in 1975 and $19.17 in 1976.[9] These data are presented in Table C-4.

TABLE C-4
Coal Production/Costs/Prices
New South Wales

	1973-73	1974-75	1975-76
Production (10^6 tons)	$ 42.0	$ 40.4	$46.6
Operating Cost (million $)	248.0	281.1	389.1
Avg. Operating Cost ($/ton)	5.91	6.96	8.39
Total Production Cost*($/ton)	8.52	10.04	12.03
Selling Price	12.41	18.33	19.17

Source: Reference 12 Bibliography
*See reference 12, pg. 2-24 for assumptions used

The cost figures in Table C-4 and costs are probably near the average for the country since New South Wales, is the largest producing State.

e. Future Coal Production

Table C-5 summarizes Australia's projected coal production for the years, 1980, 1985 and 1990. As indicated in the Table, steam coal production is expected to increase from 8.2 million tons in 1980 to 33.7 by 1990. All of the steam and coking coal is expected to be produced from New South Wales or Queensland. Several new mines are currently under construction and others are in the planning stage. Many of these mines are partially owned by foreign interests and their total production is destined for the export market.[12]

There appear to be no basic constraints to the expected growth of the Australian coal industry. Although, in recent years, inadequate port facilities in New South Wales have hindered exports, an upgrading of the Port of New Castle and large new loading facilities in the Sydney Basin have eased this problem. A large new port has also been constructed at Hay Point in Queensland to handle the mineral exports from Northern Australia.

f. Future Exports

A large part of Australia's future coal production is being developed for foreign export. Table C-6 shows maximum projected Australian coal exports for 1980, 1985 and 1990. Although there appears to be a discrepancy in the numbers between Tables C-4 and C-5, in reality there is not. Table C-6 merely shows the future production under current plans, while Table C-6 projects export tonnages based on a higher level of production that could occur under certain conditions.[12]

It is clear from Table C-6 that a large part of the Australia export market is for coking or metallurgical coal. However, steam coal exports are expected to increase from the 1975-76 level of 3.3 million short tons to 30 million short tons by 1990.

The export numbers given above agree closely with those found in a recent draft DOE study.[37] According to that study, Australia will export in 1990 25 million tons to both Japan and Western Europe. Table C-7 summarizes Australia's steam coal export projections from the cited DOE analysis.

TABLE C-5

MAXIMUM INCREASES IN AUSTRALIAN COAL PRODUCTION BASED ON CURRENT PLANS (CUMULATIVE)
(millions of short tons)

	1980			1985			1990		
	Surface	Deep	Total	Surface	Deep	Total	Surface	Deep	Total
South Wales									
:eam	6.6	-	6.6	13.9	1.5	15.4	16.1	1.5	17.6
oking	7.3	3.9	11.2	17.3	9.6	26.9	17.3	12.9	30.2
Total	13.9	3.9	17.8	31.2	11.1	42.3	33.4	14.4	47.8
ensland									
team	1.6	-	1.6	10.1	-	10.1	16.1	-	16.1
oking	18.0	-	18.0	23.7	-	23.7	26.0	-	26.0
Total	19.6	0	19.6	33.8	0	33.8	42.1	0	42.1
toria									
ignite	14.0	-	14.0	20.0	-	20.0	25.0	-	25.0
tralia									
team	8.2	-	8.2	24.0	1.5	25.5	32.2	1.5	33.7
oking	25.3	3.9	29.2	41.0	9.6	50.6	43.3	12.9	56.2
ignite	14.0	-	14.0	20.0	-	20.0	25.0	-	25.0
Total	47.5	3.9	51.4	85.0	11.1	96.1	100.5	14.4	114.9

Source: Reference 12 Bibliography

TABLE C-6

MAXIMUM AUSTRALIAN COAL EXPORTS

	New South Wales	Queensland	Total
1980			
Metallurgical	23.9	38.4	62.3
Steam	6.0	1.0	7.0
Total	29.9	39.4	69.3
1985			
Metallurgical	37.4	43.6	81.0
Steam	10.4	8.1	18.5
Total	47.8	51.7	99.5
1990			
Metallurgical	52.0	48.7	100.7
Steam	14.7	15.3	30.0
Total	66.7	64.0	130.7

Source: Reference 12 Bibliography

Table C-7

STEAM COAL TRADE - EXPORTS FROM AUSTRALIA
(Millons of Short Tons)

Year	W.Europe	Japan	Total
1977 (actual)	2	1	3
1985	9	3	12
1990	20	5	25
1995	20	10	30
2000	35	15	50

Source: Reference 37, pg. 14 Bibliography

It appears that Australia will be a strong competitor for a share of world coal demand.

g. Coal Prices

As shown in Table C-8, Australia surface-mined steam coal can be delivered in Japan for an average price of $32 (1979 $) per ton or $1.33/per million BTU. This can be compared with the $2 per million BTU for Western U.S. surface mined coal delivered to Japan and around $2.30 for Beluga, Alaska coal (see Chapter IV). The higher price of U.S. coal reflects, in part, the high cost of overland transportation from mine to port.

h. Conclusions

Australia has a stable, mature coal industry and both the State and Federal governments encourage further development. Although government regulation is kept to a minimum, neither does the government provide subsidies for the coal industry.[12] The coal industry or mining companies are responsible for providing the industrial and community infrastructure necessary for the development of energy projects.

It is apparent that Australia has both the resource and the infrastructure required to expand coal exports in the future. Australia's primary emphasis will be on the export of metallurgical coal to Japan.[12] Therefore, the future Japanese demand will, to a large degree, be the impetus that will spur coal export development.

The most likely areas for future coal development in the western conterminous U. S. are the States of Wyoming, Montana, North Dakota and Utah. The DOE estimates that the 1990 production capacity (short tons/year) in these States will be 300.3, 95.9, 58.7 and 43.3, respectively.[41]

TABLE C-8
World Steam Coal Prices
For Deliveries to Japan
($1980 per ton)

From	Delivered Price Range	Average	$Million BTU
U.S.			
West-Surface	34 - 56	45	2.25
Canada			
West-Surface	39 - 50	45	2.23
Australia			
Underground	31 - 39	39	1.49
Surface	29 - 39	35	1.44
South Africa			
Underground	29 - 37	33	1.51

Source: Reference 37 Bibliography (data in Table 4, were escalated from 1979$ to 1980" using appropriate price indices as published by each country).

In summary, Australia will probably be one of the strongest competitors for a share of the foreign coal demand market.

CANADA

Canada is rapidly becoming one of the largest coal producing and exporting countries. As shown in Table C-1, Canada exported 14 million short tons in 1978. The potential for developing Canada's coal industry is tied closely to the export market, as well as to the development of coal-fired powerplants at home.

a. Reserves and Distribution

Canada's coal reserves have not been thoroughly assessed, although the country has embarked on a National Coal Inventory that will provide more complete data. Coal reserves as currently known are shown in Table C-9. This Table indicates that Canada has a total of 63.2 billion short tons of measured and indicated coal reserves with a large part (over 38 billion tons) being low/medium volatility bituminous.

Most of Canada's coal reserves (over 97%) are located in the three western provinces of British Columbia, Alberta and Saskatchewan. This section will address only the coals in British Columbia and Alberta since the reserves in Saskatchewan are lignite and are not likely to be a viable export product.

TABLE C-9

MEASURED AND INDICATED COAL RESOURCES OF CANADA BY RANK OF COAL (in millions of short tons)

	Bituminous				
	Low/Medium Volatility	High Volatility	Subbituminous	Lignite	Total
Alberta	20,602	6,279	7,419	-	34,300
British Columbia	17,718	146	-	640	18,504
Saskatchewan	-	-	-	9,098	9,098
Ontario	-	-	-	240	240
New Brunswick	-	53	-	-	53
Nova Scotia	+*	1,039*	-	-	1,039
Total Canada	38,320	7,517	7 9	9,978	63,234

Source: Reference 12 Bibliography

British Columbia

British Columbia has over 29% of the total measured and indicated reserves of Canada. Over 95% of the coal in British Columbia is low-to-medium volatile bituminous coal suitable for metallurgical trade. The coal fields in British Columbia are widely scattered. Listed below are typical characteristics of coals from two prominent areas of British Columbia.

	Southeast Region	Northeast Region
Heat Content (BTU/lb)	13,000	14,500
Ash	15%	5%
Sulfur	0.5	0.5
Volatility	low to medium	low to medium

Alberta

The province of Alberta contains over 54% of all of Canada's coal resources. Over 60% of the coals in Alberta are bituminous of low/medium volatility suitable for metallurgical purposes. In addition, Alberta contains all of the subbituminous deposits known in Canada. Listed below are characteristics analyses of coal from three regions in Alberta. These regions are the Inner and Outer Foothills Belts and the Plains Region.

	Inner Foothill	Outer Foothill	Plains
Heat Content (BTU/lb)	13,000	11,000	9,000
Ash	10%	10%	10%
Sulfur	0.6%	0.5%	0.5%
Volatility	low/med.	high	N/A

The Plains Region, contains primarily subbituminous resources that lie in flat or gently inclined seams. The Plain Region's resources are located in a band that begins in the center of the border between British Columbia and Alberta and curves gently southward to the southeast corner of the province. Individual coal seams are 20 feet or more thick and there are often multiple seams.

b. Mining Methods

TABLE C-10

1976 CANADIAN COAL PRODUCTION
BY PROVINCE, MINING METHOD AND QUALITY
(in millions of short tons)

	Surface Mines		Underground Mines		
	Steam	Metallurgical	Steam	Metallurgical	Total
Nova Scotia	-	-	1.81	0.40	2.21
New Brunswick	0.33	-	-	-	0.33
Saskatchewan	5.16	-	-	-	5.16
Alberta	7.55	3.60	0.04	0.93	12.12
British Columbia	0.36	7.12	-	0.80	8.28
Total	13.40	10.72	1.85	2.13	28.10

Source: Reference 12 Bibliography

In 1976, Canada produced 28 million tons of coal with 24 million tons from surface mining and 4 million tons from underground mines. Table C-10 gives 1976 production by province and by mining method. In Alberta, the largest producing underground and surface mines produced, in 1976, 0.6 million tons and 2.5 million tons respectively. In British Columbia the largest underground mine produced 0.6 million tons while the largest surface mine produced 5.6 million tons of raw coal. Virtually all steam coal is surface- mined (13.4 million tons out of 15.2 million tons). Due to the geologic setting of the steam coal (subbituminous) reserves, future production expansions are expected to come from surface mining.

c. Production Costs

Little information is available on the actual production costs of Canadian coal. In a recent report, estimates of coal production costs (i.e. the recovery of capital costs and operating costs) were made using the DOE National Coal Model as a surrogate for estimating mining costs in Canada.[12]

The subbitiminous surface mines in Alberta have production costs very simular to those in the Western part of the U.S. (Montana, Wyoming). It is estimated that this cost is $9-10 (1976$) per ton. Similarly, for underground mines, production costs of $25 per ton (1976$) were estimated using the U.S. Rocky Mountain mines as an equivalent area.

d. Future Coal Production and Exports

Canada is expected to increase its coal producton from 34 million tons in 1978 to 119 million tons in 1990.[12] Table C-11 gives the breakdown by year and type of coal for the years 1980, 1985 and 1990. The estimates were developed principally with the assumption of anticipated expansion of export trade and the development of mines to support new coal-fired powerplants in Canada.

The steam coal production level increases in shown Table C-11, are partially needed to meet the Canadian demand for powerplant fuel. The projected internal demand for coal-fired powerplant consumption is 25.6, 43.6 and 58.6 million tons/year for 1980, 1985 and 1990 respectively.

Table C-12 estimates Canada's potential coal exports for the years 1976, 1980, 1985 and 1990. Total Canadian exports from 1978 were 14 million tons, most of which was metallurgical coal.[37] In 1976 Canada exported less that

TABLE C-11

ESTIMATED COAL PRODUCTION LEVELS FOR 1980, 1985, AND 1990 (in millions of short tons)

	1976	1980	1985	1990
Metallurgical Coal	12.9	15	25	36
Steam Coal	15.2	30	57	83
Total	28.1	45	82	119

Source: Reference 12 Bibliography

1 million tons of steam coal. As can be seen in Table C-12, the steam coal exports are expected to increase from 0.7 million tons in 1976 to 10 million tons by 1990. The principal market for the steam coal exports is expected to be Japan.

e. Coal Prices

According to a DOE Report, Western Canadian surface mined coal can be delivered to Japan for an average of $40 per ton or $2.00 per million BTU (1979$).[37] This is identical to the delivered price and Western U.S. coal to Japan and only slightly less than the $2.27 - 2.37 cost of Beluga coal delivered to Japan (Chapter IV).

f. Political and Institutional Factors

The future of coal mine expansion is dependent upon the attitudes and policies of the individual provincial governments. Each province has distinct development policies. A brief discussion on the policies of the Alberta and British Columbia governments follows.

In June 1975, the Alberta Cabinet passed the Coal Development Policy which many observers contend is a policy of deliberately impeding new coal developments.[12] Other observers contend that the policy is in the own self interest of Aberta since the province is rich in oil and gas reserves. The rationale behind this argument is that coal reserves can be developed later when oil and gas royalties begin to decline.

Although it is beyond the scope and intent of this study to give a thorough analysis of Alberta's Coal Policy, however, some of the more salient points are:

- Royalty payments are increased via a formula based on economic efficiency of the mine. Most mines are expected to pay between 8 and 20% of revenues in royalty payments.

- The Provincial Government will control the timing of new developments.

- The Provincial Government has classified the land in Alberta with respect to coal exploration and development. Some of the promising coal development areas are restricted by these classifications.

- The Provincial Government encourages development where the infrastruture currently exists, but is hesitant where new facilities would have to be developed.

TABLE C-12

POTENTIAL COAL EXPORTS FROM CANADA FOR 1980, 1985 AND 1990
(in millions of short tons)

	1976	1980	▲	1985	▲	1990	▲
Metallurgical Coal	12.3	14.0	1.7	25.0	11.0	34.0	10.0
Steam Coal	0.7	2.0	1.3	5.0	3.0	10.0	5.0
Total	13.0	16.0	3.0	30.0	14.0	44.0	15.0

▲ = Increase from the previous period.

Source: Reference 12 Bibliography

- The Provincial Government requires a provision in coal contracts for automatic price review and redetermination every two years for all coal going out of Alberta.

Many industry and energy officials believe this policy will restrict development in Alberta causing a shift from Alberta to British Columbiain future coal developments.

The Province of British Columbia appears to have a more liberal policy toward coal development. The government is attempting to reduce trade and investment restrictions with Japan in order to encourage the expansion of coal exports. British Columbia is attempting to obtain Federal support for building the infrastructure needed to support new coal developments.

g. Conclusion

The discussion above indicates clearly that, with Alberta's tough policy on coal development, British Columbia will become the major focus for coal development. This fact seems particularly true with respect to development for export markets, specifically to Japan. However, currently there is relatively little planned development earmarked for steam coal exports (less than one million tons). The potential for a large steam coal export market from British Columbia is somewhat limited since the most economical steam coal (subbituminous) reserves are located in the Plains Region of Alberta which has a strict development policy.

SOUTH AFRICA

Coal is South Africa's only indigenous energy resource and accounts for 75-80 percent of the total energy consumed in the country. Coal consumption in 1976 reached some 71 million tons, primarily for power generation but also for direct use in industrial transportation and for conversion to liquid and gasious fuels (12). South Africa currently has the world's only commercial-size coal liquefaction plant.

a. Reserves and Distribution

South Africa is estimated to have between two and three percent of the world's coal reserves and over 80 percent of the reserves of the African continent. Table C-13 shows the coal reserves estimates in the three coal bearing provinces of South Africa.

TABLE C-13

Proven and Indicated Coal Resource of South Africa
(millions of short tons)

Province	Steam Coal	Metallurgical & Anthracite	Total
Transvaal	58,152	1119	59,271
Natal	1,324	657	1,981
Orange Free State	4,547		4,547
	64,023	1,776	65,799

Source: Reference 12 Bibliography

Although quality of the reserves varies depending on the seams within each province the following table provides typical analyses of steam coal from each province.

TABLE C-14

Typical Steam Coal Characteristics for Coal From
Each Major Coal Bearing Province of South Africa

	Transvaal	Natal	Orange Free State
Energy(Btu/lb)	11,000-12,000	11,000-12,000	8,500-10,000
Moisture	5%	5%	10%
Ash	15-20%	10-25%	20-30%
Sulfur	1.0-2.0%	0.5-3.0%	1.0-2.0%

Source: Reference 12 Bibliography

As shown in Table C-14, most of the steam coal reserves (90.8%) are located in the Transvaal Province. In fact, 90% of all of South Africa's coal resources are in this Province. One of the disadvantages of South Africa coal as can be seen in Table C-14, is the high ash content.

b. Mining Methods

In the past, most of the coal production from South Africa was from underground mines. The use of this production technique resulted from, (1) the geologic setting of the coal seams (thick, horizonal, shallow depth seam) and (2) the availablility of low-cost labor. In 1976, out of South Africa's total production of 83 million tons, 71 million tons were produced from underground mines. This situation, is changing. There are currently several mines in various states of development with a total projected production capacity of 53.7 million tons/year, 31.1 million tons of which will be surface mined.[21]

Several factors have influenced the shift toward surface mines. Briefly, these are:

- Rapidly rising labor costs
- Uncertainty in labor policy regarding employment of non-South African Blacks
- Greater concern over maximum possible recovery of the resource (underground mining techniques leave a considerable quantity of coal underground).

c. Production Costs

Coal production costs in South Africa are low despite the fact that the majority of current production comes from labor intensive underground mines. Estimates have placed the production costs of coal from underground mines at $15 (1976$) per ton as an average for the country.[21] Similarly, estimates for surface mined coal are $8-10/ton (1976$).

d. Future Coal Production and Exports

Historically coal production in South Africa increased at an annual rate of about 3.4 to 4.2 percent in the period from 1940 through 1970.

Since 1970, however, coal production has increased at an annual rate of over 6.0 percent.

To date, South Africa has not been a major exporter of coal. The basic reasons for this are; (1) lack of adquate port and coal handling facilities, (2) the great distances to major markets, such as Japan and Europe and (3) the relatively poor quality of the coal (high ash, little metallurgical coal reserve).

Historical coal production is given below:

South Africa Coal Production

Year	Tons
1940	18.9
1950	28.6
1960	41.9
1970	58.5
1976	83.4
1978	96.0

Increases in coal production have resulted, to a large extent, from an increased demand from coal-fired electric generation plants. Approximately 96% of South Africa's electricity is generated from coal; in 1976, about 58% of South Africa's total coal consumption was for this purpose. The coal liquefaction facility (SASOL I) is also a large coal user with an annual consumption of 4 million tons.

A second coal liquefaction plant (SASOL II) is currently under construction and is expected to be in operation by 1981. SASOL II is expected to use around 14 million tons/year.

A major impetus to South Africa's coal production was the signing of the first major long-term coal contract with Japan in 1969. The contract called for 25 million tons of metallurgical coal to be delivered in a 10 year period commencing in 1976. This was South Africa's first significant entry into the world's coal market.

In 1976 South Africa exported 6.6 million tons of coal of which 3.9 million tons was steam coal. Steam coal was exported to the U.S., France, Italy and West Germany.

There is some variation in future coal production and export projections. Following are projection from two reference sources:

TABLE C-15

Coal Production Projections of South Africa
(million tons)

	1980	1985	1990	2000
ICF.[12]				
Steam	90	127	144	
Metallurgical	14	20	28	
Total	104	147	172	
OECD[21]		130	177	262

Note: Projections for Reference 21 include both steam and metallurgial coal

TABLE C-16

Coal Export Projections (million tons)

	1980	1985	1990	2000
ICF [12]				
Steam	11	20	23	
Metallurgical	2	4	7	
Total	13	24	30	
OECD [21]				
Steam		38	67	1000

The information provided above indicates that South Africa is indeed expecting to become a major coal exporter. The range in export projection for 1985 of between 24 and 38 million tons substantially exceeds the actual 1976 exports of 6.6 million tons.

e. <u>Coal Prices</u>

As shown in Table C-8 from DOE's Coal Exports Study, it is estimated that South Africa underground coal can be landed in Japan for an average price of $30 per ton or $1.36 per million BTU (all in 1979$). For comparison purposes, Western U.S. surface-mined coal is estimated to be landed in Japan for $40/ton or $2.00 per million BTU, and Beluga coal for $34.37/ton or $2.27 to 2.47 per million BTU (Chapter IV).

f. <u>Political and Institutional Factors</u>

Although the outlook is favorable for commercial development of South Africa's coal, the government's export policy is unclear. There are basically two conflicting schools of thought with respect to future coal development.[12] First, there is a nationalistic school of thought that advocates increased reliance on coal for security reasons, banning exports and reserving coal for the domestic market. On the other hand, coal producers and other elements agree on the need for further development of coal for export. The government has neither established a long-term policy on coal trade, nor put up major barriers to further development. There are two issues that may reflect unstated government policy. First, as mentioned previously, there are several on-going projects with over 10 million tons per year capacity earmarked for export by the early 1980's. Second, the South African government controls the price of domestically consumed coal at a relatively low price (i.e. $6.90/ton in 1976); however, export coal is not subject to control and thus coal producing companies could obtain significantly higher revenues for export coal than they would for domestically consumed coal.

g. Conclusion

There appear to be adequate resources to justify expanded coal exports from South Africa. Although labor costs are rising and there are delays by government in authorizing new mines, the overall outlook for expanding coal exports appears to be favorable.

In 1975, South Africa opened a new port at Richards Bay. The Richards Bay facility is expected to increase its capacity from its current 13 million tons per year to 22 million tons.[12] The availability of this port facility will assist in reducing the bottlenecks that could arise when coal exports accelarate.

CHINA

China is the third largest coal producing country in the world with a 1977 production of 551 million short tons.[11] Most of China's production is consumed domestically. In 1976 China exported only 1.2 million tons to Japan and other Asian countries.[11]

China's 10 year plan unveiled in 1978 called for a doubling of coal output from 500 million tons to 1 billion tons by 1985. However, lack of proper planning and a series of disastrous mining accidents have caused these projections to be revised downward.[16] In addition, China's rail system does not have the capacity to move greater quantities of coal even if they become available. The Chinese have been holding discussions with the Japanese in an attempt to get them to help with development costs in eleven coalfields.[16] It is estimated that these costs could be in excess of $1 billion.

Specific information on coal mine development and potential exports is difficult to obtain. However, there are estimates that minehead production costs in China are $6-12 per ton (1978$) for surface mines and $12-20 for underground mines.[10]

Estimates have been made for China coal exports of 3,4 and 6 million tons per year for 1985, 1990 and 2000 respectively; these estimates are considered to be highly uncertain.[21] Thus, it appears that China may export some coal in the future, but not in quantities that could supply a significant portion of the market.

Conterminous United States

The United States possesses tremendous coal reserves. According to a recent estimate, the U.S. has 27.8 percent of the world's technically and economically recoverable reserves. The U.S. is also the world's largest coal producer (647 million short tons in 1978) and a large exporter (40 million tons in 1978). A large part of the U.S. coal exported is sent to Canada and Mexico.

a. Resources, Distribution and Mining Methods

Table C-17 presents data on the U.S. demonstrated coal reserve base by sulfur content, mining method and geographic location. As shown in Table C-17, out of the 67 billion metric tons (74 billion short tons) of low sulfur (less than 1%) surface mineable coal, all but 5 billion tons lie west of the Mississippi River.

In the U.S., the emphasis with respect to mine development has been directed at Western surface mines. A recent DOE report indicates that by 1990 there will be 64 underground mines producing 70 million tons, and 148 surface mines producing 634 million tons in the Western U.S.[39]

b. Production Costs

Production costs in U.S. mines vary considerably with the type of mine and its location (East vs. West). Table C-8 indicates that production costs from western surface mines range from $5 to $15 per ton whereas eastern U.S. underground mine production costs range from $15 to $28 per ton. (all in 1979$)

c. Future Export Potential

The United States is projecting a significant increase in coal exports from 40 million tons in 1978 to between 157 and 250 million tons by the year 2000.[44] Coal export projections are given below for both steam coal and metallurgical coal. These projections are for the entire U.S. including Alaska.

TABLE C-17

Demonstrated U.S. Coal Reserve Base by Sulphur Content and Potential Method of Mining

Billion metric tons

	Sulfur range				Total
	<1%	1-3%	>3%	Unknown	
Underground :					
East of the Mississippi River	24	44	60	24	152
West of the Mississippi River	90	10	7	12	119
Total underground	114	54	67	36	271
Surface :					
East of the Mississippi River	5	6	13	5	29
West of the Mississippi River	62	24	4	5	95
Total surface	67	30	17	10	124
Grand total	181	84	84	46	395

Source: Reference 21 Bibliography

U.S. Coal Exports
(millions of short tons)

	1985	1990	2000
Metallurgical Coal	69.4	76.5	88.2
Thermal Coal	15.8	23.4	73.8
Total	85.2	99.9	162.0

Source: Reference 21 Bibliography, TABLE I-2., OECD, Steam Coal Prospects to 2000. 1978 (conversion factor of 1.26 used to convert tce to short tons)

d. Coal Prices

It has been estimated that U.S. western surface mined coal can be delivered to Japan for an average price of $40/ton in 1979$.[37] For purposes of comparison, the same report estimates that eastern underground coal can be delivered to Japan for an average price of $54/ton. The average price of U.S. coal delivered to utilities in 1979 was $25.77 per short ton, up from the 1978 price of $22.19.[38]

e. Political and Institutional Factors

Federal coal leasing policy is one of the major issues relating to future U.S. coal development. The Federal Government owns about 60 pecent of the recoverable coal resources in the Western States. In order to open a mine on this land, producers must obtain a Department of Interior lease. In 1971 a moratorium was imposed on the leasing of Federal Lands. The Interior Department is currently preparing EIS's on coal development in the Northern Great Plains Region. Major leasing activities are not expected to occur prior to mid-1982.

Federal regulations, permits and operating standards have become significant factors in the mining industry's planning and development process. Specific information on environmental and institutional issues can be formed in Appendices D and E, respectively.

f. Conclusion

The U.S. coal mining industry is expected to increase coal production substantially during the next decade from 775 million tons in 1979 to about 1.2 billion tons in 1990 .[21] Exports are expected to increase in a similar fashion, from 66 million tons in 1979 to 100 million tons by 1990. At this time, there does not appear to be any insurmountable problems that may cause delays in meeting these projected levels.

Western coal producers, when considering exports, will have to consider the issue of transportation linkages and the port facilities needed to get the coal to market. Most railroad officials believe they can meet the challenge of increased coal movements.[21] The need for the railroads to improve tracks and increase capacity will depend, in part, on the degree to which slurry pipelines can be used economically. Another related factor is the need for coal shipment ports on the U.S. West Coast. At the current time there are the only two West Coast ports that have coal-handling facilities: Long Beach, California and Roberts Bank, British Columbia.[15]

The most likely areas for future coal development in the western conterminous U.S. are the States of Wyoming, Montana, North Dakota and Utah. The DOE estimates that the 1990 production capacity (short tons/year) in these States will be 300.3, 95.9, 58.7 and 43.3, respectively.[39]

APPENDIX D

Alaska State Department of Commerce and Economic Development Draft Permit/Approval Requirements for Beluga Coal Development

BELUGA COAL DEVELOPMENT

— Permits Scenario —

Division of Economic Enteprise
Department of Commerce and Economic Development
October 1979

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LOCATION

The Beluga coal field is located in Southcentral Alaska and is that part of the Cook Inlet Basin which is situated between Cook Inlet and Beluga Lake. It is 60 miles west of Anchorage in the Kenai Peninsula Borough and is located along the southwest margin of the Cook Inlet-Susitna low land.

The Beluga Coal Company (Placer Amex, Inc.) has, for nearly 12 years, conducted geological explorations, exploratory drilling, and various other investigations of the area and have found a large sub-bituminous coal resource. There are three separate fields; however, major emphasis has been placed on the Capps Field which is 25 air miles from the shore of the Cook Inlet.

There are no existing roads to the Beluga coal fields; however, there are two small air strips in addition to the Tyonek landing strip. Helicopters may land virtually anywhere.

Land Status:

The land was orignally leased to Placer Amex (they hold seven State of Alaska coal leases) by the State of Alaska but the land is now (or soon will be) partially under State and partially under Native ownership. (The area covered by the original lease to Placer Amex is still honored by the new landowners.)

On Native lands the Regional Corporation has subsurface rights. The village has surface rights within their local ownership area. In this case, the Tyonek Native Corporation has surface rights and the Cook Inlet Regional Corporation has subsurface and some surface rights. However, the Bureau of Land Management (BLM) has interim management authority over Native lands between the time that the Natives select the lands and receive interim conveyance. For that reason any persons working on Native land should seek approval and assistance from the Native corporation, the village corporation and BLM.

The Bureau of Indian Affaris approved various activities on ~~uses of~~ Indian land. They have a Land Lease Authorization which gives them the opportunity to review and approve land uses and they also have a Right-of-Ways Authorization in order to approve easements and rights-of-ways across Indian land.

Companies wishing to mine coal on State-owned lands are required to obtain a Coal Prospecting Permit from the Department of Natural Resources (DNR). These permits are issued only after approval of the company's plan of operations, which describes the land to be prospected, the equipment to be used, time frames for the operation, and other information as required by DNR. Coal Mining Leases may be issued if coal in commercial quantities is discovered. A mining plan approved by DNR is required before commencement of operations. A Right-of-Way or Easement Permit may be required in some instances, as well as a Mescellaneous Land Use Permit. Use of the tidelands requires a State Tidelands Lease or Permit.

Kenai Borough government has legal jursidiction over the land where a town might be built; their involvement would include reviewing plans for subdivisions, zoning, schools, solid waste disposal and other miscellaneous permits. Roads, railroads, and communication lines may need approval from the Mat-Su Borough, as well as Kenai Borough, if they go through that area.

Any coastal activities or facilities associated with the development of the coal field will need to meet federal consistency and local plans as determined by the Alaska Coastal Management Program.

BELUGA COAL DEVELOPMENT PROJECT

— PERMITS SCENARIO —

ACTIVITY	ACTION	AGENCY
LOCATION	A. STATE	
	1. Coal Prospecting Permit - following approval of plan of operation.	1. DNR
	2. Coal Mining Lease - if commercial quantities are found - must have an approved mining plan before commencement of operation.	2. DNR
	3. Leasing of Land Other Than for the Extraction of Natural Resources.	3. DNR
	4. Tidelands Permit - (one for all purposes of tideland use).	4. DNR
	5. Tidelands Lease	5. DNR
	6. Right-of-Way or Easement Permit	6. DNR
	7. Miscelllaneous Land Use Permit	7. DNR
	B. NATIVE	
	1. Approvals	1. Tyonek Native Corporation Tyonek Native Council Cook Inlet Regional Corporation
	2. Land Lease Authorization	2. BIA
	3. Right-of-Way Authorization	3. BIA
	C. FEDERAL	
	1. Interim Authority Over Native Selected Lands.	1. BLM
	D. LOCAL	
	1. Zoning	1. Kenai Borough
	2. Building Codes	2. Kenai Borough
	3. Railroads, roads, communications lines (according to route location).	3. Mat-Su Borough, Kenai Borough
	4. Subdivision Approval.	4. Kenai Borough
	5. Consistency with Coastal Management Program.	5. Kenai Borough

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MINING OPERATION

Because of the way the coal occurs at Beluga, strip mining is the only possible method for removal of much of the coal. The Federal Office of Surface Mining, Reclamation and Enforcement, now has Strip Mining Regulations which will set guidelines on how the operation will proceed. (The Manager of Mines, Division of Minerals and Energy Management in the Department of Natural Resources should be contacted for State guidelines.) An Environmental Impact Statement or Environmental Assessment may be required as well as provisions for compliance with State and federal water and air quality regulations. Measures to protect anadromous fish streams are mandatory, and withdrawals from all State waters will require a Water Rights Permit from DNR. Provisions for use of materials such as timber or gravel from State lands should be included in the development plan submitted for approval of the mining plan. Timber and other materials would have to be purchased from the State through a material or timber sales contract. A Tidelands Lease or Permit would be required for activities on tidelands and a Miscellaneous Land Use Permit will be required for things such as use of explosives, waste dumps, etc. The Mining Safety and Health Administration (MSHA) has regulations regading safety of operation and equipment. The Alaska Department of Labor supervises some features of that safety program.

Provisions for reclamation are an important part of the application for a mining permit. Inspection and approval of a plan of reclamation and actual reclamation work done at the end of operations are required by the U.S. Department of the Interior and the State Department of Natural Resources. The site should be examinated for archeological artifacts and any excavation of this type on State lands requires a Field Archeology Permit from the Department of Natural Resources. (Results of an antiquities survey will be a necessary subject of discussion in the environmental assessment or Environmental Impact Statement.)

Department of Environmental Conservation approval for the disposal of overburden or other spoil material may be required. Specific plans and methods of operation should be discussed with the department to determine which requirements must be met.

ACTIVITY	ACTION		AGENCY	
MINING OPERATION	A.	Strip Mining Regulations	A.	Dept. of Interior, Office of Surface Mining Reclamation and Enforcement - DNR - State Manager of Mines
	B.	Labor and Equipment Regulations and Safety	B.	MSHA - DNR - DOL
	C.	Air Quality - Mine mouth power plant mining site and processing site.		
		1. Air Quality Control Permit to Operate	1.	DEC
		2. Clear Air Act - PSD	2.	EPA
		3. New Source Performance Standards	3.	EPA
		4. Construction Orders (in process of changing)	4.	DOE
	D.	Water Quality		
		1. Permit to Discharge (surface only)	1.	EPA
		2. Waste Water Discharge (land, subsurface)	2.	DEC
		3. State Certificate (Discharge into Navigable Waters)	3.	DEC
		4. Discharge of Dredged or Fill Material into U.S. Waters	4.	C of E
	E.	Anadromous Fish Protection	E.	DF&G
	F.	Water Rights Permit	F.	DNR
	G.	EIS	G.	CEQ
	H.	Noise Pollution - Equipment	H.	EPA
	I.	Material or Timber Sales - by land ownership	I.	DNR, BLM, Native Corporation, BIA
	J.	Tidelands Permit/Lease	J.	DNR
[illegible] certificate [illegible]	K.	Miscellaneous Land Use Permit - Explosives	K.	DNR
	L.	Reclamation Regulations	L.	DNR and Department of Interior
	M.	Field Archeology Permit	M.	DNR
	N.	Easements (roads, railroad, power, airfield)	N.	DNR (Division of Lands), BIA
	O.	Land Quality		
		1. Solid Waste Disposal Permit (landfill)	1.	~~DNR~~ DEC
		2. Dredge or Fill Activity	2.	C of E

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OVERLAND ROUTE

Overland access for heavy construction equipment will be a necessary prerequisite to commencement of operations. Equipment will be barged to Granite Point, from there it will be driven to the mine site. Another pssibility is a link with an extension of the Alaska Highway System, or an extension of the Alaska Railroad System. Other small roads, and rail transport systems may also be needed. A direct overland route to marine terminal facilities is the most likely form of transportation.

Requirements for both the railroad and highway are virtually the same; however, the railroad will require advice and approval from the Alaska Railroad System, if it is an extension of the present railroad system, and the road will need approval from the Alaska Department of Transportation and Public Facilities.

Both will require easements or right-of-ways from the various land owners along the route. If a bridge or culverted crossing of a waterbody is required, the Corps of Engineers, U.S. Coast Guard (USCG), Department of Fish and Game and Department of Environmental Conservation should be contacted. Gravel sources will require a permit from the owner of the land where the gravel is located. Labor and equipment safety standards are required by MSHA and the State Department of Labor.

Burning of certain materials, or burning during the fire season will require permits from the Department of Natural Resources and the Department of Environmental Conservation (DEC). If pesticides are applied aerially a Department of Environmental Consevation Pesticice Permit will be needed. Oiling of roads on State land will require a Department of Environmental Consevation Surface Oiling Permit.

ACTIVITY	ACTION	AGENCY
OVERLAND ROUTE	A. ROAD	
	1. R-O-W/Easement	
	a. State	a. DNR
	b. Federal/Native	b. BLM/Native Assoc./BIA
	c. Private	
	2. Encroachment on State Highway	2. DOTPF
	3. Gravel Sources	
	a. Miscellaneous Use Permit	a. DNR
	b. Dredging, or Structures in Navigable Waters (State Certificate)	b. C of E (DEC)
	c. Federal/Native Land	c. BLM/Native Assoc./BIA
	d. Material Sale	d. DNR
	4. Highway Construction	4. USDOT (FHWA), DOTPF
	5. Bridge	
*"Navigable Waters" is a legal definition and may include very small streams far inland.	a. Structures in Navigable* Water (State Certificate)	a. C of E (DEC)
	b. Permit for Bridges over Navigable Waters (State Certificate)	b. USCG (DEC)
	c. Anadromous Fish Protection Permit	c. DF&G
	d. Discharge of Dredge Material or Fill Material in U.S. Waters	d. C of E
	6. Air Quality Regulations	
	a. Air Quality Control Permit	a. DEC
	7. Noise Pollution - Equipment	7. EPA
	8. Labor and Equipment Safety Regulations	8. MSHA
	9. Burning Permit	9. DEC and DNR
	10. Pesticide Permit	10. DEC
	11. Surface Oiling Permit	11. DEC
	B. RAILROADS	
	1. Construction Permit and Agreement (extension of Alaska Railroad)	1. Alaska Railroad
	2. R-O-W/Easement	
	a. State Land	a DNR
	b. Native/Federal	b. BLM/Native Assoc./BIA
	c. Private	
	3. Air Quality	
	a. Air Quality Control Permit	a. DEC
	b. Clean Air Act - PSD	b. EPA
	c. New Source Performance Standards	c. EPA
	4. Bridges	
	a. Dredging or Structures in Navigable Waters (State Certificate)	a. C of E (DEC)
	b. Permit for Bridge Over Navigable Waters (State Certificate)	b. USCG (DEC)
	c. Anadromous Fish Protection Permit	c. DF&G
	5. Burning Permit	5. DEC and DNR
	6. Pesticide Permit	6. DEC

PLANE LANDING STRIP

A landing area exists at Tyonek and an agreement may be negotiated with the village in order to use the strip; it has been proposed, however, that a new landing area be built specifically for Beluga operations.

The Federal Aviation Administration (FAA) will require a Notice of Intent to Establish a Landing Strip, and material sources (such as gravel) must be obtained from owners of the material site. FAA also requires an Airport Operating Certificate for airports serving CAB certified, scheduled air carriers. A Miscellaneous Land Use Permit from DNR may be required. MSHA safety requirements must be followed.

ACTIVITY	ACTION	AGENCY
PLANE LANDING STRIP		
	A. Use Landing Area - Tyonek Village	
	1. Approval to use land	1. Village negotiated agreement/BIA
	2. Landing fees	
	B. Build a Landing Strip	
	1. Notice of Intent to Establish an Air Landing Strip	1. FAA
	2. Gravel Sources	
	a. Miscellaneous Use Permit	a. DNR
	b. Federal/Native Land	c. BLM/Native Assoc./BIA
	c. Materials Sale/Land Lease	d. DNR
	3. Miscellaneous Land Use Permit	3. DNR
	4. Noise Pollution - Equipment	4. EPA
	5. Airport Operating Certificate	5. FAA
	6. Safety Requirements	6. MSHA/DOL

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PRESERVATION OF STREAMS AND WATERWAYS

Preservation of the natural quality and life of streams and waterways is an important consideration and for this reason it has been divided out as a specific activity. All phases of development in or near natural water systems must provide for minimizing or alleviating the potential effects of damage that mining operations, as well as roads, railroads, etc., could have on the stream and its inhabitants. Effects of physical disturbance or discharge of pollutants must be controlled and minimized. The plan and environmental statement should address these concerns.

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ACTIVITY	ACTION	AGENCY
PRESERVATION OF STREAMS	A. Anadromous Fish Permit	A. DF&G
	B. Bridges	
	1. Structures and Dredging in Navigable Waters (State Certificate)	1. C of E (DEC)
	2. Permit for Bridges over Navigable Water (State Certificate)	2. USCG (DEC)
	C. Water Rights Permit	D. DNR
	D. Discharge into Water	
	1. Permit to Discharge into Navigable Water NPDES (State Certificate)	1. EPA (DEC)
	2. Discharge into Waters	2. DEC
	3. Discharge of Dredged or Fill Material in Waters of the United States (State Certificate)	3. C of E (DEC)

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CONSTRUCTION CAMP

The basic construction camp will require facilities for housing, cooking, a fresh water source and a temporary means for waste disposal.

Structures will need DEC and DOSH approval while water use and discharge must be in compliance with DEC, DNR and EPA reguations. A Food Service Permit is required from the DH&SS for any food services offered and DEC must approve solid waste handling and disposal.

There may also be some requirements from local authorities for the construction camp and its associated facilities.

The construction plans and specifications for all buildings, i.e., commercial, industrial, business, institutional, other public buildings or residential buildings containing four or more dwelling units must be submitted to the State Fire Marshall (Department of Public Safety) for examination and approval prior to starting construction. These facilities may also require DH&SS and DEC inspection.

ACTIVITY	ACTION			AGENCY	
CONSTRUCTION CAMP	A.	Food Service Permit		A.	H&SS
	B.	Environmental Health Approval (Housing)		B.	H&SS
	C.	Solid Waste Disposal		C.	DEC
	D.	Water Rights Permits		D.	DNR
	E.	Occupancy Building Plan Check		E.	DPS
	F.	Water Discharge			
		1.	Permit to Discharge into Navigable Water - NPDES (State Certificate)	1.	~~EPA~~ (DEC)
2. Waste Water Disposal Permit				2.	DEC
	G.	Drinking Water - Plan Review		G.	DEC
	H.	Air Quality			
		1.	Air Quality Control	1.	DEC
		2.	Clean Air Act - PSD (temporary facilities)	2.	EPA

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DOCK

One reason that mining the Beluga Coal Field might be economically feasible is because if its nearness to tidelands and marine transportation. A corridor to transport the coal over State land to the shoreline will be needed. A Tidelands Permit or Lease is necessary and a Corps of Engineers permit will be required for the approaches over tidelands and dispsoal of dredge spoils to tidelands and for structures in navigable water.

A dock to handle vessels carrying loads of up to 100,000 tons will be required. The tidal conditions are such that there is a need for a high pier or causeway extending out to a dock from an onshore storage and handling facility. The pier would be equipped with a conveyor belt or other continuous loading system.

Fuel storage and general freight handling facilities would help to make this a full service dock. If the facility handles fuel or any materials classified as hazardous or involves ship ballast off-loading pipes, storage tanks and clearing facilities, permits and approvals from USCG and DEC will be required, and a spill plan (SPCC) must be written and stamped by a professional engineer, in order to meet with SPCC regulations.

ACTIVITY	ACTION	AGENCY
DOCK	A. Structures and Dredging in Navigable Waters (State Certificate)	A. C of E (DEC)
	B. Tidelands Permit/Lease	B. DNR
	C. Facilities Handling Petroleum Products	C. DEC
	D. Oil Storage Facilities	D. EPA
	E. Permit for Facilities to Handle Hazardous Materials (State Certificate)	E. USCG (DEC)
	F. Petroleum Products - Request for Assignment of Supplier	F. DOE

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GENERATING POWER PLANT

A generating power plant may be required to operate the mine and coal treatment plant or the mine could supply a coal fired power plant. (Power could also be purchased from the Chugach Electric Beluga Power Plant.) Construction Orders from the Department of Energy, and EPA air quality standards will have to be considered carefully prior to operation.

ACTIVITY	ACTION	AGENCY
GENERATING POWER PLANT	A. Construction Orders (fossil fuel power plants)	A. USDOE
	B. Air Quality	
	1. Permit to Operate	1. DEC
	2. Clean Air Act	2. EPA
	3. New Source Performance Standards	3. EPA
	C. Water Quality	
	1. Cooling water returned disch to system	1. (DEC) EPA
	2. Discharge	2. DEC
	3. Cooling water is addition to or separate from mine source water.	3. DNR
	4. Anadromous Fish	4. DF&G
	5. Permit for Disch of Radionuclides	5. DEC
	6. Storage of fuels - SPCC	6. EPA

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POWERLINES

Overland powerlines will require easements from the various landowners. The FAA requires notice of proposed powerlines routed near airports. A permit is also required by the Corps of Engineers for overhead powerline crossings of a navigable water.

ACTIVITY	ACTION	AGENCY
POWERLINE INSTALLATION	A. R-O-W/Easement	
	1. State	1. DNR
	2. Federal/Native	2. BLM/Native/BIA
	3. Private	
	B. Structures which may Interfere with Airplane Flight Paths	B. FAA
	C. Dredging or Structures in Navigable Waters (State Certificate)	C. C of E (DEC)

ACTIVITY	ACTION	AGENCY
COMMUNITY		
	COMMUNICATIONS:	
	A. Radio and Wire Communications	A. FCC
	B. Structures Which May Interfere With Airplane Flight Paths	B. FAA
	C. R-O-W/Easement	
	1. State	1. DNR
	2. Federal/Native	2. BLM/Native Assoc./BIA
	3. Private	3. ~~Vares~~ Varies
	4. Other	4. Forest Service, Fish & Wildlife, etc.
	UTLITIES	
	A. Public Utilities - Certificate of Convenience and Necessity	A DCED
	B. Air Quality Control Permit	B. DEC
	C. Solid Waste Disposal Permit	C. DEC
	D. Approval by Environmental Health	D. DH&SS
	E. Water Rights Permit	E. DNR
	F. Construction Orders	F. USDOE
	G. New Source Standards	G. EPA
	H. Clean Air Act	H. EPA
	I. Plan Review	I. DEC
	J. Hazardous Materials	J. DEC
	K. Plan Review	K. DPS
	L. Permit to Discharge into Water (State Certificate)	L. EPA (DEC)
	M. Sewage System and Treatment Plant	M. DH&SS, DEC
	N. SPCC spill plan for storing fuel in large quantities	N. EPA
	O. Local Requirements	O. Borough
	SCHOOLS	
	A. School Construction	A. Doe
	B. Public Safety Plan Review	B. DPS
	C. Environmental Health Approval	C. H&SS
	D. Food Service Permit	D. H&SS
	E. DEC Plan Review	E. DEC
	F. Local Requirements	F. Borough
	MEDICAL SERVICES	
	A. Medical Facilities Construction	A. H&SS
	B. 1122 Review and Certificate of Need	B. H&SS
	C. Licensing	C. H&SS
	D. Public Safety Review	D. DPS
	E. Environmental Health Approval	E. H&SS
	F. Food Service Permit	F. H&SS
	G. Plan Review	G. DEC
	H. Accreditation of Hospitals	H. JCAH
	I. Local Requirements	I. Borough

ACTIVITY	ACTION	AGENCY
	POLICE AND FIRE PROTECTION	
	A. Environmental Health Approval	A. H&SS
	B. Food Service Permit	B. H&SS
	C. Public Safety Plan Review	C. DPS
	D. DEC Plan Review	D. DEC
	E. Local Requirements	E. Borough
	HOUSING	
	A. Subdivision Plan Review	A. DEC
	B. Approval by Environmental Health	B. H&SS
	C. Safety Plan Check	C. DPS
	D. Subdivision Approval	D. Kenai Borough
	E. Local Requirements	E. Borough
	RESTAURANTS, TAVERNS, HOTELS AND ENTERTAINMENT	
	A. Plan Review	A. DEC/DPS
	B. Environmental Health Approval	B. H&SS
	C. Tourist Accommodations	C. H&SS
	D. Food Service Permit	D. H&SS
	E. Liquor License	E. DOR
	F. Restaurant Deisgnation	F. DOR
	G. Alaska State Business License	G. DOR
	H. Zoning	H. Borough
	I. Other Local Requirements	I. Borough
	SERVICE STATIONS	
	A. DEC Approvals	A. DEC
	1. Plan Review	
	2. Hazardous Materials - Certificate	
	B. Petroleum Products Suppliers	B. USDOE
	C. Environmental Health Approval	C. H&SS
	D. Plan Review	D. DPS
	E. Alaska State Business License	E. DOR
	F. Zoning	F. Borough
	G. Other Local Requirements	G. Borough
	COMMERCIAL SHOPS	
	A. Plan Review	A. DEC
	B. Environmental Health Approvals	B. H&SS
	C. Reserve Business Name	C. DCED
	D. Register Business Name	D. DCED
	E. Articles of Incorporation	E. DCED
	F. Commodities and Measuring Devices	F. DCED
	G. Weighing and Measuring Devices	G. DCED
	H. Plan Check	H. DPS
	I. Alaska State Business License	I. DOR
	J. Borough Tax Permit	J. Borough
	K. Zoning	K. Borough
	L. Local Requirements	L. Borough
	PLANNING	
	A. Local and State planning assistance	A. Kenai and Borough and DC and RA

In its Draft Environmental Impact Statement concerning its proposed Solvent Refined Coal II Demonstration Project at Ft. Martin, West Virginia (DOE/EIS-D069-D, May 1980, pps. 1-15 to 1-16) the Department of Energy has identified the following major federal and state permits and approvals required for construction and operations of the SRC facility.

ble 1.1 Major permits and approvals required for construction

ermit/Approval	Responsible Agency	Remarks
inal Environmental tatement	DOE	Required 30 days prior to commitment to construction
ir		
Prevention of significant deterioration determination	EPA/State	
Permit to construct air contaminant source	State	
Water		
NPDES permit for construction discharges	EPA/State	Authority may be delegated to State
State permit for construction discharges		May be combined with NPDES permit if authority is delegated to State
Permit for construction in navigable waters	Corps of Engineers	Required prior to construction in navigable waters. FES required prior to issuance.
Solid Wastes		
Permit for construction waste disposal site	State	

Table 1.2 Major permits required for operation

Permit/Approval	Responsible Agency	Remarks
Air		
Operating permit	State	Based on compliance with conditions specified in construction permit and PSD determination.
Water		
NPDES permit	EPA/State	Limitations on process discharges will assure compliance with water quality standards.

		However, there are no specific standards for SRC process materials.
.te discharge permit	State	Probably will be incorporated in NPDES permit if NPDES authority is delegated to State.
id Wastes		
source conservation .d recovery act :rmit	EPA/State	Specification for disposal facilities and leachate treatment based on hazard as determined by tests now under development.
tate permit	State	Probably will be incorporated into RCRA permit program.

Department of Energy
Oak Ridge Operations
P.O. Box E
Oak Ridge, Tennessee 37830

Oak Ridge National Laboratory
ATTN: S. D. DeCicco
Energy Division
Post Office Box X
Oak Ridge, Tenn. 37830

Dear Mr. DeCicco:

SCHEDULE FOR PROCUREMENT OF ENVIRONMENTAL PERMITS FOR SRC-II

The following information should be included in the Draft Environmental Impact Statement for SRC-II. It reflects P&M's latest projections of construction and operation schedules:

Environmental Protection Permits Required by the United States Environmental Protection Agency

1. Prevention of Significant Deterioration (PSD)

This is a required preconstruction and preoperational review of the air emissions expected from the operating facility to insure that ambient air quality in the area of the proposed SRC-II plant will not be incrementally degraded below applicable standards. The PSD application information provided to the Region III office of U.S. EPA will be used to conduct a computer analysis of the atmospheric dispersion of the SRC-II plant emissions. Region III will consider emissions from other existing or proposed sources in the area in conducting this analysis. The PSD permit, granted by EPA after a negative finding of significant deterioration, must be received prior to the start of construction. The SRC-II PSD application was submitted to Region III on May 1, 1980, and the PSD permit is expected by October 1, 1980.

2. National Pollutant Discharge Elimination System (NPDES) for SRC-II Construction

The application for this water discharge permit must be submitted to U.S. EPA Region III at least 180 days in advance of site runnoff expected to be significantly affected by construction activities. The application is scheduled to be submitted by July 31, 1980.

3. National Pollutant Discharge Elimination System (NPDES) for SRC-II's Sewage Treatment Plant

This application must also be submitted 180 days before the first discharge occurs. Based on current schedules for the sewage plant's construction, the application will be submitted no later than July 1, 1981.

4. National Pollutant Discharge Elimination System (NPDES) for Water Intake Back Flushing Discharge

Water withdrawal to the project site will be required by October 1, 1982. This permit application will be submitted no later than April 1, 1982.

5. Resource Conservation and Recovery Act (RCRA) Permits

These permits are expected to be required of all entities involved in the generation, transport, treatment and disposal of hazardous wastes. Since EPA's final implementing regulations for RCRA have not yet been promulgated, no permit procurement schedule dates can be specified at this time.

Environmental Protection Permits Required by the United States Army Corps of Engineers:

1. Section 10 and Section 404 Dredge and Fill Permit for Construction in a Navigable Waterway

This permit will be required for the construction of the water intake structure, the construction phase barge slip, and the coal barge dock. The permit application will be submitted approximately six months in advance of the projected construction start date for these facilities.

Environmental Protection Permits Required by the State of West Virginia

1. Air Pollution Control Commission Permit to Construct, Modify or Relocate Air Pollution Source

These permits must be acquired prior the start of plant construction. Permit applications are scheduled to be submitted on May 1, 1980.

2. <u>Department of Natural Resources Water Pollution Control Permit Sewage Plant Discharges and [illegible]</u>

   This permit must be obtained prior to discharge. The scheduled application date is April 1, 1981.

3. <u>Department of Natural Resources Water Pollution Control Permit for Sanitary Landfill</u>

   The onsite landfill will be needed by April 1, 1982. The application is scheduled for submittal no later than December 1, 1981.

4. <u>Department of Natural Resources Certificate of Approval for Dam</u>

   Application will be submitted no later than December 31, 1981 for all SRC-II Plant structures subject to this permit criteria.

5. <u>Department of Health Permit to Construct a Sewage Treatment Plant</u>

   This permit application will be submitted on or before August 31, 1980.

6. <u>Department of Health Permit to Operate a Sewage Treatment Plant</u>

   This permit application will be submitted on or before November 31, 1981.

7. <u>Department of Health Permit to Construct a Potable Water Supply System</u>

   This permit application will be submitted on or before December 31, 1981.

8. <u>Department of Health Permit to Operate a Potable Water Supply System</u>

   This permit application will be submitted on or before May 31, 1984.

P&M has identified several other permit and licensing requirements; e.g., construction notification to FAA, insurance approvals, power agreements, etc., but none of these appear to relate to environmental protection matters. If you believe we may have overlooked anything, please let me know. My extension is 6-0349.

Sincerely,

J. K. Alexander
Environmental Protection Branch
Safety and Environmental
Control Division

MS-331:JKA

CC:
C. R. Moxley, P&M/Denver
R. Hindelister, P&M/Denver
J. Nardella, ET/HO
J. Realsnyder, SR-70

In its December 1978 report to the 46th Legislature of Washington State concerning LNG and LPG hazards management, the Oceanographic Commission of Washington identified the following Federal agency controls over facility siting and transportation.

TABLE ES-1

FEDERAL AGENCY CONTROLS OVER LNG AND LPG
FACILITIES AND TRANSPORTATION

Note: This summary is current as of the publication date. It is expected that the 96th Congress will consider legislation that could significantly extend federal jurisdiction over LNG and LPG transport and facility siting.)

AGENCY	STATUTORY AUTHORITY	PROCESS	CONCERNS
Department of Energy including Federal Energy Regulatory Commission and Economic Regulatory Administration (LNG)	Department of Energy Organization Act of 1977; Natural Gas Act of 1938; NEPA	Certification or approval: by Secretary for §3 (imports and exports); by FERC for §7 (interstate commerce)	Meeting federal safety regulations prescribed by MTB; Environmental effects, via (1) EIS, including risk analysis, and (2) environmental guidelines concerning aesthetic, recreational, historical, archaeological, fish, wildlife, and landscape values; Economic effects, including gas pricing and market control; Consistency with state and local land use, zoning, energy and other laws
Department of Transportation, Materials Transportation Bureau (LNG and LPG)	Natural Gas Pipeline Safety Act of 1968; Hazardous Materials Transportation Act	Inspection of facilities before and during operations (Washington Utilities and Transportation Commission is responsible for enforcement of pipeline regulations)	Safety on land through fire hazard regulations such as set back, diking, back-up systems and the safety of related facilities; regulation of pipeline facilities (natural gas)

TABLE ES - 1 (cont.)

AGENCY	STATUTORY AUTHORITY	PROCESS	CONCERNS
tment of Transtion, Coast and LPG)	Ports and Waterways Safety Act of 1972 (including 1978 amendments); Executive Order 10173; Dangerous Cargo Act; Magnuson Act	Inspection of vessels during construction or upon entry into U.S. waters; Issuance of Letter of Compliance or Certificate of Inspection (good for two years); Restriction and regulation of vessel movement; Inspection of waterfront facilities and facilities operations; and Hazard containment, prevention and control	Safety at sea: design and construction personnel navigation, safety, pollution control equipment cargo stowage vessel traffic control Safety at waterfront facilities: proper securement of vessels for cargo transfer proper communication between vessel and terminal during transfer safety equipment and procedures at facility personnel qualifications
partment of Army, rps of Engineers NG and LPG)	Rivers & Harbors Act; Fish & Wildlife Coordination Act; NEPA; Federal Water Pollution Control Act Amendments of 1972	Permit for activities affecting navigable waters; EIS for major and significant actions; Comments from NOAA, U.S. Fish & Wildlife Service, EPA and state and local agencies	Environment; Economics; State and local wishes; "Overall public interest".

APPENDIX E

New Techniques for Utilizing and Transporting Coal

When discussing the viability of developing and marketing a new resource, it is important to examine on-going research related to that resource. In this case, we discuss the current state-of-the-art for the following: synthetic fuels development from coal, coal transportation, and industrial use of coal. This appendix considers those techniques within each of the above groups that are considered to have both near-term commercialization potential and applicability to Alaska coal. Also, general information is presented as it is beyond the scope of this report to exhaustively examine each technology. In most cases, however, references are provided that enable interested readers the opportunity to pursue a particular subject in detail.

An obvious technology excluded from this report is underground coal gasification (in-situ). It was excluded for the following reasons: coal resources addressed in depth are mineable by surface mining techniques, and in-situ gasification has not been commercially demonstrated in the U.S., thus is probably not a viable technology to consider in the near-term (1986 or before).

All prices appearing in this Appendix have been escalated from their original source to 1980 dollars using the Producers Price Index--All Commodities published by the Bureau of Labor Statistics.

1. Synthetic Fuels Development

Synthetic fuels development from Alaska coal is a particularly relevant issue. In the past, Alaska coal has often been overlooked as a potential energy source because of its distance to markets and its often high ash and moisture content. By converting to a synthetic product this situation could change.

This section discusses those processes currently being examined for utilizing coal either to produce a liquid, gas or solid product. Generally, most coal conversion processes are designed to utilize coal with a specific range of characteristics (i.e. ash content, moisture, sulfur, and agglomerating properties, etc). In order to assess the feasibility of using Alaska coal in any of the following processes below it would be necessary to perform a detailed engineering analysis. This is beyond the scope of this report.

This section is intended to describe the state-of-the-art on several of the most promising techniques that could be viable within this decade.

a. Coal Liquefaction

Coal liquefaction is the conversion of coal from a solid to a liquid. The DOE supports several coal liquefaction processes that are in the pilot plant stage. The complex chemistry involved in these processes is only now beginning to be fully understood. Although there are generic problems that must be solved before liquefaction can be successfully commercialized, these problems are being aggressively pursued and are in various stages of analysis. The construction and operation of large pilot plants, expected during the next few years, should provide important data that can be used to address areas of concern.

This report limits its review to the three liquefaction processes receiving the most research attention from DOE. They are the: (1) Solvent Refined Coal (SRC) Process, (2) Ebullated Bed Catalytic Hydrogeneration (H-Coal) Process, and (3) Exxon Donor Solvent (EDS) Process.

(1) Solvent Refined Coal (SRC) Process

The SRC process, which began in 1962, is the oldest coal conversion process study in terms of continuous government support. It has moved through a successful pilot plant phase and is now in the initial phase of a major demonstration plant activity. The experience that is being gained in the process will be useful in other direct coal liquefaction processes.

Initially, the SRC process was conceived as a process which removed ash and sulfur from coal and produced a solid, high BTU product. The initial process is designated as SRC-I to distinquish it from the more recent liquid product process, SRC-II. The solid SRC-I product has been tested extensively at both the 6-ton per day (TPD) pilot plant at Wilsonville, Alabama and at the 50 TPD pilot plant at Fort Lewis, Washington (SRC-I is discussed in more detailed in Section C).

The Fort Lewis pilot plant has been operating in the liquid fuel mode (SRC-II) since May, 1977. Four different bituminous coals have been used in the plant. A large batch (4500 barrels) of product was used in a successful burn test at a Consolidated Edison power plant in New York City. Environmental standards were met during the test firing making the product appear promising from a marketing standpoint.

Since SRC-II has been studied at the pilot plant scale and the synthetic fuel has been tested to successfully show basic fuel utility, DOE is proceeding with activities to scale up to commercial equipment size in a demonstration plant project. In July 1978 DOE awarded contracts for the preparation of a conceptual commercial plant design and cost estimate for both the SRC-I and SRC-II processes. These have been completed and DOE is funding the detailed design phase. Results from the conceptual plant design report indicate that a 30,000 TPD plant could be constructed in 42 months with a peak labor force of 5,400 and an operating force of 500.

According to recent estimates the planned SRC-II facility will require a capital outlay of over $1.6 billion to construct and have an annual operating expense of $418 million.[13] The derived price for fuel produced is estimated to be about $4.70 per 10^6 BTU which equates to approximately $28.22 per barrel oil equivilent.

In a study done for ERDA in 1974-1975, the Stanford Research Institute (SRI) examined the possibility of locating a 100,000 barrel per stream day (approximately 20 million tons/yr of Beluga coal) SRC plant on the north shore of Cook Inlet. Although the report is dated 1976 and much has been learned since then, some of the information presented and the conlusions drawn from their analysis still apply.[10] One of the major conclusions of the study was that a SRC product from Beluga coal could not penetrate the Pacific Rim market place, primarily due to cost.

The report indicated that the delivered price of SRC fuel would be in the range of $5.74 to $6.04 per million BTU in both California and Japan. With the tremendous increases in the world price of oil since 1975, the economic viability of an SRC facility could now be more attractive. Some other conclusions brought out in the SRI study are:

- The capital investment for a 100,000 barrel/day SRC plant in Alaska is about $1.8 billion for a solid product, and slightly less to produce a liquid product.
- A variation of $1.00 per short ton in the coal price causes a variation of about $0.55 per barrel in the revenue required from the sale of a liquid product (8 cents per million BTU).
- A variation of 10% in capital investment causes a change of $1.70 per barrel in the revenue required from the sale of total liquid product (25 cent per million BTU).

It is apparent that the SRC process has the potential of becoming a mid-term (1990-2000) method for converting Alaska coal into clean export fuels. An accurate estimate of the costs for constructing and operating a SRC plant will be available when the conceptual commercial plant is underway.

(2) Ebullated Bed Catalytic Hydrogeneration (H-Coal) Process

The development of the H-Coal process has also been underway since 1962. Although some government support was involved earlier in the process development, the major DOE funding effort began in 1974. The H-Coal pilot plant is under construction in Catlettsburg, Kentucky. It is expected to be completed in the fall 1980, and ready for two years of full testing. The plant will be capable of converting up to 600 TPD of coal into boiler fuel or synthetic crude oil.

Basically, the H-Coal process is a catalytic hydroliquefaction process that converts high-sulfur coal to boiler fuels and synthetic crude. The specific operating conditions of the H-Coal process affect the type of final product. For example, to produce synthetic crude, more hydrogen is required and there is a lower yield of residual oil. To produce clean fuel and low-sulfur residual oil as major products, lower temperatures and pressures and less hydrogen are required in the reactor.

Although the H-Coal process is promising, it will be several years before a demonstration-size plant may be constructed. The decision for constructing a demonstration size facility will be made after data have been collected and evaluated from operating the pilot plant.

Therefore, for the purposes of this report we do not consider the H-Coal process to be viable before the mid 1990's.

(3) Exxon Donor Solvent (EDS) Process

This process has been pursued by Exxon for well over 10 years. In 1977, after Exxon had completed the process definition and small scale process studies, a cooperative agreement was signed by Exxon and DOE to construct a pilot plant. Since that time a 250 TPD pilot plant was constructed in Baytown, Texas. The plant began start-up operations on June 24, 1980, and is scheduled for a 2-1/2 year operating period during which time data will be collected to determine the specification for a demonstration-size facility.

Basically, the EDS process involves liquefying crushed coal in a non-catalytic tubular reactor in the presence of molecular hydrogen and a hydrogen donor solvent. The process gives a high yield of low-sulfur liquids from bituminous or subbitumnious coals or lignites. For an Illinois bituminous coal for example, the liquid yield is 2.6 barrels of liquid per ton of dry coal. Ammonia and elemental sulfur are the only by-products of major significance.

The EDS process, like the H-Coal process, is promising. Before it is possible to give accurate information on the viability of the EDS process pilot plant, operating data, currently being collected, needs to be analyzed and evaluated. The next step after the pilot plant would be a demonstration facility in which commercial size equipment would be evaluated. The decision on constructing a demonstration facility will be made after two or more years of pilot plant data have been evaluated.

It appears that the EDS process is still several years away from commercial application. It is considered, for the purposes of this report, to be commercially viable at about the same time frame as the H-Coal,i.e. not before the mid 1990's.

b. Coal Gasification

The process of making gas from coal is not a new technology. Familiar processes such as Lurgi, Koppers-Totzek and others have been used for years in making gas from coal. However, these first-generation processes typically have very low efficiencies and have associated pollution problems. Major research activities are now centered on second and third generation systems.

The second generation systems are the result of the attempt to couple new engineering know-how with a knowledge of modern concepts of coal chemistry and improvements in engineering and materials science to achieve an improved process. Representative systems classified as second generation are: (CO_2 Acceptor; HYGAS; Synthane; BiGAS; etc.). Most of these processes have advanced to the pilot plant stage.

Third generation coal gasification is defined as that technology which has not yet advanced to the pilot plant stage of development. Systems which are considered third generation include such evolving concepts as Rockwell International Corporation's Flash hydropyrolysis system, Exxon's Catalytic gasifier and Bell Aerospace's High Mass Flux system. These new concepts are taking advantage of new development in catalysis and rocket technology to achieve the objectives of this class of gasifiers.

The type of gas produced from coal gasification systems are generally subdivided by their gross heating value into low, intermediate, and high BTU gas systems. The high BTU gas system (950-1000 BTU/CF) is also referred to as synthetic natural gas (SNG) and can be distributed to customers in the same pipeline system now used to carry natural gas. Low-BTU gas (up to 350 BTU/CF) is generally considered to be economically viable only if used on site, and is not further considered in this study. Both high and low-BTU gasification processes are being developed with DOE assistance. The High-BTU Gasification program is discussed below.

High - BTU Gasification

The U.S. Department of Energy together with the American Gas Association is sponsoring the development of several high-BTU advanced conversion processes. Although the basic chemical reactions are the same for each of the processes, they each have their own unique characteristics. There are, for example, important differences in reactor design and methods for supplying heat to the reactor. Also, all of these processes require high temperatures and pressures and produce corrosive gases necessitating the concurrent development of resistent alloys and new pressure vessel design.

The High-BTU Gasification program has several systems which have reached the pilot plant stage. Contracts for designing, constructing and operating the pilot plants have been awarded to Rockwell International Corporation for the Short Residence Time Hydrogasification; Bitumimous Coal Research, Inc., for the BiGAS pilot plant in Homer City, Pennsylvania; Institute of Gas Technology for the HYGAS and steam-iron system for the production of hydrogen in Chicago, Illinois; and the Lummus Company for the Synthane pilot plant in Allegheny County, Pennsylvania.

The status on all of these projects and others can be found in several publications.[1, 36] It appears that large commercial size coal gasification facilities are still several years away and are not considered to have near-term viability for the purpose of contributing to the development of Alaska coal.

Capital cost for a plant producing 250 million cubic feet of SNG per day range from 1.6 to 2.6 billion dollars producing SNG at \$3.90 to 6.70 per million BTU.[21] The construction period for a typical SNG plant is estimated to be about five to seven years.

c. Solid Coal Conversion Process

(1) Solvent Refined Coal (SRC-I)

The SRC process, as described in Section a., can be designed to produce either a liquid product (SRC-II) or a solid product (SRC-I). The SRC-I process is a solvent extraction procedure that converts coal to a solid product with less moisture, ash and sulfur and with a correspondingly higher energy content per pound. The solid product has a melting point at 150-200° C.

Two pilot plants have operated successfully, a 50 TPD plant at Fort Lewis, Washington and a 6 TPD plant at Wilsonville, Alabama. Typical product properties are shown below.[29]

	RAW Coal	SRC-I Product
Volatile Matter	38.7	36.5
Fixed Carbon	51.7	63.0
Ash	7.1	0.5
Moisture	2.	0.0
	100.0	100.0
BTU/Pound	12,821	15,768

Although the above data are not for an Alaska coal sample, similar trends in ash, sulfur and moisture reduction would occur.

DOE is proceeding with plans to construct a 6,000 TPD demonstration plant. Thus, it appears that the technology is developing rapidly to the stage where it will be commercially viable. SRC-I product has already been successfully fired in a direct-fired furnace.

2. Methanol Production

Methanol production from coal is a technology that has potential application in Alaska. Methanol is considered to be an excellent fuel for power plants and as an additive to gasoline.[29] It is clean burning, has no sulfur and produces lower NO_x than natural gas, and emits no particulate matter. A previous study concluded that methanol is an excellent fuel for use in California power plants.

Methanol can be synthesized by the catalytic reaction of synthesis gas produced by any one of a number of commercially available coal gasification processes (first generation processes as described in section b.). The commercial-scale production of methanol has been practiced in many countries for many years using primarily Koppers-Totzek, Lurgi and Winkler gasifiers.

Various studies have examined the large-scale conversion of coal to methanol via coal gasification. Generally the studies indicate that the efficiency of the energy recovery of coal-to-methanol is about 40-50%, depending on the efficiency of the gasification process.[20] A commercial-scale plant processing about 15,000 TPD of coal will produce about 7,500 TPD on methanol.

An analysis of the potential of using Alaska coal in California performed by Lawrence Berkely Laboratories states that a major barrier to increased methanol use in California is the projected delivery price. The study lists a wide range of values that have been projected for the future cost of methanol from coal. Early estimates ranged from $5.05-6.74 per million BTU to over $11.40 per million BTU.[29] A large part of the cost is associated with the large capital investment required to build a plant, particularly in Alaska.

The cost for constructing a plant in Alaska is not known for sure; however, SRI calculated it would cost 30% more to build a plant in Alaska than on the U.S. Gulf Coast.[10] For ball park estimates Du Pont projected the cost of a 5,000 TPD methanol plant at Pittsburg, Pennsylvania would have a capital cost of $805 million and produce methanol for $10.00 per million BTU.[24]

Costs could perhaps be better controlled by construction of much of the plant on the West Coast of the United States, and transported in modular fashion, on barges, to Alaska. This was done for some of the North Slope petroleum facilities, and for the large combination power plant/pulp mill that was constructed in Japan and transported by barge in 1978 to the Jari River area in Brazil.

2. Transport of Coal

This section looks briefly at maritime and slurry transport of coal. Innovations in these two transportation modes are important factors in determining the economics of coal development.

a. Maritime Transportation

During the last decade the most significant development relative to overseas transport of coal has been the increase in the capacity of bulk carriers for ocean transport.

The largest now being used are 120,000 deadweight tons (DWT). Transportation of coal in inland and coastal waterways is being accomplished with barges and small ships, which can be self unloading.

As the world coal exports from various coal producing countries continues, the trend is toward larger capacity coal carrying ships. There will be size limitations on specific routes; however, due to physical constraints such as those imposed by the Panama Canal maximum size is approximately 60,000 DWT. Other size-limiting constraints are those of port facilities and depth of ports, particularly of eastern U.S. ports which limit the size of coal-carrying ships to about 85,000 DWT. The largest vessels used in coal trade have been between Australia and Japan where vessels up to 150,000 DWT have been reported. A gradual increase in average ship size is expected for many of the world coal trade routes. A maximum size of 200,000 DWT has been estimated for coal trade by the year 2000.[21]

b. Slurry Pipelines

Coal slurry pipelines are being given serious consideration in moving coal from the mine to its destination. The technology for coal slurry movement of coal is known and is being implemented in several areas.

For instance, in the southwestern U.S. a 273-mile coal slurry pipeline has transported 4 million tons of coal each year since 1970 between a mine in New Mexico and a powerplant in Arizona.

Slurry pipelines need approximately one ton of water for each ton of coal thereby restricting them to use in areas with adequate water supply. Disposal of dirty water after the coal has settled out presents considerable environmental problems. Another impediment to their use are the legal problems associated with obtaining right of way. The issue of granting pipeline companies the power of eminent domain is now being considered by Congress.

The costs of slurry pipelines are highly "route specific." A study on the economic viability of slurry pipeline versus unit trains found that where distance is greater and terrain is less difficult, than pipelines were cheaper.[21] In their analysis of a hypothetical route from Wyoming to Texas, they found that slurry pipeline costs were considerably lower than rail transport ($5.90/ton compared to $8.70/ton, in 1975 dollars).

3. Industrial Use of Coal

There has been considerable research during the last several years on improvements in and more environmentally acceptable ways of burning coal.

Two of the technologies which have reached the stage where they are considered by DOE as being ready for commercialization in the industrial sector are Fluidized Bed Combustion (FBC) and Coal-Oil Mixtures (COM). They are briefly discussed below.

a. Fluidized Bed Combustion (FBC)

Fluidized Bed Combustion (FBC) offers both the industrial and utility sectors a superior method of coal combustion. The basic principle of FBC consists of burning coal in a bed of non-combustible material, such as limestone. The bed is maintained in fluidized condition by the incoming combustion air, and coal is introduced above, below or directly into the bed. The advantages of FBC are reduced sulfur emmissions and, because of its lower burning temperature reduced, nitrogen oxides levels. Also, particulate matter is coarser and easier to collect. These characteristics make FBC, in general, more environmentally benign than conventional coal burning techniques.

The operation of coal-fired units have been successfully demonstrated in both the U.S. and overseas. In addition to numerous pilot-scale experiments throughout the world there are several demonstration-scale facilities. An 8 MW^e power plant in Rendrew, Scotland has operated as a prototype and test unit and has demonstrated 90 percent SO_x retention.

Other plants include: a 30 MW_e unit at Riversville, West Virginia; a 80,000 lb/hr. steam plant in Enkoping, Sweden; and a facility under contruction at Grimethorpe, England. Also, in the U.S., Johnston manufacturing has operated a 10,000 lb hr. FBC plant, since 1977 has been producing and is marketing commercial scale FBC boilers based on results from their operation.

In general, capital cost of a FBC unit appears to be about 15 percent less than a conventional boiler and scrubber, and projected steam-production costs may be 0-10 percent less than conventional units using the same fuel.[19] Recent capital costs estimates are $620/KW for FBC power plants and production costs of about 3.2 cents per KW/hr.[21] A construction period of about 6 years would be required.

b. Coal/Oil Mixtures (COM)

A Coal/Oil Mixture (COM) is a slurry-like mixture of pulverized coal and oil. The mixture has the potential for being burned as a liquid in oil-fueled furnaces. Typically, the mixture is 50 percent coal and 50 percent oil by weight. Increased fuel oil prices and uncertainty of steady supply make COM an attractive alternative for utility and industrial users.

It has been demonstrated that COM can be burned in existing boilers and blast furnaces for limited periods of time; however, long term operation has yet to be demonstrated.[18] There are some problems associated with using COM that are being addressed, such as, product stability (coal should not settle out too rapidly) erosion/corrosion (erosion on pumps and other equipment) and environmental (small fly ash particles by-pass collection systems). These problems are being actively pursued and are not expected to be a constraint to rapid development. DOE has estimated that COM could be available for commercialization as early as 1981[38].

The major market for COM is anticipated to be conversions of existing industrial and utility boilers. Conversions to COM from oil will require capital outlay for such new items as, burners, ash removal equipment, and pollution control equipment. Estimates of these capital costs, in 1980 dollars, are approximately \$99,500/MW_e for a 100 MW size facility and \$75,500 /MW_e for a 400 MW size plant. Operation and maintenance expenses would also increase due primarily to the higher viscosity and ash content of the COM. Increased costs are expected to be offset by lower fuel costs.[18]