FEASIBILITY STUDY OF MINING ALASKA COAL AND TRANSPORTATION BY SLURRY TO THE WEST COAST

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By

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16. Abstract
The extensive subbituminous coal deposits near Cook Inlet, Alaska, have received considerable attention because of their size, nearness to tidewater, and low sulfur content. As the need for increased electrical power is felt along the West Coast, a search is being made for sources of fuel other than petroleum and natural gas. The State of Washington is the only Pacific Coast State with substantial coal resources, but because of geologic setting, much of this resource will be available only at high cost. Reflecting these circumstances, if coal is to be used as a source of electrical energy, it may have to be transported from the Northern Great Plains or Rocky Mountain areas or from more remote sites if they happen to be located at or near tidewater. It is this latter situation that is represented by Cook Inlet coal since it lends itself to relatively cheap ocean transport and hence is potentially economically competitive with coal that must be brought to the West Coast by overland transport.

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FOREWORD

by

Robert S. Warfield 1/

This report was made possible through a Bureau of Mines grant to the University of Washington's Department of Mining, Metallurgical, and Ceramic Engineering to determine the technical and economic feasibility to mine Alaska's Cook Inlet coal and transport it to the West Coast at a delivered cost per Btu that will compare favorably with alternate sources of coal and other available fossil fuels. Research was conducted by a graduate student in 1976, resulting in completion of the requirements for a Master of Science degree in Mining Engineering. The Master's Thesis, "Cook Inlet Coal: Economics of Mining and Marine Slurry Transport," is a significant part of this open-file report and follows the contractor's final report, "Feasibility Study of Mining Alaska Tidewater Coal and Transportation by Slurry to the West Coast," a condensed version of the thesis.

The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies and recommendations of the Interior Department's Bureau of Mines or the U.S. Government.

1/ Mining Engineer, Alaska Field Operations Center, and Technical Project Officer for Bureau of Mines Grant G0264012.

PART I

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U.S. Bureau of Mines
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Juneau, Alaska 99802

Attention: R. S. Warfield, Technical Project Officer
Grant No. GO 264012

Subject: Final Report
Grant No. GO 264012

Project Title: Feasibility Study of Mining Alaska Coal and Transportation by Slurry to the West Coast

General:

This final report covers work done over the period January 1, 1976, to December 31, 1976. Mr. David Brian Hennagin completed the requirements for a Master of Science in Mining Engineering based on his work on this particular project. The thesis is entitled "Cook Inlet Coal: Economics of Mining and Marine Slurry Transport," a copy of which is here included.

Insofar as the final report, with some modification, is a condensation of the thesis, reference should be made to that publication for details referred to in this report.

Abstract:

The extensive subbituminous coal deposits near Cook Inlet, Alaska, have received considerable attention of late principally because of their size, nearness to tidewater, and low sulfur content.

As the need for increased electrical power is felt along the West Coast, a search is being made for sources of fuel other than petroleum and natural gas. The State of Washington is the only Pacific Coast state with substantial coal resources, but because of the geologic setting, much of this resource will be available only at high cost.

Reflecting these circumstances, if coal is to be used as a source of electrical energy, then it may have to be transported from the Northern Great Plains or Rocky Mountain areas or from more remote sites if they happen to be located at or near tidewater. It is this latter situation that is represented by Cook Inlet coal since it lends itself to relatively cheap ocean transport and hence is potentially economically competitive with coal that must be brought to the West Coast by overland transport.

Findings:

This particular study indicates that:

1. Coal can be surface mined in the Beluga area about 15 miles from tidewater.

2. Washed and prepared as a coal-water slurry.

3. Transported to tidewater as a slurry through a 30-inch diameter pipeline.

4. Loaded directly aboard an ocean transport prepared to carry coal slurry.

5. Transported to the inland waters of Washington State.

6. Unloaded as a slurry at a site in the Straits of Georgia and pumped to a steam-electric plant.

7. Delivered at the generating plant for a cost of $21.15 per short ton or $1.32 per million B T U based on 1975 costs and a 15% D.C.F. See Table 4 and Fig. 5.

Physical Setting

The Beluga coal field lies some 50 miles west of Anchorage across Cook Inlet. Although other areas have been investigated and show extensive coal resources, the zones that have received the most attention and about which more is known are referred to as Capps and Chuitna, about 15-20 miles from tidewater. See Figs. 1 and 2.

Communication from Anchorage is effected by small plane (or helicopter) to a landing strip in the general area, thence by track vehicle over logging roads or by foot as required. A potential water transport route stretches from Anchorage to a dock at Tyonek or by barge direct to North Foreland, thence overland as described.

Chuitna is situated on a plateau about 1500 feet in elevation, and much of the coal is above timberline and overlain by open lands and tundra.

Climatic conditions in winter are moderate to severe with temperature variations similar to that experienced by Minnesota.

Geologic Setting

Coal beds embraced by the study are contained within relatively young gently-dipping formations that extend to the southeast towards Cook Inlet. Much of the coal is strippable with overburden consisting of soft siltstones with some unconsolidated sand and gravel.

Coal Quality

Beluga coal is classified as subbituminous with a heat value of about 7550 B T U on an as-received basis. Average quality of the coal is reported at:

Table 1

	As-Received	Dry
Moisture	28%	-
Ash	10	13
Volatile Matter	32	44
Carbon	30	43
Sulfur	0.15	0.2
B T U	7550	10500

It is apparent that contained moisture is moderately high, which raises the question of spontaneous combustion upon conventional storage and shipping. Slurry transport would obviously eliminate such a potential.

It is also apparent that sulfur content is exceptionally low and well within present E P A limits for direct combustion.

Support Facilities and Related Factors

To develop coal production at the proposed site will require an infrastructure with all facilities to support a large-scale mining operation. A road and airstrip will be required plus a fully developed townsite. Since a labor pool does not exist, it will have to be developed at least partially from the Anchorage area and boat plus air transportation to that community maintained.

Power generation is planned on site by steam turbines powered by coal and possibly from fines reclaimed from washing residues. Since fuel is readily available, cost of power is placed at $0.02 per kw.hr. and is included under mining costs. Other support facilities costs are shown under Appendix A.

Mode of Operation

For the economic study here conducted, specific use was made of publications on coal mining, coal washing, pipeline construction and operation, pier and dock construction, and shipping by large carriers. In some instances, specific costs were taken, then updated and transferred to Alaska with a geographic increment. In other instances, material had to be indirectly assembled and supplementary costs introduced where applicable.

For construction, a factor of 1.68 was used over capital costs in effect in the lower 48. For operating costs, the factor amounts to 1.74. Both of these incremental numbers are explained in Hennagin's thesis.

Shipping costs were developed from MARAD data, Corps of Engineers and

Mining

Coal extraction will be by conventional surface mining using draglines for stripping, and because of the varied thickness and dip of the coal beds, coal will be loaded by front-end-loaders.

Thickness of coal beds varies from a few feet up to 55 feet. Overburden varies, depending on the final quantity of coal to be removed, but a strip ratio of 6:1 is estimated for reserves sufficient for a 20-year life at the rate anticipated.

Preliminary estimated mining costs are tabulated in Appendix A.

Coal Preparation and Slurry Preparation

The coal preparation plant envisioned will be a gravity type with jigs to upgrade the coal from about 7550 to 8000 B T U. Some work has been done in the past on Beluga coal at Seattle, and although additional test work will be required, it is believed that 8000 B T U coal can be delivered.

Slurry preparation can be combined with washing and the slurried coal stored wet to be repulped when required for pipeline transportation.

Water

An adequate supply of water is available from the Chacachatna River about six miles from the plant site. This glacier-fed stream has a flow much in excess of requirements and is reported to be a non-salmon river. A sump, intake system, and pumping station will be required which means that a relatively low-capacity power line will have to be built. The Chacachatna has a maximum fine silt content of 1000 p.p.m. during summer which drops to 25 p.p.m. in winter. The fine silt should be inert and should not interfere with washing, slurry preparation, or ultimate combustion. Costs are tabulated in Appendix C.

Slurry Pipeline

The optimum size of slurry pipeline is calculated to be 30 inches in diameter. Such a size is in excess of coal transport requirements if the coal was to be moved on a continuous basis. However, since ship loading will be intermittent, the line has been overdesigned to minimize ship loading time.

Insofar as pumping will be carried out against a negative (downgrade) vertical lift, power for pumping will be moderate and will not be an appreciable part of operating cost. Pipeline data and cost analyses are shown in the following:

Fig. 3
Table 2
Appendix D

Loading Pier

Because of the shallow nature of Cook Inlet, a pier to handle ships with a capacity of 100,000 dwt. will have to be located about 3500 feet offshore. The slurry pipeline will come down slope from the mine and be carried out on the trestle where it will terminate in a multispigot manifold for rapid and distributed loading. Pier and trestle concepts are illustrated in Fig. 4.

One alternative to the concept as proposed would be a smaller pipeline pumping continuously with storage and repulping facilities at the coast followed by a second pumping system to load the ships. This would have the advantage of a less costly pipeline which would be offset by the capital cost of storage and second pumping installations.

A second alternative would be an offshore monopoint buoy system with coal moving to the buoy by an underwater pipeline. This would have the advantage of eliminating the pier and trestle. The disadvantage would be the cost of the underwater pipeline which would have to be buried in the bottom sediments to eliminate potential hazards of bottom scouring plus the cost of a mooring and loading buoy sufficiently stable to withstand the tides and ice of winter loading.

Cost of pier and trestle is shown in Appendix E.

Ocean Transport

Ships designed specifically for the transport of coal slurry are not presently in use although they have been considered. However, ships are being used for moving an iron ore slurry, and hence background information is available that can be applied to coal.

One very significant question with respect to slurry transport by ship is, to what extent can the coal be dewatered so as to minimize the cost of moving the water component of the slurry? It is here proposed to remove water by drainage and to do this, it will first be necessary to remove clay contained within the coal as mined. These and other related factors are discussed in the text of Hennagin's thesis.

An optimum ship size of 100,000 dwt. is proposed that would carry 66,000 dry short tons of coal that would be contained within a slurry that is 60% coal by weight.

Ship data are shown in Table 3 and ship costs in Appendix F.

Off-Loading Pier and Dewatering

Estimated costs of these parts of the cycle are shown in Appendix G and Appendix H.

Concluding Observations

Barging costs from Cook Inlet to the State of Washington have been the subject of investigations, and barging per se appears to be more economical than slurry transport. For instance, representatives of a large eastern barging company visited Seattle in November and stated that they could move coal over the suggested route for a cost of less than $6 per short ton. This, obviously, is a considerable reduction from the $8.37 per ton here quoted for shipment by slurry. As opposed to this, no accompanying figures were presented for loading and unloading, and hence it is difficult at this stage to make a direct comparison.

Mining costs have been taken from U.S. Bureau of Mines publications based on estimated costs on the Northern Great Plains and increased by factors previously referred to for Alaskan operations. There is, however, a suggestion that the "ideal" conditions encountered in the Great Plains area cannot be attained at Beluga even with the Alaska factors introduced and that the number of employees is low which in turn would increase the size and cost of the townsite.

In summation, the estimated costs for conditions and dates cited are placed at $1.32 but could range upward to $1.50 per million B T U.

Donald L. Anderson
Professor
Mining Engineering

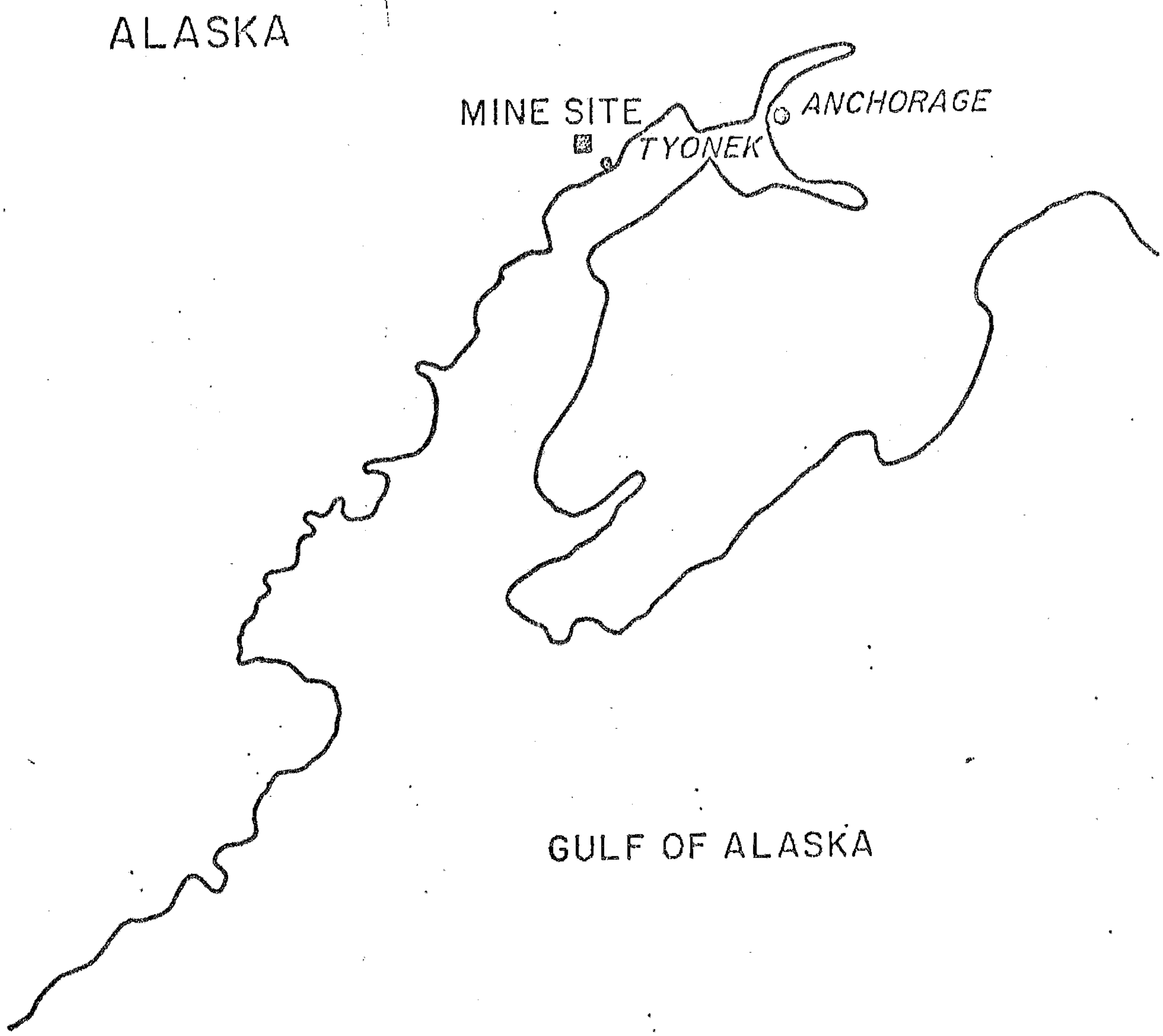
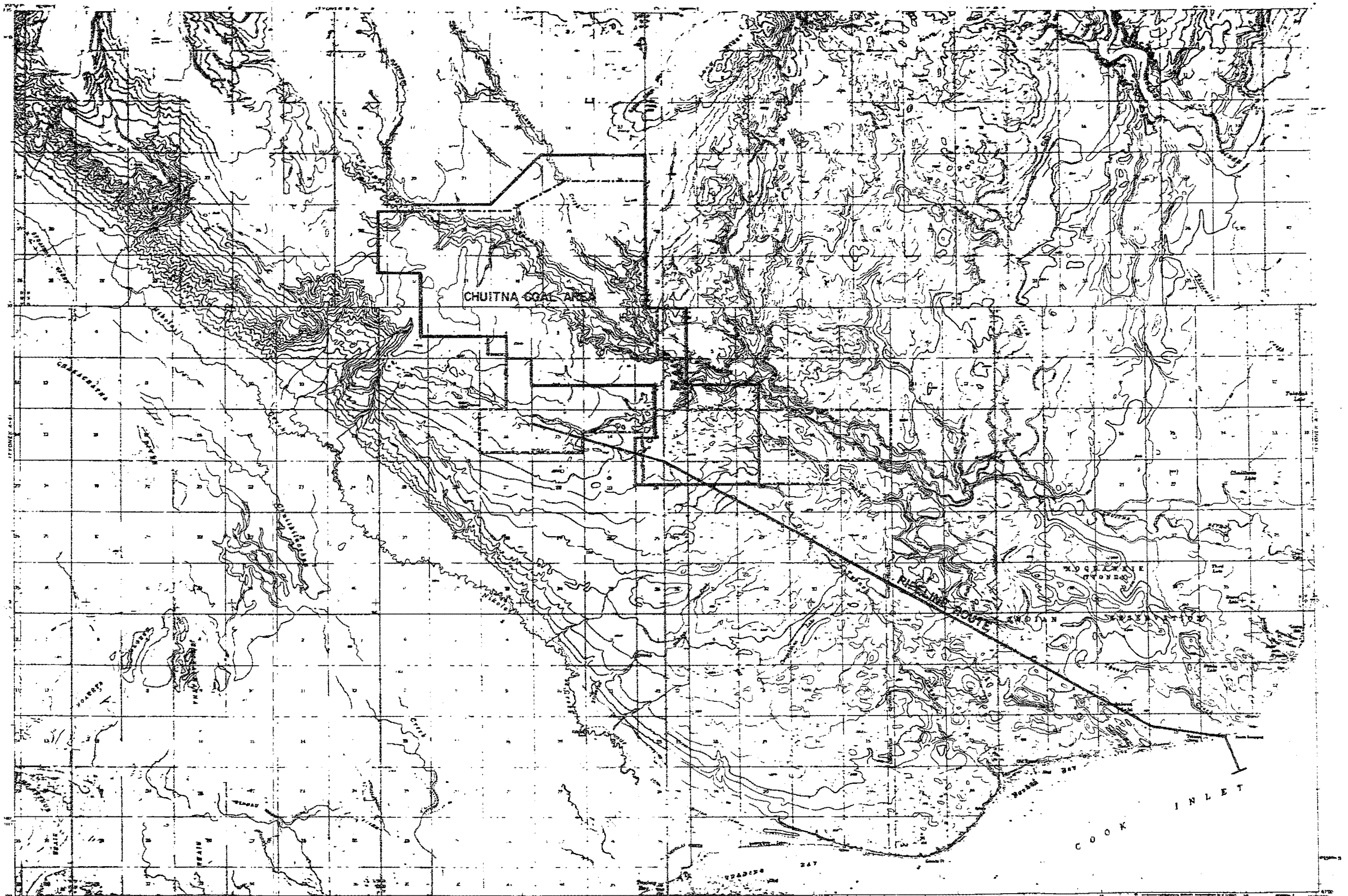


FIGURE I. LOCATION OF MINE SITE ON COOK INLET



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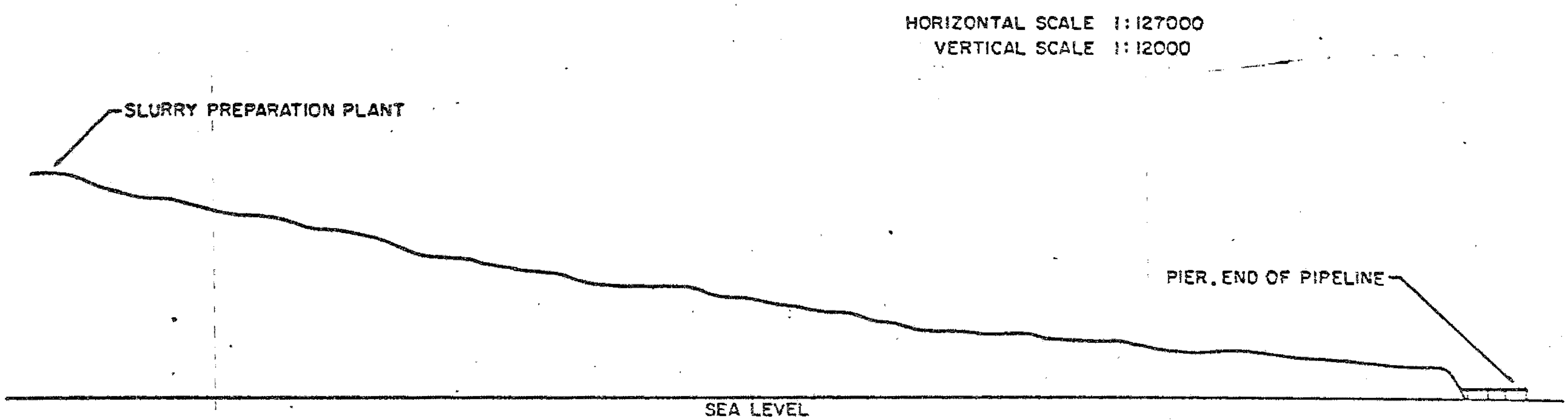

FIGURE 3. TERRAIN PROFILE OF PROPOSED PIPELINE ROUTE

Table 2

Slurry Pipeline Data

Nominal diameter, inches	24	30
Inside diameter, inches	23.25	29
Solids concentration, by weight	55%	55%
Specific gravity of slurry	1.186	1.186
Pumping velocity, feet per second	7	8
Slurry capacity, cubic feet per second	20.64	36.69
Slurry capacity, gallons per minute	9263	16466
Slurry capacity, short tons per hour	2749	4888
Coal capacity, short tons per hour	1512	2688
Head loss, feet water per 100 feet pipe	1.60	1.59
Head loss for 16 miles of pipe, feet water	1352	1343
Altitude loss, feet	(1150)	(1150)
Net loss for pipeline, feet water	202	193
Slurry horsepower required	560	950
Pump efficiency	90%	90%
Brake horsepower required	622	1055
Efficiency of motor	90%	90%
Installed brake horsepower (3 pumps operating, 1 standby)	830	1400
Energy required per year, kilowatt-hours		
for 4,380,000 tons coal per year	1,493,600	1,424,900
for 8,760,000 tons coal per year	2,987,200	2,849,800

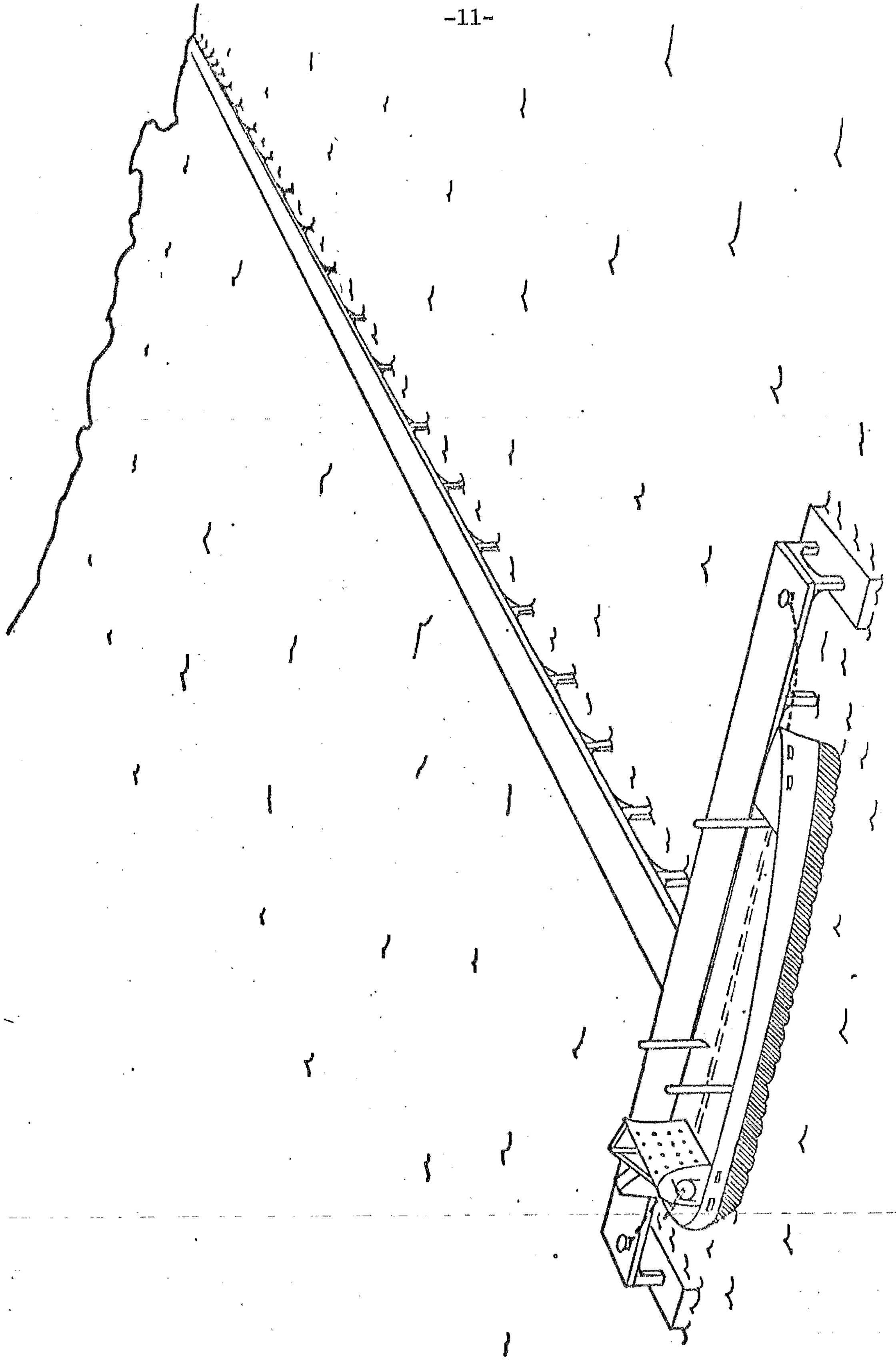

FIGURE 4. PIER FOR SLURRY LOADING.
(FOR ILLUSTRATIVE PURPOSES ONLY)

Table 3

Ship Data

Ship sizes, DWT	70,000	79,000	100,000
Average speed, knots	16.5	16.5	16.5
Length, feet	810	820	890
Beam, feet	116	121	128
Draft, feet	42	43	47
Horsepower	19,000	19,400	23,000
Capacity, short tons	78,400	88,480	112,000
Allowance for bunker fuel and fresh water, short tons	1,800	1,850	2,000
Slurry capacity, short tons	76,600	86,630	110,000
Dry coal capacity, 60% coal, short tons	45,960	51,980	66,000
Diameter of slurry pipeline, inches	24	30	30
Round-trip time, days:			
sailing	7.07	7.07	7.07
docking, both piers	0.17	0.17	0.17
wait for slurry	0.06	0.06	0.06
load	1.27	0.81	1.02
unload	1.27	0.81	1.02
delay allowance	1	1	1
Total	10.84	9.92	10.34
Round-trips per year per ship	32.29	35.28	33.85
Number ships for:			
4,380,000 tons coal per year	3	–	2
8,760,000 tons coal per year	6	5	4

Table 4

Cost Summary

Costs in dollars per short ton of clean coal

and final cost per million BTU's

System	I	II	III	IV	V
Coal tonnage per year, millions of short tons	4.38	4.38	8.76	8.76	8.76
Slurry pipeline					
diameter, inches	24	30	24	30	30
Ship size, DWT					
thousands of tons	70	100	70	79	100
Number of ships	3	2	6	5	4
Costs:					
Mining	7.80	7.80	6.40	6.40	6.40
Washing	1.95	1.95	1.70	1.70	1.70
Slurry preparation	1.95	1.95	1.70	1.70	1.70
Water	0.10	0.10	0.07	0.07	0.07
Slurry pipeline	0.46	0.57	0.23	0.29	0.29
Loading pier	1.94	2.04	0.97	0.98	1.02
Shipping	10.37	8.37	10.37	9.40	8.37
Off-loading pier	0.94	1.00	0.47	0.48	0.50
Dewatering	1.27	1.27	1.10	1.10	1.10
Total	26.78	25.05	23.04	22.12	21.15
Per million BTU's	1.67	1.57	1.44	1.38	1.32

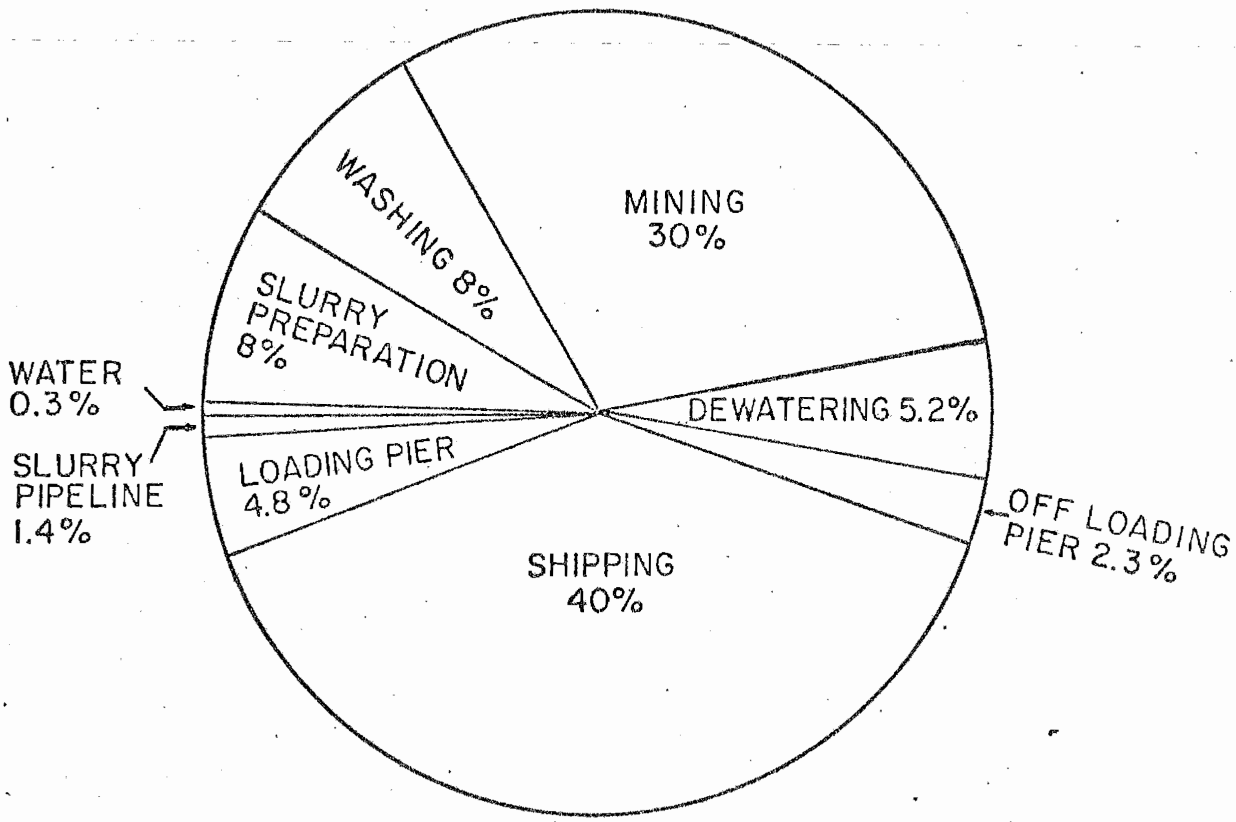

FIGURE 5. COST BREAKDOWN FOR SYSTEM V.

APPENDIX A

MINING COSTS

Production rate, millions of tons raw coal per year	4.818	9.636
Capital costs:		
Present value of total mine cost	42,540,800	70,901,300
Townsite	8,896,800	14,828,000
Road	2,371,600	2,371,600
Airstrip and facilities	2,807,600	2,807,600
Total	56,616,800	90,908,500
Annual operating cost	22,333,100	37,221,900

Discounted cash flow analysis, mine, 9,636,000

tons raw coal per year

Annual cash flow = 90,908,500 x 0.15976 =	14,523,500
less depreciation	4,545,400
Depletion + net profit =	9,978,100

Revenue	56,112,300
Operating cost	37,221,900
Subtotal	18,890,400
Depreciation	4,545,400
Gross profit	14,345,000
Depletion	5,611,200
Taxable income	8,733,800
Federal income tax	4,366,900
Net profit	4,366,900

Revenue per ton = 56,112,300 ÷ 8,760,000 = 6.40 per ton

APPENDIX B

COAL WASHING AND SLURRY PREPARATION COSTS

Coal Washing Costs

Plant capacity, tons per hour	750	1,500
Capital cost	13,440,000	23,520,000
Annual operating cost	5,792,000	10,060,000

Slurry Preparation Costs

Slurry preparation costs taken to be identical to coal washing costs.

Discounted cash flow analysis

coal washing, 1500 TPH plant

Annual cash flow = 23,520,000 x 0.15976 =		3,757,600
	less depreciation	1,176,000
	Depletion + net profit =	2,581,600

Revenue	14,908,400
Operating cost	10,060,000
Subtotal	4,848,400
Depreciation	1,176,000
Gross profit	3,672,400
Depletion	1,490,800
Taxable income	2,181,600
Federal income tax	1,090,800
Net profit	1,090,800

Revenue per ton = 14,908,400 ÷ 8,760,000 = 1.70 per ton

APPENDIX C

WATER SUPPLY COSTS

System capacity, GPM	2,250	4,500
Capital costs:		
Pumps, installed	955,500	1,114,800
Power line	144,000	144,000
Pipeline, installed	824,700	1,370,900
Total	1,924,200	2,629,700
Annual operating cost	219,000	438,000

Discounted cash flow analysis,

water supply, 4500 GPM

Annual cash flow = 2,629,700 x 0.15976 =	420,200
less depreciation	131,500
Depletion + net profit =	288,700

Revenue	1,042,600
Operating cost	438,000
Subtotal	604,600
Depreciation	131,500
Gross profit	473,100
Depletion	104,300
Taxable income	368,800
Federal income tax	184,400
Net profit	184,400

Revenue per ton = 1,042,600 ÷ 8,760,000 = 0.12 per ton*

*Including water cost of 0.05 per ton of coal already in operating costs of mine and plant, incremental cost of water per ton of coal is approximately 0.07.

APPENDIX D

SLURRY PIPELINE COSTS

Coal tonnage per year, millions of tons	4.38	4.38	8.76	8.76
Slurry pipeline diameter inches	24	30	24	30
Capital cost of pipeline and pumping station	7,442,700	9,333,400	7,442,700	9,333,400
Annual operating cost	208,200	252,200	238,100	280,700

Discounted cash flow analysis, slurry pipeline,

30-inch diameter, 8,760,000 tons per year

Annual cash flow = 9,333,400 x 0.15976 =	1,491,100
less depreciation=	466,700
Depeltion + net profit=	1,024,400

Revenue	2,542,000
Operating cost	280,700
Subtotal	2,261,300
Depreciation	466,700
Gross Profit	1,794,600
Depletion	254,200
Taxable income	1,540,400
Federal income tax	770,200
Net profit	770,200

Revenue per ton = 2,542,000 ÷ 8,760,000 = 0.29 per ton

APPENDIX E

LOADING PIER COSTS

Ship size, DWT	70,000	79,000	100,000
Capital costs:			
Berth	12,936,000	13,406,400	14,817,600
Trestle	12,348,000	12,348,000	12,348,000
Total	25,284,000	25,754,400	27,165,600
Annual operating cost	2,496,900	2,509,100	2,533,400

Discounted cash flow analysis,

loading pier, 100,000 DWT ship

Annual cash flow = 27,165,600 x 0.15976 = 4,340,000

less depreciation + 1,358,300

Depletion + net profit = 2,981,700

Revenue	8,959,200
Operating cost	2,533,400
Subtotal	6,425,800
Depreciation	1,358,300
Gross profit	5,067,500
Depletion	895,900
Taxable income	4,171,600
Federal income tax	2,085,800
Net profit	2,085,800

Revenue per ton = 8,959,200 ÷ 8,760,000 = 1.02 per ton for 8,760,000 tons per year

= 2.04 per ton for 4,380,000 tons per year

APPENDIX F

SHIP COSTS

Ship size, DWT	70,000	79,000	100,000
Capital cost per ship	36,500,000	40,800,000	45,000,000
Annual operating cost per ship	5,298,150	5,464,500	6,192,850
Number ships used for analysis	6	5	4

Discounted cash flow analysis,

100,000 DWT ships

Annual cash flow = 180,000,000 x 0.15976 = 28,756,800

less depreciation 9,000,000

net profit = 19,756,800

Revenue	73,285,000
Operating cost	24,771,400
Subtotal	48,513,600
Depreciation	9,000,000
Taxable income	39,513,600
Federal income tax	19,756,800
Net profit	19,756,800

Revenue per ton = 73,285,000 ÷ 8,760,000 = 8.37 per ton

APPENDIX G

OFF-LOADING PIER COSTS

Ship size, DWT	70,000	79,000	100,000
Capital costs:			
Berth	7,700,000	7,980,000	8,820,000
Trestle	2,100,000	2,100,000	2,100,000
Total	9,800,000	10,080,000	10,920,000
Annual operating cost	1,435,000	1,445,000	1,456,000

Discounted cash flow analysis,

off-loading pier, 100,000 DWT ship

Annual cash flow = 10,920,000 x 0.15976 = 1,744,600

less depreciation 546,000

net profit = 1,198,600

Revenue	4,399,200
Operating cost	1,456,000
Subtotal	2,943,200
Depreciation	546,000
Taxable income	2,397,200
Federal income tax	1,198,600
Net profit	1,198,600

Revenue per ton = 4,399,200 ÷ 8,760,000 = 0.50 per ton for 8,760,000 tons per year

= 1.00 per ton for 4,380,000 tons per year

APPENDIX II

DEWATERING COSTS

Coal tonnage per year, millions of tons	4.38	4.38	8.76	8.76
Slurry pipeline diameter, inches	24	30	24	30
Capital costs:				
Pipelines:				
Slurry	175,325	225,725	175,325	225,725
Water return	49,675	49,675	49,675	49,675
Dewatering plant	8,000,000	8,000,000	14,000,000	14,000,000
Total	8,225,000	8,275,400	14,225,000	14,275,400
Annual operating cost	3,328,800	3,328,800	5,781,600	5,781,600

Discounted cash flow analysis, dewatering,

30 inch diameter pipeline, 8,760,000 tons per year

Annual cash flow = 14,275,400 x 0.15976 =	2,280,600
less depreciation	713,800
net profit =	1,566,800

Revenue	9,629,000
Operating cost	5,781,600
Subtotal	3,847,400
Depreciation	713,800
Taxable income	3,133,600
Federal income tax	1,566,800
Net profit	1,566,800

Revenue per ton = 9,629,000 ÷ 8,760,000 = 1.10 per ton