IC 8602

Bureau of Mines Information Circular/1973

Estimated Costs To Produce Copper At Kennicott, Alaska

UNITED STATES DEPARTMENT OF THE INTERIOR

Information Circular 8602

Estimated Costs To Produce Copper At Kennicott, Alaska

by R. P. Maloney and R. G. Bottge
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UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, Secretary

BUREAU OF MINES
Elburt F. Osborn, Director

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This publication has been cataloged as follows:

Maloney, Raymond P

Estimated costs to produce copper at Kennicott, Alaska, by R. P. Maloney and R. G. Bottge. [Washington] U.S. Bureau of Mines [1973]

35 p., illus., tables. (U.S. Bureau of Mines. Information circular 8602)

Includes bibliography.

1. Copper ores—Alaska—Kennicott—Costs. 2. Copper mines and mining—Alaska—Kennicott—Economic aspects. I. Bottge, Robert G., jt. auth. II. U.S. Bureau of Mines. III. Title. (Series)

TN23.U71 no. 8602 622.06173

U.S. Dept. of the Int. Library

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 Price: 65 cents, domestic postpaid; 45 cents, GPO Bookstore
Catalog No. 128.27:8602 Stock No. 2404-01431

CONTENTS

ILLUSTRATIONS

TABLES

ESTIMATED COSTS TO PRODUCE COPPER AT KENNICOTT, ALASKA

by

R. P. Maloney[1] and R. G. Bottge[2]

ABSTRACT

The economic viability of four depleted mines near Kennicott, Alaska, was determined by the Bureau of Mines to assess their profitability if they were developed today and thus estimate cost data for a medium-sized mine, mill, and town complex. This information should help the State and Federal Governments appraise the potential development of similar-sized mining operations in Alaska. Modern conventional mining and milling techniques were assumed, and capital and operating costs were derived using flowsheets and standard costing methods.

A total capital investment of $37.6 million was necessary to install a 1,000-ton-per-day shrinkage stope mine, flotation-type mill, and support facilities; capital requirements were divided about evenly among the three components. Operating costs, including labor, supplies, power, water, and indirect and fixed costs, totaled $42.79 per ton of ore; the mining accounted for nearly one-half the cost. To obtain a 12-percent discounted cash flow rate of return on investment, the analysis showed that the ore could be mined and milled, and the concentrate could be trucked via public roads to a dock facility in Valdez, Alaska, barged to Tacoma, Wash., and smelted and refined for 34.7 cents per pound for copper and 104.0 cents per ounce for silver. The average May 1972 price was 52.6 cents for copper and 158.3 cents for silver.

The same set of data was used to examine the economic viability of the mine with the cost of constructing a private road from McCarthy, Alaska, to Valdez, Alaska. The 148-mile road added $53.3 million to the original capital costs and raised the required price of copper to 57.4 cents per pound and the required price of silver to 172.0 cents per ounce. The additional cost of building, maintaining, and paying taxes on a private road from McCarthy, Alaska, to Valdez, Alaska, would make this venture uneconomical.

INTRODUCTION

This is the first in a series of publications planned by the Bureau of Mines to show estimates of mining and processing costs for developing various

[1]Mining engineer (now deceased).
[2]Mining engineer.

types of deposits in Alaska. These reports will provide State and Federal Governments with information to appraise the potential for development of comparable deposits in Alaska. The detailed cost tables will be useful to industry in assessing the factors that raise mining and processing costs in Alaska over those in the 48 contiguous States.

In this report, the four mines operated by the Kennecott Copper Corp. near McCarthy, Alaska, from 1911 to 1938 were studied to determine whether or not they would be profitable if they were discovered today. The mines are good subjects to study because they are well known to the mining industry, and the size, grade, and nature of the ore bodies are known. Currently, the McCarthy area is one of active exploration by companies seeking to find deposits similar to those mined at Kennicott, Alaska.

The impact of transportation on the hypothetical mining venture is studied by first assuming the present-day road system can be used to carry the copper-silver concentrates from McCarthy, Alaska, to Valdez, Alaska, and then assuming a private road would have to be constructed by the company from McCarthy, Alaska, to Valdez, Alaska.

To perform the study, new mine, mill, and support facilities were designed and their capital and operating costs determined utilizing standard costing techniques. This type of cost estimate, prepared from flowsheets with a minimum of equipment data, can be expected to be within 20 percent of actual costs.

BACKGROUND

The original four mines of the Kennecott Copper Corp. are located near Kennicott in south-central Alaska approximately 4 miles north of McCarthy and 115 air miles east-northeast of Valdez (fig. 1). With the completion of the remaining 65 miles of road to McCarthy, the mines will be about 200 miles from Valdez. The climate in the area is alpine with cold winters and snowfalls of 15 to 18 feet annually.

The property consisted of the Jumbo, Bonanza, Mother Lode, and Erie mines and was located on a ridge lying to the east of the Kennicott Glacier (fig. 2). The ore consisted of high-grade copper replacements in limestone and dolomite. The predominate mineral was chalcocite, which occurred in nearly vertical veins ranging from a few feet to over 100 feet in width and from 150 to over 1,000 feet in length (4).[3] Some carbonate minerals in the form of malachite and azurite were scattered throughout the ore (1). Over the life of the mines, the 4,626,000 tons of ore mined provided 591,535 tons of copper and approximately 9,000,000 ounces of silver (2). This was an average of 12.8 percent copper and 1.95 ounces of silver per ton. The mines were depleted in 1938 and were shut down.

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[3]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

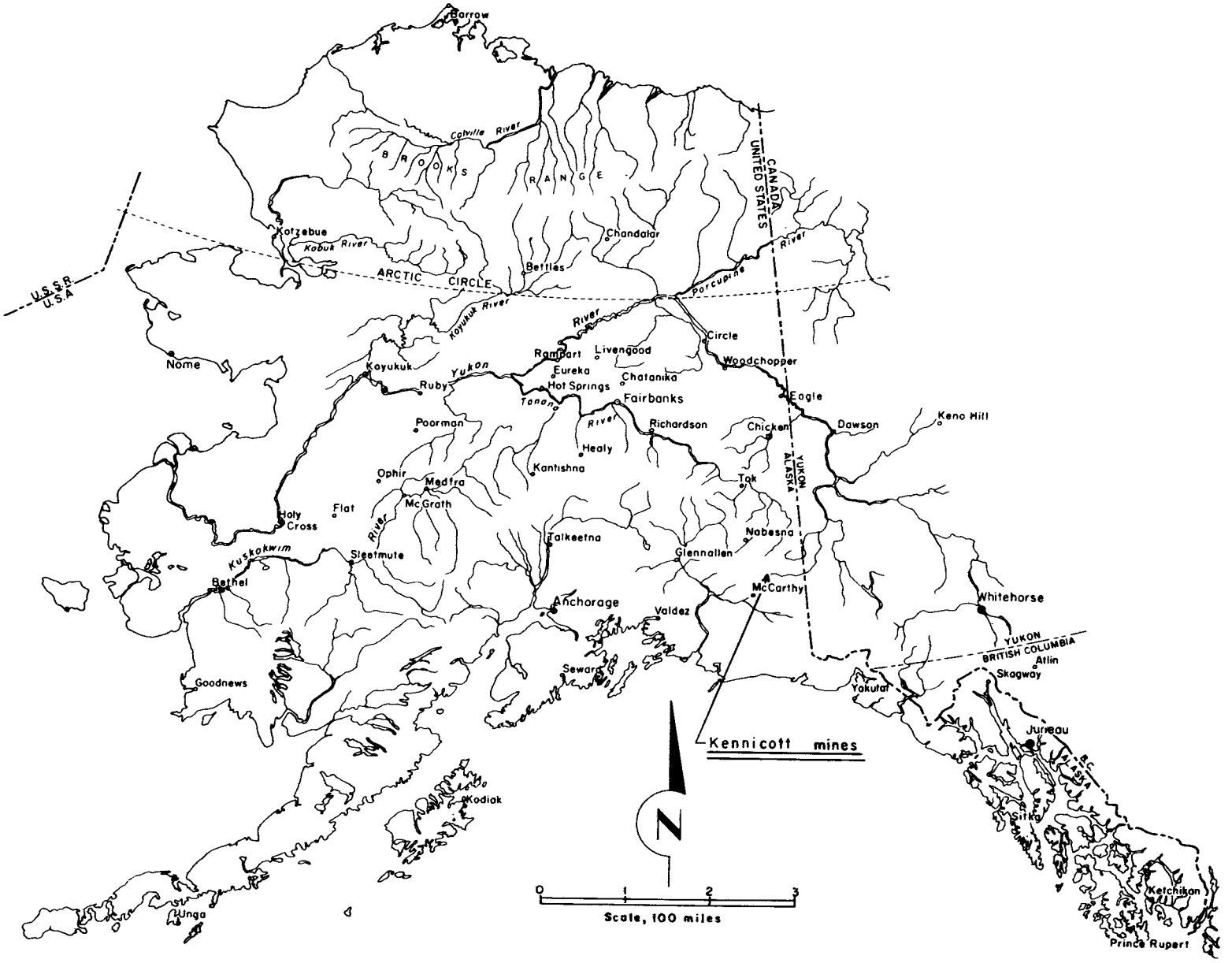
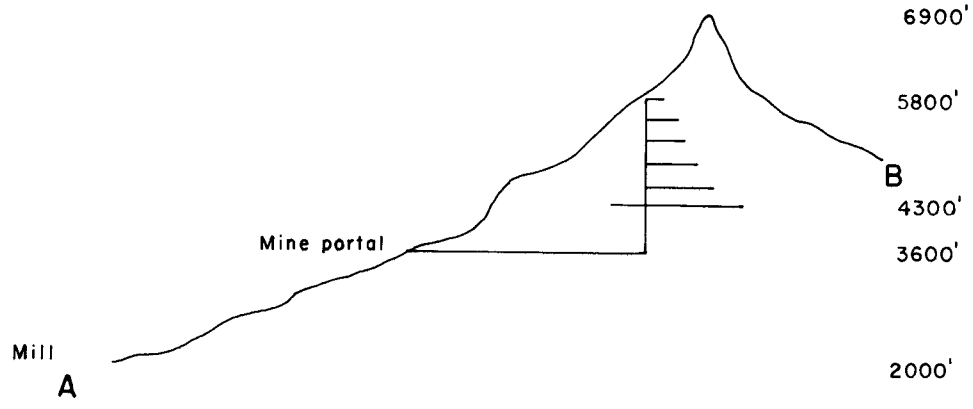
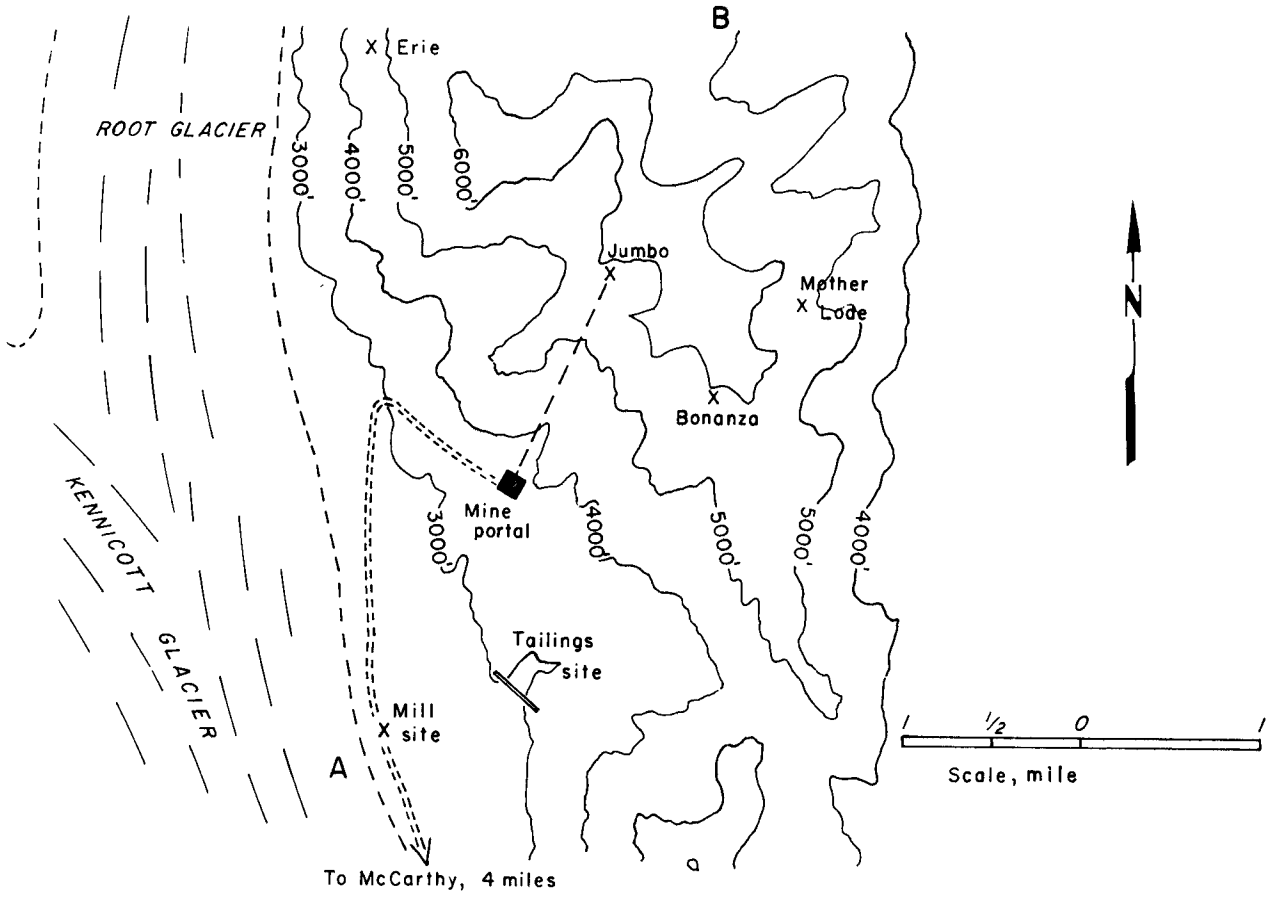


FIGURE 1. - Index map of Alaska.



Vertical exaggeration = 2:1

Cross section from mine to mill



Topographic map of mine - mill area

FIGURE 2. - Topography and cross section of mine-mill area.

ACKNOWLEDGMENTS

Acknowledgment is made to George Potter, project coordinator, Salt Lake City Metallurgy Research Center, Bureau of Mines, Salt Lake City, Utah, for his advice on the milling flowsheet, and to Phil R. Holdsworth, mining engineer, Inexco Mining Co., Juneau, Alaska, for his advice on mining methods.

OPERATION DESCRIPTION

Mine

A 3-year drilling program was assumed for delineating the ore bodies sufficiently to warrant driving a 13-foot-high by 16-foot-wide main haulage adit 6,850 feet long at an elevation of 3,600 feet beneath the Jumbo ore body. A two-compartment 10- by 16-foot haulage and ventilation shaft would be driven 2,400 feet vertically to the surface. The other mines would be connected to the Jumbo mine shaft by 9-foot-high by 7-foot-wide haulage drifts at an elevation of 4,300 feet, thus keeping all development underground and safe from avalanches.

Production would begin following 2 years of development work, primarily in the Jumbo mine. Production from the Jumbo mine would commence at elevations of 5,800, 5,650, 5,500, and 5,350 feet and continue downward at 150-foot intervals. On each level, ore and waste from each stope would be moved to a dumping station that connects to two 8- by 8-foot bins that discharge on the 3,600-foot elevation. As the other mines are developed, their ore and waste would be lowered to the 4,300-foot elevation and then hauled to the main ore and waste bins for transfer to the 3,600-foot elevation. Haulage would be accomplished utilizing electric-powered locomotives and rocker or Granby-type ore cars. Ore would be hauled from the mine to the mill by one 35-ton rear-dump truck working two shifts per day over a 2.75-mile gravel road.

Development work would be accomplished with eight two-man crews devoting full time to driving ventilation shafts and crosscuts, and excavating dumping stations for the lower levels of the Jumbo mine and for the other mines as they come into production.

Fourteen two-man crews would work two shifts per day, 5 days per week, to produce 1,000 tons of ore per day by shrinkage stoping. Assuming the equivalent of 235 full operating days per year is achieved out of a maximum of 260, the on-stream efficiency would be 90.4 percent, which would result in 235,000 tons of ore produced each year. The major portion of the maintenance would be done during the third shift. Major repairs would be made in an underground repair shop near the main shaft.

Mill

The mill would be of conventional design; gravity flow would be utilized in moving the pulp where possible (fig. 3). Operation would be three shifts per day, 7 days per week with an on-stream efficiency of 90.4 percent based on an assumed equivalent of 330 full days of operation annually out of a possible 365 days. Recovery of copper in the ore is assumed to be 96 percent.

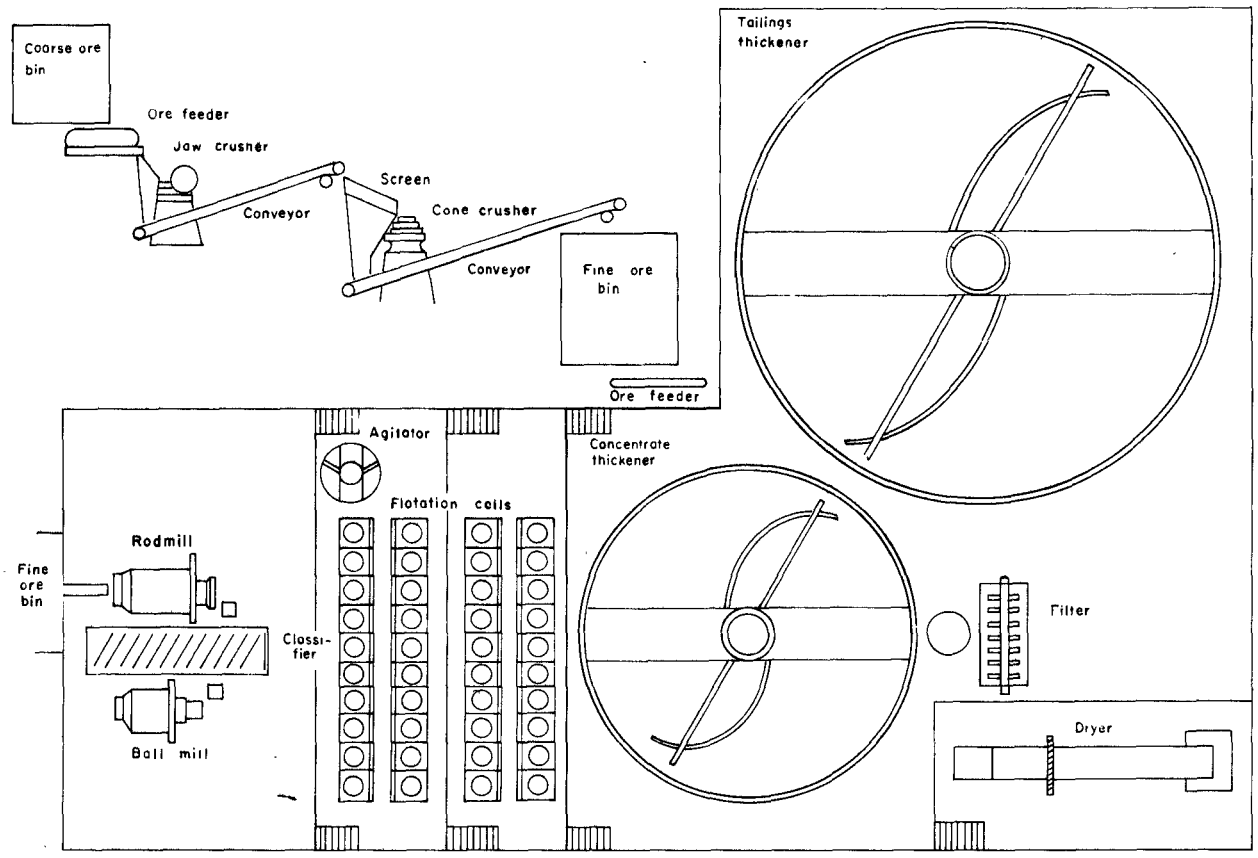


FIGURE 3. - Generalized mill flowsheet.

Ore from the coarse ore bin would be reduced by jaw and cone crushers operating 8 hours each day, 5 days per week. Crushed ore would be conveyed to a fine ore bin and fed to a grinding section operating 24 hours per day. Rod and ball mills would grind the ore to minus 65 mesh, and jigs in series with the mills would remove the coarse mineral prior to flotation.

The flotation section would consist of four banks of ten 50-cubic-foot cells. The first two banks would float the sulfide minerals; the latter two banks would float the oxide minerals following sulfidizing.

The resulting concentrate would be thickened in a 10-foot-deep by 55-foot-diameter thickener and pumped to a disk filter. The filter cake would be conveyed to a dryer where the moisture content would be reduced to less than 1 percent.

Waste material would be routed to a 10-foot-deep by 80-foot-diameter thickener where one-half of the water would be reclaimed and returned to the agitator. The remaining water would form a slurry with the tailings and be pumped 5,000 feet to a tailings pond.

Support Facilities

The milling operation would provide 198 tons of concentrate per day for shipment to a smelter. Twelve trucks with trailers would haul the concentrate in 23-ton lots via highway to a dock facility in Valdez. Chartered barges would carry the concentrate to a smelter at Tacoma, Wash. The concentrate would be hauled on specially constructed trailers capable of hauling concentrate one way and fuel or supplies in return. The maintenance garage would be located at McCarthy.

Concentrate would be stored in a 10,000-ton-capacity concrete silo until loaded by an enclosed conveyor into covered barges for shipment to a smelter.

The company would provide housing in the form of 24- by 60-foot trailers on lots in an expansion subdivision near McCarthy and would generate electricity for the subdivision. Snow removal would be provided to the company facilities and to McCarthy. Finally, a medical clinic staffed by two nurses would be provided by the company.

DISCUSSION OF RESULTS

Tables 1-10 summarize the capital and operating cost for the mine, mill, and support facilities. Table 11 gives the financial analysis of the operation assuming public roads would be utilized for concentrate haulage from McCarthy, Alaska, to Valdez, Alaska. Chartered barges were assumed available to transport the concentrate from Valdez, Alaska, to a smelter at Tacoma, Wash.

The total capital requirement was $37.6 million; mining, milling, and support facilities cost $10.9 million, $12.2 million, and $11.6 million, respectively. Working capital and interest during construction make up the remaining capital costs.

The total operating cost per year was $10.1 million, or $42.79 per ton of ore. Mining accounted for $20.33 per ton, or nearly one-half of the total. The remaining operating costs were split about equally between milling and support facilities. Labor and payroll overhead comprised 38 percent of the total operating costs; operating supplies, power, and water, 19 percent; indirect cost, 9 percent; and fixed costs, 34 percent.

The financial analysis showed that sales of $20.5 million were necessary to provide a 12-percent discounted cash flow. Thus, a revenue of $87.24 per ton of ore could be provided by the sale of recoverable copper for 34.7 cents per pound and recoverable silver for 104.0 cents per pound including transportation costs to Tacoma, Wash., and smelting and refining costs. The average May 1972 prices for copper and silver quoted in the Engineering and Mining Journal were 52.6 cents per pound and 158.3 cents per ounce, respectively (3).

TABLE 1. - Total capital requirement

	Investment, dollars
Mine	10,864,900
Mill	12,177,300
Support facilities	11,556,800
Total plant cost (insurance, tax base)	34,599,000
Interest during construction	944,900
Subtotal for depreciation	35,543,900
Working capital	2,051,400
Total investment	37,595,300

TABLE 2. - Working capital

		Cost, dollars
Direct labor	3 months	706,600
Payroll overhead	do	247,300
Operating supplies	do	420,900
Indirect cost	4 months	300,700
Fixed cost	0.5 percent of insurance base	173,000
Spare parts		105,200
Miscellaneous expense		97,700
Total		2,051,400

TABLE 3. - Mine cost summary

	Quantity	Total cost, dollars
Hoist	1	344,800
Sheave	1	13,000
Wire rope, feet	6,000	2,800
Cage with skip	2	20,200
Main ventilation system	1	50,600
Secondary ventilation system	1	48,400
Compressor	2	210,800
Air receiver	2	12,500
Locomotive	4	73,600
Batteries	8	34,800
Charging panel	4	13,400
Mine car	48	66,000
Drifter drill	15	19,000
Mucking machine	3	22,800
Slusher with bucket, sheaves	3	20,500
Portable hoist	3	14,300
Pump with motor	2	6,700
Handtools and lamps	-	6,000
Mine track, feet	5,000	21,900
Track ties	1,666	5,200
Underground parking area	1	128,700

TABLE 3. - Mine cost summary--Continued

	Quantity	Total cost, dollars
Underground repair shop	1	211,200
Maintenance equipment	-	40,000
Communication system	-	30,000
Parts inventory	-	36,000
Dump truck	1	82,400
Crawler tractor	1	45,100
Road grader	1	79,300
Supply truck	1	10,500
Personnel carrier	1	12,600
Pickup	2	6,300
Sedan	2	8,400
Powder and cap house	1	13,200
Power substations	-	39,800
Powerlines, miles	2	98,800
Water supply system	-	22,000
Road, feet	14,500	302,100
Exploration	-	3,000,000
Total direct costs	-	5,173,700
Field indirect	-	258,700
Total construction	-	5,432,400
Engineering	-	271,600
Overhead and administration	-	271,600
Subtotal	-	5,975,600
Contingency	-	597,600
Subtotal	-	6,573,200
Fee	-	328,700
Subtotal	-	6,901,900
Estimated development cost	-	7,163,000
Subtotal	-	14,064,900
Interest during development	-	351,600
Subtotal	-	14,416,500
Credit for copper mined during development at 40 cents per pound	-	3,200,000
Total	-	11,216,500

TABLE 4. - Mill cost summary

	Quantity	Total cost, dollars
Chute	1	12,300
Coarse ore bin	1	113,300
Ore feeder	1	15,700
Grizzly	1	1,900
Chute	1	1,700
Jaw crusher	1	34,000
Conveyor	1	7,700
Magnetic head pulley	1	3,900
Dust collector	3	22,900
Pump	3	5,000
Vibrating screen	1	8,900
Chute	1	1,800
Cone crusher	1	48,600
Conveyor	1	9,200
Fine ore bin	1	140,300
Ore feeder	1	11,300
Weightometer	1	3,500
Sampler	1	1,900
Rodmill	1	72,900
Initial rod feed, tons	24.5	6,200
Jig	2	21,000
Classifier	1	22,000
Ball mill	1	76,200
Initial ball charge, tons	17	5,000
Bridge crane	1	50,700
Sump with pump	2	8,500
Reagent feeder	2	5,000
Agitator	1	8,100
Flotation machine	40	99,000
Blower	1	3,300
Pump	2	3,600
Pump	2	7,300
Bridge crane	2	50,700
Sump with pump	2	8,500
Thickener	1	60,100
Sampler	1	1,900
Pump	2	6,600
Filter	1	24,000
Filter vacuum equipment	1	15,200
Conveyor	1	3,400
Concentrate bin	1	37,600
Dryer	1	35,300

TABLE 4. - Mill cost summary--Continued

	Quantity	Total cost, dollars
Conveyor	1	6,500
Concentrate bin	1	76,900
Truck scale	1	25,800
Thickener	1	90,800
Pump	4	19,600
Pump	2	3,600
Tailings pipe, feet	5,000	74,000
Tailings site preparation	-	2,600,000
Mill site preparation	-	55,000
Maintenance shop	1	220,000
Maintenance equipment	-	30,000
Warehouse	1	440,000
Mill inventory	-	30,000
Water supply system	1	44,000
Pickup	2	6,300
Sedan	2	8,400
Power substations	-	61,200
Powerlines, miles	5	246,800
Subtotal	-	5,114,900
Excavation	-	356,000
Concrete	-	803,800
Buildings	-	731,300
Piping	-	492,600
Electrical	-	753,000
Painting	-	58,800
Instrumentation	-	30,100
Insulation	-	22,900
Miscellaneous	-	170,200
Subtotal	-	3,418,700
Total direct costs	-	8,533,600
Field indirect	-	1,051,000
Total construction	-	9,584,600
Engineering	-	479,200
Administration and overhead	-	479,200
Subtotal	-	10,543,000
Contingency	-	1,054,300
Subtotal	-	11,597,300
Fee	-	580,000
Subtotal	-	12,177,300
Interest during construction	-	304,400
Total	-	12,481,700

TABLE 5. - Support facilities cost summary

	Quantity	Total cost, dollars
SUPPORT FACILITIES--McCARTHY		
Office site preparation	-	55,000
Office building	1	181,500
Office furniture	-	22,500
Road, McCarthy to mill, miles	4	440,000
Townsite expansion	-	2,500,000
Community clinic	1	330,000
Generating facility	1	1,766,200
Fuel tank	8	140,800
Truck and trailers	15	750,000
Truck maintenance building	1	495,000
Maintenance equipment	-	67,500
Sedan	2	8,400
Pickup	2	6,300
Subtotal	-	6,763,200
SUPPORT FACILITIES--VALDEZ		
Purchase of site	-	100,000
Preparation of site	-	47,500
Concentrate silo	1	146,500
Conveyor load-in system	1	52,400
Unloading shed with hopper	1	22,800
Conveyor load-out system	1	242,100
Dock facility	1	500,000
Office	1	28,500
Office equipment	-	3,600
Pickup	1	3,200
Subtotal	-	1,146,600
Total direct costs	-	7,909,800
Field indirect	-	1,186,500
Total construction	-	9,096,300
Engineering	-	454,800
Administration and overhead	-	454,800
Subtotal	-	10,005,900
Contingency	-	1,000,600
Subtotal	-	11,006,500
Fee	-	550,300
Subtotal	-	11,556,800
Interest during construction	-	288,900
Total	-	11,845,700

TABLE 6. - General manning table

	Shifts			Man shifts per day	Wages per man-hour, dollars	Wages per day,[1] dollars	Work days per year	Salaried workers, dollars per year[1]	Total annual cost, dollars
	Day	Eve-ning	Midnight						
General administration and services:									
Manager	1	-	-	1	-	-	-	30,000	30,000
Chief engineer	1	-	-	1	-	-	-	25,000	25,000
Personnel officer	1	-	-	1	-	-	-	14,000	14,000
Payroll clerk	2	-	-	2	-	-	-	9,000	18,000
Accountant	1	-	-	1	-	-	-	15,000	15,000
Draftsman	2	-	-	2	-	-	-	11,000	22,000
Stenographer	2	-	-	2	-	-	-	9,000	18,000
Sample man	1	1	1	3	5.50	44.00	350	-	47,000
Janitor	-	1	-	1	4.31	34.48	250	-	8,600
Chief of maintenance	1	-	-	1	-	-	-	23,000	23,000
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	220,600
MINE									
Administration and services:									
Mine superintendent	1	-	-	1	-	-	-	27,000	27,000
Mining engineer	1	-	-	1	-	-	-	22,000	22,000
General foreman	1	-	-	1	-	-	-	20,000	20,000
Party chief	1	-	-	1	-	-	-	16,000	16,000
Rodman	2	-	-	2	4.70	37.60	250	-	18,800
Clerk	1	-	-	1	-	-	-	9,000	9,000
Janitor-lampman	1	-	-	1	4.31	34.48	250	-	8,600
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	121,400
Production:									
Miner	11	11	-	22	6.36	50.88	250	-	282,000
Miner's helper	11	11	-	22	6.17	49.36	250	-	273,700
Timberman	2	2	-	4	6.48	51.84	250	-	52,200
Trackman	2	-	-	2	6.17	49.36	250	-	24,700
Ripper	2	2	-	4	6.02	48.16	250	-	48,600
Trammer	2	2	-	4	6.17	49.36	250	-	49,800
Motorman	4	4	-	8	6.33	50.64	250	-	102,100
Long-hole driller	1	-	-	1	6.36	50.88	250	-	12,700
Long-hole driller's helper	1	-	-	1	6.17	49.32	250	-	12,300
Hoistman	1	1	1	3	6.17	49.32	250	-	37,600
Truck driver, heavy	1	1	-	2	6.32	50.52	250	-	25,500
Grader operator	1	-	-	1	6.47	51.72	250	-	12,900
Dozer operator	1	-	-	1	6.62	52.92	250	-	13,200
Bus, light-truck driver	1	1	-	2	6.03	48.24	250	-	24,300
Shift foreman	1	1	-	2	-	-	-	18,000	36,400
Face boss	3	3	-	6	-	-	-	16,000	97,200
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	1,105,200
Maintenance:									
Mechanic	2	2	4	8	6.68	53.40	250	-	108,900
Electrician	1	1	2	4	6.92	55.32	250	-	56,400
Ventilation man	1	1	2	4	6.65	53.16	250	-	54,200
Welder	1	1	1	3	6.68	53.40	250	-	40,700
Machinist	2	-	-	2	6.92	55.32	250	-	27,700
Blacksmith	2	-	-	2	7.07	56.52	250	-	28,300
Toolroom attendant	1	1	-	2	6.17	49.35	250	-	24,900
Shift foreman	1	1	1	3	-	-	250	18,000	55,200
Laborer	1	1	2	4	5.20	41.60	250	-	42,600
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	438,900

See footnotes at end of table.

TABLE 6. - General manning table--Continued

	Shifts			Man shifts per day	Wages per man-hour, dollars	Wages per day,[1] dollars	Work days per year	Salaried workers, dollars per year[1]	Total annual cost, dollars
	Day	Eve-ning	Midnight						
MILL									
Administration and services:									
Mill superintendent	1	-	-	1	-	-	-	25,000	25,000
Metallurgist	1	-	-	1	-	-	-	22,000	22,000
Clerk	1	-	-	1	-	-	-	9,000	9,000
Warehouse man	1	-	-	1	-	-	-	9,000	9,000
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	65,000
Production:									
Shift foreman	1	1	1	3	-	-	-	16,000	68,900
Crusher operator	1	-	-	1	5.63	45.00	350	-	15,800
Mill operator	2	2	2	6	5.78	46.24	350	-	98,800
Laborer	1	1	1	3	5.00	40.00	350	-	42,800
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	226,300
Maintenance:									
Shift foreman	1	1	1	3	-	-	-	16,000	68,900
Mechanic	1	1	1	3	6.00	48.00	350	-	51,200
Electrician	1	1	1	3	6.24	49.92	350	-	53,300
Welder	1	-	-	1	6.00	48.00	250	-	12,000
Machinist	1	-	-	1	6.24	49.92	250	-	12,500
Laborer	1	1	1	3	5.00	40.00	350	-	42,800
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	240,700
SUPPORT FACILITIES									
Administration and services:									
Facilities superintendent	1	-	-	1	-	-	-	24,000	24,000
Stenographer	1	-	-	1	-	-	-	9,000	9,000
Mechanical engineer	1	-	-	1	-	-	-	22,000	22,000
Clerk	2	-	-	2	-	-	-	9,000	18,000
Dock facilities foreman	1	-	-	1	-	-	-	16,000	16,000
Clinic nurse	1	1	-	2	-	-	-	11,500	23,000
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	112,000
Production:									
Truck driver	12	-	-	12	6.32	50.56	250	-	151,700
Generator operator	1	1	1	3	5.78	46.24	350	-	49,400
Dock helper	1	-	-	1	5.20	41.60	250	-	10,400
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	211,500
Maintenance:									
Shift foreman	1	-	-	1	-	-	-	16,000	16,000
Mechanic	3	-	-	3	6.00	48.00	250	-	36,000
Electrician	1	-	-	1	6.24	49.92	250	-	12,500
Laborer	2	-	-	2	5.00	40.00	250	-	20,000
Subtotal	NAp	NAp	NAp	NAp	NAp	NAp	NAp	NAp	84,500
Grand total									2,826,300
SUMMARY LABOR COSTS:									
General administration and services									519,200
Direct labor									1,340,500
Direct labor supervision									202,500
Maintenance labor									624,000
Maintenance labor supervision									140,100
Grand total									2,826,300

NAp Not applicable.

[1]Figures in this column are rates for day shift. The shift differentials for the other shifts are reflected in the final column.

TABLE 7. - Depreciation schedule

Item	Years straight-line depreciation	Yearly charge, dollars			
		Mine	Mill	Support facilities	Total
Buildings and facilities..	20	32,000	354,300	211,400	597,700
Long-life stationary equipment.....	20	20,700	68,700	15,900	105,300
Short-life stationary equipment.....	10	29,200	3,000	186,000	218,200
Mobile equipment.....	5	98,000	2,900	153,600	254,500
Roads.....	20	15,100	0	22,000	37,100
Exploration.....	20	150,000	0	0	150,000
Other.....	5	7,200	6,000	0	13,200
Subtotal.....	NAp	352,200	434,900	588,900	1,376,000
Depreciation for field indirect, engineering, overhead and administration, contingency, fee, and interest during construction or development.....	20	[1] 302,100	197,400	196,800	696,300
Total.....	NAp	654,300	632,300	785,700	2,072,300

NAp Not applicable.

[1] Includes depreciation on cost of development less credit for copper mined at 40 cents per pound.

TABLE 8. - Utility summary

Unit	Power, kW-hr per day	Water requirement, gpm	Water recovery, gpm
Mine.....	13,523	50	0
Mill.....	19,833	500	300
Support facilities.....	231	100	0
Total.....	33,587	650	300

Power: At $0.0207/kW-hr[1]

Mine - $0.0207 × 13,523 × 260 × 0.904[2] = $65,800/year[3] = $0.28/ton

Mill - $0.0207 × (260 × 1,658 + 365 × 18,175) × 0.904[2] = $132,200/year[3] = $0.56/ton

Support facilities - $0.0207 × 231 × 260 × 0.904[2] = $1,100/year[3] = negligible

Water: $0.0375/1,000 gallons

Mine - 50 gpm × 60 × 16 × 260 × 0.904[2] = 11,282,000 gallons per year

Mill - 200 gpm × 60 × 24 × 365 × 0.904[2] = 95,028,000 gallons per year

Support facilities - 100 gpm × 60 × 24 × 365 × 0.904[2] = 47,514,000 gallons per year

Total = 153,824,000 gallons per year × 3.75 cents/1,000 gallons = $5,800/year[3] = $0.02/ton

[1] Includes fuel, lubrication, and repair parts.

[2] On-stream efficiency.

[3] Rounded to nearest 100.

TABLE 9. - Estimated annual cost, dollars

	Mine		Mill		Support facilities		Total	
	Annual cost	Cost per ton	Annual cost	Cost per ton	Annual cost	Cost per ton	Annual cost	Cost per ton
Direct cost:								
Production:								
Labor	971,600	4.13	157,400	0.67	211,500	0.90	1,340,500	5.70
Supervision	133,600	.57	68,900	.29	([1])	-	202,500	.86
General administration and services	166,400	.71	54,100	.23	76,300	.32	296,800	1.26
Subtotal	1,271,600	5.41	280,400	1.19	287,800	1.22	1,839,800	7.82
Maintenance:								
Labor	383,700	1.63	171,800	.73	68,500	.29	624,000	2.65
Supervision	55,200	.23	68,900	.29	16,000	.07	140,100	.59
General administration and services	102,700	.44	55,500	.24	64,200	.27	222,400	.95
Subtotal	541,600	2.30	296,200	1.26	148,700	.63	986,500	4.19
Total labor and supervision	1,813,200	7.71	576,600	2.45	436,500	1.85	2,826,300	12.01
Operating supplies	681,500	2.90	253,200	1.08	[2]748,800	[2]3.19	1,683,500	7.17
Power	65,800	.28	132,200	.56	1,100	([3])	199,100	.84
Water	400	([3])	3,600	.02	1,800	.01	5,800	.03
Payroll overhead[4]	634,600	2.70	201,800	.86	152,800	.65	989,200	4.21
Indirect cost: 20 percent of labor, maintenance, and supplies	498,900	2.12	166,000	.71	237,100	1.01	902,000	3.84
Fixed cost:								
Taxes and insurance[5]	217,300	.92	243,500	1.04	231,100	.98	691,900	2.94
Depreciation	654,300	2.78	632,300	2.69	785,700	3.34	2,072,300	8.81
Property taxes[5]	217,300	.92	243,500	1.04	231,100	.98	691,900	2.94
Total operating cost	4,783,300	20.33	2,452,700	10.45	2,826,000	12.01	10,062,000	42.79

[1] Included with general administration and services.
[2] Generator, fuel, lubrication, and repair parts included under power.
[3] Negligible.
[4] 35 percent of total labor and supervision.
[5] 2 percent of total plant cost.

TABLE 10. - Estimated mine development cost,[1] dollars

	Total Cost	Cost per ton[2]
Mine site preparation	75,200	0.24
Mine adit ..... 6,850 feet at $360 per foot	2,466,000	7.76
Mine shaft ..... 2,200 feet at $600 per foot	1,320,000	4.16
Hoist room and raise	107,800	.34
Dumping stations	231,100	.73
Underground ore bin ..... 2,200 feet at $145 per foot	319,000	1.00
Underground waste bin ..... 2,200 feet at $145 per foot	319,000	1.00
Underground truck turnaround	43,900	.14
Drifts and crosscuts ..... 13,300 feet at $110 per foot	1,463,000	4.61
Raises ..... 6,400 feet at $70 per foot	448,000	1.41
Timbering ..... 2,000 feet at $35 per foot	70,000	.22
Loading chutes ..... 300 chutes at $1,000 each	300,000	.94
Total	7,163,000	22.55

[1] Costs include labor and supervision, operating supplies, power, payroll overhead, indirect cost, and fixed cost.
[2] Tonnage = 317,640. Value of copper: 31,250 tons of 12.8 percent copper at 40 cents per pound = $3,200,000.

TABLE 11. - Financial analysis

Total original capital requirements	$37,595,300
5-year equipment cost at present worth value	722,000
10-year equipment cost at present worth value	1,112,300
15-year equipment cost at present worth value	232,500
Total capital requirements	39,662,100

12-percent discounted cash flow - 20-year life

i = interest rate, n = 20 years, P = capital investment
R = positive cash flow using the present worth formula

$$\frac{P}{R} = \frac{(1+i)^n - 1}{i\ (1+i)^n}$$

$$\frac{\$39,662,100}{R} = \frac{(1+0.12)^{20} - 1}{0.12\ (1+0.12)^{20}} = \frac{8.6463}{1.1576} = 7.469$$

$$R = \$39,662,100 \div 7.469 = \$5,310,200$$

Positive cash flow	$5,310,200
Less depreciation	2,072,300
Depletion plus net profit	3,237,900

Sales	$20,500,700
Operating costs[1]	15,747,100
Gross profit	4,753,600
Depletion[2]	2,089,200
Taxable income	2,664,400
Federal income tax[3]	1,332,200
State mining license tax[4]	183,500
Net profit	1,148,700

Positive cash flow = Net profit + depletion + depreciation
= $1,148,700 + $2,089,200 + $2,072,300
= $5,310,200

Sales price per ton of ore = $20,500,700 ÷ 235,000 tons = $87.24
Sales price per pound of copper = $20,043,000 ÷ 57,753,200 lb = $0.347
Sales price per ounce of silver = $457,700 ÷ 439,920 oz = $1.040

[1] Includes all operating costs, concentrate transportation costs from mill to smelter, handling costs, smelting and refining costs, and Alaska mining license tax.

[2] 15 percent of concentrate value minus transportation, smelting, and refining costs ($20,500,700 - $7,365,600 = $13,135,100 x 0.15 = $2,089,200).

[3] 50 percent of taxable income.

[4] Taxable income minus $100,000 times 7 percent plus $4,000. [($2,664,400 - $100,000) x 0.07 = $179,500 + $4,000 = $183,500]

Table 12 gives the financial analysis of the same operation including the cost of a 148-mile road from McCarthy, Alaska, to Valdez, Alaska. To show the impact of building and maintaining a private road on the mining venture, the present road system is assumed not to exist, and the company would have to construct the shortest practical private road from McCarthy, Alaska, to tidewater. Possibly the construction of such a road would be partially or totally financed by the State of Alaska, but in assuming total private ownership, the extreme case can be studied. Using Alaska State Highway Department estimates, it was found that the construction of the road would add $53.3 million to the cost of the venture and bring total capital requirements to nearly $93.0 million. The owning and operating of the road added $4.1 million to operating costs in the form of depreciation, road maintenance, and property taxes.

Sales of $33.9 million were necessary to maintain a 12-percent discounted cash flow. At that level, a price of 57.4 cents per pound for copper and 172.0 cents per ounce for silver would be required to mine and process the ore, truck the concentrate from McCarthy to Valdez in Alaska, barge it from Valdez, Alaska, to the smelter in Tacoma, Wash., and smelt and refine the concentrate. These copper and silver prices are greater than the 52.6 cents per pound of copper and 158.3 cents per ounce of silver quoted in the June 1972 issue of the Engineering and Mining Journal (3). Therefore, a mine with 12.8 percent copper ore near McCarthy, Alaska, would not be profitable if the company had to build, maintain, and pay taxes on a 148-mile private road from the mine to tidewater. Yet, in 1970, the average grade of copper ore from underground mines in the United States was about 0.75 percent (5).

TABLE 12. - Financial analysis including a private road

Total original capital requirements	$37,595,300
Cost of 148-mile road	53,300,000
5-year equipment cost at present worth value	722,000
10-year equipment cost at present worth value	1,112,300
15-year equipment cost at present worth value	232,500
Total capital requirements	92,962,100

12-percent discounted cash flow - 20-year life

i = interest rate, n = 20 years, P = capital investment
R = positive cash flow using the present worth formula

$$\frac{P}{R} = \frac{(1+i)^n - 1}{i\,(1+i)^n}$$

$$\frac{\$92,962,100}{R} = \frac{(1+0.12)^{20} - 1}{0.12\,(1+0.12)^{20}} = \frac{8.6463}{1.1576} = 7.469$$

$$R = \$92,962,100 \div 7.469 = \$12,446,400$$

Positive cash flow	$12,446,400
Less depreciation	4,737,300
Depletion plus net profit	7,709,100

Sales	$33,887,300
Operating costs[1]	20,415,200
Gross profit	13,472,100
Depletion[2]	3,356,300
Taxable income	10,115,800
Federal income tax[3]	5,057,900
State mining license tax[4]	705,100
Net profit	4,352,800

Positive cash flow = Net profit + depletion + depreciation
= $4,352,800 + $3,356,300 + $4,737,300
= $12,446,400

Sales price per ton of ore = $33,887,300 ÷ 235,000 tons = $144.20
Sales price per pound of copper = $33,130,700 ÷ 57,753,200 lb = $0.574
Sales price per ounce of silver = $756,600 ÷ 439,920 oz = $1.720

[1] Includes all operating costs, concentrate transportation costs from mill to smelter, handling costs, smelting and refining costs, Alaska mining license tax, plus the costs of owning a private road with depreciation of $2,665,000 per year, road maintenance of $415,500 per year, and property taxes of $1,066,000 per year.

[2] 15 percent of concentrate value minus transportation, smelting, and refining costs ($33,887,300 - $11,512,100 = $22,375,200 × 0.15 = $3,356,300).

[3] 50 percent of taxable income.

[4] Taxable income minus $100,000 times 7 percent plus $4,000.
[($10,115,800 - $100,000) × 0.07 = $701,100 + $4,000 = $705,100]

CONCLUSION

If the Kennicott mines near McCarthy, Alaska, were discovered today, they would be economically viable assuming a public road was provided from McCarthy to tidewater. The mine, mill, and support complex costing $37.6 million would require revenues of $20.5 million to maintain a 12-percent discounted cash flow. The addition of a 148-mile private road would require an additional $53.3 million in capital and would require revenues of $33.9 million.

Copper-silver concentrates from the mine could be trucked over public roads from McCarthy, Alaska, to Valdez, Alaska, barged to Tacoma, Wash., smelted and refined for 34.7 cents per pound for copper and 104.0 cents per ounce for silver. If the company is required to build, maintain, and pay taxes on a 148-mile private road from McCarthy, Alaska, to Valdez, Alaska, the required price would increase to 57.4 cents per pound for copper and 172.0 cents per ounce for silver. Thus, in a day when the average grade of copper mined in underground mines in the United States was 0.75 percent, a mine having 12.8 percent copper could not be economically mined near McCarthy, Alaska, without the benefit of a public road.

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APPENDIX A.--ASSUMPTIONS

The calculations in this report were based on the following assumptions concerning mining, milling, and support facilities:

Mining

1,000 tpd ore, two shifts per day, 5 days per week, 90.4 percent on-stream efficiency, shrinkage stoping of nearly vertical veins.

150 feet between levels.

10-foot average thickness of stopes.

7- by 9-foot average profile of drifts and crosscuts.

8- by 8-foot average profile of raises.

Mine adit to be 13 feet high, 16 feet wide, and 6,850 feet long.

Mine shaft to be double compartment, 10 by 16 by 2,200 feet high.

Ore and waste bin to be 8 by 8 by 2,200 feet high.

Mining done by two-man crews with stoper drills.

Haulage by trains to bins that discharge on the 3,600-foot elevation.

Main underground haulage between mines to be on the 4,300-foot elevation.

Haulage by 35-ton truck from bin discharge to the mill, two shifts per day, 5 days per week from the adit at 3,600-foot elevation.

Men will be bused from McCarthy to the main shaft by a personnel carrier.

Milling

712 tpd, three shifts per day, 7 days per week, 90.4 percent on-stream efficiency, 96 percent recovery.

Crushing performed 8 hours per day, 5 days per week.

Grinding and concentrating performed 24 hours per day, 7 days per week.

Jigs placed in series with the rodmills and ball mills to remove the coarse concentrate.

Two banks of 10 cells float the sulfide ore.

The oxide ore will be sulfidized and floated in two banks of 10 cells.

The concentrate is filtered and dried for shipment.

The tailings are pumped to a tailings site.

The final product is 40 percent copper.

Concentrate production is 197.79 tpd.

Support Facilities

The company will provide a 24- by 60-foot trailer unit on a lot for each employee.

The company will generate all electricity for the mine, mill, and subdivision.

The company will provide a medical clinic and two nurses.

The company will provide road snow removal for the mine, mill, and subdivision roads.

APPENDIX B.--DETAILED EQUIPMENT LIST, MINE

Hoist

Unit with semiautomatic controls, 300-hp motor, 500-fpm hoisting speed, 57-inch drum.

Sheave

57-inch-diameter sheave.

Wire rope

3,000 feet of 8 X 19 wire rope, 5/8-inch-diameter.

Cage with skip (two required)

Cage with 3-ton skip below.

Main ventilation fan

40,000-cfm unit with 30-hp motor.

Secondary ventilation fan (three required)

6,000-cfm booster unit with 15-hp motor.

Two 4,000-cfm booster units with 7-1/2-hp motors.

Compressor (two required)

Reciprocating, two-stage stationary unit, 1,500-cfm, 250-hp.

Air receiver (two required)

60-inch by 12-foot steel tank, 125-psi-capacity.

Locomotives (four required)

One 10-ton unit, one 6-ton unit, two 3-ton units.

Batteries (eight required)

Two 48-cell, 21-plate units; two 42-cell, 21-plate units; four 32-cell, 11-plate units.

Charging panel (four required)

Silicon diode, 440-volt, three-phase, 60-cycle, sized to fit each battery.

Mine cars (36 required)

12 62-cubic-foot Granby-type cars, 24-inch gage.

10 50-cubic-foot rocker-type cars, 24-inch gage.

14 98-cubic-foot Granby-type cars, 24-inch gage.

Drifter drills (15 required)

3-inch bore taking 7/8-inch steel.

Mucking machine (three required)

8-cubic-foot bucket, 325-cfm air requirement.

Slusher with bucket sheaves (three required)

25-hp units with 42-inch bucket, 12-inch sheaves.

Portable hoists (three required)

Electric, single-drum units, 10-hp motor.

Pump with motor (two required)

3-1/2-inch sump pump with 10-hp motor.

Handtools and lamps

Miners' lamps and hats, picks, shovels, etc.

Mine track (5,000 feet required)

3,000 feet of 30-lb rail, 2,000 feet of 45-lb rail.

Track ties (1,666 required)

Steel mine track ties.

Underground parking area

60- by 100- by 13-foot excavation.

Underground repair shop

60- by 100- by 13-foot excavation with concrete floor, structures, heating system, lights, power.

Maintenance equipment

Welding equipment, hoists, drills, tools, etc.

Communications system

Interlevel telephone network with connection to office.

Parts inventory

Repair parts for mining equipment.

Dump truck

35-ton rear-dump truck with 415-flywheel-hp diesel engine, 18.00 X 33 radial ply tires.

Crawler tractor

Unit with 120-flywheel-hp diesel engine, straight blade, rear winch, guards, power shift.

Road grader

225-flywheel-hp diesel-powered unit with automatic blade control, enclosed cab, lights, 18.00 X 25 12-ply tires.

Supply truck

5-ton flatbed truck.

Personnel carrier

66-passenger bus.

Pickup (two required)

1/2-ton pickup truck.

Sedan (two required)

Four-door sedan.

Powder and cap house

20- by 20-foot concrete block structure.

Power substations

Transformers, distribution boxes, high-voltage branches.

Powerline (2 miles required)

2 miles of 15-kV transmission line.

Water supply system

Water system for underground operations.

Road

Gravel road from mine to mill, 14,500 feet.

Exploration

3-year program, $1 million per year.

APPENDIX C.--DETAILED EQUIPMENT LIST, MILL

Chute

Unloading chute leading to coarse ore bin.

Coarse ore bin

1,500-ton capacity, bolted steel construction.

Ore feeder

36-inch by 20-foot apron-type feeder with 7-1/2-hp variable-speed motor.

Grizzly

5- by 10-foot grizzly with 5-inch opening.

Chute

5- by 5- by 10-foot chute below grizzly.

Jaw crusher

24- by 36-inch crusher, V-belt drive, 100-hp motor.

Conveyor

24-inch by 50-foot belt conveyor with 5-hp motor.

Magnetic head pulley

24-inch magnetic head pulley.

Dust collector (three required)

5,000-cfm wet-type collector with 10-hp motor.

Pump (three required)

4- by 2-inch rubber-lined centrifugal unit with 5-hp motor.

Vibrating screen

5- by 10-foot single-deck unit with 10-hp motor.

Chute

5- by 10- by 15-foot chute below screen.

Cone crusher

4-foot crusher, V-belt drive, 100-hp motor.

Conveyor

24-inch by 60-foot conveyor with 10-hp motor.

Fine ore bin

2,000-ton capacity, bolted steel construction.

Ore feeder

24-inch by 20-foot apron-type feeder with 3-hp variable-speed motor.

Weightometer

24-inch unit with 0.5-hp motor.

Sampler

Automatic sampler with 0.5-hp motor.

Rodmill

6- by 10-foot mill with drive, clutch, tongue synchronous, 200-hp motor.

Initial rod charge

49,000 pounds.

Jig (two required)

36- by 1/8-inch duplex jig with 3-hp motor.

Classifier

60-inch by 33-foot simplex unit with 7-1/2-hp motor.

Ball mill

7- by 7-foot mill with drive, clutch, tongue synchronous, 200-hp motor.

Initial ball charge

34,000 pounds.

Bridge crane

20-ton unit with 20-hp motor.

Sump with pump (two required)

1,500-gal sump with 3- by 3-inch SRL pump, 5-hp motor.

Reagent feeder (two required)

Wet reagent feeder with three compartments, mixing and feed tanks, stand compressor, 1-hp motor.

Agitator

Rake-type agitator with side airlifts, 2-hp motor, 10- by 10-foot steel tank.

Flotation machine (four banks required)

10 cells of 50 cubic feet each, 4.5 hp per cell, 180 hp total.

Blower

Low-pressure blower for flotation machines, 40-hp motor.

Pump (two required, one on standby)

3-inch rubber-lined centrifugal unit with 10-hp motor.

Bridge crane (two required)

10-ton unit with 10-hp motor.

Sump with pump (two required)

1,500-gal sump with 3- by 3-inch SRL pump, 5-hp motor.

Thickener

10- by 55-foot spiral rake thickener, 3-hp motor.

10- by 55-foot steel and concrete tank.

Sampler

Automatic sampler with 0.5-hp motor.

Pump (two required, one on standby)

4-inch duplex adjustable-stroke diaphragm pump with 5-hp motor.

Filter

Disk filter, 9-foot diameter by 8 disks, 3-hp motor.

Filter vacuum equipment

Vacuum pump, blower, filtrate receiver, moisture trap, filtrate pump, and 48-hp motor.

Conveyor

18-inch by 20-foot belt conveyor with 1-hp motor.

Concentrate bin

200-ton bolted steel bin.

Dryer

60-inch by 40-foot rotary dryer with 15-hp motor.

Conveyor

24-inch by 40-foot belt conveyor with 5-hp motor.

Concentrate bin

1,000-ton capacity, bolted steel construction.

Truck scale

200-ton capacity.

Thickener

10- by 80-foot spiral rake thickener, 5-hp motor.

10- by 80-foot concrete and steel tank.

Pump (four required, two on standby)

5- by 4-inch SRL pump with 100-hp motor.

Pump (two required, one on standby)

2-inch centrifugal pump with 5-hp motor.

Tailings pipe (5,000 feet required)

4-inch-diameter black carbon steel pipe.

Tailings site preparation

700-foot-long by 120-foot-high by 100-foot-thick dam.

Millsite preparation

5-acre site.

Maintenance shop

50- by 100-foot steel building.

Maintenance equipment

Welding equipment, hoists, drills, tools, etc.

Warehouse

100- by 200-foot steel building.

Mill inventory

Spare parts for mill, general inventory.

Water supply system

300-gpm system with 75 total pump hp.

Pickup (two required)

1/2-ton units.

Sedan (two required)

Four-door sedan.

Power substations

Transformers, distribution boxes, high-voltage branches.

Powerlines (5 miles required)

5 miles of 15-kV transmission line.

APPENDIX D.--DETAILED EQUIPMENT LIST, SUPPORT FACILITIES

Office site preparation

5-acre site with parking.

Office building

50- by 75-foot concrete block building.

Office furniture

Desks, chairs, typewriters, etc.

Road

4-mile-long gravel road from McCarthy to mill.

Townsite

Expansion of existing townsite by installation of 175 double-wide trailers on 0.25-acre lots, sewer system, road system, electrical system, and playground.

Community clinic

50- by 75-foot concrete block building with medical equipment, preparation of site.

Generating facility

Four diesel-powered 1,100-kW generators with 1,500-hp engines.

Fuel tank (eight required)

5,000-bbl tank for generating plant.

5,000-gal tank for heating office.

5,000-gal tank for heating mill.

5,000-gal tank for dryer.

5,000-gal tank for mine maintenance area.

5,000-gal tank for truck fuel.

1,000-gal tank for gasoline.

1,000-gal tank for lubricants.

Trucks with trailers (15 tractors, 30 trailers)

Dual-drive tandem axle truck with concentrate-tanker or concentrate-general cargo trailers.

Truck maintenance building

75- by 150-foot steel building.

Maintenance equipment

Hoists, drills, diagnostic equipment.

Pickups (two required)

1/2-ton unit.

Sedans (two required)

Four-door sedan.

Dock Site, Valdez

Purchase of site

5 acres.

Preparation of site

5 acres.

Concentrate silo

60-foot by 41-foot-diameter reinforced concrete silo for 10,000 tons of concentrate.

Conveyor loading system

24-inch by 120-foot covered elevating conveyor with 25-hp motor.

Unloading shed with hopper

20- by 60-foot steel covered drive-through shed with unloading hopper over conveyor.

Conveyor load-out system

36-inch by 350-foot covered conveyor with 75-hp motor.

Swinging 36-inch by 30-foot covered conveyor with 5-hp motor.

Pivoting support for conveyor 250 feet long, weightometer.

Dock facility

Two salvaged barges floating against four 4-foot-diameter concrete pilings; 40-hp winch for barge moving.

Office

20- by 30-foot concrete block office.

Office equipment

Desks, chairs, filing cabinets, etc.

Pickup

1/2-ton unit.

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