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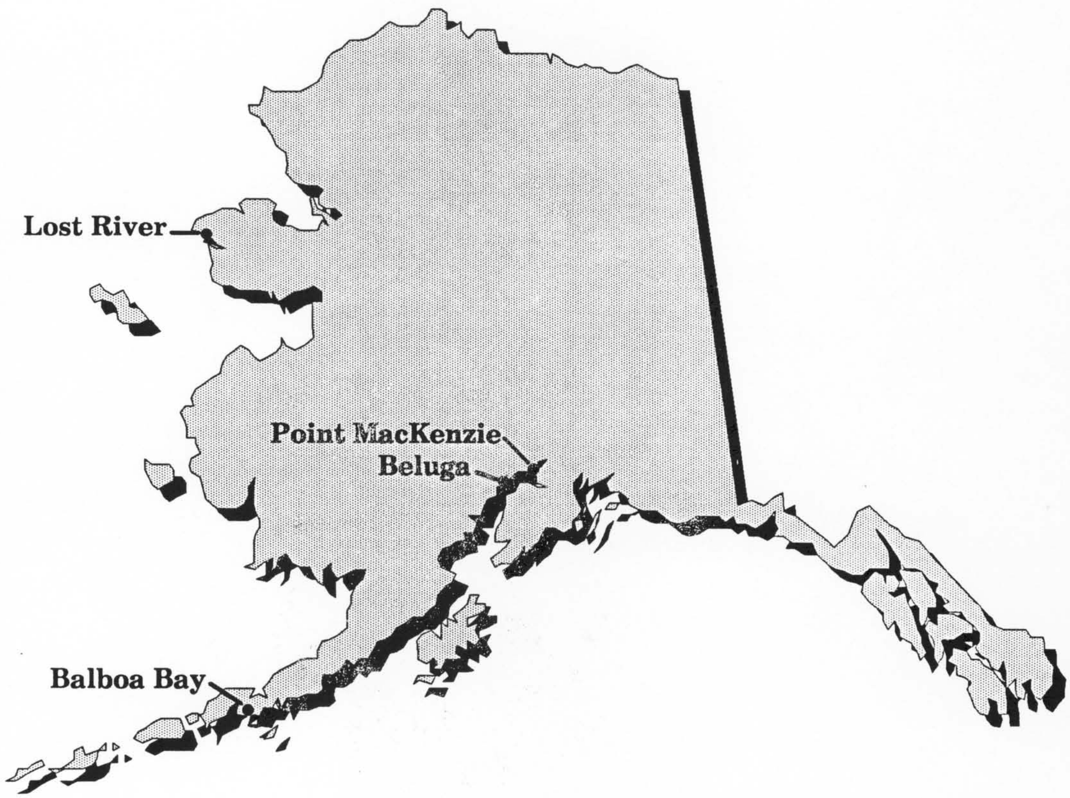

UNITED STATES DEPARTMENT OF INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

OFR 36-90

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

$/st	dollars per short ton
bbl	barrel
bcy	bank cubic yards
BTU	British Thermal Units
BTU/lb	British Thermal Units per pound
d	day
dwt	deadweight ton
ft	feet
gal	gallon
gal/d	gallons per day
in	inch
kV	kilovolt
KW	kilowatt
kwh	kilowatt-hours
KW/hr	kilowatt per hour
lb	pound
lb/yd^3	pound per cubic yard
lcy	loose cubic yards
mi	mile
MW	megawatt
NPV	net present value
st	short ton
st/d	short ton per day
st/hr	short ton per hour
st/yr	short ton per year
tr oz	troy ounces
tr oz/st	troy ounces per short ton
yd^3	cubic yards
yd^3/d	cubic yards per day
yr	year

ANALYSIS OF BALBOA BAY, BELUGA, LOST RIVER, AND POINT MACKENZIE AS PORT SITES FOR USE BY THE MINERAL INDUSTRY

By Gary E. Sherman[1], James R. Coldwell[2], Denise Herzog[3], and Mark P. Meyer[4]

ABSTRACT

To aid the U.S. Army Corps of Engineers in their Resource Development Navigation Study, the U.S. Bureau of Mines (Bureau) examined the potential for mineral development near ten Alaska port sites. This report presents the results for the following four sites: Balboa Bay, Beluga, Lost River, and Point MacKenzie. There are 579 known deposits within the area considered for these ports. The majority of the deposits are located within a highway/railroad corridor examined for the Point MacKenzie port site.

Based on the current level of knowledge, coal deposits near the Beluga and Point MacKenzie port sites are most likely to be developed in the near future. This conclusion is based on the fact that coal projects in these areas are actively being pursued for development.

The mineral wealth surrounding the four port sites is substantial. Mine models were used to examine the potential for mining tin, gold, silver, copper, and molybdenum. The models were based on published reserve and grade data and therefore do not include proprietary company data which, if available, would likely change the analysis results. Of the models examined, the tin placer mine model developed for the Lost River port site proved to be closest to being economic.

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INTRODUCTION

The objective of this study is to provide mining feasibility data to the U.S. Army Corps of Engineers for use in their on-going Resource Development Navigation Study. The study is examining the potential for developing or improving transportation infrastructure at ten proposed or existing port sites in Alaska. The port sites under consideration are Balboa/Herendeen Bay, Beluga, Bethel, Iliamna Bay, Kivalina (Red Dog), Kotzebue, Lost River, Nome, Omalik Lagoon, and Point MacKenzie. This report is the last in a series of three and examines the potential for mineral development within a 100 mi radius of the Balboa Bay, Beluga, Lost River, and Point MacKenzie port sites (the previous reports were published as OFR 21-90 and OFR 22-90). Figure 1 shows the location of the Balboa Bay and Lost River port sites; figure 2 shows the location of Beluga and Point MacKenzie. Map numbers shown on figures 1 and 2 refer to deposit summaries in the Mineral Deposit Inventory volume[5] (59)[6]. There are a total of 579 deposits (excluding placer deposits) within the area of the port sites. The breakdown by port site is: Balboa Bay - 13, Beluga - 46, Lost River - 16, and Point MacKenzie - 504. These represent deposits closest to each respective port. For Point MacKenzie, deposits within 100 mi of the port and those within 30 mi of the road/railroad corridor from the port north to the Arctic Circle on the Dalton Highway were included (see figure 2). Other deposits may fall within the 100 mi radius of the four sites but are closer to other ports such as Nome, Kotzebue, or Iliamna Bay. The feasibility of mineral development around each port site was examined for model (i.e. typical) deposit types. These models were used to estimate the capital and operating costs, mine life, transportation costs, annual tonnage produced, and mine feasibility.

METHODOLOGY

Models were built and applied to each port site based on the types of mineral deposits that occur nearby. A model in this sense refers to a mining and milling scenario, based on factors such as deposit size, grade, orebody shape and attitude, type of wall rock, orebody depth, and depth of overburden. Once the physical aspects of a deposit type were determined, capital and operating cost estimates were prepared using a number of techniques. Cost information came from the Green Guide for Equipment (25), the Bureau's Cost Estimating System Handbook (CES) (57, 58), and in the case of the coal models, from published reports. The source of costs are described in the discussion of each model. Since major lode mining in Alaska is just now seeing a revival, actual cost data have generally been lacking. Development of the Red Dog Mine in Northwestern Alaska and the Greens Creek Mine in Southeast Alaska has provided some additional cost information which can be applied to mine models. When applicable, cost information from developing or producing mines in Alaska was used in assembling the mine models.

Typical cost items for mine models include exploration, permitting, acquisition, mine equipment, mine plant, mill plant and equipment, working capital, and infrastructure. In addition to determining costs for each model, a material balance calculation was completed which determined the quantity and grade of concentrate produced for each unique mill product.

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[5]For more information on deposits, refer to the "Mineral Deposit Inventory", Open File Report 15-90, prepared by the Bureau of Mines.

[6]Underlined numbers in parentheses refer to references listed at the end of the report.

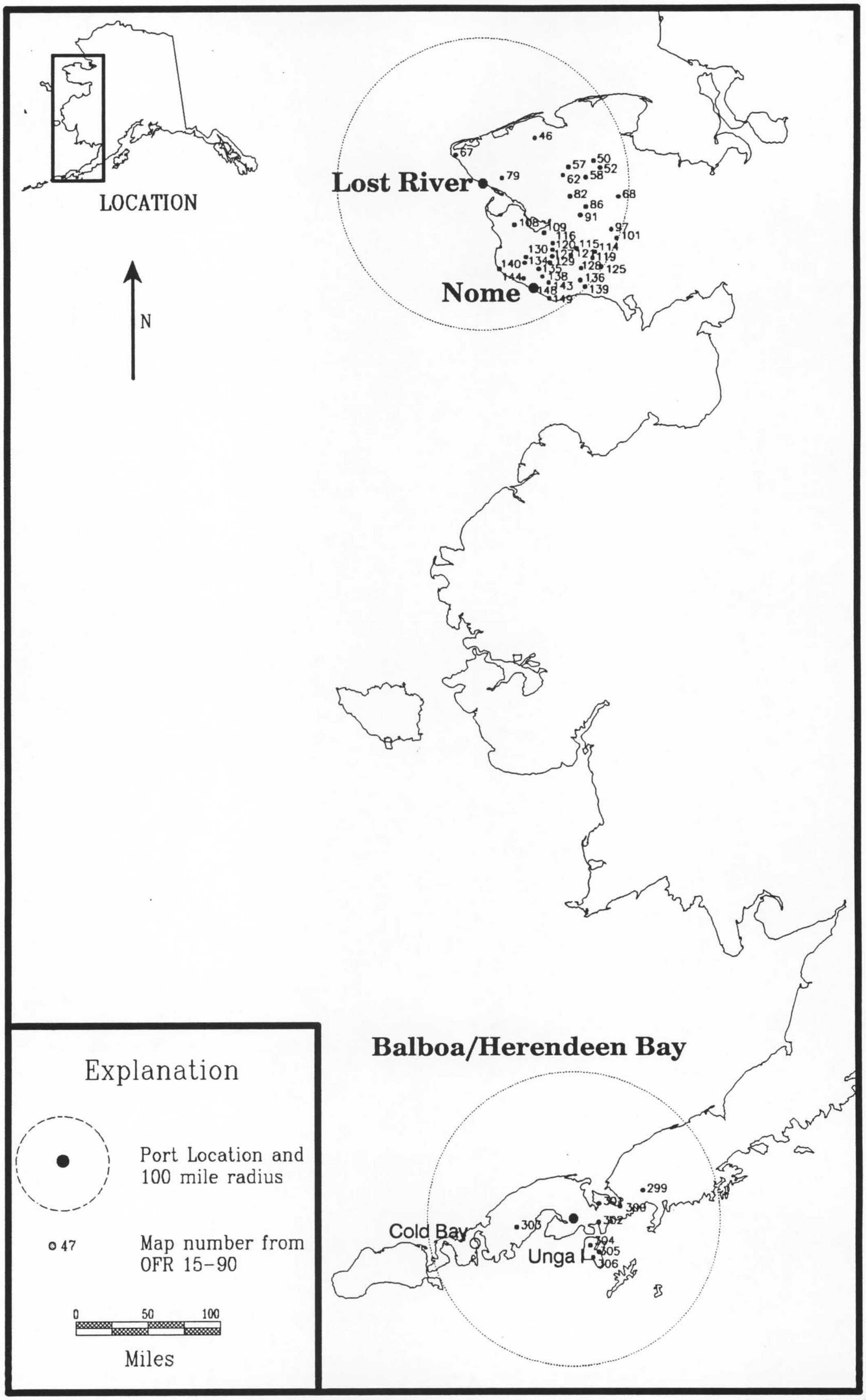

Figure 1. -- Location of the Balboa/Herendeen Bay and Lost River port sites and adjacent mineral deposits.

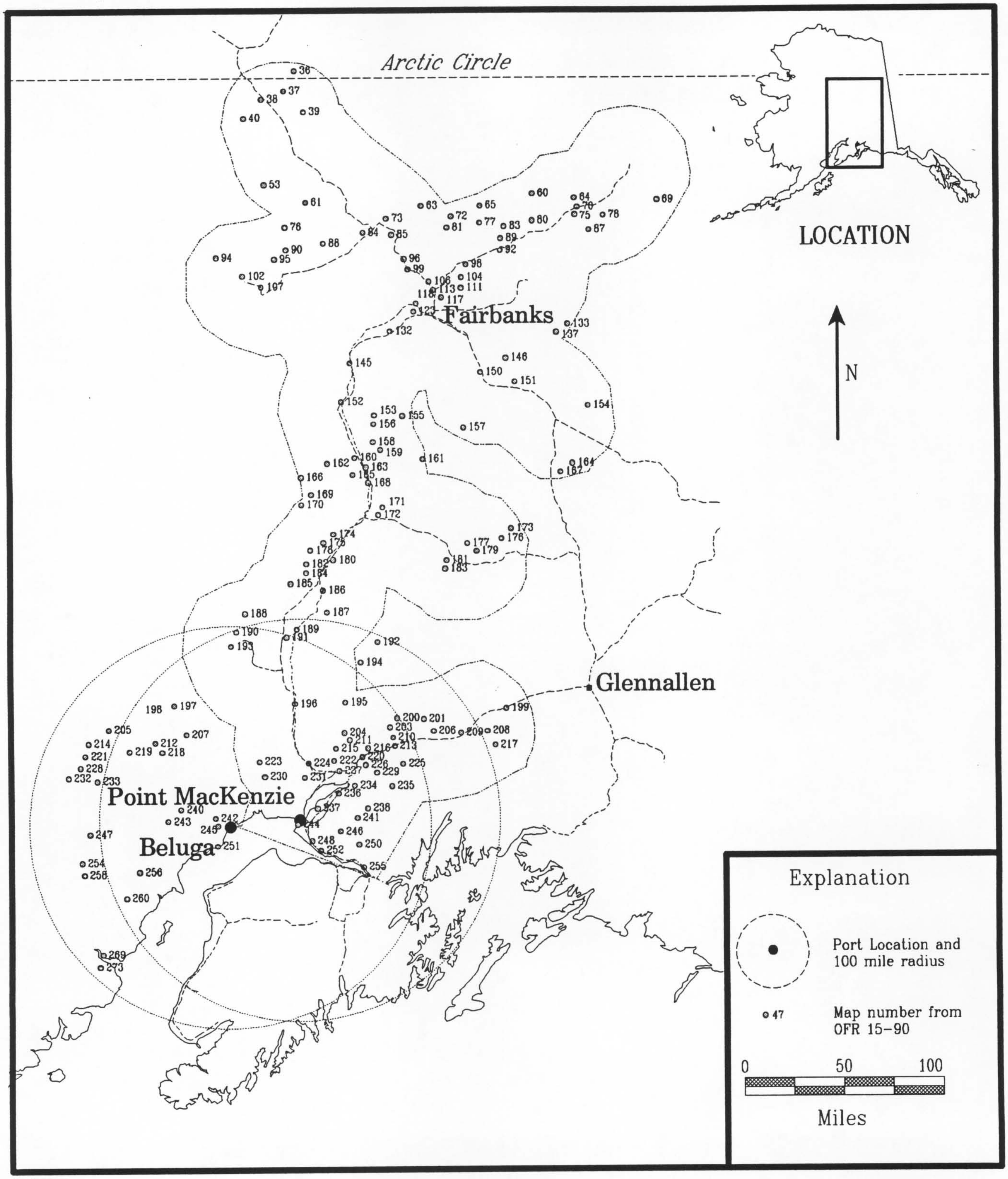

Figure 2. -- Location of the Beluga and Point MacKenzie port sites and adjacent mineral deposits.

The cost information was entered into a discounted cash flow analysis software program to determine the rate of return for each model at discount rates of 0% and 15%. These results are reported in the discussion of each port site. Estimates of when an individual deposit will become economic are very tenuous since metal markets are unpredictable and vary with world supply and demand. A discussion of supply, demand, and production for the mineral commodities considered in this study will be included in a final summary report to be submitted at a later date.

Analysis of each of the models assumes that the port exists and is capable of servicing the mining operation. Costs are included for road construction from the mine site to the port and also construction of concentrate storage and loading facilities at the port site. Transportation costs from the mine site to the port and from the port to point of sale are also included as an operating cost.

ANALYSIS OF MINING FEASIBILITY

The following is an analysis of mining feasibility for the Balboa Bay, Beluga, Lost River, and Point MacKenzie port sites. Each port and the mine models applied to it are discussed individually. Appendix A contains a summary of the mine models used in this report. The appendix includes the assumptions used in building each model, the source of costing information, and the output from each model in terms of annual concentrate or product produced.

It is important to stress that the mine models presented in this study are based on possible mining and milling scenarios for generalized deposits that may occur in a given area. The models are not meant to represent a feasibility analysis of specific deposits. To do so would be inappropriate since such an analysis requires an information base greater than that available for this study. The models can be qualitatively applied to similar deposits in the area to get a gross feel for the potential for mineral development. A number of variables govern the viability of a mineral deposit, including physical characteristics of the orebody, metal markets, availability of infrastructure, political climate, environmental constraints, and corporate policy. Any predictions of the future must consider all the variables; thus results presented here must be viewed as a "snapshot" at this point in time.

BALBOA BAY/HERENDEEN BAY

Location and Access

Balboa Bay and Herendeen Bay are located in the central Alaska Peninsula just north of Unga Island and east of Cold Bay (figure 1). The four largest villages located within the 100 mi port radius include Sand Point on Popov Island with a 1980 population of 625, King Cove with 460, Cold Bay with 192, and Perryville with 111. (54). Other villages near the port site include Bear River, Belkofski, Herendeen Bay, Long John, Pavlof, Apollo, and Port Moller.

Two localities have been identified for possible port sites; a northern site located on the north side of the Alaska Peninsula at the head of Mine Harbor which is in southeastern Herendeen Bay and a southern site located on the south side of the Alaska Peninsula at the head of Balboa Bay, north of Unga Island.

There are no existing port facilities or infrastructure at either proposed port site. The largest airstrip is located at Cold Bay with smaller airstrips located at the smaller villages. The shipping lane serving northern Alaska is located 190 mi to the west at Umiat Pass.

The Balboa Bay/Herendeen Bay area has an average annual precipitation of approximately 33 inches (6). Average temperatures range between 33 to 51° F (6). The port sites would be ice free all year (41).

Land status of the area is varied and includes the Alaska Maritime National Wildlife Refuge, Alaska Peninsula National Wildlife Refuge, Izembek National Wildlife Refuge, and lands controlled by the Bureau of Land Management, native (regional, village, and private), and the State of Alaska including the Izembek State Game Refuge and the Port Moller State Critical Habitat Area (43).

Mineral Deposits

Gold and coal are the primary mineral deposit types found near Balboa and Herendeen Bays. Figure 3 shows the distribution of mineral deposits in this area by primary commodity. There are three past producing gold mines and three past producing coal mines in the area of the port site. The Apollo Mine (map number 306) was the major gold producer in the area. It was discovered in 1891 and operated until 1904, producing 106,000 tr oz of gold (49). There has been mineral exploration for base and precious metals in this region in recent years (14, 26). Approximately 8% of the exploration dollars spent in Alaska from 1982 through 1988 were for minerals exploration of the Alaska Peninsula.

Coal production from the area has been limited to small tonnages mined near the turn of the century. The coal within the port site radius ranks from lignite to subbituminous. Dall noted that a corporation under the name of the Alaska Mining and Development Co. was formed in 1889 to develop the Herendeen Bay coal deposits (24). According to Captain Hague, one of the company's stockholders, two tunnels totalling 500 ft in length were driven on a coal seam of 4 ft average thickness. The mine was located 1.25 mi inland from Mine Harbor, a cove of Herendeen Bay. The coal was brought to the water front by a steam motor on a small tramway. Several hundred st were taken out in 1890, of which the *U.S.S. Albatross* used between 200 and 300 st.

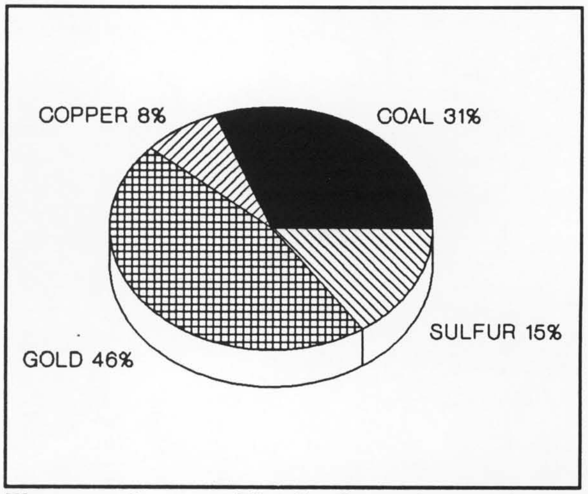

Figure 3. -- Distribution by primary commodity of deposits near the Balboa Bay port site.

Commercial coal mining ceased in 1904 due to unsuccessful attempts by several companies to find the extension of the coal seam which had been displaced by faults (56). In 1911, Atwood noted that only a few st each year were mined for local consumption (7).

Conwell and Triplehorn investigated these coal beds during 1974-75 (21). They collected nine samples in the Herendeen Bay area. The samples were analyzed for moisture, ash, volatile matter, sulfur, fixed carbon, and calorific values. The coal rank is high volatile B bituminous coal. Sink-float results revealed a washed product with a specific gravity of -1.5 would contain less than 8 percent ash and have a BTU rating above 12,200 BTU/lb (21).

Conwell and Triplehorn in 1980 suggested Herendeen Bay as a source of coal for the villages of Goodnews Bay, Togiak and Dillingham (22). They estimated coal could be delivered to these villages at a cost of $80 to $90/st (October 1980 dollars). Their estimate was an escalation of an earlier cost analysis done for the Barrow region by Bottge (11).

The Late Cretaceous and Tertiary bituminous coals of the Herendeen Bay field occupy an area over 1,100 mi^2. At Mine Harbor on Herendeen Bay, up to 17 coal beds are exposed but most are less than 2 ft thick. The strata is moderately folded and faulted (48). Published resources for the Herendeen Bay coal field are 45 million st indicated and inferred and 300 million st hypothetical (47). It is not likely that there will be any significant coal development in the Herendeen Bay coal field in the near term. Small scale underground mining methods in this remote area would very likely be uneconomic. At this time, a regional market does not exist for coal.

There is one large tonnage, low grade copper-molybdenum deposit within the area. The Balboa Bay (Pyramid, map number 302) deposit contains approximately 100 million st of ore with grades of 0.5% copper and 0.03% molybdenum. Based on present knowledge, development of a copper-molybdenum deposit in the area surrounding the Balboa Bay port site is more likely than development of deposits containing any other commodity.

Copper-Molybdenum Mine Model

The copper-molybdenum open pit model assumes the mining of a deposit with reserves similar to the Pyramid deposit (map number 302). The assumptions made in designing the model are listed in table 1 and the commodity data are listed in table 2.

TABLE 1. -- Assumptions used in designing the copper-molybdenum mine model, Balboa Bay port site.

Mine life (yr)	23.6
St ore/d	13,230
St waste/day (open-pit)	2,780
St ore mined/yr	4,629,800
Stripping ratio (open pit)	0.21:1
Personnel	225
Power generation (KW)	8,000
Operating days/yr	350
Shifts/d	3
Mill method	Flotation
Mill feed, st/d	13,230
Tailings, st/d	13,100
St concentrate produced/year	45,360

TABLE 2. -- Commodity data for the copper-molybdenum mine model, Balboa Bay port site.

Commodity	Grade	Recovery	Concentrate grade	St/d concentrate
Copper (Cu)	0.4%	90%	40%	119
Molybdenum (Mo)	0.05%	80%	50%	10.6

Costs for the copper-molybdenum open pit model were estimated using CES and should fall within ±25% of actual costs (57, 58). All costs are in July 1989 dollars and have been escalated to account for increased cost of mining in Alaska. Capital costs were escalated by a factor of 2.3, labor costs by 1.565, and supplies and equipment costs by 1.52 (12). Table 3 lists the capital, operating, and transportation operating costs for the mine model.

TABLE 3. -- Capital, operating, and transportation costs for the copper-molybdenum mine model, Balboa Bay port site.

Cost category	Capital cost	Operating cost $/st
Mine	$98,652,900	$4.22
Mill	82,054,400	6.23
Total	180,707,300	10.45
Transportation	NAp	$65.23

NAp Not applicable

The total capital costs for a 13,230 st/d open pit mine are estimated to be $180,707,300. This includes exploration, permitting, and infrastructure. The total mine and mill operating cost is $10.45/st ore mined and processed. The transportation operating cost includes concentrate haulage via truck, and shipment by barge and rail to points of sale or smelting. A summary of the costs and assumptions used in the models are presented in Appendix A.

Economic Analysis

Based on the assumptions made for the copper-molybdenum model, the discounted cash flow analysis indicated that the model was uneconomic and did not generate a positive rate of return. Metals prices would have to increase 138% ($1.51/lb copper, $3.72/lb molybdenum) for the model to achieve a 0% discounted cash flow rate of return (DCFROR) and by 150% ($2.26/lb copper, $5.58/lb molybdenum) to achieve a 15% DCFROR. For this reason, the development of a large, copper-molybdenum deposit similar to the model is considered to be unlikely in the near-term.

BELUGA

Location and Access

Beluga is located on the northern shoreline of Cook Inlet west of Anchorage (figure 2). There are several potential port sites in the area, including North Foreland, Granite Point, and Ladd. Figure 4 shows the location of these sites. The North Foreland site has an existing deep-water port facility. It consists of a T-type bulk loading facility with a 1,475 ft long 17 ft wide approach trestle. The wharf is 174 ft long, 50 ft wide, with a dolphin to provide a 685 ft berth, and has a dockside draft of 35 ft. The Granite Point site has no existing development or infrastructure. This is one of the proposed sites for the Diamond Alaska Coal Co. terminal. Ladd was identified as the preferred alternative in the final Environmental Impact Statement (EIS) for the proposed Diamond Alaska coal mine.

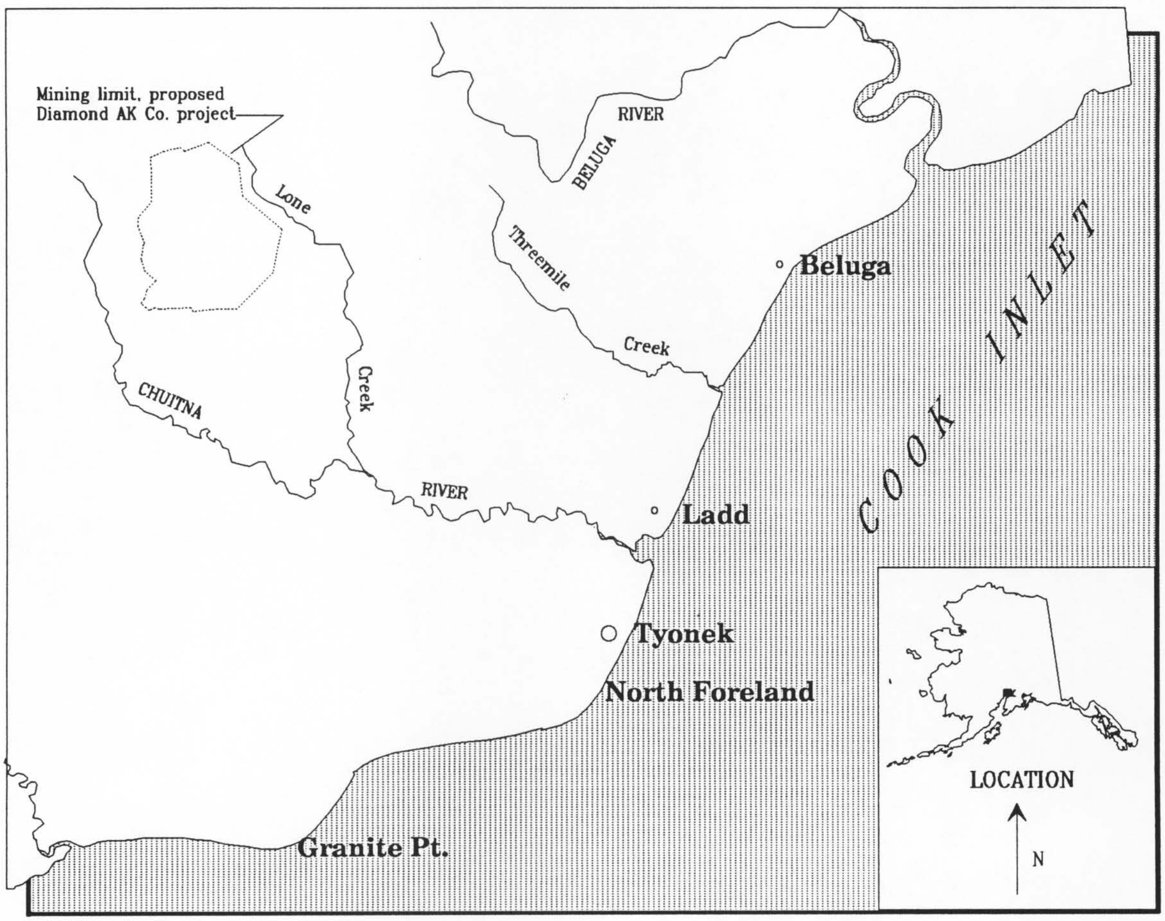

Figure 4. - Potential port sites in the Beluga area.

Anchorage is the largest city in the 100 mi radius with a 1980 population of 174,431 (54). Other large communities include Palmer with 2,141, Wasilla with 1,559, Moose Creek with 510, Houston with 370, Talkeetna with 264, Tyonek with 239, Sutton with 182, Willow with 139, Montana with 40, and Chickaloon with 37 (54). There are at least 36 other smaller communities located within the 100 mi radius.

Anchorage has an existing port facility as well as an extensive transportation network including the Alaska Railroad and the Seward, Glenn, and Park's Highways. Also included is the Anchorage International Airport with domestic and international air carrier service. The year round port facility at Seward is also accessible via the Alaska Railroad or the Seward Highway.

Annual precipitation in the Beluga area is approximately 15 inches (6). The temperature varies from an average low of -12° F to an average high of 58° F (6). The proposed port site would be ice free year round (41).

The status of lands within the port site radius include: Lake Clark National Park and Preserve, Denali National Park and Preserve, Chugach National Forest, BLM controlled lands, native lands (regional, village, and private), and State of Alaska lands including Susitna Flats State Game Refuge, Palmer Hay Flats State Game Refuge, Goose Bay State Game Refuge, Willow Creek State Recreation Area, Nancy Lake State Recreation Area, Hatcher Pass Public Use Area, Matanuska Valley Moose Range, Chugach State Park, Trading Bay State Game Refuge, and the Kalgin Island Critical Habitat Area (42).

Mineral Deposits

Copper, coal, and gold make up the majority of the known deposits within the 100 mi Beluga port site radius. Figure 5 shows the distribution of mineral deposits in this area by primary commodity. There are no past producing lode mines within the port radius and no reserve information exists for the gold and copper deposits. While coal comprises only 24% of the total deposits, it has the highest development potential in the near future. Because of the potential in this area, coal deposits are discussed in further detail below.

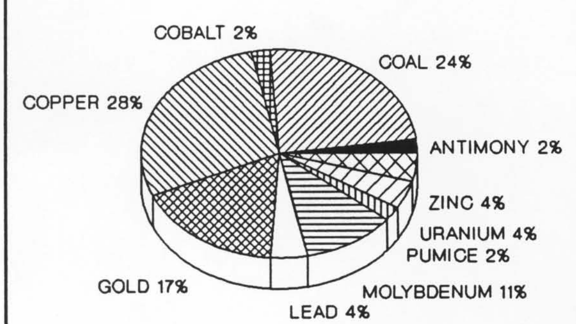

Figure 5. -- Distribution by primary commodity of deposits near the Beluga port site.

Coal

According to company figures, the Beluga coal field contains the world's largest surface minable reserves of low-sulfur coal close to tidewater and ocean shipping (52). At one time, coal leases in this area covered nearly 110 mi^2 (70,577 acres). All of the coal leases are administered by the State of Alaska with the exception of the Capps lease (9,240 acres) which was transferred to Cook Inlet Region, Inc. (CIRI) native corporation as a consequence of the Alaska Native Claims Settlement Act and subsequent land trade (40).

At the present time, only Beluga Coal Co. (a wholly owned subsidiary of Placer Dome U.S. Inc. formerly Placer Amex, Inc.) and Diamond Alaska Coal Co. (a subsidiary of Maxus Energy Corp.)

hold leases in this area. Mobil Mineral Resources dropped their Johnson and Canyon Creek leases (23,080 acres) in 1989.

Beluga Coal Co. - Lone Ridge Deposit

The U.S. Geological Survey (USGS) reported observation of coal occurrences in the Beluga region as early as 1900. In the mid 1950's Phil Holdsworth, then Commissioner of Mines for Alaska, suggested the Beluga coal field could be a source of fuel for mine-mouth power generation for the Anchorage area. The Bureau undertook coal drilling near Beluga Lake from 1959 through 1961, and in 1962 and 1963 some private coal exploration occurred. Portions of this exploration activity took place on land now leased to Beluga Coal Co. In addition to the Lone Ridge Deposit (map number 242), Beluga Coal Co. holds leases on the Capps (map number 240), Center Ridge (map number 245), and Threemile (map number 245) deposits located in the same area (50).

Placer Dome obtained a major interest in the Beluga coal fields in the late 1960s, in anticipation of oil to coal conversion and mine-mouth power generation markets. The 1973-74 and 1979-80 energy crises and resulting fuel price escalation caused Placer Dome to increase coal exploration and development activity in the region (46).

In 1979, EBASCO completed a preliminary mine-mouth power plant study for Placer Dome which incorporated two 200 MW steam turbines at an approximate capital cost of $400 million (1979 dollars). The all-in cost of electric power was estimated at $0.046/kwh (1979 dollars).

In 1981 Placer Dome and CIRI received and administered a $4 million Department of Energy grant for a feasibility study proposing the Winkler process to gasify 8.5 million st/yr of Beluga coal for manufacture of 54,000 bbl/d (7,500 st/d) of fuel-grade methanol. In addition, by-product production of 10,000 st/d of carbon dioxide to be used for injection for a miscible phase secondary recovery project to increase oil recovery from reservoirs located in offshore Cook Inlet fields was proposed. The project had an approximate capital cost of $2.3 billion (1981 dollars) (23). In 1982, the project was not successful in securing funds during the second round of solicitations examined by the U.S. Synthetic Fuels Corp. (26).

In 1982, a $2.5 million three way joint pre-feasibility study with the Electric Power Development Co. (EPDC), Nissho Iwai Corp. (NIC), both Japanese companies, and Placer Dome was conducted. This comprehensive engineering study incorporated truck and conveyor transport and a major new port complex.

The decline of oil prices and a sharp reduction in world energy demand in the mid 1980s resulted in an extreme over-supply of coal in the Pacific Basin (46). In response to the limited and highly competitive coal market, Placer Dome has completed a number of studies for producing 1.1 to 2.2 million st of coal per year. This concept is designed to minimize capital costs by using the existing dock and other improvements at North Foreland near the village of Tyonek. McFarland cited an estimated capital requirement of $65 million (1986 dollars) for a project designed to sustain shipments of 1.7 million st/yr in 65,000 dwt (Panamax class) vessels over a 20 year period (46). Coal production of 1 million st/yr would require $33 million (1986 dollars) in startup funds.

Development plans include using the existing 1,475 ft long pier (known as the Tyonek Pier) at North Foreland near Tyonek, where 40,000 dwt ships could be loaded (16). The Tyonek Pier was used from 1975 to 1983 to load wood chips on ocean going vessels as large as 40,000 dwt. Soros Associates completed a study of the pier at Tyonek in 1986 for Diamond Alaska Coal Co. Subsequent to this analysis, Beluga Coal Co. engaged various marine and engineering consultants who provided technical information on the tidal currents and ice conditions at the site. In addition a preliminary design for a 1,000 ft pier extension which will accommodate Panamax-size vessels requiring a draft of 50 ft of water has been completed (38).

Beluga Coal Co. has not started the permit process for its proposed mine. Like Diamond Alaska Coal Co., Beluga Coal Co. has not secured a contract for the purchase of its coal. Beluga Coal Co. has elected to wait for a market to develop before beginning the permit process. Permitting of the project is estimated to take two years (51).

Mobil Mineral Resources, Inc. - Johnson Creek

Mobil Mineral Resources holdings at Beluga were located about 90 mi northwest of Anchorage and 45 mi north of Cook Inlet, north of those leased by Diamond Alaska Coal Co. and Beluga Coal Co.

In 1973, Mobil became interested in the possibility of acquiring Alaskan coal. By 1975, the company had obtained prospecting permits and began a drilling program (2,000 ft in 17 holes). In 1977, drilling continued with 14 holes totalling 5,000 ft being completed. Based on the 1975 and 1977 drilling results, Mobil applied for leases on the prospecting permit areas. Upon granting of the leases in 1979, Mobil did 2,250 ft of fill-in drilling in 7 holes.

The eight leases consisted of some 23,000 acres on the western flank of the Yentna River Basin and were arranged in 2 tracts; Johnson Creek (map number 207) on the north, and Canyon Creek (map number 207) in the south. Mobil identified an in-place resource in excess of 500 million st of coal, to depths of 250 ft (10).

Mobil dropped their leases on June 1, 1989 and it is unknown when the State will lease these tracts to another party (33).

Diamond Alaska Coal Co. - Beluga 1

Significant geological ground work for the area encompassing the Beluga 1 (map number 242) leases was laid by Barnes in his 1966 report covering the regional coal outcrops (8). The majority of the lease is situated between Lone Ridge to the northwest, Lone Creek to the east and the Chuitna River to the south. Major work in the area began in 1967 when the Bass-Hunt-Wilson Venture obtained prospecting permits from the State. Exploration drilling started in 1968 and was carried on annually until 1982. The property was elevated to State Coal lease status in 1972 and became known as the B-H-W leases and the Chuitna River coal field.

In August of 1980, close spaced drilling was undertaken to study the possibility of an open pit production area outlined by Bechtel, Inc., a consulting engineering firm (53). A comprehensive drilling program was designed to generate geologic, engineering and hydrologic data for reserve computation, interburden and overburden determination and preliminary pit design (53). Bechtel, Inc. estimated capital costs for a 7.7 million st/yr mine to be $277 to $492 million with operating costs of $7.01/st to $10.13/st (December 1979 dollars) (9). Updating this cost estimate gives a range of $412 to $731 million capital cost and $10.42 to $15.06/st operating costs in July 1989 dollars.

In 1981 the Diamond Shamrock-Chuitna Coal Joint Venture was formed to develop the property. The venture partners are Maxus Energy Corp., a large integrated natural resources company, and the Lone Creek Coal Co. The operating arm of the joint venture is Diamond Alaska Coal Co. of Anchorage, a subsidiary of Maxus Energy Corp.

Diamond Alaska Coal Co. has overseen an intensified drilling program and the completion of many engineering and economic studies, including a detailed Preliminary Design Phase study. Environmental baseline studies were begun in 1982 and largely completed in 1984. Limited preconstruction monitoring has also begun. The Environmental Protection Agency (EPA), the lead agency preparing the (EIS), held public scoping meetings during January 1985 in Anchorage, Soldotna, and Tyonek on the proposed development of the mine (36). A joint market feasibility study, prepared by the EPDC of Japan and Diamond Alaska Coal Co., was also completed in 1985. Price cuts by South African, Australian, and Canadian producers caused marketing problems for the project (15).

Following release of the Draft EIS in June 1988, additional public hearings were held during August 1988 in Anchorage, Soldotna, and Tyonek. The Alaska Department of Natural Resources (ADNR) conducted a thorough review of Diamond Alaska Coal Co.'s 27 volume application for a permit to conduct surface mining. ADNR reached a final decision in June 1988 pursuant to the Alaska Surface Coal Mining Control and Reclamation Act. The Final EIS was released in February 1990 by the EPA. Diamond Alaska Coal Co. is pursuing the full range of other permits and approvals required for their proposed project. Diamond Alaska Coal Co. has not yet secured a final contract for the sale of it's coal (28).

Lack of emerging markets in the Far East are the biggest obstacle facing development at Beluga. Diamond Alaska Coal Co. has scaled back its Beluga related activities since completion of environmental studies. Its Anchorage office has cutback staff and the Tokyo office has been closed. Japan Economic Journal noted the Tokyo office closing as an indication that Diamond Alaska Coal Co. was losing its enthusiasm for Beluga. However, company officials in Alaska said it was a logical step since joint-venture economic studies on the project with Japanese participants were complete and the general market outlook was gloomy (3).

Coal Mine Model

A coal mine model was used to examine the potential for large-scale coal mining in the Beluga port site area. Based on the interest and recent work in the area, it is apparent that several companies believe that coal production could be economic and competitive. The mine model simulates mining a coal deposit similar to Beluga 1. The costs were estimated using the Bureau's CES (57, 58) and should fall within ± 25% of actual costs. The model does not attempt to estimate the feasibility of the proposed Diamond Alaska Coal Co. operation but is useful in examining costs and returns which may be expected for mines producing coal in the Beluga area. Actual feasibility analysis of a coal mine in this area would require detailed information which was not available for use in this analysis.

The mine model assumes strip mining of coal, haulage to the port site by truck (years 1 and 2) and conveyor (years 3 and on), and shipment by ocean-going vessel to market. The assumptions used in the mine model are listed in table 4 and details of the mine model are given in Appendix A. The coal in this area is subbituminous with a rating of 10,485 BTU/lb, 27.1% moisture, and 0.17% sulfur.

TABLE 4. -- Assumptions used in designing the large-scale coal mine model, Beluga port site.

Mine life (yr)	30
St coal/day	33,300
Bank yards overburden/day	153,180
St coal mined/yr	12,000,000
Stripping ratio	4.6:1
Personnel	424
Power generation (MW)	35
Operating days/yr	360

Total capital costs for the mine model were estimated at $507,168,300. The capital cost includes exploration, acquisition, mine and mill construction, and marine terminal facilities. For a more complete breakdown of mine capital costs, see Appendix A. Operating cost estimates for the mine model are summarized in table 5. In year 4 of the operation, the mine will reach its full production capacity of 12 million st of coal per year. To account for the difference in continental U.S. costs (on which CES is based) and Alaska, capital costs were escalated by a factor of 2.0 and operating costs by 1.52. All costs are in July 1989 dollars. Additional operating cost breakdowns for this mine model are given in Appendix A.

TABLE 5. -- Operating cost summary for the large-scale coal mine model, Beluga port site.

Year(s)	Million st/yr	Operating Cost $/st
1	2	21.01
2	4	18.89
3	6	12.21
4-30	12	8.69

Economic Analysis

To determine the economic viability of the coal mine model, a cash flow analysis was run at discount rates of 0% and 15%. Since coal prices vary considerably and the actual retail price of coal from this model at the point of sale is unknown, the price of coal required to achieve a 0% and 15% DCFROR was determined for coal delivered to and loaded aboard ship at the Ladd port site. The results of the analysis are listed in table 6.

TABLE 6. -- Economic analysis results for the large-scale coal mine model, Beluga port site.

DCFROR	Point of sale	Price required, $/st
0%	FOB Ladd	12.67
15%	FOB Ladd	24.29

To put the results in table 6 in perspective, prices for coal (FOB mine) from Usibelli Coal Mine (UCM) are in the mid-$30/st range and range from $30-$50/st delivered in Seward. Idemitsu Alaska Inc. (Idemitsu), which is working on developing Wishbone Hill coal in the Matanuska Valley, is estimating a $40/st cost for coal delivered in Seward (4). The Beluga coal field deposits are economic to develop; Beluga Coal Co. and Diamond Alaska Coal Co. have held leases in this coal field for nearly 20 years anticipating future development of these reserves. Development is anticipated to occur sometime in the next 5 to 10 years.

LOST RIVER

Location and Access

Lost River is located near the entrance to Port Clarence on the southern shoreline of the Seward Peninsula (figure 1). The largest community within the 100 mi radius is Nome with a 1980 population of 2,544 (54). Other communities in the area include Shishmaref with a population of 394, Brevig Mission with 138, Wales with 133, and Port Clarence with 29 (54). There are at least 38 other smaller communities within the port radius.

There is no existing infrastructure at this proposed port site. The largest airport is located at Nome with smaller airstrips located in the surrounding communities. Nome is the economic and transportation hub of the Seward Peninsula. The overland transportation system from Nome includes the 72 mi Nome-Teller Highway to the west, the 73 mi Nome-Council Highway to the east, and the 87 mi Nome-Kougarok River Highway to the north. The shipping lane supplying the North Slope is located offshore to the west of Lost River.

The Lost River area has an average annual precipitation of approximately 16 inches (6). Average temperatures range between 5 to 50° F (6). The ice free season occurs from June to September (41).

The status of the land in the area includes the Alaska Maritime National Wildlife Refuge, the Bering Land Bridge National Preserve, BLM controlled land, native (regional, village, private), and State of Alaska lands (43).

Mineral Deposits

Tin, copper, and gold are the major commodities contained in deposits closest to the Lost River port site. Figure 6 shows the distribution of deposits by primary commodity. The portion of the Seward Peninsula surrounding the Lost River port site is known for its tin deposits and potential.

Tin was discovered on the Seward Peninsula in 1900 and has been produced from lode mines within the port site radius. The Cape Mountain Mine (map number 67) produced several hundred st of tin with main production occurring from 1903 to 1909. Up to 2.2 st of ore were produced in 1983 (49). The Lost River Mine (map number 79) has an estimated 24.6 million st of ore with grades of 0.15% tin, 16.3% CaF_2 (fluorite) and 0.03% WO_3 (tungsten oxide). The mine produced 352 st of tin; primarily from 1952 to 1955 (49). All ore concentrates from the Lost River Mine were loaded on barges at Tin City, lightered to Nome, and then reloaded on container barges.

Placer tin has also been produced in the region for many years. In 1988, all 300,000 lb of tin produced in the Alaska came from the Cape Creek Placer Mine (map number 67). Tin production in 1989 amounted to 194,000 lb, the majority being produced from the Cape Creek placer by the Lost River Mining Co. Lost River Mining Co. exhausted reserves on Cape Creek and closed the operation at the end of the 1989 season (19).

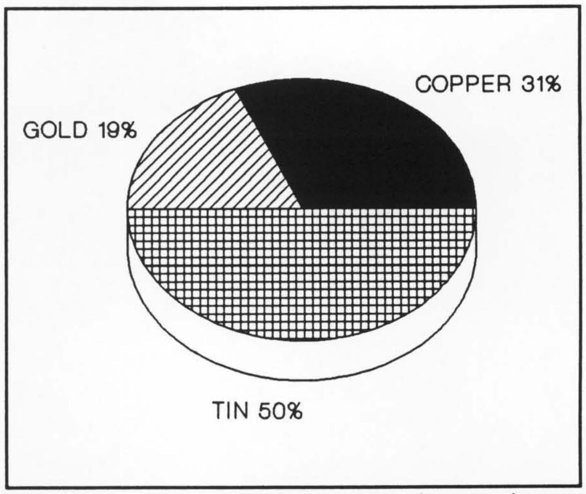

Figure 6. -- Distribution by primary commodity of deposits near the Lost River port site.

Exploration and drilling of lode tin prospects (e.g. Kougarok, map number 62) in the region has taken place in recent years.

Lode Tin Mine Models

Two mine models were built for lode tin mines within the Lost River port site radius. Tin deposits are considered to have the highest potential for development in the near-term, based on the current level of knowledge for known mineral deposits in the area. The mine models presented below are based on deposits similar to the Lost River Mine and the Kougarok tin prospect. As with other models, the results should not be interpreted as a feasibility analysis of the aforementioned deposits. Detailed geologic and engineering data required to conduct such an analysis were not available for use in this study.

Tin-Tungsten-Fluorspar Mine Model

The tin-tungsten-fluorspar open pit model assumes the mining of a deposit with reserves similar to the Lost River Mine. The assumptions made in designing the model are listed in table 7 and the commodity data are listed in table 8.

TABLE 7. -- Assumptions used in designing the tin-tungsten-fluorspar open pit model, Lost River port site.

Mine life (yr)	20
St ore/d	4,000
St waste/d (open-pit)	7,200
St ore mined/yr	1,400,000
Stripping ratio (open pit)	1.8:1
Personnel	160
Power generation (KW)	4,800
Operating d/yr	350
Shifts/d	2
Mill method	Flotation/gravity
Mill feed, st/d	4,000
Tailings, st/d	3,402
St concentrate produced/yr	209,400

TABLE 8. -- Commodity data for the tin-tungsten-fluorspar mine model, Lost River port site.

Commodity	Grade	Recovery	Concentrate grade	St/d concentrate
Tungsten (WO_3)	0.03%	45%	7%	8.8
Tin (Sn)	0.15%	50%	35%	(within WO_3)
Fluorite (CaF_2):				
Metallurgical grade	16.16%	80%	85%	456.3
Acid grade	16.16%	80%	97%	133.3

Costs for the tin-tungsten-fluorite open pit model were estimated using CES and should fall within ±25% of actual costs (57, 58). All costs have been calculated in July 1989 dollars and have been escalated to account for increased cost of mining in Alaska. Capital costs were escalated by a factor of 2.8, labor costs by 1.616, and supplies and equipment costs by 1.65. Table 9 lists capital, operating, and transportation operating costs for the mine model.

The total capital costs for a 4,000 st/d open pit mine are $127,199,400. This includes exploration, permitting, and infrastructure. The total mine and mill operating cost is $36.53/st ore mined and processed. The transportation operating cost includes concentrate haulage via truck, and shipment by barge and rail to points of sale or smelting. A summary of the costs and assumptions used in the models are presented in Appendix A.

TABLE 9. -- Capital, operating, and transportation costs for the tin-tungsten-fluorspar open pit mine model, Lost River port site.

Cost category	Capital cost	Operating cost $/st
Mine	$64,237,200	15.76
Mill	62,962,200	20.77
Total	127,199,400	36.53
Transportation	NAp	$152.00

NAp Not applicable

Economic Analysis

Based on the assumptions made for this model, the discounted cash flow analysis indicated that the model was uneconomic. Substantial increases in the tin grade and recovery would be required for the model to generate a positive DCFROR. For this reason, development of a large, low-grade tin deposit similar to the model is considered to be unlikely in the near-term.

Tin-Columbium-Tantalum Mine Model

The tin-columbium-tantalum shrinkage-stope model assumes the mining of a deposit similar to the Kougarok prospect (map number 62) with assumed reserves of 25,000,000 st. The assumptions made in designing the model are listed in table 10 and the commodity data are listed in table 11.

TABLE 10. -- Assumptions used in designing the tin-columbium-tantalum mine model, Lost River port site.

Mine method	Shrinkage
Mine life (yr)	32
St ore/d	2,000
St mined/yr	700,000
Shaft depth (ft)	1,312
Total length workings (ft)	41,958
Personnel	260
Power generation (KW)	4,800
Operating d/yr	350
Shifts/d	3
Mill method	Flotation/gravity
Mill feed, st/d	2,000
Tailings, st/d	1,984
St concentrate produced/yr	5,599

TABLE 11. -- Commodity data for the tin-columbium-tantalum mine model, Lost River port site.

Commodity	Grade	Recovery	Concentrate grade	St/day concentrate
Tin (Sn)	0.50%	80%	50%	16.00
Columbium (Nb)	0.01%	80%	1%	(contained in Sn)
Tantalum (Ta)	0.01%	80%	1%	(contained in Sn)

Costs for the tin-columbium-tantalum underground model were estimated using CES (57, 58). All costs have been calculated in July 1989 dollars and have been escalated to account for increased cost of mining in Alaska. Capital costs were escalated by a factor of 2.9, labor costs by 1.616, and supplies and equipment costs by 1.65 (12). Table 12 lists capital, operating, and transportation operating costs.

TABLE 12. -- Capital, operating, and transportation costs for the tin-columbium-tantalum mine model, Lost River port site.

Cost category	Capital cost	Operating cost $/st
Mine	$71,714,100	39.78
Mill	59,780,200	17.08
Total	131,494,300	56.86
Transportation	NAp	$152.00

NAp Not applicable

The total capital costs for the 2,000 st/d tin-columbium-tantalum underground mine are $131,494,300. This includes exploration, permitting, and infrastructure. The total mine and mill operating cost is $56.86/st ore mined and processed. The transportation operating cost includes concentrate haulage via truck, and shipment to points of sale or smelting by barge and rail. A summary of the costs and assumptions used in the models are presented in Appendix A.

Economic Analysis

Based on the assumptions made for the tin-columbium-tantalum underground mine model, the discounted cash flow analysis indicated that the model was uneconomic and failed to generate a positive cash flow during any year of operation. The relatively low grade coupled with the high underground mining cost make the model uneconomic. Substantial increases in the ore grade would be required for the model to generate a positive DCFROR. Development of an underground tin-columbium-tantalum deposit similar to the model is considered to be unlikely in the near-term. Discovery of higher grade deposits (or extensions of existing ones) and a firming up of the tin market could result in eventual development of underground deposits.

Tin Placer Mine Models

There are at least twelve placer tin deposits in the Lost River port site area. Three tin placer deposits with reserve data were used in the following models which simulate three levels of production. All models are based on 1,800 bank cubic yards of material processed per day. Costs are based on those of standard placer operations using bulldozers, front-end loaders, and dump trucks for mining. Mill costs include sluices, jigs, and trommels. Infrastructure costs were variable depending on the distance of the mine from water transportation. Concentrates will be trucked to the coast and then loaded on small barges to be shipped to the Lost River port site. The assumptions made in designing the models are listed in table 13 and the commodity data are listed in table 14.

TABLE 13. -- Assumptions used in designing the tin placer models, Lost River port site.

#1 mine life (yr)	10
#2 mine life (yr)	5
#3 mine life (yr)	11
Bcy/d	1,800
Total bcy overburden removed	225,000
Lcy ore/yr.	216,000
Personnel	5
Operating d/yr	120
Shifts/d	3
Mill feed (yd^3)	1,800
Mill method	Gravity
#1 st concentrate/yr	33.6
#2 st concentrate/yr	37.7
#3 st concentrate/yr	205.2

TABLE 14. -- Commodity data for the tin placer mine models, Lost River port site.

Commodity	Grade	Recovery	Concentrate grade	St/day concentrate
#1 Tin(Sn)	0.29 lb/yd^3	90%	85%	0.28
#2 Tin	0.33 lb/yd^3	90%	85%	0.31
#3 Tin	1.79 lb/yd^3	90%	85%	1.71

Costs for the tin placer models were estimated by using Stebbins' Cost Estimation Handbook for Small Placer Mines (CEH) (55) and fall within ±25% of actual costs. All costs have been calculated at July 1989 dollars and have been escalated to account for increased cost of mining in Alaska. Capital costs were escalated by a factor of 2.8, labor costs by 1.616, and supplies and equipment costs by 1.65. Table 15 lists capital, operating, and transportation operating costs.

TABLE 15. -- Capital, operating, and transportation costs for the tin placer mine models, Lost River port site.

Cost category	Capital cost	Operating cost $/st
Mine	1,449,900	5.96
Mill	202,300	2.50
#1 infrastructure	3,336,000	NAp
#2 infrastructure	1,080,600	NAp
#3 infrastructure	485,500	NAp
Transportation	NAp	55.00

NAp Not applicable

The above costs for mine, mill, and transportation costs are applicable for each of the three mine models considered. Infrastructure costs, however, vary with the road length required. Mine #1 needs a road 50 mi long; mine #2, 14 mi long; and mine #3, 4.5 mi long. Total capital costs for mines 1 through 3 are $4,988,200, $2,732,800, and $2,137,700 respectively. The total mine and mill operating cost for each mine is $8.46/yd^3. The transportation operating cost includes concentrate haulage to the mine port site by truck, light barge haulage to the Lost River port site, and shipment to smelters via barge and rail. A summary of the costs and assumptions used in the models are presented in Appendix A.

Economic Analysis

None of the tin placer models generated a positive DCFROR under the assumptions outlined above. A price determination was done for each of the 3 models to determine what tin price would make the models economic. Table 16 presents the results of the price determination.

TABLE 16. -- Tin prices required to obtain 0% and 15% DCFROR for each tin placer mine model, Lost River port site.

Mine model	Tin price for 0% DCFROR ($/lb)	Tin price for 15% DCFROR ($/lb)
#1	43.29	59.27
#2	38.65	47.20
#3	6.39	7.51

Multiplying the required price by the grade and recovery for each model yields a recoverable metal value[7] (RMV) in $/yd^3 needed to achieve the given DCFROR. Table 17 shows the recoverable metal values for the three tin placer models.

[7]Recoverable metal value is the dollar value which can be recovered from each cubic yard by the mill process. Operating costs are not deducted from the value.

TABLE 17. -- Recoverable metal values required to obtain 0% and 15% DCFROR for each tin placer mine model, Lost River port site.

Mine model	RMV for 0% DCFROR ($/yd^3)	RMV for 15% DCFROR ($/yd^3)
#1	11.29	15.47
#2	11.47	14.02
#3	10.29	12.10

For example, a tin placer deposit with a RMV of between $10.29 and $11.47/yd^3 could be expected to generate a 0% DCFROR under the scenario presented in mine model #3. The RMV numbers can be used to estimate a tin placer deposit's economic viability, provided the grade, metallurgical recovery, and current tin price are known.

Tin production is potentially feasible for some of the deposits in the Lost River area. While all of the mine models are presently uneconomic, tin prices have been as high as $8.60/lb in 1980, which would make model #3 economically viable. Placer tin was produced in 1989 from one mine in the region, but reserves at the placer were exhausted by the end of the year (18). The current lack of detailed information about other tin placers in the area prevents the application of the models; however it appears that potential for production still exists in the area. The tin models presented above ship relatively small tonnages of tin concentrate; however, potential may exist for mines operating at capacities of greater than 1,800 yd^3/d. Larger operations would produce and ship greater amounts of tin concentrate, particularly if the tin grade was higher than that used in the models.

POINT MACKENZIE

Location and Access

Point MacKenzie is located on the northwestern shore of Cook Inlet (figure 2), 2 mi north of Anchorage (Point Woronzof). The area under consideration for this port site includes a 100 mi radius from Point MacKenzie and a 30 mi corridor of the rail belt area north to near the Arctic Circle (see figure 2). Deposits within this corridor could presumably make use of a port at Point MacKenzie by shipping concentrates via truck and/or rail to the port site. Rail access to the port would require construction of a spur to tie into the existing rail system in Southcentral Alaska.

The largest cities located within the port site corridor include Anchorage with a 1980 population of approximately 174,431 and Fairbanks with 22,645 (54). The 1980 populations of other communities in the area include Palmer - 2,141, Wasilla - 1,559, Delta Junction - 945, North Pole - 724, Anderson - 517, Moose Creek - 510, Nenana - 470, Houston - 370, Talkeetna - 264, Tyonek - 239, Big Delta - 285, Sutton - 182, Minto - 153, Willow - 139, Fox - 123, Stevens Village - 96, Cantwell - 89, Circle - 81, Manley Hot Springs - 61, Suntrana - 56, Usibelli - 53, Rampart - 50, Montana - 40, Central - 36, and Tazlina - 31. There are at least 98 smaller villages located within the corridor.

There is no existing infrastructure at this proposed port site. Anchorage has an existing port facility as well as an extensive transportation network including the Alaska Railroad and the Seward, Glenn, and the Park's Highways. The Anchorage and Fairbanks International Airports provide domestic and international air carrier service. The year round port facility at Seward is also accessible via the Alaska Railroad or the Seward Highway.

The Point MacKenzie area has an average annual precipitation of approximately 15 inches (6). The annual temperature varies from an average low of -13° F to an average high of 61° F (6). The port site is ice free year round (41).

Because of the size of the area considered for analysis of this port site, there is a wide variety of land ownership and control. Major land units include Lake Clark National Park and Preserve, Denali National Park and Preserve, Yukon Flats National Wildlife Refuge, Chugach National Forest, Steese National Conservation Area, White Mountain National Recreation Area, Utility Corridor, National Wild and Scenic Rivers System, BLM controlled lands, native (regional, village, private), and State of Alaska lands including Kalgin Island State Critical Habitat Area, Trading Bay State Game Refuge, Susitna Flats State Game Refuge, Goose Bay State Game Refuge, Palmer Hay Flats State Game Refuge, Chugach State Park, Willow Creek State Recreation Area, Nancy Lake State Recreation Area, Hatcher Pass Public Use Area, Matanuska Valley Moose Range, Nelchina Public Use Area, Denali State Park, Delta Junction Bison Range, Tanana Valley State Forest, Minto Flats State Game Refuge, Creamers Field State Game Refuge, and the Chena River State Recreation Area (43).

Mineral Deposits

Gold, coal, and copper make up the majority of the 504 known deposits within the corridor examined for the Point MacKenzie port site (see figure 2). Figure 7 shows the distribution of deposits by primary commodity within the corridor. Of the 504 deposits, 115 (23%) are past producers. The majority of past production was from gold lodes, followed by coal. Figure 8 shows the breakdown of past producers by primary commodity. Past producing gold mines include the Mohawk (map number 106), Cleary Hill and Banner (map number 104), Golden Zone (map number 175), and Lucky Shot, Gold Bullion, Gold Cord, and Fern (map number 211). Past producing coal mines include Rampart (map number 76), Broad Pass and Dunkle (map number 174), Evan Jones and Eska (map number 216), Buffalo and Baxter (map number 215), and Castle Mountain and Chickaloon (map number 210). Coal is currently being produced at the Usibelli Coal Mine (map number 159) with total production in 1989 amounting to 1,452,353 st (18). UCM could use a port at Point MacKenzie for exporting coal; however the likelihood of this possibility was not examined in this report. Such a decision would depend on economics, existing contracts, and other factors.

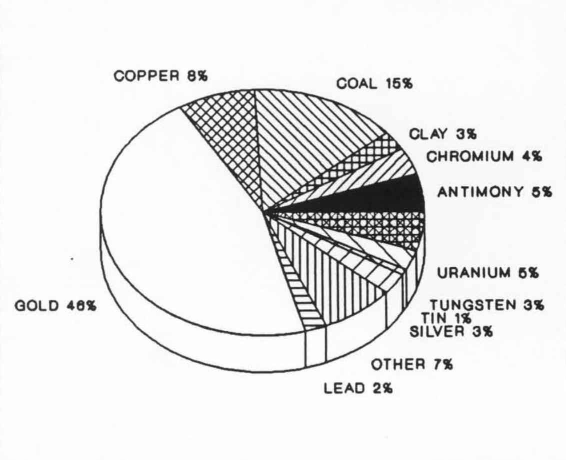

Figure 7. -- Distribution of deposits by primary commodity near the Point MacKenzie port site.

There is potential for significant mineral development within the Point MacKenzie corridor; however, gold mines typically ship low volumes of product and would not utilize a port for export of bulk materials. Substantial export use of a port would come from the development of copper, lead, zinc, and coal mines. The corridor used in this study is not all-inclusive and deposits outside the boundary could make use of the existing transportation network if road construction costs were not prohibitive.

Mine models for coal, copper, and gold-silver-copper mining were examined for this port site corridor. Since major coal production is considered likely in the near future, the history of coal in the Wishbone Hill region is discussed in further detail.

The Wishbone Hill area is currently being examined for development by Idemitsu Alaska Ltd. Germer (30) summarized the history of the Wishbone Hill district as follows:

> *The Wishbone Hill coal district is one of the four coal districts of the Matanuska coal field. It is located in the lower Matanuska Valley of Southcentral Alaska, approximately 45 mi northeast of Anchorage. This district has the greatest coal development potential of the four districts because of its relatively simple structure, excellent coal quality, location relative to existing infrastructure, and surface minable reserves. As a result of these favorable attributes, the Wishbone Hill district has produced more coal than the other three districts combined.*
>
> *Coal was first discovered in the Wishbone Hill district in the late 1800s, and by the early 1900s, all major geologic features had been described by government geologists. The first mining began in the southwestern portion of the district in 1916 at the Doherty Mine, which supplied coal to the newly formed Alaska Railroad. As coal demand for the railroad grew, emphasis shifted to the better quality reserves in the east-central part of the field.*
>
> *To secure a constant supply of coal, the federally-directed Railroad Commission opened the Eska Mine and operated it until a major private mine, the Evan Jones, could meet railroad demand. There were a number of small underground prospects during this time along Moose Creek, on the north side of Wishbone Hill, but only the Premier and Buffalo Mines produced any notable quantities of coal. For 40 years coal from the area was used by the Alaska Railroad, but with conversion of locomotives to diesel fuel in the mid-1950s, emphasis shifted temporarily to military bases near Anchorage. After the bases converted to natural gas in 1963, the domestic market was not large enough to support the Evan Jones Mine, which subsequently closed in 1968. The entire field's production is uncertain but probably totals about 7 million st, 6 million of which came from the Evan Jones Mine.*

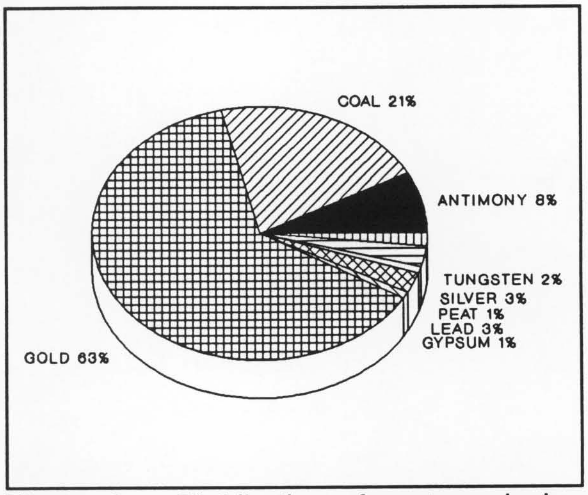

Figure 8. -- Distribution of past producing mines by primary commodity, Point MacKenzie port site.

In 1983, Hawley Resource Properties, Inc., operator for the Valley Coal Co. partnership that included Rocky Mountain Energy and Sun Eel Shipping Co., conducted a drilling program on Matanuska Valley coal leases northeast of Palmer (14). This joint venture was the successful bidder during 1984 on additional state leases that adjoined their prior holdings. During 1984, the drilling venture, named the Wishbone Hill project, continued coincidentally with the Matanuska Power Project (MPP Associates), a consortium of Rocky Mountain Energy Corp., Signal Energy Corp., Hawley Resource Properties, Inc. and CIRI. The Matanuska Power project studied the viability of a mine-mouth power plant that would produce 170 megawatts of electricity (27).

During 1985 and 1986, preliminary mine feasibility studies were conducted along with geologic mapping, channel sampling and drilling. The Matanuska Power Project study suggested that coal could compete with local oil and gas by the year 2000 (15, 16).

Union Pacific Resources (Union), known formerly as Rocky Mountain Energy, formed a joint venture partnership with Idemitsu Kosan Co. of Japan in 1987 to further explore its State coal leases. The partnership carried out a drilling and bulk sampling program. Bulk samples of six 55 gal drums each were taken from four sites for detailed evaluation. Four drums from each six-drum sample were shipped to Idemitsu's coal testing laboratory in Tokyo, and two were shipped to Union facilities in Denver. Idemitsu, Japan's largest domestic oil company, recently completed a coal import terminal in Tokyo Bay and is using coal in several of its refineries (17).

Idemitsu announced in June 1988 that Union, its partner in the Wishbone Hill Coal Project, had withdrawn from the project. Idemitsu acquired Union's interest and continued exploration activities, using McKinley Mining Consultants of Palmer for project management.

In October 1989, Idemitsu submitted a 10 volume application to the ADNR for a State mining permit for the project (5). During the 1990 session, the Alaska State Legislature authorized the State to spend $9 million on five new locomotives and 65-70 rail cars to transport Wishbone Hill coal on the State owned Alaska Railroad from Palmer to Seward.

Coal Mine Model

The coal mine model for the Point MacKenzie port site is based on mining reserves similar to those at Wishbone Hill. Coal will be surface-mined at a rate of 3,062 st/d using shovels and trucks. Table 18 lists the assumptions used in the coal mine model. Details of the model are presented in Appendix A.

TABLE 18. -- Assumptions used in designing the coal mine model, Point MacKenzie port site.

Mine life (yr)	15
St clean coal/d	3,062
St overburden/d	56,192
St coal mined/yr	1,100,000
Stripping ratio	18.4:1
Personnel	215
Power generation (MW)	35
Operating days/yr	360

The coal for the mine model is bituminous and was assumed to have the following characteristics after washing: 11,700 BTU/lb, 5.2% moisture, and 0.3% sulfur.

Costs for the coal mine model were estimated using the Bureau's CES (57, 58). All costs are in July 1989 dollars. Table 19 lists the capital and operating costs for the mine and wash plant. Wash plant operating costs include crushing, heavy media separation, tailings thickening, refuse haulback and tailing disposal. Truck transportation costs to a rail loadout facility 12 mi from the mine site are included in the mine operating costs.

TABLE 19. -- Capital and operating costs for the coal mine model, Point MacKenzie port site.

Cost category	Capital cost	Operating cost $/st
Mine	$58,004,900	21.77
Mill (wash plant)	12,421,200	5.03
Total	70,426,100	26.80

Economic Analysis

The cash flow analysis of the model was run at discount rates of 0 and 15%. Since coal prices vary considerably and the actual retail price of coal from this model at the point of sale is unknown, the mine mouth price of coal required to achieve a 0 and 15% DCFROR was determined. The results of the analysis are listed in table 20.

TABLE 20. -- Economic analysis results for the coal mine model, Point MacKenzie port site.

DCFROR	Point of sale	Price required, $/st
0%	FOB mine	$35.71
15%	FOB mine	46.88

In comparison, prices for coal (FOB mine) from Usibelli Coal Mine are in the mid-$30/st range and range from $30-$50/st delivered in Seward. It should be noted that the estimates presented in table 20 differ from a published estimate of a mine mouth price of $20/st. This estimate was based on information published when the ADNR denied Idemitsu's request for a royalty reduction. Idemitsu is estimating a $40/st price for coal delivered in Seward (4).

It appears that coal mining in Southcentral Alaska is economically feasible for a mine similar to the model. Mines further than 12 mi from rail transportation would incur increased transportation costs to bring the coal to market.

Massive Sulfide Copper Mine Model

To examine the potential for underground mining of a massive sulfide deposit containing copper, a model was constructed using cut and fill underground mining. The model assumes the mine is located along the Denali Highway and has existing transportation links via road and rail to the port site. The reserves used in calculating the mine life of the model are patterned after those found at Denali Copper (map number 177). These reserves consist of at least six small strata bound copper lodes in Triassic volcanic sedimentary rocks that may contain 5 million st ore that grade about 2% copper with credits of silver (27).

Table 21 lists the assumptions made in the model and the commodity data are listed in table 22.

TABLE 21. -- Assumptions used in designing the massive sulfide copper mine model, Point MacKenzie port site.

Mine life (yr)	16
St ore/d	1,200
St ore mined/yr	312,000
Personnel	209
Power generation (KW)	5,200
Operating days/yr	350
Mill feed, st/d	1,200
Mill method	Flotation
Tailings, st/d	1,116
St concentrate produced/yr	21,840

TABLE 22. -- Commodity data for the massive sulfide copper mine model, Point MacKenzie port site.

Commodity	Grade	Recovery	Concentrate grade	St/day concentrate
Copper (Cu)	2%	70%	20%	84

Costs for the massive sulfide copper mine model were estimated using Camm's cut and fill mine, one product flotation and infrastructure models (20). Transportation costs include trucking to Cantwell, railroad to Seward, and ocean shipping to Japan. All costs are in July 1989 dollars and adjusted to reflect the additional expense of mining in Alaska. Capital cost factors of 2.2, supplies and equipment operating cost factor of 1.52, labor operating cost factor of 1.225 were used (12). Table 23 presents the capital, operating, and transportation costs for the model. Total capital costs for the model are estimated at $111,112,100.

TABLE 23. -- Capital, operating, and transportation costs for the massive sulfide copper mine model, Point MacKenzie port site.

Cost category	Capital cost	Operating cost $/st
Mine	$55,806,000	41.34
Mill	15,296,600	6.32
Infrastructure	40,009,500	11.45
Total	111,112,100	59.11
Transportation	NAp	1.73

NAp Not applicable

Economic Analysis

A cash flow analysis of the model was run at discount rates of 0% and 15%. The model did not achieve a positive DCFROR at current metal prices. To determine the price at which the model would become viable, price determinations were done for each discount rate. The results of the price determination are shown in table 24.

TABLE 24. -- Price determination results for the massive sulfide copper mine model, Point MacKenzie port site.

DCFROR	Point of sale	Price required, $/st
0%	FOB Japan	3.01/lb Cu
15%	FOB Japan	4.35/lb Cu

As seen in table 24, copper prices would have to increase substantially from the $1.10/lb used in the cash flow analysis for the model to achieve the target DCFROR. Recovery of by-product silver which is often present in this type of deposit could increase the profitability of the mine model. Due to the high price of copper required under the assumptions made in the model, underground production of a massive sulfide copper ore is not economic at this time. There may be additional deposits in the area which have higher copper and silver grades than those used in the model. These deposits could become economic as metal prices rise. Based on present (i.e. published) knowledge of deposits in the region, production of copper from deposits similar to the mine model is considered to be unlikely in the next 10 years.

Gold-Silver-Copper Model

The gold-silver-copper model presented here could be applicable for at least four massive sulfide deposits in the Point MacKenzie port site area/corridor. The combination open-pit and cut-and-fill mine model is based on reserves similar to those of the Golden Zone Mine (map number 175). Milling costs are based on using flotation, vat leach, and heap leach methods. The assumptions made in designing the model are listed in table 25 and the commodity data are listed in table 26.

TABLE 25. -- Assumptions used in designing the gold-silver-copper mine model, Point MacKenzie port site.

Mine life (yr)	14
St ore/d	808
St waste/d (open-pit)	2,959
St ore mined/yr	282,800
Stripping ratio (open pit)	3.66:1
Underground workings (ft)	17,700
Personnel	200
Power generation (KW)	3,120
Operating days/yr	350
Shifts/d	3
Flotation/vat leach:	
Mill feed, st/d	277
Tailing, st/d	276
Heap leach:	
Mill feed, st/d	531
St concentrate produced/yr	451.5

TABLE 26. -- Commodity data for the gold-silver-copper mine model, Point MacKenzie port site.

Commodity	Grade	Recovery (%)	Concentrate grade (%)	St/day concentrate
Vat: Cu float	0.08%	35	7	1.11
Vat: Cu dore	0.08%	5	72	0.02
Vat: Ag dore	0.82 oz/st	45	22.84	(within Cu dore)
Vat: Au dore	0.16 oz/st	50	5.04	(within Cu dore)
Heap: Cu dore	0.06%	50	98	0.16
Heap: Ag dore	0.62 oz/st	25	1.73	(within Cu dore)
Heap: Au dore	0.07 oz/st	30	0.23	(within Cu dore)

Costs for the gold-silver-copper model were estimated using CES (57, 58). All costs are in July 1989 dollars and have been escalated to account for increased cost of mining in Alaska. Capital costs were escalated by a factor of 2.1, labor costs by 1.412, and supplies and equipment costs by 1.52 (12). Table 27 lists capital, operating, and transportation operating costs for the mine model.

TABLE 27. -- Capital, operating, and transportation costs for the gold-silver-copper mine model, Point MacKenzie port site.

Cost category	Capital cost	Operating cost $/st
Mine	$58,134,500	-
Mine (open pit)	-	$38.89
Mine (underground)	-	$72.50
Mill	$26,413,000	-
Mill (vat)	-	$17.74
Mill (heap)	-	$15.69
Transportation	NAp	$54.43

NAp Not applicable

The total capital costs for the model are $84,547,500. Total mine and mill operating costs are $72.32/st for the open pit mine lasting for the first two years of production; and $105.93/st for the underground period of production. The transportation operating cost includes concentrate haulage by truck and rail to Point MacKenzie and shipment to the smelters by barge and rail. A summary of the costs and assumptions used in the models are presented in Appendix A.

Economic Analysis

The mine model failed to generate a positive DCFROR in any of the cash flow analyses. To breakeven, the mine would require increased revenues which could be generated by improving the metallurgical recovery from the deposit or by an increase in metal market prices. Mining a deposit similar to the model and beneficiating using vat and heap leach is not economic at this time and is not considered likely in the near term.

CONCLUSIONS

A total of 579 known deposits are located within the area considered for the Balboa Bay, Beluga, Lost River, and Point MacKenzie port sites. The majority of the deposits (504) are located within a rail/road corridor examined for the Point MacKenzie port site.

Based on the current level of knowledge, coal deposits near the Beluga and Point MacKenzie port sites are most likely to be developed in the near future. This conclusion is based on the fact that coal projects (Beluga 1 and Wishbone Hill) in these areas are actively being pursued for development.

The mineral wealth surrounding the four port sites is substantial. Mine models were used to examine the potential for mining tin, gold, silver, copper, and molybdenum. The models were based on published reserve and grade data and therefore do not include proprietary company data which, if available, would likely change the economic analysis results.

Of the mineral models examined, the tin placer mine model, Lost River port site, proved to be closest to being economic even though relatively low tonnages of product would be shipped from such a mine. Other models were uneconomic at current metal prices and assumed deposit characteristics.

Continued exploration could prove additional reserves for known deposits in the area and thus increase the likelihood of production in the near future. All data used in the preparation of this report are non-proprietary. Confidential company data may exist on deposits within the study area which, if available, could considerably change the economic analysis of the deposit models.

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APPENDIX A. -- MINE MODEL SUMMARY

Copper-Molybdenum Open Pit Model
Balboa Bay Port Site

The copper molybdenum open pit model assumes the mining of iron-stained dacite porphyry stocks and dikes of late Tertiary age. Approximate dimensions are 6,500 ft wide, 6,500 ft long, and 60 ft deep (49). Ore and waste is drilled and blasted using rotary drills. Ore will be produced at 13,228 st/d, and will be loaded into 45-st rock trucks by an electric shovel. The rock trucks will haul the ore an average of 820 ft to a mobile crusher. After the ore is crushed to minus 7 inches the ore will be carried to the mill by conveyor belts totaling 9,184 ft. Meanwhile the waste rock will be loaded onto rock trucks by a diesel shovel at a rate of 2,778 st/d. The stripping ratio is 0.21:1, resulting in the mining of 16,005 st combined ore and waste per day. Waste will be hauled an average of 6,596 ft to waste dumps outside of the pit.

At the mill, the ore will be jaw crushed to 0.75 inch and then ground to 65 mesh. Pulp from the ball mills is thickened and conditioned before being sent to the rougher flotation circuit. The concentrates from this circuit will be reground to 200 mesh and sent through the cleaner flotation circuit to produce 129.6 st/d of combined copper and molybdenum concentrate. A second stage flotation will separate the molybdenum concentrate.

Concentrates will be thickened, dried, and then shipped 0.6 mi via truck directly to the Balboa Bay port site. The copper concentrate will be shipped to Seattle and then transferred to rail for smelters in Utah. The molybdenum concentrate will be shipped to Seattle and then transferred to rail for smelters in Michigan. This will cost an average of $65.23/st.

Tailings will be pumped 0.6 mi to a double lined impoundment. The mine and mill will operate 350 days per year, three 8-hour shifts per day. Total mine life is 23.57 years.

Costs for this model were estimated using the Bureau's CES. The costs generated from the CES are based on establishing a mining operation in the Denver area. For applicability to Alaska, escalation factors were used. Capital costs were multiplied by 2.3, labor by 1.565, and supplies and equipment by 1.52. All costs are in July 1989 dollars. Capital costs estimated for the model were:

Exploration/Acquisition	$18,902,636
Mine permitting	10,842,442
Development	20,436,392
Mine equipment	22,280,662
Mine plant	11,617,485
Infrastructure	3,400,426
Restoration	3,470,259
Mine working cap	7,702,614
Mine TOTAL:	**$98,652,916**
Mill plant & equipment	$68,967,042
Mill development	690,000
Mill restoration	1,020,733
Mill working capital	11,376,674
Mill TOTAL:	**$82,054,449**
TOTAL CAPITAL COST	**$180,707,365**

Mine and mill operating cost breakdowns in $/st were:

	Labor	Supplies	Equipment	Total ($/st)
Mine	1.73	1.49	1.00	4.22
Mill	2.28	2.78	1.17	6.23
Total	**4.01**	**4.27**	**2.17**	**10.45**

All power is produced on-site by diesel generators. Facilities at the port include load-out equipment, and a concentrate storage building capable of storing 75% of the operation's annual output. These cost are included in the mill capital costs listed above and amount to $2,066,586.

Coal Mine Model
Beluga Port Site

The Beluga coal mine model is patterned after the type of development projected to occur at Diamond Alaska's Beluga 1 mine. The following description of the mine plan is quoted from the Final EIS (28):

> Mining activities would begin with the clearing of all trees, brush, stumps, and other vegetation. Topsoil would be removed and stockpiled. Approximately 16.8 million m^3 (22 million yd^3) of overburden excluding topsoil, initially would be excavated (the "box cut") and stockpiled. This stockpile would be approximately 61 m (200 ft) high, 1,280 m (4,200 ft) long and 670 m (2,200 ft) wide and would cover about 81 ha (200 ac). After completion of the box cut, as new topsoil and overburden are excavated from the pit's advancing face to expose the coal, the overburden would be put onto the trailing edge of the pit from which the coal would have already been removed. This area would then be reclaimed by regrading it to its approximate pre-mining contours, including stream locations and drainages, covering it with topsoil and then revegetating it.
>
> During the first year of production, mining methods would employ shovels (15-19 m^3 [20-25 yd^3]) capacity), overburden haul trucks (136-154 Mt [150-170 st] payloads), and coal haul trucks (91-136 Mt [100-150 st]) for stripping and coal recovery. Two draglines would be added later, a 44 m^3 (57 yd^3) and a smaller 27 m^3 (35 yd^3) to reach full production. At full production capacity, the draglines would be used for overburden and interburden removal while the shovels and haul trucks would be used for prestripping of overburden.
>
> Coal would be loaded onto trucks directly from the seams by hydraulic backhoes, shovels, or front end loaders. Because of the unconsolidated nature of both the overburden and interburden and the tendency of the coal to crumble, no major blasting is anticipated.
>
> Run of the mine coal would be hauled by truck to a primary crusher located in front of the advancing mine face. The primary crusher would be moved every three to five years. The coal would be crushed to a maximum size of 15 cm (6 in) and carried about 3,962 m (13,000 ft) by a 1.4 m (54 in), two-span partially enclosed mine area conveyor system to a splitter hopper at the mine service area which would feed to either a secondary crusher where it would be crushed to a maximum size of 5 cm (2 in) or to a stockpile.
>
> Coal from the secondary crusher would be conveyed to the port site via a 15.9 km (10 mi) single-span conventional continuous belt conveyor from the mine service area to a port

on Cook Inlet. The conveyor would be 1.2 m (48 in) wide and capable of moving about 1,633 mt (1,800 st) of coal per hour. A light duty, minimally improved 4.6 m (15 ft) service road suitable for four wheel drive vehicles would be built immediately adjacent to the conveyor for maintenance purposes. An all weather access haul road would be constructed that roughly parallels the conveyor. The road would be gravel-surfaced, crowned to promote drainage, and would have two traffic lanes and wide gravel shoulders on each side. The proposed route would have a 29 m (96 ft) wide road. Grades would be maintained at a maximum of 6 percent. Over most of its length, the road would be separated from the conveyor by approximately 61 m (200 ft).

The coal is contained in five major seams, each varying in thickness between 1.8 and 6.1 m (6-20 ft), with a cumulative stripping ratio of 3.9:1 (i.e., 3.9 m^3 of overburden to 1 Mt of recoverable coal [4.6:1, or 4.6 yd^3 per st]). The actual area to be mined (mining limit) would be approximately 2,029 ha (5,014 ac) in size and would be divided into north and south pits which would be mined simultaneously but in separate operations during the life of the project. The pits would begin on the northeast edge of the mining limit and proceed generally west and southwest, respectively, during the life of the project.

A maximum of 182 ha (450 ac) of pit would be open at any one time. An additional maximum of 61 ha (150 ac) around the pit would be disturbed at any one time in clearing vegetation in preparation for stripping overburden, or recontouring in preparation for revegetation. A total of approximately 63 ha (155 ac) per year would be cleared for mining in two periods - most likely spring and fall. Maximum depth of the pit would range from 6.1 m (20 ft) during the first year of production to approximately 122 m (400 ft) in the final years of the project. Average pit depth would be about 61 m (200 ft).

On the northwestern and western sides of the mine area, space is available for location of adequately sized sediment ponds to handle sediment loads with little or no additional treatment. However, on the northeastern and eastern sides of the mine area, space would be limited between the mine pit and Lone Creek. In these areas, sediment ponds with additional sediment treatment structures will be necessary during periods of high runoff. Then treatment structures will consist of a series of excavations and embankments using baffles and selective routing to control, treat, and allow monitoring of runoff prior to discharge into Lone Creek.

Once the water is treated, it will be released from 18 sediment ponds into natural drainages. The 18 sediment ponds would have a combined surface area of approximately 90 acres. The sediment ponds will be dredged periodically with the dredged material put into the mine pit and covered by at least 1.2 m (4 ft) of spoil material.

The remaining description of the project on which the coal mine model was based is adapted from the Final EIS (28).

Water flows into the pit from aquifers would average 831,740 gal/d during the 3rd to 10th year of operation. This water and rainfall accumulation would be pumped from the pit into the sediment ponds for treatment before discharge.

The estimated average load electrical power requirements for the project at full capacity is 35MW, with peak demand estimated at 50MW. Electric power would be purchased from the Chugach Electric Association natural gas power station at Beluga and supplied to the mine via a 69 kV line.

Permanent housing and community facilities will consist of four buildings with 102 units and two buildings with 66 units. In addition, a dining hall/administration building, recreation center, laundry, medical facilities, security and fire services, and maintenance building would be constructed on site. Employees would be flown to the mine from Anchorage and Kenai and returned home after a 4 day work period.

The Final EIS has identified Ladd and Granite Point as two proposed port sites. The Ladd port site has two proposed overland transportation corridors (eastern and northern). The Granite Point port site has one proposed overland transportation corridor (southern). Of these three alternatives only one would be constructed to support the mine.

The Ladd port site with the eastern overland transportation corridor is identified as the preferred alternative. However, Diamond Alaska Coal Co. has been unable to negotiate a right of way across Tyonek Native Corp. land that would be required for this alternative. The other two alternatives do not cross Tyonek Native Corp. land.

Because of its importance in development of the project, construction of the mine access/haul road would begin as soon as the initial facilities were established at the port site. Regardless of which port site is chosen, road construction equipment would be landed at the existing Ladd beach barge site and transported over the existing Ladd road to the mine area so road construction could be simultaneously carried out from both ends. Completion of the road would take about 18 months.

Under the proposed development schedule, production would begin at 2 million st the first year and increase to the full capacity of 12 million st by the fourth year of operation.

Costs for the Beluga coal strip mine model were estimated using the Bureau's CES (57, 58). All costs are in July 1989 dollars. A capital cost factor of 2.0 and an operating cost factor of 1.52 were used to escalate the costs to Alaska (12). The estimated capital costs for the model were:

ITEM	Labor	Supplies	Equipment	TOTAL
Exploration	5,000,000			5,000,000
Acquisition	13,604,200			13,604,200
Clearing	591,200	85,800	198,100	875,100
Dragline			120,294,000	120,294,000
Shovel & truck			78,378,000	78,378,000
Loader & truck			13,324,600	13,324,600
Airstrip			3,997,400	3,997,400
Surface conveyor			4,452,900	4,452,900
Communication system			1,247,900	1,247,900
Electric system			2,032,200	2,032,200
Fueling system			1,514,100	1,514,100
Offices			6,223,400	6,223,400
Laboratories			907,100	907,100
Repair shops warehouses			6,923,400	6,923,400
Stockpile storage			690,100	690,100
Surface buildings			1,186,200	1,186,200
Drainage system			342,100	342,100
Water system			12,348,800	12,348,800
Access roads clearing	1,346,300		598,900	1,945,200
Access roads excavation	1,001,600		1,029,600	2,031,200
Access roads surfacing	148,100	8,452,000	79,200	8,679,300
Main power lines	2,530,600	1,935,000	873,600	5,339,200
Townsite			26,674,000	26,674,000
Wastewater clarification			1,570,400	1,570,400

Restoration			3,551,100	3,551,100
Eng & cont mgt fees		29,865,300		29,865,300
Working capital		18,732,900		18,732,900
Crushing			4,787,000	4,787,000
Mobil crushing			9,615,600	9,615,600
Marine terminal			117,886,000	117,886,000
Vehicles			3,149,600	3,149,600
TOTAL	**24,222,000**	**59,071,000**	**423,875,300**	**507,168,300**

Mine and mill operating cost breakdowns for the model in $/st were:

	LABOR	SUPPLIES	EQUIPMENT	TOTAL ($/st)
Mine:				
Year 1	7.43	4.33	5.71	17.47
Year 2	5.86	4.12	4.95	14.93
Year 3	4.88	1.71	3.79	10.38
Year 4	3.19	1.48	2.43	7.10
Mill:				
Year 1	.75	2.73	0.06	3.54
Year 2	1.20	2.70	0.06	3.96
Year 3	1.26	0.45	0.12	1.83
Year 4	1.02	0.44	0.13	1.59

Tin-Tungsten-Fluorspar Model
Lost River Port Site

The tin-tungsten-fluorspar open pit model assumes the mining of a skarn/greisen formation. Approximate dimensions are 980 ft wide, 1,062 ft long, and 318 ft deep. Ore and waste is drilled and blasted, then handled by front-end loaders and 45-st rock trucks. Ore will be produced at 4,000 st/d. The stripping ratio is 1.8:1, resulting in the mining of 11,200 st combined ore and waste per day. Waste will be hauled an average of 5,576 ft to waste dumps outside of the pit, while ore will be hauled an average distance of 6,573 ft to the mill site.

At the mill, the ore will be jaw crushed to 0.25 inch and then ground to 325 mesh. Pulp from the ball mills is thickened and conditioned before being sent to the flotation circuit. The flotation circuit will produce 589 st per day of metallurgical and acid grade fluorite with 85% and 97% concentrate grades respectively.

The flotation tailings are then cycloned and sent to a gravity separation circuit consisting of triple-deck Deister tables. The resulting product will be 8.8 st tin-tungsten concentrate per day.

Concentrates will be thickened, dried, and then shipped 6 mi via truck to the port site. There are no deep-draft vessel port facilities at the Lost River port site, therefore all concentrates must be lightered to ocean-going barges during the summer season. The fluorite will be shipped to

Tokyo at a cost of $36/st. The tin/tungsten concentrate will be shipped to Los Angeles and then transferred to rail for smelters in Texas. This will cost approximately $152/st.

Tailings will be pumped 1.8 mi to a double lined impoundment in the Rapid River Valley. The mine and mill will operate 350 days per year, two 8-hour shifts per day. Total mine life is 20 years.

Costs for this model were estimated using the Bureau's CES. The costs generated from the CES are based on establishing a mining operation in the Denver area. For applicability to Alaska, escalation factors were used. Capital costs were multiplied by 2.8, labor by 1.616, and supplies and equipment by 1.65. All costs are in July 1989 dollars. Capital costs estimated for the model were:

Exploration/Acquisition	$4,904,000
Mine permitting	2,640,000
Development	12,685,600
Mine equipment	18,715,100
Mine plant	8,123,000
Infrastructure	4,551,900
Restoration	2,025,200
Mine working cap	10,592,400
Mine TOTAL:	**$64,237,200**
Mill plant & equipment	$46,919,400
Mill development	840,000
Mill restoration	1,242,600
Mill working capital	13,960,200
Mill TOTAL:	**$62,962,200**
TOTAL CAPITAL COST	**$127,199,400**

Mine and mill operating cost breakdowns in $/st were:

Item	Labor	Supply	Equipment	Total
Mine	7.54	3.77	4.45	15.76
Mill	7.95	9.16	3.66	20.77
Total	**15.49**	**12.93**	**8.11**	**36.53**

All power is produced on-site by diesel generators. Facilities at the port include load-out equipment, and a concentrate storage building capable of storing 75% of the operation's annual output. These costs are included in the mill capital costs listed above and amount to $6,221,925.

Tin-Columbium-Tantalum Mine Model
Lost River Port Site

The tin-columbium-tantalum underground model assumes the mining of a Cretaceous quartz-tourmaline-topaz greisen. Approximate dimensions for the purposes of this model are 534 ft wide, 534 ft long, and 1,312 ft deep. Ore is mined by the shrinkage-stope method at a rate of 2,000 st/d. Underground workings include one shaft, drifts, raises, and ore shoots. Total workings are approximately 41,958 ft in length. Ore is loaded into load-haul-dump (LHD) vehicles and hauled an average of 535 ft to the shaft. After hoisting to the surface, the ore is hauled by rock trucks 3.5 mi to the mill site.

At the mill, the ore will be jaw crushed to 0.25 inch and then ground to -35 mesh. Pulp from the ball mill is thickened and conditioned before being sent to the flotation circuit. The flotation circuit will produce 8.28 st/d of tin, columbium, and tantalum concentrate.

The flotation tailings are then cycloned and sent to a gravity separation circuit consisting of triple-deck Deister tables. The resulting product will be 7.72 st tin-tungsten concentrate per day.

Concentrates will be thickened, dried, and then shipped 44 mi via truck to Teller. There are no deep-draft vessel port facilities at Teller, therefore all concentrates must be loaded onto shallow-draft barges and shipped 25 mi to the Lost River port site. From here, the concentrates will be shipped via ocean-going barges and rail to smelters in Texas. This will cost approximately $152/st.

Tailings will be pumped 0.62 mi to a double lined impoundment near the mill. The mine and mill will operate 350 days per year, three 8-hour shifts per day. Total mine life is 32.14 years.

Costs for this model were estimated using the Bureau's CES. The costs generated from the CES are based on establishing a mining operation in the Denver area. For applicability to Alaska, escalation factors were used. Capital costs were multiplied by 2.9, labor by 1.616, and supplies and equipment by 1.65. All costs are in July 1989 dollars.

Exploration/Acquisition	$3,000,000
Mine permitting	1,676,800
Development	16,383,300
Mine equipment	6,371,700
Mine plant	7,154,300
Infrastructure	12,297,800
Mine replacement	9,948,800
Mine working cap	14,881,400
Mine TOTAL:	**$71,714,100**
Mill plant & equipment	$34,453,300
Mill development	870,000
Mill replacement	17,226,700
Mill restoration	1,287,000
Mill working capital	5,943,200
Mill TOTAL:	**$59,780,200**
TOTAL CAPITAL COST	**$131,494,300**

Mine and mill operating cost breakdowns in $/st were:

Item	Labor	Supply	Equipment	Total
Mine	24.60	13.08	2.10	39.78
Mill	8.95	5.33	2.80	17.08
Total	**33.55**	**18.41**	**4.90**	**56.86**

All power is produced on-site by diesel generators. Facilities at the port include load-out equipment, and a concentrate storage building capable of storing 75% of the operation's annual output. These cost are included in the mill capital costs listed above and amount to $536,952.

Tin Placer Models
Lost River Port Site

The tin placer mine models are based on the following assumptions and operating parameters.Overburden totalling 225,000 bank cubic yards will be removed using bulldozers equipped with ripper teeth for the frozen ground. The bulldozers will push the materials to the side of the pit where it will remain until the restoration phase of the operation. Ore will be ripped with a bulldozer, then loaded into dump trucks by front end loaders at a rate of 1,800 yd^3/d. Average haulage distance will be 2,500 ft to the processing equipment. The gravel will be dumped into feed hoppers before moving through a trommel. The ore will be further reduced by sluices. The concentrate will be jigged to produce a final concentrate of 85% tin. This concentrate will be hauled to the coast by truck, loaded into light barges and shipped to the Lost River port site. Tailings will be pushed to the edge of the processing site for disposal. The mine will operate 120 days per year, three shifts per day.

Cost for these models were estimated using the *Cost Estimation Handbook for Small Placer Mines* (CEH) (55) program, and when appropriate, actual data from operating mines. The costs generated from the CEH are based on establishing a mining operation in the western United States. To use these costs, they must be escalated to account for the higher cost of doing business in Alaska. Capital costs were escalated by a factor of 2.8, labor by 1.616, and supplies and equipment by 1.65. All costs are in July 1989 dollars and English units of measurement are used throughout the model. The capital costs estimated for the models were:

Mine #1:	
Exploration/Acquisition	$250,000
Mine permitting	100,000
Development	691,300
Mine equipment	308,600
Infrastructure	3,336,000
Restoration	100,000
Mine TOTAL	**$4,785,900**
Mill plant & equipment	$202,300
Mill TOTAL	**$202,300**
TOTAL CAPITAL COST, Mine #1 .	**$4,988,200**

Mine #2:

Exploration/Acquisition	$250,000
Mine permitting	100,000
Development	691,300
Mine equipment	308,600
Infrastructure	1,080,600
Restoration	100,000
Mine TOTAL:	**$ 2,530,500**
Mill plant & equipment	$202,300
Mill TOTAL:	**$202,300**
TOTAL CAPITAL COST, Mine #2 .	**$2,732,800**

Mine #3:

Exploration/Acquisition	$250,000
Mine permitting	100,000
Development	691,300
Mine equipment	308,600
Infrastructure	485,500
Restoration	100,000
Mine TOTAL	**$ 1,935,400**
Mill plant & equipment	$202,300
Mill TOTAL	**$202,300**
TOTAL CAPITAL COST, Mine #3 .	**$ 2,137,700**

Mine and mill operating cost breakdowns in $/st were:

Item	$/st
Mine	5.96
Mill	2.50
Total	**8.46**

All power is produced on-site by diesel generators. Equipment costs are based on the use of used equipment. This reduces the capital costs significantly, but slightly increases the labor and equipment portions of the operating costs.

Coal Mine Model
Point MacKenzie Port Site

The mining plan proposed for the Wishbone Hill coal mine was used as a basis for designing the mine model. The following description of the Wishbone Hill project is quoted from Germer (31):

Coal will be mined from two surface mining areas using conventional shovel and truck mining techniques. This mining technique will allow for optimal equipment utilization and coal resource recovery from a fairly geologically complex reserve while insuring environmental protection. The basic sequence of mining will be as follows: timber salvage and clearing, topsoil removal and stockpiling, overburden removal, coal removal, backfilling with overburden, topsoil replacement, and revegetation. Topsoil removal will be accomplished with the use of dozer aided scrapers. Topsoil will be hauled for direct replacement, where possible, or stockpiled. Overburden and coal removal will be conducted with the use of a hydraulic excavator to dig and place the material into 150 st capacity haul trucks. Direct haul back of the overburden and interburden will occur where possible. Because of the steeply dipping seams and the depth of mining, direct haul back of the overburden/interburden materials is not possible during some of the mine life and these materials must be temporarily stockpiled in designated areas. Coal will be trucked from the pits to a processing plant where it will be washed to remove shale and parting material. No chemicals other than flocculants will be utilized in the wash process. Coarse coal refuse generated at the wash plant will be hauled back to the mine area for backfill into the pit. Fine coal refuse will be disposed of in a slurry pond.

All surface drainage from disturbed areas will be controlled and routed to specifically designed sediment basins. The sedimentation basins and control ponds will be designed with adequate capacity to prevent discharge to existing surface waters.

The washed coal will be transported by highway trucks along a 3-mi access road and a 12 mi section of the Glenn Highway to a rail loadout south of Palmer. From there the coal will be transported by train to the port of Seward for shipment to Japan. Idemitsu and the Alaska Department of Transportation and Public Facilities have successfully developed a plan for financing the cost of desired improvements to the existing Glenn Highway system. Construction of the highway improvements is scheduled to be completed by the latter part of 1991 and will be funded with a mix of Federal, State and private sector money.

Production in the first year of mine operation would be approximately 716,000 st and would increase to about 937,000 st in the second year. In the third year, production would increase to full capacity of approximately 1.1 million st (32).

Costs for the coal mine model were estimated using the Bureau's CES (57, 58). All costs are in July 1989 dollars. Wash plant operating costs include crushing, heavy media separation, tailings thickening, refuse haulback and tailing disposal. Truck transportation costs to a rail loadout facility 12 mi from the mine site are included in the mine operating costs.

The capital costs for the coal mine model were estimated to be:

MINE:

ITEM	Labor	Supplies	Equipment	TOTAL
Exploration	6,000,000			6,000,000
Acquisition		2,714,000		2,714,000
Shovel Truck			29,892,000	29,892,000
Communication System	218,800			218,800
Electric System	354,000			354,000
Fueling System	193,100			193,100
Offices	981,600			981,600
Laboratories	231,700			231,700
Repair Warehouses			1,773,900	1,773,900
Surface Buildings			305,400	305,400
Drainage System			184,600	184,600
Water System			1,482,300	1,482,300
Access Roads Clearing	6,500		2,200	8,700
Access Roads Drill & Blast	129,600	142,000	45,500	317,100
Access Roads Excavation	9,400	7,000		16,400
Access Roads Surfacing	7,600	402,300	2,800	412,700
Access Roads Paving	1,000	22,900	500	24,400
Glenn Highway Upgrade	149,400	3,281,800	68,800	3,500,000
Main Power Lines	809,700	619,200	279,500	1,708,400
Wastewater Clarification			785,200	785,200
Eng & Cont Mgt Fees		2,465,900		2,465,900
Working Capital		4,434,700		4,434,700
TOTAL	**9,092,400**	**14,089,800**	**34,822,700**	**58,004,900**

WASH PLANT:

ITEM	Labor	Supplies	Equipment	TOTAL
Crushing			573,500	573,500
Spirals			141,000	141,000
Heavy Media Separation			1,867,300	1,867,300
Tailings Thickening			155,700	155,700
Transport/Place Tailings			28,200	28,200
Washing/Screening			269,700	269,700
Electrical System			1,364,200	1,364,200
Loadout Facilities			599,100	599,100
Wash Plant Buildings			3,757,700	3,757,700
Miscellaneous Equipment			131,400	131,400
Offices			86,200	86,200
Laboratories			203,900	203,900
Vehicles			683,400	683,400
Water Supply			912,800	912,800
Eng & Cont Mgt Fees			958,200	958,200
Working Capital		688,900		688,900
TOTAL		**688,900**	**11,732,300**	**12,421,200**

Mine and wash plant operating cost breakdowns in \$/st were:

Item	Labor	Supply	Equipment	Total
Mine year 1[8]	11.51	3.31	8.94	23.76
Mine year 2	10.69	3.17	8.62	22.48
Mine year 3	10.22	3.10	8.45	21.77
Wash plant year 1	4.63	0.73	1.05	6.41
Wash plant year 2	3.86	0.70	0.93	5.49
Wash plant year 3	3.53	0.69	0.81	5.03

Massive Sulfide Copper Mine
Point MacKenzie Port Site

Cut and fill mining excavates the ore in horizontal slices starting at the bottom of the stope and advancing upward. The broken ore is loaded and completely removed from the stope. When a full slice has been excavated, the vacated volume is filled with waste material that supports the walls and provides a working platform while the next ore slice is mined.

The fill material can consist of waste rock, such as that from development work in the mine; the waste rock is distributed mechanically over the stoping area. Common practice is to use hydraulic filling methods. The filling material consists of fine-grained tailings from the mill, mixed with water and transported into the mine for distribution through pipelines. The material is mixed with cement to provide a harder and more durable surface with improved support characteristics. This method can be adapted to irregular and discontinuous ore bodies, extracting the high grade ore and leaving the low grade material behind in the fill (34).

Jackleg drills and stopers are used for production, with small jumbos used for drift development. Slushers move the ore from in the stope to the ore chutes, LHDs move the ore from the chutes to the ore storage pockets. The mill includes a crushing plant to prepare mine run ore for feed to the mill. The crushed ore is ground, concentrated by flotation, and dewatered to produce a concentrate. A fresh water reservoir, tailings disposal system and a diesel fuel storage system is also included. Infrastructure includes a two lane gravel access road, camp facility and power generation plant.

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[8]Transportation cost of \$2.37/st from mine to Palmer loadout facility is not included in any of the operating costs.

Costs for the model were estimated as:

Mine capital cost:	
Acquisition	4,200,000
Exploration	2,000,000
Labor	2,587,700
Equipment	43,961,000
Steel	209,600
Fuel	24,700
Chemical	526,800
Construction materials	2,264,400
Lumber	31,800
TOTAL	**55,806,000**
Mill capital cost:	
Labor	4,517,600
Equipment	5,792,200
Steel	2,340,700
Fuel	618,800
Construction materials	1,869,900
Industrial materials	157,400
TOTAL	**15,296,600**
Infrastructure capital cost:	
Labor	11,892,300
Equipment	6,273,400
Steel	96,900
Fuel	446,000
Chemical	607,800
Construction materials	20,293,900
Industrial materials	399,200
TOTAL	**40,009,500**
TOTAL CAPITAL COST	**111,112,100**

Mine and mill operating cost breakdowns in $/st were:

MINE:	
Labor	32.24
Equipment	1.22
Steel	1.98
Fuel	0.48
Chemical	1.42
Construction material	2.59
Lumber	1.41
Total	**41.34**

MILL:	
Labor	2.67
Equipment	2.59
Steel	0.02
Fuel	0.19
Industrial material	0.85
Total	**6.32**
INFRASTRUCTURE:	
Labor	1.58
Equipment	1.07
Fuel	3.28
Chemical	1.73
Industrial material	3.79
Total	**11.45**
TOTAL OPERATING COST, $/st	**59.11**

Transportation operating cost breakdowns in $/st are:

Truck	$.42
Rail	.44
Ocean	.87
TOTAL	**1.73**

Gold-Silver-Copper Model
Point MacKenzie Port Site

The gold-silver-copper mine model assumes the mining of a nearly vertical volcanic massive sulfide breccia-pipe which is cylindrical in shape. Approximate dimensions are 300 ft diameter and 1,500 ft depth. Open-pit (o-p) mining will occur during the first two years of mine production. Ore and waste will be drilled using rotary drills and handled by front-end loaders and 20-st rock trucks. Ore will be produced at 808 st/d. The stripping ratio is 3.66:1, resulting in the mining of 3767 st combined ore and waste per day. There will be no overburden to remove from the deposit. Total pit depth will be 190 ft.

In the third year of mine production, the ore will be extracted by the underground (ug) cut-and-fill method. Underground workings will consist of a concrete-lined hoisting shaft of 1500 ft in depth, a main haulage adit 102 ft in length and stretching from the surface at the 350 ft level to the shaft at the 420 ft level. The underground workings will eventually total approximately 17,700 ft. This figure includes the lengths of the main shaft and adit as well as those of the drifts, raises, and ore shoots necessary for cut-and-fill production.

The ore will be transported to the hoisting shaft via slushers at a rate of 808 st/d. After removal to the portal, the ore will be loaded on 20-st rock trucks and hauled to the mill site. Fill needed in the mine will come from waste generated from the open-pit stage as well as from partially dewatered tailings.

There are two types of ore in the deposit; a high-grade ore which will be sent through a flotation/vat-leach circuit, and a low grade ore sent to heap-leach pads. Both types of ore will be crushed to 0.25 inch. From here, the high-grade ore will be sent at a rate of 277 st/d to a cone which will grind to ore to -325 mesh.

Once the ore has been ground, it will pass through a jig for free gold recovery. The ore will then pass through a flotation circuit which will float the copper locked in arsenopyrite. The tailings from this process will be vat leached and passed through a CIL (carbon-in-leach) circuit and then electrowinned for removal of gold and silver. The tailings from this process will then be thickened and placed in a double-lined impoundment near the mill site.

Once the low-grade ore has been crushed, it will be agglomerated and placed on impermeable leaching pads. Once in place, the ore will be saturated with a cyanide solution from June 1 to October 30. Because a content of nearly 33% arsenopyrite and other sulfides, metal recovery will be characteristically low. Because of the low mineral content of the ore, neither roasting nor bioleaching (at a cost of about $20/st) is feasible at this time.

Pregnant solution resulting from the leaching process, will be passed through the CIL circuit and electrowinned for a final gold-silver-copper dore. The barren solution will be recharged with cyanide and pumped back to the pad.

Copper float and vat/heap dore will be trucked 9 mi and then shipped via the Alaska Railroad to Point MacKenzie at a rate of 449.44 st/yr. From Point MacKenzie, the ore will be barged to California for smelting.

The mine and mill are assumed to operate 350 days per year, three shifts per day. Total mine life is 14.38 years.

Costs for this model were estimated using the Bureau's CES. The costs generated from the CES are based on establishing a mining operation in the Denver area. For applicability to Alaska, escalation factors were used. Capital costs were multiplied by 2.1, labor by 1.412, and supplies and equipment by 1.52. All costs are in July 1989 dollars. Capital costs estimated for the model were:

Exploration/Acquisition	$ 4,281,500
Mine permitting	2,500,000
Development (o-p)	10,069,700
Development (ug)	8,012,300
Mine equipment (o-p)	4,392,900
Mine equipment (ug)	2,644,200
Mine plant (o-p)	5,516,000
Mine pant (ug)	2,681,300
Infrastructure	4,417,300
Restoration	1,724,100
Mine working cap (o-p)	3,959,000
Mine working cap (ug)	7,936,200
Mine TOTAL:	**$58,134,500**
Mill plant (vat)	$11,059,300
Mill plant (heap)	11,950,300
Mill working capital	3,403,400
Mill TOTAL:	**$26,413,000**
TOTAL CAPITAL COST	**$84,547,500**

Mine and mill operating cost breakdowns in $/st were:

Item	Labor	Supply	Equipment	Total
Mine (o-p)	15.98	13.45	9.46	38.89
Mine (ug)	36.35	33.86	2.29	72.50
Mill (vat)	8.24	5.54	3.96	17.74
Mill (heap)	7.28	4.90	3.51	15.69
Total	**67.85**	**57.75**	**19.22**	**144.82**

This does not include a transportation cost of $54.43/st concentrate. All power is produced on-site by diesel generators.

APPENDIX B. -- METAL PRICES USED IN THE ECONOMIC ANALYSIS

Metal prices used in the discounted cash flow analyses are presented below. Coal prices are not included since the coal models were analyzed to determine the price of coal required to meet the target rate of return.

Metal prices used in the DCFROR analyses

Commodity	Price
Columbium (niobium)	3.50 $/lb
Copper	1.10 $/lb
Fluorite, Acid grade	81.65 $/st
Fluorite, Metallurgical grade	117.94 $/st
Gold	400.00 $/tr oz
Lead	0.41 $/lb
Molybdenum	2.70 $/lb
Silver	5.00 $/tr oz
Tantalum	26.00 $/lb
Tin	2.81 $/lb
Tungsten	37.85 $/stu
Zinc	0.77 $/lb