# ANALYSIS OF BETHEL, KIVALINA (RED DOG), AND OMALIK LAGOON AS PORT SITES FOR USE BY THE MINERAL INDUSTRY

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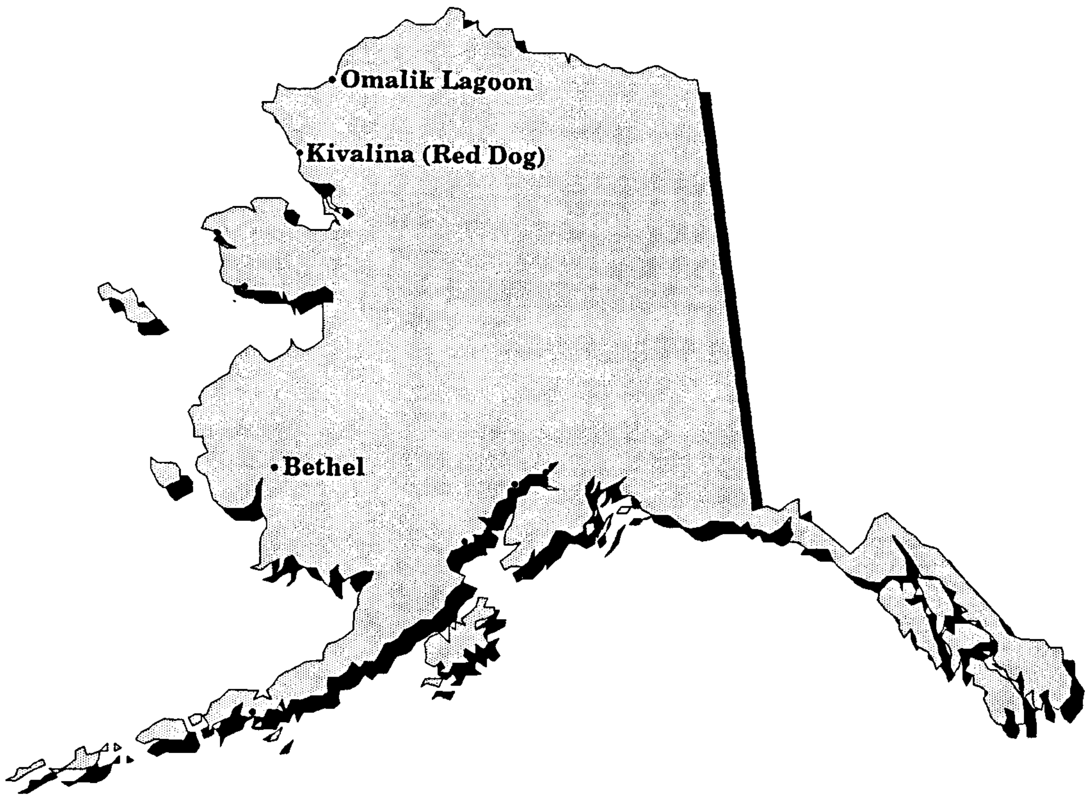


UNITED STATES DEPARTMENT OF INTERIOR
Manuel Lujan, Jr., Secretary

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T S Ary, Director

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## UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

| | |
|---|---|
| BTU | British Thermal Units |
| DCFROR | discounted cash flow rate of return |
| ft | feet |
| gal | gallon |
| KW | kilowatt |
| lb | pound |
| 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 |
| yr | year |

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

## 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 first three sites: Bethel, Kivalina (Red Dog), and Omalik Lagoon.

The mineral deposits near Bethel are primarily gold and mercury; the nearest deposit being 55 miles away. Because of the expense of constructing and maintaining a road over the poorly drained lowlands, the potential of Bethel as a port site in the near-term is considered to be low.

The Kivalina site currently serves the Red Dog mine and has the potential to handle material for similar deposits in the area. Results from a lead-zinc mine model indicate that potential for additional mine development exists in the area.

Coal is the major deposit type found near the Omalik Lagoon site. Due to environmental constraints, development of a large-scale mine producing coal for export is considered unlikely. A small-scale coal mine model was used to examine the feasibility of producing coal for regional use. This alternative may be feasible but would require conversion of heating/generating equipment in the area.

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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 first in a series of three and examines the potential for mineral development within a 100 mile radius of the Bethel, Kivalina (Red Dog), and Omalik Lagoon port sites. Figure 1 shows the location of the three port sites and the deposits[4] located within a 100 mile radius. Map numbers shown on figure 1 refer to deposit summaries in the Mineral Deposit Inventory volume[5] (36). There are a total of 46 deposits (excluding placer deposits) within the area of these three port sites. The breakdown by port site is: Bethel - 17, Kivalina (Red Dog) - 10, and Omalik Lagoon - 19. These represent deposits closest to each respective port. Other deposits may fall within the 100 mile radius but are closer to other ports such as Nome, Lost River, and Kotzebue. The feasibility of mineral development around each port site was examined for typical (model) 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 (13)[6], the Bureau's Cost Estimating System Handbook (CES) (33, 34), 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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[4]The term "deposit" is used loosely in this document in referring to a minerals location. Nothing is implied as to size or economic viability.

[5]For more information on deposits, refer to the "Mineral Deposit Inventory" prepared by the Bureau of Mines.

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

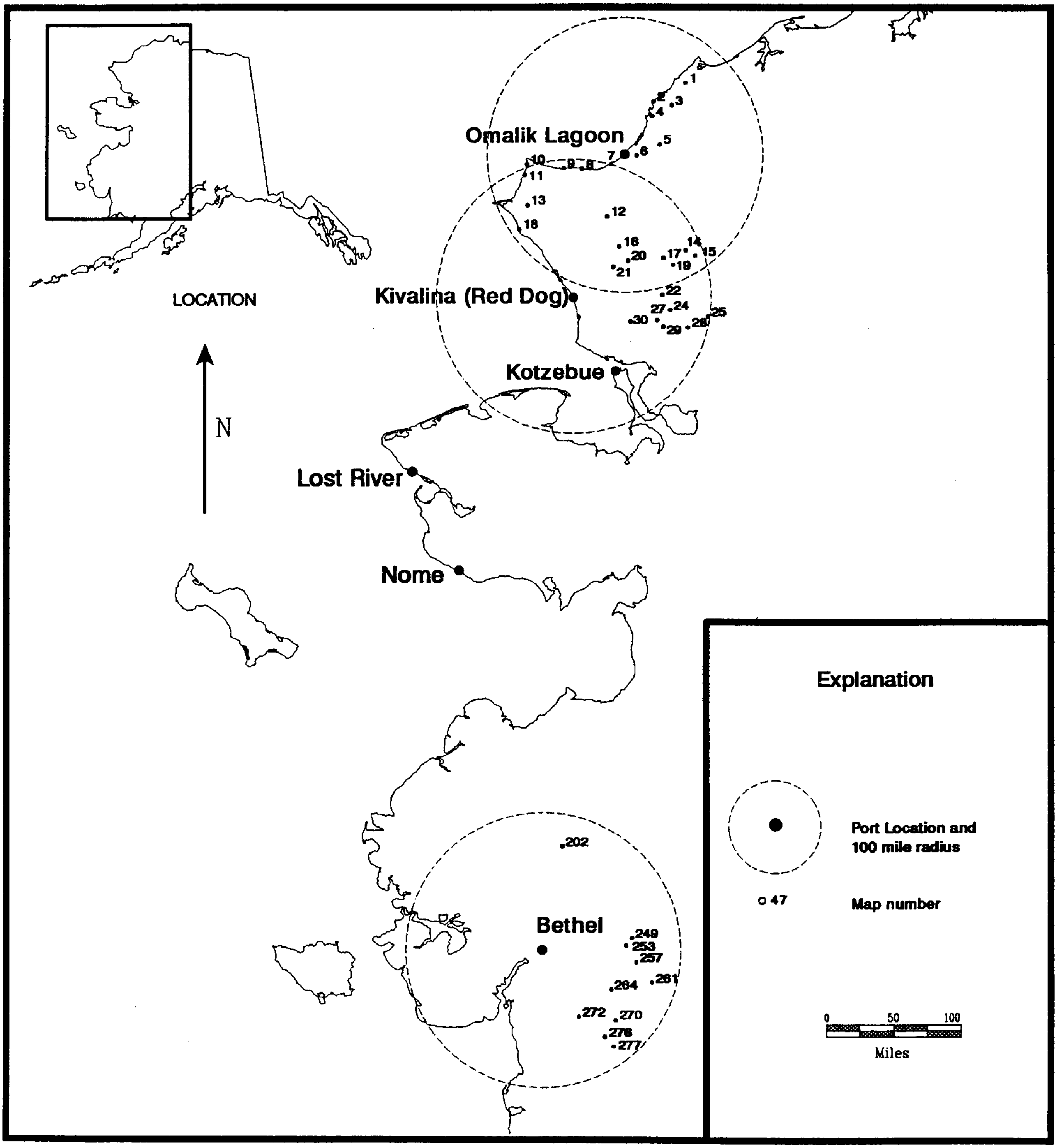


**Figure 1.** -- Location of the Bethel, Kivalina (Red Dog), and Omalik Lagoon port sites and adjacent mineral deposits.

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 Bethel, Kivalina (Red Dog), and Omalik Lagoon 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.

## BETHEL

### Location and Access

Bethel is located in southwestern Alaska 65 miles upstream from the mouth of the Kuskokwim River. An existing port site is located along the northern bank of the Kuskokwim River just downstream from Brown Slough (20).

Bethel is the largest community in the region with a 1980 population of 3,576 (29). It is the distribution center for the communities located along the Kuskokwim River and its tributaries as well as outlying villages only connected by air routes. Table 1 lists population figures for villages located along the Kuskokwim River, its tributaries, and outlying areas (29).

TABLE 1. -- Population of villages near the Bethel port site.

| Village | Pop | Village | Pop |
|---|---|---|---|
| Akiachak | 438 | Napakiak | 262 |
| Akiak | 198 | Napaskiak | 244 |
| Aniak | 341 | Nunapitchuk | 299 |
| Atmauluak | 219 | Oscarville | 56 |
| Eek | 228 | Pilot Station | 325 |
| Kasigluk | 342 | Quinhagak | 412 |
| Kongiganak | 239 | Russian Mission | 169 |
| Kwethluk | 454 | Saint Marys | 382 |
| Kwigillingok | 354 | Tuluksak | 236 |
| Lower Kalskag | 246 | Tuntutuliak | 216 |

The Kuskokwim River is a major shipping lane connected to the ocean shipping lanes servicing Northwestern Alaska. The depth of the Kuskokwim River is approximately 15 feet from its mouth upstream to Bethel and shallows upstream. This allows for line-haul 12 to 13 foot-draft barges to steam to Bethel then transfer cargo to shallower draft barges (20).

As of 1980 the city port site has one 200 foot-long berth along a steel bulkhead adjacent to a 3.5 acre sand-surfaced apron (20). Bethel currently handles bulk goods which include construction materials, food, fuel, and general commodities. Most incoming dry cargo is containerized and placed in open storage space along the wharf or in one of two unheated warehouses (19, 20). The cargo is then transferred to smaller river barges or to the airport for shipment to the outlying villages. All gravel and fuel shipments are unloaded at private port/loading facilities thus avoiding the city port site (20).

A major airport capable of handling commercial jet aircraft is located at Bethel with smaller airstrips located at Aniak, Quinhagak, and Saint Marys. All villages have an airstrip capable of handling two-seat type aircraft.

Annual precipitation in the Bethel area averages around 16 inches and the temperature varies from an average low of 5 degrees to an average high of 55 degrees Fahrenheit (2). The port is ice free from June to October once the Kuskokwim River thaws (20). Land status of the area includes the Yukon Delta National Wildlife Refuge, the Wood-Tikchik State Park, Bureau of Land Management (BLM) administered land, Native land (regional, village, and private), and land controlled by the State of Alaska (23).

## Mineral Deposits

Gold and mercury are the major mineral deposit types located within 100 miles of Bethel. Figure 2 shows the distribution of deposits in the area by primary commodity. There are also placer gold deposits in the area but these have not been considered since they typically ship low volumes of product. Placer mines could avail themselves of port facilities (assuming access is available) but their use would be limited primarily to shipping equipment and supplies into the mine rather than exporting large volumes of mine production. There has been mercury produced from one mine (Arsenic Creek, map number 276) in the area. The nearest identified deposit is 55 miles from Bethel and is a coal prospect (North Fork of Eek River, map number 272). Figure

3 is a pie diagram that shows the distribution of distances from the mineral deposits in the area to Bethel. Note that the majority (88%) of the deposits are greater than 60 miles from Bethel. Based on available information, the deposits within the 100 mile radius would probably be small-scale producers if they were to go into production. A minimum of 55 miles of road construction over poorly drained terrain would be required to access the nearest deposit. At costs ranging from $500,000 to $1,000,000 per mile, it is unlikely that any of the mines would be able to bear the cost of road access to Bethel.

Given the size of known deposits in the area the road requirement, it is probable that use of Bethel as a port site for the mineral industry in the near term is unlikely. For this reason, and the fact that resource data are lacking, none of the deposits in the area were modelled. This report does not address the possibility or potential for undiscovered mineral deposits in the Bethel area. Discovery of a major mineral deposit could result in the use of Bethel as a port site, depending on the length of road required.

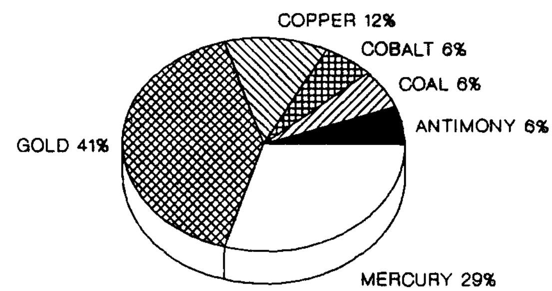


**Figure 2.** -- Distribution by primary commodity of deposits near the Bethel port site.

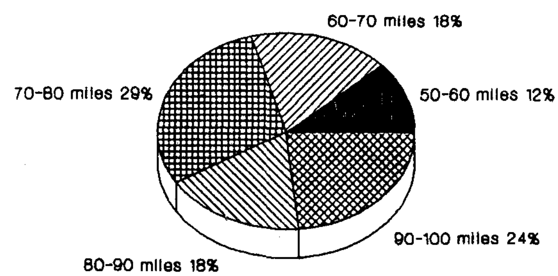


**Figure 3.** -- Distribution of mineral deposit distances from Bethel.

## KIVALINA (RED DOG)

### Location and Access

The Kivalina port site discussed in this report refers to the DeLong Mountain Transportation System (DMTS) port site that services Cominco's Red Dog Mine. The port site is located 15 miles southeast of Kivalina in Northwestern Alaska (see figure 1).

The largest community within the 100 mile port site radius is Kotzebue with a 1980 population of 2,054 (29). Other villages and their populations include Kivalina - 241, Noatak - 273, Norvik - 492, and Point Hope - 464 (29). Many smaller villages are found in the area and include Chariot, Espenberg, Kividlo, Nanyouruk, Sheshalik, Singeak, and Wevok.

The port site was completed in 1989 and was financed by the Alaska Industrial Development and Export Authority (AIDEA). The final cost of the port site was approximately $85 million. Cominco pays the annual maintenance fee for both the port and access road to the Red Dog Mine. The port facilities consist of: a shallow water dock 250 feet long (from shoreline); a trestle system with a 750 foot conveyor belt; concentrate storage building (580,000 ton capacity); on shore fuel storage tanks (2.345 million gallon capacity); power plant; domestic sewage plant; maintenance and accommodations (30 person) buildings; and equipment storage (20).

The 52 mile road that links the port site and the Red Dog Mine was also financed by AIDEA. There is no road link between the port site and the village of Kivalina 15 miles to the northwest.

The shipping lane used in supplying Barrow is located offshore. An airport capable of handling commercial jet aircraft is located at Kotzebue and smaller airstrips are found at the surrounding villages.

The average annual precipitation of the Kivalina/Red Dog area is roughly 5 inches (20). Temperatures range from an average low of -19 degrees to 44 degrees Fahrenheit (2). The port site can receive supplies and fuel, and export shipments of concentrate from late June to early October (20).

Land status of the area includes the Alaska Maritime National Wildlife Refuge, the Cape Krusenstern National Monument, BLM administered land (NPR-A), Native land (regional, village, and private), and lands controlled by the State of Alaska (23).

The DMTS site only services the Red Dog Mine at this time. Ore concentrates are exported while fuel, food, and mining supplies are imported. Other potential uses of the port facilities in the future could include servicing offshore oil and gas exploration/development of the Chukchi Sea, other interior/Brooks Range mineral developments, and facilitating general cargo movement within Northwestern Alaska.

## Mineral Deposits

Lead, zinc and chromium deposits make up the majority of the mineral deposit types found within 100 miles of the port site. Coal, gold, and lead deposits are also present within the area. Figure 4 shows the distribution of deposits by primary commodity for the Kivalina area. The chromium deposits identified in the inventory are all prospects; there has been no chrome production from this area. The Red Dog Mine, a world class lead-zinc deposit containing 85 million st of ore grading 17% zinc, 3% lead, and 2.4 tr oz/st silver, is located approximately 48 air miles from the port site. The Red Dog Mine began production in November of 1989 and at capacity will be able to process 6,000 st of ore per day and ship 750,000 st of concentrate per year (15).

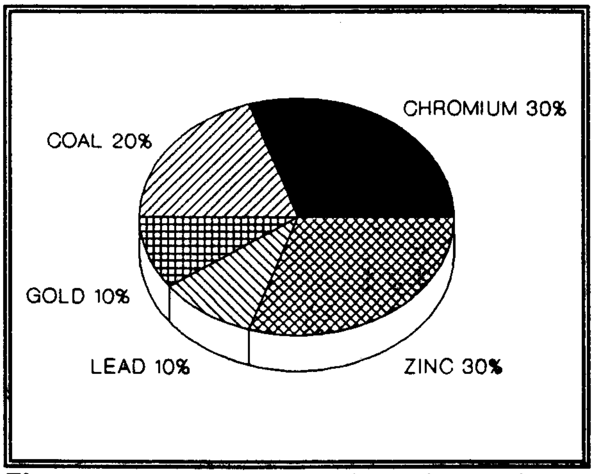


**Figure 4.** -- Distribution by primary commodity of deposits near the Kivalina port site.

There are two other known lead-zinc deposits within 100 miles of Kivalina and less than 20 miles from Red Dog: Lik and Su (map number 16). The Lik deposit has proven reserves of 24,000,000 st of ore grading 9.3% zinc, 3.3% lead, and 1.4 tr oz/ton silver (15). Reserves at the Su deposit have not been published although it may be similar to Lik. Specifics of the Lik deposit such as orebody dimensions, orebody depth, and probable mining method have not been published. The road from the Red Dog Mine to the port would aid in access to other deposits such as Lik and Su if and when development is undertaken.

## Lead-Zinc Mine Model

Based on present knowledge, development of lead-zinc deposits in the area surrounding the Kivalina (Red Dog) port site is more likely than development of the chromium, coal, or other mineral resources. An open pit mine model for extracting lead-zinc massive sulfide ore was designed based on a mining rate similar to Red Dog and using reserves comparable to those proven at Lik. As mentioned previously, the lack of orebody data prevents a detailed analysis of the Lik or Su deposits. The assumptions made in designing the model are listed in table 2 and the commodity data are listed in table 3.

TABLE 2. -- Assumptions used in designing the lead-zinc open pit mine model.

| | |
|---|---|
| Mine life (years) | 14 |
| St ore/day | 5,000 |
| St waste/day | 15,000 |
| St ore mined/year | 1,750,000 |
| Stripping ratio | 3:1 |
| Personnel | 275 |
| Power generation (KW) | 21,000 |
| Operating days/year | 350 |
| Mill feed, st/d | 5,000 |
| Mill method | Flotation |
| Tailings, st/d | 4,101 |
| Tons concentrate produced/year | 314,685 |

TABLE 3. -- Commodity data for the lead-zinc open pit mine model.

| Commodity | Grade | Recovery | Concentrate Grade | Tons/day Concentrate |
|---|---|---|---|---|
| Lead (Pb) | 3% | 95% | 70% | 203.6 |
| Zinc (Zn) | 9% | 85% | 55% | 695.5 |
| Silver (Ag) | 1.4 tr oz/st | 80% | 27.51 tr oz/st | (contained in Pb) |

Costs for the lead-zinc open pit model were estimated using CES (33, 34). 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 3, labor costs by 1.67, and supplies and equipment costs by 1.65 (6). Table 4 lists capital and operating costs for the mine and mill and transportation operating costs.

TABLE 4. -- Capital, operating, and transportation costs for the lead-zinc mine model.

| Cost Category | Capital Cost | Operating Cost $/st |
|---|---|---|
| Mine | $230,475,900 | $27.20 |
| Mill | $82,377,700 | $11.60 |
| Transportation | NAp | $42.10 |

NAp Not applicable

The total capital costs for a 5,000 st/d open pit mine are $312,853,600. This includes exploration, permitting, and infrastructure. Infrastructure development capital costs include 12 mile road construction, port loading facilities, and concentrate storage building at the port site. The total mine and mill operating cost is $38.80/st ore mined and processed. The transportation operating cost includes concentrate haulage to the port site by truck and shipment to point of sale or smelting by barge. The CES provides estimates within ± 25% of actual costs. A summary of the costs and assumptions used in the model are presented in Appendix A.

## Economic Analysis

To determine the economic viability of a deposit similar to that of the model, a discounted cash flow rate of return (DCFROR) analysis was done at discount rates of 0 and 15%. The model generated a DCFROR of 13.6% with NPVs of $450,410 (0% discount rate) and -$13,445 (15% discount rate).

To examine the affect of costs and revenues on the model, a sensitivity analysis was done by varying capital costs, operating costs, and revenues. One variable was varied over a range of 75% to 125% of the base case (100%) while the other two were held constant. The results of the sensitivity analysis reveal which variables have the most impact on the models rate of return. Table 5 shows the results of the sensitivity analysis for each of the three cost/revenue variables. Examination of the results reveals that revenue has the widest range of DCFROR's and thus the greatest single impact on the rate of return of the model. This is illustrated in figure 5. Note the relative steepness of the revenue curve compared to those for capital and operating costs. The curves cannot be used to determine DCFROR where two variables are varied concurrently, although extrapolation between the curves above the 100% level yield DCFROR estimates within ± 1% since the operating and capital cost curves essentially coincide. Below 100%, the divergence of the capital and operating cost curves prevent extrapolation.

TABLE 5. -- DCFROR at levels of expenditure/revenue from 75 to 125% of base case (base is 100%).

| Percentage of base | DCFROR when Capital costs are varied | DCFROR when Operating costs are varied | DCFROR when Revenues are varied |
|---|---|---|---|
| 75 | 18.66 | 16.62 | -1.40 |
| 80 | 17.50 | 16.09 | 2.20 |
| 85 | 16.43 | 15.52 | 5.65 |
| 90 | 15.43 | 14.92 | 8.69 |
| 95 | 14.50 | 14.28 | 11.33 |
| 100 | 13.63 | 13.63 | 13.63 |
| 105 | 12.81 | 12.94 | 15.69 |
| 110 | 12.05 | 12.23 | 17.56 |
| 115 | 11.32 | 11.48 | 19.24 |
| 120 | 10.63 | 10.69 | 20.77 |
| 125 | 9.98 | 9.86 | 22.19 |

In the base case the model has a DCFROR of 13.63%. This can be considered to be an estimate of feasibility at current metal prices. Metals prices used in the base case are \$0.41/lb lead, \$0.77/lb zinc, and \$5.00/tr oz silver. As would be expected, there is an inverse relationship between cost (both capital and operating) and DCFROR. A 15% DCFROR is considered to be the minimum acceptable for some mining companies; the actual rate is based on a number of factors including corporate policy and other ventures and opportunities. If a 15% DCFROR is assumed to be the minimum acceptable in this analysis, the lead-zinc mine model is uneconomic. Note however that the rate of return is quite close to the cutoff and an increase in metals prices would bring the DCFROR up to the 15% threshold. If the operating or capital costs have been underestimated in this analysis, the model is even further from being feasible as shown by the DCFROR results in table 5.

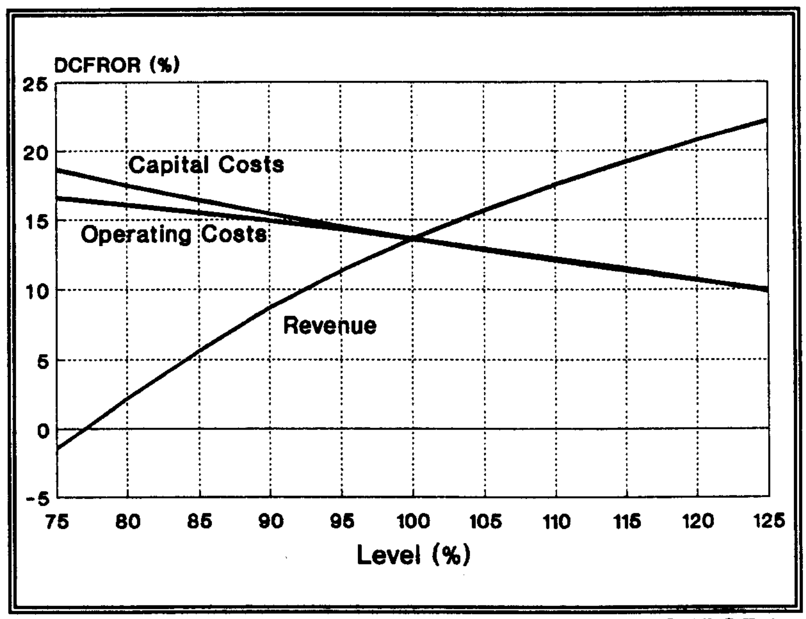

**Figure 5.** -- Affect of varying costs/revenues on DCFROR for the lead-zinc mine model.

Because of the difficulty in forecasting metals prices, it is not possible to state absolutely that the other mineral resources around the Kivalina port site will be developed in the near term.

Given the results of the mine model analysis, it appears that potential exists for development in the next 10 to 50 years. This of course depends on a multitude of factors that cannot be predicted (e.g. political and economic climate, present and future environmental restrictions, commodity prices/world supply and demand, and technologic changes). There is a vast storehouse of mineral wealth along the south flank of the Brooks Range. It is possible that future development of these deposits will occur given favorable conditions. If this does come about, the Kivalina port site may be the most likely link to the shipping lanes.

Assuming the development of two deposits similar to the mine model, a total of 629,370 st/yr of concentrate would pass through the port. If the Red Dog Mine production is included, a total of 1,379,370 st of concentrate would flow through the port each year.

## OMALIK LAGOON

### Location and Access

Omalik Lagoon is located in Northwestern Alaska along the Chukchi Sea coast 43 miles south of Point Lay (see figure 1). There is no village site at Omalik Lagoon. The three largest villages located within the 100 mile port site radius include Point Hope with a 1980 population of 464, Noatak with 273, and Point Lay with a population of 68 (29). Chariot and Wevok are also within the port radius but their populations are so low that they are only counted as part of the regional total.

There is no existing infrastructure at Omalik Lagoon. A winter trail located along the coastline is most likely used by local residents traveling between Point Lay and Noatak. Airstrips are located at the villages of Point Lay and Wevok. The shipping lane used to transport goods to Barrow is located just offshore.

The Omalik Lagoon area has an average annual precipitation level of roughly 5 inches and average temperatures range between 19 to 44 degrees Fahrenheit (2). The ice free season occurs from June to October (20).

Land status of the port site area includes the Alaska Maritime National Wildlife Refuge, the Cape Krusenstern National Monument, the Noatak National Preserve, and lands controlled by the (BLM) including the National Petroleum Reserve-Alaska (NPR-A), Native (regional, village, and private), and the State of Alaska (23).

Omalik Lagoon is a potential port site for the development of the coal deposits located in the western portion of the Northern Alaska coalfield.

### Mineral Deposits

Coal deposits make up 79% of the mineral deposit types within the 100 mile radius of Omalik Lagoon. Asbestos, zinc, gold, and copper deposits are also present. Figure 6 shows the distribution of deposits by primary commodity for the Omalik Lagoon area. Reserve and deposit data for the non-coal resources in the region are not available.

The coal resources of the northern slope of Alaska as a whole are immense; by many estimates, greater than the rest of the U.S. (31). The coal deposits to date have received little interest from the mining industry but have been the subject of study by both Federal and State agencies.

The coal resources surrounding the Omalik Lagoon area are extensive. The Cape Beaufort coal deposit (map number 7) is located approximately 12 miles southwest of Omalik Lagoon along the coast. The resources in this area were calculated by Callahan to be 35,000,000 st measured, 312,000,000 st indicated, and 186,000,000 st inferred (7). The Corwin Mine (map number 9) is located approximately 33 miles east of Cape Lisburne. The resources in this area are 56,000,000 st indicated and 926,000,000 st inferred (16). The Deadfall Syncline coal deposit (map number 6) is located approximately 19 miles northeast of Cape Beaufort. The resources in this area are 15,810,000 st measured and 59,000,000 st inferred (3).

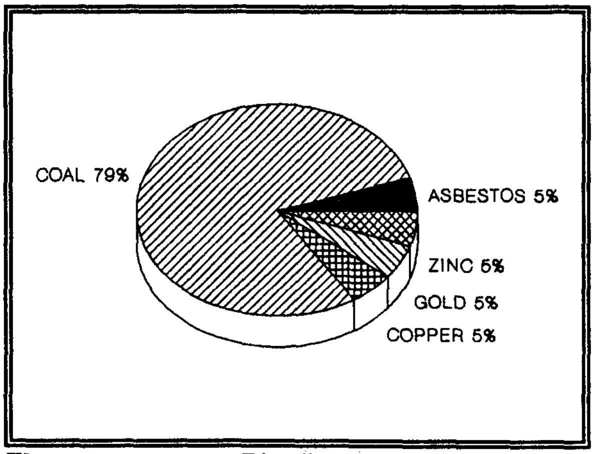


**Figure 6.** -- Distribution by primary commodity of deposits near the Omalik Lagoon port site.

## Coal Mining Constraints

Coal mining in the Arctic presents a challenge owing to the cold climate, high winds, permafrost, and remoteness from major centers of population and supply. These factors can have a major influence on productivity, transportation, personnel, dust generation and suppression, coal washing, and surface plant (20). The following is a synopsis of the economic and technologic constraints associated with mining coal in the Arctic.

The Chukchi Sea is ice free for about 100 days a year, presenting a serious limitation to the import of materials and supplies and export of coal from a mine. Because of the short shipping season, a larger than normal inventory of supplies and equipment parts would be required. Stockpiling of the coal at the port would be required until shipment during the ice-free season. Additional equipment and larger scale loadout facilities may be necessary to load out the stockpile in the time available.

Cold permafrost is considerably stronger than that with a temperature just below freezing (20). Ice-rich permafrost is more likely to cause difficulties than ice-free permafrost. Appropriate measures for preventing permafrost degradation under surface structures need to be taken, as well as measures for insuring vehicle operation.

Hiring and retaining a labor force would be difficult due to the remote location and harsh weather. To maintain a consistent labor supply, higher wages and comfortable camp accommodations would be required. High turnover rates and the resulting high training costs can be anticipated regardless of benefits provided to employees. Productivity drops due to the weather; employees aren't able to operate as efficiently in the cold weather. Frostbite can be a problem if measures aren't taken to protect the work force by providing heated equipment cabs and other necessities.

Equipment wear is accelerated in cold climates; special lubricants and maintenance procedures are required to keep equipment operating throughout the winter season. Equipment should be housed indoors when not in use so it will be functional when called into service. Cold temperatures can make steel brittle causing increased breakdowns; rippers on bulldozers are easily broken (20). Lighting expenses for portable light systems and generators increase during the long winter nights for a year round operation (40). Heating expenses also increase dramatically during the winter months.

The use of water in coal washing operations would require a heated plant and the coal would have to be dried after washing to prevent freezing in the storage piles (20). Other problems are associated with the use of water. Haulage of wet coal can result in considerable handling problems when the coal freezes in large lumps. Usibelli Coal Mine (UCM), the only producing coal mine in Alaska, has modified its coal trucks in response to this problem; the coal boxes have double floors through which vehicle exhaust is piped to keep the truck bed warm to prevent the coal from freezing to the bed (7). In addition to these problems, maintaining water supplies and availability may be a problem (4).

There is no over-riding reason, why Northwestern Alaska coal could not be mined at the present time with current technology and mining practices. However, the environmental constraints discussed above pose significant economic factors (i.e. high costs) which may inhibit development and operation of a coal mine in this region of Alaska. While mining is currently taking place in this part of Alaska (e.g. Red Dog), the fact that coal has a low unit value per ton mined compared to metals tends to limit the ability of a coal mine to absorb the increased operating costs of mining under Arctic conditions.

## Small-Scale Coal Mine Model

Since 15 out of 19 deposits that occur near Omalik Lagoon are coal deposits, metal mine models were not considered. The four non-coal deposits consist of one each of gold, asbestos, copper, and zinc. Resource data is lacking thus preventing modelling of these deposits.

The most likely scenario for developing coal resources in Northwestern Alaska in the short term is small-scale production for regional use. This assumes the development of a coal market in the nearby villages through conversion of existing equipment from fuel oil to coal fired. Because of the low probability of large-scale production in the near term, only a small-scale mine producing coal for village use was modelled. A previous study on the feasibility of large-scale coal mining is discussed in a later section.

### History

There has been some small-scale coal mining in the region. Collier noted that whalers often replenished their fuel supply from coal beds in the area; the points most frequently visited being Corwin Bluff (map number 9), where the U.S. revenue cutter *Corwin* took on 20 st of coal in 1881, and the Thetis mine (map number 8), where the revenue cutter *Thetis* coaled in 1888 and 1889 (9). Schrader noted that the Corwin mines were operated to some extent during the summer of 1901 by the Arctic Development Company, who disposed of the coal in the Nome market, mostly for domestic purposes (28).

The Bureau and the U.S. Geological Survey made several separate and cooperative investigations of Northwestern Alaska coal during 1966-1975 (8, 41, 42). In 1977, Kaiser Engineers under contract to the Bureau conducted a technical and economic feasibility study of North Slope deposits (7). In 1981, Dames and Moore in association with Resource Associates of Alaska, Inc. prepared an assessment of coal resources of Northwest Alaska for the Alaska Power Authority (APA). APA commissioned the study to determine whether Northwestern Alaska communities, which relied on costly and often difficult to obtain petroleum based fuels, could economically utilize coal resources (10, 11, 12). This report was the basis of a later report by the House Research Agency of the Alaska State Legislature (17).

Following a proposal to the State Legislature by the Alaska Native Foundation in 1983, a special appropriation was made to the State Department of Community and Regional Affairs to administer a program to determine if coal resources in the region could be economically substituted for imported fuel oil used for heat and power in remote villages of Northwest Alaska (14). From 1984 to 1988, Arctic Slope Consulting Engineers (ASCE) conducted the Western Arctic Coal Development Project under this appropriation.

ASCE concentrated it's efforts on the Deadfall Syncline coal deposits (map number 6), but considered the Cape Beaufort coal deposits as a second choice because of the shallow coastline, local property conflicts and generally poorer quality (4).

Based on field work conducted during the summer and fall of both 1986 and 1987, ASCE estimated reserves at the Mormon West block of the Deadfall Syncline at 1,047,010 st. The reserves were calculated, assuming a maximum stripping ratio of 4:1 and included 3 seams of coal (DFS 2, DFS 3, DFS 4 seams) (4).

## Model Parameters

The feasibility of small-scale coal mining near Omalik Lagoon was estimated using an open pit (stripping) mining method as delineated in the ASCE study (4). Overburden would be ripped and removed by dozer and mining would be limited to the shallow coal deposits near coal outcrops. Mining would move along strike of the seam with stripping, mining and backfilling operations being performed concurrent to one another. A tracked hydraulic excavator equipped with 48 inch bucket would load 35 ton articulated dump trucks. Run of mine coal which is primarily 6 inch minus would be produced with no further washing or crushing used. The assumptions used in the model are listed in table 6.

TABLE 6. – Assumptions used in designing the small-scale coal mine model.

| | |
|---|---|
| Mine life (years) | 30 |
| St coal/day | 200 |
| Bank yards waste/day | 530 |
| St coal mined/year | 20,000 |
| Stripping ratio | 2.65:1 |
| Personnel | 21 |
| Power generation (KW) | 200 |
| Operating days/year | 100 |

The coal that would be produced in the small-scale model is patterned after coal found in the Deadfall Syncline area and is assumed to be a high volatile bituminous B to A coal with a rating of 12,000 BTU/lb, 5% moisture, and 0.1-0.3% sulfur.

Costs for the coal mine model were estimated by updating costs from ASCE to July 1989 dollars (4). Table 7 lists the capital, operating, and transportation costs for the small-scale coal mine model. These costs can be applied in a generic manner to similarly sized coal deposits in the region. Mine operating costs include the transportation cost to the port site. Transportation operating costs are for barge transport to Kotzebue.

TABLE 7. -- Capital, operating, and transportation costs for the small-scale coal mine model.

| Cost Category | Capital Cost | Operating Cost $/st |
|---|---|---|
| Mine . . . . . . . . . . . . . . . . . . | $8,884,300 | $36.03 |
| Transportation . . . . . . . . . | NAp | $37.75 |

NAp Not applicable

Coal and supplies would be hauled to/from the port site over a 4.5 mile winter haul road and surface access would not be available between the two points until about mid-October after the winter freeze-up. A stockpile requiring 4 acres would be maintained at a proposed port site on the north end of Omalik Lagoon.

The first year's production is trucked to the port site during the winter and stockpiled for shipment to Kotzebue the following summer. Because of this, the first year's operating cost will not include the $37.75/ton transportation operating cost. In subsequent years of operation, the transportation operating cost is included. Because the first years production must be stockpiled, no revenues would be generated to cover operating costs until the second year of production.

## 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 price of coal required to achieve a 0 and 15% DCFROR was determined for coal delivered to Kotzebue and coal sold at the port site. The price determination is based on full expenditure of the capital investment in one year (i.e. one preproduction year). The results of the analysis are listed in table 8.

TABLE 8. -- Economic Analysis Results for the small-scale coal mine model.

| DCFROR | Point of sale | Price Required |
|---|---|---|
| 0% | FOB Omalik Lagoon | $54.50 |
| 0% | FOB Kotzebue | 93.64 |
| 15% | FOB Omalik Lagoon | 167.25 |
| 15% | FOB Kotzebue | 205.65 |

To put the results in table 8 in perspective, prices for coal (FOB mine) from UCM are in the mid-$30/ton range and range from $30 - $50/ton delivered in Seward. Idemitsu Alaska Inc., which is working on developing the Wishbone Hill coal deposit in the Matanuska Valley, is estimating a $40/ton cost for coal delivered in Seward (1). The cost for coal (FOB Kotzebue) is quite high and may not be competitive with fuel oil, assuming that the villages would convert to coal in the first place. Based on the recoverable heat for fuel oil (at 75% efficiency) and Deadfall Syncline coal (at 66% efficiency), it would take 14.2 lb of coal to equal one gallon of fuel oil (4). The 15%

DCFROR FOB Kotzebue scenario presented in the economic analysis required a coal price of $205.65/ton which is equivalent to a fuel oil price of $1.46/gal[7].

At present a local market for coal large enough to support the proposed model does not exist. Development of coal in the Omalik Lagoon area would require a commitment on the part of villages in the area to convert to coal-fired heat and/or power plants. ASCE estimated conversion costs for residential heating to be $1,500 per unit and for larger units (schools etc.) to be $100,000 (4).

## Large-Scale Coal Mining

The feasibility of a large-scale coal mine on the North Slope producing coal for export is considered to be very low at this point in time. Based on the environmental constraints discussed above, the high cost of materials and supplies, and the limited shipping season, competition in domestic and world coal markets would be very difficult. The results of a previous study on large-scale coal mining on the North Slope are presented below for comparison purposes.

Kaiser Engineers estimated costs for large scale surface mining of coal on the North Slope of Alaska (18). Two sizes of surface mines were considered by Kaiser; 500,000 st/yr and 5,000,000 st/yr. The costs were based on mining deposits in the Kuk River, Kukpowruk River (map number 6) and Elusive Creek areas. With steeply dipping seams in flat lying terrain, the stripping ratio increases rapidly downdip and the pit limit is reached in a relatively short distance from the seam outcrop. Stripping ratios were calculated by Kaiser using a cutoff point of 150 feet of overburden. The ratios for each of the three areas were: Elusive Creek - 9.0 $yd^3$ overburden per ton coal, Kuk River - 4.1 $yd^3$ overburden per ton coal, and Kukpowruk River - 8.0 $yd^3$ overburden per ton coal.

Both mining scenarios developed by Kaiser used electric draglines and trucks for mining the coal seams which dip approximately 15 degrees. Due to the dip of the seam, a stripping ratio of 2.4:1 was assumed in the cost estimate. Power would be generated at the minesite by diesel powered generators. The operation would be year round, operating 3 shifts/day, 7 days/week, 335 days/year after allowance for lost time due to weather, major equipment failures, and work stoppages. Camp accommodation for 100 employees would be located at the minesite. Total capital costs and operating costs (1976 dollars) reported by Kaiser for a 5,000,000 st/yr mine in the Kukpowruk River area were estimated to be $212,152,000 and $14.51/ton respectively. The study concluded that large-scale mining of the coal deposits was possible with currently available technology but was uneconomic given the existing coal resource estimates, costs and market conditions (18).

Given the high capital cost and the environmental constraints discussed above, the development of a large-scale coal mine in the near term is unlikely. Changing energy use patterns and eventual decline of world oil reserves may at some point make the exploitation of North Slope coal attractive.

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[7] $205.65/ton ÷ 2000 lb/ton X 14.2 lb coal/gal fuel oil = $1.46/gal fuel oil

# CONCLUSIONS

Based on the analysis of the deposits surrounding the Bethel, Kivalina (Red Dog), and Omalik Lagoon ports, it appears the Kivalina site has the most potential to support the mineral industry in the near future.

Bethel is surrounded by poorly drained lowlands, the nearest deposit being 55 miles distant. Because of the high cost of road construction and maintenance, and the size of the known deposits, it is considered unlikely that Bethel will be used as a port for the mining industry. Because of the distance and the nature of the surrounding deposits, no mine models were constructed for the Bethel site.

With respect to the Kivalina port site, there are additional lead-zinc massive sulfide deposits in the region surrounding the Red Dog Mine. While there is little data on the specifics of the deposits, they may have potential for development in the near term, assuming development similar to the lead-zinc mine model. Analysis of the model indicates that such a deposit is sub-economic if a 15% DCFROR is used as cutoff. However the DCFROR is relatively close to the cutoff and, depending on economic conditions, mines in the area may become feasible in the near future. The presence of the DeLong Mountains Transportation System is a real asset for those deposits in the region which could tie into the existing infrastructure.

Use of Omalik Lagoon as a port site hinges on the use of coal as a substitute for fuel oil in the villages of Northwestern Alaska. Analysis of the coal mine model yielded prices which equate to approximately $1.46/gal fuel oil for coal delivered to Kotzebue (15% DCFROR case). Whether or not this is competitive remains to be seen and depends largely on the willingness of consumers to convert to coal-fired equipment. Production of coal on a large scale for export is considered to be infeasible at the present time. This is due to the expense and hardship of operating in the Arctic environment. While technically feasible, competition in world export markets would be difficult; particularly with the short shipping season and therefore intermittent supply of coal to market.

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# APPENDIX A. -- MINE MODEL SUMMARY

## LEAD-ZINC OPEN PIT MODEL

The lead-zinc open pit model assumes the mining of a relatively flat-lying, near-surface massive sulfide orebody. Ore and waste are drilled using rotary drills and handled by diesel shovels and trucks. The model is designed around a production rate of 5,000 st/d and a stripping ratio of 3:1, resulting in the handling of 20,000 st of combined ore and waste per day. Preproduction stripping required to expose and prepare the orebody for mining was assumed to be 5.5 million st.

The mill process used in the model consists of crushing and grinding to 150 mesh, followed by froth flotation. The flotation circuit would be designed to produce a zinc concentrate and a lead-silver concentrate. Concentrates would be thickened and dried in preparation for haulage by truck to the port site. Tailings would be thickened and placed in an impoundment near the mill site. The mill would produce 203.6 st/d lead concentrate with grades of 70% lead and 27.51 tr oz/st silver and 695.5 st/d zinc concentrate with a grade of 55% zinc. Concentrates would be hauled to the port by truck and stockpiled for shipment during the summer shipping season. The mine and mill would operate 350 days per year.

Costs for this model were estimated using the Bureau's CES (33, 34) program and, when appropriate, actual data from operating mines. The costs generated from the CES are based on establishing a mining operation in the Denver area. 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 3.0, labor by 1.67, and supplies and equipment by 1.65 (6). All costs are in July 1989 dollars and English units of measurement are used throughout the model. The capital costs estimated for the model were:

| | |
|---|---|
| Exploration | $10,000,000 |
| Mine permitting | 12,017,873 |
| Development | 26,507,540 |
| Mine plant | 74,307,179 |
| Mine equipment | 22,582,171 |
| Infrastructure | 76,901,000 |
| Mine working capital | 8,160,164 |
| **Mine TOTAL:** | **$230,475,927** |
| Mill plant | $74,233,954 |
| Mill permitting | 4,662,891 |
| Mill working capital | 3,480,903 |
| **Mill TOTAL:** | **$82,377,748** |
| **TOTAL CAPITAL COST** | **$312,853,675** |

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

| Item | Labor | Supply | Equipment | Total |
|---|---|---|---|---|
| Mine | 7.10 | 2.49 | 17.61 | 27.20 |
| Mill | 3.85 | 5.98 | 1.77 | 11.60 |
| **Total** | **10.95** | **8.47** | **19.38** | **38.80** |

The high equipment operating cost for the mine is due to the high cost of diesel fuel for power generation. The mine bears the cost of all power generation and thus the high equipment operation cost.

Facilities at the port include load-out equipment, a concentrate storage building capable of storing 75% of the mines annual output, and other ancillaries. These costs are included in the mine capital costs listed above and amount to $76,901,000.

## SMALL-SCALE COAL MINE MODEL

The coal mine model described below is based entirely on costs developed by ASCE (4), and updated by the Bureau to July 1989 dollars. Based on field work conducted during the summer and fall of both 1986 and 1987, ASCE estimated reserves at the Mormon West block of the Deadfall Syncline at 1,047,010 tons. The reserves were calculated, assuming a maximum stripping ratio of 4:1 and included 3 seams of coal (DFS 2, DFS 3, DFS 4 seams).

The mining cost estimates assumed the top 5 feet of overburden could be ripped by dozer and would not require blasting. The top 5 feet of overburden represent approximately 15 percent of the total overburden for the maximum 4:1 stripping ratio. Stripping of overburden would be done in the fall. There would be no blasting or crushing of coal; it is anticipated that the run of mine coal would be primarily 6 inch minus.

The mine would have a production rate of 20,000 st/yr and be a seasonal operation, requiring a workforce of 21 persons. Mining would be limited to the shallow coal deposits near coal outcrops outside of the major drainage in order to minimize the need for water control. Mining would move along strike with stripping, mining and backfilling operations being performed concurrent to one another.

Two 100 kW generators (one primary and one standby) would be placed in a steel generator van, 8 feet X 20 feet. A 190,000 gal storage tank would be provided at the port site. Fuel would be transferred from the 190,000 gal fuel storage tank to a 10,000 gal fuel tank at the campsite as needed by a 10,000 gal fuel truck.

Coal and supplies would be hauled to/from the port site over a 4.5 mile winter haul road and surface access would not be available between the two points until about mid-October after the winter freeze-up. Equipment for loading coal onto the barge and for loading ramp construction would be brought in each year with the coal barges. A stockpile requiring 4 to 10 acres would be maintained at a proposed port site on the north end of Omalik Lagoon during the winter hauling season. Two radial stacker conveyors and a 966 size loader would be used for barge loading. The loader would be mobilized in with the barge equipment each year. A loading rate of 85 st/hr is assumed in a lightering operation.

Updating the costs from the report (4) to July 1989 dollars results in mine operating costs as follows:

| Mining Rate (st/yr) | Capital cost | Operating cost $/st |
|---|---|---|
| 20,000 | $8,884,300 | 36.03 |
| 50,000 | 13,288,900 | 37.62 |

Costs include mining and transportation to the port site.

Dames and Moore also estimated costs for two surface coal mines in the same region and the results were similar to estimates made by ASCE and others (12). The 10,000 st/yr estimate assumed a seasonal operation while the 60,000 st/yr estimate was based on a year round operation. Capital and operating costs for these two mining scenarios are presented for purposes of comparison with the ASCE estimate which was used in the economic analysis:

| Mining Rate (st/yr) | Capital cost | Operating cost $/st |
|---|---|---|
| 10,000 | 5,995,000 | 42.16 |
| 60,000 | 17,366,400 | 41.49 |

Costs were not itemized for the coal mine model used in this study since they were derived by escalating the ASCE estimates to July 1989 dollars.

# APPENDIX B. -- SAMPLE CASH FLOWS

# LEAD-ZINC OPEN PIT MODEL:

(All Values in Thousands)
Page 1
Title : Pb-Zn MS open pit
Run Date : 1/19/1990
Evaluation Date : 01/89
Project Start : 01/89
Evaluator : GES

| Period Ending | 12/89 | 12/90 | 12/91 | 12/92 | 12/93 | 12/94 | 12/95 | 12/96 | 12/97 | 12/98 |
|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | 0 | 0 | 0 | 0 | 0 | 0 | 244,022 | 244,022 | 244,022 | 244,022 |
| -Smelting Cost | 0 | 0 | 0 | 0 | 0 | 0 | -84,013 | -84,013 | -84,013 | -84,013 |
| Net Smelt Retn | 0 | 0 | 0 | 0 | 0 | 0 | 160,008 | 160,008 | 160,008 | 160,008 |
| -Royalties | 0 | 0 | 0 | 0 | 0 | 0 | -8,000 | -8,000 | -8,000 | -8,000 |
| Net Revenue | 0 | 0 | 0 | 0 | 0 | 0 | 152,008 | 152,008 | 152,008 | 152,008 |
| -Oper Costs | 0 | 0 | 0 | 0 | 0 | 0 | -67,900 | -67,900 | -67,900 | -67,900 |
| -Sever, Ad-Val | 0 | 0 | 0 | 0 | 0 | 0 | -10,641 | -10,641 | -10,641 | -10,641 |
| -Development | 0 | 0 | 0 | -6,185 | -6,185 | -6,185 | 0 | 0 | 0 | 0 |
| -Depreciation | 0 | 0 | 0 | -7,515 | -21,041 | -36,379 | -40,231 | -30,740 | -24,375 | -21,258 |
| -Amortization | 0 | 0 | 0 | -530 | -1,060 | -1,590 | -1,590 | -1,590 | -1,060 | -530 |
| -Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Before Depltn | 0 | 0 | 0 | -14,230 | -28,287 | -44,154 | 31,646 | 41,137 | 48,032 | 51,679 |
| -50% Limit | 0 | 0 | 0 | 0 | 0 | 0 | -15,823 | -20,569 | -24,016 | -25,839 |
| -Percent Depl | 0 | 0 | 0 | 0 | 0 | 0 | 32,823 | 32,823 | 32,823 | 32,823 |
| -Cost Depltn | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 |
| -Loss Forward | 0 | 0 | 0 | 0 | -14,230 | -42,517 | -86,671 | -70,848 | -50,279 | -26,263 |
| Taxable | 0 | 0 | 0 | -14,230 | -42,517 | -86,671 | -70,848 | -50,279 | -26,263 | -424 |
| -Tax @ 40% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net Income | 0 | 0 | 0 | -14,230 | -42,517 | -86,671 | -70,848 | -50,279 | -26,263 | -424 |
| +Depreciation | 0 | 0 | 0 | 7,515 | 21,041 | 36,379 | 40,231 | 30,740 | 24,375 | 21,258 |
| +Depletion | 0 | 0 | 0 | 0 | 0 | 0 | 15,823 | 20,569 | 24,016 | 25,839 |
| +Amortization | 0 | 0 | 0 | 530 | 1,060 | 1,590 | 1,590 | 1,590 | 1,060 | 530 |
| +Loss Forward | 0 | 0 | 0 | 0 | 14,230 | 42,517 | 86,671 | 70,848 | 50,279 | 26,263 |
| +Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Capitl Costs | -5,000 | -5,000 | -8,340 | -86,139 | -77,798 | -100,380 | -11,641 | 0 | 0 | 0 |
| Cash Flow | -5,000 | -5,000 | -8,340 | -92,324 | -83,983 | -106,565 | 61,826 | 73,467 | 73,467 | 73,467 |

# LEAD-ZINC OPEN PIT MODEL - CONTINUED:



(All Values in Thousands)
Title : Pb-Zn MS open pit
Run Date : 1/19/1990
Evaluation Date : 01/89
Project Start : 01/89
Evaluator : GES

| Period Ending | 12/99 | 12/00 | 12/01 | 12/02 | 12/03 | 12/04 | 12/05 | 12/06 | Salv. |
|---|---|---|---|---|---|---|---|---|---|
| Revenue | 244,022 | 244,022 | 244,022 | 244,022 | 244,022 | 244,022 | 244,022 | 244,022 | 11,641 |
| -Smelting Cost | -84,013 | -84,013 | -84,013 | -84,013 | -84,013 | -84,013 | -84,013 | -84,013 | 0 |
| Net Smelt Retn | 160,008 | 160,008 | 160,008 | 160,008 | 160,008 | 160,008 | 160,008 | 160,008 | 0 |
| -Royalties | -8,000 | -8,000 | -8,000 | -8,000 | -8,000 | -8,000 | -8,000 | -8,000 | 0 |
| Net Revenue | 152,008 | 152,008 | 152,008 | 152,008 | 152,008 | 152,008 | 152,008 | 152,008 | 0 |
| -Oper Costs | -67,900 | -67,900 | -67,900 | -67,900 | -67,900 | -67,900 | -67,900 | -67,900 | 0 |
| -Sever, Ad-Val | -10,641 | -10,641 | -10,641 | -10,641 | -10,641 | -10,641 | -10,641 | -10,641 | 0 |
| -Development | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Depreciation | -16,621 | -18,621 | -19,821 | -13,001 | -6,980 | -1,440 | 0 | 0 | 0 |
| -Amortization | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -11,641 |
| Before Depltn | 56,846 | 54,846 | 53,646 | 60,467 | 66,487 | 72,027 | 73,467 | 73,467 | 0 |
| -50% Limit | -28,423 | -27,423 | -26,823 | -30,233 | 33,243 | 36,014 | 36,734 | 36,734 | 0 |
| -Percent Depl | 32,823 | 32,823 | 32,823 | 32,823 | -32,823 | -32,823 | -32,823 | -32,823 | 0 |
| -Cost Depltn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Loss Forward | -424 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Taxable | 27,999 | 27,423 | 26,823 | 30,233 | 33,664 | 39,205 | 40,645 | 40,645 | 0 |
| -Tax @ 40% | -12,600 | -12,340 | -12,070 | -13,605 | -15,149 | -17,642 | -18,290 | -18,290 | 0 |
| Net Income | 15,400 | 15,083 | 14,753 | 16,628 | 18,515 | 21,563 | 22,355 | 22,355 | 0 |
| +Depreciation | 16,621 | 18,621 | 19,821 | 13,001 | 6,980 | 1,440 | 0 | 0 | 0 |
| +Depletion | 28,423 | 27,423 | 26,823 | 30,233 | 32,823 | 32,823 | 32,823 | 32,823 | 0 |
| +Amortization | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +Loss Forward | 424 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11,641 |
| -Capitl Costs | 0 | -10,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cash Flow | 60,868 | 51,127 | 61,397 | 59,862 | 58,318 | 55,825 | 55,177 | 55,177 | 11,641 |

# COAL MINE MODEL:



(All Values in Thousands)
Title : Small scale coal strip mine
Run Date : 12/22/1989
Evaluation Date : 01/90
Project Start : 01/90
Evaluator : JRC

| Period Ending | 12/90 | 12/91 | 12/92 | 12/93 | 12/94 | 12/95 | 12/96 | 12/97 | 12/98 | 12/99 | 12/00 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | 0 | 0 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 |
| -Oper Costs | 0 | -721 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 |
| -Sever, Ad-Val | 0 | -18 | -149 | -149 | -149 | -149 | -149 | -149 | -149 | -149 | -149 |
| -Depreciation | -1,269 | -2,176 | -1,554 | -1,110 | -925 | -925 | -925 | 0 | 0 | 0 | 0 |
| -Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Before Depltn | -1,269 | -2,915 | -1,306 | -862 | -677 | -677 | -677 | 248 | 248 | 248 | 248 |
| -50% Limit | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -124 | -124 | -124 | -124 |
| -Percent Depl | 0 | 0 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
| -Cost Depltn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Loss Forward | 0 | -1,269 | -4,184 | -5,490 | -6,352 | -7,029 | -7,706 | -8,384 | -8,260 | -8,136 | -8,012 |
| Taxable | -1,269 | -4,184 | -5,490 | -6,352 | -7,029 | -7,706 | -8,384 | -8,260 | -8,136 | -8,012 | -7,888 |
| -Tax @ 40% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net Income | -1,269 | -4,184 | -5,490 | -6,352 | -7,029 | -7,706 | -8,384 | -8,260 | -8,136 | -8,012 | -7,888 |
| +Depreciation | 1,269 | 2,176 | 1,554 | 1,110 | 925 | 925 | 925 | 0 | 0 | 0 | 0 |
| +Depletion | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 124 | 124 | 124 | 124 |
| +Loss Forward | 0 | 1,269 | 4,184 | 5,490 | 6,352 | 7,029 | 7,706 | 8,384 | 8,260 | 8,136 | 8,012 |
| +Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Capitl Costs | -8,884 | -721 | -755 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cash Flow | -8,884 | -1,459 | -507 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 |

| Period Ending | 12/01 | 12/02 | 12/03 | 12/04 | 12/05 | 12/06 | 12/07 | 12/08 | 12/09 | 12/10 | 12/11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 |
| -Oper Costs | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 |
| -Sever, Ad-Val | -149 | -149 | -149 | -149 | -149 | -149 | -149 | -149 | -149 | -149 | -149 |
| -Depreciation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Before Depltn | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 |
| -50% Limit | -124 | -124 | -124 | -124 | -124 | -124 | -124 | -124 | -124 | -124 | -124 |
| -Percent Depl | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
| -Cost Depltn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Loss Forward | -7,888 | -7,764 | -7,640 | -7,516 | -7,392 | -7,268 | -7,144 | -7,020 | -6,896 | -6,772 | -6,648 |
| Taxable | -7,764 | -7,640 | -7,516 | -7,392 | -7,268 | -7,144 | -7,020 | -6,896 | -6,772 | -6,648 | -6,524 |
| -Tax @ 40% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net Income | -7,764 | -7,640 | -7,516 | -7,392 | -7,268 | -7,144 | -7,020 | -6,896 | -6,772 | -6,648 | -6,524 |
| +Depreciation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +Depletion | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 |
| +Loss Forward | 7,888 | 7,764 | 7,640 | 7,516 | 7,392 | 7,268 | 7,144 | 7,020 | 6,896 | 6,772 | 6,648 |
| +Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Capitl Costs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cash Flow | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 |

## COAL MINE MODEL - CONTINUED:

(All Values in Thousands)



Title : Small scale coal strip mine
Run Date : 12/22/1989
Evaluation Date : 01/90
Project Start : 01/90
Evaluator : JRC

| Period Ending | 12/12 | 12/13 | 12/14 | 12/15 | 12/16 | 12/17 | 12/18 | 12/19 | 12/20 | Salv. |
|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,873 | 1,476 |
| -Oper Costs | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | -1,476 | 0 |
| -Sever, Ad-Val | -149 | -149 | -149 | -149 | -149 | -149 | -149 | -149 | -149 | 0 |
| -Depreciation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1,476 |
| Before Depltn | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 0 |
| -50% Limit | -124 | -124 | -124 | -124 | -124 | -124 | -124 | -124 | -124 | 0 |
| -Percent Depl | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 0 |
| -Cost Depltn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -Loss Forward | -6,524 | -6,400 | -6,276 | -6,152 | -6,028 | -5,905 | -5,781 | -5,657 | -5,533 | 0 |
| Taxable | -6,400 | -6,276 | -6,152 | -6,028 | -5,905 | -5,781 | -5,657 | -5,533 | -5,409 | 0 |
| -Tax @ 40% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,434 | 0 |
| Net Income | -6,400 | -6,276 | -6,152 | -6,028 | -5,905 | -5,781 | -5,657 | -5,533 | -2,975 | 0 |
| +Depreciation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| +Depletion | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 0 |
| +Loss Forward | 6,524 | 6,400 | 6,276 | 6,152 | 6,028 | 5,905 | 5,781 | 5,657 | 5,533 | 0 |
| +Writeoffs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,476 |
| -Capitl Costs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cash Flow | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 2,682 | 1,476 |